



# “Frugal 5G”: Next Generation Wireless Systems!

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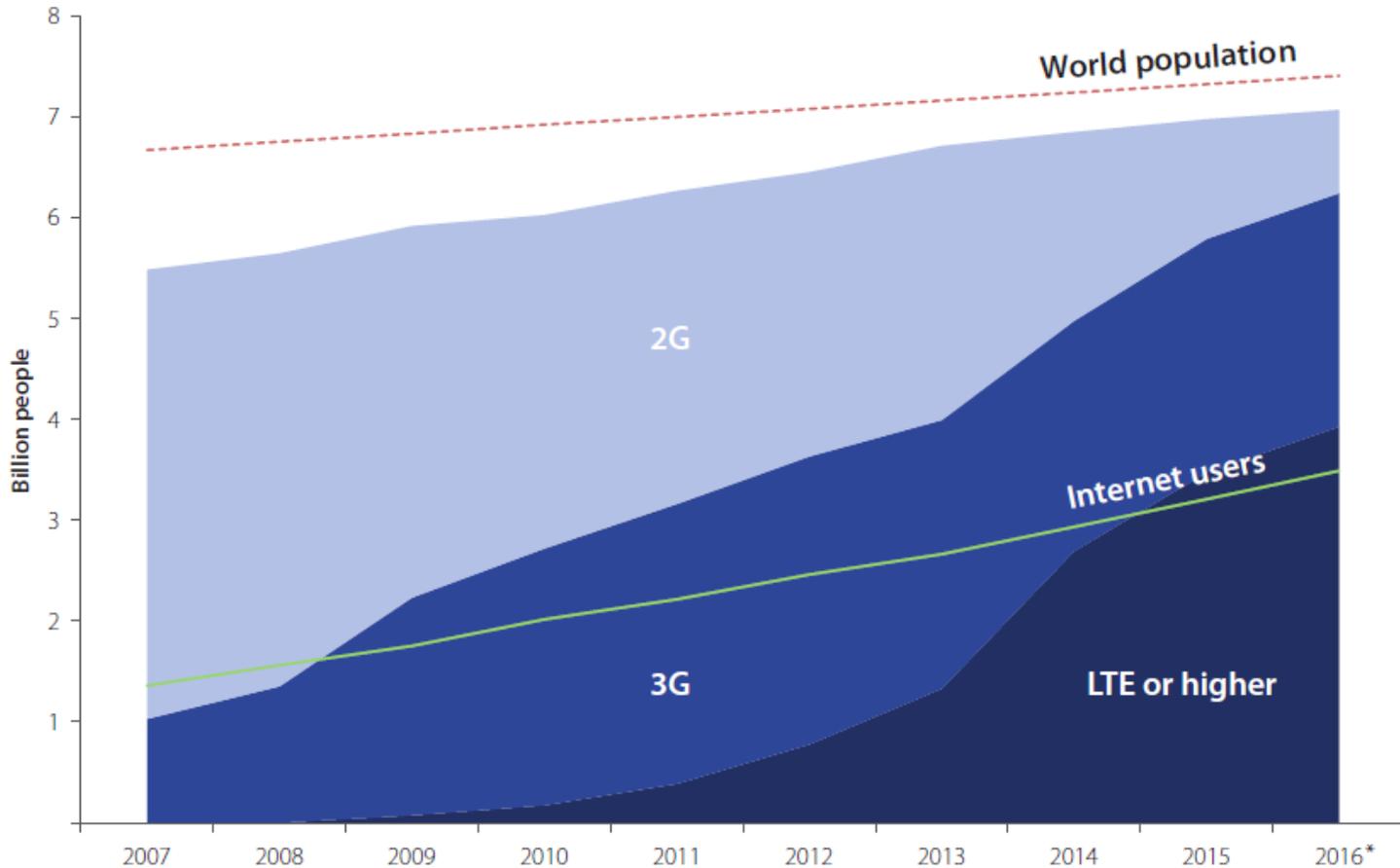
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# Outline of the Talk

- Broadband Penetration Status in India and Rest of the world
- Challenges in Affordable Broadband
- Re-thinking 5G Requirements for connecting the unconnected world
- Frugal 5G architecture with SDN based Middleware
  - SDN Control for Multi-RAT HetNet
- IEEE-SA Standards Activities

