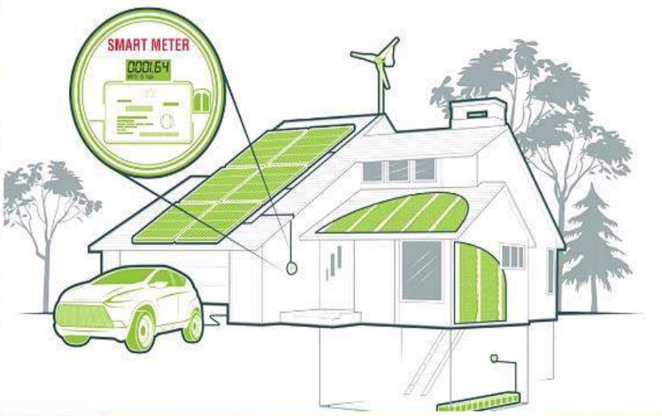
TECHNICAL REPORT

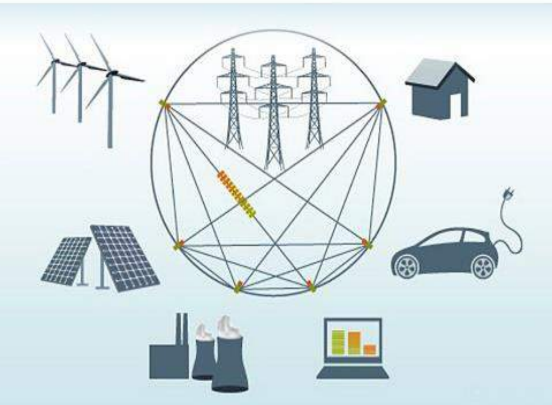
M2M ENABLEMENT IN

POWER SECTOR

TEC-TR-S&D-M2M-002-01

M2M POWER WORKING GROUP





TELECOMMUNICATION ENGINEERING CENTRE
DEPARTMENT OF TELECOMMUNICATIONS
MINISTRY OF COMMUNICATIONS & INFORMATION TECHNOLOGY
GOVERNMENT OF INDIA

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रवि शंकर प्रसाद
RAVI SHANKAR PRASAD

सत्यमेव जयते

मंत्री
संचार एवं सूचना प्रौद्योगिकी
भारत सरकार
MINISTER
COMMUNICATIONS & IT
GOVERNMENT OF INDIA

Message

I am glad to note that Telecommunication Engineering Centre is bringing out Technical Reports on M2M enablement in Transport, Health, Power and Safety & Surveillance sectors and a Report on M2M Gateway & Architecture.

M2M communications is going to change the way the humans live and control their surrounding as well as various social and economic sectors operate. It is expected to improve the efficiency of various sectors such as Automotive, Health, Power and Safety & Surveillance etc. by transmitting the information electronically and automation of information processing. It will help in providing quality sevices to our citizens.

I am confident that the Technical Reports will help in developing specifications/ standards to be used in India and opportunity of manufacturing wide variety of devices and other products in India. I congratulate TEC and all concerned for this commendable work which is very timely, and wish them success in all their endeavors.

Ravi Shankar Prasad

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Ministry of Communications & Information Technology
दूर संचार विभाग
Department of Telecommunications

08th May 2015

Message

I am extremely happy to note that Telecommunication Engineering Centre (TEC) is bringing out Technical Reports regarding M2M enablement in Intelligent Transport System, Health, Power, Security and Surveillance and a Technical Report on Gateway an Architecture of M2M communications.

2. While Government started the work of developing roadmap for M2M communications in India, TEC at the same time initiated the work of identifying technical requirements of Automotive, Health, Power, Safety and Surveillance sectors. As there has been active participation from stakeholder of each sector, the reports have taken into account the ground level status and requirement for M2M enablement.

3. India has to make strides in making its various sectors smart for which quick adoption of M2M is the necessary. These reports will help stakeholders in development and finalization of sectors specific plans for adoption of M2M.

4. I appreciate the efforts put in by Telecommunication Engineering Centre in bringing out these reports. I wish them success in all their endeavours.

(Rakesh Garg)
Secretary(Telecom)

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Message

I am happy to note that Telecommunication Engineering Centre (TEC) is bringing out technical reports regarding M2M enablement in Intelligent Transport System, Health, Power, Security and Surveillance and a report of Gateway an Architecture of M2M communications. We are aware that adoption of M2M communication will inter-alia, lead to enhancement in the efficiency of various sectors of society and economy.

Need for improvement in efficiency in various socio-economic sectors has been felt for a long time and some efforts in this direction have also been made whereby M2M based systems have been deployed. However, the solutions which have been implemented are generally based on propriety platforms. However, to achieve smart processes and functioning in all the sectors, interoperability of devices/ platforms/ applications is necessary which entails adoption of open standards.

The technical reports of TEC are a good step in this direction and will certainly help various stakeholders to take preparatory steps in their respective sectors for future adoption of M2M communications.

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A.K. Bhargava
Advisor, DoT

Message

I am pleased to note that Telecommunication Engineering Centre (TEC) is bringing out Technical Reports regarding M2M enablement in Intelligent Transport System, Health, Power, Security and Surveillance and a report on Gateway & Architecture of M2M communications.

TEC has taken timely action to take up the work of study and preparation of the Technical Reports in the Automotive, Health, Power, Safety and Surveillance sectors. The Reports have been prepared to be released along with the National M2M roadmap by virtue of relentless efforts of TEC and its Working Groups consisting of stake holders.

M2M communication is an opportunity for India not only to keep pace with the world but also to march ahead in development of specifications of new products consisting of Devices, Gateways and Platforms meeting the Indian requirements, though of course, in sync with the standards.

I appreciate the efforts of Telecommunication Engineering Centre specially its S&D Division and all the Working Groups for bringing out these technical reports in a very timely manner. I wish them success in all their endeavours.

(A.K. Bhargava)

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FOREWORD

Telecommunication Engineering Centre (TEC) is an organ of Department of Telecommunications (DoT). It provides technical support to DoT. TEC develops technical specifications of products for use in telecom networks. It carries out technology studies and proactively takes up development of specifications based on such studies Development of specifications is a transparent process with active participation of stakeholders. Certification of telecom products is also one of its activities.

M2M Communication is an area which has rapidly attracted attention of world over, primarily due to its enormous potential in bringing about fundamental changes in the delivery and use of services in almost all sectors of economy and society and the quality of human life.

M2M systems have been in use for some time past, e.g. in automotive sector. However, the use of technology/devices/application is generally proprietary in nature as standards have started involving in the recent past. We are aware that variety of social and economic activities are interdependent and in today's digital world, it is possible to link them through networks and applications to achieve enhancement in efficiency and development of new services. This is possible only when there is interoperability among devices/networks/applications. This requires standardization and development of harmonized specifications.

Towards achieving this objective, TEC in consultation with stake holders from government, industry, standards bodies and sector users, took up study of four sectors to begin with namely Automotive, Health, Power, Safety and surveillance. Four working groups (WG), one for each were formed with the participation from stakeholders as mentioned above. As it is also necessary to work out architecture for M2M domain and also service delivery models, Gateway and Architecture WG was also formed. All the groups have overwhelming participation. Chairmen, Rapporteurs & Co-rapporteurs have been elected by the WGs themselves. Joint Working Group is chaired by Sr. Deputy Director General and Head TEC.

These groups have carried out use case studies and analysis for respective sectors. Beginning the year 2014, these groups have worked relentlessly. This can be gauged from the fact that there were about 50 conference calls and four Face to Face (F2F) meetings combined of all groups and lot of many interactions within the groups. Services and Development (S&D) Division of TEC coordinated and managed the entire activity of formation of working groups, holding meetings, preparation of the reports etc.

The reports contain use cases in the sectors & their technical analysis, key challenges in implementation and the way forward. Suggestions for way forward those have emerged, require action by various stake holders as well as by TEC and the Working Groups. TEC and the Working Groups will continue further work and it is planned to bring out next release of Technical Report after further study as early as possible.

I express my sincere thanks to all the Chairmen, Rapporteurs and Co-rapporteurs and members of the Working Groups as well as the participating stakeholders as organization and as persons whose enthusiastic support and untiring efforts have made it possible to bring out these detailed reports.

Ultimate aim is to identify the areas for development of standards, harmonize Indian standards with international standards and development of product specifications ensuring interoperability. India being a big market for M2M, there is enormous potential of manufacturing devices and networking products for M2M in India. Let us all join hands to become part of the 'Make in India' programme of the Government of India.

I hope that the report will provide guidance to the stakeholders to plan standardized deployments in the concerned sectors. I also hope that the stake holders will provide their continued support to TEC to carry out further work in M2M domain. We will be enriched in our work through valuable suggestions from any quarter.

(A.K.Mittal)
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Contents

Figures

Tables

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Executive Summary

The electric grid is on the threshold of a paradigm shift – after 100 years of focus on centralized power generation and creation of massive electric grids that span the globe, the shift is now towards de-centralized generation. In the past 5 years, the picture of the grid has changed dramatically in many geographies. With the increasing share of generation resources being added at the distribution end, the traditional boundaries between generation, transmission and distribution are fast disappearing. With consumers becoming 'prosumers', the grid that is built for one-way flow of electricity is now experiencing bi-directional flow of electrons. Large fleets of Electric Vehicles that can be aggregated as virtual power plants which could support short-term supply-demand balancing will make the grid even more dynamic and complex.

This document is a Technical Report of the Telecommunication Engineering Centre (TEC) on the Power sector. Apart from introducing and explaining the need of M2M communications in the power sector, the report has identified use cases this sector which include smart metering, Supervisory Control and Data Acquisition (SCADA), Wide Area Monitoring System (WAMS), Electric Vehicles, Distributed Generation, Energy Storage, Microgrids and so on.

Machine to Machine (M2M) communications will help in monitoring and controlling the intermittent and variable generation resources. It would be vital for the functioning of the electric vehicle charging infrastructure as information regarding charging of the electric vehicles would have to be sent to the utility for billing purposes. Moreover, M2M communications are helpful in monitoring and controlling the power flow in high voltage, medium voltage and low voltage lines up to the end consumer for efficient transmission and distribution of electricity.

The report has also noted that the utilities are already installing SCADA/EMS, SCADA/DMS, PMUs etc., thus the Indian power sector has already embraced M2M communications. AMI will be a key component of smart grid roll-outs which will amplify the need for M2M communications in the power sector.

The Report has acknowledged the initiative of the Ministry of Power and India Smart Grid Forum (ISGF) for formulating a comprehensive Smart Grid Vision and Roadmap for India which is aligned to the Government's overarching objectives of 'Access, Availability and Affordability of Power for All'. The roadmap aims to transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all, with the active participation of stakeholders. This is the guiding policy document that has set some aggressive targets towards building smart grids in India. In order to achieve the objectives mentioned in the Roadmap, the Government of India has approved a National Smart Grid Mission (NSGM).

The Report has identified challenges in this sector such as high AT&C losses, inaccessibility of power to over 79 million households, ageing infrastructure, grid reliability, interoperability etc. Reliable, standard-based and secure M2M communications would alleviate such issues and result in a robust and a resilient electric grid.

This Working Group will study and provide inputs for framing the KYC norms required for SIM based devices/gateways. In addition, the spectrum requirements in sub-GHz range for low power RF devices that are expected in M2M/IoT/Smart Cities domain will be studied and prepared.

1. Introduction

Today, India operates the world's largest synchronous grid covering an area of over 3 million sq. km. with an installed capacity of 258.7 GW[1] (as on 31st January 2015) and about 200 million consumers[2]. Yet, almost 79 million[3] households in the country do not have access to electricity and its per capita consumption is one-fourth of the world's average! Transmission and Distribution losses are also quite high, about 7 per cent and 26 per cent[4] respectively. The per capita consumption of India increased from 15.6 kWh in 1950 to 957 kWh by March 2014[5]. With raising aspirations of the people and to grow at a GDP close to that of double digits, the growth in power sector is going to have a crucial say.

The transmission grid in India is one of the largest in the world. With 765 kV and 400 kV lines, it is now building 1,200 kV AC and 800 kV HVDC networks. Also, it has the most modern control centres, 5 regional, 1 at the national level and 1 back-up national control centre.

As far as the distribution sector is concerned, over 300 million people have no access to electricity. Also, large parts of the country experiences power cuts for several hours every day. In order to combat this, customers keep storage invertors/standby generation facilities. Moreover, with the quality of power being poor, consumers require voltage stabilizers, UPS, inverters and so on. Steps are now on to combat this shortage by resorting to alternative sources of energy such as solar, wind, bio energy etc.

Machine to Machine communications would monitor and control the power flow in high voltage, medium voltage and low voltage lines up to the end consumer; thereby transforming the power sector.

[1]http://www.cea.nic.in/reports/monthly/inst_capacity/jan15.pdf

[2]http://www.tatapower.com/media-corner/pressreports/press-report-09-jun-14.pdf

[3]Book titled '**Beyond the Carbon Economy: Energy Law in Transition**' edited by Donald N. Zillman

[4]India Smart Grid Forum (ISGF)-Bloomberg New Energy Finance (BNEF) Knowledge Paper on '**Smart Grids in India**' published on March 03, 2015.

[5]http://www.cea.nic.in/reports/monthly/executive_rep/feb15.pdf

2. What is M2M Communication?

It refers to the technologies that allows wired / wireless system to communicate with the devices of same ability. M2M uses a device (sensor, meter etc.) to capture an 'event' (motion, video, meter reading, temperature etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates the captured event into meaningful information. A conceptual picture is shown below:

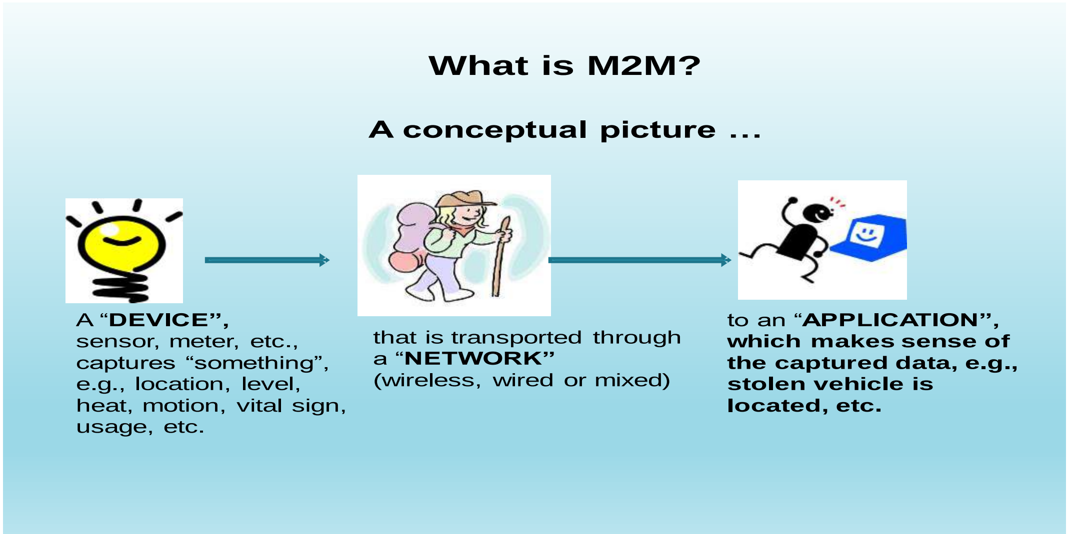

FIGURE 1 - CONCEPTUAL REPRESENTATION OF M2M COMMUNICATION

The enabling technologies for Internet of Things (IoT) are sensor networks, RFID, M2M, mobile Internet, wired &wireless communication network, semantic data integration, semantic search, IPv4/IPv6, etc. In wireless communication, Wi-Fi, ZigBee, 6LoWPAN, Bluetooth technology may be used for short range connectivity of devices/devices to the gateway and GSM 2G/3G/4G or WiMAX for connecting M2M gateway to server.

IPv4 addresses are going to exhaust. Standardization and adoption of IPv6 in telecom and ICT sector will provide an opportunity of having billions of devices which can be IP enabled and seamlessly addressable through mobile or wired broadband connections.

M2M is a subset of IoT. IoT is a more encompassing phenomenon because it also includes Human-to-Machine communication (H2M). With IoT, the communication is extended via Internet among all the things that surround us.

Various sectors such as Power, Automotive, Health, Safety & Surveillance and Agriculture etc. may be transformed and revolutionized by using M2M/IoT.

3. Need of M2M Communications in the Power Sector

Every year, India loses over 200 billion units of electricity as AT&C losses which translates to a loss of over USD 17 billion[6] (Rs 100,000 crores) per year. Transition to smart grids will achieve the objectives of reducing AT&C losses and providing 24x7 power for all households.

Traditional electricity networks have been designed for 'unidirectional' flow of electricity, revenue and information. Electricity is generated centrally at a power plant and is transmitted over high voltage transmission lines before being distributed over medium voltage and low voltage distribution lines. Communications is used only to monitor and control the power flow up to the medium voltage and low voltage substations using Supervisory Control and Data Acquisition (SCADA)/Energy Management Systems (EMS).

In a smart grid, two-way Machine to Machine (M2M) communications[7] would be used to monitor and control the power flow in the low voltage grid till the end consumers. This would be done by deploying SCADA/DMS (Distribution Management Systems). Also, there would be millions of points of electricity generation wherein electricity would be generated in a distributed manner much closer to the end consumer. Consumers would be able to generate electricity and become 'prosumers'. By doing so, they would be able to feed electricity back into the grid and generate revenue. Hence the traditional boundaries between generation, transmission and distribution are fast disappearing. M2M communications would help in monitoring and controlling these intermittent, unpredictable and dispersed sources of generation. This bidirectional flow of electricity, revenue and information in a smart grid is a major transformation from the traditional grid.

There is already a debate whether to invest in transmission or in megawatt scale energy storage technologies. This is because generating electricity in a distributed manner and storing it for local distribution seems to be an efficient, faster, less complex and a cost-effective alternative over centralized generation and transmission over long high voltage transmission lines.

Smart metering would benefit both, consumers and utilities by enabling remote reading, remote connection disconnection, remote load control via time of day or time of use prices, detecting outages early etc. Wide Area Monitoring System (WAMS) would offer a high degree of visibility in the electricity grid which would synchronously measure the phase of the current and voltage vectors.

With satisfied consumers and financially sound utilities, the Indian Government would have fulfilled the expectations of its nation. In order to reduce the carbon emission, both Government and Regulators are setting bold targets for electricity generation via renewable sources of energy.

Electric vehicles would not only provide a clean and efficient means of transport, but would act as virtual power plants which could supply power to the grid in case of an outage. By commissioning an outage management system, power outages would not only be identified in near-real time, but also help in early restoration of power.

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[6] Taking Rs 5/unit as the tariff

[7] India Smart Grid Forum (ISGF) White Paper on '**M2M Communications in the Indian Power Sector**' published on December 18, 2014.

Furthermore, by building smart microgrids, the connected loads and the electricity generation sources can be intelligently controlled. In case of an outage in the main grid or a cyber attack, these microgrids can be islanded from the main grid.

The first attempt to implement M2M Communications in the power sector was AMR (Automated Meter Reading) being implemented by distribution utilities (DISCOMS) and SCADA/EMS by transmission utilities (TRANSCOS). Now, many DISCOMS are also in the process of commissioning SCADA/DMS and many have already done so.

