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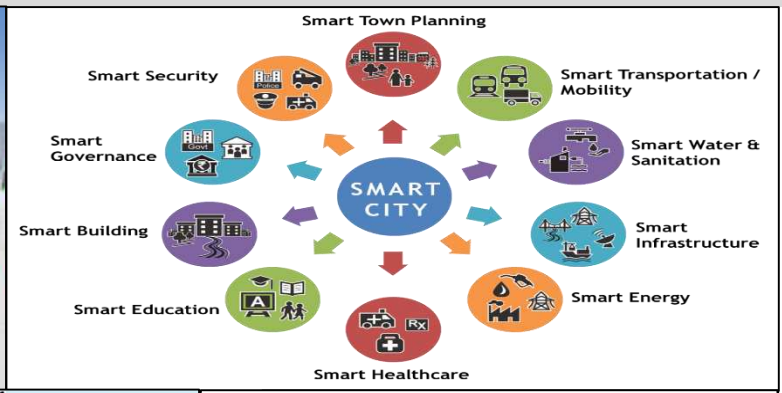
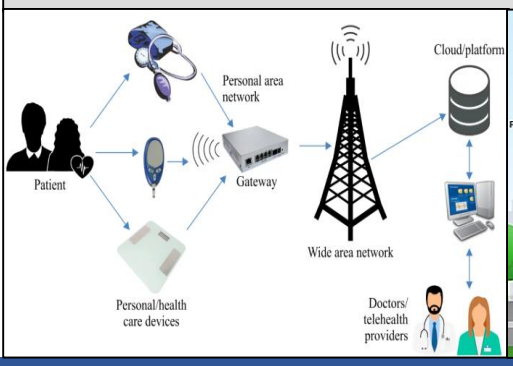
TECHNICAL REPORT

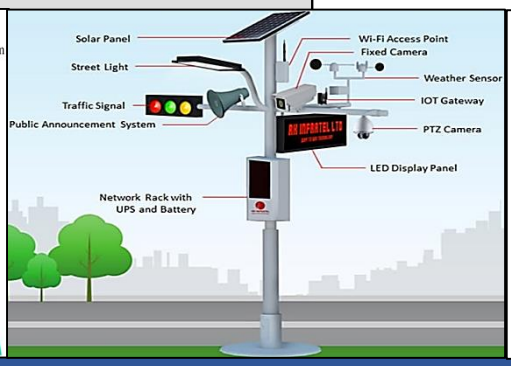
IoT/ ICT STANDARDS
for
SMART CITIES

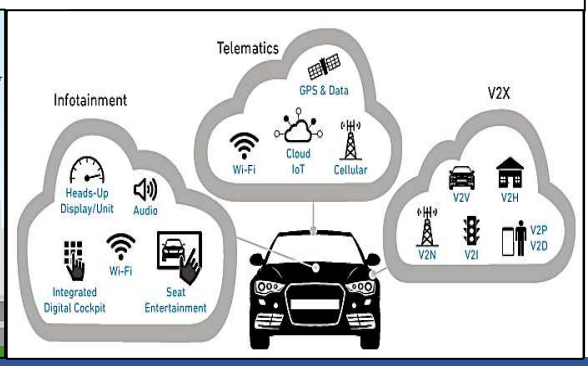
TEC 31178:2022

SMART CITY WORKING GROUP









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TELECOMMUNICATION ENGINEERING CENTRE
DEPARTMENT OF TELECOMMUNICATIONS
MINISTRY OF COMMUNICATIONS
GOVERNMENT OF INDIA

RELEASE 3.0 **MARCH, 2022**

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January, 2019	R2.0	TEC-TR-IoT-M2M-006-02	Design & Planning Smart Cities with IoT/ ICT
March, 2022	R3.0	TEC 31178:2022	IoT/ ICT Standards for Smart Cities

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Any comment/suggestions may please be sent to: **m2mreports.tec@gov.in**

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Azadi Ka Amrit Mahotsav

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Government of India
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Message

I am happy to note that Telecommunication Engineering Centre (TEC) has prepared a Technical Report on ***IoT/ ICT standards for Smart cities,*** which is being released as a guiding document for the information of Smart City SPVs and other related stakeholders.

IoT division, TEC has already released fifteen Technical Reports covering various verticals viz. Automotive, Power, Health, Safety & Surveillance, Smart Homes, Smart Cities, and in the horizontal layer - M2M Gateway & Architecture, Communication Technologies in M2M/ IoT domain, Code of practice for Securing consumer IoT etc. This document will add to the series of expert reports.

In view of rise in population and massive urbanization, smart infrastructure is required to be created in various verticals to address the challenges of daily life and also to improve the quality of life of the citizens.

This report covers Smart City Challenges, analysis of existing policies & guidelines related to IoT/ ICT in India and across the globe, Cross sectoral analysis related to telecom and ICT, Communication technologies for Smart Cities, emerging technologies like AI/ ML, Digital Twin; Platform, security etc. and the national and international standards related with the smart cities.

I hope that this Technical Report will be helpful to the Smart city stakeholders in developing the Smart City ecosystem in the country.

I appreciate the efforts put in by Telecommunication Engineering Centre in bringing out this report. I wish them success in all their endeavours.

20/3/22

(K Rajaraman)

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Message

I am happy to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on ***IoT/ ICT Standards for Smart Cities***.

I feel good that TEC has continued the excellent work, by releasing sixteen Technical Reports in the last 6 years, covering various verticals as well as horizontal layers viz. Automotive, Power, Health, Smart Homes, Smart cities etc.; M2M Gateway & Architecture, communication technologies in M2M/ IoT domain and Code of Practice for Securing Consumer IoT.

A number of actionable points that emerged from these reports such as 13-digit numbering scheme for SIM based devices/ gateways, adoption of e-SIM, spectrum for PLC and Low Power Wireless Communication technologies, spectrum for V2X applications, common service layer, spectrum for Wi-Fi 6 and Private industrial network etc. are being used in the development of standards / policies; enabling the proliferation of IoT eco-system in India.

I am delighted to share that this technical report has elaborated the technologies and standards for the development of smart cities based on the study of national / international best practices and guidelines. The report has also conered the standards released by ITU on IoT and Smart cities; and also the Key performance indicators (KPIs) for assessing the smartness of the cities. This technical report of TEC is a good reference for the related stakeholders in developing the standard based ecosystem in Smart cities.

I appreciate the efforts put in by Telecommunication Engineering Centre in bringing out this report. I congratulate IoT division for all their hard work and best wishes for the future.

A Kumar Mittal
24.03.2022

(Ashok Kumar Mittal)

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Message

I am pleased to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on ***IoT/ICT Standards for Smart Cities***. This report is in continuation to the series of sixteen technical reports already released in various verticals as well as horizontal layer of M2M/ IoT domain.

This Technical Report covers the challenges, study of international smart cities and the related standards released by ITU and other standardization bodies. Standards based solutions will help in the development of sustainable eco-system. This document is in series of other technical reports released by TEC in IoT domain.

TEC has also adopted oneM2M Release 2 specifications as National Standards; an important step towards developing standards based IoT ecosystem for smart cities.

This technical report of TEC is a good reference for the related stakeholders in developing the standard based ecosystem in the country.

I appreciate the efforts of Telecommunication Engineering Centre specially its IoT Division and the members of the Working Group for bringing out this technical report in a very timely manner. I wish them success in all their endeavours.

(A K Tiwari)

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Foreword

TEC is the National Standardization Body (NSB) for telecommunication in India and the national enquiry point for WTO-TBT (Technical Barrier to Trade) for telecom sector. TEC has also been mandated to interact with various international standardization bodies like ITU, APT, ETSI, IEEE, oneM2M, 3GPP etc. for standardization works.

TEC takes up development of standards based on study, continuous participation / submitting contributions in the meetings of standardization bodies and interaction with stakeholders. Certification of telecom products as per Essential Requirements (ERs) is also one of the major activities under MTCTE, which is being implemented in a phased manner by TEC.

M2M/ IoT is one of the most emerging technologies and it is being used to create smart infrastructure in various vertical industries and also in Smart cities. As per NDCP 2018, eco-system is to be developed for connecting five billion devices by 2022.

TEC has already released sixteen Technical Reports covering various verticals viz. Automotive, Power, Health, Safety & Surveillance, Smart Homes, Smart Cities, Smart Village & Agriculture and also in horizontal layer, the documents namely V2V/V2I Radio communication & Embedded SIM, Communication Technologies in M2M/ IoT domain, M2M Gateway & Architecture, M2M/ IoT security etc. Technical Reports released in 2021 are:

- IoT/ ICT Enablement in Smart Village & Agriculture
- Code of practice for Securing Consumer IoT
- Emerging Communication Technologies and use cases in IoT domain

Guidelines available in ***Code of Practice for Securing Consumer IoT*** may

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provide a direction to the related stakeholders in provisioning of secured consumer IoT devices and also help in reducing the vulnerabilities. All the technical reports are available on TEC website (https://tec.gov.in/M2M-IoT-technical-reports).

A number of actionable points emerged from these reports, a few important ones are 13-digit numbering scheme for SIM based devices/ gateways, Embedded SIM, IPv6 for devices / gateways to be connected to PSTN/ PLMN, Spectrum for PLC and low power wireless communication technologies, Common services layer- important for sharing of data, Spectrum for C-V2X applications, Private industrial networks etc.

TEC has adopted oneM2M Release 2 standards (transposed by TSDSI) as National standards (https://tec.gov.in/onem2m). These TEC standards have been referred by BIS in its standard on IoT Reference Architecture released in June 2021. Same has also been issued as an advisory by MoHUA for smart cities SPVs.

The TEC Working group/ committee on *IoT/ ICT Standards for Smart Cities* is having members from Government, industry, academia, R&D organisations and start-ups. Around 29 physical/ virtual meetings and a number of short meetings / discussions have already been held in drafting and finalizing the content of the Technical Report titled ***IoT/ ICT Standards for Smart Cities***. This report covers Smart City Challenges, analysis of existing policies & guidelines in India and some smart Cities across the globe; study of Cross sectoral analysis related to telecom and ICT, Communication networks, emerging technologies like AI/ ML, Digital Twin and Blockchain; Platform, Sectoral analysis and the National Requirements like human safety, environment/ climate change, security etc. Report is also having the detailed recommendations. This document may be downloaded from TEC website (https://tec.gov.in/M2M-IoT-technical-reports).

This report is expected to provide guidance to all concerned stakeholders. I hope the working group members will continue to provide their support to TEC in carrying out further study in M2M/ IoT domain for the holistic development of smart & sustainable infrastructure in the country.

22/3/2022

(Deepa Tyagi)

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Executive Summary

The United Nations (UN) estimates that around 68% of the world population will live in urban areas by 2050 and that would bring challenges as well as risks for cities in terms of, *inter alia*, traffic congestion, overloaded public healthcare system, climate change, and social instability[1].

India's population is expected to grow by 25%, with reference to 2011, to 1.52 billion by 2036, as per the projections made by the technical group on population in its final report submitted in July 2020. India's urban population will increase from 377 million in 2011 to 594 million in 2036 – a growth of 57%. So, while 31% of Indians were living in urban India in 2011, that will grow to 39% by 2036[2].

Challenges being faced due to rise in population in the urban areas may be addressed by creating smart infrastructure in various verticals related to the daily life of the common citizen by using emerging technologies i.e. Internet of Things (IoT) and ICT. Physical infrastructure in the verticals such as Automotive, Power, Health care, Safety and Surveillance, Environment monitoring and pollution control, Water management, Waste management, Agriculture, homes / buildings etc. may be made smart using IoT technologies, enabling them to transmit data in real time. This data may be further analysed for various planning and operational activities. Some of these verticals will work as a pillar for the smart cities. Smart city is said to be the super application domain of IoT.

Government of India declared the names of 100 cities to be developed in phased manner as Smart cities. Work in most of the cities is in progress by SPVs created for this purpose.

Smart city is a very complex domain and its development involves huge expenditure. Smart cities being developed should remain smart for a long time. For this, it is imperative to use standards based solutions enabling smart cities components (details in section 5) to be scalable, efficient, cost effective. This will help in ensuring interoperability at device, network, application / platform levels. A number of technological and policy challenges related to IoT are required to be addressed for the proliferation of this domain. Work is in progress at national and international level to address challenges related to IoT and Smart cities.

TEC is the National Standardization Body (NSB) for telecom & ICT sector and participates in standardisation activities at national and international level. TEC is also the WTO-TBT (Technical barrier to trade) reference point for telecom sector in India.

TEC participates and submits contributions in various standards developing organisations such as ITU, APT, ETSI, 3GPP, oneM2M, ISO/ IEC JTC 1 SC 41 etc. at international level and BIS & TSDSI in India.

ITU constituted Study Group 20 (SG-20) on IoT and its applications in Smart Cities & Communities (SC&C) in 2015. This study group has released a large range of standards related to city planning, stakeholders' engagement, Devices / Sensors, Gateways, Platforms, Big data, Open data, Smart data Governance, Frontier technologies, Use cases, KPIs for assessing the Smartness of a City etc. To coordinate with ITU-T SG-20 and submit contributions, TEC constituted National Working Group (NWG-20) in 2015.

TEC has released 16 technical reports in M2M/ IoT domain. Several important outcomes of these reports have been translated into policy / standards. (details in section 3.2).

[1] https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
[2] https://thewire.in/government/india-population-growth-government-report-2036-projections-urban-migration

TEC formed a committee (working group) having members from the related stakeholders to study / deliberate on cross-sectoral related requirements in Smart Cities related to telecom & ICT sector and prepare a comprehensive report covering national / international standards important for the development of Smart Cities.

1 Introduction and Background

1.1 Introduction

It is well known that around 100 cities are being developed as Smart Cities in phased manner by Special Purpose Vehicles (SPVs) created for this purpose. ICT/ IoT based solutions will be the core of smart infrastructure required for planning and implementing Smart Cities covering a number of priority verticals assessed by the Smart Cities mission (MoHUA) namely Safety & Surveillance, Mobility, Solid Waste Management, Energy, Water & Waste Water Management, Environment, and Health & Education. These verticals may differ from city to city as per their requirements.

During the current pandemic (Covid 19), communication technologies have played an important role especially in disseminating information, tele-consultation and tele-education. Therefore, it has become necessity to digitally transform various verticals for creating smart services in the cities as well as in rural communities.

TEC's 16 Technical Reports in M2M/ IoT/ ICT domain address verticals namely Power, Automotive, Health care, Safety & Surveillance, Smart Cities, Smart homes, Smart Village & Agriculture as well as the horizontal layers i.e., M2M Gateway architecture, Communication Technologies and M2M/ IoT Security etc. (Details in section 3.2).

Aligning with the discussions at the Smart Cities mission, and based on the recent and ongoing work and experience in TEC, the following areas in the digital space have been identified for the Smart Cities standardisation initiative-

- Energy (Smart Metering)
- Mobility (Automotive & Intelligent Transport Systems)
- Safety and Surveillance
- Health (Digital health / Telemedicine)
- Solid waste management
- Platform for the Smart cities
- Communication Technologies for Smart cities

The then Secretary (T) DoT, while addressing the conference in TEC in Jan 2019, has set an agenda for finalization of the specifications required to support the IoT/ICT Ecosystem enabling the Smart Cities. Two committees were formed for this purpose, as mentioned below:

(a) To finalize the IoT/ ICT standards for Smart cities

This committee was constituted vide TEC letter no. 2-1/2018/SD/TSDSI/TEC/5 dated 12-02-2019 and further expanded vide letter no.2- 1/2018/SD/TSDSI/TEC/6 dated 27-02-2019. Additional members from different verticals industries, Standards Development Organisations (SDOs), R&D organisations, Telecom Service Providers (TSPs), M2M/ IoT Service providers, IT companies etc. were added in this committee/ Working Group time to time.

The Terms of Reference (TOR) of the committee includes the following points: -

1. **To study cross-sector requirements like energy, transport, water management, waste management, surveillance etc. of Smart Cities related to telecom and related ICT/ IoT sector.**
2. **To consult all the stakeholders to envisage requirement of telecom/ ICT/ IoT in smart cities**

3. **To study national and international best practices, benchmarks, policies/ standards being adopted for smart cities.**
4. **To include national requirements like human safety, environment, geographical/ climatic conditions, national security etc. in the specification/ standards.**
5. **To prepare IoT/ICT based standards/ specifications/ guidelines for the smart cities.**

This document is the outcome of this committee/ working group.

(b) Adoption of oneM2M Release 2 specifications (transposed by TSDSI):

This work has already been completed with the adoption of oneM2M Release 2 specifications (14 out of 17 TS) as National standards (**TEC 30001:2020- 30023:2020**) in Sept 2020 (more details in section 3.2.3).

These TEC standards have also been included in the IoT reference architecture **IoT RA IS 18004 (Part 1): 2021** released by BIS.

Further TEC/ DoT referred these National standards and the U4SSC (United for sustainable smart cities) KPIs (Key performance indicators) (details in section 2) to MoHUA and NITI Aayog for further consideration and use in Smart cities.
As an extended outcome, MoHUA has referred BIS IoT Reference Architecture in the ICCC/ ICT Model RFP 2.0 (Section-1, Volume-II: Scope of work – Core Infrastructure) for Smart Cities and issued Advisory no. 19 (*https://smartnet.niua.org/content/6e40dcd8-ea0b-452b-b8da-c108e2f0c81f*).

NITI Aayog mapped the existing KPIs of MoHUA with U4SSC KPIs and proposed creation of two new categories namely Quality of Life ICT Infrastructure and Service Disaster Management (details available in Annexure- 9).

Smart City Challenges have been described in Section 2, Section- 3 covers the Analysis of existing policies & guidelines in India and Section - 4 covers study of some smart Cities across the globe. Section -5 covers study of Cross sectoral analysis related to telecom and ICT, Communication networks, emerging technologies like AI/ ML, Digital Twin and Blockchain; Platform, Sectoral analysis and the National Requirements like human safety, environment/ climate change, security etc.

Detailed recommendations are available in Section-6. This report is also having a number of annexures referred in the document.

This document is intended for use by Smart Cities Mission (MoHUA), Smart Cities SPVs, Smart City consultants, Telecom Service Providers (TSPs), M2M Service Providers, and other related stakeholders.

Brief of the discussion held in Jan 2019 with the stakeholders and definitions related to Smart city are available in the upcoming sections.

1.2 Significant events since initiation

As per the direction of Secretary (Telecom) for finalising Smart City Standards, during the release of Technical Report on ***Design & Planning of Smart cities with IoT/ ICT*** in a conference on 8th Jan 2019 in TEC, a meeting with stakeholders was arranged on 28th Jan 2019 in TEC. More than fifty stakeholders participated in this meeting having representation from Telecom Service Providers (TSPs), LPWAN service providers, OEMs, Vertical Industries, R&D organisations including C-DOT,

Consultancy firms and SDOs etc. The Stakeholders / Policy makers involved in the process of standardisation minutely assessed the gaps and identified the following areas to be addressed as an outcome of this meeting:

Points related to Standardization:

i. Common Service Layer standards for data sharing: *Related recommendation is available at point no. 1 of Section 6.2.*
ii. End to end security for the IoT use case: *Related recommendation is available at point no. 15 of Section 6.2.*
iii. Security by Design Principles: *Work is in progress. As part of it, a report on **Code of practice for securing Consumer IoT** has been released [details in Section 5.8.1].*
iv. National Trust Centre for M2M/ IoT : *Work is in progress*
v. Testing & Certification of LoRaWAN connected devices & gateways: It has already been incorporated in the Essential requirements under MTCTE regime. *[details in Section 3.2.2]*
vi. Harmonization of M2M Communications Standards with Sector wise Industry Policy and Standards (ISGF, MoRTH AIS140, IS 16833, IS 16444 etc.) *[details in Section 3.2.1].*
vii. Interface Requirement (IR) for the Embedded SIM / eUICC: *TEC has already released the IR for the Embedded SIM [details in Annexure 5.2].*
viii. Study of DSRC/C-V2X technologies for Implementation of Intelligent Transport System in Indian eco-system: *Covered in the Technical Report on **Emerging Communication Technologies & Use cases in IoT domain**, released in Nov 2021 [more details in Section 3.2.1].*
ix. Standard for M2M Use Case classification with Minimum Security Requirements / Assurance Level: *part of (iii) above.*

Points related to Policy:

i. M2M Service Providers Registration Policy, covering the following aspects also
    a. Machine KYC
    b. SM-DP and SM-SR geographical locations
ii. Mandate IPv6 in M2M devices/ gateways to be connected directly to PSTN/ PLMN: *Guidelines[3] have been issued by DoT time to time.*
iii. Guidelines to prevent frequency hogging in unlicensed spectrum 865-867 MHz
iv. It was pointed out in the meeting that most of the devices in the power as well as automotive sector are working on 2G technology. In the recent past, a number of 2G networks have been closed. Therefore, to facilitate long life of M2M devices, it is required to have a clarity regarding the committed support / End of Life of 2G Networks from the TSPs*: [details in Annexure-2* on *Adoption of Standards / Technology: tentative roadmap for India].*

Points related to policy as mentioned above were communicated to Network Technology (NT) division, DoT for information and necessary action. M2M Service providers' registration policy has been released by DoT in Feb 2022.

[3] https://dot.gov.in/ipv6-transition

Subsequent to the directives described above, further deliberations resulted in certain more focused items to be put on the list for immediate standardisation. These shortlisted areas of Standardisation priorities are listed below:

a. Standardization of Smart Cities Platforms- *[details in Section 5.6]*
b. Communication technologies & e-SIM- *[details in Section 5.3 and Annexure-2 & 3]*
c. Devices/gateways- *[details in Section 5.5]*
d. Data Model
e. Security- *[details in Section 5.8]*
f. Human safety- *[details in Section 5.8]*
g. API for privacy & data sharing
h. Data sharing across verticals & between platforms- *[details in Section 5.6]*

These points have been deliberated in the forthcoming sections and finally summarised in Section -6 (Recommendations), and also in Annexure-2 (Adoption of Standards/ technologies – Tentative Roadmap for India).

1.3 Definitions

1.3.1 Smart City

The Smart Cities Mission of India defines Smart Cities as those that "provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions".

Accordingly, the purpose of the Smart Cities Mission is to drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology, especially technology that leads to Smart outcomes. The mission expects that Smart Cities will act like a light house to other aspiring cities.

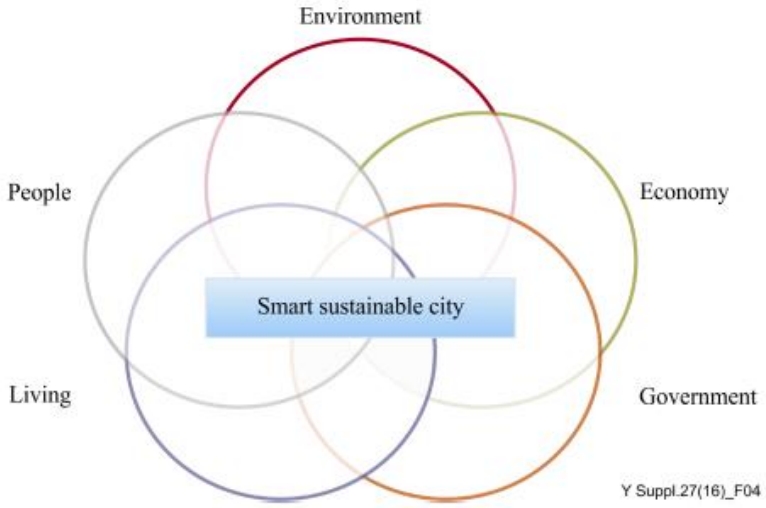
In physical terms, a Smart city refers to a local entity - a district, city, region or small country - which takes a holistic approach to employ **information and communication technologies with analytics** that encourages sustainable economic development.

1.3.2 Smart Sustainable City (SSC)

Smart Sustainable City, as defined by ITU, is an innovative city that uses Information and Communication Technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.[4]

SSCs in general, share the goal of achieving an economically sustainable urban environment without compromising the quality of life of their citizenry. A smart city and community strives to create a sustainable living environment for citizens using the Internet of Things (IoT), enabled by ICTs.

[4] [ITU-T Recommendation Y Suppl. 37] https://www.itu.int/ITU-T/recommendations/rec.aspx?id=12961&lang=en



Source: [ITU]

FIGURE 1: SMART SUSTAINABLE CITY DIMENSIONS

1.4 Key elements/verticals of a Smart City

The Ministry of Housing and Urban Affairs (MoHUA) in its initial Smart City Mission document identified 24 key areas of a Smart City. These are 1) Citizen participation, 2) Identity and culture, 3) Economy and employment, 4) Health, 5) Education, 6) Mixed use, 7) Compactness, 8) Open spaces, 9) Housing and Inclusiveness, 10) Transportation & Mobility, 11) Walkable, 12) IT connectivity, 13) Intelligent government services, 14) Energy supply, 15) Energy source, 16) Water supply, 17) Waste water management, 18) Water quality, 19) Air quality, 20) Energy efficiency, 21) Underground electric wiring, 22) Sanitation, 23) Waste management and 24) Safety. Some of these areas may not be impacted by Information and Communication Technologies directly.

In the context of applying Information and Communication Technologies, oneM2M identifies ten key verticals, namely **Smart Governance, Smart Building, Smart Healthcare, Smart Mobility, Smart Infrastructure, Smart Technology, Smart Energy and Smart Citizens.** This is illustrated in the following figure:

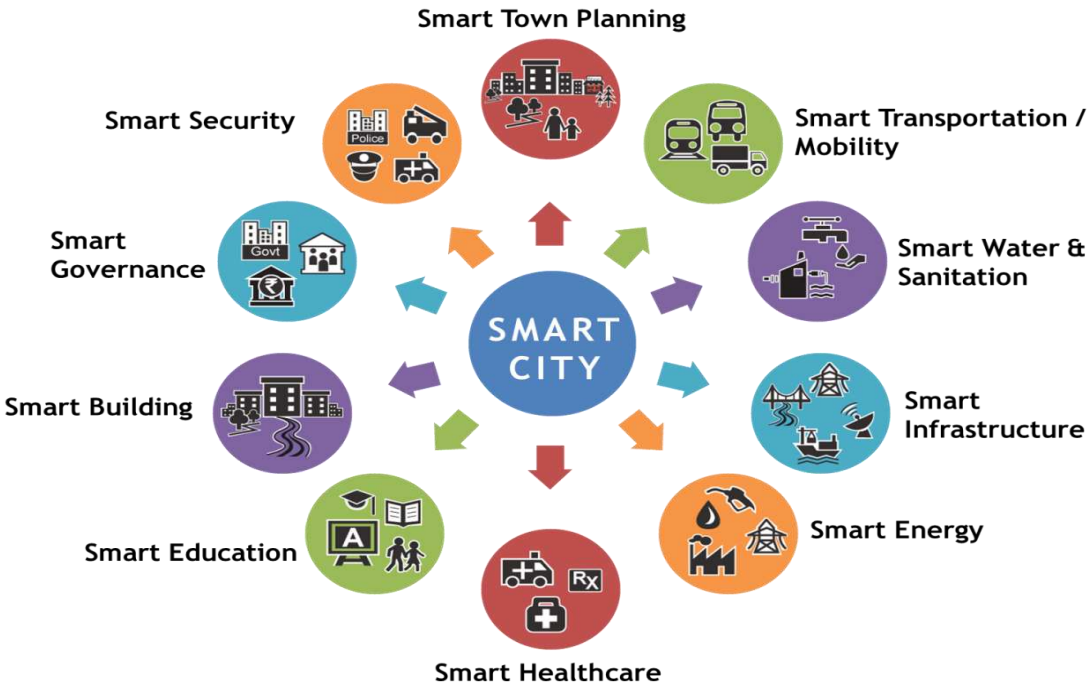


FIGURE 2: PAN CITY VERTICALS FOR A SMART CITY[5]

Their degree of use and implementation may vary from city to city as per its requirement. An ideal Smart City can be viewed as a "system of systems", where all these vertical systems within it are interconnected, in constant communication with each other in real time, exchanging information, and making smart decisions all in a sustainable and highly efficient model. This can further transform a Smart City into an open innovation platform, supporting vertical domain of business applications built upon horizontal enabling technologies.

This intelligence may be used for various planning and operational activities. Smart city is a very complex domain. Smart City deployments can have diverse types of IoT sub-systems and platforms that require interworking devices, apps and data all to one another.

1.5 IoT (Internet of Things)

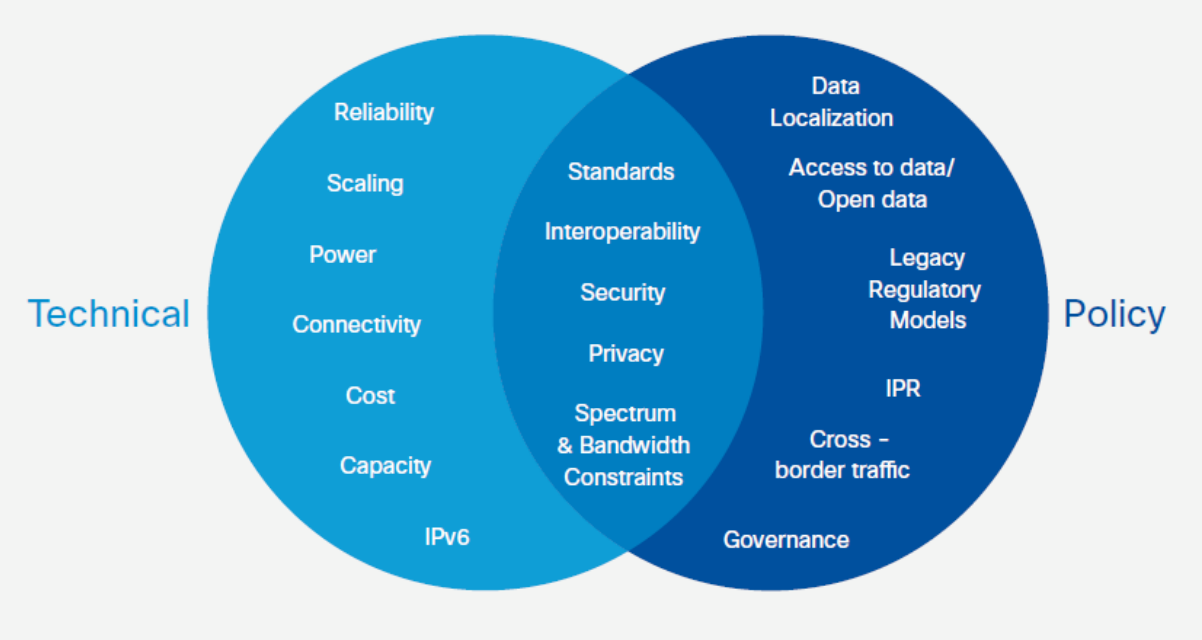
IoT is one of the most emerging technologies across the globe, being used to create smart infrastructure in various verticals such as Power, Automotive, Safety & Surveillance, Remote Health Management, Agriculture, Smart Homes and Smart Cities etc., using connected devices.

IoT is benefitted by recent advances in several technologies such as sensors, communication technologies (Cellular and non-cellular), AI/ ML, Cloud / Edge computing etc.

ITU has defined Internet of Things (IoT) as "***A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies***"[6].

[5] https://www.geospatialworld.net/blogs/pan-city-solutions-smart-solutions-for-smart-cities/
[6] Source: ITU-T Y.2060 - Y.2060 : Overview of the Internet of things (06/2012) (https://www.itu.int/rec/T-REC-Y.2060-201206-I)

There are a number of challenges related to technology and policy as depicted in the figure below, which are required to be resolved for the proliferation of IoT domain.



Source: [ITU]

FIGURE 3: CHALLENGES IN IOT DOMAIN

A number of international organizations are working on the standardization in IoT domain namely ITU, ISO, IEC, oneM2M, 3GPP, ETSI, IEEE etc. In India TEC, BIS and TSDSI are working on the standards development.

2 Smart City challenges & index

As per Census 2011 data[7], India's population was approx. 1.21 billion. Out of the total population around 31.16 % living in urban areas and contributing to 63% of India's GDP. Level of urbanization increased from 27.81% in 2001 Census to 31.16% in 2011 Census.

In 2022, India's population may be around 1.40 Billion with 35% of it living in urban areas. With increasing urbanization, urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030[8]. To address the various challenges arising due to rise in population in the cities, it is required to have a comprehensive development of the smart infrastructure in various verticals such as transportation, health care, education, power, safety etc. covering four pillars of a city namely Institutional, Social, Economic and Physical, using IoT/ ICT technologies. It will help in improving the quality of life of the citizens and attracting the people and investments to the city, setting in motion a virtuous cycle of growth and development. Development of Smart Cities is a step in that direction.

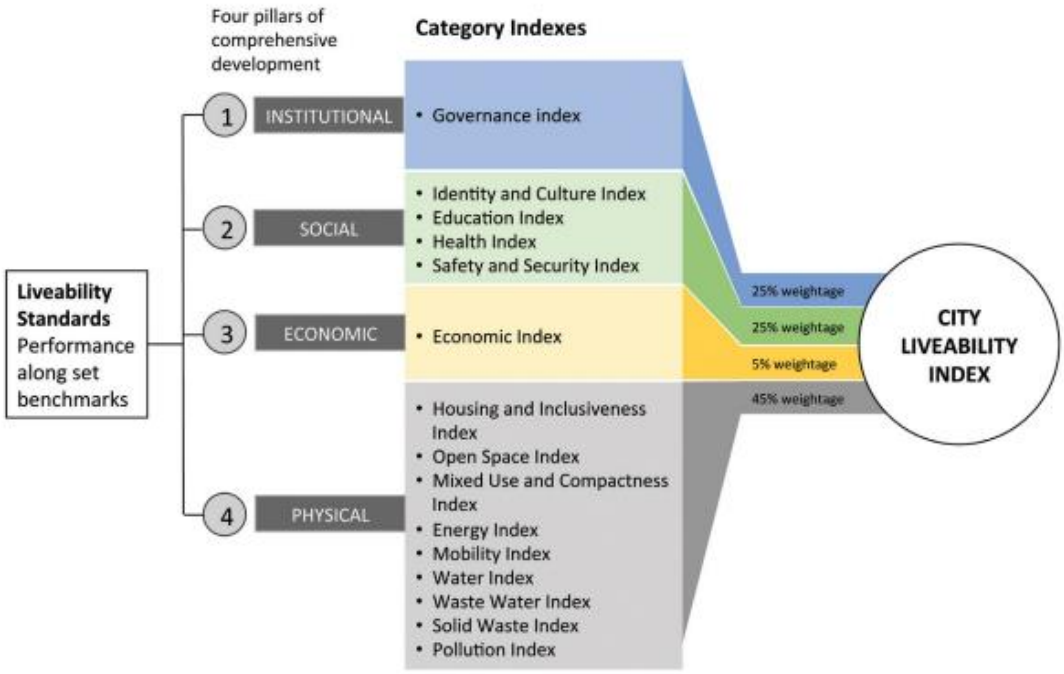
[7] https://censusindia.gov.in/2011-prov-results/paper2/data_files/india/Rural_Urban_2011.pdf
[8] https://www.india.gov.in/spotlight/smart-cities-mission-step-towards-smart-india#:~:text=Urban%20areas%20are%20expected%20to,institutional%2C%20social%20and%20economic%20infrastructure.

Smart services should be evolving and futuristic, therefore, smartness of a city is required to be evaluated/ assessed based on liveability index/ performance indicators defined by concerned authorities.

The immediate and long-term challenges, therefore, is to improve the liveability index for the cities, which are, and will continue to be, the engines of economic growth.

2.1 Liveability Index by MoHUA

The Ministry of Housing and Urban Affairs (MoHUA) has developed an elaborate method to rank cities on the liveability index[9]. The selection of the 4 pillars, 15 themes and 17 indicators are representative of the challenges Indian cities face, and must improve upon. These are indicated in the diagram below:



Source: [MoHUA]

FIGURE 4: MODEL TO COMPUTE THE LIVEABILITY INDEX

The four pillars add up to a 100% score, in which the institutional pillar of the liveability index accounts for 25% of the weight for scoring as shown below.

[9] https://smartnet.niua.org/sites/default/files/resources/Liveability%20Standards.pdf

PILLAR OF COMPREHENSIVE DEVELOPMENT	CATEGORY	INDICATOR	TYPE
INSTITUTIONAL	1. Governance	1.1 Percentage of citizen services available online	Core
		1.2 Percentage of services integrated through Command Centre	Supporting
		1.3 Percentage of citizens using online services	Core
		1.4 Average delay in grievance redressal	Core
		1.5 Tax collected as percentage of tax billed	Core
		1.6 Extent of cost recovery (O&M) in water supply services	Core
		1.7 Capital spending as percentage of total expenditure	Core
		1.8 Percentage of population covered under Ward Committees/ Area Sabhas	Core

Source: [MoHUA]

FIGURE 5: INSTITUTIONAL PILLAR OF COMPREHENSIVE DEVELOPMENT

More details about Smart Cities Mission (MoHUA) are given in section 3.5.

2.2 Smart Cities index / KPIs - Global Perspective

United for Smart Sustainable Cities (U4SSC)[10], a United Nations (UN) initiative coordinated by ITU and 16 other UN bodies with the aim of achieving SDG 11 (make cities inclusive, safe, resilient and sustainable) reports the following in describing the challenges of rapid urbanization:

"Urbanization presents unprecedented challenges. Most probably, with the exponential growth of the urban population, by the middle of the twenty-first century, four out of every five people will be living in cities. While cities are engines of economic growth, they also face diverse urban development challenges, including uncontrolled urbanization, urban sprawl, informal constructions, demographic challenges such as ageing or migration, homelessness, climate change and environmental pollution, outdated urban infrastructure and a lack of access to affordable and adequate housing. The efforts of countries and cities to address these challenges are hindered by disasters, such as earthquakes, floods and the spread of diseases that have devastating impacts on the quality of life and urban economies. It is expected, for example, that the economic crisis resulting from the COVID-19 virus pandemic will affect long-term global economic and social development much more than the global financial crash of 2008".

It acknowledges that "Multiple challenges such as knowledge gaps, limited finances, lack of coordination among actors, the absence of monitoring tools for policy implementation, emergencies and the impact of natural and human-made disasters and climate change can be roadblocks on the path towards sustainable urban development."