# Broadband Penetration Status: Worldwide

Around half of the global population is unconnected

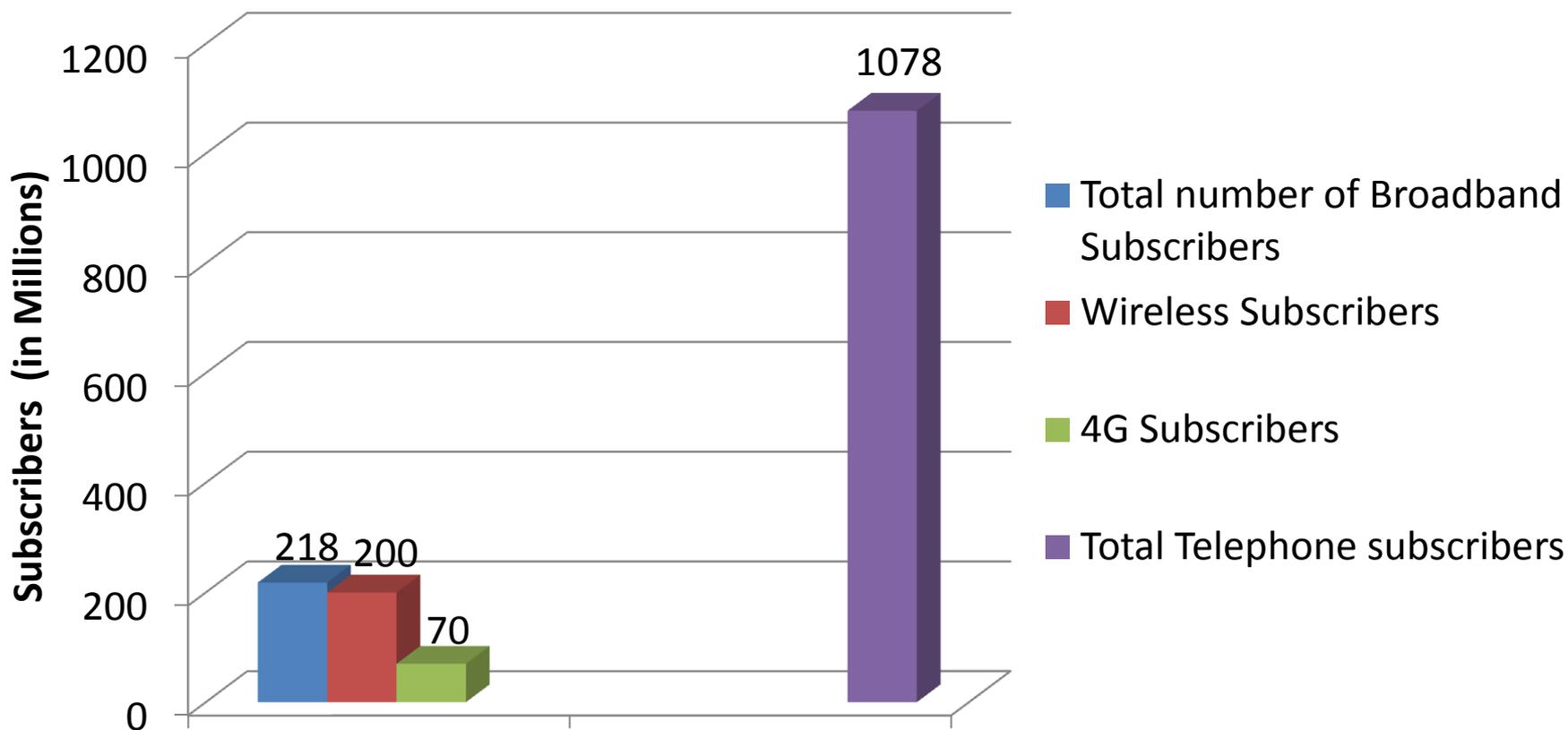


Source: International Telecommunication Union

**Around 84% of global population lives in regions covered by wireless broadband (3G/4G) but the adoption rate is only 47%**

# Broadband Penetration Status: Indian Scenario

As of 9<sup>th</sup> January, 2017



**Around 1 billion people do not have broadband access in India**

# Challenges in Connecting Rural India



Low Average Revenue Per User



Unavailability of Fiber Backhaul



Intermittant Availability of Electricity

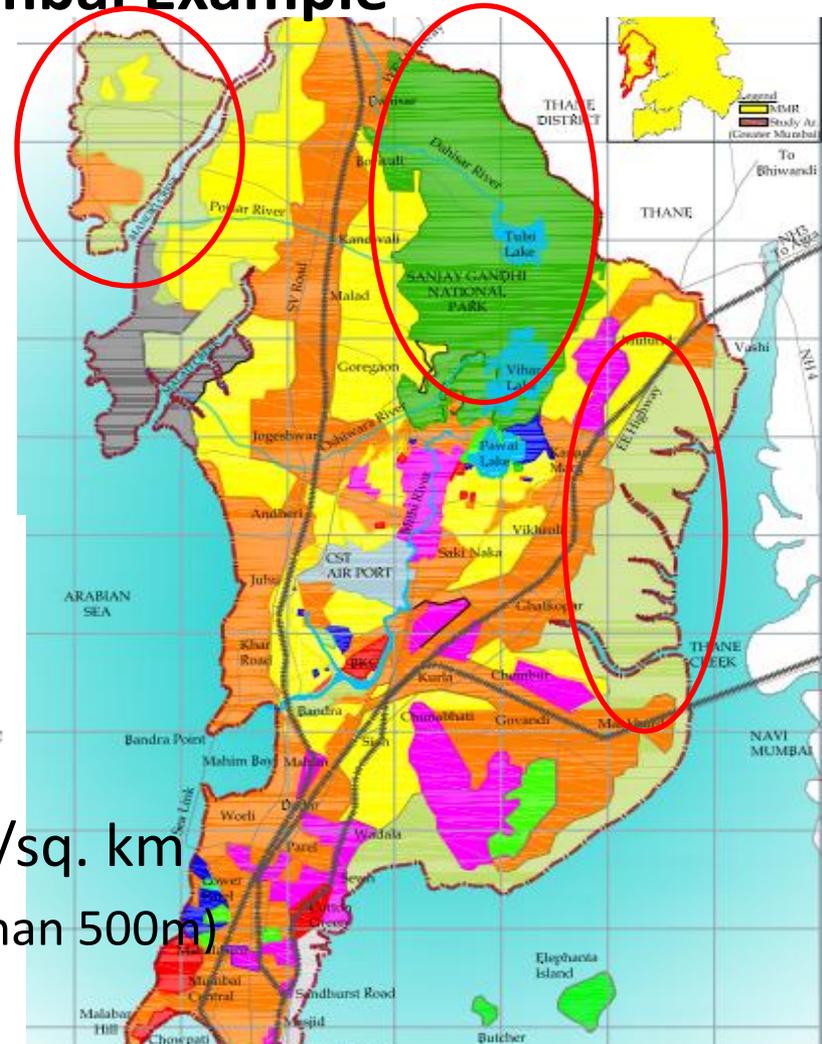
# Traffic Growth in India – 5G?

- India needs primary broadband connectivity to 250 M homes, for 250 GB/month being delivered at 2 Mbps
- Translates to 100 Exabytes per month for India alone which is 8x the expected global mobile traffic by 2017!!