It is believed that the grid will emerge as the 'Grid of Things' just like the Internet has evolved as the 'Internet of Things'. The 'Grid of Things', coupled with IoT and M2M communications can also be referred to as the 'Internet of Energy'. The following figure sheds more light into this concept:

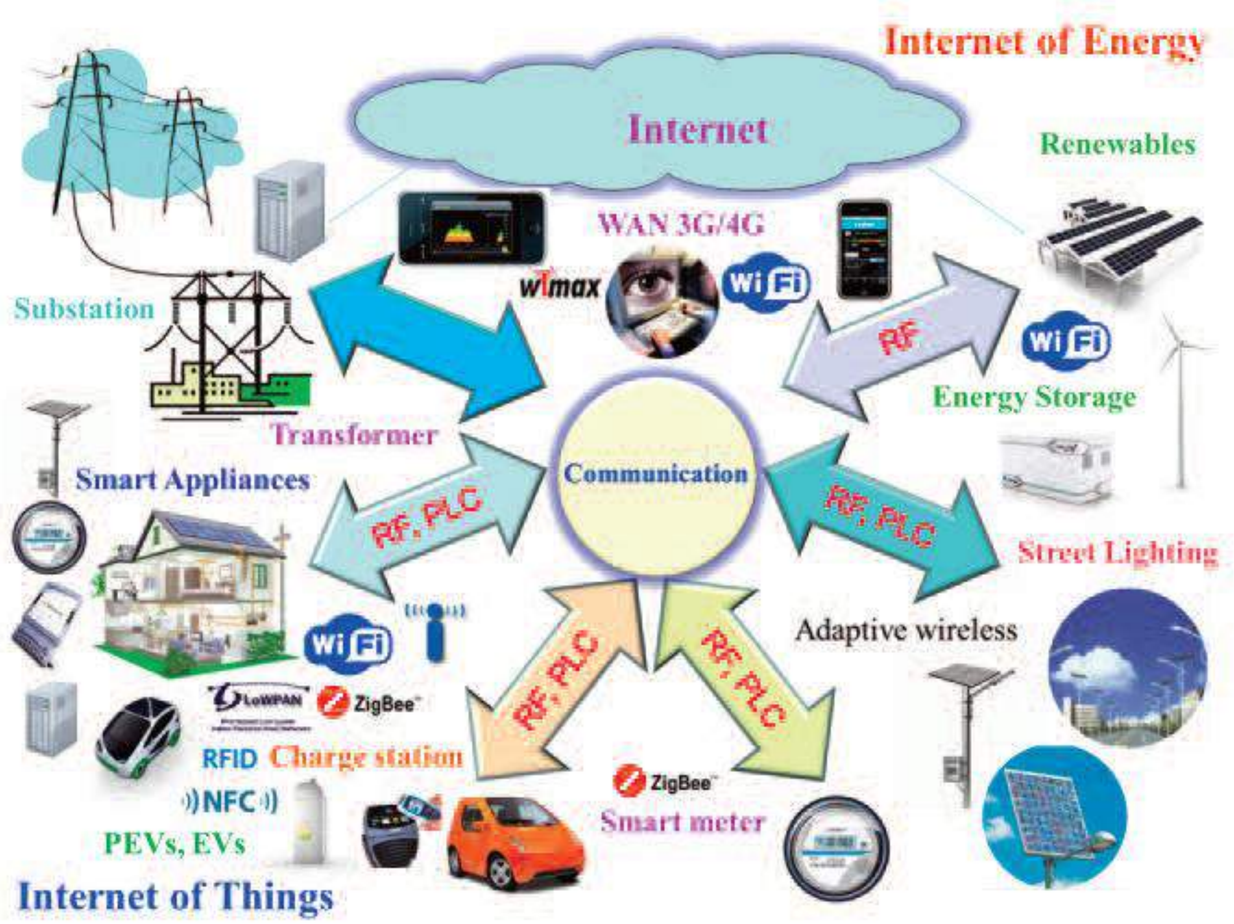

FIGURE 2 - INTERNET OF THINGS EMBEDDED IN INTERNET OF ENERGY APPLICATIONS

Source: IERC Cluster Book (2012) on Internet of Things

4. Conceptual Description of M2M Communications in the Power Sector

The various elements in M2M communication include a Wide Area Network (WAN)/Backhaul Network, Neighbourhood Area Network (NAN)/Field Area Network (FAN), Home Area Network (HAN), sensors, home gateway, Data Concentrator Unit (DCU)/Gateway and an application/data center. Presence of a home gateway would be decided by the nature of the application that is being catered to. In addition, a Backbone/Core network would also be present. The figure below depicts a typical conceptual description of M2M communications:

(Please note that this is for reference only)

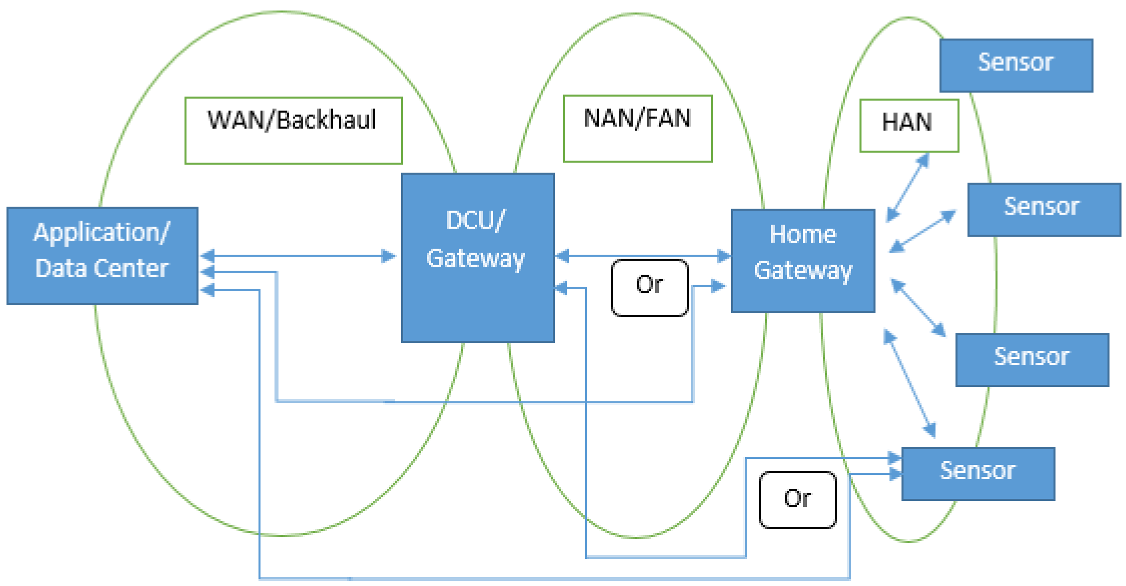

Figure 3 - Typical Conceptual Depiction of M2M Communications

Multiple sensors in a Home Area Network (HAN), Field Area Network (FAN) or Wide Area Network (WAN) would communicate with the home gateway, DCU/gateway or application/data center respectively. The home gateway, if present, would relay data from the sensors to the application/data center via the DCU/gateway. Considering Advanced Metering Infrastructure (AMI), the smart meter could act either as a sensor or a home gateway.

A typical implementation architecture for M2M Communication to support the segments as mentioned in above diagram is depicted below:

(Please note that this is for reference only)

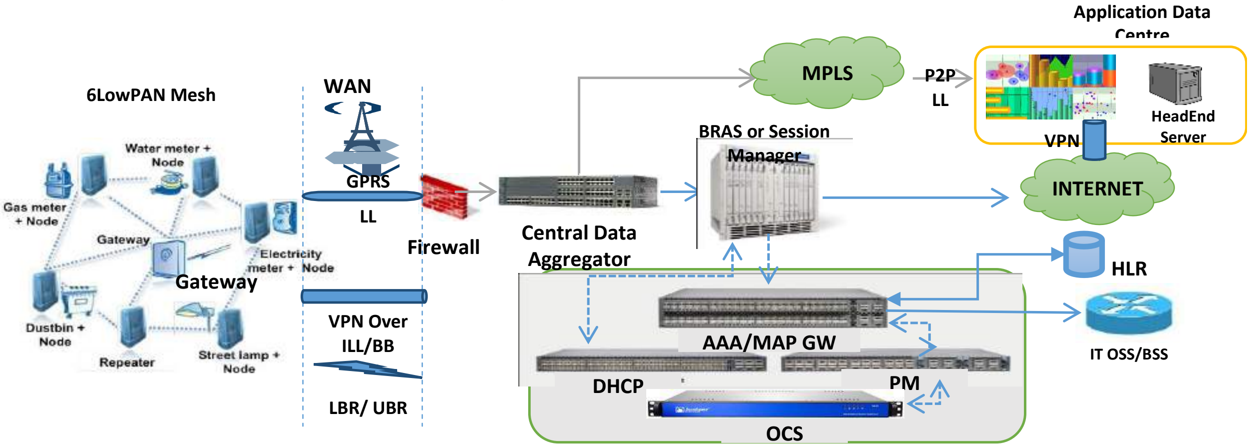

FIGURE 4 - TYPICAL IMPLEMENTATION ARCHITECTURE FOR M2M COMMUNICATIONS

In the above architecture, the field devices/sensors connect to the gateway using any of the technologies mentioned in Section 6.

The gateways establish a secure tunnel to the Central Data Aggregator (controller). This controller has data, control and management planes which establish a tunnelled communication from the gateway to the core but can also enable local data breakout.

The M2M devices receive the IP address when it connects to the gateway from the central DHCP server. Post authentication, the session is created in Session Manager/BRAS and Internet access is provided.

Functional architecture for M2M communications may be based on the OneM2M architecture or on any other architecture if found relevant to our needs in India for the power sector.

5. Use Cases in the Power Sector

The power sector has a number of use cases where M2M communications plays a vital part. These include (but are not limited to):

- Automatic Meter Reading (AMR)
- Advanced Metering Infrastructure (AMI)
- SCADA/EMS (Supervisory Control and Data Acquisition/Energy Management System) for TRANSCOS
- SCADA/DMS (Supervisory Control and Data Acquisition/Distribution Management System) for DISCOMS
- Distributed Control System (DCS) for GENCOS
- Wide Area Monitoring System (WAMS) using Phasor Measurement Units (PMUs)
- Substation Automation and Distribution Automation
- Distributed Generation
- Electric Vehicles
- Energy Storage
- Microgrids
- Home Energy Management/Building Energy Management
- Enterprise Networks

Exploring Key Use Cases in Power Sector

The following are some of the key areas where M2M communication is used in the power sector:

5.1 Automated Meter Reading (AMR)

AMR is used extensively in RAPDRP for HT consumers, distribution transformers and feeders. Both GSM and CDMA were used. It is reported that reliability is poor. The following architecture was used for AMR in RAPDRP: (Note: Communications is only ONE-WAY)

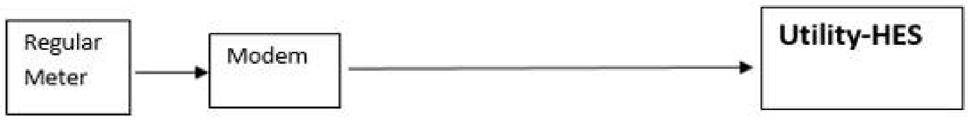

FIGURE 5 - TYPICAL ARCHITECTURE OF AMR

5.2 Advanced Metering Infrastructure (AMI)

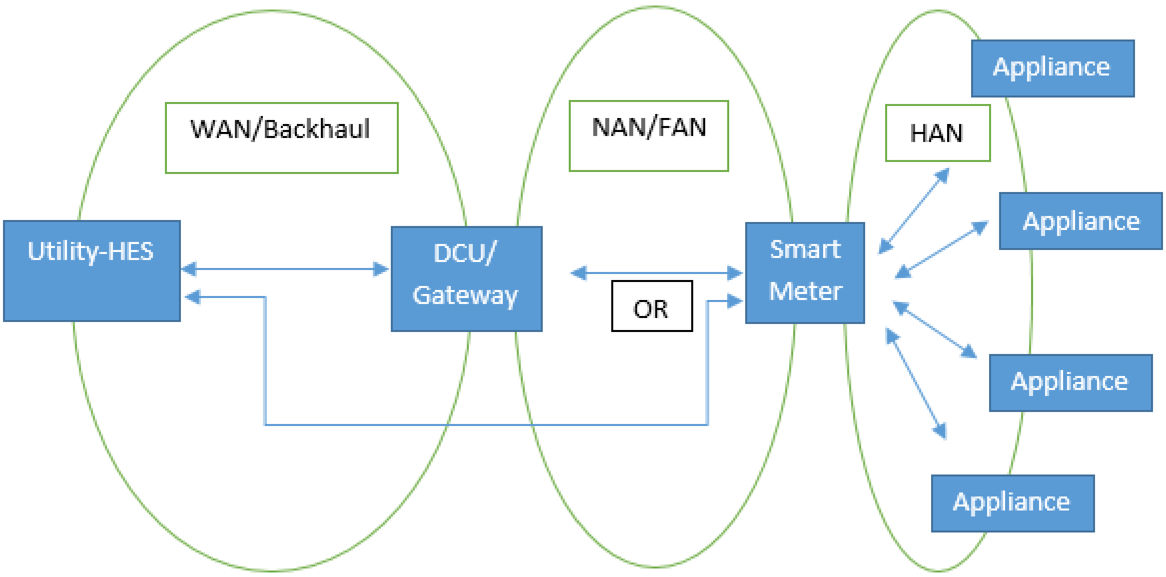

FIGURE 6 - TYPICAL ARCHITECTURE OF AMI

Advanced Metering Infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customer premises equipment. The figure below represents a typical architecture of AMI:

It is pertinent to mention the following:

1. AMI can also be implemented without using a DCU. That is, the meters may directly communicate with the Utility-HES using any of the technologies that offer wide area connectivity.
2. DCU could also be replaced by a gateway.

With the advent of an Advanced Metering Infrastructure (AMI), both consumers and the utilities would benefit. The consumers would be able to:

a. View their consumption of electricity accurately on a regular basis
b. Manage loads in different manners based on the design, ranging from remotely turning ON/OFF their appliances to managing total demand to allow curtailed supply instead of load-shedding
c. Save money from Time of Use (ToU) tariffs by shifting non-priority loads
d. Face reduced outages and downtimes, and even lower or zero load-shedding

Utilities would benefit in the following ways (which would pass on to the consumer):

a. Financial gains by
    i. Managing the load curve by introducing Time of Use (ToU)/Time of Day (ToD) tariff, demand response etc.
    ii. Reducing equipment failure rates and maintenance costs
    iii. Enabling faster restoration of electricity service after fault/events

iv. Detecting energy theft/pilferage on near real-time basis
v. Streamlining the billing process
vi. Remote meter reading which reduces human resources, human errors and time consumption for meter reads

b. Respond to power outages and detect meter failures (with no on-site meter reading)
c. Enhanced monitoring of the system resources that would significantly improve the reliability indices like CAIDI, CAIFI, SAIDI, SAIFI etc.
d. Improvement in other key performance indicators

Utilities have millions of consumers and hence millions of meters to record the electricity usage of each consumer. IPv6, with its ‘ virtually limitless’ address space, can provide IP addresses to each and every energy meter and thus assists in making every meter reachable, accessible and controllable from a remote central location. The second aspect is security. Since security is an integral part of IPv6, enhanced protection can be implemented in an end-to-end network.

Three implementation solutions for the power sector are mentioned below:

(Please note that these solutions have not taken into account all possible options. Only specific cases have been discussed for maintaining ease of understanding.)

Implementation Solution Type 1: A local mesh with remote application server

In this case, there are multiple meters in vicinity and they need to communicate to a remote application server. The two communication methodologies depicted below for LAN and WAN are 6LoWPAN to and GSM (GPRS) respectively.

The solution shall consist of 3 components, viz. a smart meter, a Data Concentrator Unit (DCU)/gateway, and the Meter Data Acquisition System (MDAS) that is part of the Utility Head End System (HES). The DCU/gateway acts as a coordinating entity and facilitates 2-way communication between the smart meter and the HES. The smart meter in this case supports 6LoWPAN-based RF-mesh communication technology. Thus, the DCU/gateway handles both short-range and long-range communications. The DCU is responsible for maintaining a group of meters. However, if a gateway is used, it will only relay packets to the HES.

FIGURE 7 - IMPLEMENTATION SOLUTION TYPE 1: LOCAL MESH WITH REMOTE APPLICATION SERVER

The network architecture for this use case is depicted in the figure above. The gateway/DCU has 6LoWPAN and GPRS modules, which interact with the end nodes over 6LoWPAN and to the HES over GPRS. From the Telco Core Network, data is typically sent to the utility via a leased line or a wireless link. The call flow between the end nodes and the DCU/gateway is mentioned below. The call flow between the DCU to the telecom packet core resembles the call flow mentioned in Implementation solution Type 2.

The client/sensor to gateway and then to the local or core network element is a critical path of M2M communication. The visibility of end client information and integration to Network Management System (NMS) is also required for diagnostics and network planning. The typical call flow is depicted below:

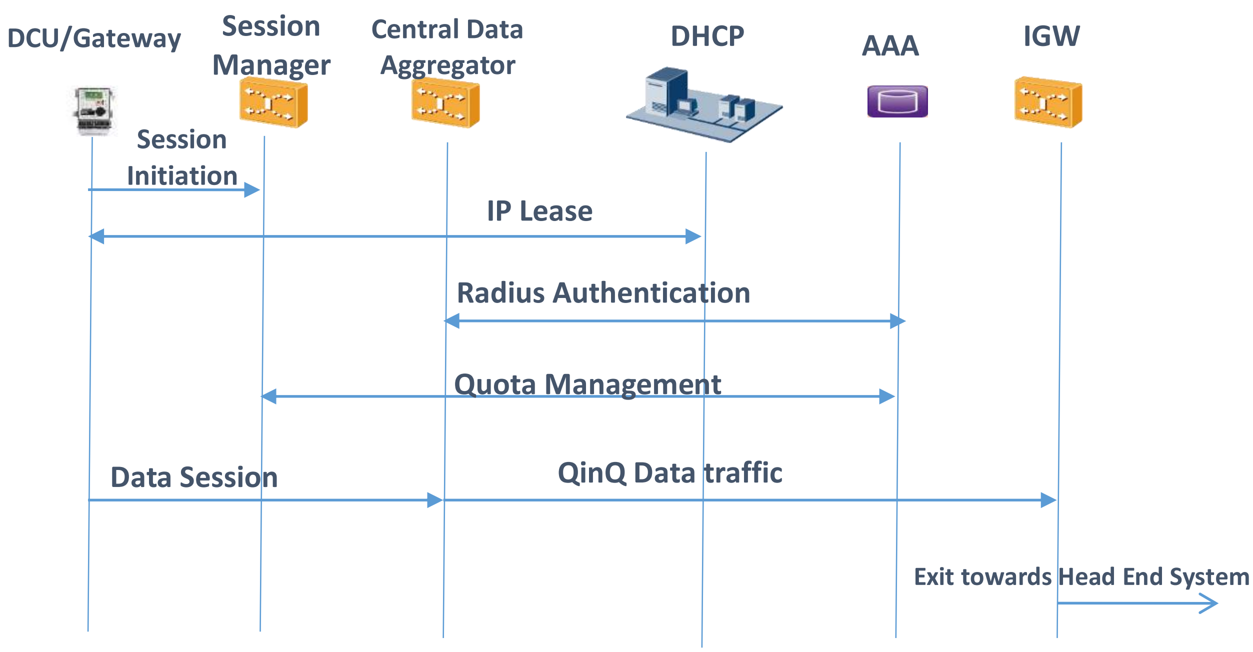

FIGURE 8 - TYPICAL CALL FLOW FROM METER/NODE TO HEAD END SERVER

The end node can be connected in a mesh to a local DCU/gateway that could be connected to the telco's data center. The local DCU/gateway is connected to the central data aggregator and node manager in the telco core network which aggregates the data from all nodes and also does the configuration management and monitoring of the local DCUs/gateways. The end clients that are latched onto the individual nodes should also be visible on the central node.

