



# *Spectral Efficiency for Mobile Telephony Services: Proposed Computational Model*

*Presentation*

*By*

*Telecom Engineering Centre*

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## Agenda

Overview

Conceptual Model for Spectrum Utilization

Techniques for Efficient Utilization

Summary



# *Phenomenal Wireless Growth*

- ❖ Global Mobile Subscriber growth has been phenomenal from negligible levels in 1992 to cross the landline's billion by 2002 and the climb to 2.6 billion by Dec. 2006
- ❖ The global mobile phone market is set to grow to 4 - 4.5 billion by 2011 fuelled by strong demand from developing economies in Asia and Latin America.
- ❖ Almost 1 billion handsets sold last year.
- ❖ *All the above point to a remarkable development that is changing the world and the way we communicate!*

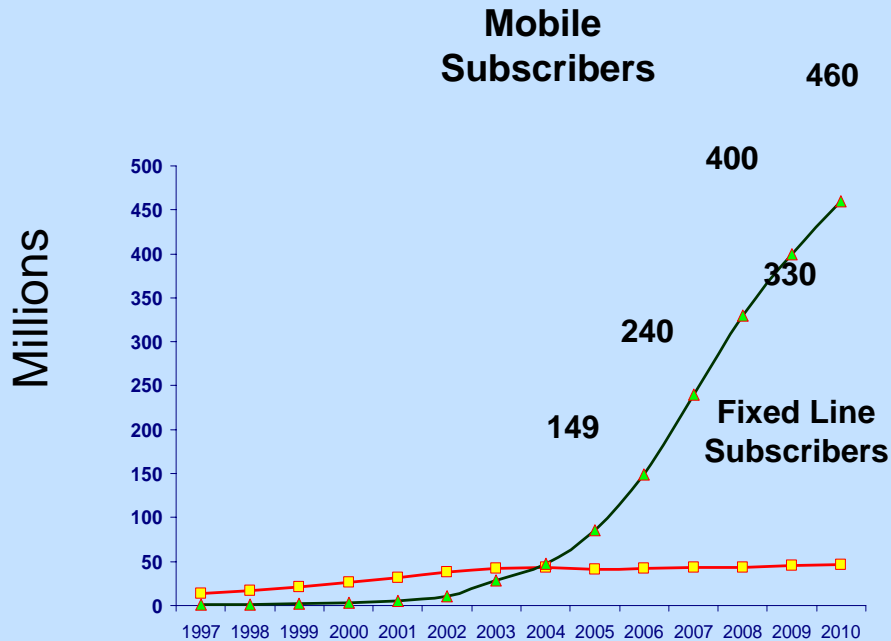


## *Indian Scenario*

- Fixed subscribers - 40 million
  - Mobile - 185 million
  - Gross - 225 million
  - Tele density - Around 20%
  - Rural Tele density - ~ 5%
- ❖ *Monthly addition during June 07 - 7.34 million*  
*(the highest subscriber growth in a month so far in the world)*
- ❖ Target
- 2007 - 250 Million subscribers.
  - 2010 - 500 Million subscribers.



