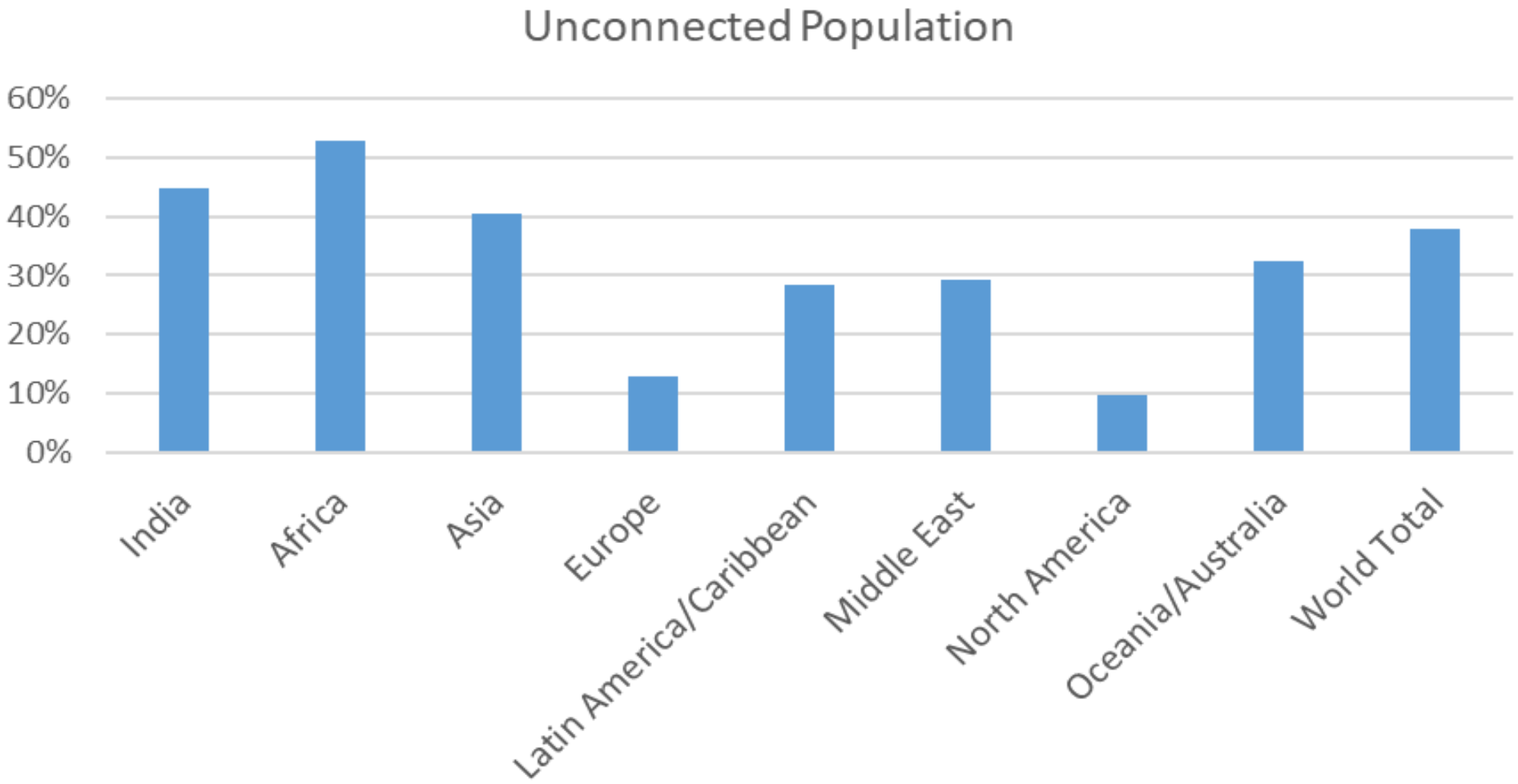
Rural Broadband Communication

Frugal 5G Network

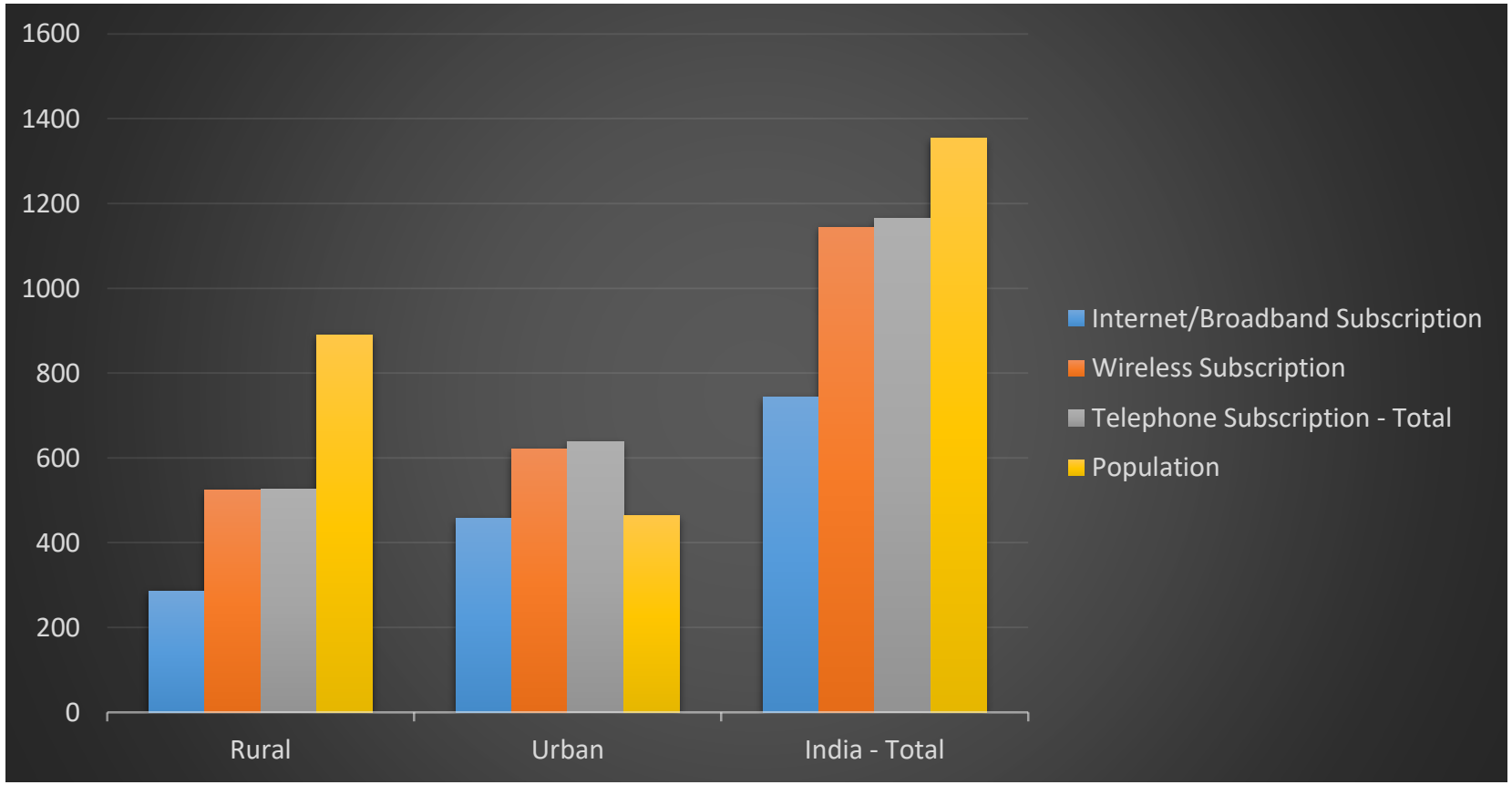
Internet Connectivity Status: Worldwide



~40% of the world population is unconnected - Majority in Developing World and in Rural Areas

Source: https://www.internetworldstats.com/ - October 2020

Internet/Broadband Penetration Status: India

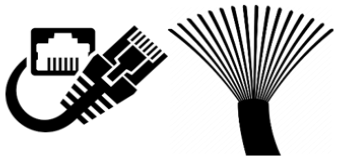


~610 million people (45%) do not have Broadband/Internet access

Source: Telecom Regulatory Authority India, October 2020 Report

Internet/Broadband Access- How is it enabled?

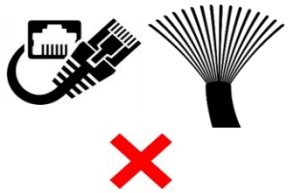
Developed Countries



Mostly enabled through wired communication infrastructure, Fiber and DSL

Developing Countries

Cellular Technology - Primary broadband access mechanism



Fiber/DSL Infrastructure - Inadequate

Challenges in using Cellular Technology in Rural Areas

1. Existing/Emerging Cellular Technology Standards

- Focused on urban usage scenarios
  - Key Targets for 5G : 20 Gbps rate, 1 ms latency, 500 km/h mobility
- Challenges and Characteristics of Rural Connectivity
  - Not factored in specification and design
- Variations in use cases across regions, countries, continents ignored