[10] https://www.itu.int/en/ITU-T/ssc/united/Pages/default.aspx

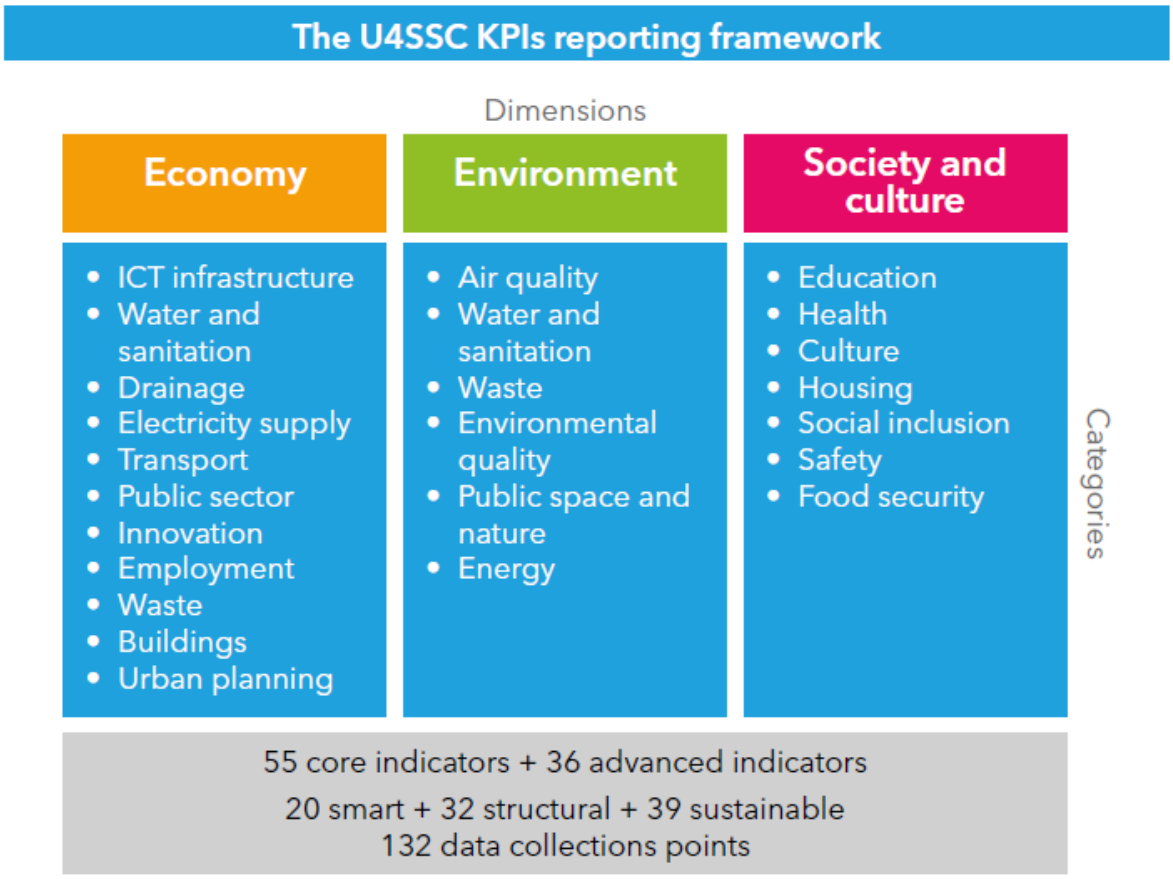
It states that "the goal of the U4SSC initiative is to promote 'smart sustainable city' approaches that support the implementation of the 2030 Agenda and help to achieve its Sustainable Development Goals - especially SDG 11: "Make cities and human settlements inclusive, safe, resilient and sustainable". **U4SSC developed key performance indicators (KPIs) for Smart Sustainable cities based on ITU standards.**

The work of the U4SSC initiative[11] is organized under the following thematic groups:

- City platforms
- Economic and financial recovery in cities and urban resilience building in the time of COVID-19
- Guidelines on tools and mechanisms to finance SSC projects
- Guiding principles for Artificial Intelligence in cities
- Blockchain for cities
- Simple ways to be smart
- Practitioner guide to measure Smart Cities and Communities
- Practitioner guide to monitor Smart Cities and Communities
- Procurement guidelines for Smart Cities and Communities
- United for Smart Sustainable Cities Index

As per U4SSC's document *"Collection Methodology for Key Performance Indicators for Smart Sustainable Cities"* comprehensive assessment is based on three dimensions - 1. Economy, 2. Environment and 3. Society & Culture.

[11] https://www.itu.int/en/ITU-T/ssc/united/Documents/U4SSC%20Publications/U4SSC_Brochure-June%202020pdf.pdf



Source: [U4SSC, ITU]

FIGURE 6: THREE DIMENSIONS OF U4SSC SMART CITY FRAMEWORK

The first sub-dimension of the Economy is ICT infrastructure as shown in the figure below:

Dimension	Sub - Dimension	Category	KPI	Type	Type
Economy	ICT	ICT Infrastructure	Household Internet Access	Core	SMART
			Fixed Broadband Subscriptions	Core	SMART
			Wireless Broadband Subscriptions	Core	SMART
			Wireless Broadband Coverage	Core	SMART
			Availability of WIFI in Public Areas	Advanced	SMART
		Water and Sanitation	Smart Water Meters	Core	SMART
			Water Supply ICT Monitoring	Advanced	SMART
		Drainage	Drainage / Storm Water System ICT Monitoring	Advanced	SMART
		Electricity Supply	Smart Electricity Meters	Core	SMART
			Electricity Supply ICT Monitoring	Advanced	SMART
			Demand Response Penetration	Advanced	SMART
		Transport	Dynamic Public Transport Information	Core	SMART
			Traffic Monitoring	Core	SMART
			Intersection Control	Advanced	SMART
		Public Sector	Open data	Advanced	SMART
			e-Government	Advanced	SMART
			Public Sector e-procurement	Advanced	SMART

Source: [U4SSC, ITU]

FIGURE 7: ICT SUB-DIMENSION FOR SMART CITIES[12]

As detailed in section 4.7.1, U4SSC KPIs have been adopted in more than 150 cities across the globe for evaluating their progress towards Smart Sustainable Cities objective and SDGs. Some of the cities are Dubai, Singapore, Wuxi (China), Moscow (Russia), Valencia (Spain), Pully (Switzerland) etc. Case study of Dubai has been detailed in section 4.6.

2.3 Summary

It is evident from the study of Indian and global criteria for smart cities assessment that the ICT sub-dimension is amongst the most important parameter for the sustainable development of smart cities. Smart cities platforms, Command and Control Centres and data management are likely to determine the future liveability of Smart Cities.

[12] https://www.itu.int/en/publications/Documents/tsb/2017-U4SSC-Collection-Methodology/files/downloads/421318-CollectionMethodologyforKPIfoSSC-2017.pdf

Ease of Living Index (EOLI) and Municipal Performance Index (MPI), defined by MoHUA are being used at present to assess the sustainability and growth of cities across various parameters in India. While reviewing the existing indices of EOLI / MPI and the U4SSC- KPIs, it was observed by NITI Aayog that the U4SSC-KPIs are unique in several sectors as well as possess certain similarities with the EOLI and MPI indices. ***The uniqueness of U4SSC-KPI lies in the inclusion of Information and Communications Technology (ICT) as an important tool for measuring the indicators as well as to measure the access to digital communication and therefore, such KPIs on ICT are very much essential keeping in view of the "Digital India" initiative of Government of India.*** The table available in Annexure-9 (developed by NITI Aayog) shows mapping of some of the unique KPIs from the U4SSC framework that can be adopted under various pillars of EOLI and MPI verticals, while some may be covered by creating new pillars under existing EOLI & MPI verticals.

IoT/ ICT is playing an important role in the development of ecosystem for digital transformation. Smart cities must be able to harness its resources and manage the challenges intelligently by sharing data across verticals (Automotive, Safety and Surveillance, Governance, Energy, Water and Waste management etc.) as well as at least with the adjacent smart cities. For this, standards-based solutions are required to be implemented at D (device) – N (Network) – A (application) / P (Platform) levels.

3 Analysis of Existing Policies, Standards and Guidelines

3.1 DoT policies on M2M/ IoT

3.1.1. National Digital Communications Policy- 2018

National Digital Communication Policy-2018[13] was released by DoT as a vision document. Salient features related to IoT, 5G and other emerging technologies in NDCP are as given below:

1. **Recognizing Digital Communications as the core of Smart Cities by:**
   a. Developing, in collaboration with Ministry of Urban Development, a Common Service Framework and Standards for Smart Cities
   b. Facilitating and supporting deployment of innovative solutions in identified Smart Cities

2. **Propel India:** Enabling Next Generation Technologies and Services through Investments, Innovation, Indigenous Manufacturing and IPR Generation
   2022 Goals:
   a. Expand IoT ecosystem to 5 Billion connected devices
   b. Creation of innovation led Start-ups in Digital Communications sector
   c. Train/ Re-skill 1 Million manpower for building New Age Skills

3. **Connect India:** Creating a Robust Digital Communication Infrastructure
   2022 Goals:
   a. Provide Universal broadband connectivity at 50Mbps to every citizen
   b. Provide 1 Gbps connectivity to all Gram Panchayats of India by 2020 and 10 Gbps by 2022
   c. Enable100 Mbps broadband on demand to all key development institutions; including all educational institutions
   d. Enable fixed line broadband access to 50% of households
   e. Achieve 'unique mobile subscriber density' of 55 by 2020 and 65 by 2022
   f. Enable deployment of public Wi-Fi Hotspots; to reach 5 million by 2020 and 10 million by 2022
   g. Ensure connectivity to all uncovered areas

4. **Accelerating Industry 4.0**
   a. Create a roadmap for transition to Industry 4.0 by 2020 by closely working with sector specific Industry Councils
   b. Establish a multi-stakeholder led collaborative mechanism for coordinating transition to Industry 4.0
   c. Developing market for IoT/ M2M connectivity services in sectors including Agriculture, Smart Cities, Intelligent Transport Networks, Multimodal Logistics,

[13] https://dot.gov.in/sites/default/files/Final%20NDCP-2018_0.pdf

Smart Electricity Meter, Consumer Durables etc. incorporating international best practices

5. **Ensuring a holistic and harmonized approach for harnessing Emerging Technologies**

   a. Creating a roadmap for emerging technologies and its use in the communications sector, such as 5G, Artificial Intelligence, Robotics, Internet of Things, Cloud Computing and M2M.
   b. Simplifying licensing and regulatory framework whilst ensuring appropriate security framework for IoT/ M2M/ future services and network elements incorporating international best practices.
   c. Earmarking adequate licensed and unlicensed spectrum for IoT/ M2M services
   d. Encourage use of Open APIs for emerging technologies
   e. Ensuring the Transition to IPv6 for all existing communications systems, equipment, networks and devices
   f. Enabling Hi-speed internet, Internet of Things and M2M for rollout of 5G technologies and services.
      - Implementing an action plan for rollout of 5G applications and services
      - Enhancing the backhaul capacity to support the development of next-generation networks like 5G
      - Ensuring availability of spectrum for 5G in < 1 GHz, 1-6 GHz and > 6 GHz bands
      - Reviewing industry practices with respect to traffic prioritization to provide 5G enabled applications and services
      - Developing framework for accelerated deployment of M2M services while safeguarding security and interception for M2M devices
      - Defining policy for EMF radiation for M2M devices, with accompanying institutional framework to coordinate government-funded and India-specific research in this regard

   g. Facilitating and supporting deployment of innovative solutions in identified Smart Cities

6. **Ensuring adequate numbering resources, by:**
   Allocating 13-digit numbers for all M2M mobile connections

7. **Promoting research & development in Digital Communication Technologies by:**
   a. Creating a framework for testing and certification of new products and services

3.1.2. National Telecom M2M Roadmap released in 2015

1. **To facilitate M2M communication standards including encryption, quality, security and privacy standards from Indian Perspective and to recognize such standards for India**: - TEC released 16 Technical reports in M2M/ IoT domain covering standardization aspects. Details are available in Section 3.2.1.

2. **To release national M2M Numbering Plan**: - 13-digit numbering scheme for SIM based devices and gateways has already been implemented in Indian telecom network. Details are available in Section 3.2.1.
3. Addressal of M2M Quality of Service aspects: Covered in TRAI recommendations, details in Section 3.3.
4. To address M2M specific Roaming requirements: Covered in TRAI recommendations, details in Section 3.3.
5. To formulate M2M Service Provider (MSP) registration process: Policy released by DoT. Details in Section 3.1.3.
6. To issue guidelines for M2M specific KYC, SIM Transfer, International roaming etc: KYC related guidelines are released by DoT[14] time to time.
7. Formation of APEX body involving all concerned stake holders: Inter ministerial consultation is in progress by DoT.
8. **To address M2M specific spectrum requirements**: - This issue has already been addressed in the Technical Reports released in TEC. Details are available in points no. 6, 7, 14 & 15 of Section 3.2.1.1.
9. **To define frequency bands for PLC communication for various Industry verticals**: - Related details are available in point no. 16 of Section 3.2.1.1.
10. **Finalization of M2M Product Certification process and responsibility centers**: - It is being implemented in Mandatory Testing and Certification of Telecom Equipment MTCTE regime (refer Section 3.2.2).
11. Facilitating M2M Pilot projects.
12. Measures for M2M Capacity building.
13. To establish Center of Innovation for M2M: IoT innovation centers have been/ are being established by academia, NASSCOM, MeitY etc. IoT experience center has been established in TEC.
14. To assist M2M entrepreneurs to develop and commercialize Indian products by making available requisite funding (pre-venture and venture capital), management and mentoring support.
15. Inclusion of M2M devices in PMA Policy: At present Preference for Domestically Manufactured Electronic Goods (PMA) policy[15] covers the telecom and few IoT products.
16. To take up matters with relevant ministries to boost M2M products and services: Similar to point no. 7 above.
17. Define procedures for energy rating of M2M devices and implementation of same-work in progress in TEC.
18. **To evolve suitable guidelines of EMF radiation of M2M devices based on research and studies by relevant bodies**: - Related details are available in point no. 4 of section 3.2.1.1 and section 3.2.2.

[14] https://dot.gov.in/access-services/subscriber-verification
[15] https://www.meity.gov.in/esdm/pma

3.1.3. M2M Service Providers Registration Policy

Guidelines for registration process of M2MSP (M2M Service Providers) and WPAN/WLAN Connectivity Providers for M2M Services[16] have been released by DoT in Feb 2022.

3.2 Initiatives taken by TEC in IoT / ICT domain

As per the terms of reference of this Committee (point no. (a) of section 1.1), a study is required for assessing the requirements of various industry verticals. Towards this, the work already carried out within the Telecom Engineering Centre in the recent past, has been taken into consideration.

TEC is working in M2M/ IoT domain since 2014 and has worked upon a no. of action points mentioned in NDCP and the National Telecom M2M Roadmap as detailed in section 3.2.1.

TEC has released a large number of standards in the form of GR (Generic requirements) / IR (Interface requirements) / ER (Essential requirements) etc. for the telecom equipment. Important GR, IR and ER related to the equipment / IoT devices expected to be used in Smart cities are available in the Annexure- 5.

3.2.1 Technical Reports released in IoT domain and important actionable points

TEC formed various multi-stakeholders working groups time to time to study the M2M/ IoT domain, with the outcome to be used in policies / standards. These working groups are having members from the related stake holders i.e. industry, academia, R&D organisations, Standards developing organisations (SDOs), Government etc. Efforts have been made to study various aspects of industry verticals namely Power sector, Automotive, Health care, Safety & Surveillance, Smart homes, Smart cities, Smart Village & Agriculture; and also in the horizontal layer (requirements common to all the verticals) such as M2M Gateway & Architecture, Communication Technologies and Security aspects in M2M/ IoT domain.

Total 16 Technical Reports have been released till date.

1. M2M Enablement in Power Sector
2. M2M Enablement in Automotive (Intelligent Transport System) Sector
3. M2M Enablement in Remote Health Management
4. M2M Enablement in Safety & Surveillance Systems
5. M2M Gateway & Architecture
6. M2M Number resource requirement & options
7. V2V / V2I Radio communication and Embedded SIM
8. Spectrum requirements for PLC and Low power RF communications
9. ICT deployment and strategies for India's Smart Cities: A Curtain Raiser
10. M2M/IoT Enablement in Smart Homes
11. Communication Technologies in M2M / IoT domain
12. Design and Planning Smart Cities with IoT/ ICT
13. Recommendations for M2M/ IoT Security

[16] https://dot.gov.in/sites/default/files/M2MSP%20Guidelines%20.pdf?download=1

14. IoT/ ICT enablement in Smart Village and Agriculture
15. Code of practice for Securing Consumer IoT
16. Emerging Communication technologies and Use Cases in IoT domain

Technical reports mentioned at sl. no. 14, 15 & 16 above have been released in 2021. Technical reports mentioned at sl. no. 9 and 12 released in 2015 and 2019 respectively are related with the Smart Cities. All the Technical Reports are available on TEC website[17].

3.2.1.1. Summary of important actionable points emerged from the Technical Reports (TRs) released in TEC and action taken thereafter: -

A large number of actionable points have emerged from these technical reports. Some of the important, which are in process at different levels of adoption in policy / standards:

1. **13-digit numbering scheme for SIM based devices/ Gateways: -**As per the recommendation in Technical Report on "M2M Number resource requirement & options", 13-digit M2M Numbering scheme for SIM based devices/ Gateways, which will co-exist with the existing 10-digit numbering scheme in use, was prepared in TEC. **DoT has approved this scheme and issued orders to all the Telecom Service Providers for implementation. Five codes of 3 digit each (559, 575, 576, 579 and 597) have been allotted as a M2M identifier[18].**

2. **M2M SIM / Embedded SIM and remote subscription management:** Based on the Technical Report on "V2V / V2I Radio communication and Embedded SIM", Interface Requirement (IR) has been prepared by TEC (details available in annexure 5).
    - DoT has approved the use of Embedded SIM with OTA provisioning in May 2018[19].
    - Ministry of Road Transport and Highways, India has already included Embedded SIM with OTA provisioning based on TEC specifications in AIS140 standard which specifies the conditions and specifications for the use of connected devices in vehicles[20].
    - The Bureau of Indian Standards has released a new Standard for Automotive Tracking Device and Integrated Systems (IS: 16833/2018) which mandates the use of the embedded SIM as per the Standards/Specifications of the TEC.

3. **Multi-protocol gateway / IoT Gateway:** It is Important for Smart homes/ building solutions for interconnecting the devices with the communication networks and it performs the necessary translation between the protocols used in the communication networks and those used by devices.

4. **Testing and Certification of M2M devices: -** Now it is the part of Mandatory Testing and Certification of Telecom equipment (MTCTE) regime. Essential Requirements (ERs) for the IoT devices namely Smart security camera / CCTV camera, Smart electricity meter, Smart watch, Tracking device, Feedback device, Gateways and their variants have already been finalised and uploaded on the MTCTE portal.

[17] https://www.tec.gov.in/M2M-IoT-technical-reports
[18]https://dot.gov.in/sites/default/files/M2M%20numbering.pdf?download=1
[19]http://www.dot.gov.in/sites/default/files/M2M%20Guidelines.PDF?download=1
[20]https://hmr.araiindia.com/Control/AIS/14201910518PMAIS-140.pdf

5. **Licensing/ Registration for non-cellular LPWAN technologies such as LoRa, Sigfox etc. for providing communication services in IoT domain: -** It is important from the policy as well as security perspective to have the details of agencies providing public services. This may be the part of M2M Service provider registration policy, expected in near future.

6. **Additional Spectrum requirement for Low power wireless communication technologies:**
   - Based on the Technical Report on "Spectrum requirements for PLC and Low power RF communications", additional Spectrum of 12MHz for Low power RF communication technologies in Sub GHz band, adjacent to existing delicensed spectrum (865-867 MHz) was recommended to reserve and release as per requirement.
   - DoT referred the case to TRAI.
   - TRAI had recommended 7 MHz spectrum [1 MHz spectrum in 867- 868 MHz and 6 MHz in 915-935 MHz band] to be delicensed on priority, in its recommendation on "Spectrum, Roaming and QoS related requirements in Machine-to-Machine (M2M) Communications" released in Sept. 2017.
   - DoT approved the TRAI recommendations.
   - 1MHz spectrum has been released adjacent to 865-867MHz increasing it to 865-868MHz vide GSR 853(E) dated 10th Dec 2021.

7. **Spectrum requirement in 5.9 GHz band for DSRC/ C-V2X technology for intelligent transport system in India:**

   As per ITU-R Recommendation M.2121, 5850 – 5925 MHz spectrum has been reserved for ITS applications. Same has also been recommended by TEC in its report ***V2V/ V2I Radio Communication and Embedded SIM*** released in 2015 and also in ***Emerging Communication Technology and use cases*** released in 2021. DSRC being an outdated technology at present, C-V2X is expected to be deployed for Intelligent Transport System in India. The current National Frequency Allocation Plan allows for use of frequency band 5875 – 5925 MHz for Intelligent Transport Networks (IND 30). For realizing the full potential of V2X, a unified technology and enabling regulatory provision for a deployment authority is required.

8. **Common service layer: -** Common service layer is important for sharing of data between various verticals connected at the platform for ensuring interoperability. It will help in breaking silos.
   At present most of the smart cities are using proprietary platforms, therefore two adjacent and different proprietary platforms are not able to share the data in real time. Moreover, these platforms may not be scalable and will be difficult to integrate new services and further innovation.

   oneM2M, Release 2 specifications (transposed by TSDSI) have been adopted as a National standard by TEC [Section 3.2.3 and section 5.6 may be referred for more details].

9. **Devices / Gateways having direct connectivity with PSTN / PLMN should have static IP (IPv6 or dual stack):-** As IPv4 addresses are going to exhaust, it will be better to migrate on IPv6 as an earliest.
   BIS in its standard IS 16444 has mandated IPv6 for Smart meters to be connected on Cellular technologies. DoT has issued guidelines on IPv6 time to time[21].

10. Sensors are at the bottom of pyramid for IoT systems, however, at present most of the typically used sensors are imported. Further, there is a dire need to develop new sensors all the time. Looking at these requirements, sensors need to be developed indigenously with focus on low cost, high throughput and scalable manufacturing techniques such as printing based techniques.
11. Smart City platforms should be able to manage the emergency health services to the public of city as well as rural areas by analysing data from the connected health care devices as well as respond to the calls of the public, especially in a pandemic situation.
12. IoT devices should be safe and secured. To ensure this, devices are required to be tested and certified in designated labs under MTCTE (Mandatory Testing and Certification of Telecom Equipment) regime of TEC[22].
13. For managing vulnerabilities and to develop secure eco system in IoT domain, at least the first three guidelines of TEC document ***Code of Practice for Securing Consumer IoT*** as listed below, are recommended to be adopted by the IoT device manufacturers:

    (a). No universal default passwords ie Ban default password.
    (b). Implement a means to manage reports of vulnerabilities.
    (c). Keep software updated

    However, if any IoT device (whether tested under MTCTE or not) deployed in the network is hacked or exposed to any vulnerability, it should be detected by the IoT platform. It is the responsibility of the platform to address the vulnerability and further report it to some central entity such as CERT, NTC or others for cataloging the vulnerabilities.
14. **Spectrum requirements for Private networks in India**: Based on the recommendation of Technical Report ***Emerging Communication technologies and use cases in IoT domain*** released in 2021, following is recommended:
    1. Spectrum bands widely adopted for the industry applications are required to be considered. 3GPP TS 36.101-1 and 38.101-1 provides supported channel bandwidths in Sub-6GHz (e.g., 5, 10, 20, 40, 100 MHz) and mmWave (e.g., 200-400 MHz).
    2. Frequency bands identified for IMT globally / regionally, but not identified in India should also be considered for private networks.
    3. Frequency bands identified for IMT by India, but not assigned due to other users in limited regions (e.g., certain limited locations in the country) should be considered. A technical feasibility study/mechanism to protect incumbent users may be considered on a case-by-case basis.
    4. Contiguous spectrum is essential for providing efficient network deployment which ensures interference management. This also helps in efficient coordination for:
       - Re-use of the spectrum across multiple private industries.
       - Interference management and coordination between Public network and Private networks.

[21] https://dot.gov.in/ipv6-transition
[22] https://tec.gov.in/mandatory-testing-and-certification-of-telecom-equipments-mtcte

5. Sharing / leasing spectrum from public networks may be studied/ considered.

15. Spectrum requirement for Wi-Fi 6E technology in India

As per the recommendation available in technical report ***Emerging Communication Technology and use cases*** released in 2021, study of 6 GHz band for delicensing is required as it will be used in Wi-Fi 6E technology.

16. Spectrum requirements for PLC technology: Based on the outcome of Technical Report ***Spectrum requirements for PLC and Low power RF communications*** released in 2015, frequency band of 0 - 500 KHz for narrowband PLC and 2 MHz - 200 MHz for broadband PLC was recommended for allocation.

17. Smart phones / Tablets/ Laptops may be out of the budget of the economically poor households. Low cost devices with minimum features such as Wi-Fi, Bluetooth, cellular connectivity and long battery life are required to accelerate the use of technology in various applications in rural areas.

18. Cities should use available resources - smartphone-based sensor-networks as well as crowdsourced data from its citizens to enrich its services where possible.

19. The different city services should break walls and share data. Common Service principles/Common Service layer and Open Data concepts should be adopted by Cities.

20. Smart City planners should employ Design, Systems and Future thinking frameworks to conceptualize, design and develop solutions using IoT that are long lasting and resilient.

21. Society 5.0, a super smart nation with digitalization across all levels of society, to positively transform India is what we should work towards.

22. There is a need for proper town planning using GIS for efficiently deploying various solutions such as traffic management, street light, waste management etc.

23. Technology for Smart cities– both legacy and new requirements should be standards compliant and conform for interoperability in general. Standards released by various National / International bodies such as ITU, ETSI, 3GPP, oneM2M, IEEE, NIST, BIS, TEC etc. may be followed to ensure interoperability.

24. A framework needs to be created for access to national databases like UIDAI, CCTNS, NCRB, etc. for security & surveillance systems.

25. Biometric authentication of users using Aadhaar (UID) database and UID Number may be adopted as the authentication process electronic health record system. A design and implementation plan for this work item needs to be created.

3.2.2 MTCTE

The Department of Telecommunications, Ministry of Communications, Government of India vide Gazette Notification No. G.S.R. 1131(E) dated 5th September, 2017 has amended the Indian Telegraph Rules, 1951 (Amendment 2017) to introduce Mandatory Testing & Certification of Telecom Equipment (*http://tec.gov.in/pdf/Whatsnew/eGazetteNotif.pdf*). Telecommunication Engineering Centre (TEC) is implementing Mandatory Testing & Certification of Telecommunication Equipment in India in phased manner.

In MTCTE, every telecom equipment needs to undergo mandatory testing and certification

prior to sale, import for use in India. Details are available on TEC website *http://www.tec.gov.in/mandatory-testing-and-certification-of-telecom-equipments-mtcte/*

The testing is to be carried out for conformance to Essential Requirements (ERs) for the equipment. ERs are available on MTCTE Portal (*https://www.mtcte.tec.gov.in/*).

3.2.3 Adoption of TSDSI / International Standards

Telecommunication Engineering Center (TEC) is the National Standardisation Body for Telecom and related ICT sector in India. "**Standardization Guide –A policy document for adoption of Domestic/ international standards into national standards[23]"** was issued vide O.M. No. 2-1/2018/SD/TSDSI/TEC/5 dated 08-05-2020.

TSDSI (Telecommunications Standards Development Society of India) is a membership based, standards development organization(SDO) for Telecom/ICT products and services in India. TSDSI is a Partner Type I member of oneM2M and 3GPP.

oneM2M: ETSI (Europe), TTC (Japan), ARIB (Japan), ATIS(USA), TIA (USA), TTA (Korea) CCSA (China) had come together and created a partnership project oneM2M in 2012, to avoid creation of competing M2M standards. Later, TSDSI from India had also joined as a partner member in oneM2M. They are working to **create standards for the common service layer**.

oneM2M released its first set of specifications (Release 1) in Jan 2015, Release 2 in March 2016 and Release 3 in Dec 2018. Work is in progress on Release 4 and Release 5.

TSDSI transposed oneM2M Release 2 specifications, submitted by TSDSI to DoT, were forwarded to TEC in Jan 2018, for considering them for adoption / ratification.

TEC, after complying with the consultation process as per the Standardisation guide, adopted TSDSI transposed oneM2M Release 2 specifications, as National standards[24]. These national standards shall be voluntary unless made mandatory by its use, reference or adoption by regulation / Govt. directive. Details of the standards is available in Annexure- 6.

3GPP: 3GPP is a 3rd Generation partnership project bringing together seven national Standards Development Organizations (SDOs) namely ARIB, ATIS, CCSA, ETSI, TSDSI, TTA and TTC from around the globe, to develop technical specifications for the mobile/ cellular telecommunications. 3GPP has published various specifications in the form of different releases, ranging from 2G GSM, WCDMA, LTE etc. to 5G. Currently 3GPP is in process of publishing its Release 17, by Q2 of 2022.

Adoption of 3GPP standards: TEC has adopted 402 specifications of 3GPP (Release 10 to 14) as National Standards[25].

3.2.4 Contributions at International level

1. **TEC achievements in ITU-T SG-20 on IoT and its applications in Smart Cities and Communities:**
   ITU-T Recommendation Y Suppl. 53 (12/2018) on IoT use cases (having five IoT use cases

[23] https://tec.gov.in/standards-adoption-policy
[24] https://tec.gov.in/onem2m
[25] https://tec.gov.in/standards-adoption-policy

from India and one from Egypt) and Y Suppl. 56 (12/2019) on Smart city use cases (having smart city use cases from Japan, Korea, UK and India) are having significant contributions submitted by TEC.
These use cases may be implemented to create smart infrastructure, which will resolve a number of issues of the respective vertical and in turn improve the quality of life.

2. TEC participation and contributions in APT meetings:

a) Contributions were submitted and presented in APT WTSA-20 meetings, 2020 on **Resolution 98 "Enhancing the standardization of Internet of things and smart cities and communities for global development".**

b) Following contributions were prepared, submitted and presented on behalf of Indian Administration in **26th Meeting of APT Wireless Group (**AWG-26 Meeting), September 2020.

i. Proposal for working document towards a draft new APT Report on "Technology and Spectrum Management Techniques for IoT Networks"

ii. Proposal for LTE and 5G NR based V2X in Working Document Towards "Cellular Based V2X for ITS applications in APT Countries"

These contributions have been incorporated suitably in the documents under development.

3.3 TRAI recommendations on Spectrum, Roaming and QoS related requirements in Machine-to-Machine (M2M) Communications

TRAI released the recommendation on "Spectrum, Roaming and QoS related requirements in Machine-to-Machine (M2M) Communications[26]" in September, 2017 and sent to DoT for consideration. These recommendations have been accepted by DCC, DoT. Work is in progress and will help in the development of eco system in M2M/ IoT domain. Some of the important recommendations are as given below:

(a) All basic service licensees and ISP licensees shall be allowed to provide M2M connectivity including on unlicensed band, within the area of their existing authorization, barring M2M cellular services.
(b) Connectivity provider using LPWAN technologies operating in unlicensed spectrum should be covered under licensing through a new authorization under Unified License (UL) namely UL (M2M).
(c) Government, through DoT, should identify critical services in M2M sector and these services should be mandated to be provided only by connectivity providers using licensed spectrum.
(d) M2M Service Providers (MSPs) should register as M2M service providers as envisaged by DoT in its draft for public. This registration will be exclusive for the MSP and not part of existing OSP registration. Exclusive guidelines for MSP Registration should be

[26] https://trai.gov.in/sites/default/files/Recommendations_M2M_05092017.pdf

issued. MSPs shall provide details of the connectivity provider who would be providing connectivity in their M2M application.

(e) Device manufacturers should be mandated to implement "Security by design" principle in M2M device manufacturing so that end-to-end encryption can be achieved.

(f) The government should provide comprehensive guidelines for manufacturing/ importing of M2M devices in India.

(g) A National Trust Centre (NTC), under the aegis of TEC, should be created for the certification of M2M devices and applications (hardware and software).

(h) QoS: The TRAI Act, 1997 mandates the Authority to lay down the standards of quality of service to be provided by the service providers and ensure the quality of service and conduct the periodical survey of such service provided by the service providers so as to protect interest of the consumers of telecommunication services.

(i) Spectrum allocation should be technology and service neutral. No separate spectrum band is to be allocated exclusively for M2M services.

(j) In order to facilitate smooth roll out of M2M services utilizing the license exempt spectrum, 1 MHz of spectrum from 867-868 MHz and a chunk of 6 MHz of spectrum at 915-935 MHz is recommended to be delicensed.

(k) Devices with pre-fitted eUICC should be allowed to be imported only if it has the ability to get reconfigured 'Over the air' (OTA) with local subscription. GSMA approved guidelines shall be followed for provisioning of new profile remotely with 'Over-the-air' (OTA) mechanism.

(l) Devices fitted with eUICC shall be allowed in operation in roaming for maximum three years from the date of activation of roaming in the network of Indian TSP and mandatorily converted/ reconfigured into Indian TSP's SIM within the stipulated period or on change of ownership of the device, whichever is earlier. The Authority/Licensor shall review the condition later based on the developments and requirements.

(m) In case imported equipment to which the SIM/ device is fitted with such as automobile/ machines (like earth movers), arms etc. (requiring mandatory registration at local authorities such as RTO, State/ District administration) is transferred/ sold to another party before three years, the roaming device (eUICC) shall also be immediately configured with local subscription/ eUICC of Indian TSP. The KYC details of the new owner/ buyer must be compulsorily updated in the database of concerned authorities.

3.4 MoRTH

Ministry of Road Transport & Highways (MoRTH), Government of India had issued a notification on 28th November 2016 wherein Vehicle Location Tracking (VLT) Device and Emergency Buttons were mandated to be fitted in all public service vehicles with effect from 1st April, 2018. In order to standardize the specification of VLT and Emergency button across the country, AIS 140 standards were released by ARAI for MoRTH. The standard mainly includes the specifications for Vehicle Location Tracking Device (VLTD) and vehicle tracking backend system. The vehicle location tracking device and the emergency button are required to be fitted by the

manufacturers or their respective dealers or operators, as the case may be, in accordance with the AIS 140[27], as amended from time to time, till corresponding BIS Standards are notified under the Bureau of lndian Standards Act, 1986.

Subsequently, the MoRTH has notified in Gazette 5453(E)[28], Motor Vehicles (Vehicle Location Tracking Device and Emergency Button) Order dated the 25th October, 2018 which states "Whereas the Central Government is of the opinion that it is necessary and expedient so to do in the public interest to notify standards in respect of equipping or fitment of vehicle location tracking device and emergency button in all public service vehicles." The overall approach for installation of Vehicle Location Tracking Device and Emergency Button (VLT) on public service vehicles is specified in this notification.

3.5 MoHUA Policies

The objective of the Smart Cities Mission is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. The focus is on sustainable and inclusive development. Brief strategy of the Smart Cities Mission is as given below:

- Pan-city initiative in which at least one Smart Solution is applied city-wide.
- Develop Areas step-by-step – three models of area-based developments –
    - Retrofitting: Development of an existing built area greater than 500 acres
    - Redevelopment: Replace existing built environment in an area of more than 50 acres and enable co-creation of a new layout,
    - Greenfield: Develop a previously vacant area of more than 250 acres

Key Smart City features followed by Indian Smart Cities:

- Promoting mixed land use in area based development
- Creating walkable localities –reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security.
- Promoting a variety of transport options - Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;
- Making governance citizen-friendly and cost effective - increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices.
- Applying Smart Solutions to infrastructure and services in area-based development in order to make them better. For example, making areas less vulnerable to disasters, using fewer resources, and providing cheaper services.

In the context of Indian Smart Cities, the six fundamental principles are given in the following figure.

[27] https://hmr.araiindia.com/Control/AIS/14201910518PMAIS-140.pdf
[28] https://morth.gov.in/sites/default/files/notifications_document/File3406.pdf

Source: Smart Cities Mission[29]

FIGURE 8: SIX FUNDAMENTAL PRINCIPLES IN A SMART CITY

MoHUA vide letter number K- 15016/61/2016-SC-I dated 20th May 2016[30] endorsed Cyber Security Model Framework for Smart Cities prepared by National Security Council Secretariat. This defines cyber security requirements which may be necessary to be incorporated while inviting proposals/offers from the companies implementing Information Technology and applications as part of Smart Cities.

3.6 Smart Water & Solar (Kusum)

The Government of India has published the guidelines for the implementation of Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM) scheme[31] for installation of solar pumps and grid-connected solar power plants by farmers.

At present, over 30 million agricultural pumps are installed in India, out of which nearly 10 million pumps are diesel based. Over 20 million grid-connected agriculture water pumps installed in the country consume more than 17 per cent of the total annual electricity consumption of the country.

Solarization of these pumps is expected to reduce their dependence on conventional sources of energy supplied by Distribution Companies (DISCOMs) and thus reduce their burden of subsidy on agriculture consumption of electricity. This will also provide an additional source of income to farmers who will be in a position to sell the surplus power to DISCOMs.

Under this scheme, the government has planned to develop decentralized solar energy and other renewable energy generation plants of capacity up to 2 Megawatt (MW) which would enable savings in transmission system requirement and also bring down T&D losses. This scheme has three major components. Under Component-A, the government plans to establish 10,000 MW of decentralized ground or stilt mounted grid-connected solar or other renewable energy based power plants. Component-B includes installation of 17.50 lakh standalone solar agricultural pumps while Component-C deals with solarisation of 10 Lakh grid-connected agriculture pumps.[32]

[29] https://smartcities.gov.in/about-the-mission
[30] http://mohua.gov.in/pdf/58fd92b5545b85821b621a862dCyber_Securitypdf.pdf
[31] https://mnre.gov.in/img/documents/uploads/8065c8f7b9614c5ab2e8a7e30dfc29d5.pdf
[32] https://energy.economictimes.indiatimes.com/news/renewable/kusum-scheme-for-solar-uptake-by-farmers-a-fineprint/68514675

The Component-A and Component- C will be implemented initially on pilot mode for 1,000 MW capacity and 1 lakh grid-connected agriculture pumps, respectively and component B will be implemented in a full-fledged manner. After successful implementation of the pilot project of Components A and C, same will be scaled up with necessary modifications based on the learning from the pilot phase. All the three components of the scheme aim to add solar capacity of 25,750 MW by 2022.

3.7 MoHFW Digital Health Policy

Ministry of Health & Family welfare included digital health in National Health Policy released in 2017, envisaging creation of a digital health technology eco-system. NABH is working to finalize the digital health standards. In 2015, the Ministry of Health and Family Welfare has proposed to establish a National e-Health Authority (NeHA) as a promotional, regulatory and standards setting organization to guide and support India's journey in e-Health.

- To formulate "National eHealth Policy and Strategy" for coordinated eHealth adoption
- To formulate and manage all health informatics standards for India
- To lay down data management, privacy and security policies, guidelines and health records of patients in accordance with statutory provisions

3.8 Bureau of Indian Standards (BIS)

BIS is having a number of committees for finalizing standards in various areas. Some of the important committees related to ICT are listed below[33]:

- LITD 6 : Wires, Cables, Waveguides And Accessories
- LITD 9 : Electromagnetic Compatibility
- LITD 10: Power system control and associated communications
- LITD 11 : Fibre Optics, Fibers, Cables And Devices
- LITD 17 : Information Systems Security And Privacy
- LITD 27: IoT and related technologies
- LITD 28: Smart Infrastructure
- LITD 30 : Artificial Intelligence

LITD 28 has released a number of standards related to Smart cities as given below:

1. Low-Rate Wireless Networks (Adoption of IEEE 802.15.4)
2. Unified Digital Infrastructure Data Layer Part 1 Reference Architecture
3. Unified Data Exchange Part 2 API specifications
4. Smart Cities- GIS Part 1 Reference Architecture
5. Municipal Governance - Part 1 Reference Architecture
6. Municipal Governance Part 3 Property Tax Section 1 Taxonomy
7. IoT System Part 1 Reference Architecture

[33] https://www.services.bis.gov.in:8071/php/BIS_2.0/dgdashboard/published/new_subcommtt?depid=NjY%3D

IoT Reference Architecture, IoT RA IS 18004 (Part 1): 2021 has referred the TEC National standards TEC 30001:2020 to 30023:2020 as a normative/ informative references. BIS has submitted this document to MoHUA for use in Smart cities.