# Future Wireless Broadband Demand

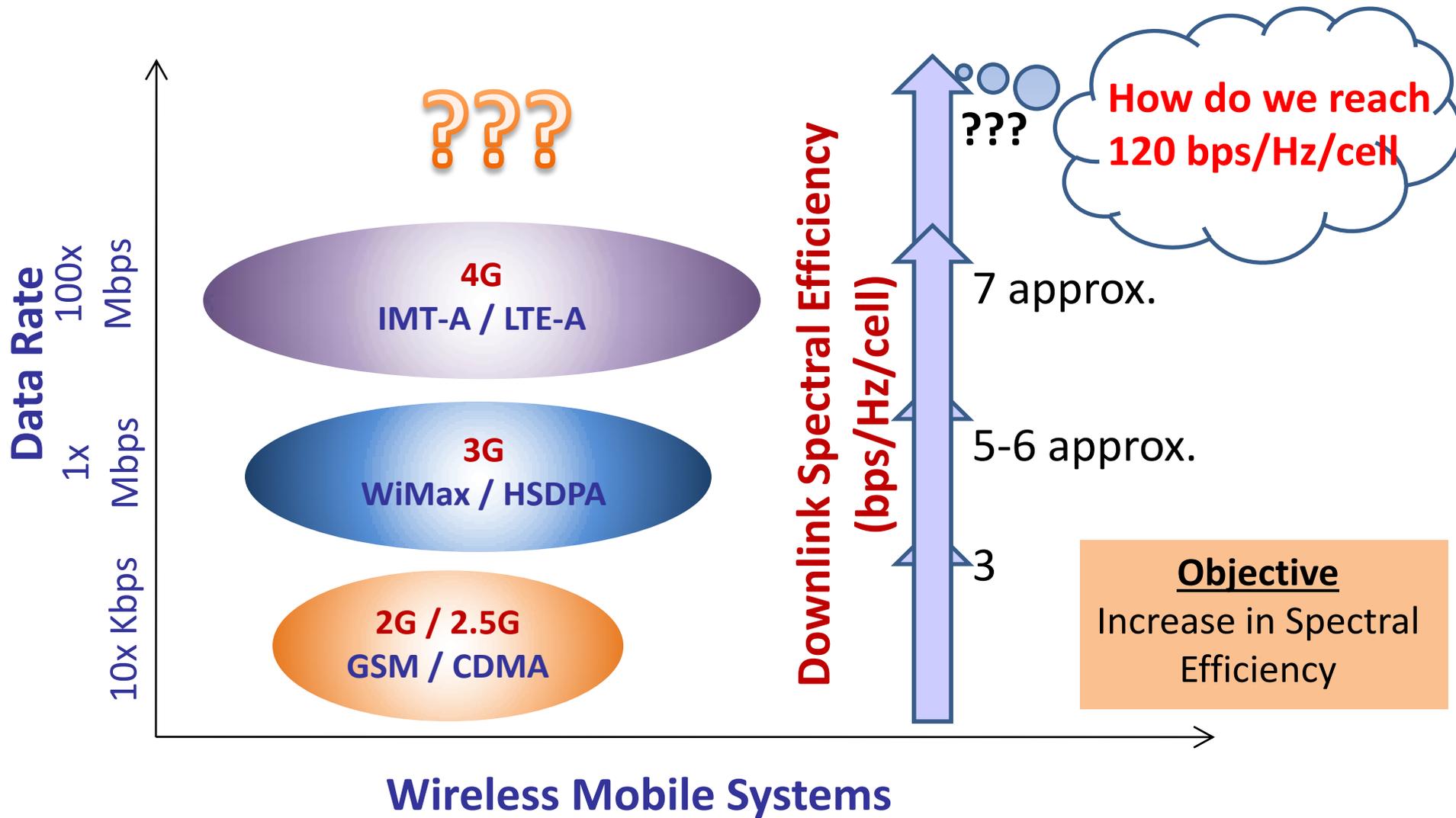
## Broadband through Wireless – Mumbai Example

- Population density – 21k/sq. km
- Approx 34% wet land and forests
- Actual population density ~ 90-100k/sq. km in some areas or even more
- 25k households/sq. km
- Assume 100% households have broadband
- 2 Mbps per household
- Very high capacity required: 50Gbps/sq. km
  - Assuming 3-4 cells/sq. km (radius less than 500m)
  - We need about 12 Gbps per cell



