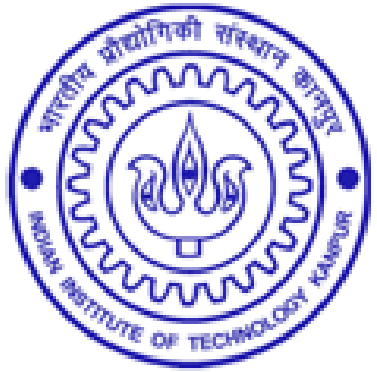

tsdsi
India's Telecom SDO

"Standards Driven Research"
Online Workshop at the NCC2021

29 July 2021, 0900-1215 IST

The 5Gi Story – from Academic Research to a Global Standard

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Former Chair, TSDSI

Agenda

- Characteristics of 5G and Standardization Landscape
- Requirements of Rural India
- Low Mobility Large Cell configuration
- TSDSI RIT- 5Gi
- Impact

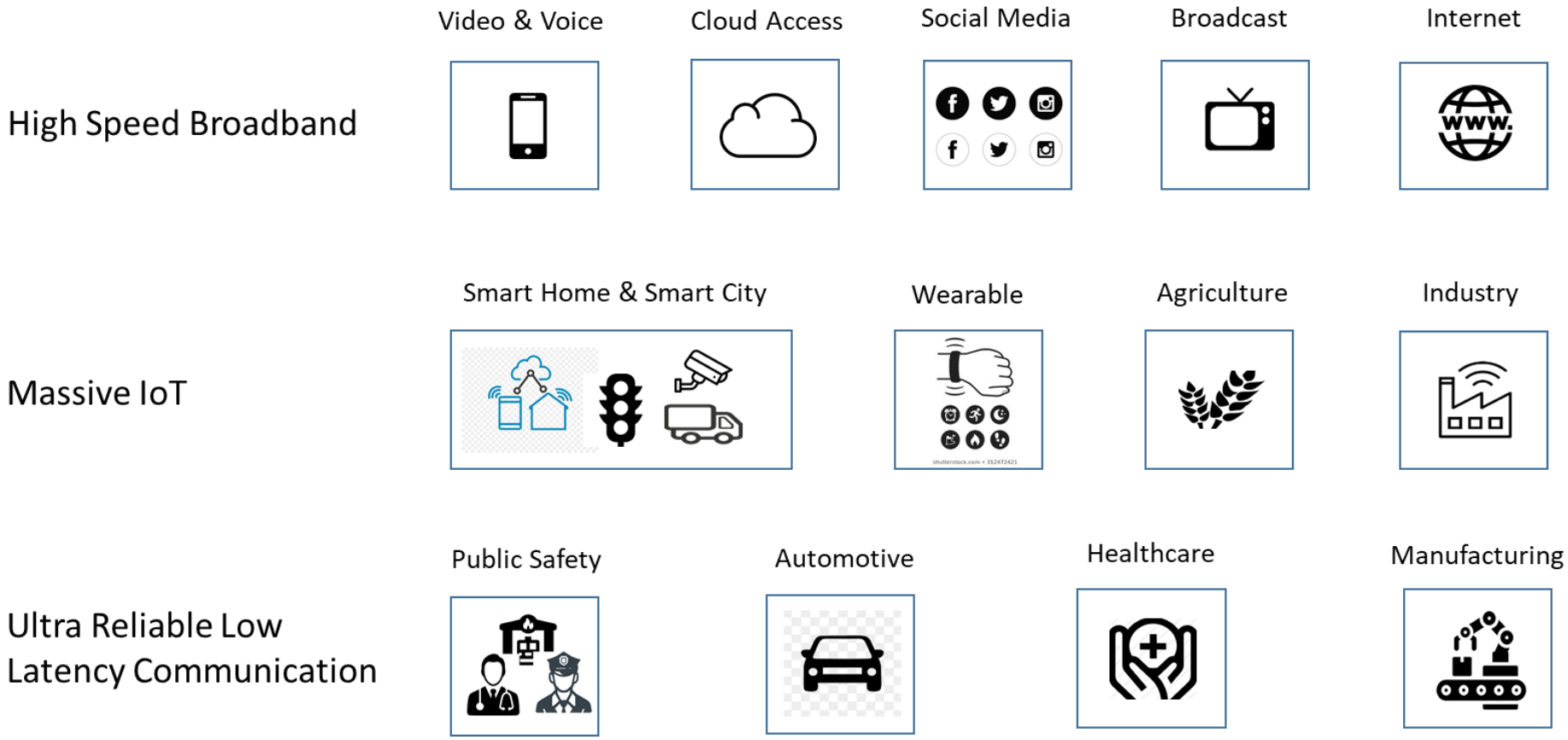
Credits-Key Contributors

- IIT Madras team - Prof Bhaskar Ramamurthi and Prof Radhakrishna Ganti
- IIT Hyderabad team- Prof UB Desai, Prof Kiran Kuchi and Dr Sai Dhiraj, Anirudddh Venkatakrishnan
- CEWiT Team - Dr Klutto Milleth and Ms Priyanka Dey
- TSDSI Leadership: Prof Bhaskar Ramamurthi, Dr Kumar Sivarajan, Mr A K Mittal, Ms Pamela Kumar
- DoT and TEC - Sr leadership up to Secretary level

5G & beyond – All Pervasive Digital Connectivity

- Human – Human Communication
- Human – Machine Communication
- Machine – Machine Communication

- Expected to touch almost all parts of human life
- 5G has far bigger implications than earlier systems



Characteristics of Communication Technology (1/2)

Innovation Driven

- Driven by Continuous Innovations
  - Rapid changes in wireless technology
    - 2G->3G->4G->5G within a few decades
  - Swift development in transport technology
    - e.g. Optical Communication Networks
- Convergence of Computing and Communication
  - Increased Softwarization
  - Commoditization of Network
  - Increased usage of Cloud, Fog/Edge based paradigms

Characteristics of Communication Technology (2/2)

Importance of Standards

- Global Standards Bodies drive the development of technology
  - ITU, 3GPP, IEEE, IETF
  - Membership - Equipment Manufacturers and Operators
- Interoperable Equipment Landscape
- IPRs owned by Individual Member Companies
  - Standard Essential Patents

Few Other Factors

- Capital Intensive
- Costly Equipment & Resources (e.g. Spectrum)
- Skilled Manpower

Standardization and Innovation Play a Significant Role

Major Contributors to 5G – Standards Participation

Countries with bigger telecom manufacturing base has *higher participation in telecom standard development*