# Wireless Subscribers Growth is Exponential

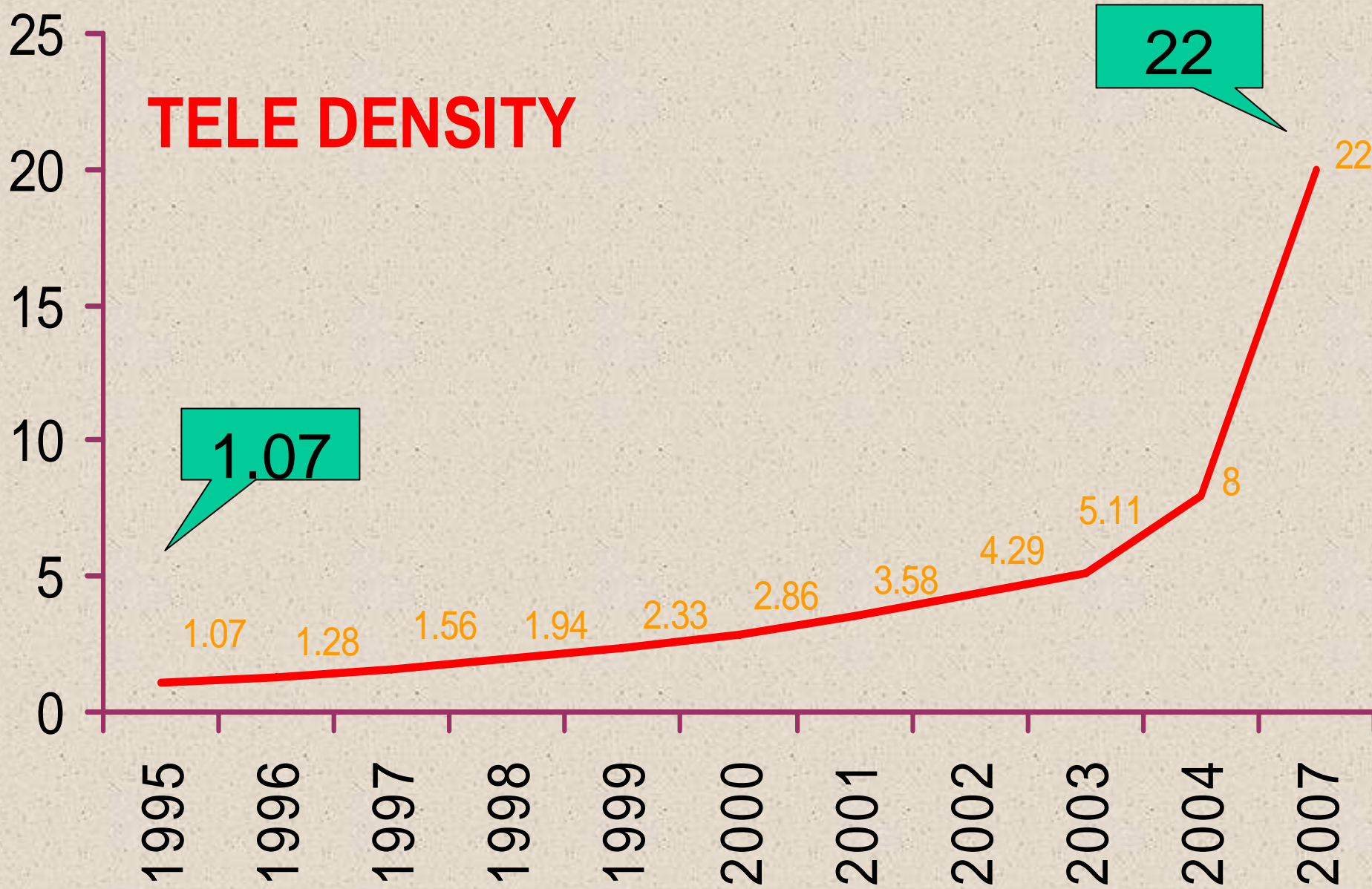


India's wireless market is growing at ~6-7 Million new subscribers every month

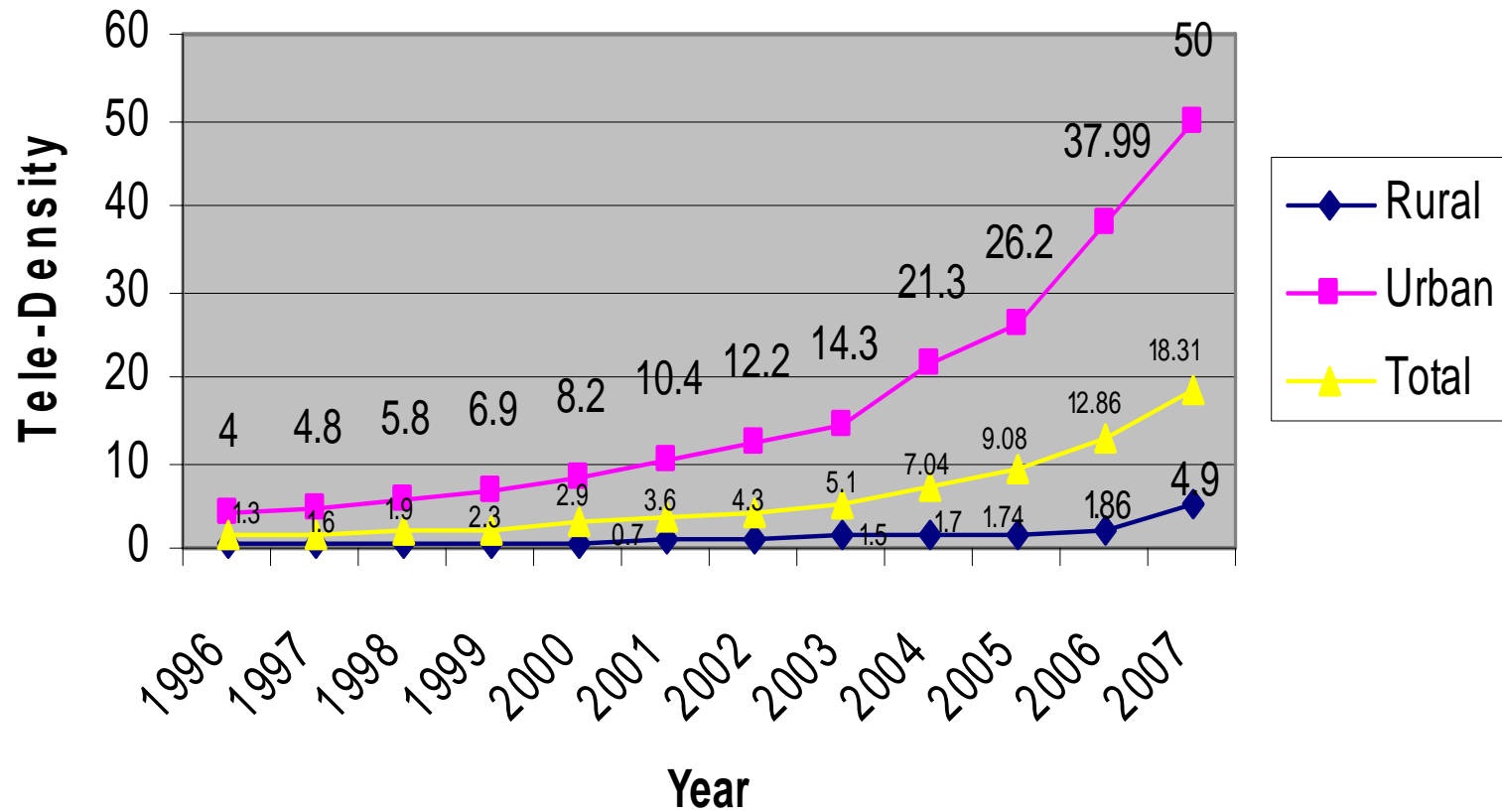
- Third largest cellular market in the world
- Fastest growing telecom market in the world – 500 Million subs by 2010



# Phenomenal Growth



# Tele-Density Urban- Rural





## *Relation of Growth and Spectrum*

- The overall growth in tele-density has been possible only on account of large-scale growth in mobile communication in the country.
- Wireless networks are fastest and most cost-effective means of extending access to voice and data communications.
- In such a mobile-driven growth scenario, as being witnessed in India, requirement of ‘spectrum’ – a critical resource for the development of telecom network in the country – would be increased significantly in the days to come.
- “Projection of Spectrum requirements” and review of many of the spectrum related issues is, therefore, the need of the hour.

## *The growth projections need to be translated into spectrum requirements*

- There is no empirical formula which can establish the spectrum requirement.
- Additional spectrum requirement depends on various parameters like
  - ❖ Number of subscribers,
  - ❖ the density of subscribers
  - ❖ Morphology : urban, semi-urban, rural terrain,
  - ❖ Type of applications (voice, data, multimedia application such as video/audio streaming, video on demand, mobile TV, etc.)
  - ❖ and pattern of traffic, (voice, data, multimedia services),
  - ❖ Environment : type of mobility (fixed, pedestrian, vehicular)
  - ❖ and the technology itself, etc, {2G (CDMA IS95A, GSM), 3G (WCDMA/CDMA2000), WiFi, WiMax }

## *The growth projections need to be translated into spectrum requirements. contd...*

- In a multi-operator scenario where market forces are in a position to decide the business strategies, it is difficult to assess the value of various parameters mentioned above.
- While a few parameters such as current subscriber base, current growth rate, etc. are known, there are several indeterminate factors, which can substantially alter the spectrum requirement estimates, the prominent among them are:-
  - ❖ Nature of traffic, i.e. extent of voice and data traffic in the network.
  - ❖ Market share of different operators at a future date for which projections are being made.
  - ❖ Mergers and acquisitions, which change the total number of players in the market.
  - ❖ Network design and the deployment of the spectrum optimization techniques.