**With 100 MHz per cell (multiple operators and multiple technologies) ~ whopping 120 bps/Hz/cell !!!**

# Evolution of Wireless Systems

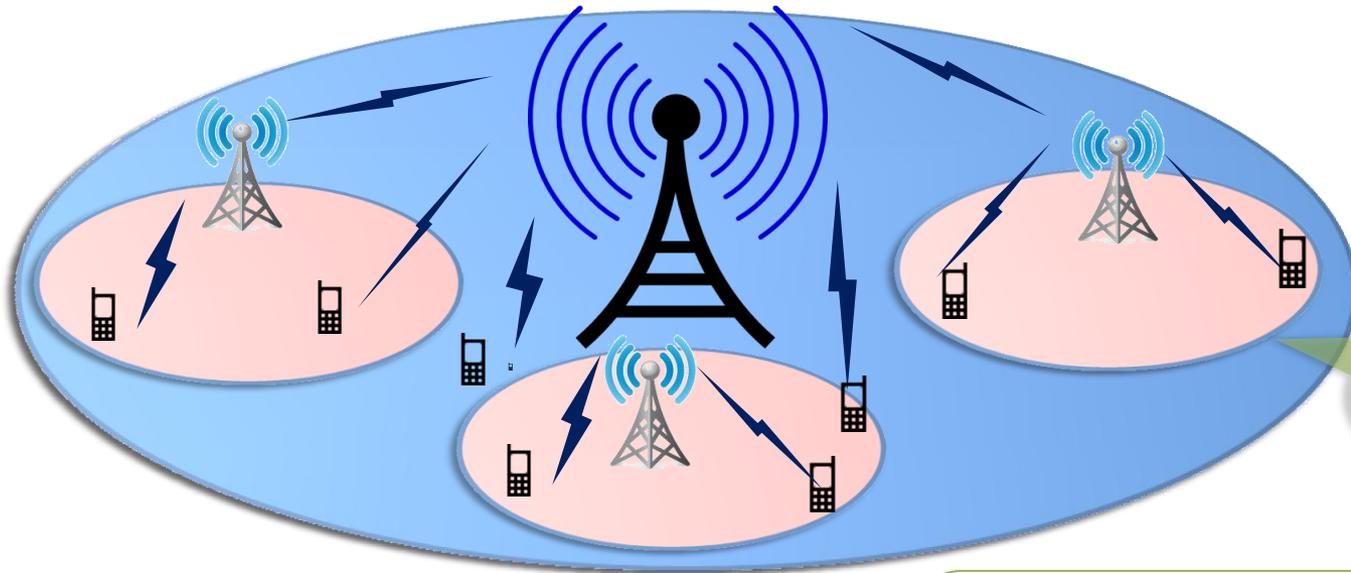


# Small Cells

Macro Cell

## Macro Cells

- Cover radius of 500m to 1km
- High transmit power (46dBm / 40W)
- Low spectral efficiency



Small Cell

## Small Cells

- Cover very small radius ( $< 100\text{m}$ )
- Lower Transmit Power! (30dBm/1W)
- High Spectral Capacity

# Small Cell Enablers

- Cellular Technology Small Cells
  - 3GPP technologies like UMTS / LTE / LTE-A and beyond
- Fixed Wireless Access solutions
  - IEEE technologies like IEEE 802.11 and its variants

**Challenge:** Effective Management and Control  
of Large Scale WiFi deployments

# What does India need for 5G?

- Can we have more efficient use of spectrum?
  - Cost is transferred to end-customer
  - Makes the solution unaffordable
- Do we need to support high-speed mobility (300 km/h)?
  - in cities 40-60 km/h; 80-100 km/h on highways
  - Mobility is required but Fixed Primary Access is key
- Do we need to address multiple device connectivity?
  - Urgent need is for primary broadband connectivity

**We need a focussed and cost-effective solution!**

# Rethinking 5G Requirements

- Low cost solutions
  - Low Device costs
    - Simpler Hardware and RF Design reducing the device costs
  - Low cost Connectivity / backhaul solutions
    - Using wireless backhaul/middle mile instead of fiber
  - Lower spectrum cost
    - Efficient usage of spectrum
    - Using network sharing options to share spectrum across Radio Access Technologies (RATs) across operators
- Limited mobility support
  - Mobility is required but not very high speed
  - Fixed primary access is the key

# Rethinking 5G Requirements (Contd.)

- Energy efficient solutions
  - Lowering system energy consumption
  - Support for operation in power saving mode
  - To enable working off non-conventional energy sources
- Large coverage area support
  - Support for large cells to reduce CAPEX and OPEX
- Less stringent availability requirements