China as a country is the biggest participant world-wide

Courtesy: 3GPP

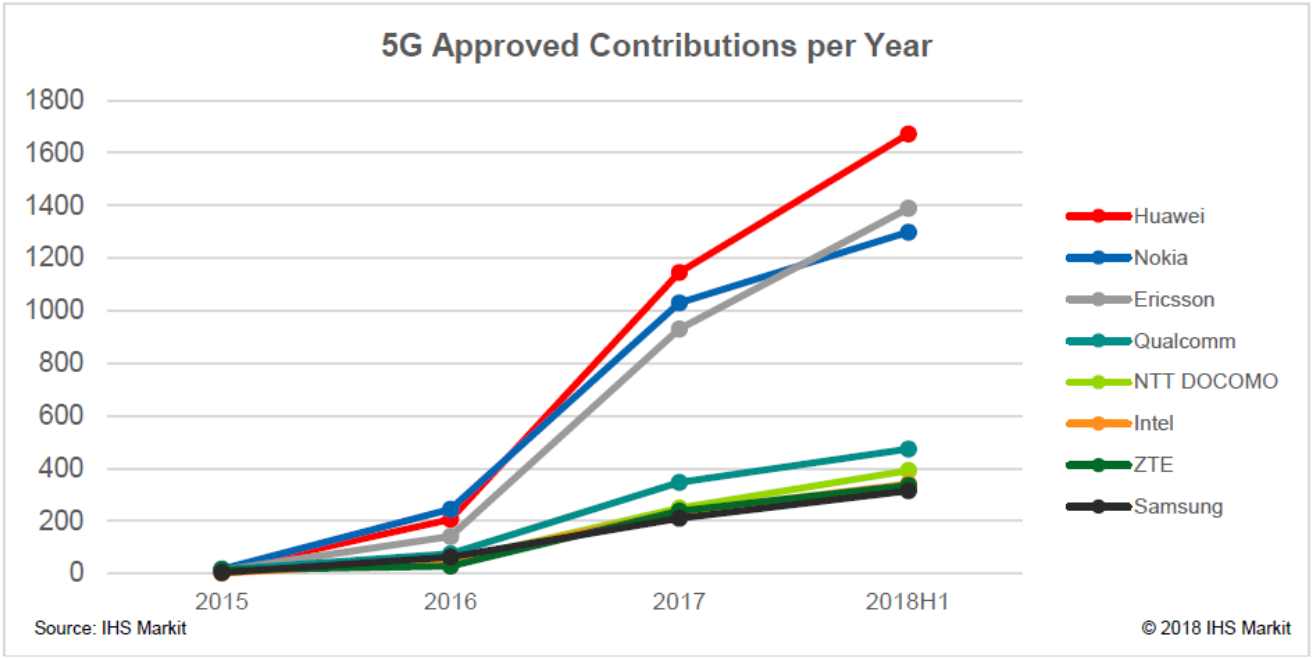