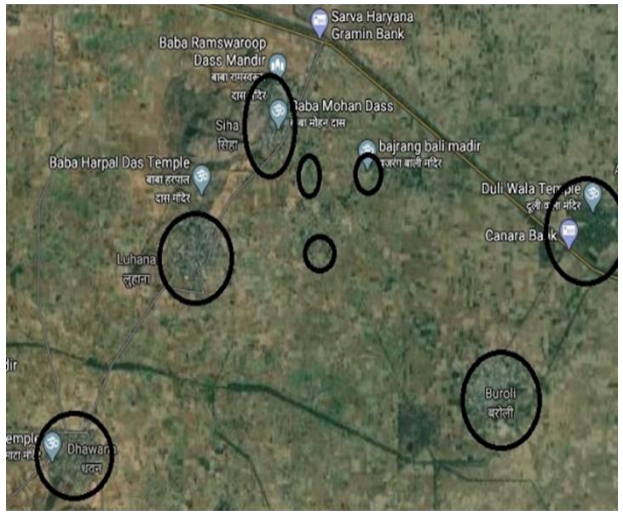
2. Operators Roll our networks in urban/semi-urban areas

- No compelling commercial reason for them to target rural areas

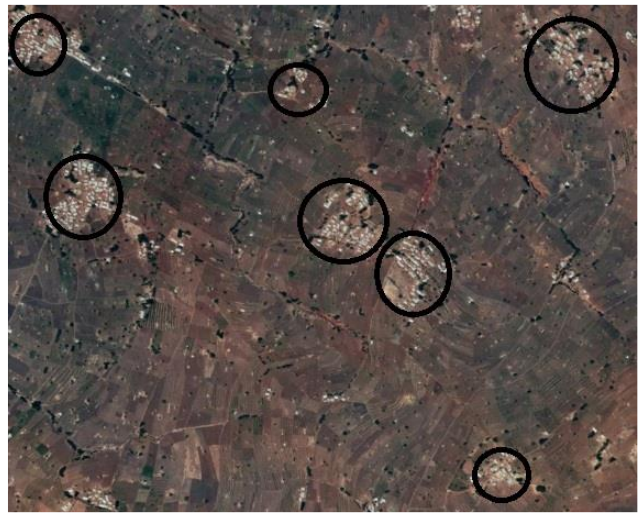
Connecting the Unconnected - Challenges

- Sparsely Populated (as shown in the figure)
  - Not typical to Africa or India
  - Other continents and countries similar
- Remote and Difficult to Reach Regions
  - Not all but a significant %
- High CAPEX & OPEX
  - Spectrum Cost
  - Cost of Backhaul

Rural Settlements



India



Ethiopia

Source: Google Earth
(Circles denote habited areas, Rest of the areas have no population)

Connecting the Unconnected – Challenges contd.

- Scarcity of Resources
  - Uninterrupted Electric Power Supply from the grid
- Low Average Revenue per user
- Access Constraints
  - Right of Way
- Challenges of Manageability
  - Unavailability of Trained Manpower
- Relevance of Content
  - Most Content on Internet is in English and a handful of other Languages

Rethinking 5G Requirements for Rural Areas

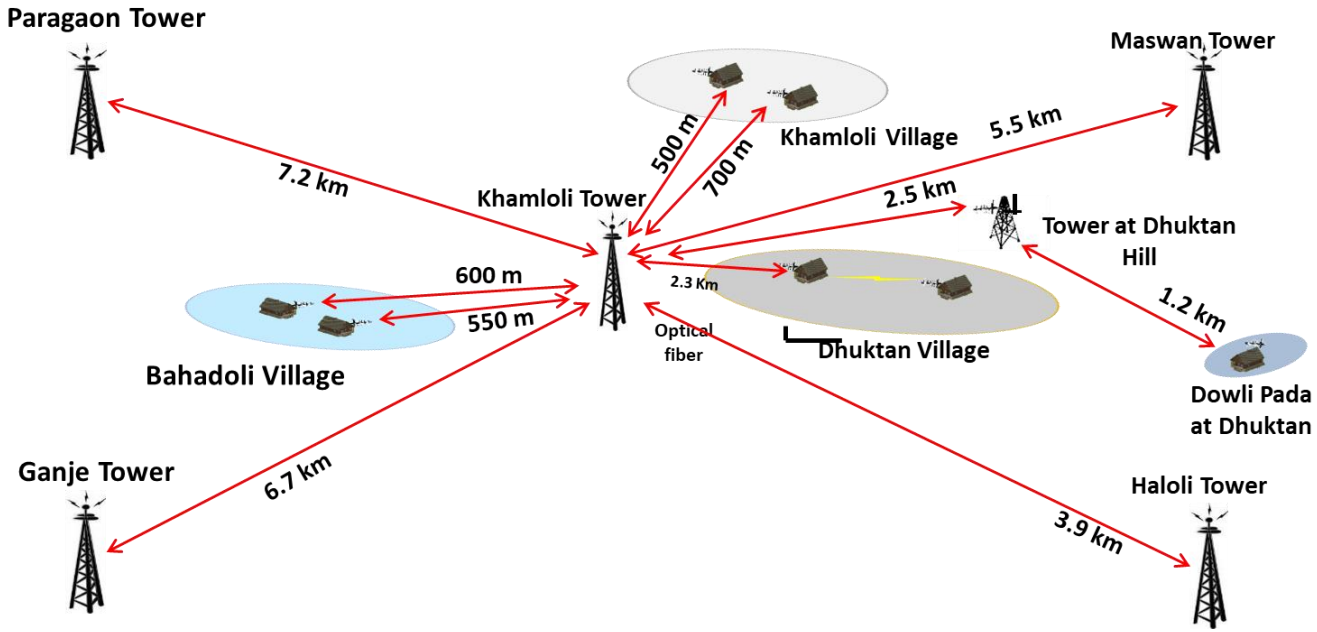
- Low cost Solution
  - Low Cost Backhaul Solutions
    - Wireless backhaul instead of Fiber
  - Lower Spectrum Cost
    - Unlicensed Spectrum wherever possible
- Limited Mobility Support
  - High-Speed Mobility Not Required
    - Small no of vehicles in Rural Areas
    - Slow moving vehicles
  - Fixed Access is the Key
- Large Coverage Area Support
- Energy Efficient Solution