**Low Cost**

**Low Mobility**

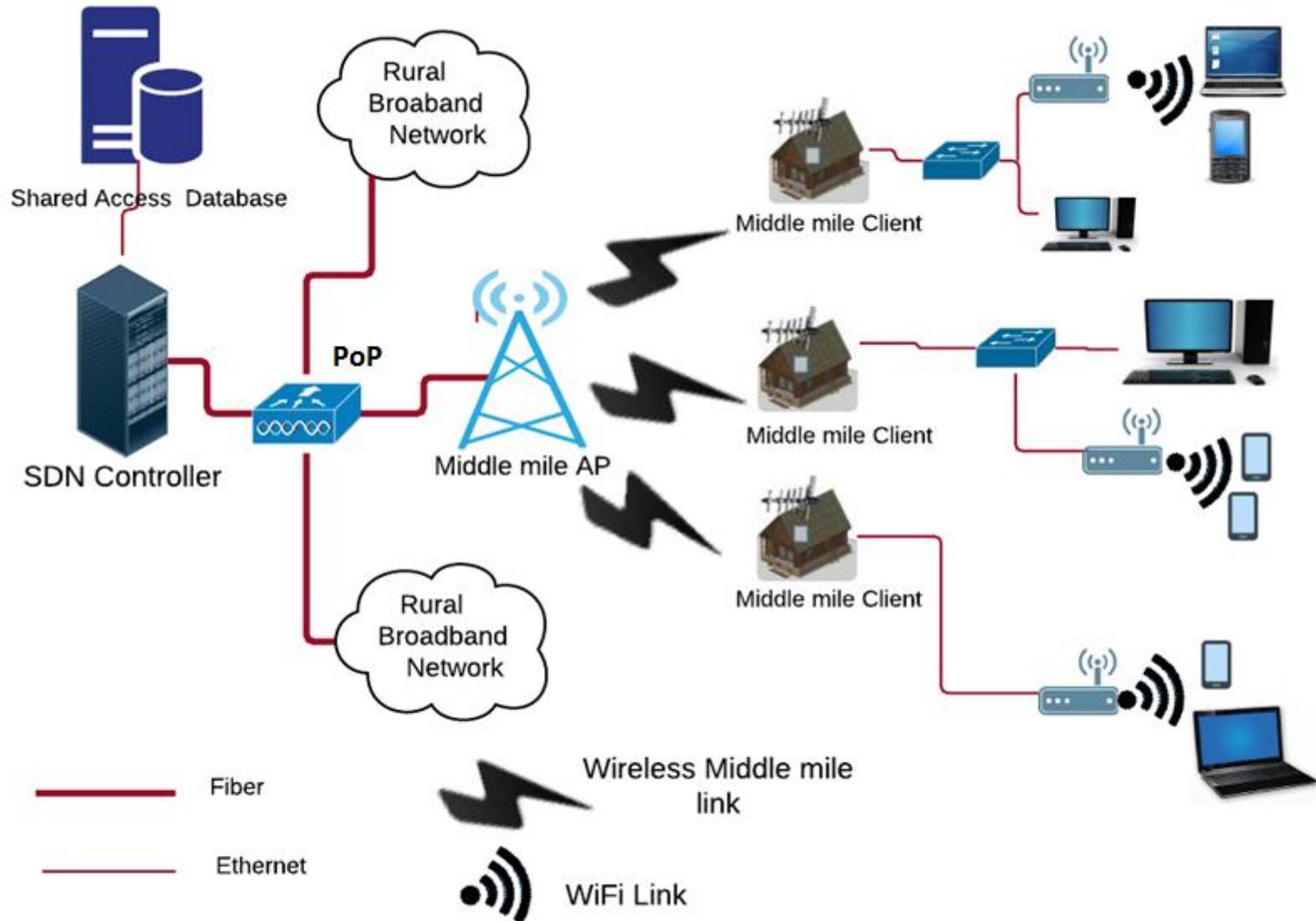
**Large Coverage**



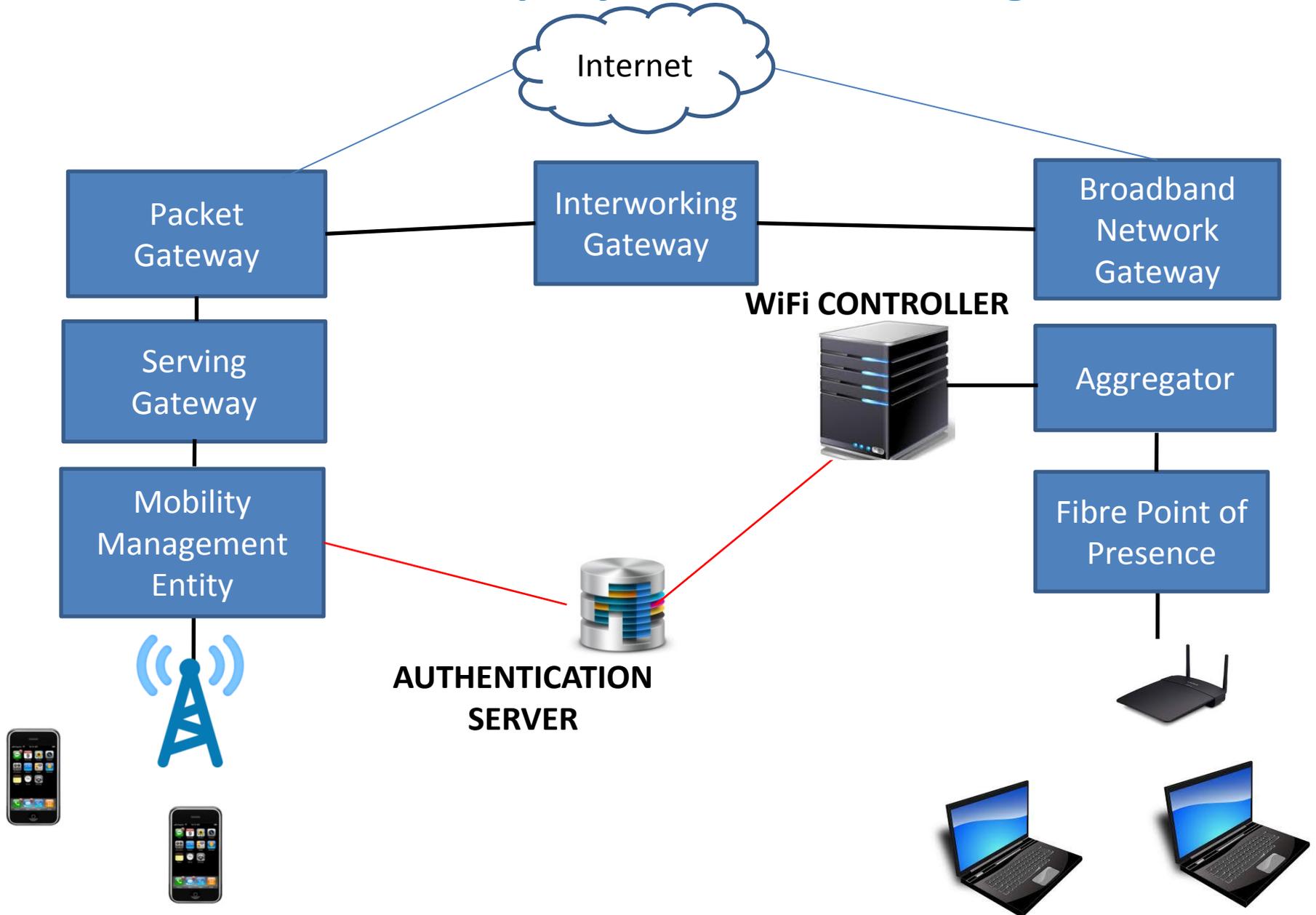
**Frugal 5G**



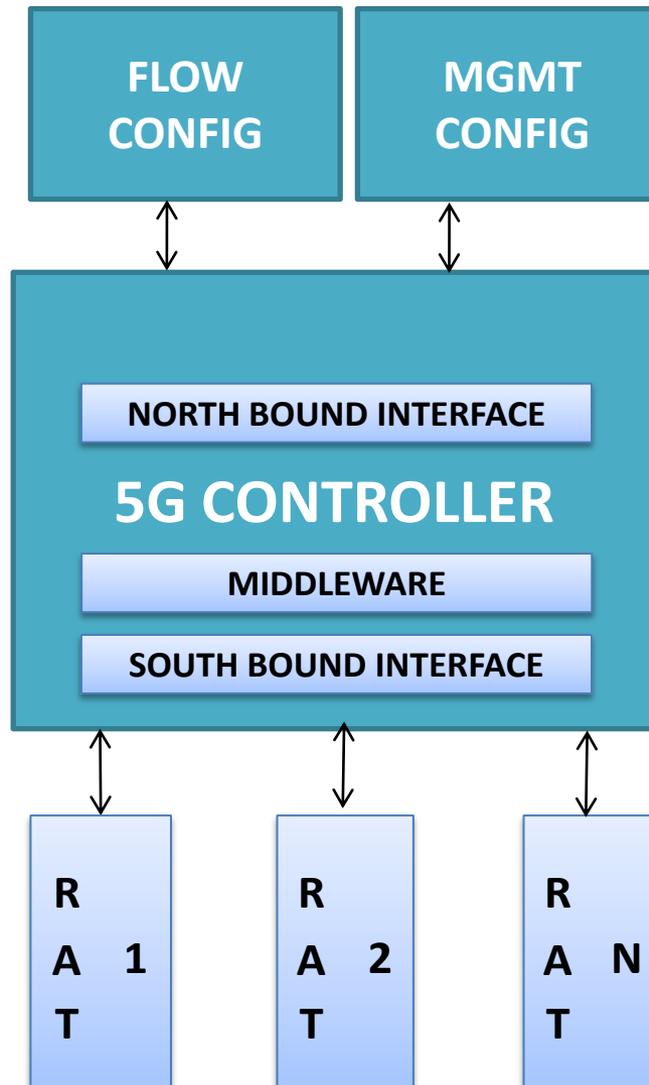
# Frugal 5G – Envisioned Architecture



# Multi-RAT HetNet Deployments in Existing Networks



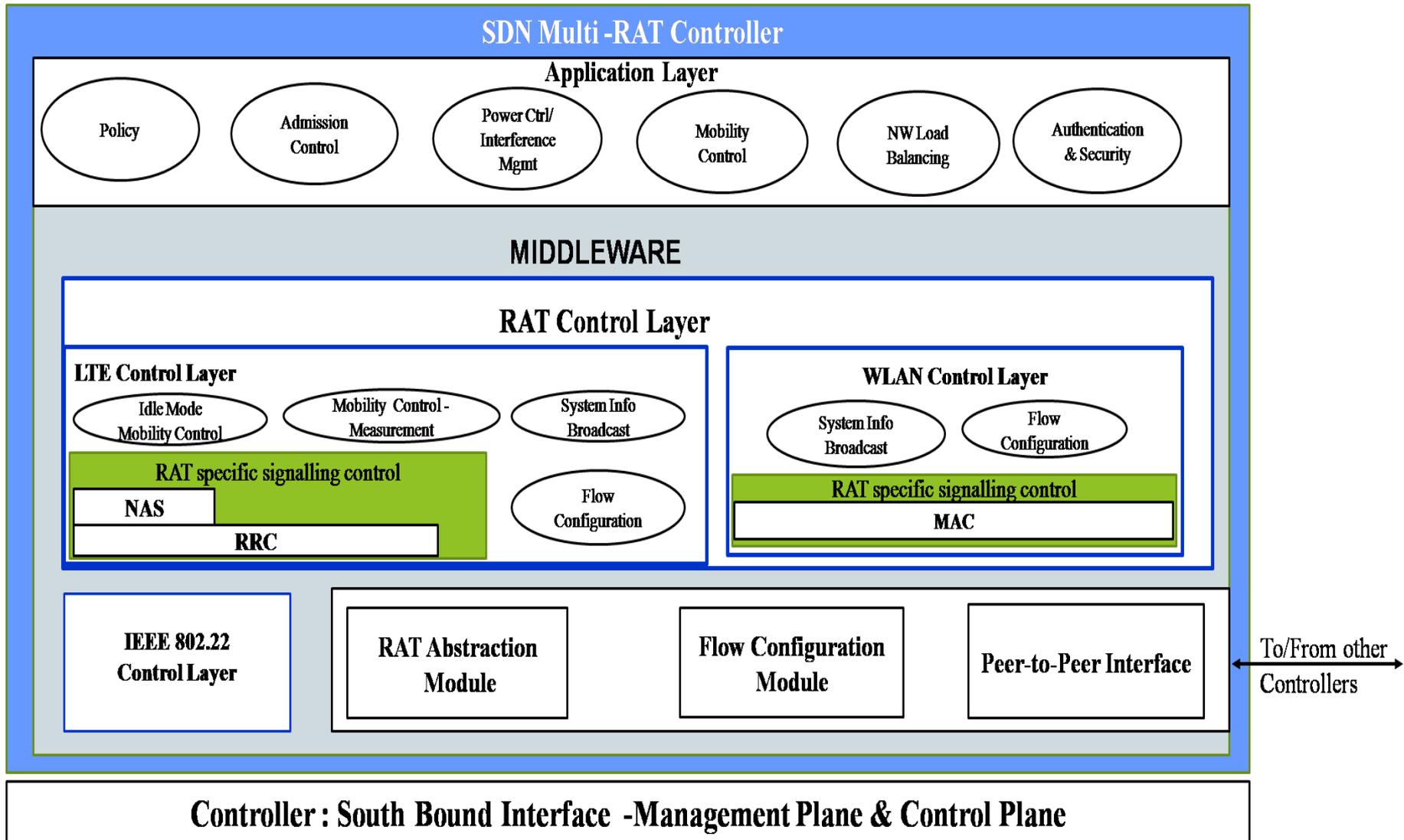
# Proposed 5G SDN Architecture



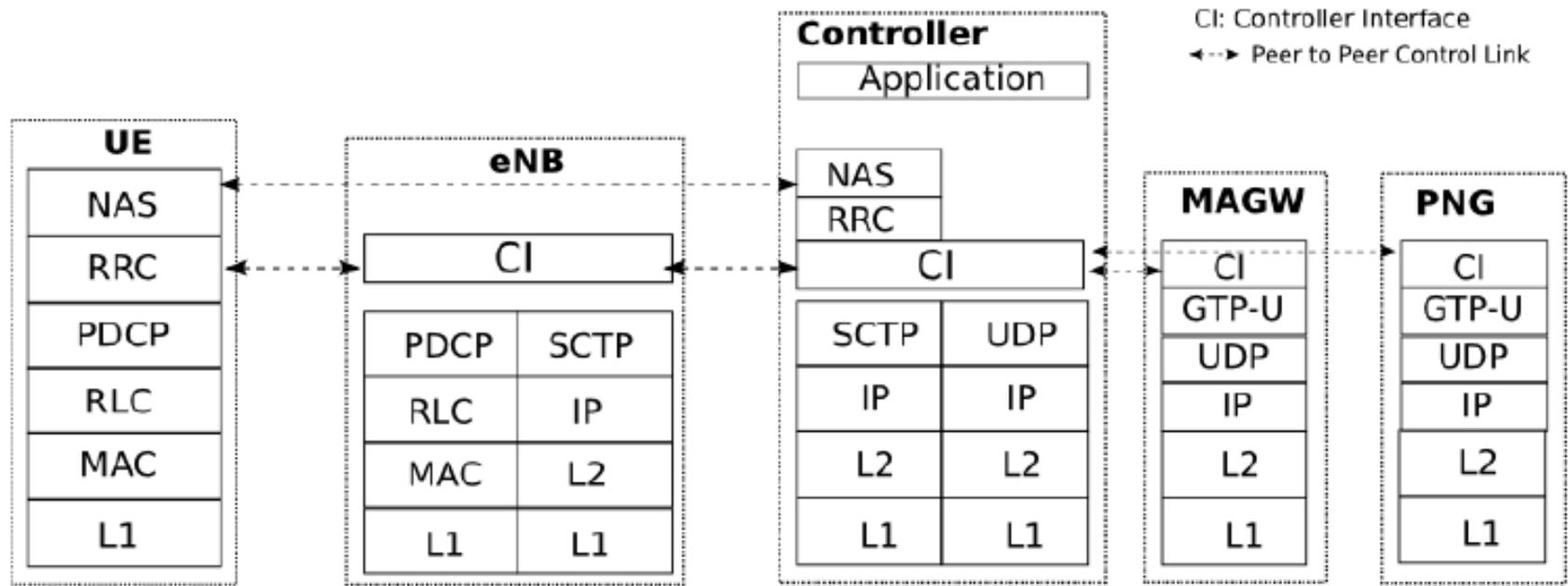
# SND Multi-RAT HetNet Architecture

- Unified SDN controller for control and management of different RATs without UE side changes
  - Network traffic can be better regulated
  - Interoperability across equipment vendors is achieved
  - Load balancing and interference management can be done in a better manner
- Patents Filed
  - **“Methods and systems for controlling a SDN-based multi-RAT communication network”**
    - US Patent Application no - **15/582145**
    - Indian Patent Application no – **201721008015**

