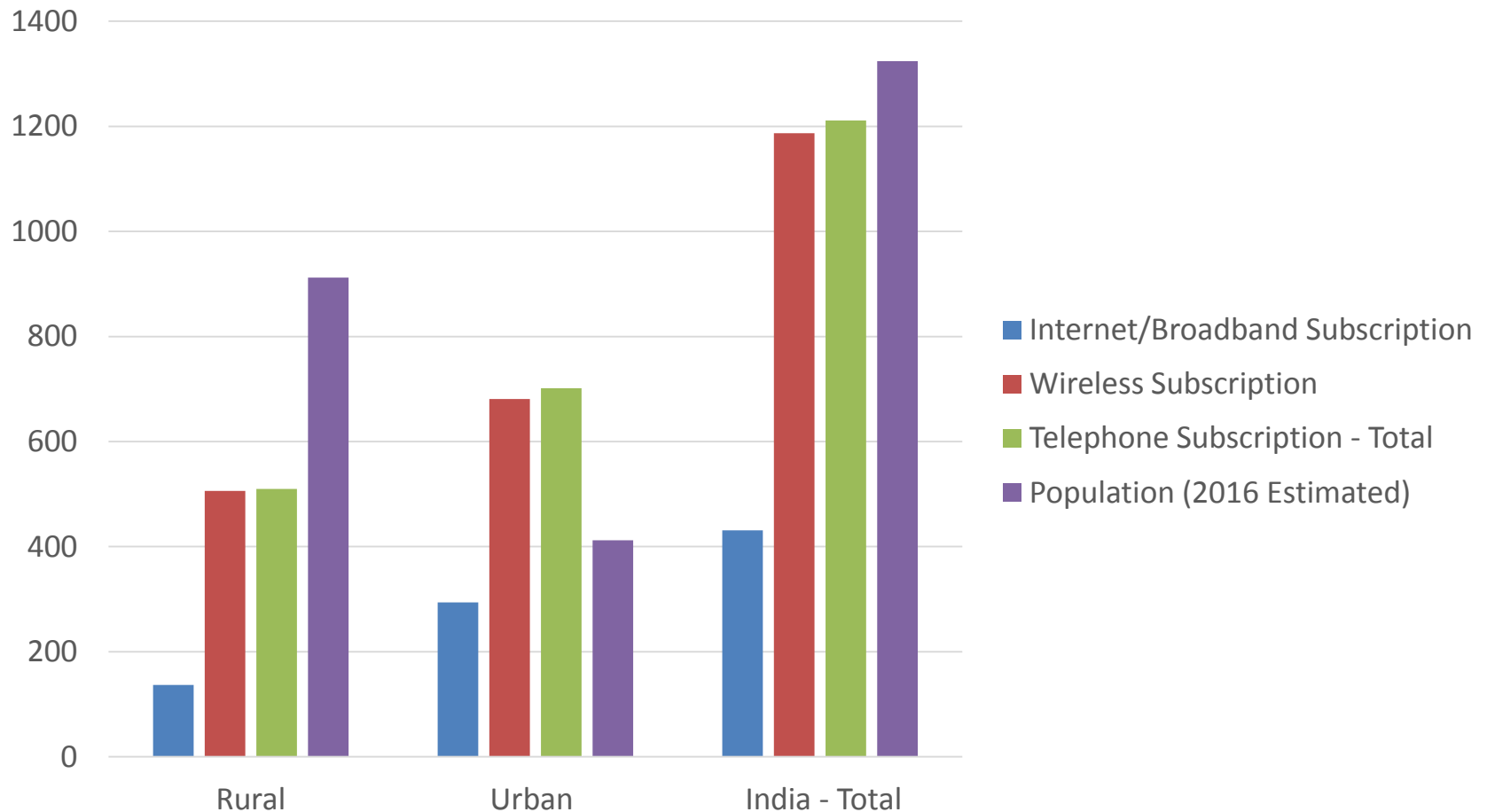


Rural Broadband Communication & Frugal 5G

Broadband Penetration Status: India



**Close to 1 billion people do not have broadband access in India
Penetration much lower in Rural India as compared to Urban India**

Source: Telecom Regulatory Authority India, as on 30th June 2017

Challenges in Connecting Rural India



Low Average Revenue Per User



Unavailability of Fiber Backhaul



Intermittant Availability of Electricity

What does India need for 5G?

- Can we have more efficient usage of spectrum?
 - Spectrum Cost is transferred to end-user
 - Makes the solution unaffordable
- Do we need to support high-speed mobility (300 km/h)?
 - Vehicles moves @ ~40 km/h in cities; ~80 km/h on highways
 - Small % of people use vehicles in rural areas
- Do we need to address multiple device connectivity?
 - Urgent need is for primary broadband connectivity

A focussed and cost-effective solution is required!