The central data aggregator is a device manager and data collator for the local DCUs/gateways. The local DCUs/gateways support open protocols and security mechanisms like IPSec so that the data is sent over a secure tunnel. This architecture supports L3 based routing. All elements (central nodes, central data aggregator and local DCU/gateway) support IPv6.

<u>Implementation Solution Type 2: Metering for scattered locations</u>

In some scenarios such as DT metering or metering of consumers at scattered locations, the meters might be placed in a distributed manner and the possibility of local mesh communication via DCU/gateway might not be feasible. For such scenarios the meter can communicate directly to the application server via the Telecommunication Service Provider's network over IPv6 protocol.

FIGURE 9 - IMPLEMENTATION SOLUTION TYPE 2: FOR METERING OF CONSUMERS AT SCATTERED LOCATIONS

The network architecture for this use case is depicted in the above figure. The meter communicates directly with the HES over the TSP's network. The call flow explained in the Implementation Solution Type 1 is applicable here as well.

The call flow for different scenarios in WAN connectivity is provided in the 3GPP standard document "TS 23.060 V7.9.0 (2009-12)" for IPv6 communication over WAN and core network.

Implementation Solution Type 3: Latency Critical Applications

For latency critical applications, ILL or broadband may be used. The reference architecture for low latency applications is mentioned below:

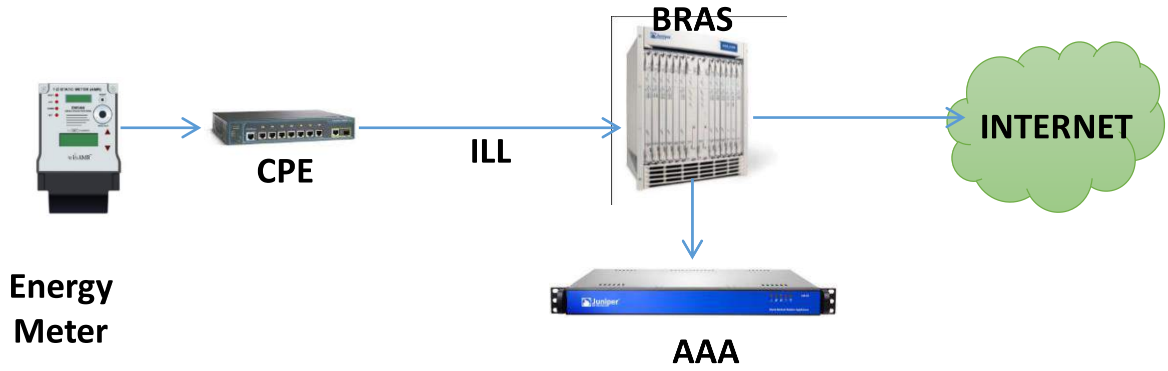

FIGURE 10 - IMPLEMENTATION SOLUTION TYPE 3: FOR LATENCY CRITICAL APPLICATIONS

The meter is connected to an Internet leased Line via a switch or a CPE and is further connected to Broadband Remote Access Server (BRAS) over MPLS. The BRAS is integrated to AAA for customer authentication, authorization and accounting on the control plane while the data plane exits to the Internet via the Internet Gateway (IGW).

The high level call flow for the same is depicted below:

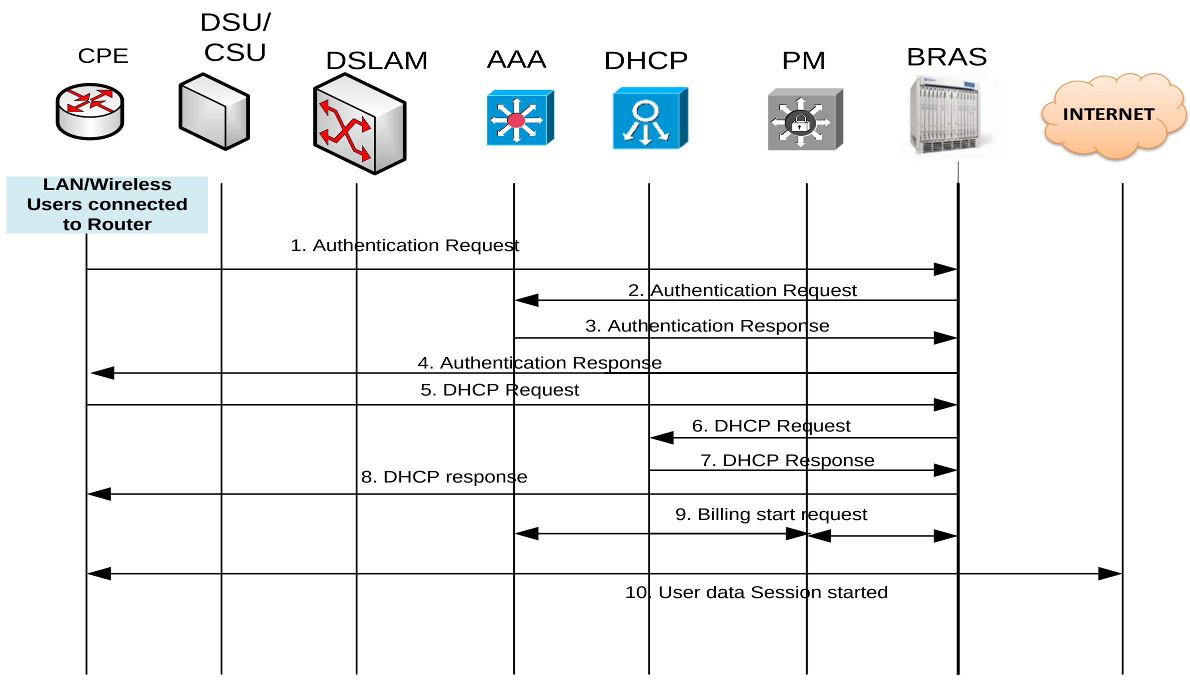

FIGURE 11 - TYPICAL CALL FLOW FOR WIRELINE CONNECTIVITY

COMMUNICATION BETWEEN SERVICE PROVIDER DATA CENTER AND REMOTE APPLICATION SERVER

For communication from service provider data center to the remote application server, the following two architectures could exist:

Connectivity Use Case Type 1: MPLS Connectivity

The first approach requires connectivity to the utility data center over MPLS.

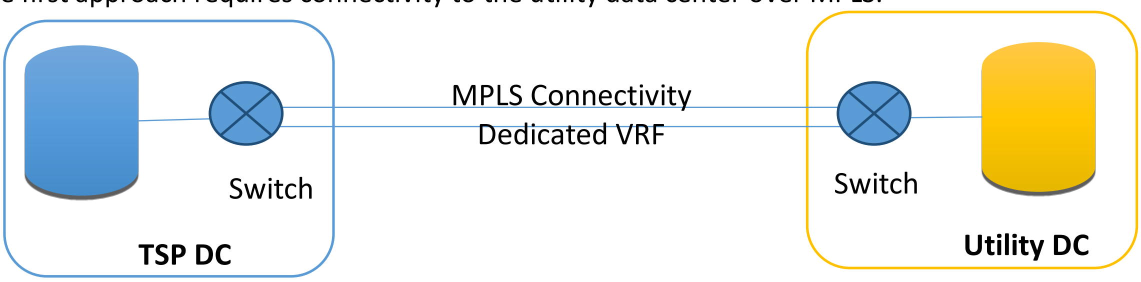

FIGURE 12 - MPLS CONNECTIVITY

This ensures high bandwidth and uptime between the two data centers. Also service level assurance can be committed in such architecture by the TSP.

A VRF has to be created between both the data centers and the servers can be connected over private IP resulting in a secure network.

Connectivity Use Case Type 2: Over Internet

If the Connectivity Use Case Type 1 (mentioned above) is not feasible, the connectivity between the TSP and utility data center can be established over the Internet with a VPN connectivity.

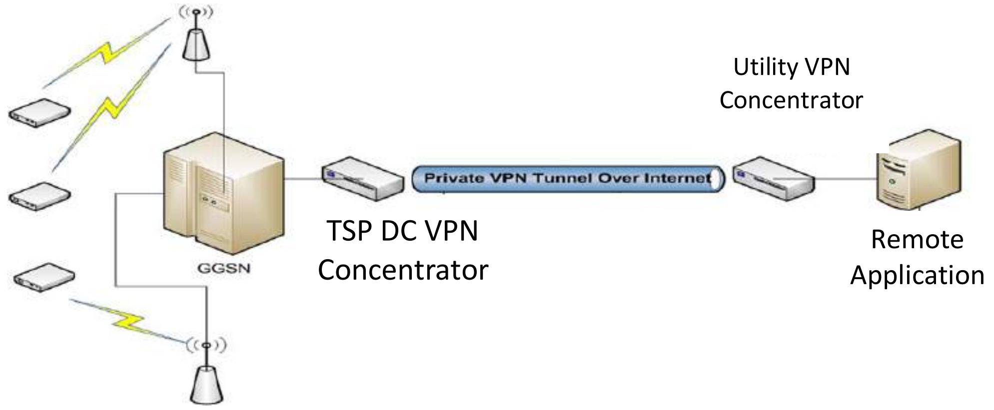

FIGURE 13 - CONNECTIVITY OVER THE INTERNET

In this scenario, there should be a VPN concentrator at the utility data center. The communication between the TSP and Utility Data Center will be provided via a secure VPN tunnel established over the Internet.

This may be a solution for low bandwidth requirement as there may not be guaranteed service assurance by the Internet service provider. Also, such connectivity could be used if the data needs to be sent to servers in international locations (which are not on MPLS).

The following table depicts a snapshot of the smart meter deployment status in select areas around the world:

TABLE 1 - SNAPSHOT OF GLOBAL SMART METER DEPLOYMENT

Country/Continent	Total number of meters currently deployed (in millions)	Number of smart meters already deployed (in millions)	Smart Meters as share of total deployment
USA	150	46	30.7 %
Europe	281	61.2	22.0 %
Australia	9.5	3	31.6 %
Canada	15	7.3	49 %
India	200	-	<<1 %

Source: ISGF White Paper on 'Smart Metering Scenario in India' published on March 31, 2014

Today smart meters in India are deployed only for pilot projects and are less than 1 per cent of the total number of metered households.

By 2022, India is expected to roll out about 200 million smart meters.

5.3 Supervisory Control and Data Acquisition (SCADA)

SCADA (Supervisory Control and Data Acquisition) is a system for acquiring and analyzing information obtained from numerous devices placed on the electrical grid. In addition, various grid elements can be controlled using SCADA.

Apart from measuring voltage, current, active power, reactive power, power factor, etc., SCADA enables acquiring the status of switches, protection relays and faults of Feeder Terminal Unit (FTU) as well. Flow detection and momentary voltage drop measurement can also be achieved. On the other hand, switches and relays can be controlled from the control center.

Typically, a Remote Terminal Unit (RTU) serves as an intermediate entity between the control center and Intelligent Electronic Devices (IEDs) on the grid.

The communication requirements for SCADA are very stringent. These include (but are not limited to) extremely high availability, reliability and information security, along with very low latency.

The SCADA system is used both, at the distribution level (SCADA/DMS) and at the transmission level (SCADA/EMS). SCADA/DMS is operated by the distribution companies (DISCOMS) for low voltage distribution lines. SCADA/EMS is operated by the transmission companies (TRANSCOS) for high voltage transmission lines. A typical architecture of SCADA/DMS and SCADA/EMS is depicted below:

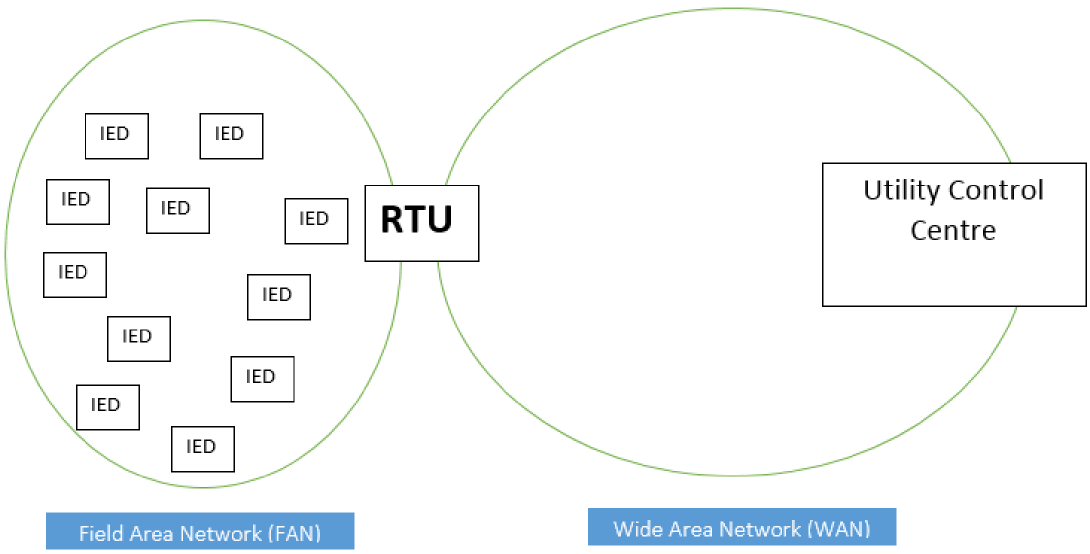

FIGURE 14 - TYPICAL ARCHITECTURE OF SCADA/DMS AND SCADA/EMS

SCADA/EMS has been implemented for all the state transmission grids and the 5 regional grids (now a single unified grid) for reliable and integrated operation. As a result, the number of grid failures have also reduced.

As part of RAPDRP (Part A), all the state owned DISCOMS are implementing SCADA/DMS systems in large towns.

5.4 Wide Area Monitoring System (WAMS)

Wide Area Monitoring System (WAMS) is used to obtain both, magnitude and phase of the voltages and currents using Phasor Measurement Units (PMUs). The reading is time synchronized using Global Positioning System (GPS).

Real time situational awareness is achieved by using WAMS via voltage stability assessment, state estimation, oscillation detection and post-fault analysis.

A typical architecture of a Wide Area Monitoring System consists of Phasor Measurement Units (PMUs) that send the data to a Phasor Data Concentrator (PDC) which in turn, send the data to the utility control center.

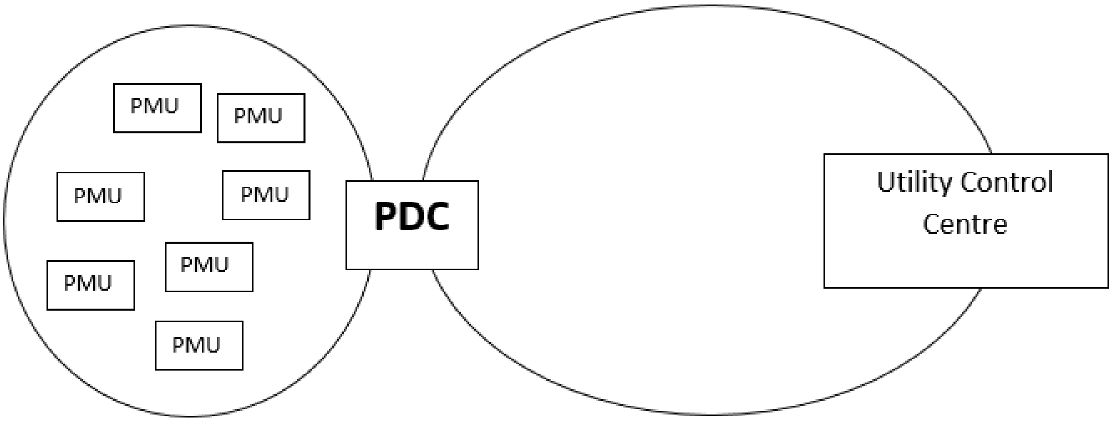

FIGURE 15 - TYPICAL ARCHITECTURE OF WAMS

Power Grid Corporation of India Limited (PGCIL) is in the process of commissioning 1700 Phasor Measurement Unites (PMUs) at various sub-stations and power plants across the Indian power sector. In addition to this, 34 Phasor Data Concentrators (PDCs) are also being installed at NLDC, RLDCs, SLDCs and other strategic locations. Currently, Phase 1 is being carried out where 1154 PMUs and 34 PDCs are to be installed by January 2016.

5.5 Substation Automation and Distribution Automation

Apart from transforming the voltage levels, modern substations include 'smart' devices for monitoring and controlling the operation of transformers, circuit breakers, protective relays, capacitor banks, switches, voltage regulators, static VAR compensators, etc.

Substation automation and distribution automation, being critical for the functioning of a utility, impose stringent communications requirements of availability, reliability, latency and security.

Distribution automation involves employing automation elements at various places on the electricity grid such as Ring Main Units (RMUs), distribution transformers, reclosers etc. This centralized monitoring and control of the distribution networks improves the reliability and efficiency of the electrical network.

Currently in India, IEC 60870-5-104 is widely used for substation automation. Very few utilities are using IEC 61850 because of the limited expertise in implementing this protocol.

5.6 Distributed Generation

Distributed generation refers to the generation of electricity by using small scale technologies very close to the end user. Examples of distributed generation using renewables include solar, small hydro, wind, biogas and hydrogen energy. Non-renewable fuels such as diesel, natural gas and kerosene are also used for distributed generation of electricity.

Distributed generation of electricity would not only reduce the demand supply gap, but would also enable consumers in becoming ‘prosumers’ wherein they would feed electricity into the grid and generate revenue.

The renewable resources that are used for distributed generation in India are small hydro, solar, water pumping windmills, aero-generators, wind-solar hybrid generators and biogas. Small hydro is by far the dominant technology contributing to distributed generation. It is the most mature of all the technologies followed by solar and biogas. Water pumping windmills along with aero-generators and wind-solar hybrid generators are relatively new technologies that implement distributed generation.

Apart from communicating the amount of electricity generated in near real-time to a control center, M2M communications would be used for remote asset monitoring and controlling the amount of energy generation as per the needs of the utility.

The Government of India has set a target of generating 40 GW of power by deploying rooftop RV systems.

The following states have released net metering policies (some have been released as drafts):

1. Andhra Pradesh
2. West Bengal
3. Uttarakhand
4. Kerala
5. Punjab
6. Delhi
7. Tamil Nadu
8. Assam
9. Haryana
10. Madhya Pradesh
11. Karnataka
12. Bihar
13. Maharashtra
14. Goa (also applicable for all Union Territories except Delhi)

In addition, Gujarat has taken a different route by launching its gross metering policy in September 2011. Other states are following suit by expediting the process of preparing their policies.

5.7 Electric Vehicles

Apart from offering a clean, eco-friendly and an efficient mode of transport, electric vehicles act as virtual power plants which can provide electricity to the grid, households and buildings during the peak hours.

India has launched the National Mission for Electric Mobility (NMEM) for expediting the adoption and manufacturing of electric and hybrid vehicles in India. To achieve this objective, a National Electric Mobility Mission Plan 2020 was released in 2012 which lays the vision and provides a roadmap for achieving significant penetration of these efficient and eco-friendly vehicles in India by 2020. It aims to transform India as a leader in the two-wheeler and four-wheeler market (encompassing electric and hybrid vehicles) with anticipated sales of around 6-7 million units by 2020.