# Proposed Multi RAT Controller Architecture<sup>+</sup>



# Proposed SDN based LTE Architecture



- S1-AP layer of eNB protocol stack is removed
- Radio Resource Control (RRC) and Radio Resource Management (RRM) centralized at the controller
- Control functionality of gateways moved to Controller
- Policies are implemented as a service over the controller

# IEEE ComSoc Project P1930.1–Initiated by our group

- “Recommended Practice for Software Defined Networking (SDN) based Middleware for Control and Management of Wireless Networks”
- Standardization of the middleware between the Controller and IEEE Wireless Networks
  - Interoperability between Controller and BSs of different vendors
  - Application development by third-party vendors
- <https://standards.ieee.org/develop/project/1930.1.html>

# Motivation for IEEE P1930.1

- An open standard for SDN based middleware to control and manage the wireless networks (IEEE WLAN, WRAN) would
  - Facilitate the development of interoperable equipment by different vendors
  - Enable rapid deployment of these networks and faster introduction of new services
- Shall bring in additional advantages of SDN paradigm to IEEE WLANs and WRANs
  - Dynamic control of the Access Points(and Base Stations) through programmable open interfaces
  - Optimized resource utilization & granular control over deployment of policies/services in the network
  - Such a standard may also enable seamless integration with non-IEEE radio access technologies within SDN framework

# Frugal 5G – IEEE ComSoc RRSA Study

- Study & analysis of existing wireless broadband technologies
  - IEEE 802.11 WLAN, IEEE 802.22 WRAN, 3GPP-UMTS, 3GPP-LTE
  - Gap analysis with respect to following requirements
    - Low Cost Solution
    - Reduced Energy Consumption
    - Low Mobility scenarios
    - Usage of non-conventional energy sources