3.9 National Smart Grid Mission (NSGM)

National Smart Grid Mission was established by Govt. of India in 2015 to accelerate Smart Grid deployment in India.

The National Smart Grid Mission (NSGM) charter is to plan, design and support the rollout of the Smart Grid in the country. The NSGM facilitates formulation of state/utility specific Smart Grid roadmap, regulations and implementation plan. At the utility level, the NSGM, through state Smart Grid cells, engages with key stakeholders to ensure that they have the required structure and plans in place for successful implementation of Smart Grid.

Utility Preparedness: Specific to Smart Grid rollout, the NSGM will focus on utility preparedness with technology, policies and processes in place to launch and support the Smart grid intervention. The strategy includes Skill development through Smart Grid Knowledge Centre established by PGCIL at Manesar. The other aspect of preparedness is about learning through doing and NSGM has facilitated rollout of Pilot projects[34].

Advanced Metering Infrastructure (AMI): AMI is the basic building block for Smart Grid implementation as this facilitates a real time two-way communication between the consumer and the utility. This is critical for efficient flow of information between the utility and the consumer for decision making and ensuring service quality.
Distribution Automation/ Supervisory Control and Data Acquisition (SCADA): The automation of the distribution system function includes planning, construction, operations and maintenance (O&M) of the power system and interaction with the end-users as an essential function for achieving the comprehensive benefits offered by Smart Grid.
SCADA/Distribution Management System (DMS) shall be implemented along with sub-station automation in select areas for achieving comprehensive benefits associated with Smart Grid.

Microgrids and renewable integration: Country-wide microgrids rollout as a strategy for increasing access to electricity and energy generation from small-scale RE projects will also be facilitated by the Smart Grid. In this regard, it is expected that all utilities will gain experience in RE microgrid projects (capacity 1 megawatt [MW]) within a stipulated timeframe.

Electric vehicle: Smart Grid deployment encourages the adoption of EVs allowing bidirectional energy exchange between the EVs and the grid. The National Electric Mobility Mission Plan (NEMMP) works on the expansion of electric mobility by supporting recharging infrastructure and related policies. Goals related to the utilities are gaining adequate tools, experience and expertise to successfully participate in the NEMMP.

[34] https://www.nsgm.gov.in/en/sg-pilot

The NSGM goals impact the Smart Cities in a significant manner through its initiatives such as Advanced Metering Infrastructure (AMI) rollout in all towns, Network mapping, consumer indexing, Distribution automation (SCADA/DMS) in Urban census towns with population as per IPDS and support to Utilities with technological capabilities to deploy EV Infrastructure. NSGM has sponsored technical studies on emerging low power wide area communication technologies such as NB-IoT and overall ICT infrastructure for optimising the AMI and SCADA deployments[35].

[35] https://members.tsdsi.in/index.php/s/i7QMwwGk7maWks7

4 Analysis of International Standards and Guidelines

4.1 Excerpts from Singapore Standardisation:

4.1.1 Challenges related to IoT

Infocomm Media Development Authority of Singapore (IMDA) in its document has mentioned Interoperability and Standards, Licensing, Spectrum and resource allocation, Data protection and Security as the key challenges to be resolved for the proliferation of IoT. IPv6 will be a key enabler for IoT and it was ensured that all the ISPs will support IPv6. IMDA has already allocated access code 144xx for M2M services[36].

4.1.2 Key items for the development of IoT

Five vectors have been identified as critical for the proliferation of IoT[37]:

a. **Standardization of IoT Platforms:** There is increasing proliferation of platforms as both large and small players are launching solutions that make it easier to integrate IoT hardware, networks, and applications. A survey from IDC indicates that 57% of enterprise use IoT platforms. However, this has led to multiple heterogeneous platforms that are not all interoperable. Therefore, standards based platforms are required to have interoperability.

b. **Artificial Intelligence:** Predictive analytics capabilities that derive insights and predict future outcomes though machine learning solutions are increasingly becoming a key to unlock greater value from IoT networks. Thus, there is increasing convergence of AI and IoT across sectors.

c. **Analytics at the Edge:** For many applications of IoT, latency is critical and the processing time for information in the cloud and response time is too long to be meaningful. Thus, the devices at the edge of the networks (either end devices or IoT gateways) needs to be more intelligent with higher computing power and AI capabilities to do more “analytics at the edge”. This is expected to address specific industry needs.

d. **Low Power Networks:** Most existing wireless networks typically have high power requirements for devices to transmit and receive data. This has been a key challenge for IoT networks, given the scale and the low cost nature of devices. There has been an inherent trade-off between range and power efficiency. This led to the development of network standards with lower power requirements specifically geared towards IoT networks, such as NB-IoT and Bluetooth Low Energy. With increasing standardization and wide usage, more devices are likely to be built on these network standards, enabling greater scalability and positive network effects.

[36] [IMDA document on IoT and Smart cities: Challenges and opportunities for regulators, Sept 2016] https://www.tmforum.org/wp-content/uploads/2016/09/12.20-Ken-Wei-Chng-IOT-and-Smart-Cities-Chanllenges-and-Opportunities-for-Regulations.pdf

[37]https://www.imda.gov.sg/-/media/imda/files/industry-development/infrastructure/technology/technology-roadmap/annexes-a-1-future-communications-and-iot_full-report.pdf

e. Security: Security has been one of the key concerns for IoT networks, particularly in sectors like Healthcare, and Consumer applications, where privacy concerns are paramount. Security solutions tailored for IoT networks are increasingly being deployed and embedded in the underlying hardware.

4.1.3 Technology adoption roadmap for IoT

i. Platform based on standards enabling Interoperability, scalability, modularity.
ii. Intelligence- Support for AI and analytics at the edge / cloud.
iii. Security: Support for embedded security solutions like encryption, network security, security by design (Hardware & software).
iv. Low power wireless networks: support for extended battery life for the unmanned devices in which charging is not possible.
v. High speed and reliable internet in fixed and mobile devices

4.1.4 Standards related recommendations for IoT

i. **Encourage Industry to adopt Standard based Technologies including eSIM**: - It is very crucial to adopt standards-based technologies. There are several standards and standard developing bodies including IEEE, 3GPP, Wi-Fi Alliance, Bluetooth Special Interest Group (SIG), Open Mobile Alliance (OMA). Standards enable interoperability, prevent vendor lock-in and facilitate the rapid adoption of technologies. The countries shall encourage industry to work together towards adopting globally recognised standards to enable rapid growth of IoT and Future Communications technologies.
ii. **Establish a common standard based framework for Platforms to enable rapid adoption of IoT: -**Globally, platforms have been one of the key drivers for the adoption of IoT but rapid proliferation of proprietary platform has led to fragmentation. Adoption of IoT can be further accelerated with the development and adoption of standardized platform to connect the different hardware and software solutions. Well-defined technical specifications can be developed with the technology providers for standardized protocols, APIs and interfaces for the collection, management and access to services and data.
iii. Establish an ecosystem for companies to embrace cloud native architecture
iv. Enable industries to leverage innovation hubs focused on IoT and related communication technologies.

4.1.5 Smart City Use Cases

For Singapore, given the Smart Nation Initiative, Smart Cities will be a key sector of focus to develop solutions that can be launched in other global and regional markets. The four key areas for Smart Cities that is likely to witness widespread adoption of IoT and connected services: Mobility, healthcare, public safety and supply chain. These are the likely areas where Singapore has strong potential to develop technologies and solutions to support smart city initiatives to be used in Singapore and subsequently export them to other countries in the region and worldwide.

4.2 Smart City: Policy Initiatives and standardization activities in Europe

4.2.1 Excerpts from standardisation related documents of European Union: -

European Union (EU) included IoT as a key pillar under horizon 2020 work programme.[38] As mentioned in this document, there are around 450 IoT platforms in EU, which differ by technological depth, segment-focus, and technology implementation offering. These platforms require a process of evaluating the IoT platforms maturity, monetisation, interoperability and the new IoT business models. Artificial intelligence, cognitive and machine to machine (thing to thing) learning frameworks are also required for effective synchronisation and adaptability. For heterogenous coexistence of different IoT platforms, it is required for them to be based on open standards and interoperability.

Few important recommendations listed under H.2020 programme are as given below:

a. Related to standardization-

1. Considering the current lack of standardization and the variety of protocols and technologies emerging in the IoT domains, it is necessary to define a common framework of standards to enable interoperability among technologies and domains.

2. The adoption of a common IoT architecture reference model needs to be promoted among the different IoT domains and players.

3. A common data model is needed to facilitate integration (assembly of sub-systems) and interoperability (interoperation of heterogeneous sub-systems).

4. IoT platforms need to ensure data privacy, and integrity according to the data/information sensitivity.

5. High network availability with certified performance figures, are needed necessary, to make sure no sensitive data is lost.

6. Promoting and encouraging regulatory bodies (SDOs/SSOs) to strengthen collaboration, is necessary to converge into an interoperable and standardized IoT adoption

b. For "enabling" cross-sector fertilization

1. Foster the development of common IoT platforms for aggregating and interchanging data by multiple actors from different sectors and industries.

2. Foster and adopt standards for data exchange which support interoperability between different sources.

3. When standards are not sufficiently deployed, data gateways must be provided for achieving semantic interoperability.

[38] **[Create IoT Project: H2020 work programme 2016-17]** https://european-iot-pilots.eu/wp-content/uploads/2017/10/D04_01_WP04_H2020_CREATE-IoT_Final.pdf

c. For "facilitating" cross-sector fertilization

1. Define appropriate data governance models considering multiple actors accessing data: who can access which data, for what, under which conditions.

2. Foster large scale pilots connecting multiple industries for testing cross-sector IoT platforms and new cross-sector business models.

d. Related to communication technologies

1. Speed up research on enabling IoT technologies for fine tracing of goods and products throughout the full value chain, including low-cost tags for objects, energy-efficient tags (ideally running without batteries).

2. Heterogeneous existence of different communication technologies, cellular (5G/4G, LTE, etc.), Wi-Fi, LPWAN (NB-IoT, LoRaWAN, Sigfox, etc.), WSNs (ZigBee, 6LoWPAN, etc.), and satellite technologies.

3. Software defined, cognitive, artificial intelligence and machine learning based communication networks.

4. Spectrum requirements, considerations and global harmonization.

5. Networks based end-to-end security and network access management, including authorization, authentication, etc.

6. Alignment of V2X over cellular networks (3GPP RAN) LTE (Long Term Evolution) new releases (with beginning of 5G) to fulfill requirements for V2X over licensed and unlicensed spectrum and IEEE 802.11/ITS-G5-based V2X communication technology is a short-range ad hoc broadcast system developed for the exchange of object information and not for the exchange of sensor data.

7. Support for integrated cloud, mobile edge computing and edge analytics solutions in current IoT platforms.

8. Simplify the sharing and access to data (generated by connected products) from different points of the value chain to allow for better tracing and collective decision making.

9. Scalable IoT platforms integrating new components and modules for emerging industrial IoT applications, Tactile Internet and autonomous/robotic systems that require integration of actuators and much faster reactivity at the edges of the networks.

4.2.2 Standardisation activities in ETSI

ETSI through its various technical committees has been developing standards related to smart cities. Few are given below:

i. ETSI Smart M2M committee (TC SmartM2M) has analyzed the impact of smart cities on the Internet of Things in an ETSI Technical Report (TR 103 290). ETSI TC SmartM2M has also released SAREF (Smart Applications Reference Ontology) specifications for various sectors including Automotive, e-Health, wearable, water,

Energy, Environment, Building, Smart Cities, Industry and Manufacturing, and Smart Agriculture and Food Chain. The ETSI Smart Applications Reference (SAREF) ontology is intended to enable interoperability between solutions from different providers and within various activity sectors in the Internet of Things (IoT).

ii. ETSI Access, Terminals, Transmission and Multiplexing committee (TC ATTM) and particularly the working group ATTM SDMC (Sustainable Digital Multiservice Communities) is working towards the creation, development and maintenance of standards relating to the relationship between deployment of ICT systems and implementation of services within cities and communities. This committee is working on efficient ICT waste management in sustainable communities.

iii. ETSI Industry Specification Group on Operational energy Efficiency for Users (ISG OEU) is supporting development of standards for efficient sustainable communities, e.g., efficient engineering and global Key Performance Indicators for green smart cities, covering both residential and office environments.

iv. ETSI ISG on cross-sector Context Information Management (ISG CIM) develops technical specifications and reports to enable multiple organisations to develop interoperable software implementations of a cross-cutting Context Information Management (CIM) layer, for smart cities applications and beyond.

v. ETSI's Human Factors Technical Committee has released a Technical Report giving an overview of standardization relating to the needs of inhabitants of (or visitors to) smart cities and communities. The Report explores how links between local communities and standardization can be improved and make appropriate recommendations to standards bodies, cities and policy makers.

4.2.3 Standardization activities in ETSI, CEN and CENELEC

European Standardization Organizations (ESOs) i.e., ETSI, CEN & CENELEC are also working on standardisation activities in emerging technologies such as Artificial Intelligence (AI), Internet of thing (IoT), Machine to Machine (M2M) and Blockchain etc. associated with smart cities in close cooperation with ISO, IEC , ITU and with other SDOs on related activities.

Since 2012, the CEN-CENELEC and ETSI Coordination Group 'Smart and Sustainable Cities and Communities' is in place to advice on European interests and needs related to standardization on Smart and Sustainable Cities & Communities. Later on this group has been transferred into a long- term joint group "CEN-CENELEC-ETSI Sector Forum on Smart and Sustainable Cities and Communities (SF-SSCC)"[39] that acts as an advisory and coordinating body for European standardization activities related to smart and sustainable cities and communities.

The CEN-CENELEC-ETSI Sector Forum on Smart Cities and Communities created a mapping which aims at listing relevant standardization activities and published standards, relevant for the development of Smart Cities. It also lists the different policy and research initiatives in this respect. This mapping is designed as a living document, to which any interested stakeholder can contribute.

CEN, CENELEC and ETSI have more than **100 technical committees** developing standards in support to the deployment of smart cities (energy management and energy efficiency,

[39]http://www.cencenelec.eu/standards/Sectors/SmartLiving/smartcities/Pages/SSCC-CG.aspx

telecommunication, data management, transport, healthcare, construction, cybersecurity, household appliances, etc.). Moreover, CEN, through its members, supports the activities of ISO/TC 268 'Sustainable Cities and Communities'.

4.2.4 Smart Cities Marketplace

The Smart Cities Marketplace was created by merging two former platforms, the "Marketplace of the European Innovation Partnership on Smart Cities and Communities (EIP-SCC Marketplace)" and the "Smart Cities Information System (SCIS)". It aims to bring cities, industries, SMEs, investors, banks, researchers, and many other smart city actors together to improve citizens' quality of life, increase the competitiveness of European cities and industry as well as to reach European energy and climate targets. Marketplace mainly focuses on the following areas of operations for providing smart city solutions[40].

- sustainable urban mobility
- sustainable districts and built environment
- integrated infrastructures and processes in energy, information and communication technologies and transport
- citizen focus
- policy and regulation
- integrated planning and management
- knowledge sharing
- baselines, performance indicators and metrics
- open data governance
- standards
- business models, procurement, and funding

4.2.5 European Energy Research Alliance Joint Programme Smart Cities (EERA JP SC)

EERA Joint Programme on Smart Cities aims to develop new scientific methods, concepts and tools designed to support European cities in their transformation into smart cities. The key focus is on large-scale integration of renewable energies and enhanced energy efficiency, enabled through smart energy management at city level[41]. It is structured in four sub-programme as listed below:

I. Energy in Cities takes an integrated approach towards urban energy planning and transformation processes.
II. Urban Energy Networks concentrates on the intelligent planning, design and operation of thermal and electrical networks in cities.
III. Energy-efficient Interactive Buildings focuses on sustainable buildings as interactive elements of the urban energy system.
IV. Urban City-related Supply Technologies addresses renewable supply technologies and their integration into the urban infrastructure.

[40] https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en#related-policies

[41] https://www.eera-sc.eu/

4.3 Smart Cities initiatives in South Korea

South Korea has initiated smart cities projects and has become one of global leaders in this space. The city of Songdo is one of the world's first 'smart cities' where the development activities started in 2003. The city is equipped with ubiquitous wireless networks, pervasive RFID, sensor networks, CCTV, telepresence systems, etc. These technological systems enable Songdo to provide its residents with smart services such as effective traffic management, smart health care or smart home management. Numerous sensors are installed throughout the city to monitor air pollution, water pollution, traffic and city facilities[42].

oneM2M based platforms have already been deployed in Busan and Goyang smart cities of South Korea. Daegu is having daily healthcare platform based on oneM2M and ISO/ IEEE 11073 standards[43].

4.4 Smart City in Hong Kong

The Government published the Smart City Blueprint for Hong Kong in December 2017, setting out 76 initiatives under six smart areas, namely "Smart Mobility", "Smart Living", "Smart Environment", "Smart People", "Smart Government" and "Smart Economy". It also includes the digital infrastructure projects and other major initiatives such as Faster Payment System, installing free public Wi-Fi hotspots, and the "iAM Smart" one-stop personalised digital services platform etc.

Smart City Blueprint for Hong Kong (Blueprint 2.0)[44] published in 2020 puts forth over 130 initiatives which continue to enhance and expand existing city management measures and services with the aim to bring benefits and convenience to the public so that residents can better perceive the benefits from smart city innovation and technology (I&T) in their daily lives. It also includes a chapter on "Use of I&T in Combating COVID-19", which covers measures already undertaken and being planned.

4.5 Smart Cities initiatives in Japan

The Japanese government is promoting the Society 5.0 concept for the attainment of the SDGs in order to realize a smart society that brings a richer life to people by highly integrating cyberspace and physical space.

Society 5.0 is defined by the Japanese Government as "A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space."

For the realization of Society 5.0, in order to create new value by combining cyber space and physical space, Japan aims to transform into a society that creates a dynamic virtuous cycle that constantly changes. In this way, a digital twin with high-quality and diverse data is created in cyber space, and physical space is changed based on this digital twin while actively using AI and the results are reproduced in cyber space.
Smart cities are the initiatives to solve social issues, such as energy supply, traffic congestion, disaster preparedness, and healthy longevity, through digital transformation. It is not simply

[42] https://www.aboutsmartcities.com/songdo-smart-city/
[43] https://www.indiaeu-ictstandards.in/wp-content/uploads/2017/04/oneM2M-Smart-Cities-in-Korea-KETI-v4.pdf
[44] https://www.smartcity.gov.hk/modules/custom/custom_global_js_css/assets/files/HKSmartCityBlueprint(ENG)v2.pdf

about introducing AI, IoT and other digital technologies to social infrastructure, but aims to induce a digital transformation and solve social issues.[45]

An example of smart city implementation is Takamatsu, Kagawa Prefecture, Japan where cross-domain data utilization is achieved. In Takamatsu, real-world data is collected by means of IoT in the fields of disaster preparedness and tourism, both of which are high priority areas, and a system is developed that visualizes data and a FIWARE-based data utilization platform that can also be utilized by other industries. This has led to an actual advantage in terms of taking early action.

The smart cities embodying Society 5.0 are developed across Japan and they involve the participation of various stakeholders including citizens to resolve regional issues.

4.6 Smart Cities initiatives in Dubai, UAE

As part of Dubai's vision to become a smart sustainable city, their governance model brings together multiple stakeholders to drive growth and promote the use of smart services, launched smart city initiative in 2014. Active participation by citizens and establishing private–public partnerships are also elements of the City's governance strategy.[46]

Dubai is the first city in the world to have analyzed the smartness and sustainability of its urban services taking the Recommendations ITU-T Y.4901/L.1601 and ITU-T Y.4902/L.1602 as reference. Within the smart city framework, Dubai has utilized the Smart Sustainable Cities KPIs contained in ITU-T's Recommendations ITU-TY.4901/L.1601 and ITU-T Y.4902/ L.1602 to evaluate the implementation of their smart city initiatives. Dubai smart city project became the part of the on-going standardisation activities for smart sustainable cities within ITU.

Recommendations-

1. Cities should define and continually update their city profile and boundaries in order to facilitate the scope of the KPI analysis to a homogeneous city model.
2. Cities should reinforce the process of clarification of the boundaries of the KPIs reported on a national or city level to avoid data deviations.
3. Cities should work in coordination with different entities and facilitate interaction between those institutions responsible for KPIs that could influence a particular dimension or sub dimension.
4. Cities should work closely with the relevant entities to ensure that the aim of the KPI is mutually understood. This will help with the overall collection process and improvement of future KPIs.
5. Cities should suitably adapt the ITU KPIs collection process to their requirements and procedures and to the mechanisms used by the entities to collect primary data.
6. Cities should develop and implement internal quality control mechanisms to ensure the consistency of the data reported.
7. Cities should identify and differentiate the data sources and data owners of the different KPIs and establish required procedures. This will allow for the identification

[45]https://www.nec.com/en/global/techrep/journal/g18/n01/pdf/180102.pdf
[46]https://www.itu.int/en/publications/Documents/tsb/2016-DubaiCase/files/downloads/Dubai%20Case%20Study-410059-FINAL.pdf

of data gaps, avoid duplication, and help improve the data quality.

8. Cities should determine the frequency of data collection for the KPIs and try to standardize and coordinate the deadlines with the different entities for the reporting process.
9. Cities should define a general protocol to standardize the process of data collection based on surveys. Cities interested in initiating the KPI data collection process are also encouraged to collect all KPIs on an annual basis, with the exception of KPIs that are collected every two years in consideration of the survey collection period.
10. Cities may wish to establish a "lessons learned process" with inputs from all entities involved to review and improve the data collection process.
11. Cities should consider using multiple sources internally, which can yield a more complete picture for the KPI verification process and also build credibility for the smart city project. By collecting information from multiple sources, it is also possible that one source of data will compensate for a weakness in another source.
12. Cities should establish the initial process for defining smart-sustainable city targets and utilize the KPIs of Recommendations ITU-T Y.4901/L.1601 and ITU-T Y.4902/L.1602 as referential inputs for the same.
13. Within the smart city framework, Dubai has utilized the Smart Sustainable Cities KPIs contained in ITU-T's Recommendations ITU-T Y.4901/ L.1601 and ITU-T Y.4902/ L.1602 to evaluate the implementation of their smart city initiatives.

4.7 Standardisation activities in global SDOs (Standards developing organisations)

At International level, ITU, oneM2M, IEEE, ISO/IEC JTC1 SC41, 3GPP, ETSI etc. are working to create standards in IoT/ ICT and Smart City domain. International standards may provide crucial guidance, and technical and policy recommendations that urban stakeholders can use to set their city's priorities, navigate global challenges and implement innovative solutions to accelerate digital transformation and make cities and communities, and ultimately countries, smarter and more sustainable.

4.7.1 International Telecommunication Union (ITU):

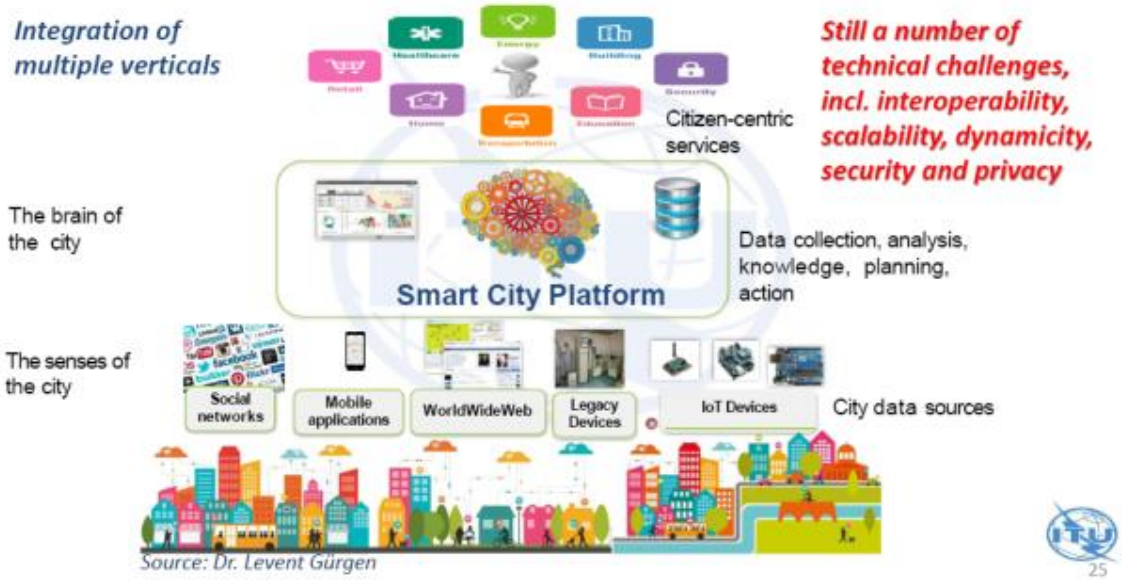
ITU is the United Nations specialized agency for Information and Communication Technologies (ICTs). ITU is having around 193 member states and over 700 private sector entities and academic institutions as members. ITU-T created a new Study Group (SG)-20 to work on IoT and its applications including Smart Cities and communities in year 2015. ITU-T SG-20 is broadly working on the following items / question areas:

- Q1/20: Interoperability and interworking of IoT and SC&C applications and services
- Q2/20: Requirements, capabilities and architectural frameworks across verticals enhanced by emerging digital technologies
- Q3/20: IoT and SC&C architectures, protocols and QoS/QoE
- Q4/20: Data analytics, sharing, processing and management, including big data aspects, of IoT and SC&C

- Q5/20: Study of emerging digital technologies, terminology and definitions
- Q6/20: Security, privacy, trust and identification for IoT and SC&C
- Q7/20: Evaluation and assessment of SC&C

ITU-T SG-20 is also having the focus group on Data processing & management (FG DPM); and Artificial intelligence (AI) and IoT in digital agriculture (FG AI4A).

ITU has defined Smart city as a super application domain of IoT and the same has been shown in the figure below:



Source: [ITU]

FIGURE 9: SMART CITIES AS SUPER APPLICATION DOMAIN OF IOT

To address the various issues/ challenges related to the standardisation in IoT and Smart cities, ITU-T through its study group ITU-T SG-20 has released a large range of standards on Devices / Sensors, Gateways, Platforms, Big data, Open data, Smart data Governance, Frontier technologies, Use cases, Key performance indicators (KPIs), city planning, stakeholder's engagement etc. (Related standards available in annexure -1) and the work is in progress to develop more standards.

ITU-T standards may be used to accelerate the deployment of the Internet of things (IoT), artificial intelligence (AI), digital twin, blockchain and other emerging technologies in smart cities eco system. These standards provide necessary guidance to build a trusted infrastructure capable of supporting a large number of digital applications, overcoming silos in cities and aligning technologies, to actualize global commitments under the Sustainable Development Goals, especially SDG 11: Sustainable Cities and Communities.

As mentioned in section 2.2, U4SSC has developed key performance indicators (KPIs) **for Smart Sustainable cities based on ITU standards** ITU-T Y.4903, refer **annexure-3).** More than 150 cities across the globe are evaluating their progress towards Smart Sustainable Cities objective and SDGs using these KPIs. Some of the cities are Dubai, Singapore, Wuxi (China), Moscow (Russia), Valencia (Spain), Pully (Switzerland) etc. More details may be accessed using link *https://www.itu.int/en/ITU-T/ssc/united/Pages/default.aspx*.

Three case studies related to the implementation of the KPIs for SSC in Dubai, Singapore[47] and Moscow[48] have been published and are available on ITU website. Case study of Dubai has been detailed in section 4.6.

4.7.2 ISO / IEC

ISO/IEC JTC 1 on "Information Technology" is a joint technical committee (JTC) of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Its purpose is to develop, maintain and promote standards in the fields of Information and Communication Technology (ICT). **ISO/IEC JTC 1 SC 41: Internet of things and digital twin** is working for the development of standards on IoT and related technologies. Some of the important outcomes are as given below:

- ISO/IEC 30141:2018 Internet of Things (IoT) — Reference Architecture
- ISO/IEC 21823-1:2019 Internet of things (IoT) — Interoperability for IoT systems — Part 1: Framework
- ISO 37122:2019 Sustainable cities and communities — Indicators for smart cities

4.7.3 Joint Smart Cities taskforce:

ITU, ISO and IEC have established a Joint Task Force to coordinate international standardization for smart cities and communities to build synergies in the ongoing work. This task force represents an integrated response towards achieving UN SDG11 'Make cities inclusive, safe, resilient and sustainable goals'.

[47] https://www.itu.int/en/publications/Documents/tsb/2017-Implementing-ITU-T-International-Standards-to-Shape-Smart-Sustainable-Cities-The-Case-of-Singapore/files/downloads/418504- ITU_Case-Study-Singapore-E.pdf
[48] https://www.itu.int/en/publications/Documents/tsb/2018-U4SSC-Case-of-Moscow/files/downloads/The-Case-of-Moscow-E_18-00503.pdf

5 Review of Current Smart Cities IoT/ICT Ecosystems

5.1 Study of Cross-Sector Requirements related to Telecom and IoT / ICT for Smart Cities in India

The following positive results are expected to be addressed by the proposed Smart Cities Projects / Interventions:

1) Efficient traffic management
2) Efficient transport management
3) Enhanced safety and security
4) Better management of utilities and quantification of services
5) Asset Management
6) Disaster Management and Emergency Response
7) Integration with all existing, proposed and future services as identified by a Smart City including but not limited to (with provision for future scalability):
    i. CCTV based Real Time Public Safety system
    ii. Adaptive Traffic Control System
    iii. Intelligent Transport Management System
    iv. Solid waste management
    v. Smart Parking
    vi. Panic Button/Emergency Call Box
    vii. Public Address System
    viii. Environmental sensors
    ix. GIS based System
    x. Citizen Application Mobile App and Web Portal
    xi. Smart Poles
    xii. Smart Lighting
    xiii. Smart Governance- including service delivery gateway like National e-Governance Service delivery Gateway (NSDG), State e-Governance Service delivery Gateway (SSDG), Mobile e-Governance Service delivery Gateway (MSDG) etc.
    xiv. City Wi-Fi network
    xv. Tele- medicine/ e-Health
    xvi. Tele-education
    xvii. Smart metering (electricity/ water/ gas)

8) Smart Policing and Integrated Module:
    i. Crime and Criminal Tracking Network and Systems (CCTNS)
    ii. e-Prison
    iii. e-Courts
    iv. Interoperable Criminal Justice Systems (iCJS)

It is critical to be able to integrate directly or through bridge with all available applications which are launched by Smart cities time to time.

9) Future Services

i. Water SCADA
ii. Sewerage
iii. Storm water drainage
iv. Disaster Management
v. Grievance Management
vi. Fire

The various applications of Smart Cities enabled by IoT/ICT are summarised in the table below:

TABLE 1: IOT/ ICT ENABLED APPLICATIONS IN SMART CITIES

Sr. No.	Vertical	Vertical related applications
1	Smart City	Intelligent transport System, Waste management, Street Light control system, Water management, Smart Parking, Intelligent buildings, Safety & Security, air quality monitoring
2	Automotive/ Intelligent Transport System	Vehicle tracking, emergency call system (e-call: 112 adopted in India), Cellular V2X applications, traffic control, Navigation, Infotainment, Fleet management, asset tracking, manufacturing and logistics
3	Utilities	Smart metering (electricity/ water/ gas), smart grid, Electric line monitoring, gas/ oil / water pipeline monitoring, sewage monitoring
4	Health Care	Remote monitoring of patient after surgery (e-health), remote diagnostics, medication reminders, Tele-medicine, wearable health devices
5	Safety & Surveillance	Commercial and home security monitoring, Surveillance applications, Video analytics and sending alerts, Fire alarm, Police / medical alert
6	Smart Home	Security & alarm, Connected appliances, Smart lighting system
7	Agriculture	Remotely controlled irrigation pump, Crop Management, Soil analysis, livestock management
8	Smart Manufacturing	Proactive maintenance of machines, Shop floor monitoring, Industry automation

An IoT-based infrastructure, enabled using ICTs, can continue to play a pivotal role in SSCs by functioning as a platform for the aggregation of information and data that can help government officials and citizens understand how the city is functioning in terms of resource consumption and services.

5.2 IoT / ICT enabled Smart City solutions

5.2.1 Key Technologies for IoT/ICT enabled Smart City Solutions

IoT use cases are significantly enabled by the disruption in several technology areas such as sensor networks, Location Based Services (LBS), wired and wireless communication technologies (cellular and non-cellular), Artificial Intelligence (AI), Machine Learning (ML), Big Data Analytics, Cloud Computing, Edge/Distributed Computing and Blockchain. Communication technologies have been described in detail in Section 5.3 and AI/ ML, Digital Twin etc. in Section 5.4.

5.2.2 Smart City ICT components

TABLE 2: ICT COMPONENTS IN A SMART CITY

Sr. No.	Components	Scope of work - brief description
1	City Communication Network	▪ It is critical that the City uses Optical Fibre Cable (OFC) and cellular network of the telecom service providers, LPWAN (Low power wide area network) from the concerned service provider for the smart city project. ▪ Make a detailed survey of available OFC network of Telecom Service Providers & electrical supply network availability and GIS mapping of proposed locations of all CCTV cameras, Smart Bus Stops, IoT Sensors (Environment, etc.), Display Signage, Traffic Lights, Solid Waste Management Infrastructure, etc. in order complete the various components of smart city projects.
2	Integrated Command and Control Center (ICCC)	▪ It is critical that the City Command and Control Center be the central repository for management and monitoring of all ICT based Smart City components such Solid Waste Management system, smart street lighting control system, Wi-Fi, Smart Transport, Smart Bus Stops, CCTV Surveillance, Digital Signages, IoT Sensors (Environment, etc.), and Public Information System (PIS) and all other smart city applications will be integrated, centrally monitored, tracked and managed from the Operations Command Center ▪ It is critical that the CCC be ergonomically designed with area for video wall, operators, offices, conference room, all other amenities, etc.
3	Data Center and Disaster Recovery	▪ It is critical that the City setups its own Data Center, Disaster Recovery Center & Data Backup storage facility may be in the cloud.

4	City and Enterprise GIS Solution	The broad objective is to develop a comprehensive GIS Application for planning, management and governance in context of entire functioning of the organization. The major activities of the departments to be supported by the system are as follows: ▪ Creation and Updating of Geospatial Data – Area Based Development (ABD) Supply of Enterprise GIS Platform Suit – Pan-City ▪ Design and Develop Enterprise Web GIS Municipal Application for all Departments in the Pan-City ▪ Design and Develop Geo-enabled Mobile Application for the Pan -City
5	CCTV based real time Public Safety System	▪ CCTV based real time public safety system is a security enabler to ensure public safety ▪ Install CCTV cameras at various locations across the city for safety along with Public Address System and Variable Message Signboard (VaMS), Emergency/Panic Box System, etc.
6	Intelligent Traffic Management Solution	▪ Install CCTV cameras and traffic violation sensors at various locations across the city for traffic management & enforcement system like RLVD/ ANPR, Speed Detection, etc.
7	Environmental Sensors	Smart environmental sensors will gather data about pollution, ambient conditions (light, noise, temperature, humidity and barometric pressure), weather conditions (rain), levels of gases in the city (pollution) and any other events on an hourly and subsequently daily basis. It is for information of citizens and administration to further take appropriate actions during the daily course/cause of any event.
8	ICT Enabled Solid Waste Management	Install GIS/GPS enabled Solid Waste Management System to provide end to end management & monitoring of garbage collection and processing
9	Adaptive Traffic Management System	Install system for control & management of traffic by controlling the traffic signals on certain stretch of road with sensor based automation of signals
10	Integration Components	Integrate the following system with the Integrated Command and Control Center (present and in future): ▪ E-Governance System ▪ Smart LED Lighting ▪ Smart Bus Stops ▪ SCADA System ▪ Sewage System

		▪ WiFi Hotspots ▪ Citizen Engagement Applications for a Smart City
11	Interoperability	Interoperability should be available at Device, Network, Application and Platform functional level. It is critical that Platforms have the feature of Common Service layer for sharing of data across verticals. It is expected that smart city platforms be interoperable with other smart city platforms and use open interfaces for sharing of data [ITU-T Recommendation Y.4200], [ITU-T Recommendation Y.4201], [ITU-T Recommendation Y.4413]

5.3 Communication Network for Smart City

Communication technologies will play a crucial role in the development of Smart Cities for connecting smart devices and transmitting data in real time.

Smart cities are characterized by their unique application needs, which may utilize different communication technologies and modelling methodologies as per the requirement of each smart city. Smart Cities may comprise tens of thousands of smart devices in different types of use cases, among which some applications will require high bandwidth (e.g. surveillance cameras) while other may require low bandwidth (e.g. only few Kbps for transmitting data from panic button of a cab/ bus).

The communication network in a smart city is a mixture of wireless and wireline networks. A large number of widely different communication technologies co-exist such as Wired (OFC in backbone network as well as in access network, Fixed Line Broadband), Wireless (Cellular/ Non-cellular), LPWAN technologies and Low Power Wireless technologies etc., each operating at a different trade-off point between communication ranges, energy consumption and throughput. The wireless connectivity is predominantly for sensors and low bandwidth applications with the primary focus being coverage. The wireless networks are serviced from Base Stations for Cellular and Gateways for other Low-Power Wide Area Networks. These wireless aggregation nodes are connected via the wireline connectivity to the Service Network. The wireline network also carries data intensive, video based applications like city surveillance and public Wi-Fi.

5.3.1 Backhaul for Smart City Communication Network

Backbone network of a Smart City is majorly created using Optical Fiber Cable (OFC) as it provides secure, reliable, scalable, manageable, interoperable, and resilient network connectivity for all requirements.

Cameras for city surveillance and the devices for adaptive traffic management should be planned to be connected on high bandwidth & reliable network such as OFC for transmitting video / data in real time. For vehicle location tracking services, cellular connectivity from the Telecom Service Providers is being used. In waste management, QR code and the smart phones are widely used which eventually connect to the wireline network using Wi-Fi or Mobile data.