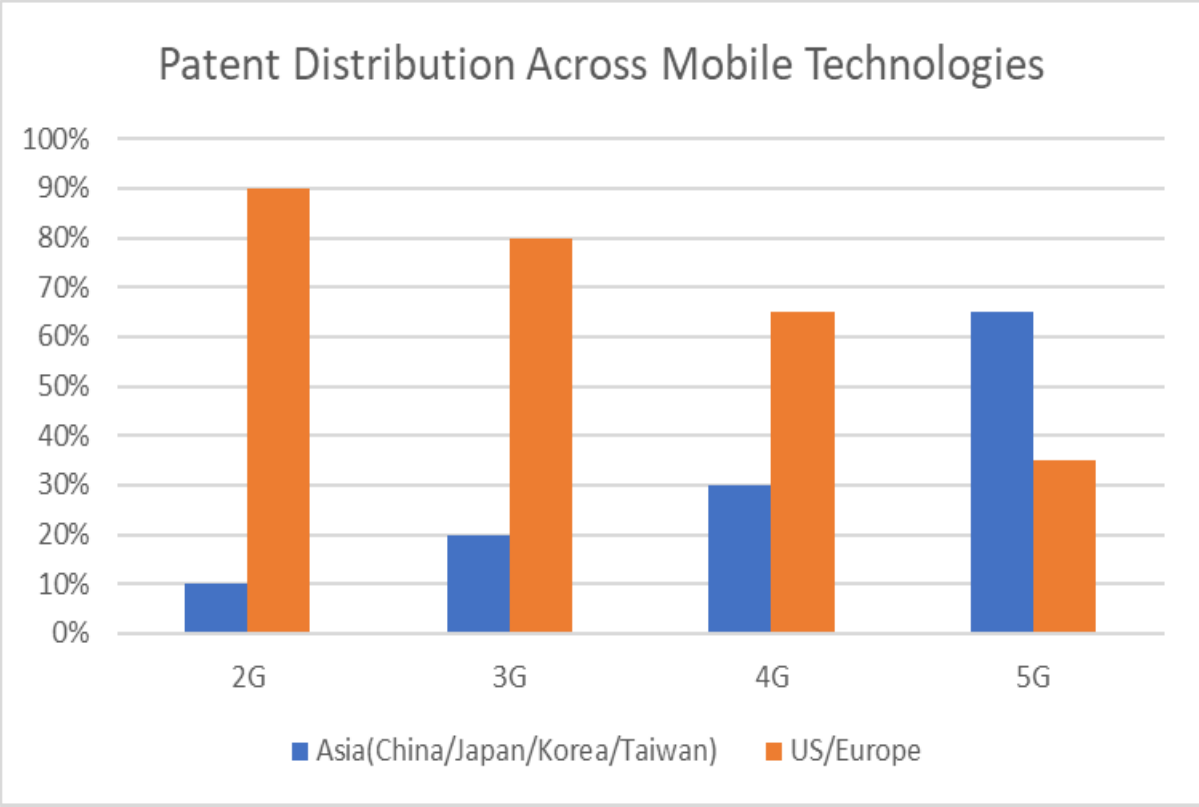
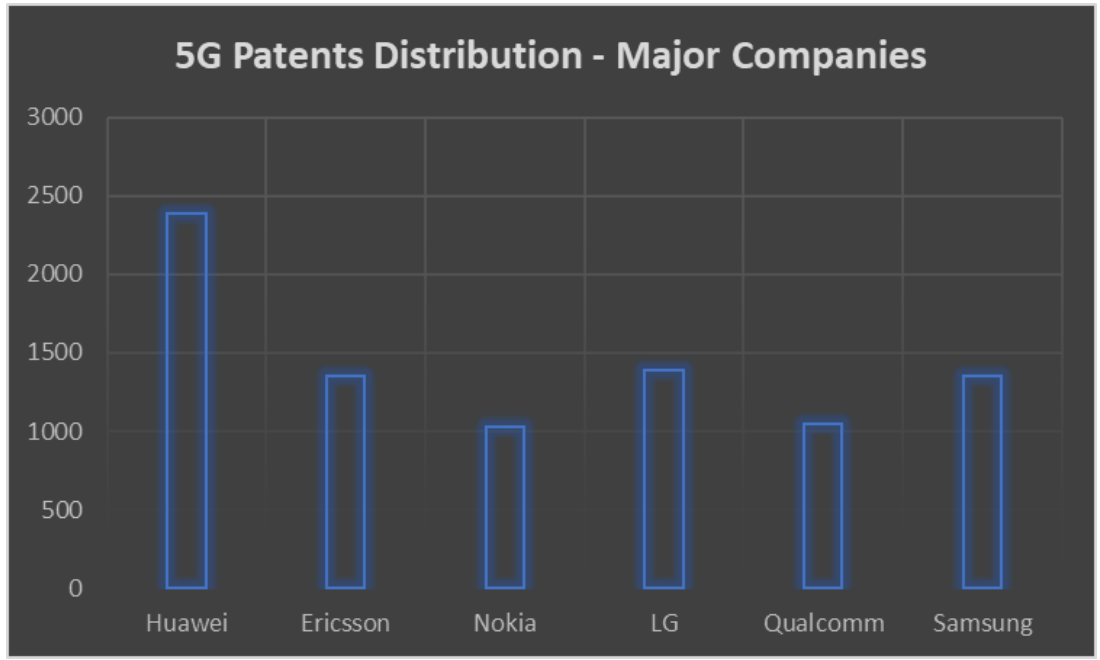