# *Importance of Spectrum*

- The continuous growth of telecom sector is important
- It is also essential for development of IT sector, international competitiveness and for raising the standard of living of people of our country.
- All telecom service providers want to provide services through Wireless Systems
- Spectrum, therefore becomes a key resource.
- One of the most important task is to find strategies for enhancing and sustaining the growth of mobile networks with limited spectrum
- There is a requirement to dwell upon various methods for growth of wireless telecom services viz-a-viz limited scarce resource i.e. spectrum.

## *Why Review?*

- ❑ Many parameters are time dependent & vary at different stages in growth trajectory. So periodical review is expected.
- ❑ Number of LSAs have achieved higher numbers of subscriber base in comparison to allocation criteria.
- ❑ There is a need to study and analyze changes in pattern of traffic within city and across cities or rural area.
- ❑ With deeper & wider penetration of mobile it is needed to define *Computational model for utilization of spectrum in more comprehensive manner.*



*Spectrum----- a scarce resource.*

- ‘Spectrum’ is a natural resource that cannot be replenished and, therefore, has to be used efficiently and that is where lies the significance of ‘Spectral Efficiency’.

## *Spectrum efficiency - an ongoing debate*

- ❑ Efficiency is relative and does not have fixed parameters.
- ❑ No metrics for defining spectrum efficiency due to changing parameters and measures possible in all technologies to improve spectral efficiency.
- ❑ Intrinsic incentive must be present in the allotment policy for encouraging efficiency and innovation.

## *Malthus' dire predictions.....*

- ❑ The food supply turned out to be not as “scarce” as Malthus(18th-19th century political economist )had originally believed because technology and innovation have drastically increased yields beyond what was thought possible at the end of the eighteenth century.
- ❑ Indeed, we have largely escaped Malthus' dire predictions because technology has enabled a much more efficient use of a scarce resource, land.
- ❑ While Malthus' concerns were based on the ever-increasing population, similar “scarcity” arguments have been, and are still being made about the radio spectrum. While the number of spectrum users and uses continually increases, the amount of spectrum is still considered a limited resource.

## *Malthus' dire predictions.....*

- ❑ However, many have argued that this system makes the same mis-calculations about the “productivity” of spectrum as Malthus made on the productivity of farm production in the late 1700s.
- ❑ They argue that spectrum isn't as “scarce” as it appears because new technologies make much more effective use of spectrum, mitigating the scarcity problem.
- ❑ Essentially, technological advances, if implemented, could outpace the growth of our demand for spectrum in the same way as aggregate food production has outgrown population growth!

*(source:ITU-TDocument:RSM/08 Feb2004)*

# Conceptual Model For Spectrum Utilization

**Definition of Spectral Efficiency (SUE)**

**Conceptual Computational Model**

**Parameters of Model**

# *Spectral Utilization Efficiency*

- ❖ Spectral Efficiency quantifies the amount of traffic a network can carry for a given spectrum. Furthermore, it is a measure of the radio performance efficiency, thus higher spectral efficiency provides higher QoS provided to the end user for a given traffic load.
- ❖ Network is more spectrally efficient if for a certain benchmarked QoS it can carry more traffic

# *Spectral Utilization Efficiency* Contd...

- ❖ ITU-R Recommendation SM.1046-1 on “DEFINITION OF SPECTRUM USE AND EFFICIENCY OF A RADIO SYSTEM” mentions
- ❖ “ Efficient use of spectrum is achieved by (among other things) the isolation obtained from antenna directivity, geographical spacing, frequency sharing, or orthogonal frequency use and time-sharing or time division and these considerations reflected in definition of spectrum utilization. Therefore, the measure of spectrum utilization- Spectrum Utilization factor,  $U$ , is defined to be the product of the frequency bandwidth, the geometric (geographic) space, and the time denied to other potential users:

$$U = B \cdot S \cdot T$$

*where, B: Frequency bandwidth, S: geometric space (usually area) and T: time”.*

# *Spectral Utilization Efficiency Contd...*

- ❖ Also ITU-R Recommendation SM.1046-1 mentions
- ❖ “ According to the definition of SUE (or Spectrum efficiency as a shortened term) of a radio communication system, it can be expressed by:

$$SUE = M \div U = M \div (B \cdot S \cdot T)$$

*where, M: amount of information transferred over a distance”.*

*For cellular mobile system, it can be expressed as*

$$SUE = (\text{Traffic in Erlang}) \div (\text{Amount of spectrum in MHz} \times \text{Area in Sq. Kms.})$$