High Level Design Schematic of Optical Fiber Cable Based Backhaul Systems is depicted below:

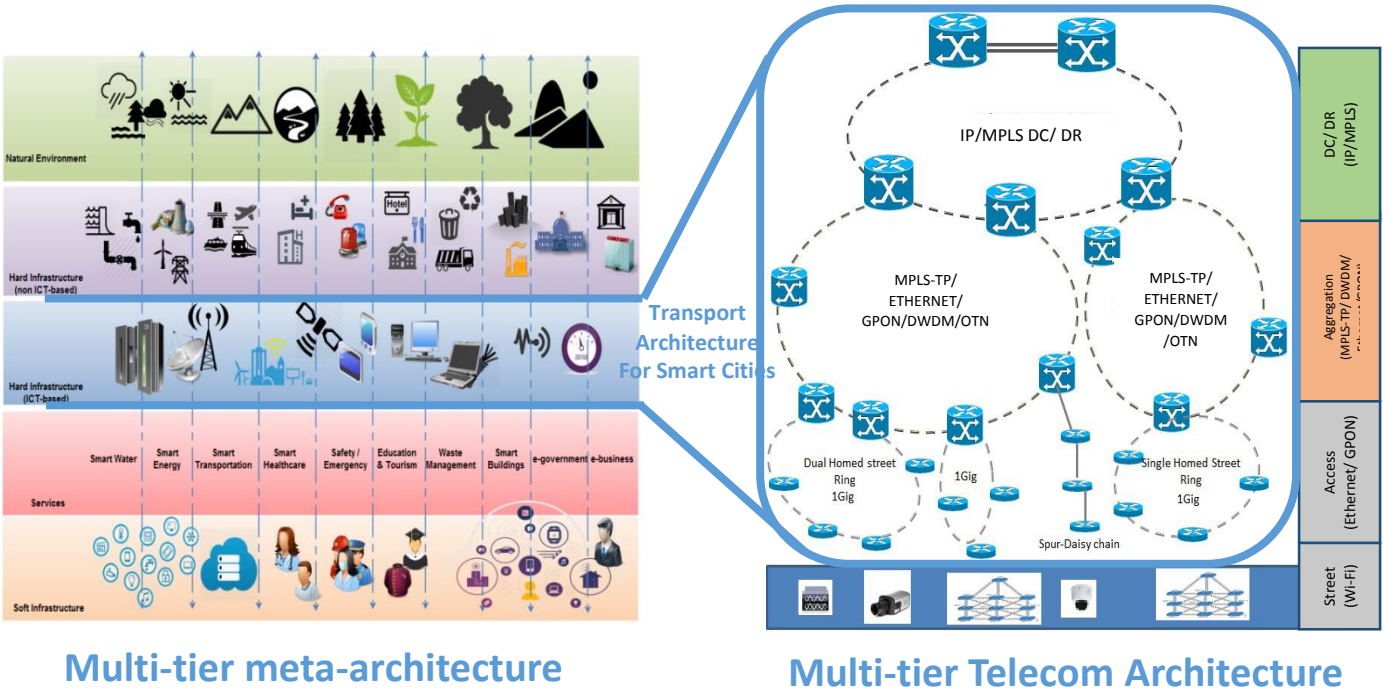


FIGURE 10: HIGH LEVEL TELECOM ARCHITECTURE IN A SMART CITY

Design considerations applied for developing the network backbone are:

- High performance: the network should provide better user experience while connecting with Citizens, Government, Business, and Communities. The system should be up and running without any single point of failure as per the demands of various mission critical applications running on the network. Considerations like ring, Hub-spoke, partial mesh topology at appropriate layers of the Network to be ensured for availability greater than 99.99%.
- Scalability: it is critical that the network shall be scalable to future growth of smart city initiatives. It is also important that the network infrastructure supports these scalability requirements. The last mile connectivity is also expected to be able to meet future requirements.
- Security: it is critical that the network has built-in security features so that network access is controlled. Access control is critical to be implemented at all levels. In the Network Operation Center (NOC) and for internet access Firewall, Intrusion Protection System and VPN solutions are critical to be employed to prevent attacks from hackers and secure the systems effectively. For the field area network, it is essential that all connected devices be authenticated prior to gaining network access.
- Manageability: it is critical that the entire network be seamlessly managed with a centralized network management software. It is critical that all the network components be manageable using open standard management protocols such as SNMP (simple network management protocol) and using standard interfaces like CLI (command line interface) with authenticated access
- Fault tolerance and resiliency: the network is expected to have built-in redundancy features for providing high availability. Redundant connectivity is critical to be proposed for all locations to ensure that single link failure does not affect the functionality. Similarly, equipment level redundancy is critical at DC, DR and Aggregation Level.

- Intelligence: it is critical that the network be capable of supporting Quality of Service (QoS) features to prioritize the traffic based on the application and handle the traffic accordingly.
- Interoperability: it is critical that all products be open standards based and it is expected they are interoperable with different vendors' products following industry standards, in order to avoid vendor lock-in.

Based on the design objective, geographical spread and the expected usage, the following technical features are envisaged for the network backbone:

- A protocol independent network, designed to carry multi-protocol traffic.
- Capable of offering multiple-services with well-defined service attributes and a way to monitor these services. The O&M (Operation and Management) ability is critical to trouble shoot the networks and enforce Service Level Agreements (SLAs) between the stake holders.
- Connectivity at the Ethernet Layer so as to realize transport and VPN service for IPv4 and IPv6 over the same infrastructure and handoff.

The Fiber-Optic backbone is a critical aspect of the smart city and also an asset that requires investment in terms of laying the fiber (preferably underground) and maintaining it. Smart city SPVs may look at various models and evaluate them with respect to their decision metrics. The options are mentioned below:

A. Leveraging Telecom Service Provider (TSP) infrastructure:

Since most cities have telecom infrastructure (OFC, Mobile BTS towers etc) already available. Smart city SPVs may enter into agreements with the TSPs to lease out the telecom resources (Bandwidth, dark fiber, space on tower etc.) for providing services for Smart City. Of course, getting a reasonable commercial agreement and the city being able to enforce SLAs is critical in making this model successful. Perhaps easing the right-of-way charges could motivate the TSPs to increase the fiber penetration and provide cores/bandwidth to use. In the case of leasing dark fiber the city still has to get the right active networking equipment deployed. In the case of connectivity services, a standard service template, SLA monitoring and enforcement is required.

B. Creating a City-owned Fiber Optic Network (FON):

Some cities view their investment in a city-owned Fiber Optic Network as creating an asset that can not only be used for the Smart City use, but also can be monetized and used as a magnet to attract business growth in the city. With proper coordination between the city services (water, gas, electricity, sewer, drainage etc.) the fiber can be laid when civil works for these initiatives are being undertaken. The technology that the city deploys should be universal and able to support newer network architectures based on standards. Similar to the case of the TSP networks, a low-cost Access and Aggregation based on Carrier Ethernet/Layer1/Layer0 technology and an intelligent IP/MPLS core is the right architecture.

C. Using a combination of TSP Services and City Owned FON:

This is a combination of the above, perhaps the result of business constraints or lack of fiber capacity available with the TSP for city use that need to be addressed from the

very start of deployment. The mixed use case also serves to understand the transition from a TSP led initial deployment to a city-owned fiber model, as the reach of city fiber increases organically with each city initiative to improve infrastructure.

The above also aligns very well with the standardized definition of Ethernet Connectivity Services by the MEF (Metro Ethernet Forum), which is followed by both Service Providers and Equipment vendors to have a common definition of Ethernet Services. These Ethernet services have well defined functionality and service attributes and allow for the city to ask for these services from the TSP. The TSP can use any technology to offer these services as long as they meet the service definition and pass the certification tests.

Standardized Ethernet services definitions are available for

- E-Line Service: Point-to-point Ethernet connectivity, port-based or VLAN-based
- E-LAN Service: Multi-point Ethernet connectivity, port-based or VLAN-based
- E-Tree Service: Point to Multi-point Ethernet connectivity, port-based or VLAN-based

Some of the typical mapping of standard MEF services with respect to smart city services are listed below for reference:

S. No.	Smart City Service Type	Network Service Mapping/ Technology
1	Video Surveillance	Pt-to-Pt (E-Line – Carrier Ethernet/GPON)
2	Smart Lighting	Pt-to-MP (E-Access -> Carrier Ethernet/ GPON)
3	Smart Traffic Control/Parking	Pt-to-MP (E-Access- Carrier Ethernet/ GPON)
4	Smart Waste Management/Water Metering	(MP-to-P – from sensors to Control & Command center) – ELine
5	E-Governance (Similar to ATM connectivity)	Hub & Spoke (E-Access -> Carrier Ethernet/ GPON)

- These Ethernet services allow any IP or non-IP network overlay and solution to be created by the customer offering great flexibility and future-proofing. The Ethernet service is agnostic to the type of IP traffic, IPv4 or IPv6, MPLS or non-MPLS, unicast or multicast. The smart city has complete control of its IP-network overlay which includes its addressing and protocols, the endpoints and the application servers that are connected to it.
- By using a lower-layer of the networking stack we can ensure support for multiple higher-layer services to ride over it. Different layers in a networking stack are listed below-

a. **Sensors/ Street layer (Access Layer):** Devices at the street layer will be outdoor network access point's gateways for smart street light LED, environmental sensors etc.
One key technology is PoE (Power over Ethernet) which allows an Ethernet cable to connect the devices for traffic backhaul as well as to power them. Of course, as with any electrical cabling the appropriate shielding of exposed wiring is critical. The use of Fiber in the Access layer using either Ethernet switches or GPON is recommended. TEC has issued GRs for both types of equipment which should be followed. Various GRs/ IRs/ ERs issued by TEC have been listed in Annexure-5.
By deploying GPON technology (Industrial Grade PoE+ ONT) in this layer, multiple devices like CCTV Cameras, smart devices (Outdoor Wifi Hot spots, Smart Street lighting, pollution monitoring, Waste Management sensors) will be connected for collecting the real time user/ sensor data. This information will be transferred to aggregation layer thereafter carried towards the core. GPON technology offers the advantage of having no active element between any nodes in last mile of access layer. This is very important especially in security surveillance type of environments where once surveillance device is not inter-dependent on another device to eliminate complete network intrusion/compromise. The schematic depicting Access layer through GPON is given below:

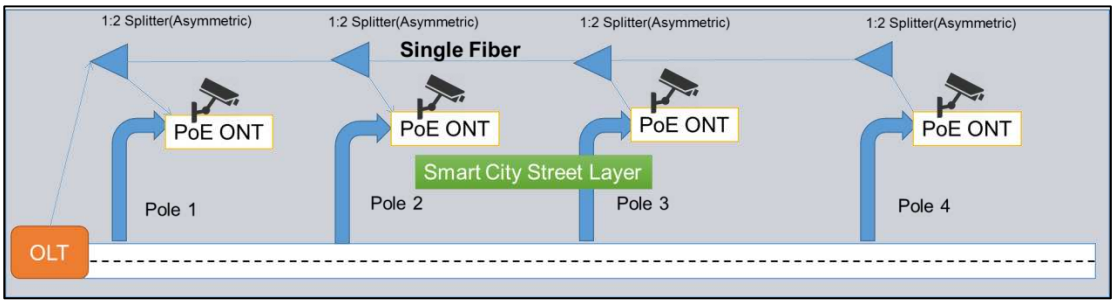


FIGURE 11: ACCESS LEVEL GPON BASED TELECOM ARCHITECTURE IN A SMART CITY

b. **Aggregate network layer (Aggregation Layer):** It acts as an aggregate layer comprising of high bandwidth telecom equipment connecting to the core and other locations used for monitoring and managing the infrastructure. As a common practice, 4~8 access rings/ spurs will terminate at one aggregate node. Deterministic paths are envisaged in packet network at this layer to localize the faults efficiently and control the convergence time. This is an important layer as it acts as buffer between access/edge layers and core layers. Aggregate Layer should be self-sustained, having resilient architecture, with least dependency on the Core Layer. Network managers use this layer often to provision new services, lower layer connectivity and complexity should be moderate only with point and provision functionality.

c. **Core layer:** The core will consist of two packet-optical core nodes co-located for the parenting of the aggregation switches & to handover traffic to the Data Center where application servers will be hosted. It is preferable to have the core network leased from Telecom Service Provider in view of its robustness & complexity.
Schematic of the Carrier Ethernet enabled GPON based OLT Ring Architecture with Industrial grade PoE+ architecture is depicted in the figure below

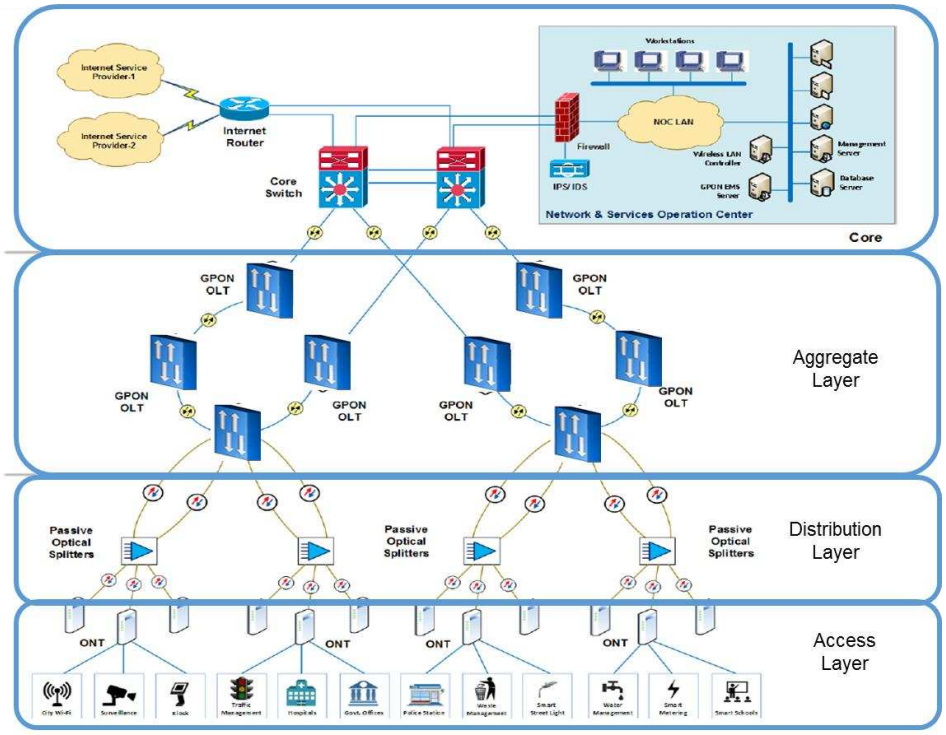


FIGURE 12: COMPLETE VIEW OF GPON BASED TELECOM ARCHITECTURE IN A SMART CITY

Schematic of the Carrier Ethernet Switches Based Architecture with Industrial grade PoE+ Switches is depicted in the figure below:

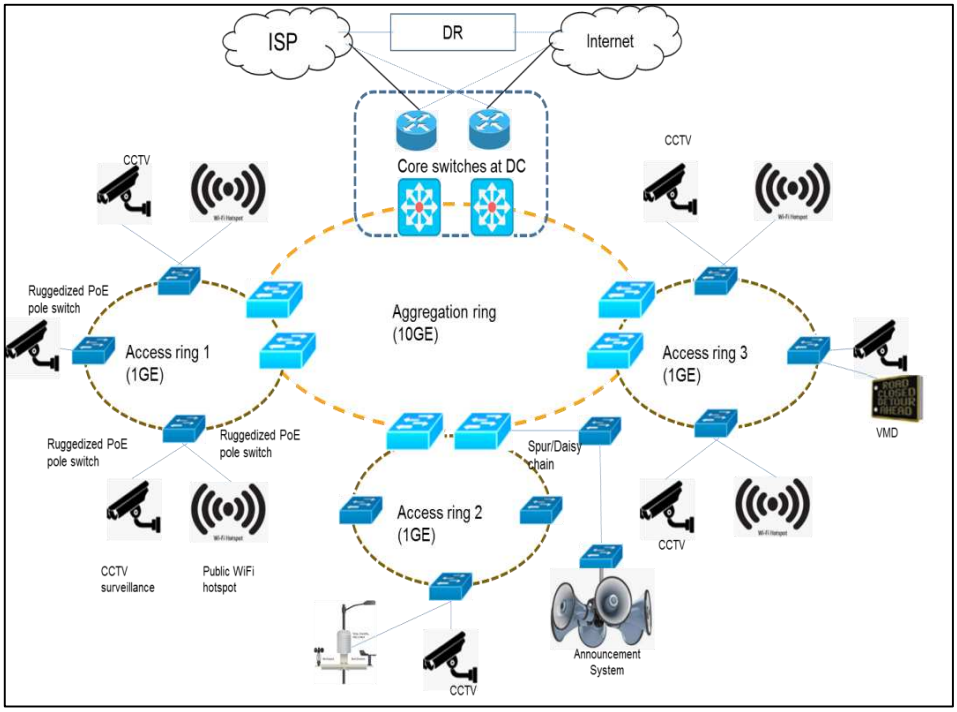


FIGURE 13: COMPLETE VIEW OF CARRIER ETHERNET SWITCHES BASED TELECOM ARCHITECTURE IN A SMART CITY

Generic guidelines recommended for designing fibre Backbone Communication network using Carrier Ethernet Switches for Smart City are enlisted below:

- Access/ street switches (preferably be dual homed or access rings) should terminate on different aggregation switches.
- Aggregate switches should be dual homed or Aggregate-rings, terminating on different Core switches.
- Access/ street layer Ring bandwidth should have minimum 1 Gigabit Ethernet.
- The Aggregate ring should have minimum capacity of 10GE.
- Dual packet-optical core node locations should be co-located, with inter-connectivity on 40G/100G. To scale up the network, it should be upgradable to multiples of 100GE or multiples of 40G capacity over DWDM.
- Ring architecture should support ERPS (ITU-T G.8032) and open ERPS (Ethernet Ring Protection Scheme) at Access and Aggregation Layer for ensuring sub 50ms resiliency against any link failure, as most of the mission critical services shall be backhauled on this architecture.
- Common fibre path to be avoided while closing aggregate and access rings.
- Locations to be chosen for Aggregation and Core in such a manner that optimum fibre route gets utilized.

The recommended architecture will ensure that functional requirement of City-wide IT Network layer will be built to provide the following: -

- Higher Network Uptime
- Visibility of Network
- Better Utilization of WAN Links
- Segregation of Traffic and QOS
- Better Network Management

GPON and Ethernet Switches complement each other in building a highly secure, reliable and resilient Smart City Network. However, the short comparison of both the architecture are given below:

Parameters	***Carrier Ethernet Enabled GPON Architecture***	***Carrier Ethernet Based Architecture***
Scalability	***1 Gbps** Bandwidth at each Access Location (Street Pole)*	*1 Gbps Bandwidth shared across Ring of 8~10 Nodes* *Hence **80~100 Mbps** per Access location (Street Pole).*
Reliability	*Protection against **multiple equipment failure***	*Protection against **single** equipment failure*
Latency	*Low Latency* *(P2P connection between Aggregate Location(OLT) & Access Device (ONT) hence no latency*	*Higher latency*

	been added by intermediate access sites)	*(Switches are part of Access Ring hence latency getting added by intermediate Access Node)*
Cost	*Cost effective*	*Higher*
Security	*Inherent AES 128 Encryption as per ITU-T G.984 between Aggregation Node & Access Node.*	*Security provided by enabling ACL (Access Control List) and other security polices. No inherent encryption.*
Architecture & Operation Simplicity	*Simple* *(Linear at Access while Ring at Aggregate)* ***Open ERPS is a key for implementation in Aggregate Layer.***	***Ring Architecture*** *ERPS & Open ERPS are key for implementation in Access & Aggregate Layer.*
Recommended Architecture	*It is recommended to have a mix of both the architecture depending upon the network schematics and service requirements.*	

5.3.2 Cellular technologies:

Evolution of cellular technologies has been depicted in the figure below-

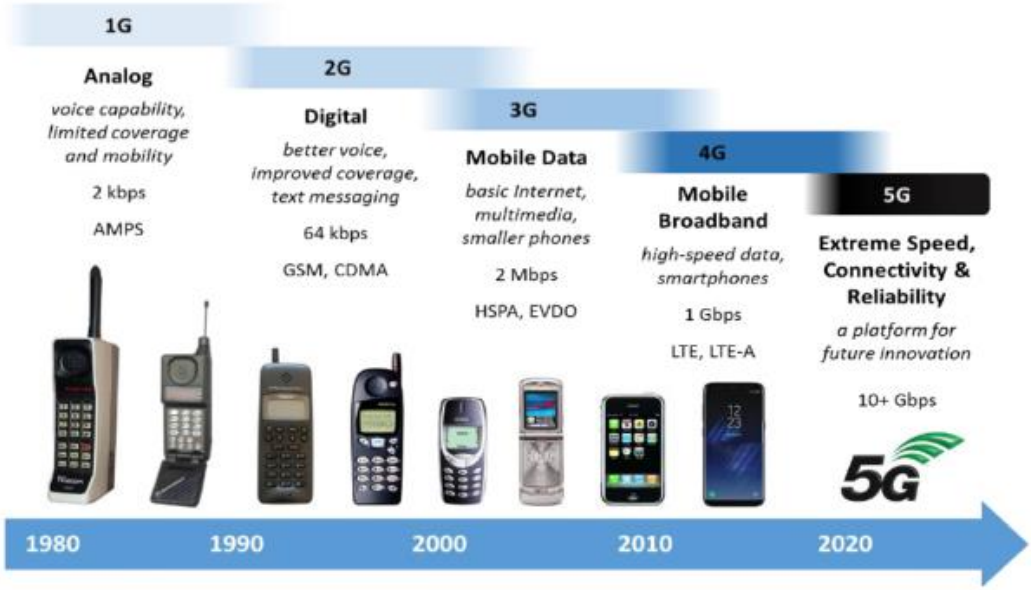


FIGURE 14: EVOLUTION OF CELLULAR TECHNOLOGIES [SOURCE: 5G AMERICAS]

5G as an emerging communication technology. 5G has been designed to provide the features such as enhanced Mobile broadband (Higher data rate : 100x faster, peak data rate – 10 Gbps), Mission critical services (Ultra reliable & low latency communication) such as V2V/ V2I applications, Robotics surgery, Drones etc. and Massive M2M (100x more connected devices). 5G will provide the features such as beam forming, small cells, consume less energy than 4G. 5G radio access will provide a total solution for wider range of requirements. These features are not available in 2G - 4G technologies as 4G was developed for providing real broadband services, 3G for voice and data and 2G for voice. Most of these features have already come in 3GPP Release 15 and 16.

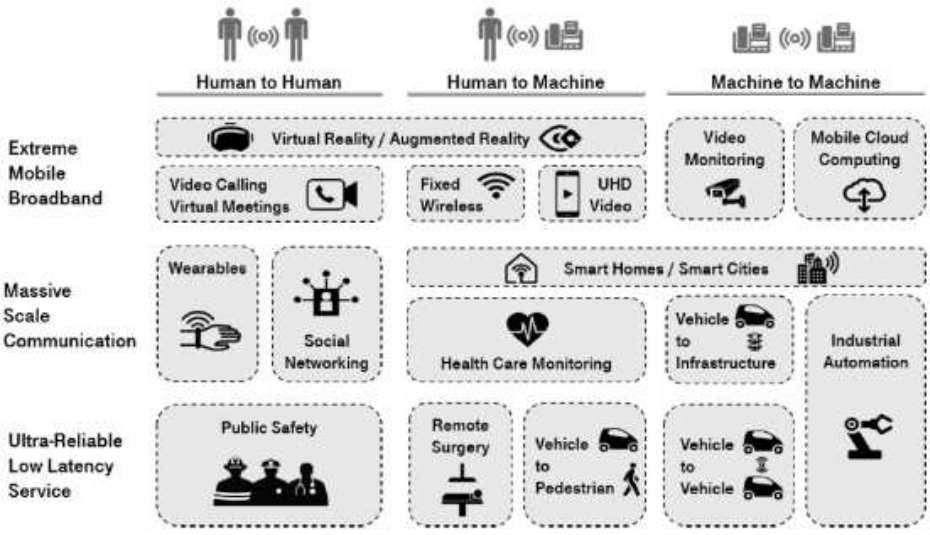
In Nov 2020, ITU-R SG-5 approved three radio interface technologies as IMT 2020 capable

1. 3GPP 5G- SRIT (LTE Advanced pro for eMBB, NB-IoT for mMTC and NR for uRLLC)
2. 3GPP 5G RIT (NR satisfying eMBB, mMTC and uRLLC)
3. 5Gi from TSDSI (NB-IoT for mMTC and TSDSI RIT for eMBB and uRLLC)
   Note: 5Gi standards have been merged with 3GPP[49] in Release 17.

Work on 3GPP Release 17 is in progress and expected to be released in Q2 of 2022.

5G will continue to evolve with new enhancements over the next decade; the Subsequent 3GPP releases will make 5G yet more powerful.

Some of the use cases related to various features of 5G technology have been shown in figure given below



Source: [5G Americas]

FIGURE 15: SOME 5G USE CASES

LTE/ 5G based C-V2X technology may be deployed for Intelligent Transport System. 5G features will be quite useful for Industry 4.0 also.

[49] https://www.3gpp.org/news-events/2243-3gpp_5gi#:~:text=In%20addition%2C%20the%20objectives%20of,5Gi%20updates%20in%20ITU%2DR.

5.3.3 M2M SIM (Embedded SIM)

The normal SIM card is not suitable for harsh conditions of vehicles like vibrations, temperature, and humidity as Its life expectancy is around five years. To address such type of requirements, GSMA created the specifications for Embedded SM with Over-the-Air (OTA) provisioning suitable for use in vehicles and in industrial applications.

It can tolerate the temperature variation ranging from -40 degree to +125 degree Celsius, having life expectancy around 12-15 years. Embedded SIM / M2M SIM (e-SIM) is quite useful for the vehicle tracking services as it is in the form of IC and is tamper proof. Embedded SIM may have subscriptions from more than one telecom service providers (up to five) and switching is possible from one TSP to another remotely or at the time of non-availability of signal from the main TSP. In this way the vehicle will always remain connected.

SM-DP and SM-SR are the key network element for provisioning embedded SIM services. TEC released a Technical report (TR) V2V/ V2I Communication and Embedded SIM. Based on this Technical Report, Interface Requirement (IR) of Embedded SIM was released by TEC.

5.3.4 Low Power Wide Area Network (LPWAN) technologies:

LPWAN technologies have been developed to carry small data packets to large distances while consuming very low power. It covers 2-3 Km in urban- (dense) areas and 12-15 Km in rural (open) areas. Expected battery life is around 10 years. LPWAN technologies are available on 3GPP (Cellular) as well as non 3GPP (non-cellular) standards, as shown in Figure - 13.

Possible use cases: Smart metering (electricity/ water/ gas), Smart bin, transmitting pollution sensor data, transmitting fire alerts, Smart farming (transmitting Soil testing data), etc.

FIGURE 16: LOW POWER WIDE AREA NETWORK (CELLULAR AND NON-CELLULAR) TECHNOLOGIES

In non-cellular domain, LPWAN technologies such as LoRaWAN and Sigfox are being deployed across the globe. They leverage delicensed sub GHz frequency band for wireless communication (presently, at 865-867 MHz in India). TATA Communications Ltd. (TCL) and SenRa Tech Pvt. Ltd. are deploying LoRaWAN based network in India. Important updates on LoRaWAN technology and its deployments

are available on LoRa Alliance website[50]. Sigfox network is also expected to be deployed in India in near future.

In cellular domain, 3GPP has already released specifications in its Release 13 and onwards for LPWAN services, which may co-exist in the existing cellular networks. Three variants in LPWAN technologies in cellular domain are EC-GSM, NB-IoT and LTE MTC. Cellular operators can enable LPWAN services in the existing GSM / LTE networks by upgrading the software. Trials have been done and deployments are in progress in several countries across the globe.

A brief description of various communication technologies along with their suitability in different applications is given in Annexure-3.

TEC has released specifications documents (Generic Requirements / Interface Requirements / Essential Requirements) related to telecom equipment and Smart devices (refer Annexure -5). Related specifications should be referred in procurement of materials such as Optical fibre cables, switches, routers and other active/ passive elements related to WAN and IoT devices by Smart cities SPVs.

ITU-T Recommendation Y Suppl. 27 and Y Suppl. 30 on Smart sustainable cities - Setting the framework for an ICT architecture may be referred for more details.

TEC Technical Report on ***Communication technologies in M2M/ IoT domain***[51] *released in 2017 may be referred. This Technical Report had covered in detail the cellular technology (up to LTE 3GPP release 14), Low power wireless communication technologies, Low power wide area network technologies, IEEE 802.11 a, b, g, n, ac (variant of Wi-Fi), 802.11p (DSRC), wire line (PLC, DSL, FTTH) etc. and the related use cases.*

Technical Report on ***Emerging Communication Technologies and Use cases in IoT domain***[52] *released in November 2021 covers 5G, Wi-Fi 6, WiFi 6E, WiFi HaLow, Bluetooth Mesh and some important use cases such as Intelligent transport system (Connected vehicles, C-V2X etc.), Private Industrial Network (Smart factories, Industry 4.0) , Smart homes etc.*

5.4 Frontier Technologies for transforming Smart Cities

Data generated from the various types of IoT devices deployed in a smart city may be huge and diverse. The data may be of different types like high order of magnitude (volume), more diverse including structured, semi –structured and unstructured data (variety) and arriving at a faster speed (velocity). Generally Big Data has five characteristics i.e. volume, variety, veracity, velocity & value. The complexity of data makes it difficult for the organisation to analyse through traditional data bases.

To resolve these issues, advanced data analytics techniques like AI/ ML algorithms, together with cloud computing are used. In critical applications, data is required to be analysed at the edge of a router / mobile network, nearer to the device/sensor network, to avoid any delay.

[50] https://lora-alliance.org/lora-alliance-press-release/stronglora-alliancesup-sup-achieves-goals-to-drive-scale-of-lorawansup-sup-for-massive-iot/

[51] https://tec.gov.in/pdf/M2M/Communication%20Technologies%20in%20IoT%20domain.pdf

[52] https://tec.gov.in/pdf/M2M/Emerging%20Communication%20Technologies%20&%20Use%20Cases%20in%20IoT%20domain.pdf

5.4.1 Artificial Intelligence (AI)/ Machine Learning (ML)

A huge amount of data will be generated from the sensors/ devices. Raw data has got no meaning. Big data analytics may be used to create intelligence. Intelligence may be used in various planning and operational activities. AI and ML based algorithm may be used to have better results. Data is generally stored in the cloud. As the high bandwidth and low latency communication media will be required to send the data to the cloud, therefore technologies like Edge Computing / Mobile Edge Computing have emerged. Such type of solutions are required in the critical applications, where the action is required to be taken immediately.

5.4.2 Blockchain

Blockchain technology plays an important role in ensuring data processing, circulation, sharing and management for all trust operations in supply chain management. Blockchain provides a trust free, tamper-proof, auditable and self- regulating system for data exchange and sharing in support of IoT and smart cities & communities. ITU-T SG-20 has released a number of standards on blockchain for the development of IoT and Smart cities (table in section 6.1 and annexure-1).

5.4.3 Digital Twin

Digital Twin is an emerging concept that has been given a lot of attention in recent years. It is well recognized that IoT makes a Digital Twin possible to the extent that Digital twins are a subset of IoT applications, and more particularly has its origins in Industrial IoT. The purpose behind Digital Twin technology is to build a precise digital counterpart of a physical system to support simulation, analysis, prediction and optimization, thereby providing more insights for the physical world.

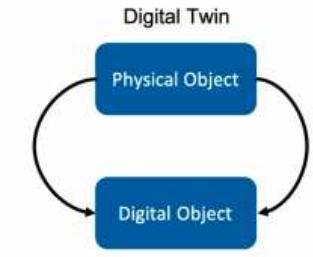


FIGURE 17: DIGITAL TWIN CONCEPT

In the Industrial space, several companies already use Digital Twins to spot problems and increase efficiency. The popular application areas of the Digital Twin include but are not limited to smart manufacturing, smart cities, smart building, smart healthcare, etc. While Digital Twins have been around with active development in them for the past few years, there is an accelerated increase in the number of Digital Twin related products and services in the past 2-3 years.

It has been mentioned in this document that cities are complex systems interconnected and managed by disparate entities and departments like Water, Energy, Waste, Transportation, City Administration to name a few and these are further connected to economic, ecological and demographic conditions. The ability to understand fluctuations in their entire context

and in terms of interdependencies that exist among these various entities across time and space is crucial for cities to improve their smartness. This is where the Smart City Digital Twin paradigm, a model that can provide increased visibility and forecasting into cities' functioning and requirements becomes relevant and important. From urban planning to land-use optimization to long term impact of policy, smart city digital twin has the power to enable the governance of the city in a more effective manner.

5.4.3.1. IoT/ ICT enabling Smart City Digital Twins

Digital twins are built and operated through multiple complementary ICT that collect, compute, and visualize data. A set of fundamental systems (such as enterprise application systems), which are already in place in most organizations today, provides data and business process support to digital twins. However, it is a group of new technologies that are usually deployed as part of organizational digital transformation efforts that enables digital twins to reach their true potential and become live data models that span ecosystems[53].

Internet of Things (IoT) Edge: IoT sensors and platforms continuously collect and orchestrate the data necessary for organizations to derive value from physical assets. This feed of real-time data is what ensures that a digital twin maintains an actual live copy of an asset, process, or ecosystem. When digital twins are used to optimize operations, speed and accuracy become paramount. Distributed processing at the cloud edge becomes critical in such scenarios.

4G/5G: A continuous real-time data flow between physical and virtual versions is critical for digital twins. With its ultrafast speeds, low latencies, and capacity to support high densities of devices, 5G becomes an essential digital twin accelerator.

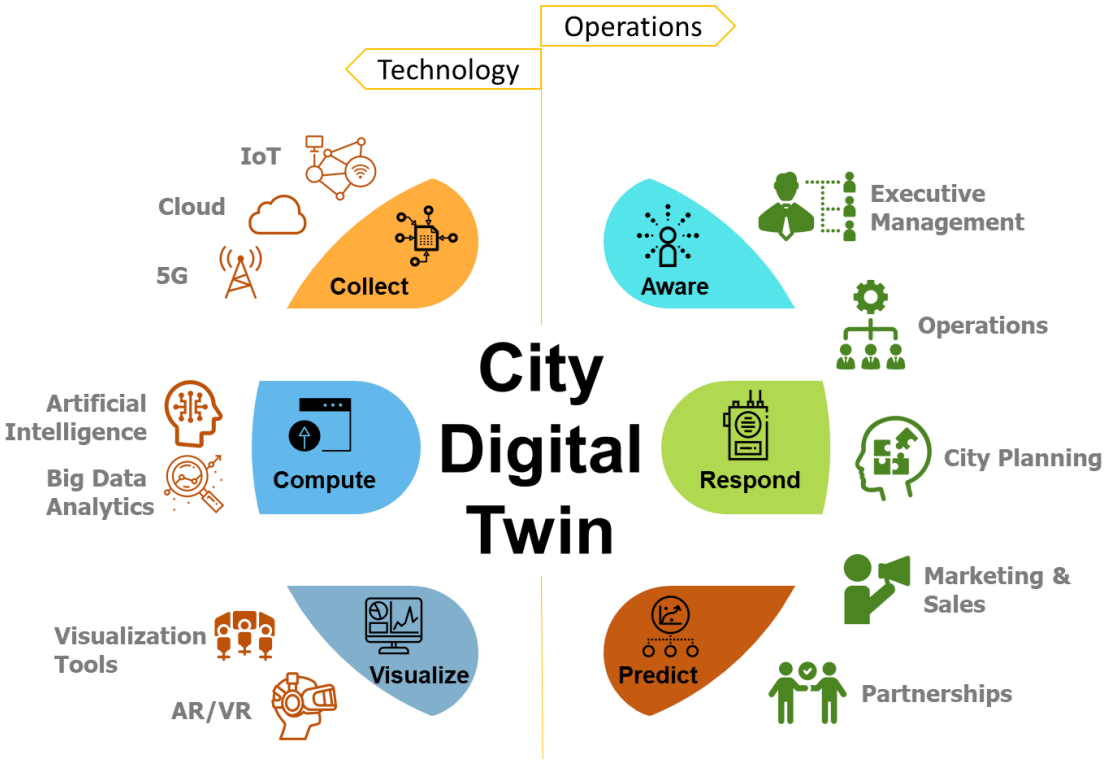
AI and Big Data Analytics: AI, combined with analytics tools, supports city operators' decision making and enables the automation of operational tasks. For example, an audio sensor that is part of city infrastructure can alert operations center personnel of an accident and provide a list of possible responses. This kind of sensor can also automatically trigger drone surveillance of the affected area.

Visualization Tools: Real-time Command and Control Centers with video walls and 3D visualization tools such as Building Information Modeling (BIM) are essential components of digital twins. Augmented reality and virtual reality technologies can take these tools to the next level, enhancing the effectiveness and accuracy of digital twins. These technologies also have major implications in operations, training, design, and simulation.

City Digital Platform: A digital platform, like oneM2M performs the integration of all these technologies, connecting applications and data to eliminate silos. The platform also connects various enterprises and ecosystem partners to fully explore the ecosystem's value and exceed the capabilities of standalone systems.
It is at the confluence of human-infrastructure-technology interactions that spatiotemporal fluctuations of the city recorded through IoT are integrated into an analytics system and City Digital platform that provide real-time view of city reality, virtually. Through this learning and exchange of information with the city, enabled through virtualization, the connectivity offered by 4G/5G and gathered through Internet of Things (IoT), this Digital Twin of the city becomes smarter over time, able to provide predictive insights into the city's smarter performance and

[53] https://e.huawei.com/in/eblog/industries/insights/2020/how-digital-twins-enable-intelligent-cities

growth.



Source: [IDC, 2020[54]]

FIGURE 18: ENABLERS IN A CITY DIGITAL TWIN

Benefits of the Smart City digital twin

The digital twin of a city system has several benefits. A few of them include:

1.Pre-empting infrastructure and asset maintenance needs, thereby reducing costs

2.Reducing infrastructure or service downtime

3.Improving overall city efficiency

4.Optimizing job work times by individual departments

5.Reducing time to offer a new service to citizens. Assess its impact across other services

6.Control service quality issues of citizen services and be able to determine when an issue started

7.Predict service downtimes

However, as the Smart City Digital Twin is a new concept with a relatively short history comprising of technologies rapidly changing, there still exists many different opinions about it in the areas of reference architecture, interoperability, collaboration, testing and evaluation, etc.

[54]https://www.idc.com/research/viewtoc.jsp?containerId=US43677519

Implementation of Smart City Digital Twins

Singapore is amongst the most tech-savvy countries in the world. Singapore believes that creating a digital twin is paramount for any city embarking on the journey of the digital transformation. With digital twin in place, government agencies can effectively analyze what can be done with the data and improve citizen living, create economic opportunity and revitalize a closer community."[55]

The UK is taking the concept to the next level by building a national digital twin that will be a system of multiple connected digital twins. In 2018, Cambridge university's Centre for Digital Built Britain launched the National Digital Twin project to support a UK network of digital twins "for the public good"[56]. It has created a common definition for information management to enable open and secure data sharing between future digital twins. They have also created a Digital Twin Hub (DT Hub), a web-enabled community for early adopters of Digital Twins to learn through sharing and progress through practical application.

Amaravati, the new capital of the Indian state of Andhra Pradesh, is thought to be the first entire city born with a digital twin[57]. Amaravati is proposing a digital twin user ID scheme for every citizen that will serve as a single portal for all government information, notifications, forms and applications. In the UK, post-graduate students from Newcastle University, working with Northumbrian Water, have created a digital twin of the city to help it better respond to incidents and disasters. The virtual model allows the water company to run computer-generated simulations of incidents such as burst pipes, heavy rainfall or serious flooding to demonstrate the impact it could have on people's homes and communities over a 24-hour period in just minutes.[58]

5.5 Gateway

IoT Gateway may be used to connect the IP and non IP devices working on short range communication technologies in the LAN / HAN/ FAN to the Head end server / cloud, using cellular / broadband technologies in the wide area network. The communication technologies in LAN/ HAN/ FAN may be 6LoWPAN, ZigBee, Z Wave, BLE, Wi-Fi, NB-PLC etc, and ADSL, ONT, Cellular, NB-IoT and LTE-MTC in WAN.