Frugal 5G Networks (IEEE P 2061)

Vision of providing broadband access to rural areas by addressing these Requirements

Learnings from Our Palghar Testbed (Maharashtra, India)

- TV UHF band (470-590 MHz)
  - Largely Underutilized in India
- TV UHF band for Backhaul
  - Covers Large distances
  - Non-line-of-sight links can be formed
  - Low Power consumption
    - 5–10 W in our testbed
    - Can be powered via Solar Energy
  - Throughput - 6-15 Mbps in 5MHz
- Wi-Fi for Access in Villages
  - Cost Effective
  - Easy to Manage



Frugal 5G Network Architecture - Features

Large Coverage Area Cells to provide Ubiquitous Connectivity

Small Cells (WiFi Hotspots) as high speed Access Points

Wireless Middle Mile Network to Backhaul Data

Point to Point Wireless links to connect the nodes in Villages

SDN based unified control

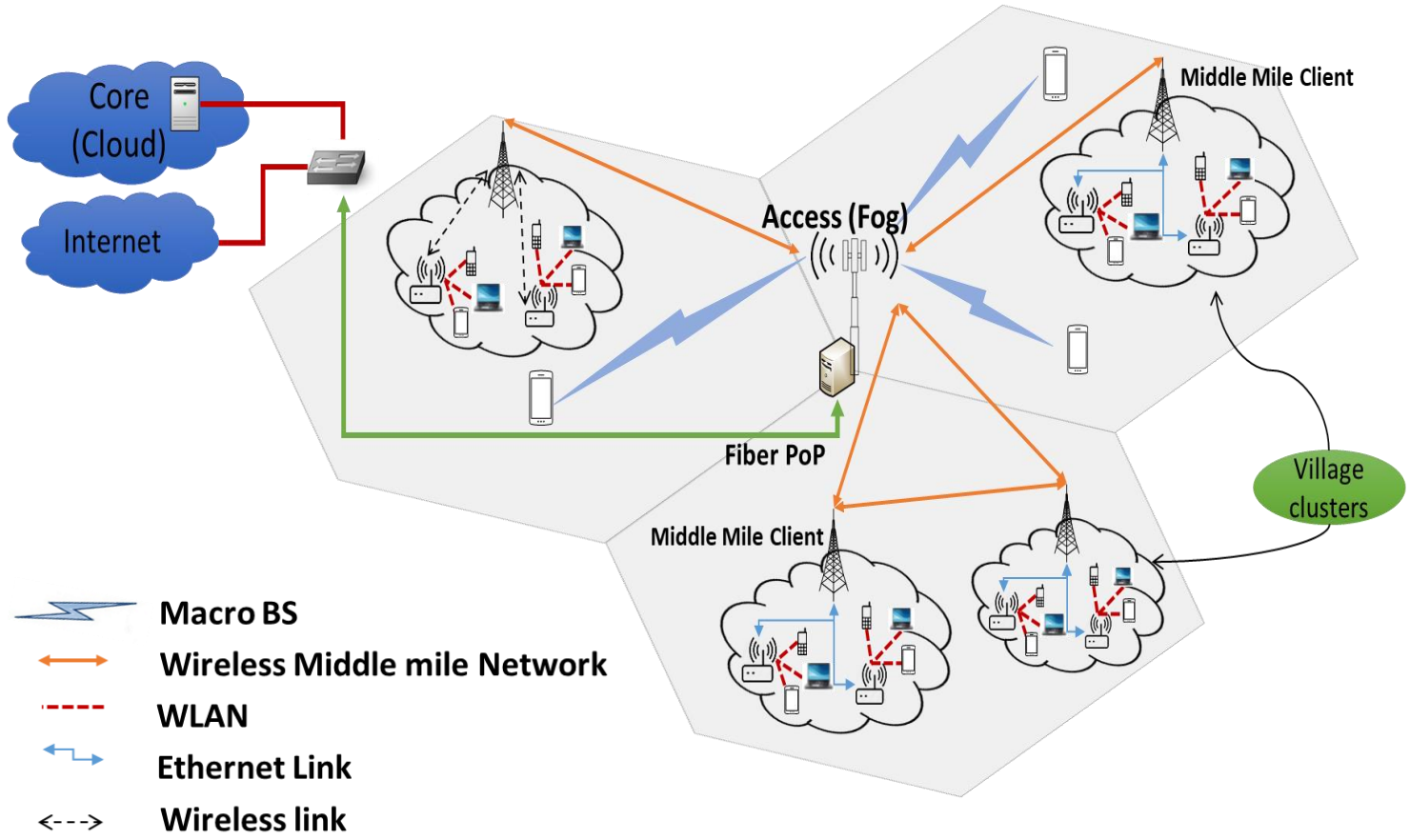
- Efficient Service Delivery
- Independent Evolution & Development of Control & Data Plane Entities