Rethinking 5G Requirements

- Low cost solutions
 - Low cost Devices
 - Low cost Connectivity/backhaul solutions
 - Using wireless backhaul/middle mile instead of fiber
 - Lower spectrum cost
 - Efficient usage of spectrum/Usage of Unlicensed Spectrum
 - Using network sharing options to share spectrum across Radio Access Technologies (RATs) and operators
- Limited mobility support
 - Mobility is required but not high speed
 - Fixed primary access is the key
- 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

Rethinking 5G Requirements

Low Cost

Low Mobility

Energy Efficient

Large Coverage

Frugal 5G



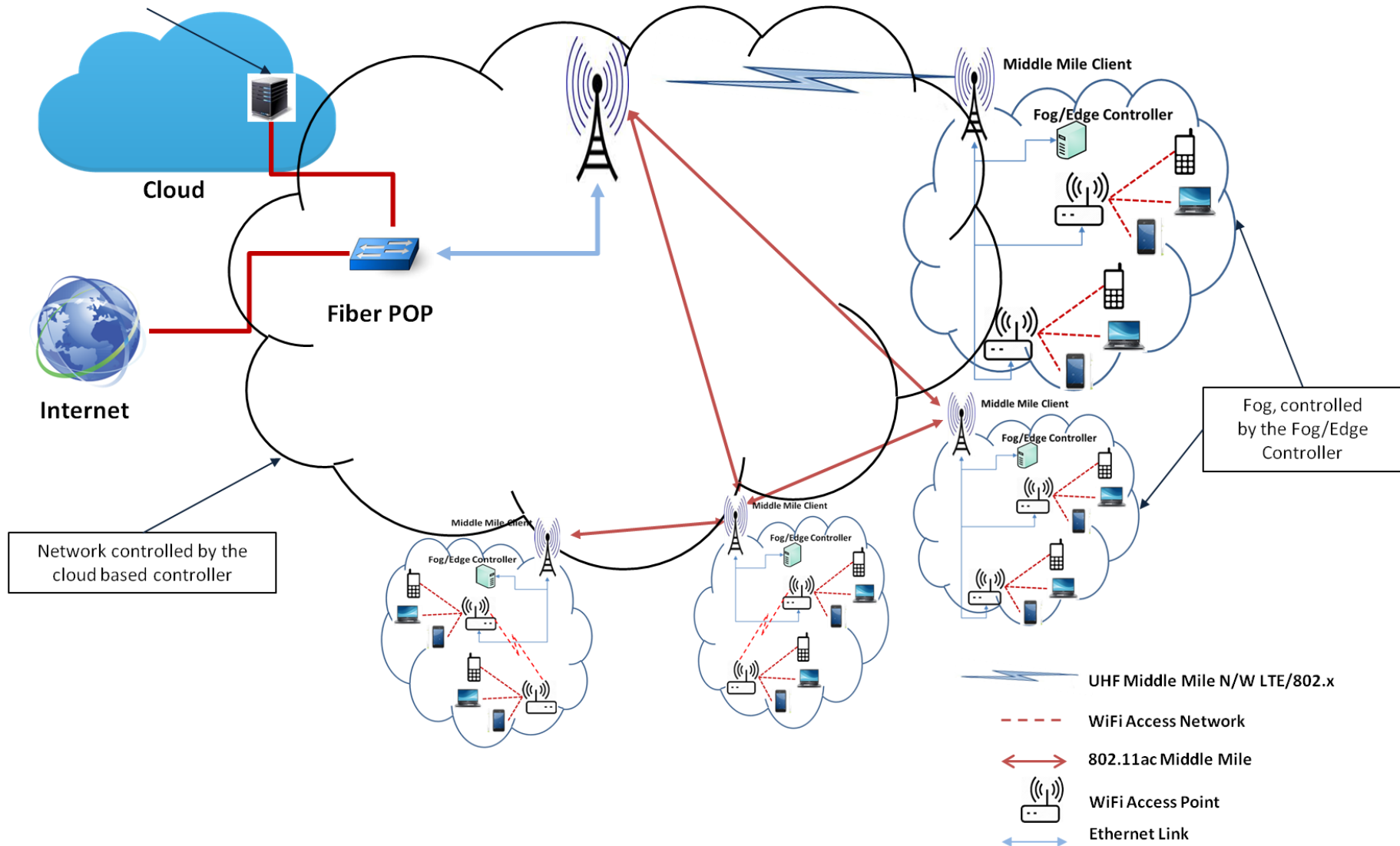
```
graph LR; A[Low Cost] --- B{ }; B --- C[Frugal 5G]; D[Low Mobility] --- B; E[Energy Efficient] --- B; F[Large Coverage] --- B; C --- G[Wireless Signal Icon]
```

Frugal 5G Research@IIT Bombay

- Investigation in
 - Small Cell based Solution for Rural Broadband Communication
 - Ultra dense deployment of WiFi Hotspots/LTE small cells
 - Backhauled using fiber or TV UHF/5.8GHz/mmWave band
 - Point-to-Multi-Point/Multi-hop Mesh Network as Middle-Mile
 - SDN based control and management of the network
 - Fog and Cloud Computing Paradigm for system design
 - Cloud based SDN controller
 - » Control and Management of the Middle-Mile Network
 - Fog/Edge based SDN Controller
 - » Local Controller at Middle Mile Client site
 - » Backhaul Bandwidth Optimization
 - » Content Optimization
- Propose solution for standardization under IEEE

Frugal 5G Research@IIT Bombay – Fog & Cloud based Architecture

Cloud based Global Controller



UHF Middle Mile N/W LTE/802.x

WiFi Access Network

802.11ac Middle Mile

WiFi Access Point

Ethernet Link