TABLE 3: IOT GATEWAY INTERFACES

S. No.	Interface	Frequency range	Standard
1.	NFC	13.553 MHz to 13.567MHz	ETSI EN 300 330
2.	RFID	50KHz to 200KHz or 865 MHz to 867 MHz or 13.553 MHz to 13.567MHz	ETSI EN 300 330, ETSI EN 300 220
3.	Wi-Fi	2.4GHz, 5GHz	IEEE 802.11 based specifications
4.	BLE	2.4 GHz to 2.4835 GHz	ETSI EN 300 328
5.	RF Mesh	865 MHz to 867 MHz	EN 300 220
6.	ZigBee	2.4 GHz	IEEE 802.15.4

[55]https://www.challenge.org/insights/digital-twins-and-smart-cities/
[56] https://www.ft.com/content/15851b06-1b6f-11ea-81f0-0c253907d3e0
[57]https://www.smartcitiesworld.net/news/digital-twin-created-for-new-indian-smart-city-3674
[58]https://www.smartcitiesworld.net/special-reports/special-reports/the-rise-of-digital-twins-in-smart-cities

7.	LPWAN LoRaWAN/ Sigfox	865 MHz to 867 MHz	EN 300 220-2

Essential Requirements (ERs) of IoT devices / gateway having detailed specifications are available on TEC MTCTE portal[59].

Most of the Smart phones are having BLE, NFC, Wi-Fi communication protocols, enabling it to work as a Gateway. Devices working on these technologies may connect with the Smart phones for further transmitting the data to the server / cloud. Most of the wearable health devices are on BLE protocol and may use the Smart phone as a Gateway for further transmitting the data to distant end.
Some inbuilt sensors in Smart phones such as Image Sensors (Camera), GPS, Inertial Sensor, Barometer, Gyroscope, Accelerometer, Microphone etc. may also be used for crowd sourcing/ collecting data through citizens, thus in turn improving the quality of services in smart cities, wherever possible.
For detailed architecture of Gateway, ITU-T Recommendations Y.4101, Y.4553 may be referred.

5.6 Platform

5.6.1 The Common Essential needs of all Smart City Applications

International study in Section 4 mentions Smart City platform as one of the most important entities in a Smart city ecosystem. Standardised Smart City platforms help achieve the following:

- interoperability among variety of devices and applications
- Data sharing between divergent applications and also among various platforms.
- help in avoiding vendor lock-in owing to standardized and open interfaces
- authenticated and authorized application onboarding
- assured data privacy and secured communication
- faster rollout of new and innovative applications
- Low CAPEX and OPEX and low TCO (total cost of ownership) for Smart City Ecosystem

As the Smart cities aim to connect a large number of divergent applications belonging to different vertical domains on the Smart City platform, therefore it becomes a necessity that the data collected from the connected devices of one vertical is shared with other verticals as well, to create ambient and collaborative intelligence while avoiding duplicity of the hardware and software. When such platforms are deployed in multiple cities it is also a necessary objective to have seamless integration between such platforms along with sharing of data. However, in reality, the proprietary platforms installed even in two adjacent cities are not able to talk to each other / capable of sharing data.

Another important aspect that is expected from the Smart city platform that it should be agnostic to communication technologies. Majority of the prevailing communication technologies (RF, Optical, Copper etc.) and standards (3GPP, IEEE etc.), LoRa, Sigfox etc. are expected to be accommodated in the specifications of such platforms. The connectivity provisions may be either direct or through Gateway.

[59] https://www.mtcte.tec.gov.in/

In order to have a cost effective and efficient deployment of Smart City Applications, irrespective to their types and target consumer, the following features for Smart City platforms are essential-

a) Interoperability

In order to have a sustainable large-scale deployment of Smart City Solutions, it is essential to have interoperability of applications, devices, networks and also semantics. However, true interoperability can never be achieved unless the solutions as well as the platforms become free from vendor lock-in.

b) Data Sharing among Divergent Applications

In real world Smart City Deployments, it is essential to have data sharing among divergent applications. This not only eliminates the need for exclusive and duplicate deployment of sensors, but also reduces a lot of burden on the network resources. Data sharing also enables efficient management of divergent Applications. The following example [Figure 19] of connected cars further illustrates the benefits. For this the common service layer is required.

Example of silos working and data sharing among verticals in a City-

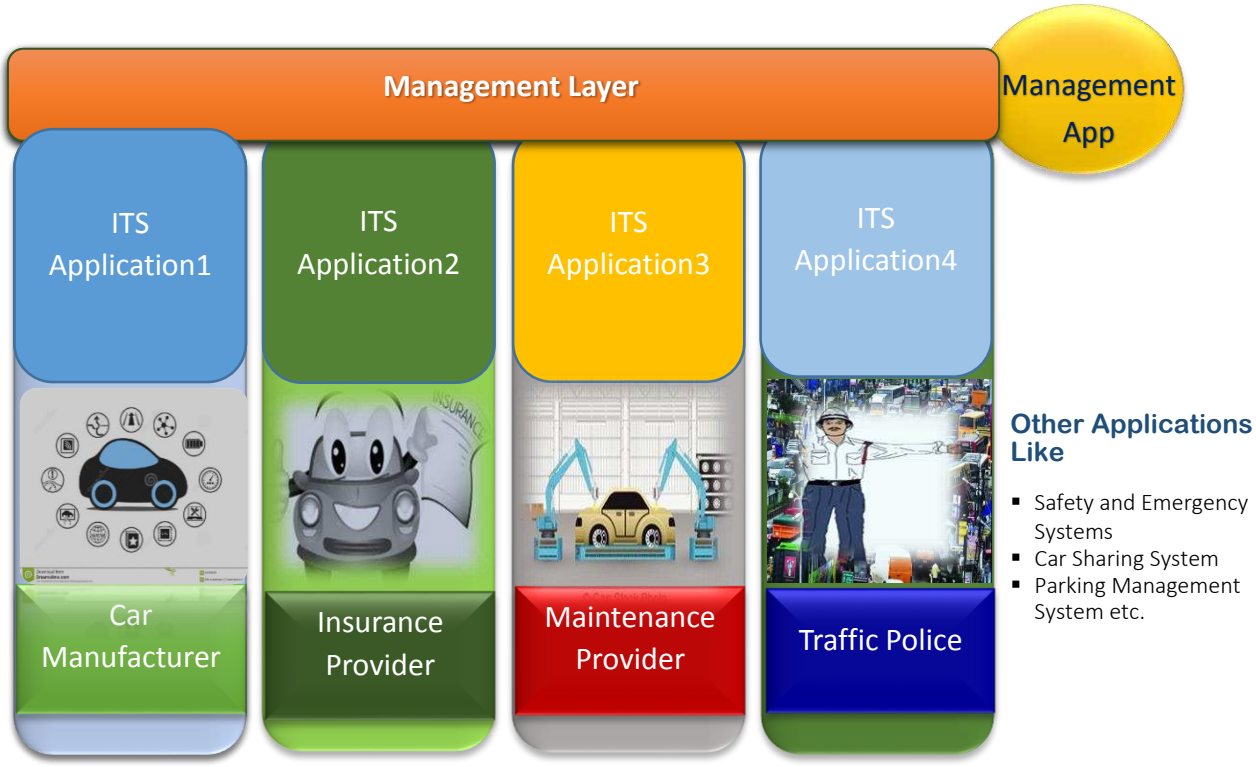


FIGURE 19: CURRENT STATE OF VERTICAL CENTRIC SILOED ECOSYSTEM

Now, in order to share data among these divergent applications, the application providers of these applications would have to provide information to some third party who would create a management layer which can extract data from all these applications. In such a scenario, every application would have its exclusive set of sensors to generate inputs. It is a scenario which is practically non-feasible as it not only requires impracticable hardware deployment, it would also

require the respective parties to expose their APIs for extracting data and thus letting go their monopolistic business opportunities. In extremely rare case, if it becomes possible, it would be highly expensive proposition. The scenario is illustrated in Figure 20 below.

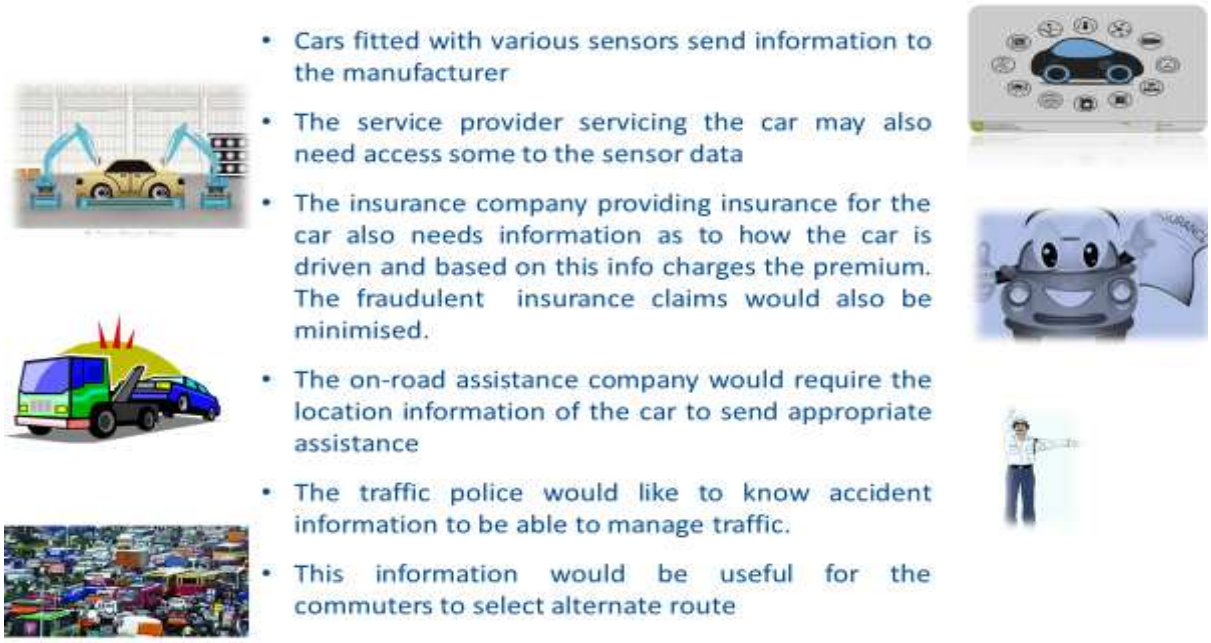


FIGURE 20: AN EXAMPLE OF DATA SHARING IN A VERTICAL

c) Security and Privacy

The large proliferation of IoT/M2M applications also raises the concern about the security of the devices and applications. Like any other interconnected system, the susceptibility of smart cities to cyber-attacks is something that all security experts agree upon. A Smart City architecture which does not have security as its core element is considered to be insecure.

One of the greatest weaknesses of IoT is the utilisation of insecure devices that lack sufficient security testing owing to non-standardized security framework, allowing the devices to be hacked and fake data to be fed to them. The reason this happens is because during the development of IoT devices and applications, functionality and customer orientation still have the highest priority for the vendors and not adherence to the standards.

In various demonstrations of hacking it has been shown how thousands of traffic control sensors were vulnerable to attack. It was shown how information coming from these sensors could be intercepted due to one company failing to encrypt its traffic data. Such lapses allow the hackers and cybercriminals to manipulate traffic data, permitting them to cause faulty traffic light circuits, traffic jams, large-scale obstruction traffic or even dramatic accidents[60].

Data privacy is another concern which is equally alarming. Consider a case wherein the Smart Home application data is leaked out and the miscreants are able to attack the CCTV Camera, the Electronic Security System and other connected devices when the house owner is away from home(which can also become public information if the location data is leaked out).

[60] https://www.wired.com/story/hacking-traffic-lights-netherlands/

Therefore, it is necessary that a standardized practice of robust security framework should be mandated for all Smart City Applications which do not escape the regulations for mandatory testing and certification.

d) Deployment of only authorized devices and applications

While deploying large scale IoT/M2M applications, it becomes a matter of grave concern for the authorities as well as the users that whether the devices and the applications which are being deployed are the legitimate or the authorized ones or not. In a proprietary vendor locked-in scenario such fears and apprehensions are very difficult to be assuaged.

In IoT/M2M Solutions, the sensors and actuators play the most vital role i.e. the role of "data generators" and that of "Acting upon it" respectively. Needless to say, the situation can be catastrophic if these are compromised. It is therefore necessary to have a standardized framework where no unauthorized device (sensor or actuator) or even application is allowed to communicate.

e) Management interfaces and Dashboards

The city authorities in a Smart City would always like to keep a tap on all that which is going on in the city without peeping into the actual data. This is needed for

a) identifying the problem areas
b) identifying the needs
c) identify future revenue streams
d) better planning of resources
e) allocation of funds

and many more.

f) Seamless integration of divergent applications

As it is quite evident that any Smart City would require applications which are different from each other, even if they are catering to the same vertical. For example, a smart street light application may be using devices and technologies which are suitable for one area within a city. Another smart street light application may use different technology and therefore it is necessary that they integrate with each other seamlessly so that the management of these devices (street lights in this case) become uniform.

Moreover, all smart city applications would not get deployed at once. Therefore, there should be ample opportunity for technological advancements get accommodated by virtue of having a standardized framework of interworking.

g) Faster Development and rollout of new applications

Any application development which requires a painstakingly long development lifecycle is rarely acceptable to small players as they would mean higher cost and unfavourable competitive environment for small players and start-ups. This favours only the large players as they are able to push dated applications and technologies to the market in a vendor locked-in scenario. Moreover, such solutions are never cost-effective and lack innovations.

h) Promote Innovations

Like any other technology area, the sustainability of a solution lies on its ability to withstand and accommodate change i.e. it should not curb innovations. A standardized practice which promotes innovations is the one which is going to survive the test of time and would witness the economies of scale.

To meet these numerous requirements iterated above, oneM2M has developed a horizontal framework [Figure 21 below] based on Common Service Layer concept as described below. This framework is based on open standards and open API interfaces. This enables the city planners to sidestep the "vertical" rollouts which do not scale. Dedicated devices tied to a particular app and network, are highly inefficient. It would be far more cost-effective if sensors could multitask and generate data for different use cases. It is now being widely understood that the vertical deployments are not sustainable if smart cities are to support multiple use cases and enable data re-use. It would be far more cost effective if a single platform could support not only street lighting, but also related services like smart parking, waste management, traffic management and pollution control, to name a few.

What is Common Service Layer?

A very simplistic approach which is now becoming widely accepted by majority of the SDOs (Standard Development Organisations) as the standardised horizontal approach consisting of a Service Layer concept. This service layer consists of all the essential components of the majority of IoT applications including those used in Smart City applications. These essential components are accessed as services by the southbound applications (deployed on the field nodes, closer to the sensors/actuators etc. and are predominantly the data generators) and the northbound applications (the applications usually sitting in the cloud/head-end systems which are used for data consumption, monitoring, running analytics or taking actions etc.) from the service layer. Since this service layer provides common essential components as services, this is called the "Common Service Layer".

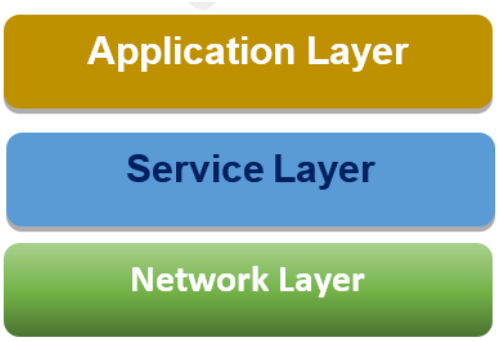


FIGURE 21: THREE LAYERS OF A STANDARDISED IOT ECOSYSTEM

To summarise, the Common Service Layer is a software/middleware layer which sits between applications and underlying communication networking HW/SW. It typically rides on top of IP protocol stack and provides functions that applications across different industry segments commonly need. It exposes common set of functions to applications via developer friendly APIs.

The Standardised horizontal architecture proposed by oneM2M

Based on the Common Service Layer concept, oneM2M has developed comprehensive sets of specifications around a horizontal architecture as shown in Figure 22 below.

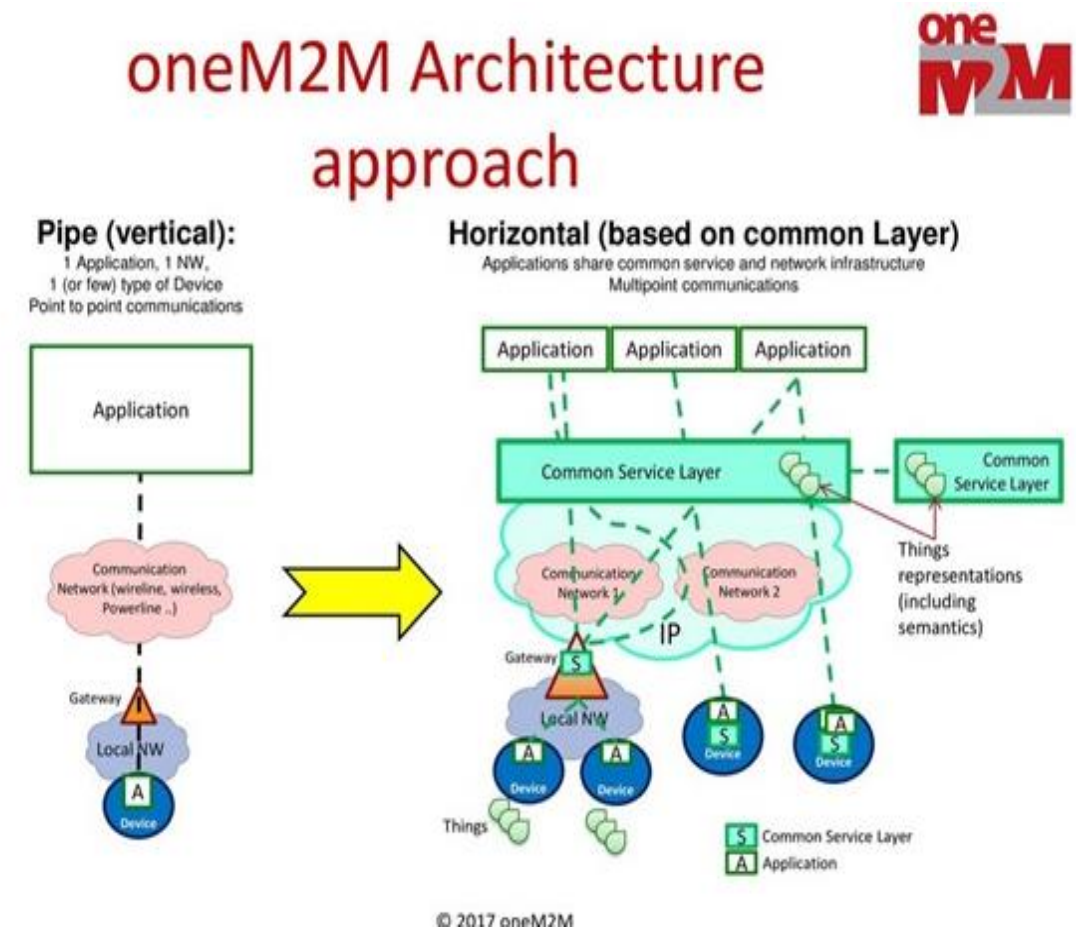


FIGURE 22: ONEM2M HORIZONTAL FRAMEWORK

In this standard architecture the applications become lightweight as they are not required to carry the burden of information about the devices, network, technology used as well as semantics as they are all abstracted/taken care of by the Common Service Layer. In this standard all the information elements are represented by things in the Common Service Layer and the applications are provided information pertaining to them by the Common Service Layer. The constituents of the Common Service Layer are the following 14 common service functions. These are the common set of functions used by all the IoT/M2M applications.

1. Registration
2. Discovery
3. Security
4. Group Management
5. Data Management & Repository
6. Subscription & Notification
7. Device Management
8. Application & Service Management
9. Communication Management and Delivery Handling

10. Network Service Exposure
11. Location
12. Service Charging & Accounting
13. Transaction Management
14. Semantics

These functions are exposed to the applications (both at the field domain as well as in the infrastructure domain) via standardized developer friendly APIs. The Common Service Function is not confined only to the core infrastructure. Rather, it is integrated into devices/gateways/servers and allows distributed intelligence.

While all the aforementioned Common services functions are extremely important for all IoT applications, the following may be mandated for all IoT platforms in Smart cities:

I. Registration
II. Discovery
III. Security
IV. Data Management & Repository
V. Subscription & Notification
VI. Application & Service Management
VII. Communication Management and Delivery Handling
VIII. Semantics

Other common services like group management, device management, network service exposure, location, service charging & accounting, and transaction management may be provisioned on need basis.

ITU–T SG-20 has adopted oneM2M Release 2A specifications and published as ITU-T recommendations. TEC has adopted oneM2M Release 2 specifications as National standards, as mentioned in section 3.2.3. Details of these specifications are available in Annexure- 6. These TEC national standards have been referred by BIS in its document on IoT RA IS 18004 -1: 2021.

5.6.2 Data Quality Management

As Cities generate ever more data, particularly real-time data, it can contain all sorts of imperfections e.g. imprecision, uncertainty, ignorance and/or incompleteness. These imperfections can eventually adversely affect the performance of urban services and decision making.

In addition, this data is multi-modal, coming from heterogeneous sources –

a) autonomous distributed devices and not restricted to various types of the Internet of Things (IoT) data such as traffic sensors, air and pollution sensors, parking sensors etc.

b) Citizen generated data and data from other sources that include payment details, residential information, geographical information, weather data to name a few.

c) Government produced data in the form of notices, policies, laws, subsidies, etc.

Data generated from distributed IoT devices also can have-
a) errors in measurements or precision of the data collection devices
b) noise in the environment and quality of data communication and processing (including network dependent quality of service -QoS- parameters)
c) granularity of the observations and measurements in both spatial and temporal dimensions.

Citizen and Government generated data will also have to deal with-
a) manual errors in spelling and semantics
b) incomplete information that are prone to language and other barriers
c) huge volumes of data that is created
d) the high velocity of data that is generated from various sources
e) the dynamicity and variety of types of data for the same information generated from the different departments
f) the co-relation and annotation of data in different attributes sourced from different departments.

For the aggregated and complex data that are integrated from multiple sources, data quality parameters become a fundamental need. It is inevitable that cities will require both processes that enforce Data Quality and platforms that ensure Data Quality Management. Data quality parameters are further necessary for interoperability and knowledge based information fusion that Common Services, essential for Cities, will be built on.
ITU-T has published standards on Smart data governance and are available in Annexure -1.

5.6.3 Indian Urban Data Exchange

The IUDX Program is a collaborative initiative of the Smart Cities Mission through the Ministry of Housing and Urban Affairs (MoHUA) as well as the Ministry of Electronics and Information Technology (MeitY) and the Indian Institute of Science (IISc), Bengaluru. IUDX is an open-source initiative, based on an underlying framework of open APIs, data models, security, privacy and accounting mechanisms that will facilitate, easy and efficient exchange of data among disparate urban data silos. IUDX draws on ideas and, where feasible, code from projects such as Fiware (fiware.org). IUDX compliant applications are expected to be able to use APIs to pull data from any of the underlying data platforms (both IoT as well as non-IoT platforms) and using the publisher APIs to push data to any of the applications behind the individual platforms. IUDX consists of three main components:

i) Catalogue service provided by a Catalogue server
ii) Authorization and Authentication services provided by an Authorization server
iii) Data access and data ingestion services provided by one or more Resource servers

The main functions of IUDX catalogue server are:

- Search and discovery of data resources
- Provide unambiguous description of data from a given resource thereby leading to improved data understandability and interoperability
- Provide additional context for a given resource that may improve its usage in applications

The IUDX Authorization Server allows data sharing while respecting ownership, privacy and compliance requirements. The IUDX authorization server ensures that only the authorized person can get tokens to access the private/protected data. The main functions of the authorization service are:

- Resource access authorization to grant access to access-controlled resources
- Resource access policy management to manage policies which specify access rules
- Authentication and registration services

The resource server constitutes the data plane for IUDX and provides data access for the resources available with the exchange. It serves data to data consumers in compliance with the access policy requirements set by the provider of the resource. IUDX resource access APIs shall be harmonized with ETSI NGSI-LD Specifications. The data access service provides APIs for:

a) Search and count
    - Get data using spatial, temporal, attribute and complex searches
b) Subscriptions
    - Get access to streaming data using Advanced Message Queuing Protocol (AMQP)

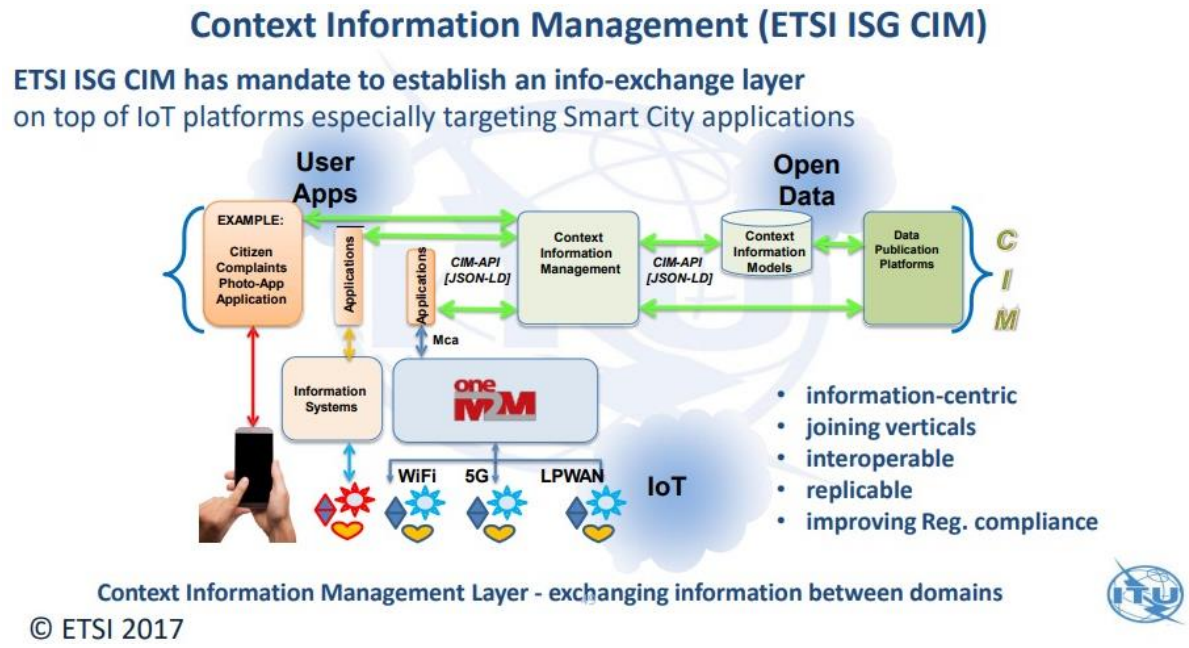
5.6.4 Fiware

Fiware is an open source data utilization platform for cross-domain data utilization-such as in a smart city. This platform has been developed by the Future Internet-Public Private Partnership (FI-PPP) in Europe.
FIWARE Foundation was established in 2016 and carries out promotional efforts to make FIWARE the de facto standard in Europe. Being an open architecture, it can prevent vendor lock-in.

5.6.5 ETSI NGSI LD

ETSI specifications (NGSI-LD with OMA authorization) on Application Programming Interface (API) aims to enable applications to discover, access, update and manage data and context information from many different sources as well as to publish it through interoperable data publication platforms like Open Data platforms. NGSI-LD has been standardized by ETSI through the Context Information Management (CIM) Industry Specification Group (ISG), following a request from the European Commission.

NGSI-LD API re-uses the JSON-LD protocol, which is already supported by many groups for linking data. Similar topics are also under discussion within W3C Web-of-Things and the Dublin Core groups.



Source: [ETSI, ITU]

FIGURE 23: CONTEXT INFORMATION MANAGEMENT (ETSI ISG CIM)

Indian standard on Unified Data Exchange Part 2 API specifications (IS 18003: Part 2: 2021) refers NGSI-LD (ETSI CIM) specifications.

More information about ETSI ISG CIM and list of standards published by ETSI ISG CIM is available on ETSI website.[61]

[61] https://www.etsi.org/committee/cim

5.6.6 Smart city ICT Architecture

Since the Smart City Applications have many other non-IoT data sources as well as applications, it becomes important to have a unified data layer centric architecture which can expose a common API that would help application developers to develop applications which can contextualise IoT as well as non-IoT Data. Given below is the Smart City ICT Architecture which fulfils this need.

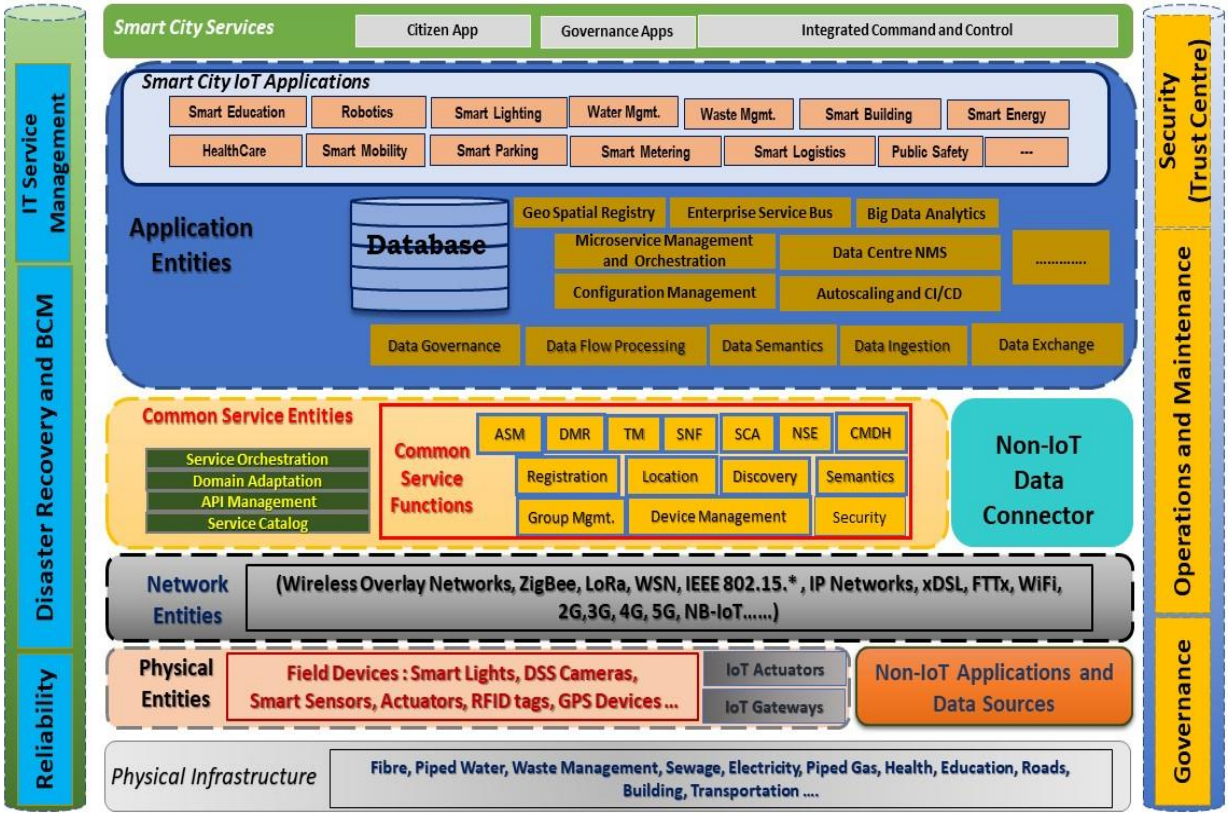


FIGURE 24: SMART CITY ICT ARCHITECTURE

5.7 Sectoral Analysis

Analysis and Recommendations for Industry Verticals- based on interactions with stakeholders in meetings / con-calls after the formation of committee in Feb 2019.

5.7.1 Energy

Managing electric grid infrastructure and ensuring operations, power generation, transmission, and distribution is a complicated task and is critical to the safety and comfortable functioning of a city and its citizens. Smart grids are the new evolution to electrical grid systems for managing sub-second load generation balance by adjusting consumption to match generation (The balancing obligation will be increasingly shouldered by demand side due to dominance of supply by Renewable Energy Sources which are inflexible due to their dependency on natural forces of Sun and Wind). With the inclusion of smart meters, smart appliances, smart switches and other sensors to make operations and energy consumption more flexible, power transmission and

distribution processes are now more automated and provide more insight to power companies. The IoT and other advanced technologies have not only introduced new and better ways of leveraging demand flexibility but has also created strong platform enabling saving money and improving the quality of lives.

India plans to invest Rs.3,03,758 crore ($39.74 billion USD) with an estimated GBS from Central Government of Rs.97,631 crore ($12.77 billion USD) under the Revamped Distribution Sector Scheme. Major interventions under this scheme include around 250 million Smart meters to be implemented in Public-Private-Partnership (PPP) mode, SCADA (Supervisory control and data acquisition system) in all urban areas, Distribution Management system (DMS) in 100 urban centers, feeder segregation for solarization under KUSUM scheme and System strengthening etc[62].

TEC released two technical reports related to Power sector namely (a). ***M2M Enablement in Power Sector***, and (b). ***Spectrum requirements for PLC and Low power RF communications*** addressing spectrum and communication related issues (details in Section 3.2.1).

The **ITU-T Recommendation Y Suppl. 53** provides AMI use case[63] in detail.

Central Electricity Authority (CEA) released a document on ***Functional Requirements of Advanced Metering Infrastructure (AMI) In India[64]*** in 2016; which will be able to embrace new communication technology innovation.

The emerging area of AMI is well supported by BIS Smart Meter standard ***IS-15959, IS-16444***.

[62] https://powermin.gov.in/sites/default/files/uploads/Final_Revamped_Scheme_Guidelines.pdf.
[63] https://www.itu.int/rec/T-REC-Y.Sup53-201812-I
[64] https://www.ipds.gov.in/Whats_New_Files/ami_func_req-Aug%202016.pdf

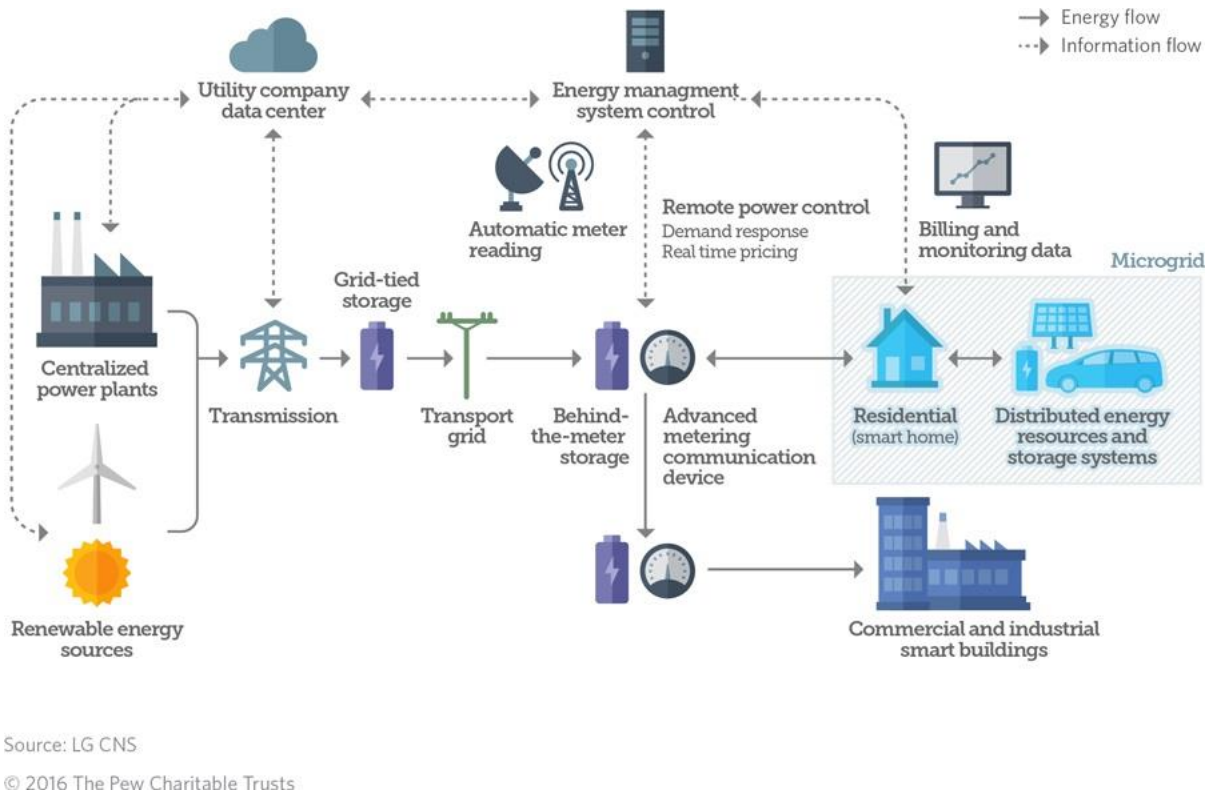


FIGURE 25: ENERGY MANAGEMENT

Many organizations have worked together to develop smart metering solutions with global and local standards and policies. As an example, DLMS association and the LoRa Alliance made efforts in standardizing the ability to move DLMS/COSEM messages over LoRaWAN networks leveraging SCHC (Static Context Header Compression) techniques[65].

5.7.2 CCTV based real time safety system (City Surveillance)

Closed Circuit Television (CCTV) is a system which uses cameras to transmit signal to a specific place which helps to monitor any kind of activities going on in any area. CCTV / City Surveillance Cameras should be able to view traffic situations, accidents, and incidents with clarity along with other objects on road. CCTV is a growing market as it is being widely used in many applications all over the world. Technology is the main concern in the CCTV camera market in India.

PTZ cameras can be used to zoom into any object on the road for detailed identification and recognition. The cameras with starlight technology (sensor based technology for night vision), high zoom with data analytics features such as face detection, no helmet detection etc. are recommended.

Fixed cameras with built-in face recognition shall recognize faces, match with database and generate real-time alerts.

ANPR and LPR cameras are used to read and store data on registration plates and these devices will help to obtain copious information in a high traffic area to keep any city secure.

[65] https://tech-journal.semtech.com/new-official-communication-profile-for-running-dlms-standard-over-lorawan

IP (Internet Protocol) and non-IP CCTV cameras are the two types of CCTV cameras that are traditionally used.

Technology wise non-IP dominates the Indian market but in the coming years IP is expected to take the lead soon. Non -IP technology constitutes analog and HD CCTV cameras. Analog is technology which is in a depleting stage and it's share is expected to be taken by the IP technology and the HD type CCTV camera. In City Surveillance, IP based camera should be used.

Surveillance network being the most critical security measure coming up globally and supported by OTT applications with AI like facial recognition to combat growing security implications needs special consideration and minimum active node or network element dependency between the CCTV camera locations in the network.