M2M communications are vital for the functioning of the electric vehicle charging infrastructure because information regarding charging of the electric vehicle needs to be sent to the utility for billing purposes. Hence choosing a reliable and secure communications technology is a necessary requirement for the electric vehicle charging infrastructure.

It is reported that 1-2 lakh E-rickshaws (in Delhi), 2-3 lakh two wheelers and 2000-3000 electric vehicles (by Reva) are operational in India. Overall, existence of electric vehicles in extremely limited in India.

5.8 Energy Storage

Renewable energy generation being intermittent and variable, requires energy storage technologies for viable operation. Storage facilities would not only store electricity during non-peak hours and provide power during outages, but also provide low cost ancillary services such as load following and spinning reserves.

M2M communications, both at the supply side and the demand side, would provide the necessary visibility in the grid by being able to monitor and control the amount of electricity storage in near real-time.

With India aiming to aggressively increase renewable generation capacity, lost cost and efficient energy storage technologies along with reliable M2M communications would provide another stimulus to achieve the envisaged targets.

CERC[8] has proposed ancillary service introduction which could create a 3-4 GW opportunity for frequency regulation by 2018. Out of the 600,000 telecom towers in India, more than 70% utilize diesel generators for backup/primary source. Hence the Department of Telecommunication (DoT)[9] has issued guidelines making it mandatory for telecom companies to power at least 50 per cent of mobile towers in rural areas and 20 per cent in urban areas by hybrid power(consists of power from renewable sources, hydrogen fuel cells- and grid electricity) by 2015. India has over 100,000 bank ATMs and these require back-up solutions. In addition, India Plans to Install 26 million solar-powered water pumps. Over 9 million diesel-powered water pumps are in operation.

[8] http://www.cercind.gov.in/2013/whatsnew/SP13.pdf

[9]http://www.trai.gov.in/WriteReadData/Direction/Document/Green%20Directions%20for%20Access%20SPs0001.pdf

In India, over 300 million people do not have access to grid electricity and India's national mission for energy access aims to provide at least 8 hours of access by 2017. Energy storage would be a step towards solving this problem. Furthermore, Indian railways is 5th largest rail network (over 65,000 km long) in the world and is driving integration of energy storage for public transportation systems.

Looking at the increasing importance of energy storage for integrating renewable energy, the Ministry of New and Renewable Energy (MNRE) [10] has proposed to support demonstration projects for energy storage to assess feasibility of energy storage technologies for small scale and grid connected MW scale renewable energy applications.

5.9 Microgrids

A microgrid[11] is a local grid with an integrated energy system that intelligently manages the interconnected loads and distributed energy resources. The generation and distribution of power can be operated in island mode or grid connected mode.

Microgrids can customize the local energy demand curve for a particular area by integrating conventional power supply with locally installed distributed generation viz. solar, wind, biomass, waste to energy etc. As a result, they reduce load on main grid, encourage distributed power generation, allow for islanding from main grid which in turn lead to grid independence and offer a reliable and un-interrupted source of energy to the users connected to the microgrid.

The driving factors of microgrids include (but are not limited to) efficiency, reliability, energy security, economic savings, revenue generation and sustainability.

The main components of a microgrid are a master controller (that matches the load with generation by optimising the integration, dispatching and control of distributed energy resources and loads), AMI, distributed energy resources and energy storage.

The Smart Grid Vision and Roadmap[12] for India envisions 1000 microgrids by 2017; 10,000 microgrids by 2022 and 20,000 microgrids by 2027. The National Smart Grid Mission (NSGM) would serve as the implementation body of these projects. The World Bank is in the process of rolling out microgrids in 7 districts in Uttar Pradesh. With solar energy being an abundant resource in most parts of our country and the sharp decline in cost of solar PV technology in recent years, community level Solar PV microgrids can be a viable option to achieve the 'power for all' goal. JNNSM is also taking steps in setting up solar PV minigrids.

[10] http://mnre.gov.in/file-manager/advertisement/EoI-Energy-Storage-Demonstration-Project-for-supporting-Renewable-Generation.pdf

[11] ISGF White Paper on '**Role of Smart Grids in Distribution**' published on April 16, 2015

[12] '**Smart Grid Vision and Roadmap for India**' released by Ministry of Power, Government of India in September 2013.

5.10 Home Energy Management/Building Energy Management

Smart homes[13] would offer monitoring and control of the electricity usage within the consumer premises. Aggregators or energy management systems would form the core of home automation by providing a means to efficiently consume electricity. In addition to a smart meter that would remotely connect and disconnect the supply, smart appliances would provide the energy consumption data to the consumer and the utility. The consumer could view the consumption data via an In-Home Display (IHD) device or via SMS, e-mail or by logging on to a consumer portal. Loads could also be remotely controlled via the aggregators or energy management systems.

OneM2M had a dedicated working group called 'European Smart Metering Industry Group (ESMIG)'. As part of the activities undertaken by this group, home energy management has been identified as a key area. These may be adopted in India if found relevant to our needs in India for the power sector.

5.11 National Optic Fiber Network (NOFN)

The Government of India is in the process of connecting 250,000 gram panchayats on a fiber network. Presently, Phase 1 is in progress, according to which 20,000 gram panchayats are to be connected by March 2015. There is a plan to connect all 33KV and above substations using optical fiber to create a backbone network for the power sector.

Integrated Power Development Scheme (IPDS)[14] and Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)[15] were launched by Government of India in November 2014 to reform the power sector. While IPDS includes strengthening of sub-transmission and distribution network, metering of distribution transformers /feeders/consumers and IT enablement of distribution sector in urban areas, DDUGJY includes separation of agriculture and non-agriculture feeders, strengthening and augmentation of sub-transmission and distribution infrastructure in rural areas (including metering of distribution transformers/feeders/consumers) and rural electrification.

The Government has allotted Rs 120 crores for IPDS and Rs 280 crores for DDUGJY for connecting NOFN to all substations. [16]PGCIL will coordinate the extension of fiber to all 132 kV and above substations. For 33 kV and 66 kV substations, CEA will coordinate all activities.

5.12 Fourteen Smart Grid Pilot Projects in India

In order to kick-start smart grids in the country, GoI allotted 14 pilot projects to different distribution companies in various states. The combined cost of these projects is about Rs 408 crores ($68 million) and they will help technology section guidelines and business case developments for larger projects in the next phase. These projects will be partly funded by GoI (50 per cent of the project cost will come as a grant from GoI).

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[13] ISGF White Paper on '**Role of Smart Grids in Distribution**' published on April 16, 2015

[14] Ministry of Power Website - http://powermin.nic.in/upload/pdf/Integrated_Power_Development_Scheme.pdf

[15] Ministry of Power Website - http://powermin.nic.in/upload/pdf/Deendayal_Upadhyaya_Gram_Jyoti_Yojana.pdf

[16] Central Electricity Authority Website - http://www.cea.nic.in/reports/articles/god/mom_300115.pdf

With recent activities centering around these 14 Smart Grid pilot projects, 100 Smart Cities project, Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), Integrated Power Development Scheme (IPDS), "100 GW solar power by 2022", National Electric Mobility Mission (NEMM) and National Smart Grid Mission (NSGM), India has emerged as a key destination for smart grids.

The functionalities envisaged in the 14 pilot projects include AMI (residential and industrial), SCADA/DMS, OMS, PLM, PQM, Microgrids and Distributed Generation.

The following table throws more light on the details about these pilots:

Table 2 - Snapshot of the 14 Smart Grid Pilot Projects (GoI Approved)

State	Utility & Area	Functionalities
Assam	**Utility:** Assam Power Distribution Company Limited, Assam **Project Area:** Guwahati Distribution Region **Consumers:** 15,000	AMI R, AMI I, PLM, OMS, and PQM, DG
Chhattisgarh	**Utility:** Chhattisgarh State Power Distribution Company Limited, Chhattisgarh **Project Area:** Siltara and DDU Nagar of Raipur **Consumers:** Around 1,987	AMI I, PLM
Gujarat	**Utility:** Uttar Gujarat Vij Company Limited, Gujarat **Project Area:** Naroda of Sabarmati circle and Deesa- II of Palanpur circle **Consumers:** 39,422	AMI I, AMI R, and OMS
Haryana	**Utility:** Uttar Haryana Bijli Vitran Nigam Limited, Haryana **Project Area:** Panipat City Sub-division **Consumers:** 31,914; revised to 11,000	AMI I, AMI R, and OMS, SCADA/DMS
Himachal Pradesh	**Utility:** Himachal Pradesh State Electricity Board Ltd, Himachal Pradesh **Project Area:** KalaAmb **Consumers:** 1,251	AMI I, PLM, OMS, and PQM
Karnataka (Mysore)	**Utility:** Chamundeshwari Electricity Supply Corporation Limited, Mysore, Karnataka **Project Area:** VV Mohalla, Mysore **Consumers:** 24,532	AMI R, AMI I, PLM, OMS, and PQM, DG/MG
Kerala	**Utility:** Kerala State Electricity Board, Kerala **Project Area:** Restructured to the R-APDRP towns (8 nos) **Consumers:** 25,078 revised to 15,700	100% AMI I (for LT)
Maharashtra	**Utility:** Maharashtra State Electricity Distribution Company Limited, Maharashtra **Project Area:** Baramati Town **Consumers:** 29,997	AMI I, AMI R, and OMS

Puducherry	**Utility:** Electricity Department of Government of Puducherry **Project Area:** Division 1 of Puducherry **Consumers:** 87,031	AMI I, AMI R
Punjab	**Utility:** Punjab State Power Corporation Limited, Punjab **Project Area:** Industrial Division of City Circle Amritsar **Consumers:** 9,818	AMI, PLM
Rajasthan (Jaipur)	**Utility:** Jaipur Vidhyut Vitaran Nigam Ltd, Rajasthan **Project Area:** VKIA Jaipur **Consumers:** 34,752	AMI R, AMI I, PLM
Telangana	**Utility:** Telangana Southern Power Distribution Company Limited, Telangana (formerly Andhra Pradesh Central Power Distribution Company Limited, Andhra Pradesh) **Project Area:** Jeedimetla Industrial Area **Consumers:** 11,904	AMI I, AMI R, PLM, OMS, PQM
Tripura	**Utility:** Tripura State Electricity Corporation Limited, Tripura **Project Area:** Electrical Division No.1 of Agartala town **Consumers:** 46,071	AMI I, AMI R, PLM
West Bengal	**Utility:** West Bengal State Electricity Distribution Company Limited, West Bengal **Project Area:** Siliguri Town in Darjeeling District **Consumers:** 4,404	AMI I, AMI R, and PLM

Source: India Smart Grid Forum (ISGF)

AMI R – AMI for Residential consumers
AMI I – AMI for Industrial consumers
PLM – Peak Load Management
OMS – Outage Management System
PQM – Power Quality Management
DG – Distributed Generation
PQM – Power Quality Management
MG – Microgrid

5.13 Enterprise Networks

In addition to the above mentioned use cases, communications will be used by a utility for establishing enterprise networks as well.

6. Communication technologies & Standards Available for Use in the Power Sector

6.1 Communication Technologies for NAN and HAN

For NAN and HAN connectivity, any of the following options could be used:

a. 6LoWPAN-based RF mesh
b. PLC
c. Bluetooth
d. NFC
e. RFID
f. Wi-Fi (Peer to Peer or Mesh)
g. ZigBee
h. Z-Wave
i. Television White Space (TVWS)
j. Private Microwave Radio Networks (P2P and P2MP)
k. FTTx (x = curb/premises/home)
l. Serial interfaces (RS-232, RS-422 and RS-485)
m. Ethernet

6.2 Communication Technologies for WAN

For WAN connectivity, any of the following options could be used:

a. Cellular communications
b. Ethernet
c. PLC
d. Satellite Communications
e. Private Microwave Radio Networks (P2P and P2MP)
f. Carrier Wi-Fi
g. DSL
h. Low Power Wide Area (LPWA)
i. Long Wave Radio
j. Television White Space (TVWS)

However the success of any of the technologies listed above or introduced in future would depend on the device ecosystem as well as interoperability with IP networks.

The existing breakup of **Wireless** WAN technologies used in the M2M domain has been depicted in the chart below. GPRS communication dominates the technology share in WAN communication.

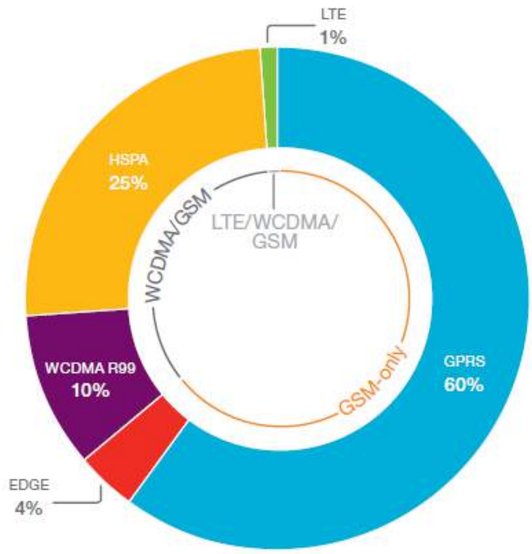

FIGURE 16 - BREAK-UP OF WIRELESS WAN TECHNOLOGIES USED FOR M2M APPLICATIONS

Source: Ericsson Mobility Report published in June 2014

6.3 Comparison of M2M Communication Technologies

The table below compares the technologies/protocols that could be used for M2M communications in a smart grid.

Please note:

1. Content in the following table is to be treated as guidelines only.
2. While making the comparison, the 'openness' and standards-based nature of the technologies has NOT considered because the term 'open' is perceived in different ways by individuals/organizations. For example, some believe a standard is open if it is universally available to everyone or if it is available free of cost. Another perspective is that if a standard can be implemented free of cost, it is 'open'.
3. The list is not exhaustive.

TABLE 3 - M2M COMMUNICATION TECHNOLOGIES COMPARISON

Technology/ Protocol	Typically used Frequency Band/Bands	Advantages	Limitations	Relevance for Smart Grids in India
Wireless				
Low Power RF				
6LoWPAN – based RF Mesh	Various frequency bands in the 800 MHz, 900 MHz and 2400 MHz bands	• Lightweight • Versatile (can be used with any physical and data link layer)	• All low power wireless personal area networks are unreliable due to uncertain radio	• AMR - NAN • AMI - NAN • SCADA/DMS - NAN • SCADA/EMS - NAN • DCS for Generation

		• Ubiquitous • Scalable • Manageable and secure connectivity (IPSec is inbuilt) • Can be used in the sub-GHz range	connectivity, battery drain, device lock ups, physical tampering etc. 6LoWPAN being a low power wireless PAN would also encounter this limitation[17].	• WAMS - NAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage • Microgrids • Home/Building Automation
Bluetooth*	2.4 GHz	• Mature technology • Easy to implement	• Low data security • Extremely short range • Only connects 2 devices at a time • Not very reliable • Not interoperable with all devices	• Reading data from smart meters using a HHU • Home/Building Automation • Enabling prepayment functionalities
InfraRed	2.4 GHz	• Low power consumption • Inexpensive • Less interference	• Communication is line of sight • Extremely short range • Easily blocked by objects such a people, walls, plants etc.	• Reading data from smart meters using a HHU • Home/Building Automation • Enabling prepayment functionalities
NFC	13.56 MHz	• Consumes less power • Almost instantaneous connectivity between devices	• Extremely short range • Expensive • Low information security • Low market penetration	• Reading data from smart meters using a HHU • Enabling prepayment functionalities

[17] http://tools.ietf.org/html/rfc4919

RFID	Various frequency bands from 100 KHz to 2.4 GHz	• Mature technology • Can penetrate through objects (plastic, human body, wood etc.)	• Extremely short range • Low data security • Expensive modules • Connectivity can be hampered easily	• Reading data from smart meters using a HHU • Enabling prepayment functionalities
Wi-Fi**	2.4 GHz	• Mature technology • High home/office penetration • High data rates achievable • Easy to implement	• Limited range • Poor building penetration • High interference from other sources • Power consumption higher than those technologies that operate in the sub-GHz band	• AMR - NAN • AMI - NAN • Home/Building Automation
ZigBee	Various frequency bands in the 800 MHz, 900 MHz and 2400 MHz bands	• High market penetration in the home-automation domain • Low cost communication modules	• Low reliability • Larger stack size • Not interoperable with non-ZigBee devices • Range is less (In India can only be used in the 2.4 GHz band) • Higher power consumption as compared to those protocols that operate in the sub-GHz range • Need a middleware for communication between nodes and server • ZigBee IP is designed to operate only in 868 MHz, 915 MHz and 920 MHz	• AMR - NAN • AMI - NAN • SCADA/DMS - NAN • SCADA/EMS - NAN • DCS for Generation • WAMS - NAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage • Microgrids • Home/Building Automation

			• All low power wireless personal area networks are unreliable due to uncertain radio connectivity, battery drain, device lock ups, physical tampering etc.	
Z-Wave	Various frequency bands from 865 MHz to 956 MHz	• Low power consumption • Can be used in the sub-GHz range	• Poor market penetration in India • Expensive modules • Not very scalable • Only 1 manufacturer (Sigma Designs) produces Z-Wave modules	• AMR – NAN • AMI - NAN • SCADA/DMS - NAN • SCADA/EMS - NAN • DCS for Generation • WAMS - NAN • Substation Automation • Electric Vehicles • Distributed Generation • Energy Storage • Microgrids • Home/Building Automation
Cellular	For India, 900 MHz, 1800 MHz, 2100 MHz and 2300 MHz is allocated	• Mature technology • Rapid deployment • Communication modules are low cost and standardised	• Unsuitable for online substation control due to reliability and coverage issues • Coverage not 100% • Reliability not the best • Short technology life-cycle (2G, EDGE, 3G, LTE etc.)	• AMR - WAN • AMI - WAN • SCADA/DMS – (WAN and Backbone) • SCADA/EMS – (WAN and Backbone) • DCS for Generation • WAMS - WAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage

				• Microgrids • Home/Building Automation
Low Power Wide Area (LPWA)	TV spectrum, 900 MHz, 2.4 GHz, 5 GHz	• Long range • Low power consumption • Require low bandwidth	• Not available in India (as on today) • Require cheap modules with a long battery life to outweigh cellular technology • Additional spectrum may need to be allocated	• AMR - WAN • AMI - WAN • SCADA/DMS – (WAN and Backbone) • SCADA/EMS – (WAN and Backbone) • DCS for Generation • WAMS - WAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage • Microgrids • Home/Building Automation
Satellite	Various frequency bands from 1-40 GHz	• Broad coverage • Quick implementation • Useful for hilly remote areas	• Affected by severe weather • High cost	• AMR - WAN • AMI - WAN • SCADA/DMS – (WAN and Backbone) • SCADA/EMS – (WAN and Backbone) • DCS for Generation • WAMS - WAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage • Microgrids

				• Home/Building Automation
Long wave Radio	Typically 100-200 KHz	• Extremely high range • Reliable • Energy efficient as lower frequency is used • Reception is possible at basements as these waves travel very close to the Earth's surface	• Propagation of waves is affected by obstacles such as forests, mountains and high-rise buildings • Need regulatory approval to use the spectrum (typically in the 100 KHz -200 KHz range). In the sub-GHz region, only 865-867 MHz is license free • Very high radiated power	• AMR - WAN • AMI - WAN • SCADA/DMS – (WAN and Backbone) • SCADA/EMS – (WAN and Backbone) • DCS for Generation • WAMS - WAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage • Microgrids • Home/Building Automation
TVWS	TV frequency bands specific to different countries	• Unused TV channels are used • Antenna height is nominal - Typically 30-40 meters • Low radiated power (<5W typically)	• Require regulatory approval for spectrum usage, effective radiated power and other necessary parameters • Dynamic allocation of TV frequency bands is complex	• AMR –(WAN and NAN) • AMI –(WAN and NAN) • SCADA/DMS – (NAN and WAN) • SCADA/EMS – (NAN and WAN) • DCS for Generation • WAMS - WAN • Substation Automation • Distributed Generation • Electric Vehicles • Energy Storage • Microgrids