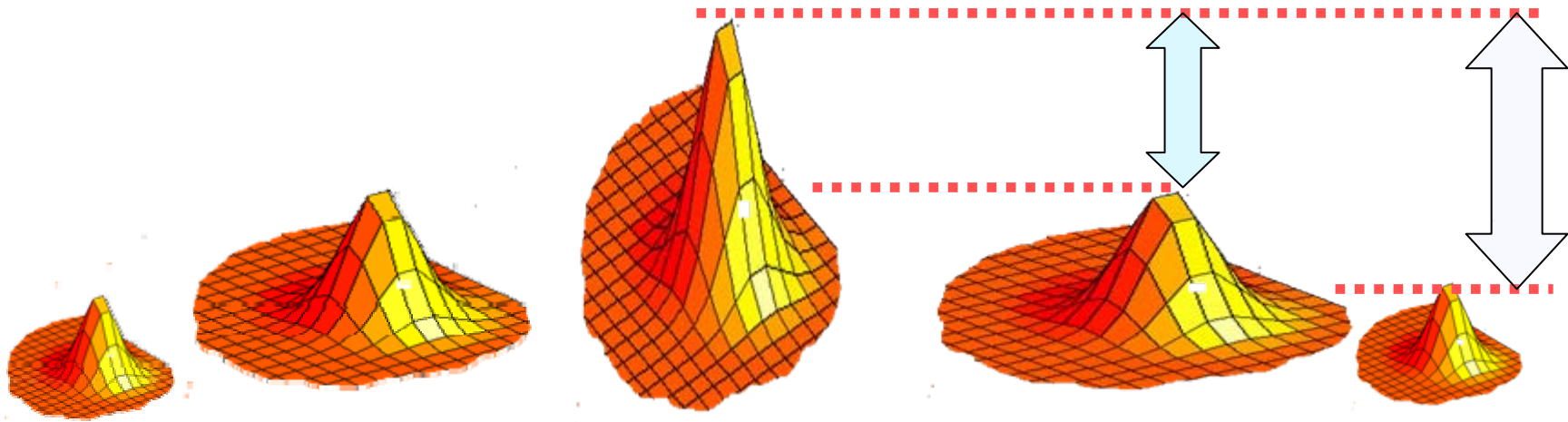
*For a specified GoS*

## *Spectral Utilization Efficiency* Contd...

- ❖ The definition takes into account the traffic carrying capacity of a technology to replicate the available spectrum in the unit area for a specified QoS.
- ❖ But in a deployed network and uneven distribution of traffic, parameters in definition like geographical spacing varies within city and also city to city therefore to apply definition we need to identify traffic variation in city & develop computation model for SUE.