High speed and reliable connectivity is required to connect the surveillance system with the back end system. GPON technology on OFC or Cellular technology (4G/5G) may be used to provide bandwidth of around 10Mbps or more to each camera. City Wi-Fi network, if available, may also be used for providing connectivity to camera, preferably on 5 GHz.

Video Streaming Standards

Streaming should be unicast/multicast with H.264 or H.265. Multiple streaming capabilities should be possible at three resolutions. One stream can be utilised for recording at local level, other can be used for control room & third stream can be utilised for live viewing.

New ONVIF standard protocol, which works over HTTP, is also recommended so that cameras are automatically identified and listed & recorded by the video management software. Out of many ONVIF profiles, ONVIF –G profile camera interface is recommended due to simplicity & recording synchronisation of edge storages such as SD cards. Also, cameras should have streaming over RTSP as well as HTTP protocol.

CCTV cameras shall be certified under TEC MTCTE as per ER of Smart Camera/ CCTV (details in Annexure-5.4).

Deep learning technologies are making it possible to process and analyze vast streams of video streams simultaneously. Mimicking the human brain, the technique uses sophisticated, multi-level, "deep" neural networks to create systems that can perform Intelligent Video Analytics and security agencies can now mine massive amounts of visual data to glean valuable insight about what is happening in their respective cities.

Due to increased availability of processing power near IP cameras, an edge analytics (or near edge analytics) based approach can also offer device-specific selection of applications. By deploying video analytics, end users can leverage specific analytics data and leverage it into actionable intelligence for functions such as safety, security and personnel management. Analytics can offer tools such as heat mapping and queue monitoring for retail and hospitality, as well as face recognition, people tracking, vehicle tracking, people counting and traffic management. Some analytics use-cases with the type of locations are described in Annexure-10.

Protecting citizens, government buildings, monuments of importance and ensuring public safety is one of the topmost priorities for any government agency. It requires advanced security solutions to effectively fight threats from activities of terrorism, organized crime,

vandalism, burglary, random acts of violence, and all other forms of crime. CCTV based video surveillance is a security enabler to ensure public safety.

Surveillance system shall have the capability to deploy intelligent video analytics software on any of the selected cameras. This software shall have the capability to provide various alarms and triggers. The software shall essentially evolve to automate the suspected activity capture and escalation; eliminate the need of human observation of video on a 24x7 basis.

Analytics software shall bring significant benefit to review the incidences and look for suspicious activity in both live video feeds and recorded footages.

The smart city video analytics solution shall enable simultaneous digital video recording from network, intelligent video analysis and remote access to live and recorded images from any networked computer. It shall be able to automatically track and classify objects such as cars, people and push content to the respective security personnel as required for real time analysis. The system shall also have display of time line, customizable site map, live video, video playback, integrated site map, remote live view, multi-site capability, encryption, watermarking and event based recording.

All cameras should support motion detection, tampering detection and audio/ video capability; as well as multi source video streams.

Solution shall be so designed to have Automated PTZ camera control for zooming-in on interesting events like motion detection etc. as picked up by camera without the need of human intervention. It shall be completely scalable, with a many-to-many client-server model allowing multiple physical systems to be used in an array of servers.

5.7.3 Transport and Automotive

Automotive and transport is the backbone of the country and also an important vertical of a Smart city. In view of rapid growth of the automotive sector, there is a lot of congestion on the city roads / highways but there is a limit for the expansion of roads. IoT/ ICT solutions will help in managing the traffic as well as in reducing the crimes happening due to vehicles such as accidents/ kidnapping etc.

In view of passenger's safety in commercial passengers vehicles such as buses, cabs, autos etc., Ministry of Road Transport and Highways (MoRTH) has mandated the use of tracking devices with camera and panic button vide its standard **AIS 140**. This standard has mandated the use of embedded SIM, mentioning TEC specifications and the cellular technology as per DoT regulation with the subscription of two TSPs. BIS has also adopted it as **IS 16833**.

In view of development of cellular technologies such as LTE / 5G, provision for these technologies in tracking device radio module may be made. Tentative roadmap for technology adoption in India is available at Annexure-2.

In future, Intelligent transport system based on C-V2X may be deployed in the country. 3GPP Release 14 (published in 2017) provided the specifications for LTE based C- V2X which provides improvements over 802.11p / DSRC technology for active safety use cases and beyond. 3GPP Release 15 (published in 2018) provides further improvement in C-V2X safety, range and reliability.

3GPP Release 16 (published in 2020) provides specifications for 5G and NR based C-V2X, with continuing evolution path for future releases. 5G NR based C-V2X will have backward compatibility with Release 14/ 15 C-V2X.

5G roadmap will further improve the connected vehicle segment built on cellular V2X.

C-V2X is designed to work in ITS 5.9 GHz band for vehicles to talk to each other on harmonized dedicated spectrum. C-V2X support in ITS band was added in 3GPP Release 14 published in 2017. V2V, V2I and V2P services require low latency network, therefore operate through RSU (Road Side Units) in 5.875-5.925 GHz band and is independent of cellular communication. V2N operates through cellular network.

Intelligent Transport System (connected vehicles, C-V2X) has been covered in detail in TEC Technical Report on ***Emerging Communication technologies and Use cases in IoT domain,*** released in Nov 2021.

NITI Aayog floated a policy paper on Intelligent transport system in 2020. TEC / DoT had given the comments on policy as well as technology related issues.

i. Standardization Matters

a. UICC / eUICC preparation and certification as per TEC ESIM IR including GSMA Official Document SGP.02 - Remote Provisioning Architecture for Embedded UICC.
b. Device Certification as per TEC MTCTE ERs applicable for Automotive Devices (details in Annexure-5.4)
c. Mobile App as a Sync Node as per ITU –T Recommendation Y.4553
d. Field Device Configuration as per ITU-T Recommendation Y.4500.22
e. Requirements and capabilities of a gateway for Transport Applications as per ITU-T Recommendation Y.4101/Y.2067
f. Web Socket protocol binding for Devices as per ITU-T Recommendation Y.4500.20 oneM2M
g. Automotive Emergency Response Systems

IP-based emergency services mechanisms are introduced to support the next generation of the Pan-European in-vehicle emergency call service in May 2017. The de jure ITU-T Recommendation identifies requirements of an Internet of things (IoT)-based automotive emergency response system (AERS), i.e. eCall, for factory preinstalled and aftermarket devices in March 2018. Important standards are as mentioned below

I. Next-Generation Pan-European eCall[66]
II. Requirements and capability framework for IoT-based automotive emergency response system, ITU-T Y.4119, March 2018.
III. Minimum set of data structure for automotive emergency response system, ITU-T Y.4467, January 2020.
IV. Minimum set of data transfer protocol for automotive emergency response system, ITU-T Y.4468, January 2020.

[66] https://unece.org/sites/default/files/2021-02/ECE-TRANS-WP.29-343-Rev.29-Add.1.pdf

V. Telecom Regulatory Authority of India (TRAI) has issued a guideline for piloting the e-call in India in its recommendation on M2M in September 2017[67].

ii. Vertical Industry Standards

a. VTS Device Ontology and Protocols as per AIS140 / BIS 16833

b. Standard Operating Procedure (SOP) 5453 (E) for Vehicle Location Tracking (VLT), registration and activation in VAHAN[68]

Use cases related to automotive sector namely (a). ***Vehicle Emergency Call System for automotive road safety***; and (b). ***Digitization and automation of Vehicle Tracking, Safety, Conformance, Registration and Transfer via the application of e-SIM and Digital Identity*** may be referred from **ITU-T Recommendation Y Suppl. 53** for implementation in the automotive sector for resolving various complexities.

5.7.4 Water Management

Water has become one of India's leading topics of discussion amongst government, cities, and urban decision makers in the recent years. Water scarcity, water pollution, and water consumption have become some of the most challenging issues to address for cities in India today. The key factors to this crisis are - increased water consumption and wastage in urban areas, industrial growth, political and regulatory disputes, water cycle imbalances, increased irrigation due to agricultural demands, and lack of technology. The International Energy Agency has estimated that 34% of all water worldwide becomes non-revenue water[69]. The problem varies from region to region. Approximate NRW figures for Singapore is 5-6%, USA 15-20% and India 30-40%.

In addition to the above-mentioned factors, overall population, which is expected to increase to 1.64 billion by year 2050, will also contribute to the water crisis in India. Hence the need to put technology in the fore front of this problem is the need of the hour.

The term "Smart Water Management" refers to the efficient distribution of water and proper infrastructure management to ensure water is saved and leveraged in the best possible manner. Incorporated into the smart water process are systems designed to gather, analyze, detect, and notify concerned parties about the current water flow, consumption, distribution and cleanliness of a city's water. Leveraging cutting edge technology to send water data over long distances, wirelessly, at low-cost are key factors in creating an efficient solution for water management and related water maintenance activities.

In India, most of the water-consumption monitoring is done manually by physically visiting the meter sites and taking the readings. The major drawback of the physical collection of water-consumption readings is that they are reported only once-a-month and as these are done manually, there are high chances of errors. Another challenge for water distribution companies is to monitor the non-revenue losses. It has been realized that the only way to control and

[67] https://trai.gov.in/sites/default/files/Recommendations_M2M_05092017.pdf
[68] https://morth.nic.in/sites/default/files/circulars_document/VLT%20reg%20and%20activation.pdf
[69] https://www.fluencecorp.com/what-is-non-revenue-water/

increase their revenue base is to bring in smart meters which can provide real-time feedback of water consumption and promote water conservation methods.

The most efficient manner to achieve the above is to deploy Advanced Metering Infrastructure (AMI) instead of the old-fashioned Automated Meter Reading (AMR) methodology. Smart AMI water meters provide end-to-end automated mechanisms, including wireless communication, secure data transfer, and real-time analytics. These mechanisms offer the end customer, in this case, typically the utility companies, distribution companies, and city administrators, a clear view of their day-to-day processes. This information will provide insights for managing the entire distribution eco-system much more efficiently, enabling the city administration to predict the behaviour of the consumption & overall loss. Moreover, this will influence consumers' behavioural changes, creating a better awareness of water-saving strategies.

In the past, access to water meter data was a very resource heavy process, requiring a lot of manpower to physically obtain information directly off the meter. With this old process, there was no real time data visibility and there were many opportunities for data to be incorrectly captured and/or altered. With the smart AMI water meters, the city is now for the first time able to obtain insight on the water metering data in real-time and make water management decisions virtually in a matter of seconds.

The following table explains the pitfalls in the existing water meter solutions and the benefits of leveraging a smart AMI water meter solution.

TABLE 4: BENEFITS OF SMART AMI WATER METER SOLUTION

Existing Water Meter Solution	Smart AMI Water Meter Solution
No real time data availability	Real time data availability
Huge investment on CAPEX and OPEX	Reduced CAPEX and OPEX
No proper billing cycle	Automated bill generation
Increased Non-Revenue Water	Minimized Non-Revenue Water
High error rates	Minimal error rates
Manual device reading	Real time reading
Battery for display purposes only (Optional)	Long battery life (typically 10-12 years, based on use case) which supports the display, processing and communication
Data analysis is slow and process heavy	Real time data analytics leveraging artificial intelligence
Limited consumption visibility for end user	Detailed analysis of consumption provided to end user
No integrated theft detection	Theft and tampering detection available
No leak detection	Real time leak detection
High maintenance needed	Minimal maintenance required

With integrated application servers / platforms the city can access information which was never available in the past. Leveraging cloud computing, artificial intelligence/ machine learning algorithms, and big data processing, the city can improve the existing water management, distribution, and consumption. The technology to be used in the metering space should offer a secure long-range communication system with low-power devices running for a longer period

(say 10-12 years) on battery. Since most of the water meters are installed at deep indoor locations, LPWAN technologies may be preferred. Annexure-3 may be referred for more details.

5.7.5 Waste Management

India generates 62 million tons of waste every year, of which less than 60% is collected and around 15% processed[70]. Due to the rate of waste accumulation, India landfills are unable to process waste at desired speeds causing greenhouse gas emissions and hazardous toxins being released in the environment. With an expected waste generation annual growth rate of 4% and the growing population in India, the pressure of addressing the waste issue is one of the top priorities for the Government of India. To address this problem, in 2014, the Government rolled-out a nation-wide campaign called "Swachh Bharat Abhiyan" or "Swachh Bharat Mission" with the objective of cleaning up the streets, roads and infrastructure of India's cities, towns, and rural areas.

Companies across India, from start-ups to large corporations, are investing resources, finances, and time to solving this massive problem which India is facing. Leveraging IoT and data processing, waste management, waste processing, and waste monitoring are improving slowing with more innovations and available solutions.

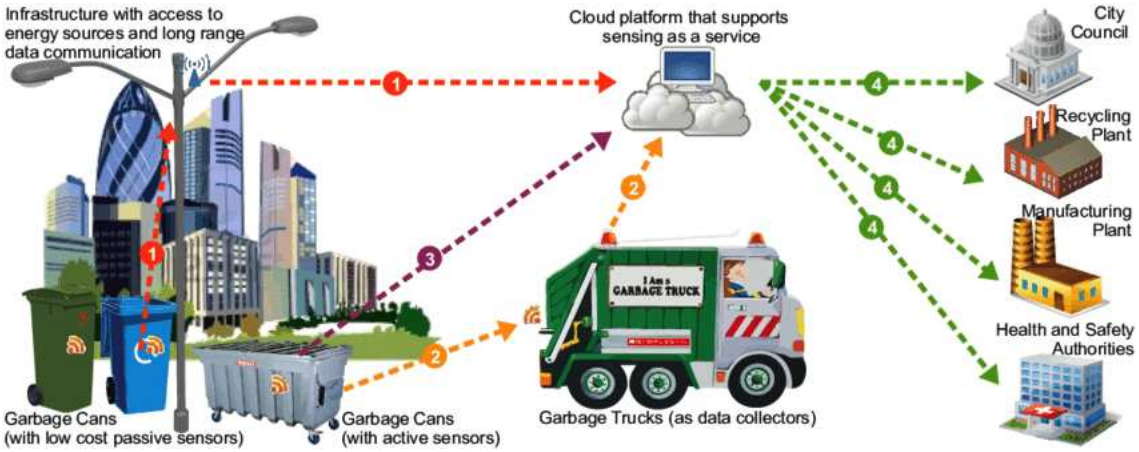


FIGURE 26: WASTE MANAGEMENT IN A SMART CITY[71]

One example which uses smart sensing, wireless connectivity, and data analytics is smart bins. Smart bins simplify parts of the waste management process by providing alerts when bins have accumulated too much waste, reducing operational costs such as fuel and manpower, and determine where waste build up is more prone to occur in different parts of the city.
Smart Bins are composed of a sensor-integrated module that will capture bin-information and wirelessly transmit it to the nearby base-station to be routed to smart-city application. The

[70] https://www.epw.in/engage/article/institutional-framework-implementing-solid-waste-management-india-macro-analysis#:~:text=India%20generates%2062%20million%20tonnes,Waste%20Management%20after%2016%20years..

[71] https://www.researchgate.net/publication/253646221_Sensing_as_a_Service_Model_for_Smart_Cities_Supported_by_Internet_of_Things

sensor modules can use 'distance-based' or 'weight-based' calculations to report the bin-fill levels. Apart from capturing bin fill-level, the solution can be used to optimize the path to be travelled by the garbage-collector trucks. This will keep the city-bins clean & save fuel.

5.7.6 Digital Health/ e-Health

Digital health is the part of the health policy released by Ministry of Health & Family welfare in 2017. Digital/e-Health promises to improve the quality of healthcare, reduce costs and help to foster independent living. Healthcare use cases leveraging IoT / ICT may be classified into five main categories:

- **Remotely monitoring a Patient** – remote monitoring applications, patient's medical data collection and management, administration of precision medicine, improvement and facilitation of medical care.

  Smart devices (IoT devices) like thermometer, SPO2 meter, portable ECG machines with Bluetooth connectivity may be used to monitor the patients remotely by the doctors as there may be shortage of beds in the hospitals.

  Such type of application may also be used for remote monitoring of patients after surgery, who can be shifted to their homes and vacant beds may be used for other patients. It also reduces the cost of treatment in case of surgery.

  Using Remote Health Monitoring, even a person with moderate education / semi-skilled worker may use wearable devices to measure the vital parameters of patients which may be communicated to the laptop / tablet and stored in the concerned page. Unique Identity number allotted to individual (e.g., Aadhaar in India) may be used as an identifier and then data may be transferred to the platform located in the cloud.

  IoT devices in health care domain will be quite useful in the pandemics and thereafter in managing the health care in the urban as well as rural areas.

  - Augmented doctor – strengthening medical technical expertise, aiding the doctor in medical procedures and creating new uses like remote diagnosis, surgeries etc.
  - Smart ambulance – having emergency and lifesaving care with facility to transmit vital parameters to the hospital
  - Connected hospital – flow management, communication and disinfection activities, hospital applications like telemetry, quicker transmission of large imaging files, VR used in medical trainings
  - Medical data management systems
  - Remote Surgery

Once 5G network is deployed, uRLLC feature may be used for remote surgery of patients. Places which are not connected on OFC, 5G will be beneficial in providing high speed connectivity for provisioning of smart services in rural areas.

TEC has released a Technical Report on ***M2M Enablement in remote health management***, which is available on TEC website[72].

A detailed use case on "***Remote monitoring the health of a patient***" is available in **ITU-T Recommendation Y Suppl. 53**. This document may be accessed using link[73].

Success of Digital health implementation relies on the widespread digitization of all sectors of society. One of the problems currently hindering the development of the digital health eco system is lack of interoperability. Standards therefore have a key role to play in assisting the development of new eHealth products and the growth of telemedicine[74]. Standards in health sector:

- Promote interoperability among healthcare systems.
- prevent single vendor lock-in.
- reduce costs by enabling market competition and eliminating the need for expensive and customized solutions.
- address specific concerns about privacy, security, and patient identification
- encourage widespread adoption.

In India, National Accreditation Board for Hospitals & Healthcare Providers (NABH) is working to decide digital health standards.

International Organizations working on Health Standards globally:-

Many Standards Developing Organizations are working towards development of standard for M2M communication in health sector.

In Europe, ETSI and CEN, through their technical committees have been developing standards related to digital health:

- **ETSI TC eHEALTH** is responsible for coordinating ETSI's activities in the eHealth domain, identifying gaps where further standardization activities might be required and addressing those gaps. List of Published Standards covering COVID, use cases, architecture etc. are available on ETSI website[75].
- **CEN/TC 251 'Health informatics'** is responsible for standardization in the field of Health Information and Communications Technology (ICT) to achieve compatibility and interoperability between independent systems and to enable modularity. This includes requirements on health information structure to support clinical and administrative procedures, technical methods to support interoperable systems as well as requirements regarding safety, security and quality. CEN/TC 251 has developed/published more than 110 standards[76].

[72] https://tec.gov.in/pdf/M2M/M2M%20Enablement%20in%20Remote%20Health%20Management.pdf
[73] https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13867&lang=en
[74] https://www.etsi.org/technologies/ehealth
[75] https://www.etsi.org/committee/1396-ehealth
[76] https://standards.cencenelec.eu/dyn/www/f?p=205:32:0::::FSP_ORG_ID,FSP_LANG_ID:6232,25&cs=17A8DF68AE459FA05A3DD08F026BCF538

Some of the important standards developed by global SDOs are as given below:

TABLE 5: HEALTH RELATED STANDARDS

Standards	Subject
ISO EN 13606	Electronic Health Communication (EHRCOM)
ISO 13485:2003	Medical devices - Quality management systems - Requirements for regulatory purposes
ISO/TR 14969	Medical devices - Quality management systems - Guidance on the application of ISO 13485:2003
Health Level Seven (HL7)	HL7 provide a framework (and related standards) for the exchange, integration, sharing, and retrieval of electronic health information (http://www.hl7.org/implement/standards/)
DICOM	The Digital Imaging and Communications in Medicine (DICOM) standard is used for the exchange of images and related information. (ISO 12052) (*http://medical.nema.org/Dicom/about-DICOM.html*)
HSTP-H.810	Introduction to the ITU-T H.810 Continua Design Guidelines
ITU (International Telecommunication Union)	[ITU-T Recommendation Y. 4110] - Service and capability requirements for e-health monitoring services. [ITU-T Recommendation Y. 4408] – Capability framework for e-health monitoring services. [ITU-T Recommendation Y Suppl. 53] - IoT Use cases – It is having use case on ***Remote monitoring the health of a patient***. **Focus Group on Artificial Intelligence for Health** The ITU/WHO Focus Group on artificial intelligence for health (FG-AI4H) works in partnership with the World Health Organization (WHO) to establish a standardized assessment framework for the evaluation of AI-based methods for health, diagnosis, triage or treatment decisions.
ISO/ IEEE 11073	personal health data (PHD) Standards- group of standards addressing the interoperability of personal health devices
Electronic Health Record Standards for India	Government of India intends to introduce a uniform system for maintenance of Electronic Medical Records / Electronic Health Records (EMR / EHR) by the Hospitals and healthcare providers in the country. (*https://mohfw.gov.in/sites/default/files/17739294021483341357.pdf*)
BIS Standards for Health	MHD-17, BIS has released Health informatics related standards, available on the link (*https://www.services.bis.gov.in:8071/php/BIS_2.0/dgdashboard/published/standards?commttid=MjM%3D&commttname=TUhEIDE3&aspect=&from=&to=)*

5.7.7 Smart Pole

Smart Pole is an integrated system that comprises of intelligent lights / smart lights, camera, communication points (such as Wi-Fi Hot spots), and sensors. The Smart Pole has evolved over the years with respect to technological changes. Today Smart Pole can also be referred to as Digital Pole as it more than a light pole catering to the societal needs and helps in creating new business

opportunities. More than this, it also gives opportunities to generate business revenues by advertisements and other services in the field of Internet of Things, Artificial Intelligence and Edge Intelligence. The use-case has been described in Annexure- 7.

Smart street lighting solutions are quite important for a Smart city for efficient energy usage. Smart street lighting use cases on different communication technologies such as LoRaWAN, 6LoWPAN, ZigBee are available in TEC Technical Report on ***Communication Technologies in M2M/ IoT domain*** (annexures 4, 5 & 8).

5.7.8 Smart homes / Smart buildings

Smart homes / buildings are the integral part of a Smart city. A smart home / smart building may have Smart lighting system, Smart Camera/ CCTV, connected appliances, smoke detector/ fire alarm etc. Information may be displayed on the gateway dashboard or communicated to the concerned person as an information / alert. TEC Technical Report on ***IoT/ ICT Enablement in Smart Homes***[77] may be referred for details. With the advancement in communication technologies, Wi-Fi 6 / 6E may be used in providing high-speed internet services at homes/ buildings/ stadium etc. and the connectivity on OFC / 5G may be used for backend. Details of various communication technologies and related use cases are available in Annexure-3. For laying optical fiber cable (OFC) for fiber to the home solutions in multi storeyed buildings, BIS standard on National Building Code may be followed. Part 8/ Section 6 (Page no. 714-736) of this document covers essential requirements for ICT enabled installations, technology systems and cabling installations in a building. It also covers basic design and integration requirements for telecommunication spaces within buildings along with their cabling infrastructure, pathway components and passive connectivity hardware.

5.8 National requirements like human safety, environment, geographical/ climatic conditions, national security etc.

5.8.1 Requirements related to human safety and security

Testing and certification of telecom products in respect of EMI/ EMC, Safety, SAR, Security and other technical requirements have been covered in the Essential Requirements (ERs) under MTCTE regime.

TEC is working on the following work items mentioned in the TRAI recommendations on 'Spectrum, Roaming and QoS related requirements in Machine-to-Machine Communications' and further communicated by DoT:

1. Device manufacturers should be mandated to implement "Security by design" principle in M2M devices manufacturing so that end to end encryption can be achieved.

2. A National Trust Center (NTC), under the aegis of TEC, should be created for the certification of M2M devices and applications (hardware and software).

A report on ***Code of practice for Securing Consumer IoT*** [78] has been released by TEC in August 2021. This report provides baseline requirements for securing Consumer IoT devices, aligned

[77] https://tec.gov.in/pdf/M2M/M2M_IoT%20Enablement%20in%20Smart%20Homes.pdf
[78] https://www.tec.gov.in/M2M-IoT-technical-reports

with global standards and best practices. Guidelines available in this report will be helpful in securing consumer IoT devices & ecosystem as well as managing vulnerabilities. This report is intended for the use by IoT device manufacturers, Service providers/ system integrators and application developers etc.

In a move towards ensuring National security, The Department of Telecommunications (DoT), Government of India has amended the telecom licenses to mandate the use of equipment only from "trusted sources" from June 15, 2021[79]. DoT in its press release has mentioned that "The government through the designated authority will have the right to impose conditions for procurement of telecommunication equipment on grounds of defence of India, or matters directly or indirectly related thereto for national security". It further quotes "With effect from 15th June 2021, the licensee shall only connect trusted products in its network, and also seek permission from designated authority for upgradation of existing network utilising the telecommunication equipment not designated as trusted products".
The TSPs will be notified of the categories of equipment for which the security requirements related to trusted sources are applicable and also the vendors from whom one can procure equipment, by NCSC (National Cyber Security Coordinator).

5.8.2 Role of IoT/ ICT in protecting environment and climate change

ITU along with seven other UN bodies published a report on “Frontier technologies to protect the environment and tackle climate change“ in the year 2020. This report has mentioned eight key emerging technologies namely artificial intelligence (AI), the Internet of Things (IoT), 5G, clean energy technology, digital twins, robotics, Space 2.0 technologies, and digitalization and Big Data, each having the potential to be instrumental in tackling the climate change and meeting the goal of United Nations (UN) Sustainable Development Goal (SDG) -13

UN SDG- 13: ‘Take urgent action to combat climate change and its impacts’ was developed to guide and ensure a comprehensive response to the many facets of climate change[80]The goal may be accompanied by the following environment-related targets:
Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.
Target 13.2: Integrate climate change measures into national policies, strategies and planning (including urban planning).
Target 13.3: Improve education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.
Target 13.a: Implement the commitment undertaken by developed-country Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to a goal of mobilizing jointly USD 100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation, and fully operationalize the Green Climate Fund (GCF) through its capitalization as soon as possible.

[79] https://dot.gov.in/sites/default/files/2021%2003%2031%20UL%20Proc%20AS-I.pdf?download=1
[80] https://www.itu.int/en/action/environment-and-climate-change/Documents/frontier-technologies-to-protect-the-environment-and-tackle-climate-change.pdf

Target 13.b: Promote mechanisms for raising capacity for effective climate change-related planning and management in Least Developed Countries and Small Island Developing States, including focusing on women, youth and local and marginalized communities.

Frontier technologies are enhancing the well-being of many people around the globe by allowing, for instance, greater access to medicine, improving communication and connectivity through the proliferation of mobile technologies, and making financial services accessible to millions in developing countries through innovative digital financial mechanisms. These technologies can be key enablers of smartness, sustainability and environmental resilience – offering important opportunities to help assess, mitigate and adapt to climate change.

International Telecommunication Union (ITU)'s Study Group 5 (ITU-T SG-5) on "Environment, climate change and circular economy" is working closely with policy makers, industry leaders, and the academia to develop international standards (also called ITU-T Recommendations) that support the sustainable use of ICTs. ITU-T SG5 is working on:

i. Electromagnetic compatibility, lightning protection and electromagnetic effects;
ii. ICTs related to the environment, climate change, energy efficiency and clean energy;
iii. Circular economy, including e-waste.

Some of the examples of use of frontier technologies in managing the clmate change are as given below:-

i. 5G can enable the adoption of more driverless cars, seamlessly operate public cameras, and provide high connectivity speeds to magnetometers that track traffic flows and volumes in real-time. Water availability, air quality, and energy efficiency in a city can be improved by a network of 5G-enabled sensors and corresponding computers analysing data in real time. Positive outcomes and cost savings can be realized for overall public health and environmental conservation by reducing waste using 5G technologies.
ii. IoT may be used to create smart energy infrastructure management to help reduce carbon dioxide and greenhouse gas emissions
iii. In cities, AI can help with route and traffic optimization, cutting waiting times, enabling better traffic flows, facilitating autonomous and ride-sharing services (in effect cutting the number of vehicles on roads and helping increase driver compliance with environmental regulations).
iv. Digital twins is an emerging technology and will be helpful in planning disaster response in cities, although to best leverage this technology, cities will still need to define their approach, establish how the project will be managed end to end, facilitate the widespread adoption of the end results and be ready to engage in activities to help combat climate change.
v. Robotics may be useful for monitoring the impacts of climate change underwater, and observing marine life to help protect biodiversity

6 Recommendations

Existing policies, standards and guidelines related to IoT / Smart cities in India have been studied and brief is available in section 3. Review of Current Smart Cities IoT/ICT Ecosystems in India has been described in section 5. Similar study has also been done for some countries across the globe and also the related recommendations from the standardization bodies like CEN, CENELEC, ETSI, oneM2M, ITU, U4SSC, ISO/IEC etc., have been described in section 4. Based on this, following is recommended:

6.1 Available Standards

S. No.		Topic	International Standard	Related Indian SDOs/ SSOs and standards	Related section of this Report
1.	Smart City Verticals	Power/ Energy	ITU-T Recommendation Y. 4251(Capabilities of ubiquitous sensor networks for supporting the requirements of smart metering services).	BIS standards (IS16444), TEC ER on Smart Electricity meters	Section 5.7.1 and Annexure - 5
2.		Automotive/ Transport	ITU-T Recommendation Y. 4119 (AERS), Y. 4456 (Smart Parking), Y. 4457 (transportation safety services), Y. 4809 (Unified IoT Identifiers for Intelligent Transport Systems).	AIS (MoRTH standards) 140 and BIS standards. TEC ER on tracking device.	Section 5.7.3 and Annexure - 5
3.		Water Management	ITU-T Recommendation Y. 4107(Requirements for water quality assessment services using ubiquitous sensor networks (USNs)), Y Suppl. 36 (Smart water management in cities)	Section 5.7.4	
4.		Waste Management		Section 5.7.5	
5.		CCTV based real time safety system (City Surveillance)	ITU-T F.743 (Requirements and service description for video surveillance), ITU-T F.743.11 (Requirements for video surveillance with mobile premises units), ONVIF (open network video interface forum) standards.	TEC ER on Smart Camera / CCTV	Section 5.7.2 & Annexure -5, 10
6.		Health	ITU-T Recommendation Y. 4110 (Service and capability requirements for e-health monitoring services) & Y.	BIS MHD 17	Section 5.7.6

			4408(Capability framework for e-health monitoring services), Y.4117 (Requirements and capabilities of the Internet of things for support of wearable devices and related services).		
7.	National Requirements	EMI/ EMC, Human Safety	As per references to International SDO Standards in the relevant national standards	BIS LITD 09 Electromagnetic Compatibility Sectional Committee Standards; TEC ERs covering EMI/ EMC, Safety, SAR, Security and other technical requirements for telecom products.	Annexure -5 on TEC GR/ IR/ ER
8.		Security of Telecom Equipment, Connected Devices and Applications	As per references to International SDO Standards in the relevant national standards.	TEC ERs, TEC National Standards	Section 5.8.1 and Annexure -5
9.		Telecom Data Security and Privacy	As per references to International SDO Standards in the relevant national standards, ITU-T Recommendation Y.4810 (Requirements for data security of heterogeneous Internet of things devices) ISO 27701	BIS Standards, TEC National Standards, Data protection bill 2019 is under review by the Parliament.	
10.		Geographical/ Climatic conditions	ITU-T Recommendation Y.4700 (Deployment guidelines for ubiquitous sensor network applications and services for mitigating climate change), ITU-T L.1502 Adapting ICT infrastructure to the effects of climate change	Section 5.8.2	
11.	Smart City Components	Device	ITU-T Recommendation Y.4811 (Reference framework of converged service for identification and authentication for IoT	TEC ERs for telecom devices	Section 5.1, 5.2 and 5.5

			devices in a decentralized environment)		
12.		Gateway	ITU-T Y. 4101(Common requirements and capabilities of a gateway for Internet of things applications), Y. 4418(Gateway functional architecture for Internet of things applications) and Y. 4553 (Requirements of smartphone as sink node for IoT applications and services),		
13.		Platform	ITU-T Y. 4200 (Requirements for the interoperability of smart city platforms) & Y. 4201(High-level requirements and reference framework of smart city platforms).	TEC National Standards [TEC 30001 - 30023: 2020], BIS IoT RA IS 18004 -1	Section 1.1 (b), 5.6 and Annexure -6.
14.		M2M Service Layer	ITU-T Y. 4413 (Requirements and reference architecture of the machine-to-machine service layer)		
15.		oneM2M specifications adopted by ITU-T SG-20	ITU-T Y.4500.1 to Y.4500.32		
16.		Unified Data Exchange specifications	NGSI-LD (ETSI CIM) specifications	BIS Standards IS 18003: Part 2: 2021	Section 5.6.3 to 5.6.5
17.		Data Layer	ITU-T FG-DPM D3.3(data interoperability)	BIS Standards IS 18002: Part 1: 2021	
18.		Big data, open data	ITU-T Y.3601 (Big data - framework and requirements for data exchange), Y.3602(Big data - Functional requirements for data provenance), Y.4114(Specific requirements and capabilities of the Internet of things for big data),Y Suppl. 40(Big data standardization roadmap).	BIS Standards	
19.	Communication Technologies for	Backhaul network on Optical Fiber Cable	ITU-T Y Suppl. 27 (SSC-setting the framework for an ICT architecture)	TEC GRs/ IRs/ ERs	Section 5.3 and Annexure -5

	Smart Cities		ITU-T Y. Suppl. 30 (SSC-overview of SSC infrastructure)	TEC National Standards	
20.		Cellular Networks	ITU and 3GPP Specifications		
21.		Non- cellular LPWAN such LoRa, Sigfox etc.	Specifications released by concerned alliances / SDOs, for LoRaWAN- ITU-T Y.4480		
22.		Wi-Fi	IEEE standards	TEC ERs	
23.		Embedded SIM	GSMA guidelines / ETSI standards	TEC IR	
24.	Smart Sustainable City (SSC)	Smart sustainable city (SSC) ICT architecture	ITU-T Y Suppl. 27(Smart sustainable cities - Setting the framework for an ICT architecture), Y Suppl. 56 (Supplement on use cases of smart cities and communities).	BIS Standards BIS IoT RA IS 18004 -1 TEC National Standards	Section 5.6.6
25.		SSC Key Performance indicators (KPIs)	ITU-T Y.4903/ L.1603 U4SSC KPIs are based on this standard	MoHUA Guidelines	Section 2, 4.6, 4.7 and annexure – 9.
26.		SSC Impact Assessment	ITU-T Y.4905(Smart sustainable city impact assessment)		
27.		SSC planning	ITU-T Y Suppl. 32 (Guide for city leaders), Y Suppl. 33 (Master plan), Y Suppl. 34 (Stakeholders engagement)	TEC Technical Report on ***Design & Planning Smart Cities with IoT/ ICT***	

NOTE:

1. **Communication technologies and related use cases are available in Annexure-3**
2. **TEC National Standards - details in section 3.2.3 and annexure 6.**

6.2 Detailed Recommendations

1. **Smart City Platform:**

1.1. IoT platform: An IoT platform is an important entity in a Smart City, as it facilitates communication, data flow, device management, and the functionality of different applications. As mentioned in section 4.2.1, there is heterogeneous co-existence of around 450 different IoT platforms in EU, which faces issues related with interoperability and data sharing. As sharing of data across verticals connected to a platform is required in a smart city and also between two adjacent smart cities.

It is recommended that the IoT/ Smart city platforms should be based on open standards enabling interoperability, scalability and modularity. *Platform* has been described in detail in

Section 5.6. TEC has already adopted oneM2M Release 2 specification as National Standards (TEC 30001:2020-30040:2020), details available in Annexure- 6.

These TEC standards have also been included as normative/ informative references by BIS in its standard on IoT reference architecture **IoT RA IS 18004 (Part 1): 2021**.

MoHUA has referred BIS IoT RA in the ICCC/ ICT Model RFP 2.0 for Smart Cities and issued Advisory[81] no. 19.

It is therefore recommended to have IoT platforms based on TEC standards (TEC 30001:2020-30040:2020) or any other national/ international standard having interworking/ interoperability with these standards. It will help in the development of standardized ecosystem in the country.

Compliance and certification for the platforms shall be published separately.

1.2. IoT and non IoT data convergence platform

For converging IoT and non IoT data, platform based on standards like NGSI-LD is recommended. Same has been elaborated in the Sections 5.6.3 to 5.6.5 of this report.

1.3. Smart City ICT architecture

Smart City ICT architecture as described in Section 5.6.6 is recommended.

2. **Communication Technologies**: Smart city may have heterogeneous existence of different communication technologies in the backbone and access network.
   i. In the backbone network OFC in ring structure as described in Section 5.3.1.may be followed. Bandwidth / dark fibers from two TSPs having widespread network may preferably be hired.
   ii. Devices requiring high speed connectivity such as city surveillance cameras should be connected on OFC / 4G/ 5G.
   iii. Wi-Fi preferably Wi-Fi 6 based routers/ wireless access points may be used for high-speed connectivity in homes, offices, stadium, shopping malls etc.
   iv. LPWAN (NB-IoT, LTE-MTC, LoRaWAN, Sigfox, etc.) may be used for connecting the devices as per the use case requirement (refer Annexure – 3 for more details).
   v. If Smart city lays its own OFC and develop the transmission network, the standards related to OFC, transmission equipment, IT equipment etc. as mentioned in the annexure - 5 (List of TEC GRs/IRs/ ERs) are recommended for procurement of related material.
   vi. High speed and reliable internet services on fixed and mobile devices of the citizens is required. For this fiber to the home/ building concept as detailed in Section 5.7.8 is recommended.
   vii. For deploying integrated systems having various type of devices such as smart lights, cameras, EV charging etc., and the communication technology points (such as Wi-Fi Hotspots, LoRa etc.), smart pole concept may be preferred (refer Section 5.7.7 and Annexure 7 for more details).

[81] https://smartnet.niua.org/content/6e40dcd8-ea0b-452b-b8da-c108e2f0c81f

3. Intelligence- Support for AI and analytics at the edge / cloud. Frontier technologies like AI/ML, Blockchain, Digital Twin etc. will be an enabler in managing data and creating intelligence for the planning and operational activities (details in Section 5.4).

4. As IPv4 are going to exhaust and its support may not be available in future developments. Therefore, it will be better to procure the equipment having IPv6 / Dual stack (IPv4 and IPv6) features. Guidelines released by DoT regarding IPv6 are available on DoT website[82].

5. Smart solutions in a city may be architected using global standards in a way which guarantees interoperability between the various stake holders of the IoT/ M2M eco system including but not limited to S (Services) – P (Platforms) –N (Networks) – D (Devices) and also ensures security and privacy therein.

6. **Smart Energy & Metering**
   Smart Cities must encourage the use of Smart Meters, Solar roofs and local energy generation. The standards recommended to be followed are specified at the serial no. 1 (related to Power) of the table in Section 6.1 and details in section 5.7.1.

7. **City Surveillance**
   CCTV based real time public safety system is a security enabler to ensure public safety. It is recommended to use the certified cameras as mentioned at the serial no. 5 of the table in section 6.1and details in Section 5.7.2, Annexure- 10.