Chart 7: Number of 5G Approved Contributions per Vendor/Operator per Year – 2015 to 2018H1

Major Contributors to 5G - Patents

Asia has gradually been increasing its share of Standard Essential Patents in Mobile Technology





Asian Countries, especially China owns a much larger % of Standard Essential Patents in 5G Technology than US & Europe

Huawei is the biggest holder of 5G Patents among global Telecom Giants

Standards Driven Research & Innovation

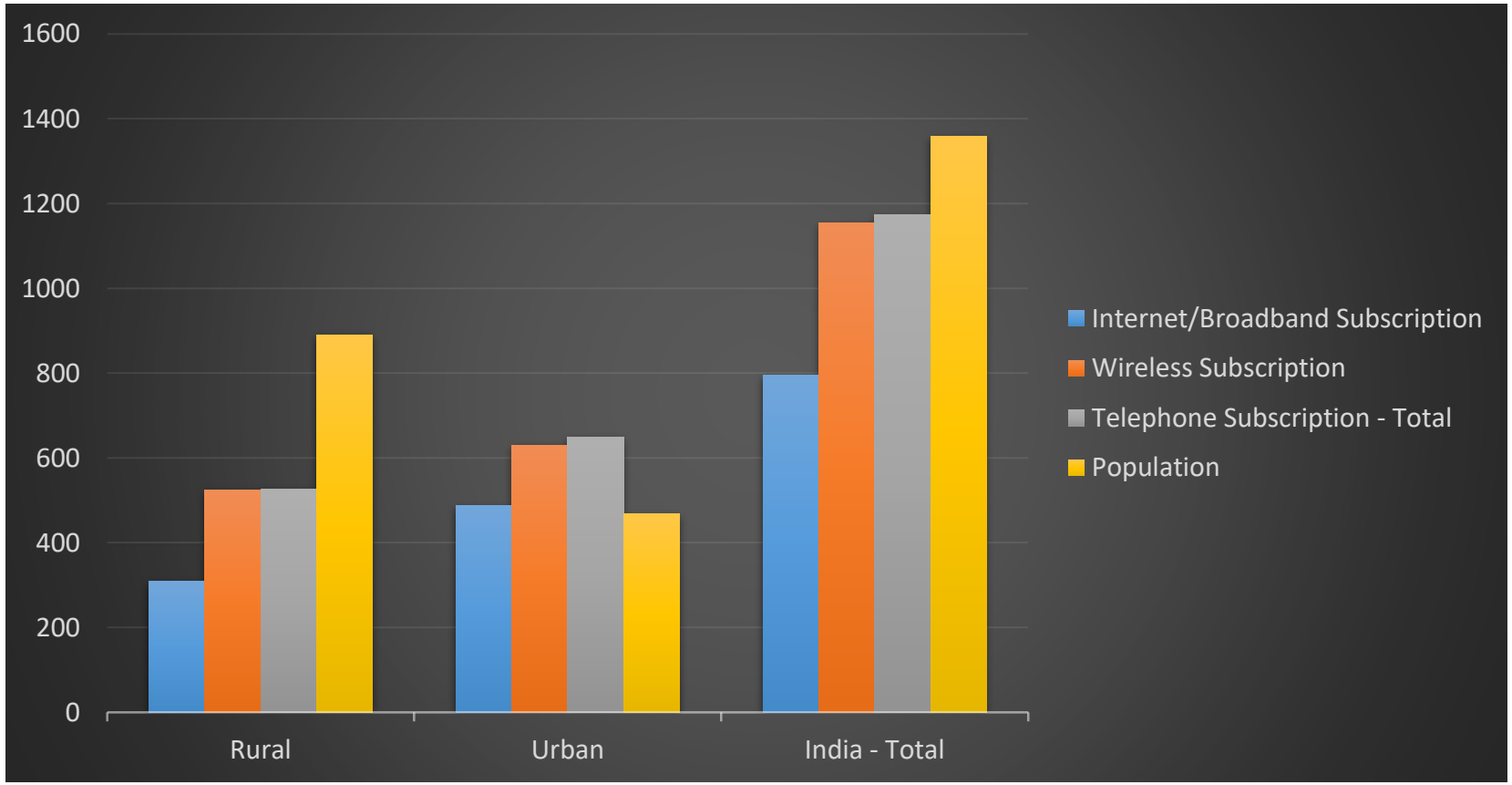
- Reliance on Communication Services Increasing
  - 5G & beyond to touch almost all aspects of our lives
  - IPR ownership in Wireless/ICT technologies may dictate Economic & National Sovereignty
  - Country(s) controlling Cyber Physical Systems, 5G+AI may control the World
- Technologies Developed & Standardized address needs of participants (Stakeholders)
- Those not Participating in Standardization forced to use not-so-suitable technologies