# Frugal 5G – RRSA Study Phase(Contd.)

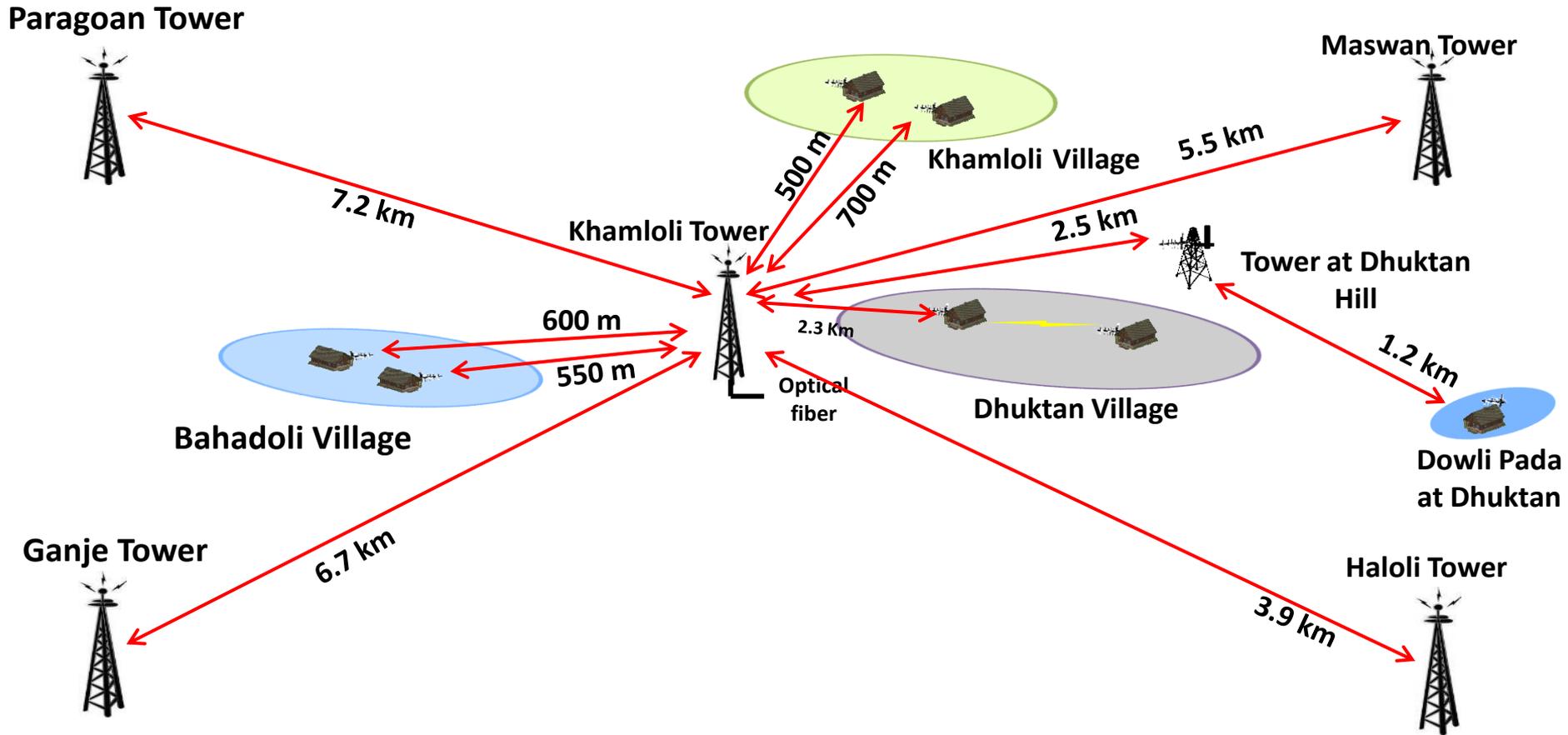
- Usage of affordable Wireless middle-mile network to connect the core network to IEEE 802.11 based access network
  - TV UHF spectrum based solution
  - Mesh network in mmWave
- Dynamic spectrum sharing for multi-operator co-existence
- Scalable control and management of access and middle mile network
  - Software defined network (SDN) based control and management
  - A simplified IP based network architecture



**GRAM MARG**

Enabling Rural India Digitally

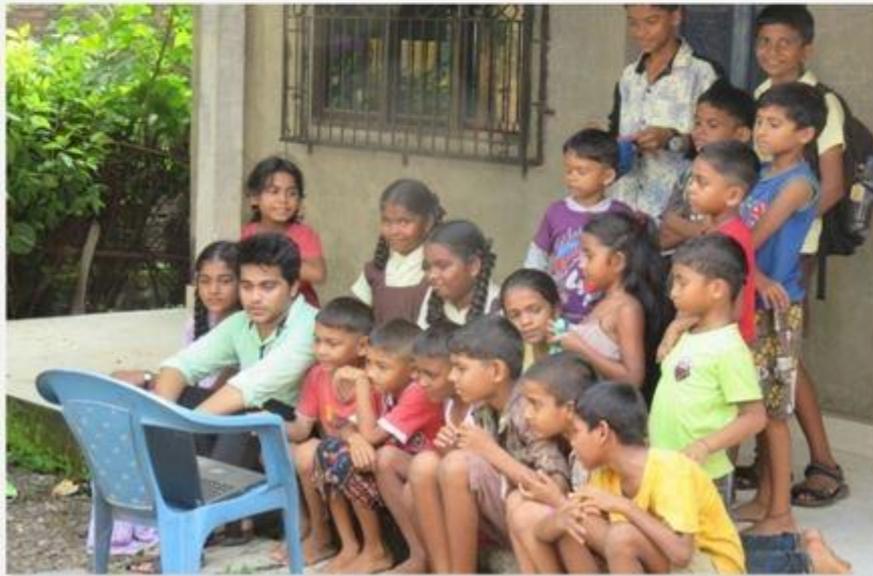
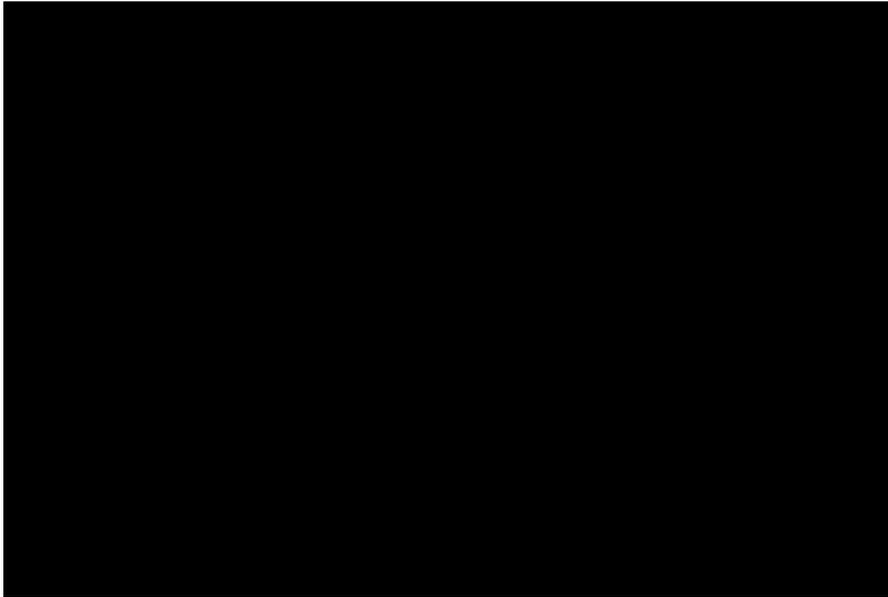
# Network Topology of UHF TV Band Pilot at Palghar



# Our Deployment on Field



# Villagers using Internet in Palghar



# Meet our Team



**Thank you**