8. **Intelligent Transport System**
   Intelligent Transport Systems are the backbone of Smart Cities that enable fast and smooth to and fro travel. The standards recommended to be followed are specified at the serial no. 2 (related to Automotive) of the table 6.1 with details in Section 5.7.3.

9. **Smart Water Management**
   Smart Cities must encourage the use of Smart Meters, pipeline sensors and over-head tank leak protection. The choice of communication technology that suits the AMI water-meter deployments, plays a crucial role in the overall success of the project. The standards recommended to be followed are specified at the serial no. 3 (related to Water Management) of the table in Section 6.1.

10. **Waste Management**
    Detailed use-case is available in Section 5.7.5 and the standards recommended to be followed are specified at the serial no. 4 (related to Waste Management) of the table in Section 6.1.

11. More than 150 cities across the globe are using U4SSC KPIs based on ITU standards for assessing the performance towards smart city objectives. It is recommended that some Indian Smart cities should use these KPIs for assessing the objective and its impact (details in Section 2.2).

[82] https://dot.gov.in/ipv6-transition

12. Smart city platforms may be used for emergency health services for the urban as well as the rural population.

13. **Security:** In view of security of Telecom infrastructure, Mandatory Testing and Certification of Telecom Equipment (MTCTE) has been notified by Government of India. Under this scheme all the telecom equipment and Smart devices are to be tested as per the Essential Requirements released by TEC. Manufacturer is responsible for getting the testing done. MTCTE certification may be made as a requirement in procurement of telecom equipment / Smart devices. (Details in Section 3.2.2.)
Requirements related to human safety and security are available in Section 5.8.1. List of GR/IR/ER is available in Annexure-5.
For securing Consumer IoT devices, guidelines available in the TEC report ***Code of practice for Securing Consumer IoT*** may be followed.

14. To ensure security by design, the presence of tamper resistant secure element with encryption capabilities is considered important for secure identification and authentication of Smart devices and applications.

7 Abbreviations

S. No.	Abbreviation	Full Form
1.	3GPP	3rd Generation Partnership Project
2.	AI	Artificial Intelligence
3.	AR	Augmented Reality
4.	BIS	Bureau of Indian Standards
5.	CCTV	Closed Circuit Television
6.	DoT	Department of Telecommunications
7.	DSRC	Dedicated Short Range Communication
8.	ER	Essential Requirements
9.	ETSI	European Telecommunication Standards Institute
10.	GPON	Gigabit Passive Optical Network
11.	GR	Generic Requirements
12.	ICCC	Integrated Command and Control Center
13.	ICT	Information and Communication Technology
14.	IEC	International Electrochemical Commission
15.	IEEE	Institute of Electrical and Electronics Engineer
16.	IoT	Internet of Things
17.	IPv4/ IPv6	Internet Protocol version 4/ version 6
18.	IR	Interface Requirements
19.	ISO	International Organization for Standardization
20.	ITU	International Telecommunication Union
21.	KPI	Key Performance Indicator
22.	LAN	Local Area Network
23.	LPWAN	Low Power Wide Area Network
24.	M2M	Machine to Machine
25.	ML	Machine Learning
26.	MoHFW	Ministry of Health & Family Welfare
27.	MoHUA	Ministry of Housing and Urban Affairs
28.	MoRTH	Ministry of Road Transport and Highways
29.	MoUD	Ministry of Urban Development
30.	MSDG	Mobile e-governance Service Delivery Gateway
31.	MSP	M2M Service Provider
32.	MTCTE	Mandatory Testing & Certification of Telecom Equipment
33.	NABH	National Accreditation Board for Hospitals & Healthcare Providers
34.	NDCP	National Digital Communications Policy
35.	NSDG	National e-governance Service Delivery Gateway
36.	NTC	National Trust Centre
37.	OFC	Optical Fibre Cable
38.	SDG	Sustainable Development Goals
39.	SDO	Standards Developing Organization
40.	SPV	Special Purpose Vehicle
41.	SSC	Smart Sustainable City
42.	SSDG	State e-governance Service Delivery Gateway
43.	TEC	Telecommunication Engineering Centre
44.	TRAI	Telecom Regulatory Authority of India
45.	TSDSI	Telecommunications Standards Development Society of India

46.	TSP	Telecom Service Provider
47.	UN	United Nations
48.	U4SSC	United for Smart Sustainable Cities
49.	VR	Virtual Reality
50.	WAN	Wide Area Network

Annexure-1: Important ITU-T standards on IoT and Smart cities

Standard Number	Title
ITU-T Y.3601	Big data - framework and requirements for data exchange
ITU-T Y.3602	Big data - Functional requirements for data provenance
ITU-T Y.4101	Common requirements and capabilities of a gateway for Internet of things applications
ITU-T Y.4102	Requirements for Internet of things devices and operation of Internet of things applications during disasters
ITU-T Y.4104	Service description and requirements for ubiquitous sensor network middleware
ITU-T Y.4107	Requirements for water quality assessment services using ubiquitous sensor networks (USNs)
ITU-T Y.4110	Service and capability requirements for e-health monitoring services
ITU-T Y.4111	Semantics based requirements and framework of the Internet of things
ITU-T Y.4112	Requirements of the plug and play capability of the Internet of things
ITU-T Y.4113	Requirements of the network for the Internet of things
ITU-T Y.4114	Specific requirements and capabilities of the Internet of things for big data
ITU-T Y.4116	Requirements of transportation safety services including use cases and service scenarios
ITU-T Y.4117	Requirements and capabilities of the Internet of things for support of wearable devices and related services
ITU-T Y.4119	Requirements and capability framework for IoT-based automotive emergency response system
ITU-T Y.4123	Requirements and capability framework for smart shopping mall systems
ITU-T Y.4200	Requirements for the interoperability of smart city platforms
ITU-T Y.4201	High-level requirements and reference framework of smart city platforms
ITU-T Y.4204	Accessibility requirements for the Internet of things applications and services
ITU-T Y.4205	Requirements and reference model of IoT-related crowdsourced systems
ITU-T Y.4211	Accessibility requirements for smart public transportation services
ITU-T Y.4212	Requirements and capabilities of network connectivity management in the Internet of things
ITU-T Y.4213	Internet of Things requirements and capability framework for monitoring physical city assets
ITU-T Y.4250	Sensor control networks and related applications in a next generation network environment
ITU-T Y.4251	Capabilities of ubiquitous sensor networks for supporting the requirements of smart metering services
ITU-T Y.4252	Energy saving using smart objects in home networks
ITU-T Y.4407	Framework of networked vehicle services and applications using NGN
ITU-T Y.4408	Capability framework for e-health monitoring services
ITU-T Y.4411	Overview of application programming interfaces and protocols for the machine-to-machine service layer
ITU-T Y.4413	Requirements and reference architecture of the machine-to-machine service layer

ITU-T Y.4418	Gateway functional architecture for Internet of things applications
ITU-T Y.4456	Requirements and functional architecture for smart parking lots in smart cities
ITU-T Y.4457	Architectural framework for transportation safety services
ITU-T Y.4461	Framework of open data in smart cities
ITU-T Y.4470	Reference architecture of artificial intelligence service exposure for smart sustainable cities
ITU-T Y.4477	Framework of service interworking with device discovery and management in heterogeneous Internet of things environments
ITU-T Y.4478	Requirements and functional architecture for smart construction site services
ITU-T Y.4480	Low power protocol for wide area wireless networks
ITU-T Y.4500.1	oneM2M – Functional architecture
ITU-T Y.4500.2	oneM2M – Requirements
ITU-T Y.4500.4	oneM2M – Service layer core protocol specification
ITU-T Y.4500.5	oneM2M management enablement (OMA)
ITU-T Y.4500.6	oneM2M management enablement (BBF)
ITU-T Y.4500.8	oneM2M – CoAP protocol binding
ITU-T Y.4500.9	oneM2M – HTTP protocol binding
ITU-T Y.4500.10	oneM2M – MQTT protocol binding
ITU-T Y.4500.11	oneM2M – Common terminology
ITU-T Y.4500.12	oneM2M base ontology
ITU-T Y.4500.13	oneM2M – Interoperability testing
ITU-T Y.4500.14	oneM2M – LwM2M interworking
ITU-T Y.4500.15	oneM2M – Testing framework
ITU-T Y.4500.20	oneM2M – Web Socket protocol binding
ITU-T Y.4500.22	oneM2M – Field device configuration
ITU-T Y.4500.23	oneM2M – Home appliances information model and mapping
ITU-T Y.4500.32	oneM2M- MAF and MEF Interface Specification
ITU-T Y.4553	Requirements of smartphone as sink node for IoT applications and services
ITU-T Y.4560	Blockchain-based data exchange and sharing for supporting Internet of things and smart cities and communities
ITU-T Y.4561	Blockchain-based data management for supporting Internet of things and smart cities and communities
ITU-T Y.4562	Functions and metadata of spatiotemporal information service for smart cities
ITU-T Y.4563	Requirements and functional model to support data interoperability in Internet of things environments
ITU-T Y.4700	Deployment guidelines for ubiquitous sensor network applications and services for mitigating climate change
ITU-T Y.4800	Requirements and functional architecture of an automatic location identification system for ubiquitous sensor network applications and services
ITU-T Y.4801	Requirements and common characteristics of the IoT identifier for the IoT service
ITU-T Y.4802	Multimedia information access triggered by tag-based identification - Registration procedures for identifiers
ITU-T Y.4803	Information technology – Automatic identification and data capture technique - Identifier resolution protocol for multimedia information access triggered by tag-based identification
ITU-T Y.4804	Multimedia information access triggered by tag-based identification - Identification scheme
ITU-T Y.4805	Identifier service requirements for the interoperability of smart city applications

ITU-T Y.4806	Security capabilities supporting safety of the Internet of things
ITU-T Y.4807	Agility by design for telecommunication / ICT systems security used in the IoT
ITU-T Y.4809	Unified Internet of things identifiers for intelligent transport systems
ITU-T Y.4810	Requirements for data security of heterogeneous Internet of things devices
ITU-T Y.4811	Reference framework of converged service for identification and authentication for IoT devices in a decentralized environment
ITU-T Y.4900	Overview of key performance indicators in smart sustainable cities
ITU-T Y.4901	Key performance indicators related to the use of information and communication technology in smart sustainable cities
ITU-T Y.4902	Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities
ITU-T Y.4903	Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals
ITU-T Y.4904	Smart sustainable cities maturity model
ITU-T Y.4905	Smart sustainable city impact assessment
ITU-T Y.4907	Reference architecture of blockchain-based unified KPI data management for smart sustainable cities
Y Suppl. 27	Smart sustainable cities - Setting the framework for an ICT architecture
Y Suppl. 28	Smart sustainable cities - Integrated management
Y Suppl. 29	Smart Sustainable Cities - Multi-service infrastructure in new-development areas
Y Suppl. 30	Smart sustainable cities - Overview of smart sustainable cities infrastructure
Y Suppl. 31	Smart sustainable cities - Intelligent sustainable buildings
Y Suppl. 32	Smart sustainable cities - A guide for city leaders
Y Suppl. 33	Smart sustainable cities - Master plan
Y Suppl. 34	Smart sustainable cities - Setting the stage for stakeholders' engagement
Y Suppl. 36	Smart water management in cities
Y Suppl. 40	Big data standardization roadmap
Y Suppl. 53	IoT use cases
Y Suppl. 56	Smart City use cases
ITU-T F.743	Requirements & service description for video surveillance
ITU-T F.743.11	Requirements for video surveillance with mobile premises units
ITU-T L.1502	Adapting ICT infrastructure to the effects of climate change
ITU-T X.1369	Security requirements for IoT service platform
ITU-T X.509	Public key and attributes certificate framework

All the standards released by ITU-T SG-20 are available on the following links:

https://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=20.

https://www.itu.int/en/ITU-T/focusgroups/dpm/Pages/default.aspx.

Annexure-2: Adoption of Standards / Technology: tentative roadmap for India

Technology available at present (2022)	Technology adoption by 2025	Technology adoption in 2025- 2030	
Short range & Low Power wireless			
Bluetooth Low Energy NFC, RFID ZigBee Z-wave Wi-Fi 6 (IEEE 802.11ax) 6lowpan Bluetooth 5	IEEE 802.15.4 technologies BLE Mesh 802.11ah Low power Wi-Fi Wireless USB		
WAN – Cellular			
Cellular 4G-LTE LTE advanced / LTE pro LTE-MTC (catM1)/ cat M2	LTE-U / LTE-LAA, LTE-M, Elevation beamforming / Full Dimension MIMO, Indoor positioning, Cellular 5G	Cellular V2X	
LPWAN – Cellular			
3GPP Release 13/14 and beyond based Cellular LPWAN Technologies NB-IoT Embedded SIM*	3GPP Release 14 and beyond based Cellular LPWAN Technologies NB-IoT (cat NB2) Embedded SIM	eNB-IoT	
LPWAN - non cellular			
LoRaWAN 1.0.4 Sigfox	Ingenu Weightless		
Fixed lines			
Ethernet			
PLC			
Other Technologies			
Narrow Artificial Intelligence (AI) oneM2M Release 2 standards	Edge computing AI, Machine Learning Facial Recognition/ object detection oneM2M Release 3 standards Block-Chain for IoT data security and data integrity checking. Embedded SIM to be used for application layer authentication and authorization in IoT devices.	AR/ VR, Digital Twin, Blockchain for Smart cities, oneM2M Release 4	
Technologies expected to be closed			
Cellular 3G Technology - closed by Airtel, in process of closing by VodafoneIdea			
Extra items			

	Standard for Machine KYC (Machine-Device-Custodian KYC) Review for IPv6 implementation for devices/ gateways to be connected directly to PSTN/ PLMN		

***Important links related to e-SIM [Source: GSMA]**

1. SM-DP/SM-SR

   o The only information available we have it is the SM-DP and SM-SR that have been accredited with the SAS:

   - Please see the link: *https://www.gsma.com/security/sas-accredited-sites/*

2. List of FAB / E-SIM manufacturer

   o Here, you could find the list of EUMs (eUICC Manufacture) that have been accredited with SAS:

   - Please see the link: *https://www.gsma.com/security/sas-accredited-sites/*

   o Here, you could find the list of EUM product that have been certified according to Global Platform:

   - *https://globalplatform.org/certified-products/?filter-certification-type=functional*

3. Certifying agency

   o The certifying agency for SAS are indicated in the link below:

   - *https://www.gsma.com/security/sas-auditors/*

   o The certifying laboratories for the Functional certification in the link below:

   - *https://globalplatform.org/laboratories/?utm_source=iseepr&utm_medium=Website&utm_campaign=Secure%20Component*

Annexure-3: Communication Technologies for deploying smart services in Smart Cities

Technology/Protocol	Frequency band(s)	Advantages	Limitations	Suitable for the sectors / applications
1. Low power short range technologies				
Bluetooth Low Energy	2.4 GHz	• Mature technology • Easy to implement • Low Power • Powered by coin cell • Longer battery life •	• Small data packets	• Healthcare devices • Fitness devices • Remote Health Monitoring • Smart Metering
Bluetooth Mesh	2.4 GHz	• Enables creation of large-scale device networks • Secure and reliable • Interoperable • Offers extended range • backward compatible with other BLE devices	• more complex and difficult to build and maintain • useful only for transmission of small packet sized data	• Control and monitoring industrial applications such as lighting control systems • Smart home and building automation • Asset Tracking • Healthcare
NFC	13.56 MHz	• Consumes less power • Almost instantaneous connectivity between devices • No power is required in-case of passive Tags	• Extremely short range • Expensive • Low information security • Low market penetration	• Healthcare devices • Fitness devices • Smart Metering
Wi-Fi 4 IEEE 802.11n Wi-Fi 5 IEEE 802.11ac	2.4 GHz and 5 GHz 5GHz	• Mature technology • High home/office penetration • High data rates achievable • Easy to implement • Wi-Fi 4 uses MIMO while Wi-Fi 5 MU-MIMO technology • Max throughput speed • Wi-Fi 4 : 600 Mbps • Wi-Fi 5: 3.5 Gbps	• Limited range • Poor building penetration • High interference from other sources • Power consumption higher than those technologies that operate in the sub-GHz band	• Base station in Health Clinics • Smart Metering • Home Automation

Wi-Fi 6 802.11 ac	2.4 GHz and 5 GHz	• MU-MIMO and OFDMA technology • Max throughput speed 9.6 Gbps	•	• For better user experience even for dense indoor/outdoor deployments such as airports, railway stations, shopping malls, stadiums, homes, school campuses
Wi-Fi 6 E IEEE 802.11 ax	2.4 GHz, 5 GHz and 6 GHz	• 6 GHz band provides 1200 MHz additional spectrum to Wi-Fi 6 enabled devices, Which Doubles the bandwidth and throughput of Wi-Fi 6 enabled devices.	• Smaller range compared to 5GHz spectrum • 6 GHz band (5.925 GHz to 7.125 GHz) is required to be delicensed.	• Applications like 8K video, AR/VR gaming and mission critical requirements.
Wi-Fi HaLow IEEE 802.11 ah	900 MHz delicensed band	• Low power • Longer connectivity range (approx. 1 Km) • IP support available	• Comparatively larger antenna size	• IoT use cases in industrial applications, agriculture, health care smart building, smart homes and smart city
Z-Wave	Sub 1GHz for India (865-867 MHz)	• Standardized by CSR 564 (E) • very successful due to its ease of use and interoperability • Majority share of the Home Automation market	• Proprietary radio systems available • Limited Range drives up costs	• Security systems. • Home automation. • Lighting controls
ZigBee	2.4 GHz, 920 MHz, 915 MHz, 868 MHz, 780 MHz	• Full support of IEEE 11073 device specialization profile • Longer battery life from low cost coin cells for wearable devices (source: ZigBee alliance) • Wireless range up to 70 meters indoor and 400 meters outdoor (source: ZigBee alliance)	• Not widely adopted • BLE is the direct competition for ZigBee providing different modes/profiles of operation. BLE is getting adopted faster than ZigBee within short span of time	• Health Monitoring and Safety • Client Activity Monitoring • Health and Wellness monitoring
2. Cellular Technologies				

Cellular (2G-GSM/EDGE, 3G-UMTS, 4G-LTE)	For India, 900 MHz, 1800 MHz, 2100 MHz and 2300 MHz is allocated .	• Mature technology • Developed by global community of 400+ companies from 39 countries • Rapid deployment • Communication modules are low cost and standardized. • Roaming • Wide availability of Network Infrastructure	• Coverage not 100% • Reliability not the best • Short technology life-cycle (2G, EDGE, 3G, LTE etc.)	• Tele-Health • Remote Health Monitoring • Smart Metering • Remotely switching ON/ OFF the water pump in rural areas, using mobile phone • Tracking devices for connected vehicle
Cellular 5G		• High speed internet services (eMBB) • Low latency (<1ms) (uRLLC) • Large number of devices may be connected / Sq Km. (massive M2M) • Wider coverage • Technology for vertical applications		• e-Governance, • Remote surgery, • Drones, • Remote maintenance of machines • City surveillance • Connected vehicles (tracking device) • Precision agriculture • Livestock monitoring and management • Industry 4.0 • Intelligent transport system based on 3GPP C-V2X standards
3. Cellular Low power wide area network technologies				
Cellular: EC GSM IoT	2G Bands	• Network infrastructure is backwards-compatible to previous releases to allow the technology to be introduced into existing GSM networks	• Eco system is yet to be developed	• Smart cities & homes • Smart utilities • Industrial automation • Wearables • Smart energy • Intelligent transport systems

Cellular: NB-IoT	Conventional LTE cellular bands like 700 MHz, 800 MHz and 900 MHz, and re-farmed 2G bands	• Standards based defined by 3gpp, the global standardization organizations supported by a mature global ecosystem • wide area ubiquitous coverage • deployed through upgrade of existing network (reuses existing network infrastructure) • Ultra-low-power consumption in devices • Enhanced for 20+dB additional coupling gain. (reaches deeper in-building & underground) • low cost terminal • plug and play • high reliability and high carrier-class e2e network security (based on LTE)	• Limited Mobility is not yet supported (limited support based on cell reselection) • Voice is not supported • Low Data rate applications with link peak DL = 60~100kbps & UL=~50kbps	• Sensor based applications, with low data rate requirement. • Applications not requiring high speed mobility handovers. • Systems where devices/sensor measurements are expected to be for long ~10years
Cellular: eMTC	Conventional LTE cellular bands like 700 MHz, 800 MHz and 900 MHz	• Developed by 3GPP a mature global ecosystem • Low power consumption • Works over existing LTE networks • Easily configurable on demand scaling possible • Supports full mobility • Supports voice through VoLTE • high reliability and high carrier-class e2e network security (based on LTE)	• Support of higher bandwidth limits the other optimizations possible, compared to NB-IoT and EC-GSM-IoT	• Wearables, • Asset Tracking, • Pet Trackers • Telematics, • KIOSK, • Parking, • Industry environment monitoring, • Connected Healthcare personal & Enterprise equipment • Industrial IoT with Emergency Voice call support
4. Non Cellular Low Power Wide Area Network technologies				
LoRaWAN (https://lora-alliance.org/)	Sub 1 GHz (865 – 867) MHz	• Supports ultra-low power & supports battery life up to 10-12 years. • Secure with AES-128 encryption. • very-low subscription cost	• Private deployment with no subscription fees • Works in unlicensed band.	• Smart Metering • Smart street Lighting solutions • Smart homes and building

		• Low cost infrastructure • Deep indoor penetration • Deployment in public as well as private networks • International Roaming (https://lora-alliance.org/lora-alliance-press-release/lorawan-roaming-now-available-in-more-than-25-countries/)	• Limited data rate (upto 5Kbps) and payload size (upto 222 bytes) are supported.	• Asset monitoring • Tracking • Soil monitoring • Weather forecasting • Environmental Monitoring • Bi-directional use-cases to instruct WSN devices and fire alerts etc. • Wild-Life monitoring • Combinative use-cases with RFID, BLE, RS232 and other short-range communication technologies.
SIGFOX	Sub 1 GHz (865 – 867) MHz	• Provide long range and low power connectivity services. • Deliver high quality of service operating in unlicensed spectrum. • Enable long battery life and energy efficiency • No pairing required between device and base station. • One global network (in 60 countries till date) with no roaming charges • Low cost • Security by design	• Voice not supported • Limited to low throughput usage • Works in unlicensed spectrum	• Logistics & Transportation • Utility & smart metering • Industrial Mfg. • Asset Tracking • 0G – back up connectivity • Condition monitoring • Locations
5. Wireline Technologies				
DSL	0-2.208 MHz	• Inexpensive (installation and use) • High SLA • Less installation time • Bonded DSL provides inherent redundancy	• Low data security • Lower throughput • Higher latency	• Gateway for Remote Health Monitoring • Concentrator for Tele-Health • Home Automation
Ethernet	16,100,250 ,500, 600 MHz 1 GHz, 1.6-	• Inexpensive (installation and use) • Excellent throughput • Low installation time • Easily scalable	• Lowest data security • Lowest SLA • Highest latency	• Gateway for Remote Health Monitoring • Concentrator for Tele-Health • Smart Metering

	2.0 GHz		• Bursts of additional bandwidth not possible	• Home Automation
PLC	No defined frequency band in India	• Ready infrastructure • Communication possible in challenging environments such as underground installations, metal-shielded cases etc. • Long technology life-cycle • Many standards and protocols available	• Point-to-point communication • Can cause disturbances on the lines • Not suitable where power cables are not in a good condition; initial and ongoing line conditioning and maintenance can add significant O&M costs • Highly trained manpower required for O&M • Communication not possible in case of an outage • Absence of regulations on use of frequency bands	• Smart metering • Home automation

Annexure-4: Synopsis of delicensed spectrum in Sub-GHz band in various countries

Table: Synopsis of delicensed spectrum in Sub-GHz band in various countries[83]

Country/ Region	Frequency Band
North America, Mexico and South America	433.075-434.775 MHz and 902-928 MHz
Africa and Middle Eastern countries	433.05-434.79 MHz and 863-870 MHz
Europe	433.05-434.79 MHz, 863-870 MHz, 870-876 MHz, 915-921 MHz
Japan	426-430 MHz and 920-928 MHz
Australia/ New Zealand	915-928 MHz
India	433-434 MHz and 865-868 MHz
China	470-510 MHz and 920.5-924.5 MHz
Singapore	866-869 MHz and 920-925 MHz
Hong Kong/ Thailand/ Vietnam	920-925 MHz
Brazil	902-907.5 MHz and 915-928 MHz
Philippines	915-918 MHz
Malaysia	919-923 MHz

[83] https://tec.gov.in/pdf/M2M/Communication%20Technologies%20in%20IoT%20domain.pdf

Annexure-5: List of TEC GRs, IRs, ERs and Standards (SD)

5.1. List of Generic Requirements (GRs):

S. No.	Category	Title of the GR	TEC Number
1.	OF-cable	Metal free Optical Fibre Cable (G.652 D Fibre)	GR/OFC-17/01.JUN.2007 with Amendment No. 1 dated 28.8.08 or TEC 85140:2007
2.	OF-cable	ADSS Optical Fibre Cable For laying along Power line alignments (Type-I & Type-II)	TEC 85190:2022
3.	OF-cable	Riser Optical Fibre cable (For Indoor Applications)	TEC/GR/TX/OFC-025/01/MAR-17 or TEC 85210:2017
4.	OF-cable	Installation Accessories and fixtures of Self Supporting Metal free Aerial Optical Fibre Cable	TEC/GR/TX/OAF-001/03/MAR-17 or TEC 87060:2017
5.	OF-cable	Self Supporting Metal Free Aerial Optical Fibre Cable (For Hilly & Rural Area)	TEC/GR/TX/OFC-003/04/APR-18 or TEC 85020:2018
6.	OF-cable	Self Supporting Metal Free Aerial Optical Fibre Cable (For Urban areas)	TEC/GR/TX/OFC-012/02/APR-18 or TEC 85090:2018
7.	OF-cable	Aerial Optical Fibre Drop Cable for FTTH applications (For Short span)	TEC/GR/TX/OFC-026/01/APR-18 or TEC 85220:2018
8.	OF-cable	Optical Fibre Cable for FTTH application (G.657 A Fibre)	TEC 85160:2021
9.	OF-cable	Aerial Drop Optical Fibre Cable (For Last Mile Application)	TEC 85200:2022
10.	OF-cable	Non Zero Dispersion Shifted Single Mode Metal Free Optical Fibre Cable	TEC/GR/TX/OFC-007/03/DEC-15 or TEC 85050:2015
11.	OF-cable	Self Supporting Metal Free Aerial Optical Fibre Cable (For Urban areas)	TEC/GR/TX/OFC-012/02/APR-18 or TEC 85090:2018
12.	OF-cable	Aerial Optical Fibre Drop Cable for FTTH applications (For Short span)	TEC/GR/TX/OFC-026/01/APR-18 or TEC 85220:2018
13.	OFC-Acc.	Optical Fibre Splice Protection Sleeves	TEC/GR/TX/PTS-01/03/JAN-2011 or TEC 89020:2011
14.	OFC-Acc.	Optical Fibre Splice Protection Sleeves for Optical Fibre Ribbon	TEC/GR/TX/PTS-02/03/JAN-2011 or TEC 89030:2011
15.	OFC-Acc.	Digital Distribution Frame	TEC/GR/TX/DDF-001/05/SEP-12 or TEC 89090:2012
16.	OFC-Acc.	Optical Fixed Attenuator (Type-A & Type-B)	TEC/GR/TX/OPA-003/03/OCT-14 or TEC 88040:2014
17.	OFC-Acc.	Optical Variable Attenuator (Type-A & Type-B)	TEC/GR/TX/OPA-001/04/OCT-14 or TEC 88050:2014

18.	OFC-Acc.	High Precision Cleaver for Ribbon Fibre	TEC/GR/TX/OCR-001/03/DEC-15 or TEC 89040:2015
19.	OFC-Acc.	Hot Jacket Remover for Ribbon Fibre	TEC/GR/TX/OJR-001/03/DEC-15 or TEC 89050:2015
20.	OFC-Acc.	Optical Fibre Jumpers (Type-I to Type-IV) & Adaptors (Type-I to Type-IV) and Hybrid Jumpers (Type-I to Type-VI) & Hybrid Adapters (Type-I to Type-VI)	TEC/GR/TX/OFJ-01/05/NOV-09 with Errata No. 1 dated 07.05.13 or TEC 87070:2009
21.	OFC-Acc.	Installation Accessories and fixtures of Self Supporting Metal free Aerial Optical Fibre Cable	TEC/GR/TX/OAF-001/03/MAR-17 or TEC 87060:2017
22.	OF-Equip	STM-16 Synchronous Multiplexer for TM, ADM & Multi-ADM Applications	TEC/GR/TX/SDH-008/03.JAN.2011 or TEC 86040:2011
23.	OF-Equip	STM-64 Synchronous Multiplexer at bit rates for (TM & ADM) for Metro Applications	TEC/GR/TX/SDH-007/02.JAN.2011 or TEC 86050:2011
24.	OF-Equip	Optical Fibre Splicing Machine	TEC/GR/TX/OSM-001/04/SEP-12 or TEC 88090:2012
25.	OF-Equip	Optical Fibre Splicing Machine for Ribbon Fibre	TEC/GR/TX/OSM-002/03/SEP-12 or TEC 88100:2012
26.	OF-Equip	Ethernet Media Converter	TEC/GR/TX/EMC-001/02/SEP-12 or TEC 89070:2012
27.	OF-Equip	40/80 Channel Dense Wavelength Division Multiplexing (DWDM) System with Channel bit-rate of 100/200 Gbps for Core/Metro Network Applications	TEC 86070:2021
28.	OF-Equip	40/80 Channel Dense Wavelength Division Multiplexing (DWDM) Equipment with Channel Bit-rates upto 10Gbps for Metro/Core Network Applications	TEC/GR/TX/WDM-010/01/DEC-16 or TEC 86080:2016
29.	OF-Equip	Multi-Service Optical Transport Network (OTN) platform with DWDM bearer transport system for Metro and Core Network applications	TEC/GR/TX/OTN-001/02/DEC-17 or TEC 86090:2017
30.	OF-Equip	Optical-Electrical-Optical (O-E-O) based Digital Cross-Connect (DXC) Equipment with Automatic Switched Optical Network (ASON) Capability	GR/DXC-03/02.SEP.2008 or TEC 86120:2008

31.	OF-Equip	Fibre Distribution Management System (Type I, Type-II & Type-III)	GR/FDM-01/02.APR.2007 with Amendment No.1 dated 02.05.12 or TEC 87010:2007
32.	OF-Equip	Ethernet Traffic Analyzer for Ethernet Transport Service Testing - Hand-held model	TEC/GR/TX/ETA-004/02/FEB-15 or TEC 88200:2015
33.	OF-Equip	Optical Time Domain Reflectometer (Type-II) (1550 nm & 1625 nm wavelength) for Long Haul Applications	TEC/GR/TX/OTD-03/02/APR-2010 or TEC 88140:2010
34.	OF-Equip	PON OTDR (Type-A) for FTTH Applications	TEC/GR/TX/OTD-04/01/APR-2010 or TEC 88170:2010
35.	OF-Equip	PON OTDR (Type-B) for FTTH Applications	TEC/GR/TX/OTD-05/01/APR-2010 or TEC 88180:2010
36.	OF-Equip	PON Power Meter (For FTTH applications)	TEC/GR/TX/OPM-03/01/APR-2010 or TEC 88190:2010
37.	OF-Equip	Next Generation SDH Transport Network Tester @ STM-1/4/16 Rates at 1310 & 1550nm & STM-64 Rates at 1550nm wavelengths	TEC/GR/TX/SDA- 003/02/ APR-2010 or TEC 88250:2010
38.	OF-Equip	FTTX based Broadband Access Applications using GPON technology with Mini-OLT	TEC/GR /FA/PON-002/02/ NOV- 2018 or TEC 71040:2018
39.	OF-Equip	FTTH/FTTB/FTTC BROADBAND ACCESS APPLICATIONS USING GIGABIT PASSIVE OPTICAL NETWORK (GPON) TECHNOLOGY	TEC/GR/TX/PON-001/03/MAR-17 or TEC 71010:2017
40.	OFC Test Equip	Ethernet Traffic Analyser upto 10G (Hand Held Model)	TEC/GR/TX/ETA-007/01/MAR-16 or TEC 88230:2016
41.	OFC Test Equip	Ethernet Traffic Analyser 100G (Hand Held)	TEC/GR/TX/ETA-008/01/MAR-19 or TEC 88240:2019
42.	OFC Test Equip	Optical Time Domain Reflectometer (Mini) (Type-A & Type-B)	TEC/GR/TX/OTD/002/04/AUG-19 or TEC 88130:2019
43.	OFC Test Equip	Optical Time Domain Reflectometer (Type-I) (1310 nm & 1550 nm wavelength) for Long Haul Applications	TEC/GR/TX/OTD-001/05/SEP-19 or TEC 88120:2019
44.	OFC Test Equip	10G Ethernet Traffic Analyzer for Ethernet Transport Service Testing	GR/ETA-06/01.SEP.2008 or TEC 88220:2008
45.	OFC Test Equip	Ethernet Traffic Analyzer for Ethernet Transport Service Testing - Hand-held model	TEC/GR/TX/ETA-004/02/FEB-15 or TEC 88200:2015
46.	OFC Test Equip	Optical Dispersion Analyzer	TEC 88030:2021
47.	OFC Test Equip	Optical Power meter (Type-A & Type-B)	TEC/GR/TX/OPM-001/04/NOV-13 or TEC 88060:2013

48.	OFC Test Equip	Optical Transport Network (OTN) Analyzer	TEC/GR/TX/OTA-001/02/MAR-14 or TEC 88290:2014
49.	IT-Equip	Narrowband Remote Access Servers	TEC/GR/IT/RAS - 002/02.APRIL.2009 or TEC 48000:2009
50.	IT-Equip	Internet Data Centre	TEC/GR/SA/IDC - 001/02 MAR 2010 or TEC 51040:2010
51.	IT-Equip	Video Surveillance Platform	TEC/GR/SA/VSP - 001/01/MAR – 10 or TEC 51050:2010
52.	IT-Equip	Optical Router	TEC/GR/SA/DCA-22/03 MARCH.2011 or TEC 48030:2011
53.	IT-Equip	ADSL Based Broadband Network	TEC/GR/I/PDN - 012/02 MARCH.2012 or TEC 49040:2012
54.	IT-Equip	BGP/MPLS Virtual Private Network	TEC/GR/I/VPN - 001/03.MAR.2012 or TEC 49050:2012
55.	IT-Equip	Broadband Access on Cable TV Architecture	TEC/GR/I/CAB - 001/02.MAR.2012 or TEC 49060:2012
56.	IT-Equip	ISP (Internet Service Provider) Applications	TEC/GR/I/ISA - 001/02 MARCH.2012 or TEC 51070:2012
57.	IT-Equip	Cloud Infrastructure	TEC/GR/I/CLI-001/01 OCT 2012 or TEC 50000:2012
58.	IT-Equip	Digital Network Synchronization Equipment	TEC/GR/SW/SYN-001/01/OCT2012 or TEC 49080:2012
59.	IT-Equip	Router for MPLS Based Transport Network	TEC/GR/IT/TCP-004/01.FEB2014 or TEC 48050:2014
60.	IT-Equip	Content Delivery Network	TEC/GR/IT/CDN - 01/03. MAR 2014 or TEC 51080:2014
61.	IT-Equip	Firewall System	TEC/GR/IT/FWS - 001/04. MAR.2014 or TEC 49090:2014
62.	IT-Equip	Local Area Network Switch	TEC/GR/IT/LSW - 001/05.MAR.2014 or TEC 48060:2014
63.	IT-Equip	Integrated Gateway Router	TEC/GR/IT/TCP-005/01. MAR 2014 or TEC 48070:2014
64.	IT-Equip	Ethernet Electrical to Optical media Converter	TEC/ GR/ IT/ EOC - 001/0 4 SEP 2014 or TEC 48080:2014
65.	IT-Equip	Relational Database Management System for Telecom Applications	TEC/GR/IT/RDB-001/01/MAR 2015 or TEC 51100:2015
66.	IT-Equip	NMS	TEC/GR/IT/NMS-003/01 NOV 2015 or TEC 48100:2015
67.	IT-Equip	Data Storage Infrastructure	TEC/GR/IT/DSI - 001/04.DEC.2015 or TEC 49100:2015
68.	IT-Equip	Integrated Systems	TEC/GR/IT/SRV-002/01/MAR 2016 or TEC 48110:2016
69.	IT-Equip	Software Defined Network [SDN] Controller, and Additional Requirements for LAN Switches,	TEC/GR/IT/SDN-001/01/MAR 2016 or TEC 50010:2016

		Carrier Ethernet Switches and Routers for SDN	
70.	IT-Equip	Call Centre	TEC/GR/IT/CLC-001/04/AUG-16 or TEC 51110:2016
71.	IT-Equip	Element Management System (eMS) For Next Generation Networks (NGN)	TEC/GR/IT/NMS-001/02/AUG-16 or TEC 49110:2016
72.	IT-Equip	MPLS SDN Router	TEC/GR/IT/TCP-006/01/AUG-16 or TEC 48120:2016
73.	IT-Equip	Multi-Protocol Label Switching Transport Profile (MPLS-TP) Based Carrier Ethernet Network (CEN) for Access and Aggregation Network Applications	TEC/GR/IT/CEN-004/03/MAR-17 or TEC 48130:2017
74.	IT-Equip	Interactive Voice Response System	TEC/GR/IT/IVR - 001/06.MAR-17 or TEC 51120:2017
75.	IT-Equip	VoIP Protocol/Performance Analyser	TEC/GR/IT/DCI - 001/04 MAR-17 or TEC 52110:2017
76.	IT-Equip	Unified Threat Management	TEC/GR/IT/UTM-010/02 MAR-18 or TEC 49120:2018
77.	IT-Equip	Intrusion Detection System for IP Network Security.	TEC/GR/IT/IDS-001/04/SEP-18 or TEC 49130:2018
78.	IT-Equip	Intrusion Prevention System	TEC/GR/IT/IPS-001/03/SEP-18 or TEC 49140:2018
79.	IT-Equip	Server	TEC/GR/IT/SRV-001/02/MAR-18 or TEC 48140:2018
80.	IT-Equip	Network Function Virtualization Infrastructure (NFVI) and Virtual Infrastructure Manager (VIM)	TEC/GR/IT/NFV-001/01/MAR-18 or TEC 50020:2018
81.	IT-Equip	Primary Reference Clock cesium frequency standards	TEC/GR/IT/SYN-003/04/MAR2019 or TEC 49150:2019
82.	IT-Equip	Network Timing Protocol Server	TEC/GR/IT/NTS-001/02/MAR-19 or TEC 48150:2019
83.	IT-Equip	Software Defined Wide Area Network (SDWAN)	TEC/GR/IT/SDW/001/01MAY2019 or TEC 49160:2019
84.	IT-Equip	MPLS Performance Analyser	GR/DCS-10/02 FEB-07 or TEC 52070:2007
85.	IT-Equip	MPLS Protocol Analyser	GR/DCS-11/02 FEB-07 or TEC 52080:2007
86.	IT-Equip	SIP Application Server	TEC/GR/SW/SAS-S01/02/NOV2009 or TEC 59170:2009
87.	Wi-Fi Equip	Standard for GR for Wi-Fi Access Point	TEC 38020:2021
88.	Wi-Fi Equip	Wi-Fi Hotspot	TEC/GR/RS/WFS-001/02/MAR-17 or TEC 38030:2017