# Traffic Density Variations across City

Relative density



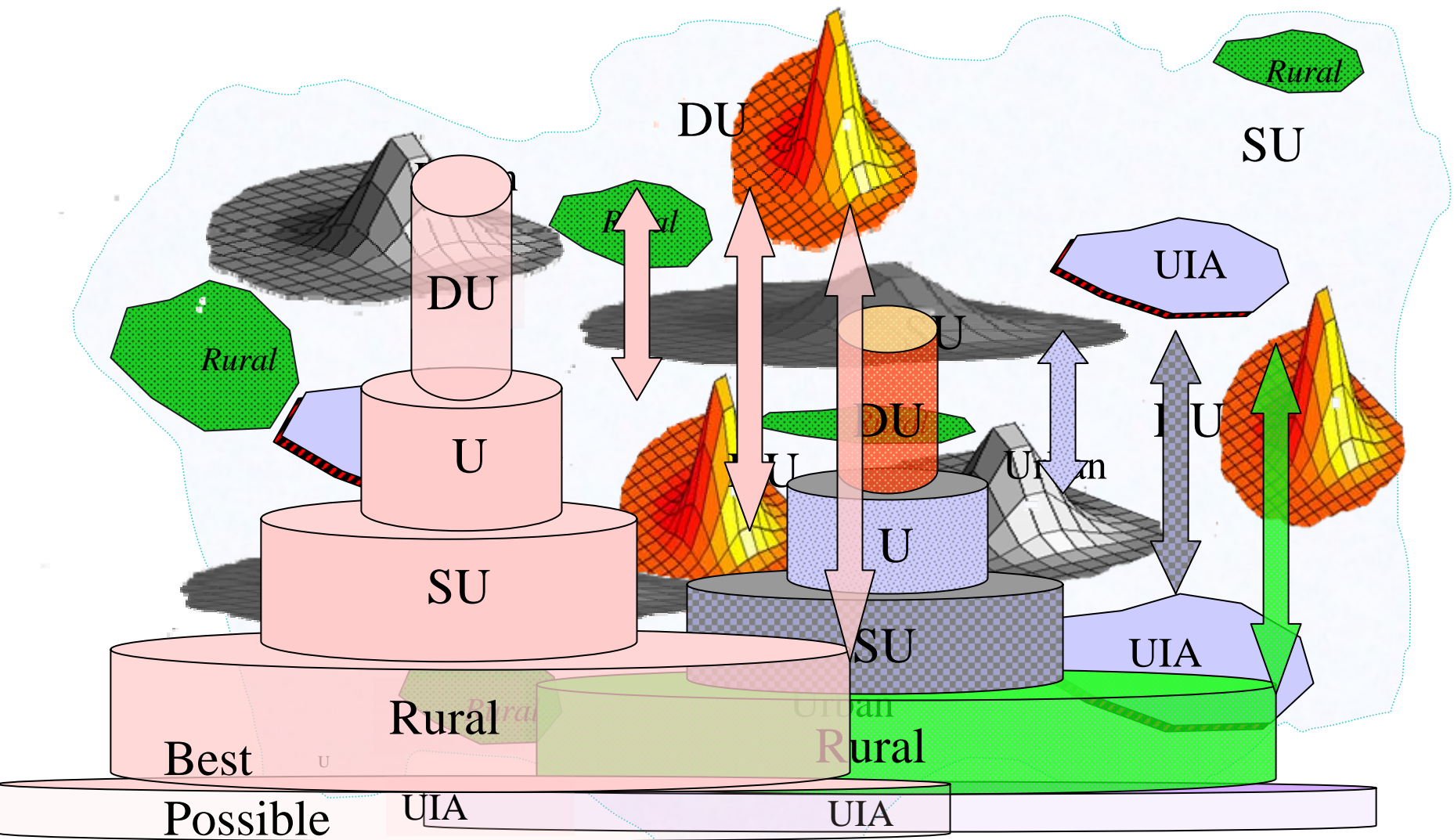
Sub-Urban

Urban

Dense Urban

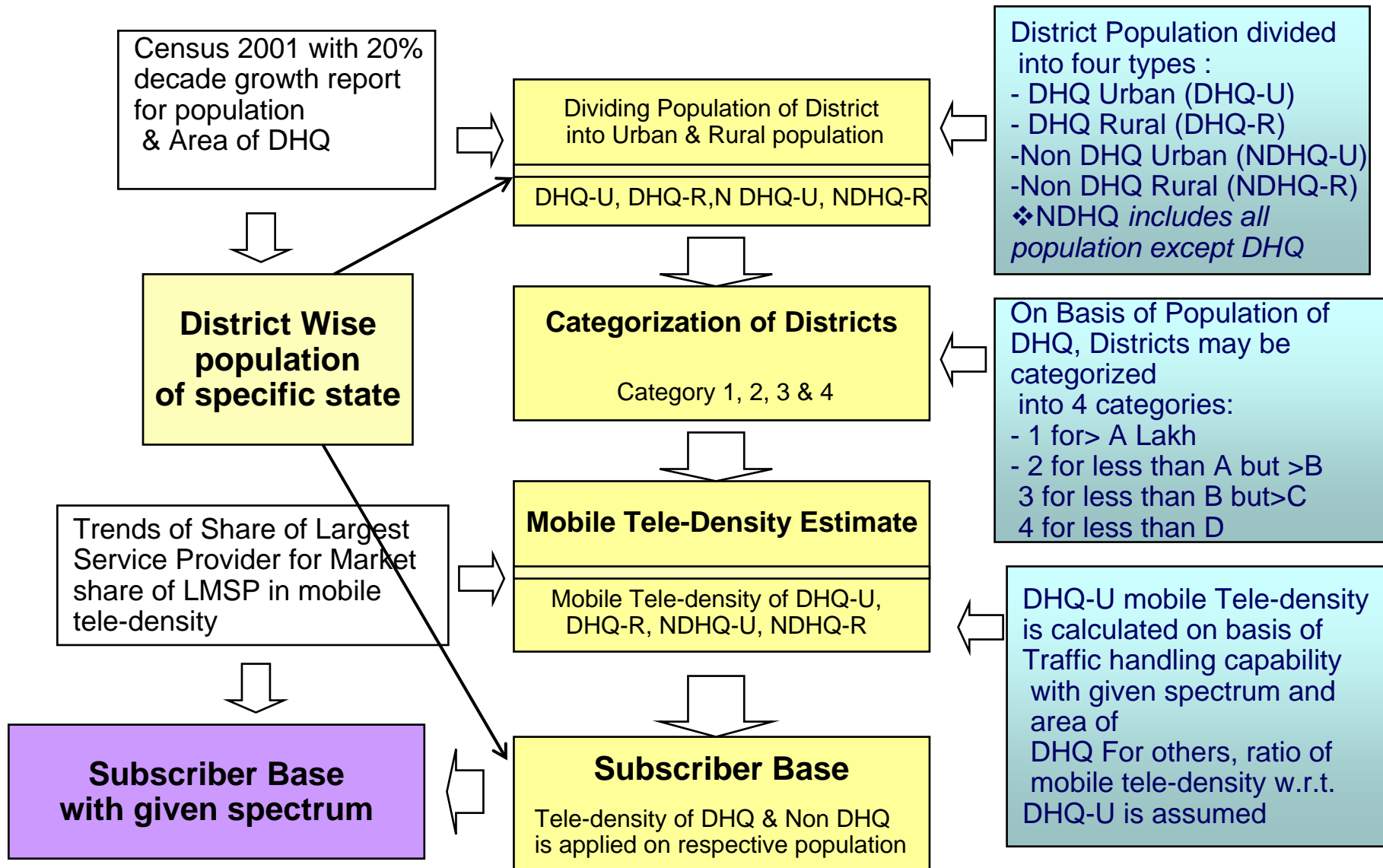
Urban

Sub-Urban



❖ *Area of DU, U, SU, R & UIA is to be summed up*  
*Option is to calculate from Planning Tool*

# Calculation Process Flow



# *Parameters for Computational Model*

- ❖ Spectrum Bandwidth
- ❖ Technology e.g. GSM, CDMA etc
- ❖ Techniques Employed e.g. SFH, AMR, SAIC
- ❖ Penetration level of Specific type of Mobile Stations e.g. AMR, SAIC etc

# *Parameters for Computational Model* Contd..

- ❖ DHQ-U Area
- ❖ DU, U, SU, R Area
- ❖ Inter-Site Distances
- ❖ Classification of Districts
- ❖ Population Decade Growth Rate
- ❖ Relative Tele-Density in DHQ-R, NDHQ-U, NDHQ-R etc
- ❖ Average traffic per Subscriber



# Techniques For Efficient Utilization

# *Introduction*

- ❖ To meet demand of capacity with limited spectrum it is required to use all the existing capacity enhancement methods.
- ❖ By Cell Splitting and tightening frequency reuse, the capacity of the macro network can be increased substantially.
- ❖ However, Cell splitting can be reduced only to a certain extent to maintain the desired quality of Service (QoS).

# *Techniques*

- **Single Antenna Interference Cancellation (SAIC)**
  - SAIC is new development for improved downlink performance for GSM networks..
  - SAIC is basically a technique to boost the capacity of GSM network without needing any change in the network.
  - SAIC enables mobiles to work in high interference level.
  - SAIC enabled mobiles need even less transmit power from network which in turn reduces the interference for non SAIC mobiles.
  - Theoretical studies shows that with 100% SAIC mobile penetration a capacity gain of 60 to 80% is achievable. There are various approaches possible to have a SAIC enabled phone.

## *Techniques* Contd..

- **Capacity Boost by Antenna Arrays**
  - Channels is confined to a narrow beam.
  - It improves the C/I.
  - The gain obtained by the antenna arrays can efficiently reduce interference and thereby increase capacity.