Far Reaching Consequences

Imperative that India whole heartedly adopts Standards Driven Research

5Gi Journey

Internet/Broadband Penetration Status: India

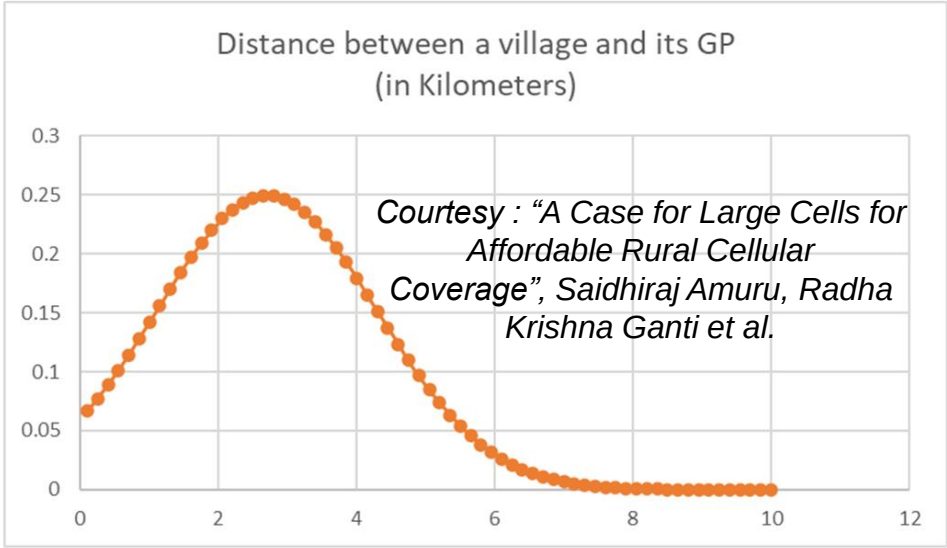


Sizeable Population (up to 45%) in Rural India may not have Broadband/Internet access – Much Lower in 2015

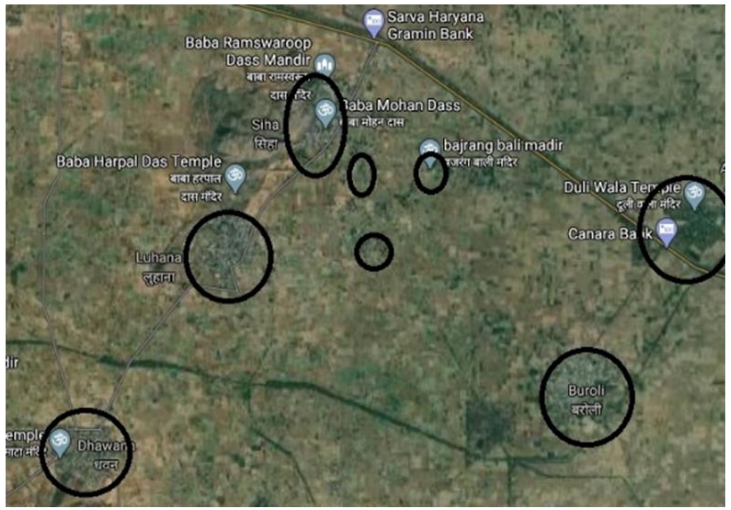
Source: TRAI, The Indian Telecom Services Performance Indicators, April, 2021