				• Home/Building Automation
Private microwave radio networks(P2P and P2MP)	Various frequency bands in the 400 MHz range, 900 MHz range, and 2.4 GHz to 70 GHz range.	• Inexpensive installation as compared to optical fiber • Increased reliability (as a result of using licensed spectrum – less interference)	• Typically use licensed radio spectrum • Expensive as compared other RF technologies	• AMR (NAN and WAN) • AMI (NAN and WAN) • SCADA/DMS (NAN, WAN and Backbone) • SCADA/EMS (NAN, WAN and Backbone) • DCS for Generation • WAMS (NAN and WAN) • Substation Automation • Distributed Generation • Energy Storage • Microgrids • Home/Building Automation
Wireline				
PLC	Narrowband PLC: 200 Hz–500 KHz Broadband PLC: 2–30 MHz	• 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 • Bespoke engineering and	• AMR (NAN and WAN) • AMI (NAN and WAN) • SCADA/DMS (NAN, WAN and Backbone) • SCADA/EMS (NAN, WAN and Backbone) • DCS for Generation • WAMS (NAN and WAN) • Substation Automation

			trained manpower required for O&M • Communication not possible in case of an outage • Absence of regulations on use of frequency bands	• Distributed Generation • Energy Storage • Microgrids • Home/Building Automation
FTTx	Depending on application	• Extremely fast • Very high bandwidth • Very low attenuation	• Limited availability • High installation cost	• AMR - NAN • AMI - NAN • Distributed Generation • Energy Storage • Microgrids • Home/Building Automation
Serial interfaces (RS-232, RS-422 and RS-485)	Depending on the signal frequency.	• Mature protocols • Easy to implement • Inexpensive installation	• Wires add to the network complexity • Less range • Network architecture limited to point-to-point or daisy chain • Extremely less throughput	• AMR (between meter and modem) • SCADA/DMS - NAN • SCADA/EMS – NAN • DCS for Generation • WAMS - NAN • Substation Automation • Distributed Generation • Energy Storage • Microgrids • Home/Building Automation
DSL***	0-2.208 MHz	• Inexpensive (installation and use) • High SLA • Less installation time	• Low data security • Lower throughput • Higher latency	• AMR (NAN and WAN) • AMI (NAN and WAN) • SCADA/DMS (NAN, WAN and Backbone)

		• Bonded DSL provides inherent redundancy		• SCADA/EMS (NAN, WAN and Backbone) • DCS for Generation • WAMS (NAN and WAN) • Substation Automation • Distributed Generation • Energy Storage • Microgrids • Home/Building Automation
Ethernet	16 MHz, 100 MHz, 250 MHz, 500 MHz, 600 MHz, 1 GHz, 1.6-2.0 GHz	• Inexpensive (installation and use) • Excellent throughput • Low installation time • Easily scalable	• Lowest data security • Lowest SLA • Highest latency • Bursts of additional bandwidth not possible	• AMR (NAN and WAN) • AMI (NAN and WAN) • SCADA/DMS (NAN, WAN and Backbone) • SCADA/EMS (NAN, WAN and Backbone) • DCS for Generation • WAMS (NAN and WAN) • Substation Automation • Distributed Generation • Energy Storage • Microgrids • Home/Building Automation

*Inadequate information security of Bluetooth has led to limited applications in Smart Grid.

** PSK based authentication is not recommended. Mac, IP and device specific credential-based authentication is more reliable.

*** DSL, Leased Lines and Ethernet have been compared relative to each other.

Note: Leased lines can be built on any physical media and offer a private network, highest level of data security and SLA, excellent throughput, lowest latency and possibility of obtaining bursts of additional bandwidth. However, these are expensive (use and installation) and require the highest installation time.

The network requirements for some applications in a smart grid are given below:

TABLE 4 - NETWORK REQUIREMENTS IN A SMART GRID

Application	Network Requirements				
	Bandwidth	Latency	Min Reliability	Security	Power Backup
AMI	10-100 kbps/ node, 500 kbps backhaul	2-15 sec	99%	High	Not Necessary
Demand Response	14-100kbps/ node	500 ms to several minutes	99%	High	Not Necessary
Wide Area Situational Awareness	600-1500 kbps	20-200 ms	100.00%	High	24 Hours or more
Electric Vehicles (Transportation)	9.6-56 kbps	2 sec - 5 min	99.99%	Relatively High	Not Necessary
Distribution Grid Management	9.6 - 100 kbps	100 ms - 2 sec	99%	High	24- 72 Hrs

Source:
http://energy.gov/sites/prod/files/gcprod/documents/Smart_Grid_Communications_Requirements_Report_10-05-2010.pdf

The selection of a technology will depend on the envisaged application:

- For mission critical applications (such as SCADA/DMS, Wide Area Monitoring System, Distribution Automation etc.), security, reliability and latency will be the key criteria for deciding a communication technology. Cost will be of least priority.
- For non-critical applications (such as AMI, connectivity for Distributed Generation, etc.) cost will be decisive.

6.4 Wireless Frequency Bands

6.4.1 Global Scenario

The table below depicts the wireless frequency bands used in a few countries/regions:

TABLE 5 - SNAPSHOT OF GLOBAL FREQUENCY ALLOCATION FOR WIRELESS COMMUNICATIONS

USA/Canada:	
260 – 470 MHz	FCC Part 15.231; 15.205
902 – 928 MHz	FCC Part 15.247; 15.249
2400 – 2483.5 MHz	FCC Part 15.247; 15.249
Europe:	
433.050 – 434.790 MHz	ETSI EN 300 220
863.0 – 870.0 MHz	ETSI EN 300 220
2400 – 2483.5 MHz	ETSI EN 300 440 or ETSI EN 300 328
Japan:	
315 MHz	Ultra low power applications
426-430, 449, 469 MHz	ARIB STD-T67
2400 – 2483.5 MHz	ARIB STD-T66
2471 – 2497 MHz	ARIB RCR STD-33
India :	
2400 – 2483.5 MHz	FCC Part 15.247; 15.249
865 – 867 MHz	*www.wpc.dot.gov.in/Static/RFIDDelicensing.doc*

Source: Texas Instruments (India) Pvt. Ltd. White Paper on 'Last mile connectivity challenges in Smart Grid' by Chander B Goel and Shailesh Thakurdesai

6.4.2 Indian Scenario

6.4.2.1 The 433 to 434 MHz band

As per the notification G.S.R. 680 (E), this frequency band was de-licensed in September 2012. The specifications require that the maximum effective radiated power and maximum channel bandwidth be 10mW and 10 KHz respectively. In addition to using an in-built antenna, the devices (that operate on this frequency band) are meant for indoor applications only. Currently, there are very few devices in this band.

6.4.2.2 The 865 to 867 MHz band

As per the notification G.S.R. 168 (E), this frequency band was de-licensed in March 2005. The specifications require that the maximum transmitted power, maximum effective radiated power and maximum channel bandwidth be 1 W, 4 W and 200 KHz respectively. This band can be used for Radio Frequency Identification (RFID) or any other low power wireless devices or equipment.

Currently this band is not congested as M2M/IoT/Smart cities initiatives are still gathering pace. However, with introduction of more and more devices, this frequency band may not remain adequate to meet the expected demand.

6.4.2.3 The 2.4 to 2.4835 GHz band

As per the notification G.S.R. 45 (E), this frequency band was de-licensed in January 2005. The specifications require that the maximum transmitted power, maximum effective radiated power and maximum antenna height be 1 W (in a spread of 10 MHz or higher), 4 W and within 5 meters above the roof-top of an existing authorized building respectively. This band can be used for any wireless equipment or device.

At present, too many devices use this frequency band. These include (but are not limited to) Wi-Fi and Bluetooth devices, microwave ovens, cordless phones etc. High interference, limited range and high power consumption (of the devices) limit the use of this band for M2M/IoT/Smart Cities.

6.4.2.4 The 5.150 to 5.350 GHz band and 5.725 to 5.875 GHz band

As per G.S.R. 46 (E), these frequency bands were de-licensed in January 2005. The specifications require that the maximum mean effective isotropic radiated power and maximum mean effective isotropic radiated power density be 200 mW and 10 mW/MHz respectively in any 1 MHz band. In addition, the antenna must be in-built or indoor. This band can be used for indoor applications only. These include usage within the single contiguous campus of an individual, duly recognized organization or institution.

Although this frequency band offers low interference, it is not widely used in today's scenario.

6.4.2.5 The 5.825 to 5.875 GHz band

As per the notification G.S.R. 38 (E), this frequency band was de-licensed in January 2007. The specifications require that the maximum transmitted power and the maximum effective isotropic radiated power be 1 W (in a spread of 10 MHz or higher) and 4 W respectively. This band can be used for any wireless equipment or device.

This frequency band also offers low interference, but will not be ideal for low power applications due to relatively high power consumption and limited range. However this band could be used for point to point and point to multipoint links.

SELECTION OF A FREQUENCY BAND:

The sub-GHz frequency bands offer compelling advantages as compared to other (higher) frequency bands. Below 1 GHz, the further down we go, the better the performance will be in terms of range, interference, signal to noise ratio, penetration and power consumption.

At present, the 865-867 MHz band is the most suitable frequency band for outdoor applications by virtue of the reasons mentioned above. For indoor applications, the 2.4-2.4835 GHz band is preferred.

6.5 PLC Frequency Bands and Standards

PLC technology is at a nascent stage in India. It can be used for providing last mile connectivity as well as for creating a wide area network. A key requirement of this technology is the existence of a clean network of cables for carrying information. Issues such as noise generated by different loads on the power line, dynamic changes in the line impedance and absence of trained man-power capable of bespoke engineering are some of the issues that will need to be addressed in order to make this technology ready to use.

In addition to the above mentioned, there needs to be a frequency band allocated for PLC communications.

Globally, IEEE 1901.2[18], PRIME, G3-PLC, ITU-T G.hnem[19], IEC 61334, TWACS, Meters and More, and HomePlug C&C are some of the popular standards/protocols available for implementing **Narrowband PLC** systems.

The following table throws more light into the technical details:

Table 6 - Snapshot of Global Standards/Protocols on Narrowband PLC Systems

Standard/Protocol	Frequency band	Maximum data rate
IEEE 1901.2 - 2013	<500 KHz	500 Kbps
PRIME	42-89 KHz	128.6 Kbps
G3-PLC	35-91 KHz	33.4 Kbps
ITU-T G.hnem	10-490 KHz	1 Mbps
IEC 61334	60-76 KHz	Upto 2.4 Kbps
TWACS	200-600 Hz	100 bps
Meters and More	3-148.5 KHz	28.8 Kbps (nominal) and 4.8 Kbps (effective)
HomePlug C&C	10-450 KHz	7.5 Kbps

Source: ISGF White Paper on 'Need for Allocating a Frequency Band for Power Line Carrier Communications' published on December 18, 2014

Globally, IEEE 1901-2010, HomePlug Green PHY and ITU-T G.hn (G.9960/G.9961) are some of the popular standards/protocols for implementing **Broadband PLC** systems.

The following table throws more light into the technical details:

Table 7 - Snapshot of Global Standards/Protocols on Broadband PLC Systems

Standard/Protocol	Frequency band	Maximum data rate
IEEE 1901-2010	< 100 MHz	> 100 Mbps
HomePlug Green PHY	2-30 MHz	10 Mbps
ITU-T G.hn (G.9960/G.9961)	25-200 MHz	2 Gbps

Source: ISGF White Paper on 'Need for Allocating a Frequency Band for Power Line Carrier Communications' published on December 18, 2014

[18]http://standards.ieee.org/findstds/standard/1901.2-2013.html

[19] Developed by ITU-T: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6094004&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D6094004

Europe, USA, Japan and China are some examples of regions where frequency bands have been allocated for PLC communications. The following table mentions the regions and frequency bands allocated for PLC:

TABLE 8 - SNAPSHOT OF GLOBAL FREQUENCY ALLOCATION FOR PLC COMMUNICATIONS

Region	Frequency band for PLC
Europe	CENELEC A: 3-95 KHz for power utilities CENELEC B: 95-125 KHz for any application CENELEC C: 125-140 KHz for in-home networking with mandatory CSMA/CA protocol CENELEC D: 140-148.5 KHz Alarm and Security systems
USA	10-490 KHz, and 2-30 MHz
Japan	10-450 KHz
China	3-500 KHz

Source: ISGF White Paper on 'Need for Allocating a Frequency Band for Power Line Carrier Communications' published on December 18, 2014

7. Key Challenges

The Indian power sector today faces a number of challenges pertaining to M2M Communications. Some of the major challenges are mentioned below:

7.1 Spectrum for Low Power RF Technologies

As the number of gateways and devices increase, there may be interference-related issues. This will lead to packet drops and other RF issues. The existing frequency bands may not be enough for billions of M2M devices.

7.2 Interoperability

Interoperability is required at the device level, network level, data transport level and software (database) level. This has been a global challenge, especially in view of the fact that the existing development and implementation are proprietary. India has adopted DLMS for smart meters and released a companion specification (Indian Standard 15959) to achieve data transport level interoperability.

7.3 Network Latency

Network latency poses a major threat to the operation of a smart grid. Near real-time applications such as SCADA/DMS and Wide Area Monitoring System require data to be transmitted & received almost instantly. However, applications such as AMR and AMI do not impose such a strict latency requirement. For latency requirements in a smart grid, Table 4 may be referred.

7.4 Technology Lifecycle

As on today, the lifecycle of the technologies is very short. Hence, the ecosystem of devices and network also tend to become obsolete quickly. Hence, a modular approach with ability to upgrade elements and devices should be the key objective of M2M service providers.

8. Way Forward

8.1 IPv6 for all Devices

Apart from being able to transmit data over multiple media and protocols, the Internet Protocol (IP) can be used for all applications in a smart grid. In addition, IP provides efficient device identification, data management, and a scalable, cost effective and interoperable foundation for communication. IPv6 would not only provide virtually limitless address space, faster routing of data, packet flow identification, but also provide inherent data security via the IPSec protocol suite. Hence, it is advisable to have compatibility with IPv6 for all devices used in the power sector.

8.2 Low Power RF Devices

Low power RF is expected to be the most effective communications technology that would offer connectivity to a large number of devices. The main reasons for this include, but are not limited to low operating cost, less power consumption, less interference, high signal to noise ratio and more penetration.

The 865-867 MHz band[20] (de-licensed in 2005) may not be sufficient to cater to the needs of the IoT/M2M/Smart Cities initiatives in which billions of devices would be connected. Another de-licensed band in the sub-GHz range, the 433-434 MHz band[21], which was de-licensed in 2012, may only be suitable for indoor applications because of the current regulations. The sub-GHz frequency bands are best utilized when they are used for outdoor applications in NAN/ FAN/ LAN.

The table below lists the applications that could use low power RF technology:

TABLE 9 - LIST OF APPLICATIONS THAT COULD USE LOW POWER RF DEVICES

Potential applications on low power RF technology	Potential applications on low power RF technology (contd.)
Electricity (Grid)	Buildings (Automation and Management) • Residential Buildings • Commercial Buildings • Industrial Buildings • Shopping Malls
Renewable Energy	EV Charging Stations
Gas	Parking Lots
Water Distribution: • Portable Water • Non-portable Water • Industrial Water • Agricultural Water • Other Water Bodies (Ponds, Lakes, Tanks etc.)	Hospitals and E-Healthcare • Primary Healthcare Centers • Super Specialty Hospitals • E-Healthcare
Rivers and Canals – Monitoring and Management	Theater and Auditoriums

[20] Delicensing notification by Government of India: G.S.R. 168 (E)
[21] De-licensing notification by Government of India: G.S.R. 680 (E)

Waste Collection, Monitoring and Management • Hazardous Waste (Toxic/Reactive/Corrosive/Explosive) • E-Waste • Medical/Bio-Medical Waste • Sanitation and Sewage • Rain Water/Storm Water/Drainage • Radio Active Waste • Municipal Solid Waste (incl. Religious Waste)	Places of worship
Sports Academies	Training Centers
Smart Agriculture	Industrial Automation
Home Automation	Street Lighting

As a large number of devices are expected to be connected in near future, present allocation of frequency band (865-867 MHz) may not be sufficient for the entire M2M/IoT/Smart Cities space.

Furthermore, in a discussion chaired by Sr. DDG, TEC at India Smart Grid Week (ISGW) in March 2015 at Bangalore, global Industry experts had the view that India would certainly need more spectrum for low power RF devices in near future. It was also agreed that the Industry, in coordination with ISGF, would study and project the requirement of spectrum and submit a report in two-three months time.

8.3 Power Line Carrier (PLC) Communications

There is an urgent need to allocate frequency bands for both, narrowband and broadband PLC communications. The above mentioned frequency bands and standards in Section 6.5 need to be studied while allocating frequency band/ bands for PLC in India. We may examine different frequency bands identified by CENELEC for different domains such as Power Utilities, In-Home networking, Alarms and Security systems etc.

> **Note:** CENELEC[22] stands for 'European Committee for Electrotechnical Standardization' and is responsible for standardization in the Electrotechnical Engineering field in Europe. It works closely with International Electrotechnical Commission (IEC), a global standard-publishing body for all electrical, electronic and related technologies. CENELEC and IEC signed the Dresden Agreement[23] in 1996, for avoiding duplication of effort and reducing time when preparing standards. As a result, new standards projects are now jointly planned between CENELEC and IEC.

8.4 Television White Space (TVWS) Technology

Television White Space (TVWS) is a communications technology that uses the unused TV broadcast channels (or white spaces) for data exchange. Apart from offering a large range and potential for high speed connectivity, TVWS signals penetrate obstacles with ease because of the non-line-of-sight

[22] http://www.cenelec.eu/aboutcenelec/whoweare/index.html

[23] http://www.cenelec.eu/aboutcenelec/whoweare/globalpartners/iec.html

characteristic of this technology. Furthermore, a host of IoT/M2M applications could use TVWS technology for providing connectivity.
India would need rules/regulations to enable the operation of this technology. A few countries have already issued rules/regulations and others will follow suit.

8.5 Architecture for AMI

The Government has taken a proactive step by launching IPDS[24] and DDUGJY[25] for extending the optical fiber links from NOFN (that envisages to connect 250000 gram panchayats) to all substations that is expected to act as a backbone network that could be used by multiple applications in a smart grid.

Hence, AMI could use this fiber link to connect the substations and the utility data center. For communications between the smart meter, DCU and substations, the utility may choose any communications technology.