Usage of Virtual Network Functions

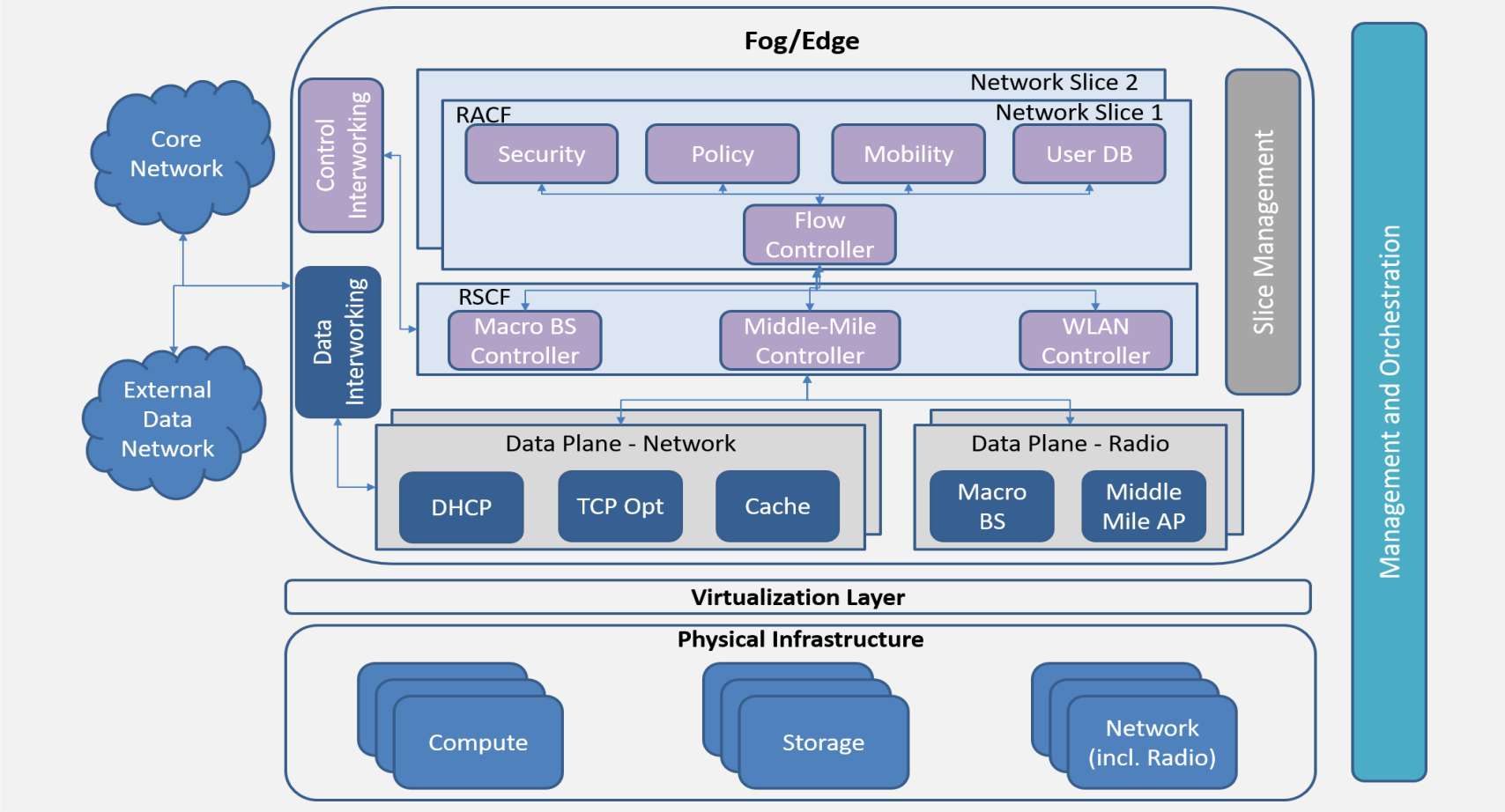
- Cost-effective System

Intelligence at the Edge

- Enables Local Communication
- Reduces Resource Usage



Frugal 5G Network Architecture – Edge Components



Hierarchical SDN based control of the multi-RAT network

RAT Specific Control Functions:

- Provides an abstract view of underlying RAN to higher level control entities;
- Enables unified control of multi-RAT network;
- Enables RAN virtualization and Network Slicing

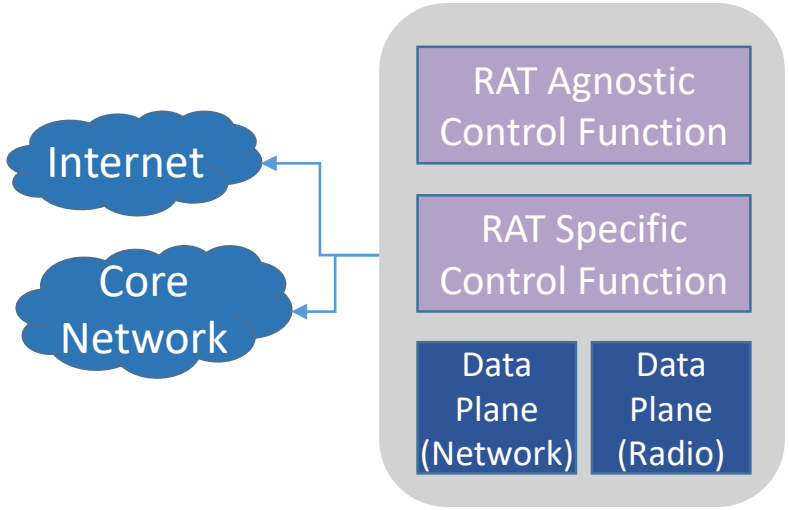
RAT Agnostic Control Functions:

- Operates over abstract resources provided by RSCFs;
- Analyses individual traffic flows and acts on it with help from other RACFs;
- Enables localized communication under fog element

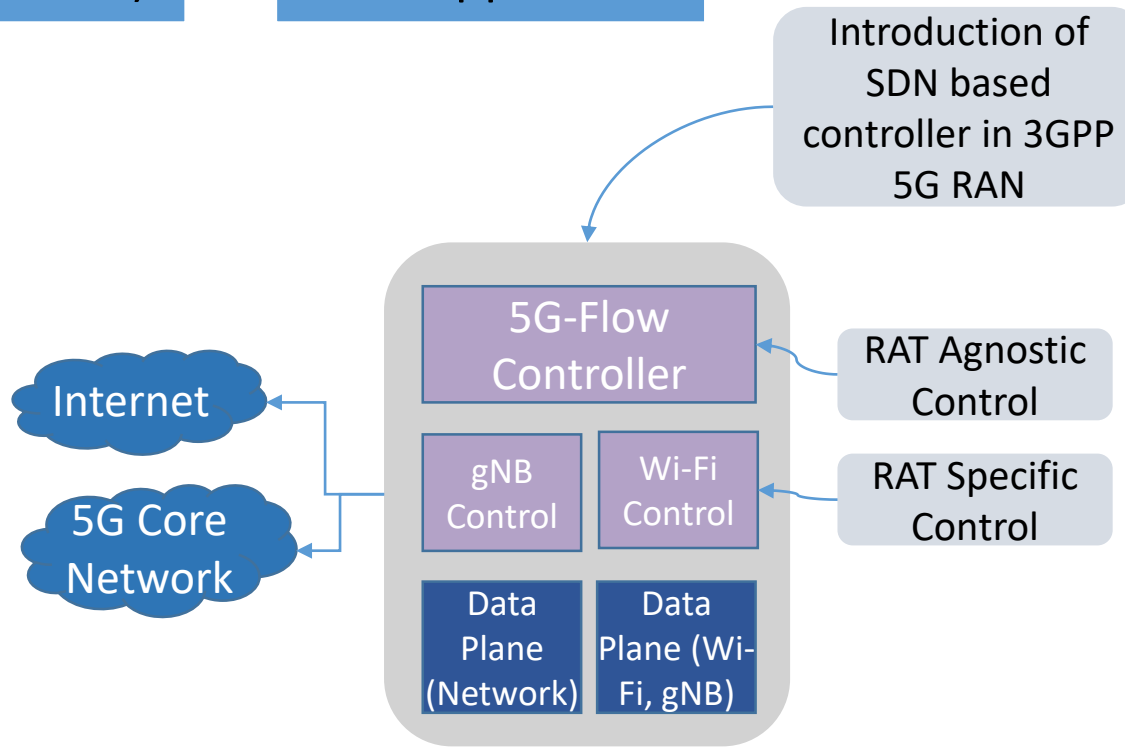
5G-Flow: Realizing Frugal-5G Architecture using 3GPP 5G

Desired Network Characteristics

- SDN Based Unified Access Control at Edge
- Direct Internet Connectivity from RAN (w/o Core)
- Local Communication Support