Rethinking 5G Requirements for Rural Areas

- Relatively Sparse Population
  - Every Village
    - Part of a Gram Panchayat
    - Typically 1-3 Villages in a GP
  - Almost all Villages within 10 Km radius of GP
    - >90% Villages within 6 Km radius
    - >60% Villages within 3 km radius
- Low Average Revenue per user
  - ARPU for Cellular Services in the country
    - ~100 Rs/Month
    - One of the lowest in the world
  - Lower in Rural India
- Large Coverage Area Support
- High-Speed Mobility Not Required
  - Relatively small vehicular traffic
  - Slow moving vehicles



Courtesy : "A Case for Large Cells for Affordable Rural Cellular Coverage", Saidhiraj Amuru, Radha Krishna Ganti et al.



Typical Rural Settlements - India
(Source Google)

Legend
Areas shown under circles/ovals are villages or small clusters of human population. Rest of the areas are open spaces (in between) with minimal human presence

Motivations for 5Gi

- 5G Not so suitable for Rural India
  - Focused on
    - Very higher throughput (eMBB), IoT, URLLC
    - Smaller Cell-size for higher capacity
    - High Speed Mobility Support
    - Driven by needs of Major Stakeholders - China, Europe, USA
  - Original Rural eMBB Configuration of IMT-2020
    - Indian (esp. Rural) Requirements Not Well Supported
- Increase Indian footprint in International ICT Standards

IMT-2020 Rural eMBB – Original Test Configuration

- Cell Radius - ~1 km
- Caters to High-Speed Vehicles
  - 120 km/hour
- Mobility KPI
  - High-speed Vehicular Traffic - Up to 500 km/hour
- Essentially Models
  - Connectivity to High-speed Vehicular Traffic in Rural Areas in Economically Developed Countries
- Not Suitable for “Connecting the Unconnected”

IMT-2020 – Original Rural – eMBB Test Configuration used in ITU		
Parameters	Config A	Config B
Carrier Frequency	700 MHz	4GHz
Inter-Site Distance (ISD)	1732 meters	1732 meters
Bandwidth	20 MHz (DL+UL)	Up to 200 MHz (DL+UL)
BS Tx power	49 dBm	
BS Antenna Height	35 meters	
User Equipment (Device) Distribution	50% outdoor vehicles (120km/h) and 50% indoor (3km/h) 500 km/h for evaluation of mobility in high-speed cases Uniform User distribution	

Courtesy ITU M.2410 and 2412

LMLC - Augmenting IMT-2020 for Rural Broadband

- Utilizes BHARATNET Infrastructure
  - BharatNet deploying Fiber in Rural India
  - A Fiber POP terminates at GP Office
- Cellular Connectivity around a Fiber PoP
  - Large Coverage Area
  - Focus on Low Mobility Users
  - A new Channel Model
  - Takes Indian-rural needs into consideration
  - Also needs of other similar geographies

IMT-2020 – LMLC Test Configuration for Rural Broadband		
Parameters	Config A (Original)	LMLC - Config C
Carrier Frequency	700 MHz	700 MHz
Inter-Site Distance (ISD)	1732 meters	6000 meters
User Equipment (Device) Distribution	50% indoor, 50% outdoor (in-car) Randomly and uniformly distributed	40% indoor, 40% outdoor (pedestrian), 20% outdoor (in-car) Randomly and uniformly distributed
BS Tx power	49 dBm	
BS Antenna Height	35 meters	
User Equipment (Device) Speeds of interest	50% outdoor vehicles (120km/h) and 50% indoor (3km/h) 500 km/h for evaluation of mobility in high-speed cases	Indoor users: 3 km/h; Outdoor users (pedestrian): 3 km/h; Outdoor users (in-car): 30 km/h

Courtesy ITU M.2412

LMLC Requirement Accepted @ ITU

eMBB

Indoor Hotspot eMBB

- Config A 4GHz
- Config B 30GHz
- Config C 70GHz

Dense Urban eMBB

- Config A 4GHz (1 layer)
- Config B 30GHz (1 layer)
- Config C 4/30GHz (2 layers)

Rural eMBB

- Config A 700MHz ISD 1.732 km 120/500 Km/h
- Config B 4GHz ISD 1.732 km 120/500 Km/h
- LMLC 700 MHz ISD 6Km 30 Km/h