Given below is a recommended architecture for AMI:

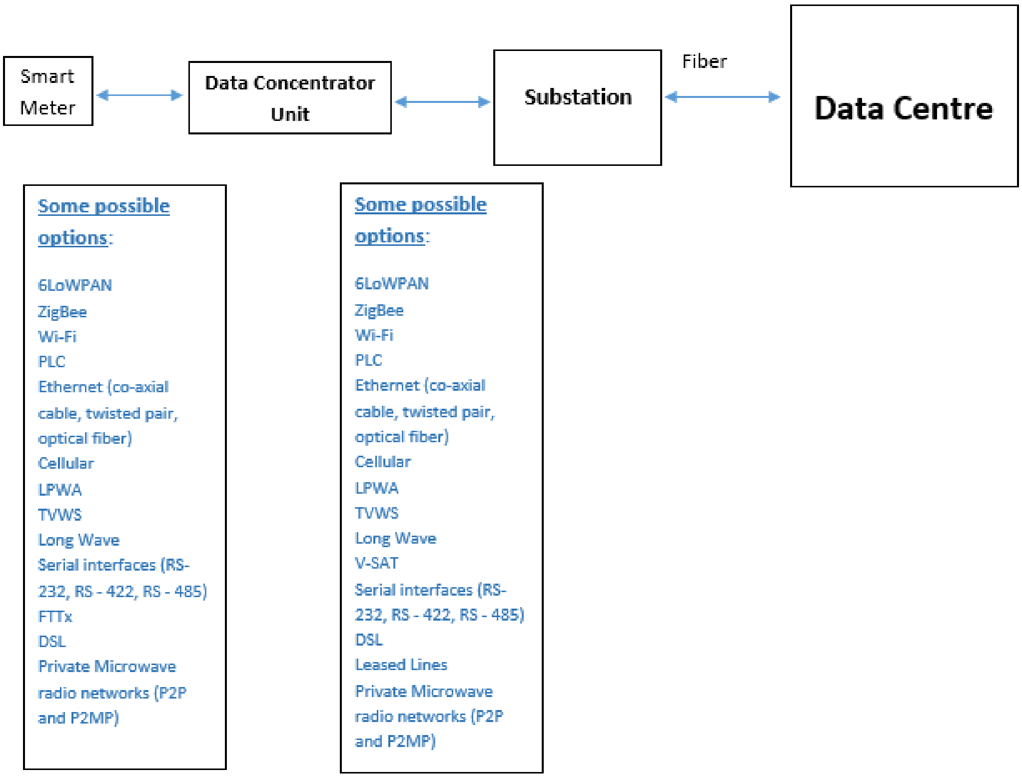

FIGURE 17 - RECOMMENDED ARCHITECTURE FOR AMI: INTEGRATION WITH NOFN

Source: ISGF White Paper on 'M2M Communications in the Indian Power Sector' published on December 18, 2014

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[24] Ministry of Power Website - http://powermin.nic.in/upload/pdf/Integrated_Power_Development_Scheme.pdf

[25] Ministry of Power Website - http://powermin.nic.in/upload/pdf/Deendayal_Upadhyaya_Gram_Jyoti_Yojana.pdf

8.6 Cyber-Physical Security

Power sector is a critical infrastructure and hence is prone to many types of attacks in the cyber space. Since this sector has physical assets associated with the cyber space, ensuring cyber-physical security defines the need of the hour. To cater to the security aspects of M2M communications, a separate working group has been established in TEC. A number of other agencies such as the Bureau of Indian Standards (BIS) and the National Critical Information Infrastructure Protection Centre (NCIIPC) are also working on cyber security. This Working Group will submit its report in near future.

As described in the above sections, a number of projects are being carried out in the power sector focusing on M2M communications. The power sector is progressing rapidly in adopting M2M communications. With use cases such as AMI, SCADA/DMS and WAMS being implemented at a large scale, the power sector has already embraced M2M communications and also depicted its importance in the power sector. Data analytics, communications and cyber security are very important horizontals in the smart grid which require both, immediate and constant action. Organizations such as BIS and NCIIPC are already working on formulating standards for smart grids and the work being carried out will be taken as inputs to the working groups at TEC. Furthermore, M2M communications needs to be improved in terms of quality of service, interoperability, latency, configurability etc. and the working group will undertake exhaustive studies for achieving this.

The Working Group will study and provide inputs for framing the KYC norms required for SIM based devices/gateways as these KYC norms will be different from the existing KYC norms for personal SIMs used in mobile phones.

Moreover, the spectrum requirements in sub-GHz range for low power RF devices that are expected in M2M /IoT/Smart Cities domain (in the next 20-35 years) will be studied and prepared by this Working Group.

9. Use Case Analysis

9.1 Title

Advanced Metering Infrastructure (AMI)

9.2 Objective

Advanced Metering Infrastructure is a system which includes smart meters, data concentrators or gateways, one or more Head End Systems (HES) and a Meter Data Management System (MDMS). The following functionalities can be achieved:

a. Scheduled meter reading
b. Meter reading on demand
c. Remote firmware upgrade
d. Clock synchronization
e. First breathe and last gasp signals to the HES
f. Remote connect/disconnect on the following conditions
g. Over current
h. Load control limit
i. Pre-programmed tamper conditions
j. Disconnect signal from utility control center
k. In case of prepaid facility under defined/agreed conditions
l. Event logging
m. Remote meter configuration such as maximum demand threshold or updating meter's balance in case of pre-paid metering

9.3 Source

Smart Grid Use Case Repository
Smart Metering Use cases – OneM2M Requirements Document
Hem Thukral, ISGF
Dheeraj Agarwal, WIPRO
Narayanan Rajagopal, TCS
Narang N. Kishor, Narnix Techno Labs
Anirban Ganguly, TTSL
B S Chauhan, CDOT
Raunaque Quaiser, STMicroelectronics
Nandan Kumar Jha, IITB
Bindoo Srivastava, IITB

9.4 Background

9.4.1 Current Practice

Consumer meter reading data is acquired manually by meter readers who visit the meter premise monthly/bimonthly either by visual reading or through spot meter reading handheld devices. Generally, total energy consumption for the entire 'billing' period is taken for the purpose of billing. This reading is uploaded to the billing system of the utility at the end of the day or later. Meter readers follow a meter reading route sequence to cover the meters in an area. This often results in missed readings (due to meter premises locked or other reasons), 'coffee shop' readings, wrong readings (visual reading error), missed consumers (meter not listed in the reading list) etc. Errors creep in during the uploading process (incorrect manual upload, validation failures etc.). The entire process is time consuming.

Apart from the errors in the billing readings as described above, there is no information on the consumption pattern of individual consumers at a granularity less than the billing period. Also, the quality of supply to the end consumer cannot be monitored and the tampers or faults in meter go unnoticed.

Utilities have already established meter reading systems that use hand held units for meter data acquisition of their 'high revenue' consumers (HT, Bulk LT etc.). Meters have been installed at Distribution Transformers for monitoring the aggregated energy consumption of downstream consumers. AMR for these meters is being implemented.

This use case extends AMR to the last mile – the LT consumer. It also aims at providing meter reading data to the utility at a daily/hourly periodicity for monitoring the consumption trend and use the information to predict load for the upcoming time blocks, observe and monitor voltage, frequency and power factor profile at the various nodes in the grid.

9.4.2 Need for Use Case

With the advent of an Advanced Metering Infrastructure (AMI), both consumers and the utilities would benefit. The consumers would be able to:

a. View their consumption of electricity accurately on a regular basis
b. Manage loads in different manners based on the design, ranging from remotely turn ON/OFF their appliances to managing total demand to allow curtailed supply instead of load-shedding
c. Save money from Time of Use (ToU) tariffs by shifting non-priority loads
d. Face reduced outages and downtimes, and even lower or zero load-shedding

Utilities would benefit in the following ways (which would pass on to the consumer):

a. Financial gains by
   i. Managing the load curve by introducing Time of Use (ToU)/Time of Day (ToD) tariff, demand response etc.
   ii. Reducing equipment failure rates and maintenance costs
   iii. Enabling faster restoration of electricity service after fault/events
   iv. Detecting energy theft/pilferage on near real-time basis
   v. Streamlining the billing process
   vi. Remote meter reading which reduces human resources, human errors and time consumption for meter reads
b. Respond to power outages and detect meter failures (with no on-site meter reading)
c. Enhanced monitoring of the system resources that would significantly improve the reliability indices like CAIDI, CAIFI, SAIDI, SAIFI etc.
d. Improvement in other key performance indicators

9.4.3 Indian Ecosystem Specifics

In India, manual meter reading activity for billing is cheaper than remote reading. (Globally, manual meter reading for revenue is more costly than AMR or AMI). However, a remote meter reading system allows utility to acquire data frequently from the meter, which can be used for monitoring the energy flow quality and reliability etc.

The Indian utilities, regulators, policy makers are aware about the potential of AMI as the foundation for not only smart grids, but also to improve their operations in a business as usual scenario to serve their consumers.

On the electrical domain front, AMR has been implemented in more than 50 Utilities in 1400 towns of the country covering on an average 50000 meters per utility under the RAPDRP scheme alone. Here meters installed for HT consumers and at distribution transformers are connected directly to a Meter Data Acquisition Systems (MDAS) (part of Head End System) through GPRS modems. This program is being extended to cover other parts of the country under the Integrated Power Development Scheme (IPDS).As part of the IPDS scheme, all distribution transformers, HT consumers and ring-fencing boundary meters will be covered.

India's smart grid vision is to 'Transform the Indian Power Sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of all stakeholders'. Visibility into the each and every power system node – at across the value chain, is a key pre-requisite for realizing this vision. Smart grid technology pilots are being implemented in a few utilities to gain experience as a pre-cursor to a full rollout. The primary focus of these pilots is AMI and peak load management.

9.5 Description

9.5.1 Business Scenario #1: Remote Meter Registration

A new meter installed at a consumer premise or on the electric grid node (example feeder or distribution transformer) is commissioned into the AMI system.

Actors: Meter, AMI System Administrator.
Pre-requisite: Meter is installed in the field with a previously activated communication module. AMI Head-end and Gateway (if applicable) are available.
Pre-condition: Meter details are available in the AMI head-end Master. (This is similar to the IMSI-MSISDN configuration into TSP's system as part of SIM card activation).
Trigger: New meter is installed in the field and powered up.

A typical process flow is depicted below:

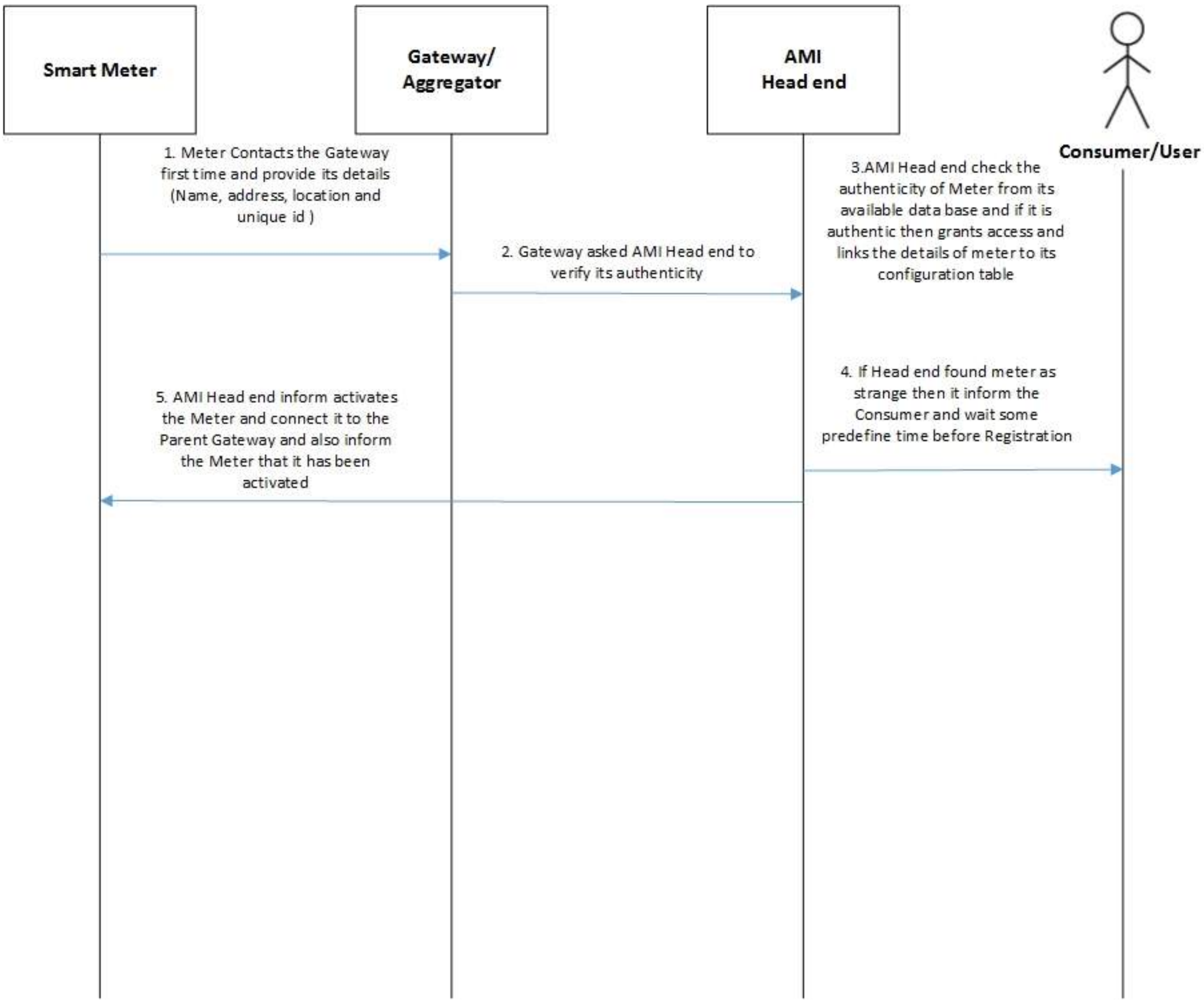

FIGURE 18 - CALL FLOW: REMOTE METER REGISTRATION

Scenario #1: Deployment architecture – Meter to Gateway to Head End System (HES). Meter contacts the gateway first time and provides its details (name/serial no., unique identifier and address). Gateway verifies with the HES that this meter is authentic and valid for its AMI system. This will help in blocking devices from entering AMI masquerading as meters. HES links meter name, identifier and its address in its configuration table and 'activates' the meter. HES links the meter to its parent gateway if the gateway is expected to work as an aggregator/DCU. Note- here another precondition is that connectivity between gateway and head-end is also there. A response is provided to meter that it has been activated and its initial readings are obtained.

Scenario #2: Same flow as Scenario #1, except that gateway has prior information about the meters expected to be in its range. Hence, gateway can validate new meters on its own and informs the HES about this to complete registration. Here, connectivity between gateway and HES need not be there at the time of registering meter at the gateway.

Scenario #3: Deployment Architecture - meter to HES direct connection. Meter contacts the HES directly. Here, the meter authentication happens directly from HES. Here, connectivity between meter and head-end is required as a precondition.

Alternate flow#1: Precondition of meter details being known a-priori at HES is not essential. Here, when a new 'strange' meter comes into the system, the HES notifies the user or an external system and awaits approval before registering the meter.

Note: Several meters may come up concurrently in the system for registration.

Post conditions: Valid meter is registered in the system and meter gets activated. Newly registered meter location is mapped to its electrical, geographical and AMI network hierarchies. Meter is linked to the related consumer (if applicable). Initial meter readings and date of activation of meter at the current location are recorded in the system.

Unknown meter discovered in the system is reported to the AMI configurator.

It the new meter does not receive a response from the HES/gateway, it waits for a pre-configured duration and attempts to register into the system again. The number of such attempts can be predefined in the meter. Meter logs all attempts of registration as part of its diagnostic logs.

Information exchange: Meter details, location (geographical, electrical and AMI network), time of registration, registration and activation messages. It is triggered from meter end anytime; bidirectional flow of small data in real-time; high security requirements. Requires high priority handling.

Note: This scenario is applicable for AMR applications also.

9.5.2 Business Scenario#2: Remote Meter Configuration

Device parameters can be configured remotely through a Head-end application.

Actors: Meter, AMI Configurator, DR Service Provider
Pre-requisite: Communication link between Meter and HES is available.
Precondition: Meter has been previously registered into the system.
Triggers:
Trigger#1 - After meter registration by the AMI configurator or by a software module.
Trigger #2- Meter configuration can be changed by AMI Configurator.
Trigger #3 – Demand Response (DR) Service Provider can configure meters of DR enrolled consumers for DR event behaviour.
Trigger # 4 – Credit amount update in Meter for pre-paid metering.
Trigger #5: AMI configurator wants to configure behaviour of gateway remotely through the head-end.

A typical process flow is depicted below:

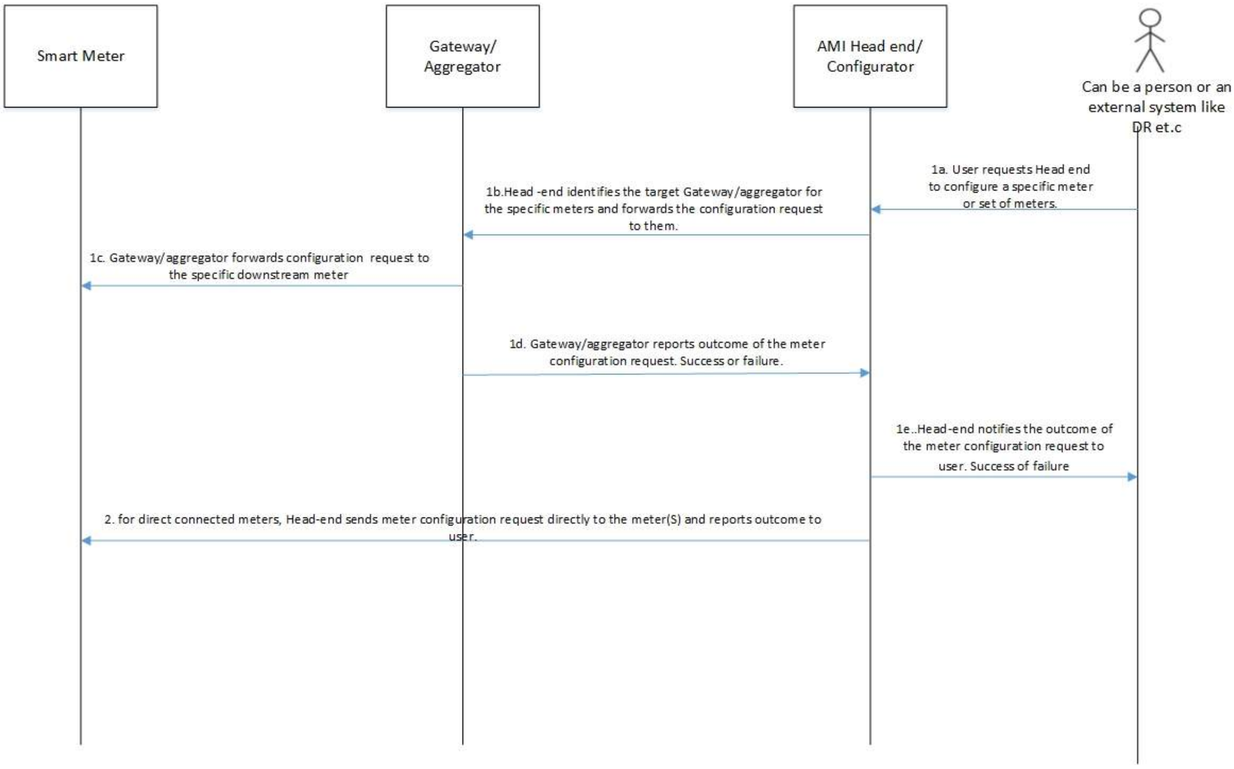

FIGURE 19 - CALL FLOW: REMOTE METER CONFIGURATION

AMI system is configured for meter reading schedule (meter parameters to be acquired and acquisition periodicity). There can be separate 'schedules' for reading different parameters (example – monthly billing parameters reading, daily load profile, hourly instantaneous etc.). Data Acquisition schedule can be configured to start at a defined instant, and end at another instant (example instantaneous values of voltage, current and energy data to be acquired from meter at half-hourly periodicity from date XX till date YY (for vigilance purposes). Scheduled meter reading can be configured in 'pull' or 'push mode according to the configuration chosen.
Event handling behavior is configured in the AMI system. Critical events are configured to be notified to the HES immediately on detection. Note – Detection of event can be later than its actual occurrence, with or without a guaranteed SLA for delivery notification. Example – current smart grid pilots in India have specified that critical events must be notified to the HES within 1 minute of their occurrence. Normal priority events can be notified to the HES at a scheduled frequency or when the total number of events exceeds a threshold number. Events can be detected by the meter (example- tamper events recognized by the meter. There are approx. 50+ tamper events for electricity meters in the Indian ecosystem) or gateway (example –request for registration from a new meter is an event) or aggregator (example – scheduled meter reading failed).