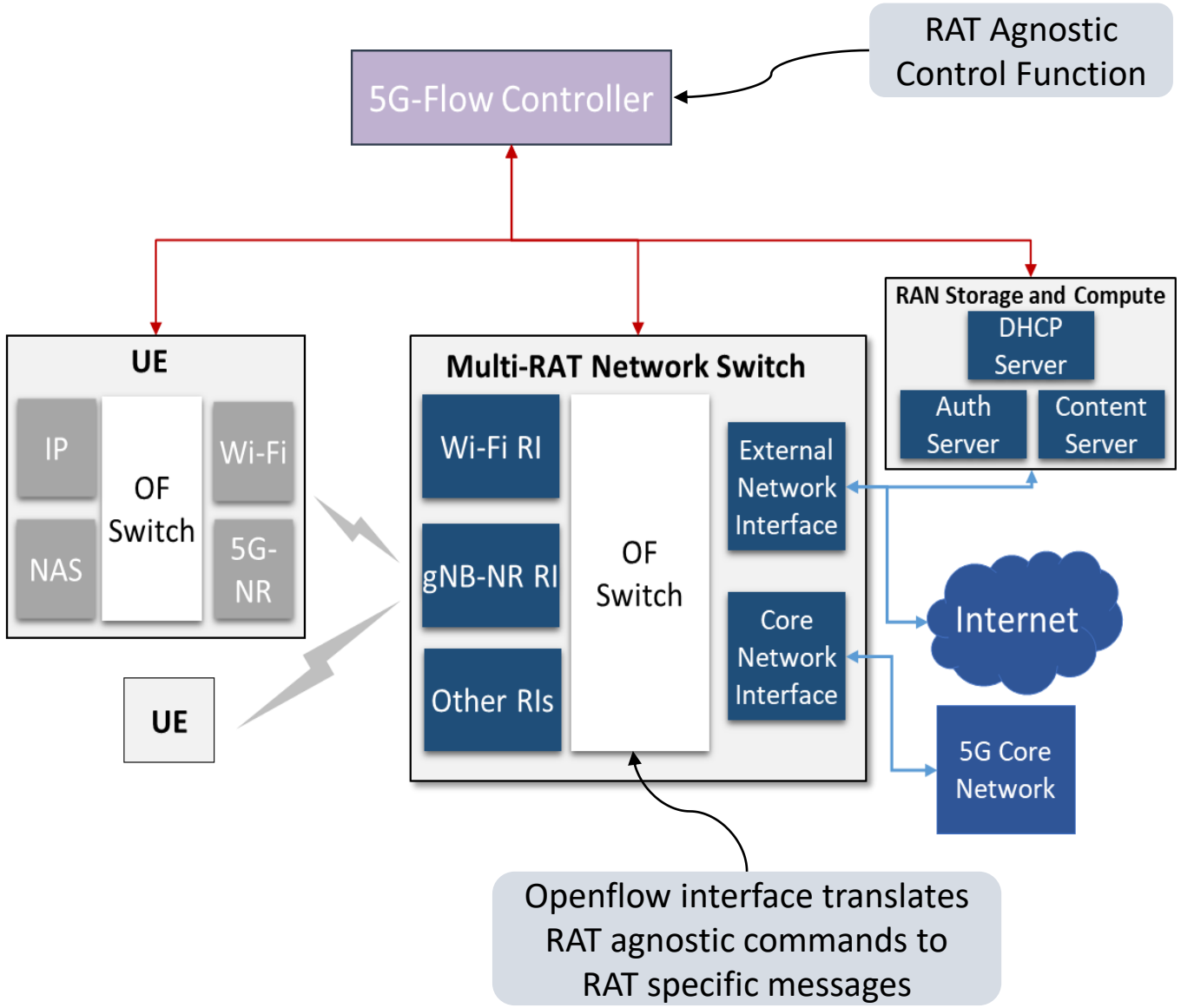
Frugal 5G Network (Edge Component)