MMTC

Urban Macro MMTC

- Config A ISD 500m
- Config B ISD 1.732 Km

URLLC

Urban Macro URLLC

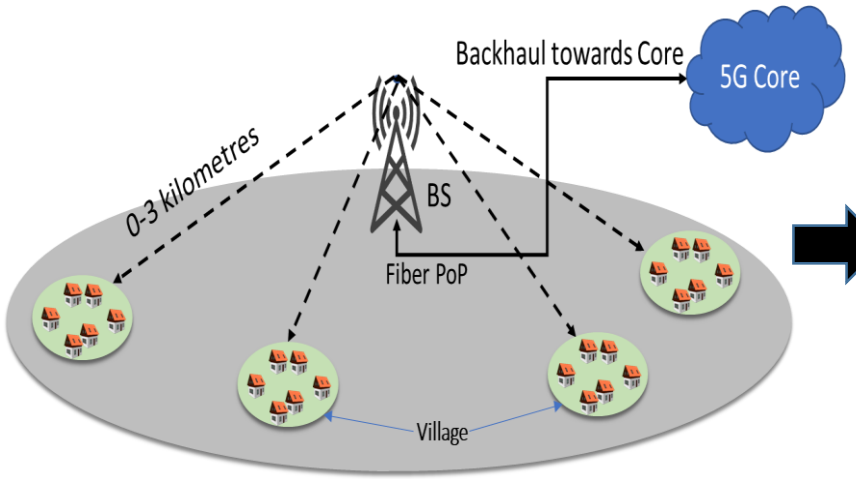
- Config A 4 GHz
- Config B 700 MHz

In addition, for the Rural-eMBB test environment, the average spectral efficiency value should meet the threshold values for the LMLC evaluation configuration with ISD of 6 Km and evaluation configuration A & B with ISD of 1.732 Km

Low Mobility Large Cell Requirement accepted as Mandatory IM2020 Usage Scenario (M.2083) @ WP5D Mtg# 28 Oct ‘17

5Gi Journey: Requirement -> Innovation -> Standard

Courtesy : "A Case for Large Cells for Affordable Rural Cellular Coverage", Saidhiraj Amuru, Radha Krishna Ganti et al.



Config A
- 700 MHz
- ISD 1.732km
- 120/500 km/h

Config B
- 4 GHz
- ISD 1.1732km
- 120/500 km/h

Existing rural models 3G, 4G, 5G

Config C (LMLC)
- 700 MHz
- ISD 6 km
- 3/30 km/h

New model 5G

3GPP 5G Standard + Indian Enhancements

To address Indian needs

Technical studies and finalization done in TSDSI

India Requirement

TSDSI's Low Mobility Large Cell (LMLC) Requirement incorporated as a mandatory Requirement at ITU in Q3 2017