89.	Wi-Fi Equip	Wireless Local Area Network	TEC/GR/WS/WLAN-001/03/SEP-11 or TEC 38040:2011
90.	Wi-Fi Equip	WLAN Controller	TEC/GR/RS/WFS-002/01/MAR-17 or TEC 38010:2017
91.	Wi-Fi Equip	RADIO ACCESS SYSTEM FOR BROADBAND APPLICATION IN 3.3 – 3.4 GHz BAND	TEC/GR/R/RAS/001/01.MAR 2015 OR TEC 36110:2015

5.2. List of Interface Requirements (IRs):

S. No.	Category	Title of the IR	TEC Number
1.	IT-Equip	Routers	TEC/IR/IT/TCP-001/05.MAR.2014 or TEC 48012:2014
2.	IT-Equip	Customer Premises Equipment for MPLS Network	TEC/IR/IT/ CPE - 003/02 MAR 2014 or TEC 48022:2014
3.	IT-Equip	Ethernet Electrical to Optical media Converter	TEC/IR/IT/EOC-002/01 SEP 2014 or TEC 48032:2014
4.	IT-Equip	Firewall System	TEC/IR/IT/FWS-002/01 SEP 2014 or TEC 49002:2014
5.	IT-Equip	LAN Switch	TEC/IR/IT/LSW-003/01 SEP 2014 or TEC 48042:2014
6.	IT-Equip	Interactive Voice Response System	TEC/IR/IT/IVR-002/05 JAN-18 or TEC 51012:2018
7.	Wi-Fi Equip	Wi-Fi Access Point	TEC/IR/R/WIFIAP/001/01 MAR-2015 or TEC 38012:2015
8.	Wi-Fi Equip	Wi-Fi Data Card USB	TEC/IR/CP/WFU-001/01/DEC-13 or TEC 38022:2013
9.	MT	Embedded Subscriber Identity Module (ESIM)	TEC/IR/WS/ESM-101/01/MAR-19 or TEC 20062:2019

5.3. List of Service Requirements (SRs):

S. No.	Category	Title of the SR	TEC Number
1.	IT-Equip	Audio Conferencing	TEC/SR/IT/ACS-01/02/JUN-20 or TEC 51014:2020
2.	IT-Equip	Integrated Disaster Management System (IDMS) using Common Alert Protocol (CAP)	TEC/SR/IT/CAP-211/02/MAR- 20 or TEC 51004:2020

5.4. List of Essential Requirements (ERs):

S. No.	Category	Title of the ER	TEC Number
1.	OF- Equip	Transmission Terminal Equipment (having variants- SDH Equipment, Multiplexing	TEC7883xxxx

		Equipment, Digital Cross Connect (DXC), Dense Wavelength Division Multiplexing (DWDM) Equipment)	
2.	OF- Equip	PON family of Broadband Equipment	TEC1476xxxx
3.	OF-Cable	Optical Fibres (Single Mode)	TEC7001xxxx
4.	IT-Equip	Router (having variants IPv4, IPv6, MPLS, BNG/BRAS Router, Cloud Control Capable Router)	TEC3768xxxx
5.	IT-Equip	LAN Switch (having variants L2, L3 Switch, MPLS TP CEN Switch)	TEC3794xxxx
6.	IT-Equip	IP Security Equipment (having variant Firewall, UTM, IPS, IDS)	TEC3473xxxx
7.	Radio	Equipments Operating in 2.4 GHz and 5 GHz	TEC5943xxxx
8.	Radio	Mobile Radio Trunking System	TEC5678xxxx
9.	Radio	Satellite Communication Equipments	TEC5728xxxx
10.	Radio	VHF UHF Radio System Equipment	TEC5843xxxx
11.	Radio	HF Radio	TEC5437xxxx
12.	Radio	PTP PMP Microwave Fixed Radio Systems	TEC5642xxxx
13.	Radio	Radio Broadcast Receiver RBR	TEC5001xxxx
14.	IoT	IoT Gateway	TEC2449xxxx
15.	IoT	Tracking Device	TEC2873xxxx
16.	IoT	Smart Electricity Meter	TEC2836xxxx
17.	IoT	Smart Watch	TEC2898xxxx
18.	IoT	Smart Security Camera / CCTV	TEC2882xxxx
19.	IoT	Feedback Device	TEC2323xxxx
20.	FN	POS (Point of Sale) Devices	TEC1767xxxx
21.	FN	Modem	TEC1663xxxx
22.	MT	Mobile User Equipment (having variants Mobile Handset i.e. feature phone and smart phone, Tablets /Phablets, Data Card/Dongle(with/ without Wi-Fi) or any other device having cellular interface)	TEC4772xxxx

Note: *The last 4 digits of ER number represent month and year of the issue which will keep changing with every new issue/ version of ER on the portal.*

5.5. List of Standards related to human safety:

S. No.	Category	Title of the standard	TEC Number
1.	Radio	Specific Absorption Rate (SAR) for Wireless Communication Devices used in close proximity to human body	TEC 13016:2020
2.	Radio	Standard for Environmental Testing of Telecommunication Equipment	TEC 14016:2010
3.	Radio	Electromagnetic Compatibility Standard for telecommunication Equipment	TEC 11016:2016

Note:

1. *Safety standard **IS 13252-1 / IEC 60950-1 / IEC 62368-1** is being used in the ERs of telecom equipment and IoT devices mentioned above.*
2. ***TEC documents are freely available.** GR / IR/ SR may be accessed using link https://www.tec.gov.in/tec-divisions/ and ERs may be accessed using link https://www.mtcte.tec.gov.in/.*
3. Latest standards released by TEC may also be referred from the link *https://www.tec.gov.in/standards-specifications*

Annexure- 6: oneM2M Release 2 specifications adopted as National Standards by TEC

Technical Specifications (TS):

	oneM2M Rel 2 transposed by TSDSI			Identical adoption as National Standards		
S. No.	**oneM2M Specification Title**	**oneM2M TS Number**	**TSDSI Standard Number**	**TEC Adopted Standard Title**	**TEC Adopted Standard Number**	**Remarks**
1	Functional Architecture	TS-0001	TSDSI STD T1.oneM2M TS-0001-2.10.0 V1.0.0	oneM2M-Functional Architecture	TEC 30001:2020	
2	Requirements	TS-0002	TSDSI STD T1.oneM2M TS-0002-2.7.1 V1.0.0	oneM2M-Requirements	TEC 30002:2020	
3	Security Solutions	TS-0003	TSDSI STD T1.oneM2M TS-0003-2.4.1 V1.0.0	oneM2M-Security Solutions	TEC 30003:2020	
4	Service Layer Core Protocol	TS-0004	TSDSI STD T1.oneM2M TS-0004-2.7.1 V1.0.0	oneM2M- Service Layer Core Protocol	TEC 30004:2020	
5	Management Enablement (OMA)	TS-0005	TSDSI STD T1.oneM2M TS-0005-2.0.0 V1.0.0	oneM2M-Management Enablement (OMA)	TEC 30005:2020	
6	Management enablement (BBF)	TS-0006	TSDSI STD T1.oneM2M TS-0006-2.0.1 V1.0.0	oneM2M-Management enablement (BBF)	TEC 30006:2020	
7	*Service Components*	*TS-0007*	*TSDSI STD T1.oneM2M TS-0007-2.0.0 V1.0.0*			**skipped*
8	HTTP Protocol Binding	TS-0009	TSDSI STD T1.oneM2M TS-0009-2.6.1 V1.0.0	oneM2M- HTTP Protocol Binding	TEC 30009:2020	
9	MQTT protocol binding	TS-0010	TSDSI STD T1.oneM2M TS-0010-2.4.1 V1.0.0	oneM2M- MQTT protocol binding	TEC 30010:2020	
10	Common Terminology	TS-0011	TSDSI STD T1.oneM2M TS-0011-2.4.1 V1.0.0	oneM2M-Common Terminology	TEC 30011:2020	
11	Base Ontology	TS-0012	TSDSI STD T1.oneM2M TS-0012-2.0.0 V1.0.0	oneM2M- Base Ontology	TEC 30012:2020	
12	LWM2M Interworking	TS-0014	TSDSI STD T1.oneM2M TS-0014-2.0.0 V1.0.0	oneM2M-LWM2M Interworking	TEC 30014:2020	
13	Testing Framework	TS-0015	TSDSI STD T1.oneM2M TS-0015-2.0.0 V1.0.0	oneM2M- Testing Framework	TEC 30015:2020	
14	WebSocket Protocol Binding	TS-0020	TSDSI STD T1.oneM2M TS-0020-2.0.0 V1.0.0	oneM2M-WebSocket Protocol Binding	TEC 30020:2020	
15	*oneM2M_and_AllJoyn_Interworking*	*TS-0021*	*TSDSI STD T1.oneM2M TS-0021-2.0.0 V1.0.0*			**skipped*

16	Home Appliances Information Model and Mapping	TS-0023	TSDSI STD T1.oneM2M TS-0023-2.0.0 V1.0.0	oneM2M- Home Appliances Information Model and Mapping	TEC 30023:2020	
17	*OIC_Interworking*	*TS-0024*	*TSDSI STD T1.oneM2M TS-0024-2.0.0 V1.0.0*			**skipped*

Technical Reports (TRs):

	oneM2M Rel 2 transposed by TSDSI			**Identical adoption as National Standards**	
S. No.	**oneM2M Document Title**	**oneM2M TR Number**	**TSDSI Standard Number**	**TEC Adopted Standard Title**	**TEC Adopted Standard Number**
1	Use Cases Collection	TR-0001	TSDSI STD T1.oneM2M TR-0001-2.4.1 V1.0.0	oneM2M- Use Cases Collection	TEC 30031:2020
2	Study on Abstraction and Semantics Enablement	TR-0007	TSDSI STD T1.oneM2M TR-0007-2.11.1 V1.0.0	oneM2M- Study on Abstraction and Semantics Enablement	TEC 30032:2020
3	Security	TR-0008	TSDSI STD T1.oneM2M TR-0008-2.0.0 V1.0.0	oneM2M- Security	TEC 30033:2020
4	End-to-End-Security and Group Authentication	TR-0012	TSDSI STD T1.oneM2M TR-0012-2.0.0 V1.0.0	oneM2M- End-to-End-Security and Group Authentication	TEC 30034:2020
5	Authorization Architecture and Access Control Policy	TR-0016	TSDSI STD T1.oneM2M TR-0016-2.0.0 V1.0.0	oneM2M- Authorization Architecture and Access Control Policy	TEC 30035:2020
6	Home Domain Abstract Information Model	TR-0017	TSDSI STD T1.oneM2M TR-0017-2.0.0 V1.0.0	oneM2M- Home Domain Abstract Information Model	TEC 30036:2020
7	Industrial Domain Enablement	TR-0018	TSDSI STD T1.oneM2M TR-0018-2.0.0 V1.0.0	oneM2M- Industrial Domain Enablement	TEC 30037:2020
8	Dynamic Authorization for IoT	TR-0019	TSDSI STD T1.oneM2M TR-0019-2.0.0 V1.0.0	oneM2M- Dynamic Authorization for IoT	TEC 30038:2020
9	Continuation and Integration of HGI Smart Home activities	TR-0022	TSDSI STD T1.oneM2M TR-0022-2.0.0 V1.0.0	oneM2M- Continuation and Integration of HGI Smart Home activities	TEC 30039:2020
10	3GPP_Release13_IWK	TR-0024	TSDSI STD T1.oneM2M TR-0024-2.0.0 V1.0.0	oneM2M- 3GPP_Release13_IWK	TEC 30040:2020

These standards may be accessed on TEC website using link (*https://tec.gov.in/onem2m*)

Annexure 7: Smart Pole

The figure given below shows a snapshot of representative smart pole with different use-cases.

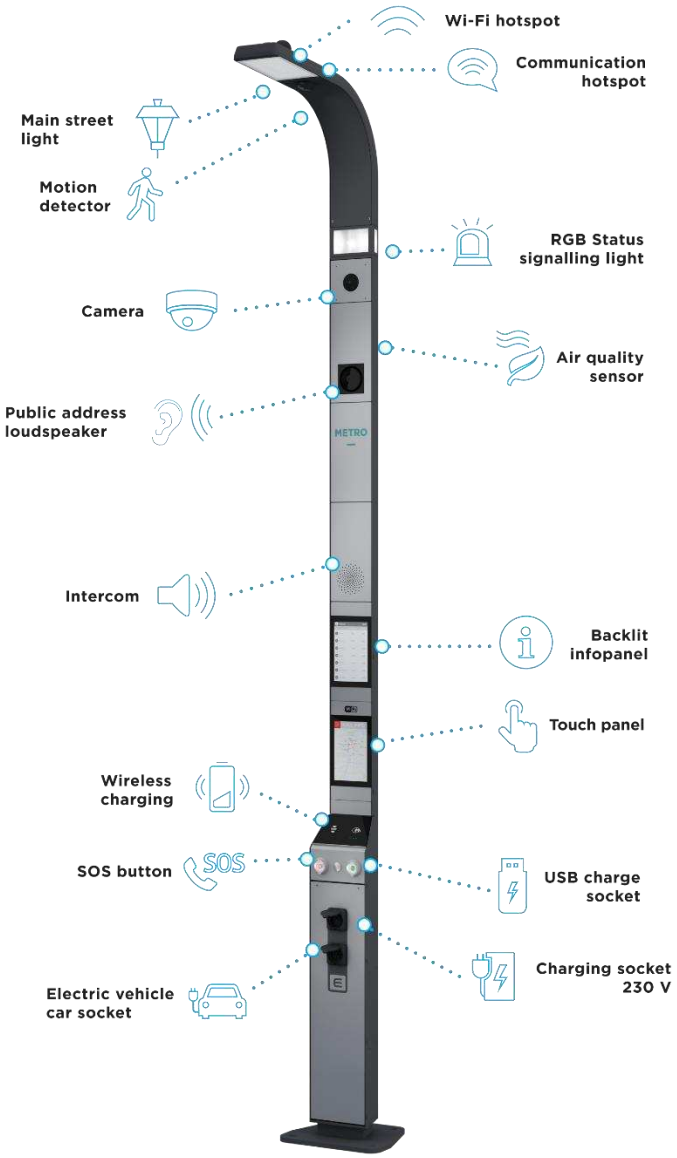


FIGURE 27: SMART POLE[84]

The Smart Pole has different components or electronic system and can be technically classified in the following categories.

Sensors: Sensors are the major contributors to the Smart Pole. These sensors can monitor air pollution, noise pollution and environmental parameters such as temperature, humidity etc. Apart from this, there are motion sensors that get triggered when there is a motion and accordingly the intensity of light is controlled, thus helping in energy conservation. There can be many other use cases also, based on the sensors present on the Smart Pole.

[84] https://www.elkoep.com/smartpole

Connectivity: Connectivity is the key element for making the Smart Pole smart. There are different technologies for communications that can be deployed on case to case basis. Some of the technologies are Wi-Fi, GPRS, LoRa and Sub1-GHz. There may be a possibility that a Smart Pole has support of two or more communication technologies depending on the requirements and topologies. The Smart Poles can also serve as an Internet Hotspot for public service.

Smart Pole also has the provision of intercom and public address system in the Smart Pole in case of emergency. Some of the Smart Pole carry SOS button in case of emergency where the person is not able to make a call. There are new Smart Poles coming up with audio sensors that can be activated based on the requirement to get the audio in the surroundings.

Camera: Camera is another utility of the Smart Pole required for the safety and security applications. With the rise in crimes and violation of traffic rules, camera serves a deterrent for the rule breakers as it provides real time evidence.

Display: Some of the Smart Poles are coming with digital display that can be used for public addressing, signages and advertisements. The digital display can be connected to the command and control center. Selective messages can also be sent on the Digital Signage in case of urgency.

Computation: Computation is brain of the Smart Pole. The computation block is the control block of the Smart Pole. It fetches sensor data and coordinates with other electronic sub-system of the Pole and communicates with the command and control. Some of the Smart Poles are coming with edge intelligence in which some of the actions are performed without taking any inputs from the command and control system such as switching of the LEDs in mid-night, actions based on input of motion sensors, or updating the message on the Digital display in case of inputs from camera, sensors etc.

Miscellaneous: The new generation of the Smart Poles are coming up with Electric Vehicle Charger sockets, USB sockets and wireless charging pads for mobile phones. These services can be a free community services or paid services by the vendor who is managing the smart poles. Apart from this there are other new business opportunities are being created with new emerging technologies.

Deployment

There are different topologies in which Smart Poles can be deployed. Smart pole can be put in the master – slave topology such that one Smart Pole act as concentrator for a limited series of Smart Poles and the concentrator Smart Pole communicates with the Command and Control System. The other topology is that each Smart Pole is directly communicating with the Command and Control Centre. In the era of Smart Cities, Smart Pole is the need and the deployments are taking place already. The Smart Pole with integrated electronic sub-system will help us to solve many of the societal challenges and create business opportunities.

Annexure 8: EV Charging Infrastructure and the Smart City

Source - M/s STMicroelectronics

With the push to move to electric mobility at a national scale, and with the government focussing on deployment of electric vehicles, the electronic industry can expect to see a lot of activities around indigenous development and manufacturing. While electric vehicles are being worked upon by major OEMs, an ecosystem for development of chargers, charging stations and software & cloud services is steadily being built. Established companies as well as various start-ups, have started working on these areas and results are starting to show. Eventually, EV charging infrastructure would become as common as petrol pumps.

The government, with the help of BIS (Bureau of Indian Standards), ARAI (Automotive Research Association of India), EESL (Energy Efficiency Services Limited) and other bodies, have already released technical specifications on charging stations and some of the original specifications like the AC-001 and the DC-001 have already been developed and charging stations have been deployed at selected locations. The newer guidelines require the charging stations to be equipped with multi standard chargers, viz. AC Type 2, the CCS (combined charging system) and the CHADEMO [CHArge de Move (EV charging standard)], in addition to the lower power AC and DC-001. A full-fledged charging station is supposed to be equipped with all the 5 types of chargers while provision may also be kept targeting a specific segment of EVs in a geography. For example, a dense metro parking lot, may cater to EV charging points for e-rickshaw and e-bikes while a mall parking might cater to 10 bays or more for EVs while a highway side resort, may house a fully featured charging station including that for buses.

It is foreseen that a successful EV charging infrastructure is to be deployed around a mix of grid and renewable along-with distributed energy storage. Power conditions in India have vastly improved over the years, however it is still fossil based to a larger extent. Fortunately, India has seen successful solar deployment and the abundance of solar energy due to its geographic location. One-time installation and capital expense, works well for at least 20-25 years, with the return on investment, taken care of in a few years. The energy input henceforth, becomes virtually free. The subsequent sections will illustrate a feasible implementation that may be adopted to harness solar energy, store it, and use it for EV charging in addition to using grid. It will touch upon energy harnessing & storage schemes, distributed battery management, power conversion and connectivity, which are the basic building blocks for a modular, scalable, solar powered EV charging station.

In essence, an EV infrastructure deployment will have the following key components:

1) **A power electronics at back end**: This is the main power block that harnesses and utilizes energy from many available sources and intelligently routes it to the vehicle for charging
2) **A user interface, billing, and monetizing console**: this is the most visible part of the system, that is accessible to the normal user. It takes care of billing, tariffs, value added services and user authentication
3) **A communication backbone**: wired and wireless, this backbone connects the charger to the cloud and the smart city infrastructure. Multiple physical layer options are available as is explained later on. Nothing can operate in silos in a smart city, and the beauty of this intercommunication is the efficiency of deployment and returns on investments are maximized. It also allows features that a standalone system would not be able to provide. For example, it is possible to use an idle charging station as a “peak shaving unit” when the grid is facing a peak during daytime working hours!

A typical hybrid EV charging station implementation is depicted through the diagram below. The major building blocks are self-explanatory.

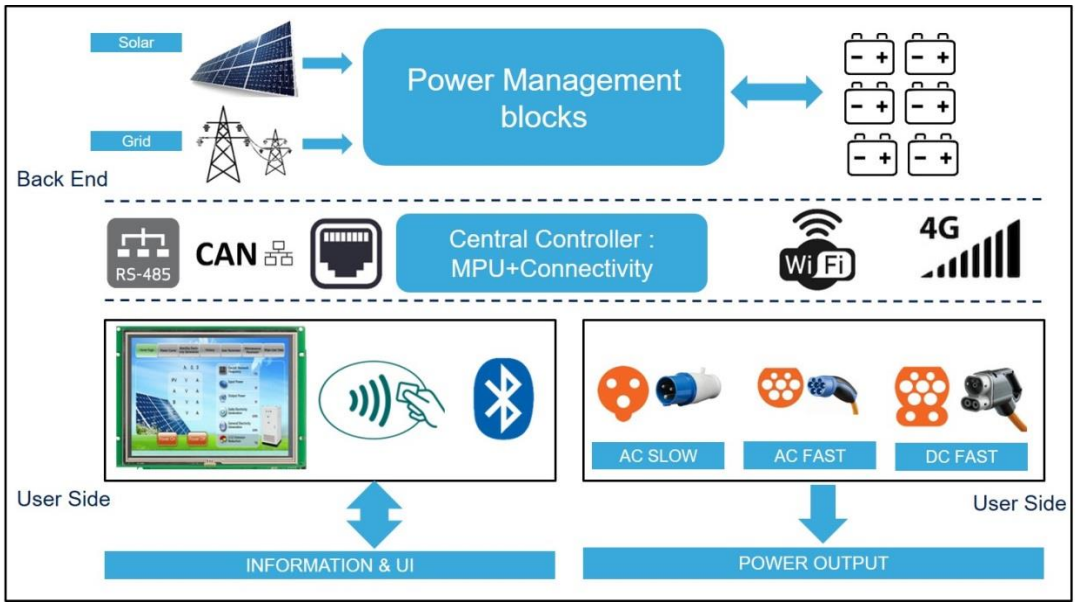


FIGURE 28: SOLAR EV CHARGING STATION FUNCTIONAL BLOCKS

There is the user side, which basically depicts the functionalities visible to the end user. Information exchange and the user interaction is taken care of, here. It would typically consist of a TFT screen with touch sensing, NFC card readers for authentication or payments, and maybe also a Bluetooth interface for more advanced features. The vehicle is physically connected to any of the output ports: AC slow charge for smaller vehicles and e-rickshaws, AC fast charging for some classes of vehicles and of course, DC fast charging. The user has to authenticate himself, set his charge preferences and he needs to wait till the charge session is over. However, the more complex functions go on behind the scene, which are controlled and monitored by the central controller in conjunction with many different other modules.

Power flow and energy management: The system has 3 sources of power. First and foremost, are the solar panels, having size of about a few kilowatts at the minimum. A panel would typically produce at rated irradiance, about 150 W/square meter. The solar panels feed the MPPT (Maximum Power Point Tracking) module. This is a DC-DC converter with a maximum power point tracking algorithm running inside it. These are typically very high efficiency units, running at excess of 98% electrical efficiency. These are typically multiphase interleaved buck or buck-boost converters, and operating levels are at a few hundred volts at both the input and output side. Isolation may or may not be a requirement, but most implementations are galvanically isolated for regulatory and safety reasons. The output feeds a common DC bus, from which downstream energy may be provided to the load. The implementation may be analog, fully digital or a mix of analog and digital control.

The second source is the grid. This may be optional, as the intent is to maximize the usage of solar. However, in areas where intermittent grid is available, or where the solar insolation is not entirely sufficient for operation year-long, or during certain seasons, grid helps in fulfilling the demand. Since the system is essentially a solar energy storage setup, it is also possible to use this station to supplement the grid, during peak hours or as a solar farm, using bidirectional grid tied inverters. With proper policies in place for exporting to the grid from solar farms or from captive plants with net metering, this serves a dual purpose too.

The third source and the sink/storage, is the battery. The trend these days is to use Lithium ion batteries which have very high life cycle, lends itself well to quick charging, very high depth of discharge and very high volumetric efficiency. It is possible to house these batteries underground, to save real estate. These Lithium Ion battery packs are arranged in a suitable series parallel combination, and in several strings. The batteries terminate themselves into a junction box and termination unit, which also functions as a supervisor. Each battery has a data port, typically CAN or RS485, and these are daisy chained and fed to this termination unit, which then has a top level view of the health and status of every individual battery, string or the entire battery bank. This is essentially a data concentrator and a switching unit, putting battery packs IN or OUT of circuit. In addition, this communicates with the central controller to decide the charge and discharge of the batteries.

The following diagram makes the power system architecture quite clear. This is a modular system, to allow for suitable expansion, and modules are typically expandable and 3-5 kW each with a communication bus, typically CAN or MODBUS/RS485. The central controller is able to configure the modules as per the functional requirement at any point of time: be it charge management, be it load management or be it diagnostic checks. There is a provision within the controller to also monitor the energy usage, basically kWh consumed, kWh stored and kWh generated/exported. It can also communicate with industry standard certified energy meters for billing and tariff setting purposes.

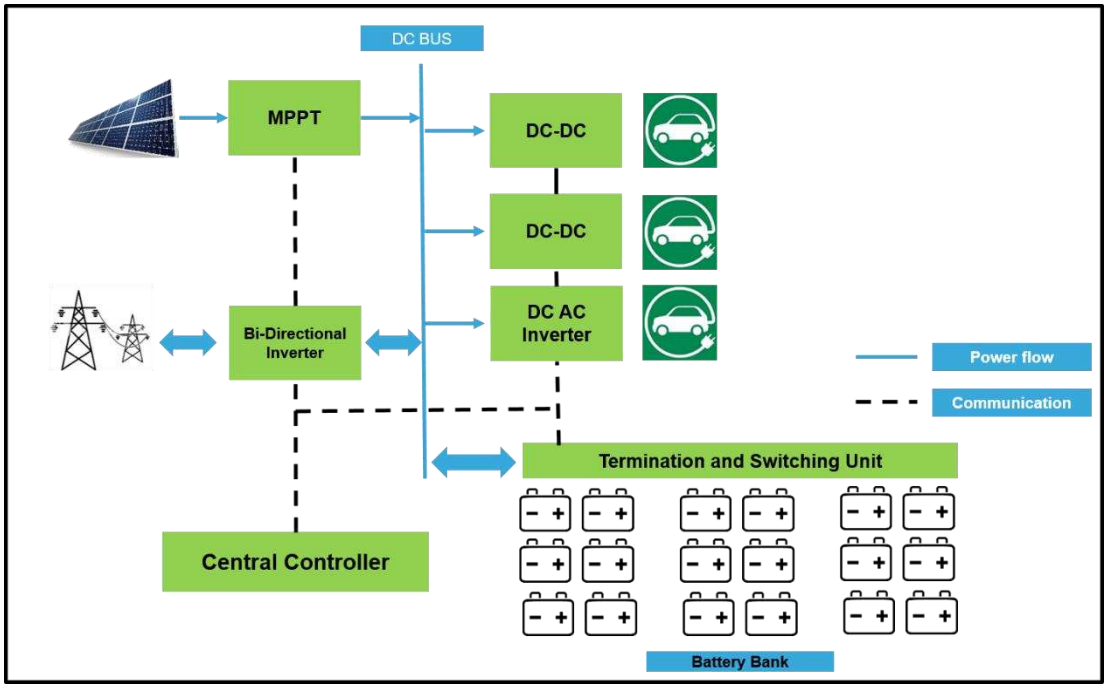


FIGURE 29: EV CHARGING BACK END POWER SYSTEM ARCHITECTURE

Major power management blocks: The DC-DC converter block is fed from the DC bus. Depending on the type of vehicle connected, and the demand raised by the vehicle BMS for the required voltage and current, the central controller configures the DC-DC converter over the communication bus. This option is typically for DC fast charging, and multiple DC-DC converter modules would work in tandem to fulfil the load. The DC-AC inverter, is also fed from the DC bus, but this caters to vehicles which can only accept AC to charge or for general slow charging applications. The bi-directional inverter serves two purposes: It either feeds the DC bus to fulfil the demand or, it exports power back to the grid, when the charging station is lying idle or is needed to supplement the grid during peak hours. The key figures of merit for any power conversion block these days are:

1. Very high efficiency: >95% end to end.
2. Very high power densities: Smaller and even smaller systems, as real estate is a significant deployment cost

Both of the above points are met with, using advancements in silicon. Wide band gap semiconductors, especially silicon carbide devices, are able to work at very high switching frequencies, at much higher junction temperatures and with higher efficiencies. In addition to this, there is an automatic reduction in the size of the passive components like magnetics and capacitors. Better magnetics materials also lend to smaller and low loss designs handling much higher powers.

The master central controller is the brain of the station. It performs functions starting from identifying and engaging the user/subscriber till ensuring the vehicle is charged in an optimal manner. It is a powerful combination of high performance computing, connectivity and sensing. The major functionalities are as mentioned below-

1) User ID and payment: This is the most visible functionality as far as the user is concerned. This is done through a smart card, an OTP, NFC enabled phones or even Bluetooth. All these sub systems are controlled by the MPU/MCU on board.

2) Power management: This is the most critical yet invisible part of the station. The system controller continually monitors the power scenario: supply and demand. Then it decides how to fulfill the demand, from the supply. Whether solar alone is able to supply the load, or is a combination of solar and storage is needed or it needs partial input from the grid as well. There may be scenarios, where there could be excess availability or excess demand. It is intelligent enough to route power correspondingly, by altering the settings of the various power blocks described above.

3) Connectivity: These days, stations and deployments need to be connected to the cloud for remote monitoring and control. It has to talk to the CMS (Central Management System) periodically, to report transactions, parametric, diagnostics and operational data. It also needs to take operational commands and settings from the CMS. So a multitude of connectivity options, both wired and wireless is provided. 3G/4G, Wi-Fi, Ethernet and even LoRa has been used for remote monitoring.

4) Protections, diagnostics and fault reporting: The system, in order to prevent malfunction, has very fast acting protection mechanisms that may be triggered by external events like surges or lightning strikes, or due to operational issues, accidental or deliberate misuse/abuse or from short circuits, over temperature or over voltage/over current conditions. To keep operational costs low and to have minimal downtime, systems are able to self-report issues that may arise from time to time. Modular build allows pin pointing which faulty section needs to be replaced at the field, so the technician can arrive well prepared.

Annexure 9: Mapping of U4SSC-KPIs with relevant EOLI (Ease of Living Index) or MPI (Municipal Performance Index) Categories

(Source: Niti Aayog)

U4SSC Category	U4SSC-KPI	Relevant EOLI Pillar	Relevant MPI Vertical
1. ICT Infrastructure	Household Internet Access	1***. Quality of Life ICT Infrastructure (New Category)***	3. Technology 3.2 Digital Access
	Fixed Broadband Subscriptions		
	Wireless Broadband Subscriptions		
	Wireless Broadband Coverage		
2. Water and Sanitation	Smart Water Meters	1. Quality of Life WASH and SWM	1. Services Water and Wastewater
	Water Supply Loss		
	Freshwater Consumption		
3. Electricity Supply	Smart Electricity Meters	3. Sustainability Energy Consumption	1. Services Infrastructure (Electricity)
	Electricity Supply ICT Monitoring		
	Demand Response Penetration		
	Electricity System Outage Frequency		
	Electricity System Outage Time		
4. Transport	Dynamic Public Transport Information	1. Quality of Life Mobility	1. Services Infrastructure (Mobility)
	Public Transport Network		
	Public Transport Network Convenience		
	Bicycle Network		
	Transportation Mode Share		
	Travel Time Index		
	Shared Bicycles		
	Shared Vehicles		
	Low-Carbon Emission Passenger Vehicles		
5. Innovation	R&D Expenditure	2 Economic Ability 2.2 Economic Opportunities	2. Finance 2.2 Expenditure Management
	Patents	2 Economic Ability 2.2 Economic Opportunities	
	Small and Medium-Sized Enterprises	2 Economic Ability 2.2 Economic Opportunities	5. Governance 5.2 Human Resource
	Unemployment Rate		

U4SSC Category	U4SSC-KPI	Relevant EOLI Pillar	Relevant MPI Vertical
6. Employment	Youth Unemployment Rate		
	Tourism Sector Employment		
	ICT Sector Employment		
7. Buildings	Integrated Building Management Systems in Public Buildings	3. Sustainability 3.2 Green Spaces and Buildings	1. Services Infrastructure
8. Environment Quality	EMF Exposure	3. Sustainability 3.1 Environment	1. Services 1.2 Health
9. Public Space and Nature	Green Area Accessibility	3. Sustainability 3.2 Green Spaces and Buildings	
	Protected Natural Areas	3. Sustainability 3.1 Environment	
10. Energy	Electricity Consumption	3. Sustainability 3.3 Energy Consumption	1. Services Infrastructure (Electricity)
	Residential Thermal Energy Consumption		
	Public Building Energy Consumption		
11. Education	School Enrollment	1. Quality of Life 1.1 Education	1. Services 1.1 Education
	Higher Education Degrees		
	Adult Literacy		
12. Health	Electronic Health Records	1. Quality of Life 1.2 Health	1. Services 1.2 Health
	Life Expectancy		
	Maternal Mortality Rate		
	Health Insurance / Public Health Coverage		
13. Culture	Cultural Expenditure	2 Economic Ability 2.2 Economic Opportunities	2. Finance 2.2 Expenditure Management
14. Housing	Housing Expenditure	1. Quality of Life 1.3 Housing and Shelter	
15. Social Inclusion	Gender Income Equity	2 Economic Ability 2.2 Economic Opportunities	5. Governance 5.2 Human Resource
	Poverty	1. Quality of Life 1.3 Housing and Shelter	1. Services
	Child Care Availability	1. Quality of Life 1.1 Education	1. Services 1.1 Education / Health

U4SSC Category	U4SSC-KPI	Relevant EOLI Pillar	Relevant MPI Vertical
16. Safety	Disaster Related Economic Losses	3. Sustainability 3.4 City Resilience	***1. Services*** ***Disaster Management (New Category)***
	Population Living in Disaster Prone Areas		
	Emergency Service Response Time		
	Police Service		
	Fire Service		
17. Food Security	Local Food Production		1. Services 1.2 Health

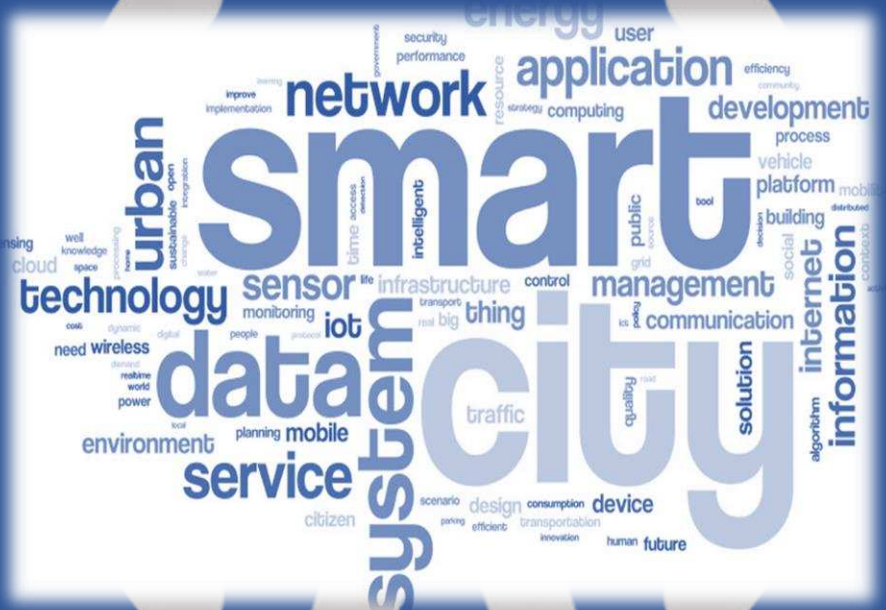
Annexure 10: Suggestive Analytics use-cases with the type of locations

Sr. No	Type of Locations	Analytics Use cases
1	Roads & Junctions	Vehicle Classification
		Vehicle counting
		ANPR
		Wrong side driving detection
		Illegal Parking
		Helmet detection
		Red Light Violation Detection
		Over-speeding detection
		People counting
		Face recognition
		Person & Vehicle tracking
2	Critical Points and Stretches	Fight Detection
		ANPR
		Abandoned Object Detection
		Vehicle Counting
		Classification of Vehicle
3	Ground / Stadium	Fight detection
		Mob Detection/People counting
		Face recognition at Entry and Exit
4	Govt. Offices/ Important buildings	Intrusion Detection
		Face Recognition at Entry points
		Illegal Parking
		People counting/Mob Detection
		ANPR
5	Monuments	Face Recognition
		People counting
		Intrusion detection/perimeter safety
6	Parks	Face Recognition
		People Counting
		Fight detection
7	Bus stops	Face Recognition
		People Counting
		Fight detection
		Abandoned Object Detection
8	Tourist Locations	Face Recognition
		People Counting
		Fight detection
		Abandoned Object Detection
		Perimeter security

9	City Entry/Exit points	ANPR
		Vehicle count
		Vehicle Classification

Annexure 11: List of the meetings of Committee

S. No.	Date
1.	Meeting in TEC, 28th Jan 2019
2.	Meeting/ audio con-call, 5th March 2019
3.	Meeting/ audio con-call, 9th April 2019
4.	Meeting through GoToMeeting bridge, 27th May 2019
5.	Meeting through GoToMeeting bridge, 29th July 2019
6.	Meeting through GoToMeeting bridge, 3rdSep 2019
7.	Meeting through GoToMeeting bridge, 21st Nov 2019
8.	Meeting through GoToMeeting bridge, 8th Jan 2020
9.	Meeting through GoToMeeting bridge, 31st Jan 2020
10.	Meeting through GoToMeeting bridge, 13th Feb 2020
11.	Meeting through GoToMeeting bridge, 24th April 2020
12.	Meeting through GoToMeeting bridge, 25th May 2020
13.	Meeting through GoToMeeting bridge, 25th June 2020
14.	Meeting through GoToMeeting bridge, 24th July 2020
15.	Meeting through GoToMeeting bridge, 25th August 2020
16.	Meeting through GoToMeeting bridge, 8th October 2020
17.	Meeting through GoToMeeting bridge, 23rd November 2020
18.	Meeting through GoToMeeting bridge, 23rd December 2020
19.	Meeting through GoToMeeting bridge, 12th February 2021
20.	Meeting through GoToMeeting bridge, 8th March 2021
21.	Meeting through Microsoft Teams platform, 20th April 2021
22.	Meeting through Microsoft Teams platform, 17th May 2021
23.	Meeting through Microsoft Teams platform, 10th June 2021
24.	Meeting through C-DOT VC platform, 2nd July 2021
25.	Meeting through Microsoft Teams platform, 16th August 2021
26.	Meeting through C-DOT VC platform, 30th September 2021
27.	Meeting through C-DOT VC platform, 24th November 2021
28.	Meeting through C-DOT VC platform, 10th January 2022
29.	Meeting through C-DOT VC platform, 7th February 2022



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