5G-Flow: Implementing Frugal 5G concepts at 3GPP 5G RAN

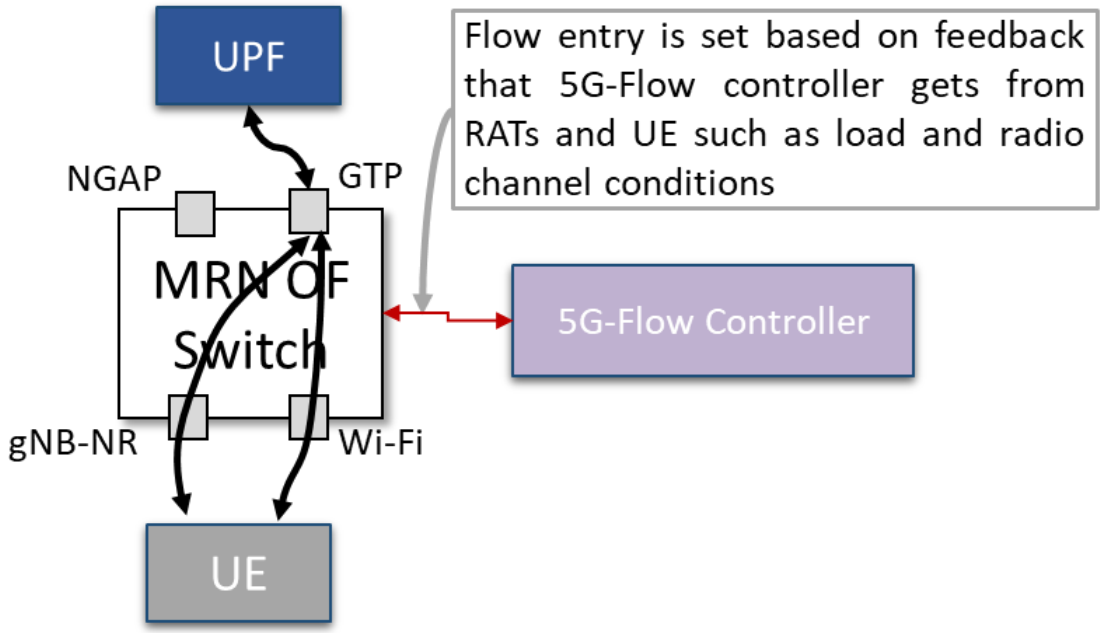
5G-Flow – Unified Multi-RAT RAN

- Logically Centralized Multi-RAT RAN Control
  - Light-weight OF (5G-Flow) Controller for Unified Control
- Decoupled Protocol Stacks at RAN Nodes and UE
  - CN and Radio Interface Stacks Decoupled
- OF-Switch based Unified Multi-RAT RAN Data Plane
  - Protocol Stacks used as Interfaces of an OF Switch
  - Even NAS Signaling Exchange treated as data passing through an OF-Switch



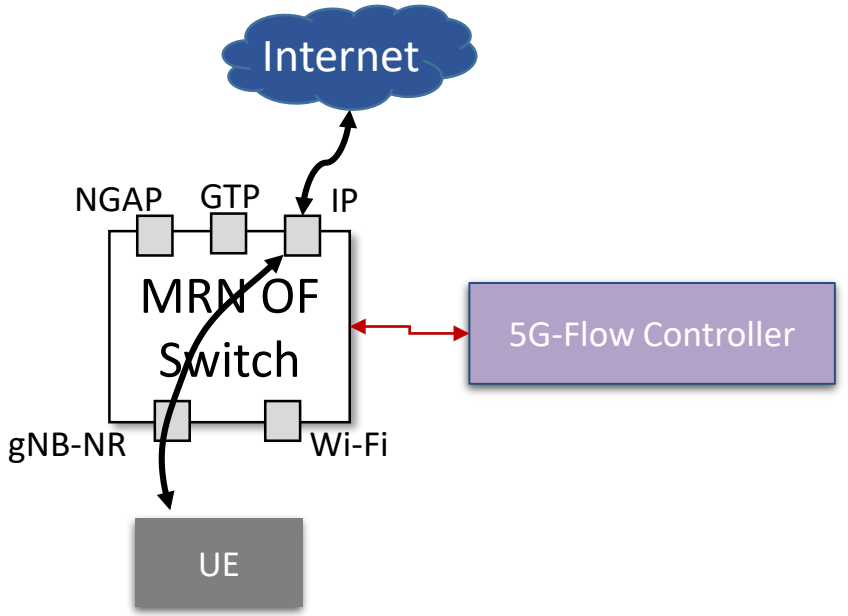
5G-Flow Capabilities - Unified Access Control at RAN

- Existing 3GPP 5G Network handicapped by limited RAN-level Information
- 5G-Flow enables RAN level management
- Full visibility into Radio Link Information
  - Exploits it for Data Flow Management
  - Can be used for other applications such as dynamic spectrum sharing



5G-Flow Capabilities - Direct Connectivity to Internet

- Existing Cellular Technologies, e.g., LTE/5G NR requires support of Core Network
  - Can not work in a standalone manner without CN
- 5G-Flow Network Architecture allows Usage of Cellular Technologies (5G NR…) without involving CN
  - UE's connectivity with RAN is decoupled from it's connectivity with CN
  - 5G-Flow controller sets up the flow entry and creates radio bearer at RAN to enable direct connectivity with Internet



Conclusion

- Proposed an abstract architecture (Frugal 5G) for rural broadband network; Implemented Frugal 5G using 3GPP 5G Network
  - Unified Access Control
  - Direct Internet Connectivity from RAN (w/o Core)
  - Integration of Middle-mile and Access Network
  - Local Communication Support
    - End-to-end data path may be fully contained within a single edge/fog element
    - Reduced end-to-end latency
- IEEE P2061 Standardization
  - Ongoing; Expected to complete in early 2022

THANK YOU