TSDSI RIT (5Gi) approved as a IMT2020 Technology in (M.2150) in Feb 2021

5Gi Journey

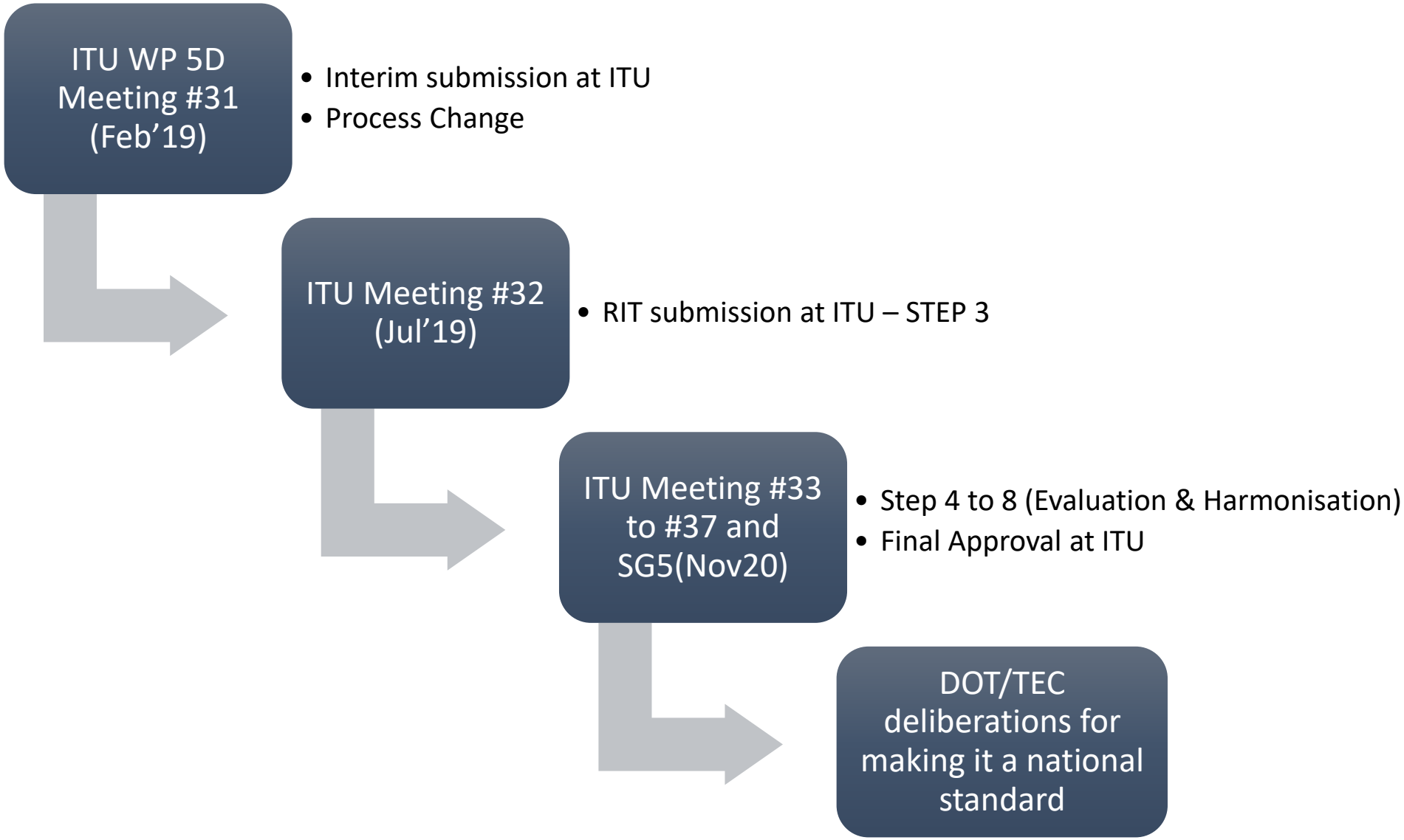
- 5Gi
  - TSDSI Radio Interface Technology (RIT)
  - Based on 3GPP 5G technology
    - Enhancements over 3GPP Release 15
- Provides larger coverage as compared to the 3GPP base specifications
- Supports
  - ITU Low Mobility Large Cell (LMLC) Test Configuration
  - Improved building penetration for NB-IoT

5Gi Solution – Pi/2 BPSK

- Uplink Transmission Limits define Cell Coverage Area
  - UE Tx Power in uplink limited to 23 dBm
    - Hardware Limitations
      - Battery size, PA sizing, Thermal limits and Cost Considerations
  - Uplink design crucial in enabling large coverage area cells
- Pi/2-BPSK Waveform
  - New waveform to increase Uplink Coverage
    - Valid for a cell radius of 6 km
  - Both for uplink Data (PUSCH) & Control (PUCCH) Channel
- Salient Properties of Pi/2-BPSK Waveform
  - Low Peak-to-Average Power Ratio (PAPR)
  - Resilient to Non-Linearities of Power Amplifier (PA)
  - Low-order Modulation Scheme, Tolerant to Distortions

Courtesy : "A Case for Large Cells for Affordable Rural Cellular Coverage", Saidhiraj Amuru, Radha Krishna Ganti, Kiran Kuchi, J Kluto Mileth, Bhaskar Ramamurthi, Journal of the Indian Institute of Sciences, April 2020

Incorporation of 5Gi Solution into the Standard



Benefits of 5Gi and Impact on Ecosystem

BENEFITS

- Rural coverage (exceeding ITU requirements)
- Affordable
  - Improved performance only with primarily software changes
  - Globally inter-operable and compatible
- Improved building penetration for NB-IoT: Important for smart cities mission
- Increases the number of supported users, the spectral efficiency and reduces signalling overhead

ECOSYSTEM IMPACT

Device

- Software changes
- Some vendors might change PA
  - Even then, high volumes in India should maintain price
- Fully inter-operable (roaming)

Infrastructure

- Only software changes
- Inter-operable with devices minus Indian enhancements

Testing

- One-time investment for additional testing
- Test equipment manufacturers to incorporate Indian enhancements
- Impact on cost of network or equipment negligible

Long-term benefits outweigh the initial work and one-time cost

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- “A Case for Large Cells for Affordable Rural Cellular Coverage”, Saidhiraj Amuru, Radha Krishna Ganti, Kiran Kuchi, J Kluto Mileth, Bhaskar Ramamurthi, Journal of the Indian Institute of Sciences, April 2020
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THANK YOU

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