Meter parameters can be configured remotely through AMI. Some example of parameters that can be configured remotely are sanctioned demand, disconnection threshold for load control, credit balance in case of prepayment mode of operation etc.

AMI system can configure meter behavior for predefined triggers. Example – meter can be configured to disconnect supply when load exceeds sanctioned demand. Meter can disconnect supply when load breaches a threshold, reconnect after 1 minute and if load is still above the threshold limit, disconnect supply, generate an event for this action and notify the ;upstream master (gateway or aggregator or directly HES about this disconnection event).

Meter can be configured for load control (example - if load exceeds a threshold demand, say sanctioned demand, the supply should be cutoff and this action should be logged as an event) or for Demand Response events. The credit balance update for prepayment meters can also be remotely configured. Furthermore, health and diagnostic monitoring of meters and meter location is configurable.

All configurations are initiated via the HES. Configurations may be done in the form of configuration request messages. Feedback on outcome of configuration is expected to be provided to the HES which in turn provides report and error logs to the AMI configurator.

Scenario #1: Aggregator/DCU in the middle: HES provides meter configuration to the aggregator/DCU that in turn manages configuration of its downstream meters.

Scenario #2: Gateway in the middle: HES configures the meters with the gateway acting as a bridge. Data acquisition periodicity can be configured in the gateway or in the meters.

Scenario #3: Direct meter: HES configures meter directly.

Alternate scenario: In certain scenarios, AMI configurator may also remotely connect with the data concentrator/gateway and directly configure it or its downstream meters.

Note: several meters may be required to be configured concurrently within a specified time duration.

Post conditions: Certain configurations are done in the meter while a few maybe done in the gateway/DCU. Meter or gateway/DCU reports successful configuration to the HES. Failed configuration attempt is notified to the AMI system administrator.

Information exchange: meter parameter configuration details, time of configuration, configuration messages. It is triggered from HES at anytime; bidirectional flow of small data in real-time; high security requirements. Some configuration scenarios may require priority handling.

Note: This scenario is applicable for AMR applications also.

9.5.3 Business Scenario #3: Scheduled Meter Reading

Actors: Meter, AMI System Administrator, Meter Data Management System.
Prerequisite: Communication link between device and upstream entity is available. It will have to establish a communication session with the meter for this purpose. Alternately, it can have an 'always on session with the downstream meter/s.
Precondition: Meter or gateway has been configured previously for the data acquisition.

Trigger: none.

Case #1a: At the predefined instances, aggregator/DCU acquires data from its meter/s. Data acquisition can be initiated by the meter end (push data) or by the aggregator (pull data). Data from multiple downstream meters is collated at the aggregator end and then sent upstream to the HES. Aggregator can apply local intelligence for managing acquisition failures or enriching the acquired data with location based information. Sending data upstream to the HES and acquiring data from downstream meters can be run independently (with data acquired from meters being buffered at the aggregator end).

Case #1b: Same as for case of Aggregator, except that gateway does not 'analyze or collate' the data acquired, but simply pushes this data upstream as individual files.
Data acquisition can be initiated by the upstream entity (pull data) or from the downstream device (push data) in both these segments.

A 2 step data acquisition process (meter to gateway and gateway to HES) is popularly done to optimise the concurrent data acquisition volume at the HES by reducing the no. of tail-end nodes. It also helps in optimizing the underlying network infrastructure.

A communication device (modem or gateway) will poll a previously registered electricity Meter for acquiring data previously stored or current in the meter. It can acquire data from a single meter or from several meters in its 'downstream network'.

After acquiring data from the meter/s, it will establish a communication session with its upstream 'head-end application' to upload the meter reading data. Alternately, the upstream communication session can be 'always on'. The meter data will be uploaded to the HES as a file or data stream. Data can be uploaded individual meter-wise or for a set of meters. It is assumed that the HES and Gateway have prior agreement on the list of meters for which data has to be uploaded. Alternately, gateway can act as a simple router that connects meter to the head-end and meter data is then polled by the head-end. Gateway can also poll a downstream meter for data and then push this data file to the head-end.

In the exception condition of gateway not being able to poll a downstream meter (exhausting retries), it should record inability to communicate with the meter and notify this to the head-end. In case gateway is able to establish communication with meter but not able to obtain data, this should be recorded and notified to the head-end. Gateway should monitor its last successful poll of a meter and be able to acquire data from the meter from that instant. In case gateway is not able to establish connection with head-end (exhausting retries), it should record this in its memory and push the previously unsent data at the next scheduled upload instant.

Note: Several meters may be scheduled to provide their readings concurrently. Similarly, multiple gateways may be scheduled to upload data to the head-end concurrently.

Post condition: Data is made available to the head-end at the scheduled instances. Summary result of scheduled data acquisition activity is updated at the HES at each scheduled instant (success or fail). If required, log of scheduled reading activities at downstream entities (gateway or meter) can also be uploaded to the HES periodically or on request. Detailed Logs are then flushed from the downstream entities. Meter reading data can be flushed from the gateway/DCU after successful transmittal to the HES. This data maybe retained in the gateway if required to perform any local aggregation and analytics functions. Data from HES is provided to a Meter Data Management System that processes the same further. Reports, error alerts and logs are provided to the AMI System Administrator.

Information exchange: meter reading data, time stamp, reading process messages. It is triggered from meter end at predefined time instances; primarily upload of data from meter end that is delay tolerant. Data size can be small as well as streaming (example - load profile) according to the data parameters. Normal security requirements. Does not require priority handling.

Note: This scenario is applicable for AMR applications also.

9.5.4 Business Scenario #4: On-Demand Meter Reading

Utility may want to acquire data from a single or a set of meters in between scheduled meter reading instants. This scenario is same as scheduled meter reading except that the meter reading is triggered by the upstream entity either due to AMI user request or because missing data is required from the downstream device.
Example- Meter billing data acquisition is typically scheduled monthly or bimonthly. User may want to take a billing reading of the meter as a last reading before disconnecting the supply to the user or before performing a meter replacement activity.
Users for this feature at utility end are typically vigilance team (for monitoring tampering), O&M team (for monitoring supply quality and reliability), and billing team (to obtain meter billing reading).

On-demand meter reading requests typically have a specific timeout duration within which the data is expected to arrive.

Information exchange: meter reading data, time stamp, reading process messages. It is triggered from HES at any time; primarily upload of data from meter end that has to be provided within a specified latency duration. Data size can be small as well as streaming (example - load profile) according to the data parameters. Normal security requirements. Requires priority handling.

Note: This scenario is applicable for AMR applications also.

9.5.5 Business Scenario #5: Event Notification

Actors: Meter, AMI administrator, Meter Data Management System, Consumer, Utility user
Pre-requisite: Meter to upstream Gateway link is available. Gateway to upstream HES link is available.
Precondition: Meter is configured to detect events and report their occurrence.
Trigger: Occurrence of an event is detected by the meter.

Description: Meter can notify the upstream entity of occurrence of the event immediately on its occurrence or can report a list of all events since last update. The event notification can be initiated by the meter or gateway/HES which can poll the meter for acquiring this information. A meter can be configured to detect several types of events. Events can be classified as critical requiring immediate notification to the upstream entity or can be normal events that can be uploaded at a fixed interval. As part of event notification, a snapshot of meter parameters can also be provided. In Indian Power ecosystem, there is a large variety of 'Tamper' events that are typically configured in meters.

One of the critically important events in electricity meters is regarding power supply status at the meter location. Meter should report power outage to the HES immediately (last gasp message). Similarly, meter should report restoration of power supply immediately to the HES. This helps remote monitoring of power supply status to the consumers, to help improve reliability of power supply.

Some events are monitored by the gateway/Aggregator/Data Concentrator entity (like meter link) using local analytics. Example - Aggregator/Data concentrator can collate power outage or power restoration event messages from all its downstream meters and notify a single event to the HES. This not only helps reduce the data volume flow to the upstream entity, it also helps improve speed of decision making.

Events can also be generated at the HES level.

Events generated in the AMI system can be further propagated through AMI HES to a Meter Data

Management System for processing, collation and analytics as well as for further routing to other systems like CRM (for outage reporting), Asset/Maintenance management systems.
Events can be notified to the relevant users from HES level or from the MDM system. User can be utility staff (example O&M field staff or vigilance team etc.) or consumer (to notify power outage).

Post conditions: Events are made available at the HES. Interim entities can flush events data and event notification activity logs after propagating to the head-end. Some events can be retained in the aggregator if required for local aggregation/analytics.

Information exchange: Meter events data, time stamp, reading process messages. It is triggered from meter at any time; primarily upload of data from meter end that has to be provided within a specified latency duration. Data size is small. Normal security requirements. Requires priority handling.

Note: This scenario is applicable for AMR applications also.

9.5.6 Business Scenario #6: Communicate with Consumer over AMI through IHD

Actors: Meter, consumer, Utility staff, Utility meters, especially electricity meters, are typically installed outside the consumer premises (in the building common area or on poles outside the home). Therefore, consumers find it difficult to regularly monitor their consumption by visually reading the meters. In-Home-Displays are portable devices that are connected to the meter over a wired/wireless communication medium and can be used by consumer for monitoring their consumption from the comfort of their homes. In future, In-Home-Displays maybe rendered on the Home TV or mobile phone (home automation segment). Consumer can monitor and in some cases, even remotely control their home appliances through this device for better managing their consumption. Utility can send important messages to consumer on this device through the AMI network (similar to message notifications from Dish TV service providers).

Information exchange: messages from meter or head-end. It is triggered from HES or meter at any time; primarily southbound data from head-end or meter that has to be provided within a specified latency duration. Data size is small. Normal security requirements. Requires priority handling.

9.5.7 Business Scenario #7: Remote Meter Operation

Actors: Meter, consumer, utility staff, AMI system administrator
Pre-requisite: Meter to upstream Gateway link is available. Gateway to upstream HES link is available.
Precondition: Meter is configured to accept remote operation commands.
Triggers:
Trigger #1: User triggered- Utility authorised person (in response to consumer request for temporary disconnection OR for disconnecting supply to consumers found tampering etc.)
Trigger #2: User triggered – consumer wants to operate their meter remotely using AMI infrastructure (say from utility website, if utility so allows)
Trigger#3: Utility Revenue system (remote disconnection due to non-payment of dues or reconnection after pending dues have been cleared)
Trigger#4: Prepayment system initiated on breaching minimum credit balance limits
Trigger#5: for Remote load control (initiated from HES)

Description:
Meter receives request for connect or disconnect supply from HES (through gateway or direct in case there is no gateway in the AMI infrastructure). Meter validates the request by authenticating the requestor credentials. Meter then checks the current status of supply and if it finds it to be in the

requested state already, it reports back to HES that no action is required. Otherwise, meter performs the desired operation and reports outcome of the action (success). Meter can send an acknowledgement for receipt of command request to the initiator. HES propagates the outcome of the command request to the originator of the request (user or external system). Remote Switching operation of consumer meter has to be notified to the consumer on their registered mode of communication (email/SMS) and/or published on utility portal as a notification for the consumer. These can also be notified to the consumer on their in-home-display.
This entire flow is expected to be performed in a predefined duration from the instance of the command request. Meter can be configured to reject command requests that are old (i.e. received after a long time gap). If requestor does not receive any feedback from meter on outcome of the command request, it can send an on-demand status update request to meter in order to ascertain the actual status. It is assumed that a command once dispatched from the requestor to the meter, cannot be cancelled.

Certain meter operations can be initiated locally at the meter itself, based on predefined triggers in the meter. These are notified to the HES as events.

Generally, meter operations are priority actions that need to be executed within predefined duration.

Post conditions: Meter operation is executed and result of the same is provided to the initiator. Detailed execution logs can be provided to the head-end for post mortem/performance diagnostics purposes.

Information exchange: messages between head-end and meter. It is triggered from HES at any time; bidirectional data exchange between head-end and meter in real time. Data size is small. High security requirements. Requires high priority handling.

9.5.8 Business Scenario #8: Demand Response

Utilities enroll consumers into a Demand Response (DR) program, whereby they can control consumer demand remotely through their meters during predefined Demand Response periods. This can be done by cutting off supply to the premise through meter operation in case it exceeds a pre-agreed demand response threshold (load curtailment upto say 80% of sanctioned demand). Demand Response can also be implemented by controlling consumer appliances remotely through a Home Area Network system over the AMI (controlling the load offered by the appliance). Appliance control can be in the form of switching on/off the appliance. Example - utility may be able to remotely switch off non-essential loads like air conditioners and washing machines in order to reduce load of the consumer (rather than switching off supply to the premise through the meter). Utility can control appliance settings to reduce its load (example – thermostat control of air-conditioners; drier control of washing machines etc.).

Demand Response schemes help utilities restrict overall system demand during peak periods, which helps them avoid the need to purchase expensive supply. In our country, it can also help in avoiding the need for load shedding. Consumers who enroll in such events can get a tariff incentive from utilities for the same.

A new category of Demand Response aggregators/service providers is emerging in the country to address this segment. These service providers ‘enroll’ retail consumers and execute demand response events on behalf of the utilities.

Utility schedules a demand response event for a specific date and time in future. It advertises the same to its consumers on various communication media (consumers' registered mobile phone, email address, utility website – consumer portal etc.). Note – one of the communication channels can be the HAN which connects the In-Home-Display unit of consumers to the meter. The demand response event information covers the expected load relief and tariff concession on offer.
Interested consumers enroll in the scheme by registering for the same on the utility website or by accepting registration request through their mobile phone/email. A consumer can opt out of the scheme at any time before the actual start of the event.

Given below is detailed description of call flow for consumers registered for the DR event.

Actors: Meter, consumer, DR Service provider.
Pre-requisite: Meter of enrolled consumers have load control switching capability. Meter supports DR events. Meter is time synchronised with the overall system.

Preconditions: Consumer enrolls for a DR event.

Trigger: Consumer enrolment is notified to the DR administrator user in the utility or at service provider end and/or to the DR application.

Description:
DR application or administrator remotely configures the enrolled consumer's meter for the DR event through the AMI infrastructure (following the configure meter call use case flow). This covers – configuring the meter for restricting the load to a fixed load value or to a % of the sanctioned demand of the consumer for the DR period duration. Meter switch is configured to reconnect after a wait period of say 5 minutes to check if load has been brought down to under DR threshold. The number of reconnect attempts by meter before locking out the supply for the remaining DR event duration is also configured.

When the DR event starts, meter monitors the load consumption and disconnects supply if it exceeds the predefined DR threshold.
Example – Consumer has enrolled for a DR event for tomorrow from 4pm to 5pm, where load has to be restricted to less than 80% of sanctioned demand. DR system or DR user remotely configures the meter over AMI for DR as follows: DR threshold is set to 80% of sanctioned demand. Meter reconnect wait period duration is set to 5 minutes and reconnect frequency is set to 3 attempts before lockout. This is set for the time period tomorrow from 4pm to 5 pm. This means that tomorrow at 4pm, meter will start monitoring the total load and will disconnect immediately when load exceeds 80% of sanctioned load. It will send a notification of this to the In-Home-Display unit and to the upstream HES and wait for 5 minutes. Consumer is expected to switch off some of their appliances to bring down the load within this wait period of 5 minutes. (Note – disconnection of supply will be noticed by the consumer and if they are aware that they are in the DR event, they can take action without waiting for notification from meter). Meter will reconnect after 5 minutes wait period and if load is less than the DR load, it will remain connected otherwise it will "trip" again with a notification. It will attempt such reconnections 3 times before tripping out completely for the remaining duration of the DR event. Once DR event has elapsed, meter will reconnect on its own. All actions by meter will be logged in its memory for as well as notified to the utility over AMI and to consumer on the IHD. DR event log can be uploaded to the Head-end after the DR event is passed. Note- notifications of DR actions during the event can be propagated to the HES immediately on occurrence or can be sent later.

Consumer opts out of DR event. This information is forwarded to the DR administrator/DR system. System immediately cancels the DR configuration in the meter over the AMI infrastructure.

Post condition: Meters of enrolled consumers are configured for DR event. Log of Meter actions during DR event are uploaded to the DR system through the AMI.

Information exchange: Messages between head-end and meter. It is triggered from HES at any time; bidirectional data exchange between head-end and meter in realtime. Data size is small but continuous during DR event duration. High security requirements. Requires high priority handling.

9.5.9 Business Scenario #9: Remote Over The Air Programming

Actors: Meter, AMI configurator

As applications based on AMI evolve, meter and gateway firmware may need to be upgraded suitably. Meter firmware may have to be updated in part or in full. The way Apps. Versions are upgraded remotely when the device is online, similarly the firmware versions of meters and gateways can be upgraded. However, it is expected that the firmware versions of all devices deployed in a project get upgraded within a fixed time duration (as system may not be able to support devices with different versions).

Pre-requisite: Communication link is available. Meter firmware version is maintained in the HES database.

Precondition: It is expected that power supply and communication connection between the meter and the firmware source location is maintained throughout the firmware upgrade session. Note: can M2M platform support partial download of firmware on the device?

Trigger: AMI configurator may trigger a firmware upgrade for a single meter, set of meters or all meters in an area.

Description:

HES can delegate the responsibility of meter firmware upgrade to the gateways. In this case, new firmware version is downloaded onto the gateway and it can manage the firmware upgrade of its downstream meters. Alternately, HES establishes connection with meter through the gateway as bridge for the download. (Note- firmware upgrade can be initiated when the meter establishes connection with the head-end and head-end detects that meter firmware version is lower than that in the target version.

Firmware version of meter (destination device) is compared with the 'target' firmware version. If the meter version is lower, HES initiated transfer of the higher version to the meter. Once the transfer is completed, meter switches onto the higher version. This may require a power cycling action – that needs to be pre-programmed in the meter (As part of firmware upgrade logic). After switching onto the new version, meter reports back its new version to the HES. HES updates the meter version in the AMI database. If firmware download is interrupted due to power failure or break in communication link, HES and meter will terminate the download session. HES will have to initiate the download activity afresh when conditions restored. Meter always reports its firmware version to the head-end as part of handshake activity after power cycling.

There can be several concurrent sessions for firmware upgrades on a set of meters. The same process applies to firmware upgrade of gateways. Normal operations of meters/gateway is suspended during a firmware upgrade session.

It is possible that target firmware version may differ across different meters (example APIs for different make or models of meters maybe different – hence firmware version may have to be managed accordingly).

Firmware upgrade status and progress log is managed at the HES. It is assumed that there is a master firmware management module that orchestrates firmware upgrade activity of all target meters in that event.
Firmware upgrade of gateways can be done directly without need to go through the AMI infrastructure if remote login of the gateway can be taken.