## *Techniques* Contd..

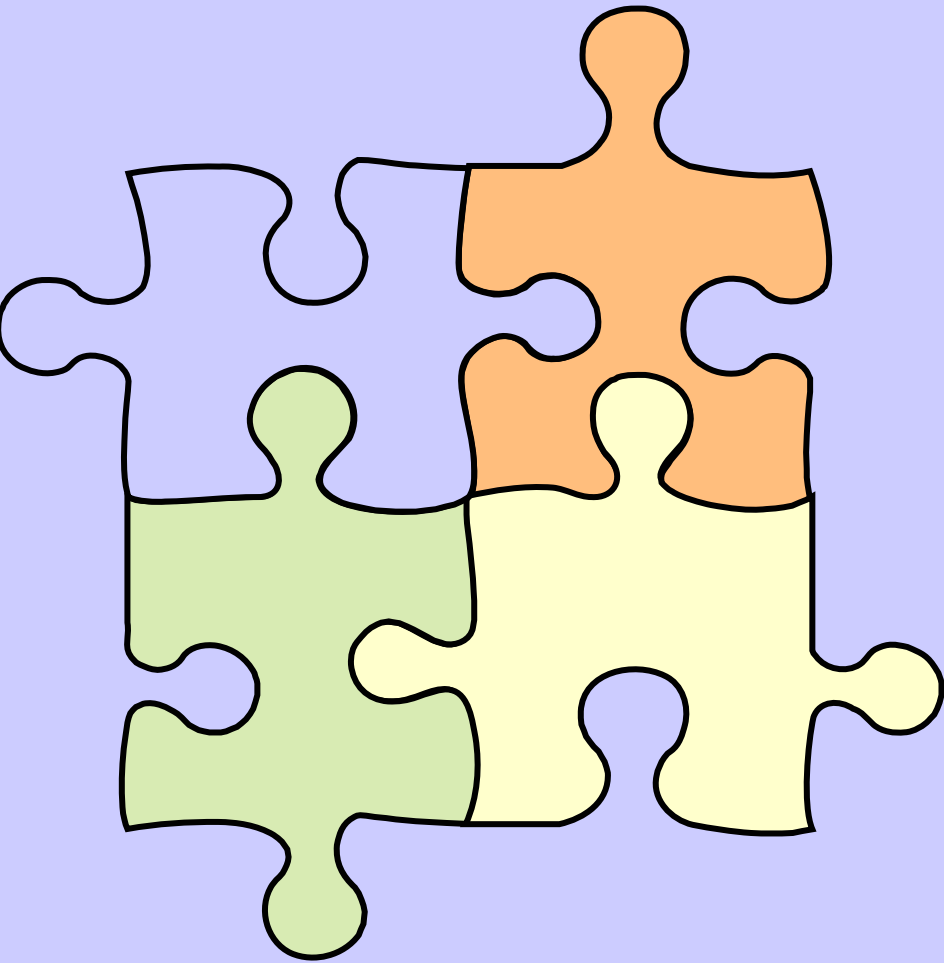
- In-Building Solutions e.g. Micro BTS with DAS, Leaky Cable
  - Methods are to be thought for offloading major traffic concentrations i.e. in-door
  - In-building is a major technical possibility of optimal utilization of spectrum.
  - In –building solutions are to be deployed in much larger numbers.
  - Neutral host for exclusive indoor-solution to be studied
- How indoor-solution can be implemented with shared spectrum or by dedicated spectrum need consideration by the Industry.

# *Fixed Mobile Convergence*

- The very effective strategy may be to use unlicensed spectrum
- In the best interest of network operators to use the unlicensed spectrum because
  - Extend GSM voice & data services over wireless broadband connection
  - Advantage of economics of IP
  - Availability of Dual-mode handsets
  - Availability of low cost wireless Access Point supporting GAN
  - save substantial spectrum charges
  - Overcomes spectrum bottleneck.
- Standards developed for products supporting both WiFi and GSM / WCDMA
- Dual Mode handsets work on WiFi while inside a WiFi zone and switch over to GSM or WCDMA working when moving out of WiFi zone.
- Research firm In-Stat forecast use of more than 66 million dual-mode handsets
- Senza Fili consulting firm also predicted 55 million dual-mode handsets

# Summary

- ❖ *Substantial Component of additional subscribers will be from rural or Non- DHQ cities where spectrum is not a constraint.*
- ❖ *In Metro cities & Major Cities of Circles, more number of in-building solutions are to be deployed.*
- ❖ *New advanced techniques for capacity enhancement techniques are to be planned & deployed by all the service providers on priority basis*
- ❖ *Study for technology and sharing may be taken up by the industry*
- ❖ *Industry may provide inputs and suggestions for the proposed model.*



Thanks