Post condition: Firmware version in the meter is upgraded and meter is able to resume operations with the new version successfully. In case a meter firmware is not upgraded because its link was down or power supply was down or process failed, this will be updated in the HES accordingly and error notification sent to concerned user.

Information exchange: Data from HES, messages between head-end and meter. It is triggered from HES at any time; primarily large data stream from head-end to meter. Large data stream. High security requirements. Requires normal handling. All other AMI processes between meter and Head-end are put on hold during this activity.

Note: This scenario is applicable for AMR applications also.

9.5.10 Business Scenario #10: Remote Meter Power Supply Status

Monitoring status of power supply at the meter end, helps monitor supply reliability to the end-consumer.

Actors: meter, utility staff, consumer
Pre-requisite: Meter is capable of reporting a power outage event in the absence of power supply to it. Here an outage of power supply to the meter is considered as a power outage event by the meter. Meter time clock is synchronised with the system.

Triggers:
Trigger #1: Meter loses mains Power supply
Trigger #2: Meter power supply is restored.
Trigger #3: Head-end or gateway initiates a check meter condition request in case meter has not communicated with head end/gateway for a predefined duration.

Description: Meter power supply change is notified to the HES immediately on occurrence. When the power supply connection goes off (due to a power failure or fault) meter reports loss of power supply to the head-end as a last gasp message. For this, it must have sufficient battery power. (Note – this is not supported in meters operating on PLC communication mode). Loss of power supply is also recorded as an event in the meter event log along with time stamp. When power supply is restored, or there is a power cycling event due to any reason, meter reports back to head-end this event along with snapshot of its instantaneous data.

For PLC based systems, gateway can keep monitoring connectivity of meters. If a meter fails to respond to gateway after predefined number of retries, gateway notifies HES about loss of communication with meter. This can be due to a link failure or because of power failure at the meter end.

Alternately, HES can 'ping' meter to test its power supply status. If meter responds to HES query, it is powered, else it may be out of mains power.

Post condition: Meter status is available at the head-end.
Information exchange: Data from meter. It is triggered from meter at any time; small data size. High security requirements. Requires high priority handling.

Note: This scenario is applicable for AMR applications also.

9.5.11 Business Scenario #11: Remote Meter Health Monitoring

Actors: Meter, AMI system administrator
Prerequisite: Meter and gateway have self-health monitoring and self-diagnostic features.

Trigger: Meter health data can be uploaded to the HES at scheduled intervals. It can also be provided to HES on demand.

Description: Meter conducts self-health checks periodically and records the same in its log. It can be configured to notify alert health situations to upstream gateway or head-end on occurrence. The health log is transferred to the HES periodically or on demand. Meter can be designed to perform some self-diagnostic routines for predefined trigger situations. The self-diagnostic features include monitoring communication link status and strength etc. Gateway can also perform diagnostic tests on its downstream meters and log results. The health parameters to be monitored include power supply status, communication link status.

Post condition: Health data is made available to the AMI head end from where alerts can be dispatched to concerned users for alarm situations.

Information exchange: Same as scheduled meter reading and on-demand meter reading.

Note: This scenario is applicable for AMR applications also.

9.5.12 Business Scenario #12: Remote Meter Time Synchronization

Meter time clock is synchronized with the system reference clock (preferably GPS based). Meter time is checked by the system and if found out of step, it is updated.

Information exchange: Messages between HES and meter. It is triggered from HES or meter at any time; small messages in realtime. High security requirements. Requires priority handling. All other AMI processes between meter and Head-end are put on hold during this activity.

Note: This scenario is applicable for AMR applications also.

9.6 Actors

The table below depicts the various actors in AMI and their description:

Table 10 - Actors in AMI

Actor Name	Actor Type (person, organization, device, system)	Role Description
Meter	Device	The meter is the device that measures and stores the electricity parameters of interest
AMI Configurator	Person/system	Configures type of data to be acquired, periodicity of its acquisition and list of meters from which to acquire.
AMI administrator	Person/system	Monitors the AMI process for error free operations.
Consumer	Person	Consumer of electricity
Utility Staff	Person	Utility staff are users of the AMI system with predefined roles and access privileges
Demand Response Service Provider	Person/System	This person or system configures meters of DR enrolled consumers for DR events. DR event notifications and logs are provided to this person/system during and post the event.
Meter Data Management System	System	MDM is the repository of meter readings. It validates data arriving from AMI for completeness and accuracy. If data for some intervals has not arrived from a meter, MDM flags this to the AMI Administrator or requests the AMI to re-acquire this data on-demand.

9.7 Contextual Illustration

The contextual illustration of AMI is depicted below:

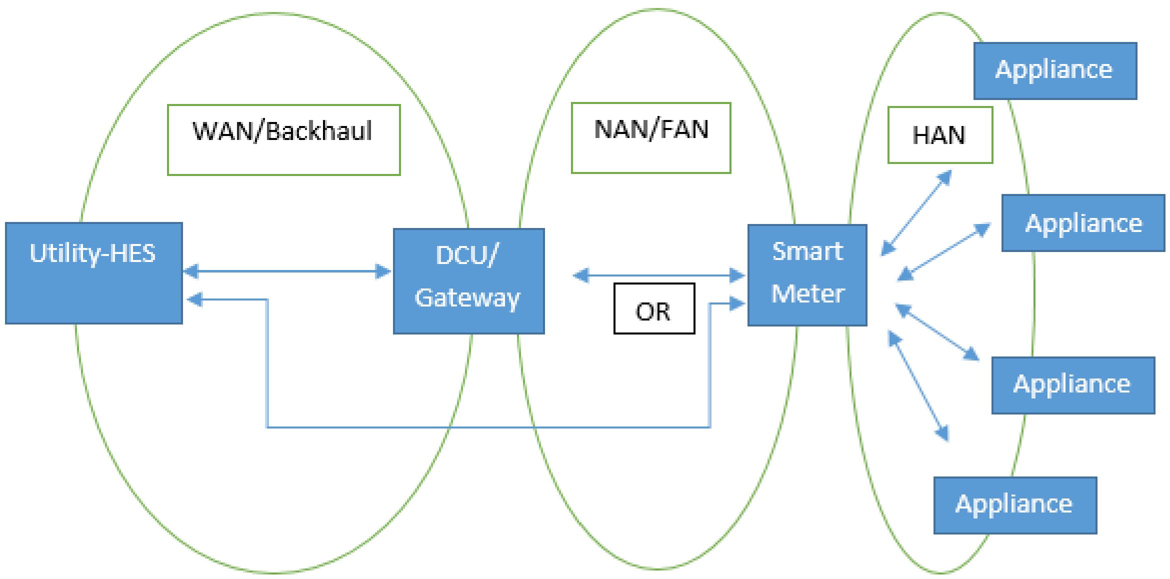

Figure 20 - Contextual Illustration of AMI

9.8 Potential New Requirements

In future, other utility meters on the premise like water and gas meters may also be connected to the electricity AMI. Electricity meter may act as the router in this scenario.

9.9 Information Exchange

India has DLMS/COSEM and has formulated IS 15959 – the Indian companion standard for metering used in distribution network for Distribution transformers, end consumers and feeders. This will ensure interoperability at the data transport level.

9.10 Architectural Considerations (Non Functional Requirements)

9.10.1 Interface Requirements

The interface requirements based on open standards are depicted below:

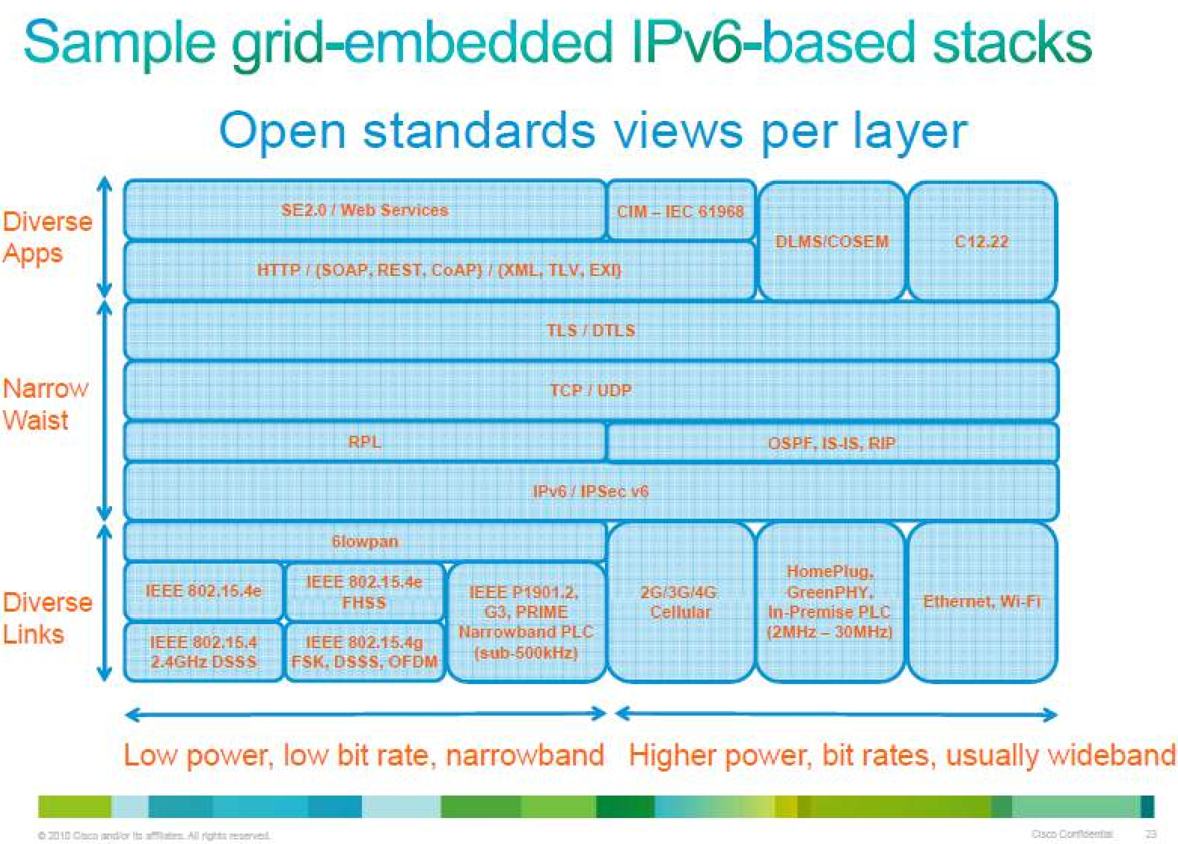

FIGURE 21 - INTERFACE REQUIREMENTS IN AMI

Source: Overview of sample grid-embedded IPV6 based stacks

9.10.2 APIs to be Exposed to the Application from Platform

The following APIs will be exposed from the platform to the application:

1. APIs for monitoring and managing the NAN and WAN segments of AMI. A Network Management System would be required for connectivity and desired data throughputs.
2. APIs for tracking location of meters and gateway.
3. APIs for configuring data transfer priority.

9.10.3 Performance Criteria

For seamless operation of AMI, reliability, latency, security and total cost of ownership of the communication technologies will be the key.

9.10.4 Interoperability

Data transport level interoperability is enabled via using DLMS at the higher layers of the OSI stack. In addition, it is desired that the communication modules (in the smart meter) can be replaced in a modular/pluggable manner. This would enable interoperability at the device level as well.

9.10.5 User Interface

Remote user interface for configuring and troubleshooting the gateways. M2M platform should support remote IP link for the same.

9.10.6 Communication Infrastructure

The communication technologies in the various AMI segments (WAN, NAN and HAN) are depicted in Section 6. The DCU should be able to work offline with respect to the HES.

9.10.7 Deployment Considerations

Meters are installed in consumer premises that can be prone to electrical noise interference. Installation of DCUs may not have good power supply hence battery powering maybe required.

9.10.8 Geographical Consideration

Meters can be widely dispersed or installed in clusters. DCUs/gateways are widely dispersed. In case of rural areas, meshing of meters may not be possible. Hence point to point connectivity using cellular communications may be used.

9.10.9 Security

DCUs/gateways need to be protected from vandalism. On the cyber security front, smart meter data need to be confidential, and integrity and non-repudiation needs to be maintained. In addition, denial of service attacks must be prevented.

9.10.10Start-up/Shut-down Process

Meter end will register itself with the HES on each power cycling event (normal power on event that can be hardwired or soft power cycling). DCU/gateway power cycling or restart will trigger meters to register afresh with it. It is expected that HES is operational before the DCU/gateway. DCU/gateway is expected to be operational before meter.

9.10.11Data Management

A MDMS and a network management system will be responsible for data management and network management respectively.

9.10.12 Data Backup and Archiving

Gateway data backup can be taken remotely. DCU would have storage capabilities.

9.11 Potential Market Growth

Under the IPDS scheme of the GoI, AMI/AMR for all Distribution transformers in the country is likely to be rolled out.

9.12 Contracts and Regulations

All meters installed in India have to follow CEA regulations regarding installation and operation of meters.

In addition, all communicating devices have to follow norms set by WPC (Wireless Planning and Coordination) regarding frequency bands, channel bandwidth, transmitted power etc.

9.13 Challenges

The following are the challenges for AMI rollout in India:

- Limitations in various last mile connectivity solutions
- Availability of limited RF spectrum
- End-to-End interoperability standards to integrate AMI systems
- System security – need standards and regulations
- Latency in the reception of signals
- Coverage of the communications network not 100%
- Industry readiness for manufacturing of smart meters
- Utilities lack clarity on functional requirements and business models
- Security concerns especially balancing firmware upgradability with usability
- Manpower limitations for deployment, usage, and management - both in the DISCOMs as well as in the industry

9.14 Available Indian Standards

The following are the available Indian standards related to AMI:

- IS13779: Indian Standard for AC Static WattHour Meters Class 1 & 2 -Specification

- IS 15959: Indian Standard for Data exchange for electricity Meter reading, Tariff and load control - companion standard.

- IS 15884: Indian Standard for Alternating Current Direct Connected Static Prepayment Meters for Active Energy (Class 1 and 2) - Specification

- BIS is currently finalizing standards for smart meters and AMI.

10. References

- '**Smart Grid Vision and Roadmap for India**' released by Ministry of Power, Government of India in September 2013
- India Smart Grid Forum (ISGF) White Paper on '**M2M Communications in the Indian Power Sector**' published on December 18, 2014
- Central Electricity Authority website - http://www.cea.nic.in/reports/monthly/executive_rep/jan15.pdf
- Ministry of Power Website - http://powermin.nic.in/upload/pdf/Integrated_Power_Development_Scheme.pdf
- Ministry of Power Website - http://powermin.nic.in/Rural-Electrification
- India Smart Grid Forum (ISGF) White Paper on '**Smart Metering Scenario in India**' published on March 31, 2014
- Central Electricity Authority Website - http://www.cea.nic.in/reports/articles/god/mom_300115.pdf
- Internet Engineering Task Force (IETF) document - http://tools.ietf.org/html/rfc4919
- India Smart Grid Forum (ISGF) White Paper on '**Smart Meter Specifications of Leading Meter Manufacturers in India**' published on August 12, 2014
- CENELEC website - http://www.cenelec.eu/aboutcenelec/whoweare/index.html
- CENELEC website - http://www.cenelec.eu/aboutcenelec/whoweare/globalpartners/iec.html
- India Smart Grid Forum (ISGF) White Paper on '**Need for Allocating a Frequency Band for Power Line Carrier Communications**' published on December 18, 2014
- Texas Instruments (India) Pvt. Ltd. White Paper on '**Last mile connectivity challenges in Smart Grid**' by Chander B Goel, Shailesh Thakurdesai
- IoT European Research Cluster (IERC) Cluster Book on **Internet of Things** published in 2012- http://www.Internet-of-things-research.eu/pdf/IERC_Cluster_Book_2012_WEB.pdf
- **IERC Cluster Book** (2012) on Internet of Things - http://www.Internet-of-things-research.eu/pdf/IERC_Cluster_Book_2012_WEB.pdf
- **Ericsson Mobility Report** published in June 2014

- US DoE Report on "**Smart Grid Communications Requirements**"*http://energy.gov/sites/prod/files/gcprod/documents/Smart_Grid_Communications_Requirements_Report_10-05-2010.pdf*
- India Smart Grid Forum (ISGF) White Paper on '**Role of Smart Grids in Distribution**' published on April 16, 2015

Abbreviations

TABLE 11 - ABBREVIATIONS

Abbreviation	Full Name
MoP	Ministry of Power
MNRE	Ministry of New and Renewable Energy
DoT	Department of Telecommunications
NSGM	National Smart Grid Mission
ISGF	India Smart Grid Forum
JNNSM	Jawaharlal Nehru National Solar Mission
RAPDRP	Restructured Accelerated Power Development Reforms Programme
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
IPDS	Integrated Power Development Scheme
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
NEMM	National Electric Mobility Mission
DISCOMS	Distribution Companies
TRANSCOS	Transmission Companies
WAN	Wide Area Network
NAN	Neighbourhood Area Network
FAN	Field Area Network
HAN	Home Area Network
DCU	Data Concentrator Unit
RTU	Remote Terminal Unit
IED	Intelligent Electronic Device
GPS	Global Positioning System
PDC	Phasor Data Concentrator
AMI	Advanced Metering Infrastructure
DER	Distributed Energy Resources

Abbreviation	Full Name
IHD	In-Home Display
ESMIG	European Smart Metering Industry Group
HT	High Tension
NLDC	National Load Dispatch Centre
RLDC	Regional Load Dispatch Centre
SLDC	State Load Dispatch Centre
IoT	Internet of Things
IEEE	Institute of Electrical and Electronic Engineers
ITU	International Telecommunication Union
TWACS	Two Way Advanced Communications System
6LoWPAN	IPv6 over Low Power Wireless Personal Area Network
RF	Radio Frequency
PLC	Power Line Carrier
P2P	Point to Point
P2MP	Point to Multipoint
LPWA	Low Power Wide Area
TVWS	Television White Space
ILL	Internet Leased Line
CERC	Central Electricity Regulatory Commission
SERC	State Electricity Regulatory Commission
HVDC	High Voltage Direct Current
T&D	Transmission and Distribution
AT&C	Aggregate Technical and Commercial
M2M	Machine to Machine
SCADA	Supervisory Control And Data Acquisition
DMS	Distribution Management System
EMS	Energy Management System

Abbreviation	Full Name
WAMS	Wide Area Monitoring System
PMU	Phasor Measurement Unit
GSM	Global System for Mobile communications
CDMA	Code Division Multiple Access
HES	Head End System
ToU	Time of Use
ToD	Time of Day
FTU	Feeder Terminal Unit
NOFN	National Optic Fiber Network
PGCIL	Power Grid Corporation of India Limited
CEA	Central Electricity Authority
GoI	Government of India
OMS	Outage Management System
PLM	Peak Load Management
PQM	Power Quality Management
IEC	International Electrotechnical Commission
IP	Internet Protocol
IPv6	Internet Protocol version 6
CENELEC	European Committee for Electrotechnical Standardization
HHU	Hand Held Unit
NCIIPC	National Critical Information Infrastructure Protection Centre (NCIIPC)
NFC	Near Field Communications
RFID	Radio Frequency Identification Device
DCS	Distributed Control Systems
DG	Distributed Generation
CPE	Consumer Premises Equipment

Abbreviation	Full Name
BIS	Bureau of Indian Standards
IS	Indian Standards
ISAC	Incident Sharing and Analysis Centre
EV	Electric Vehicles
UPS	Uninterruptible Power Supply
SLA	Service Level Agreement
O&M	Operations and Maintenance
DR	Demand Response

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