# Fog and SDN paradigms in 5th Generation Wireless Communication Networks

## SPCOM 2018

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# Agenda

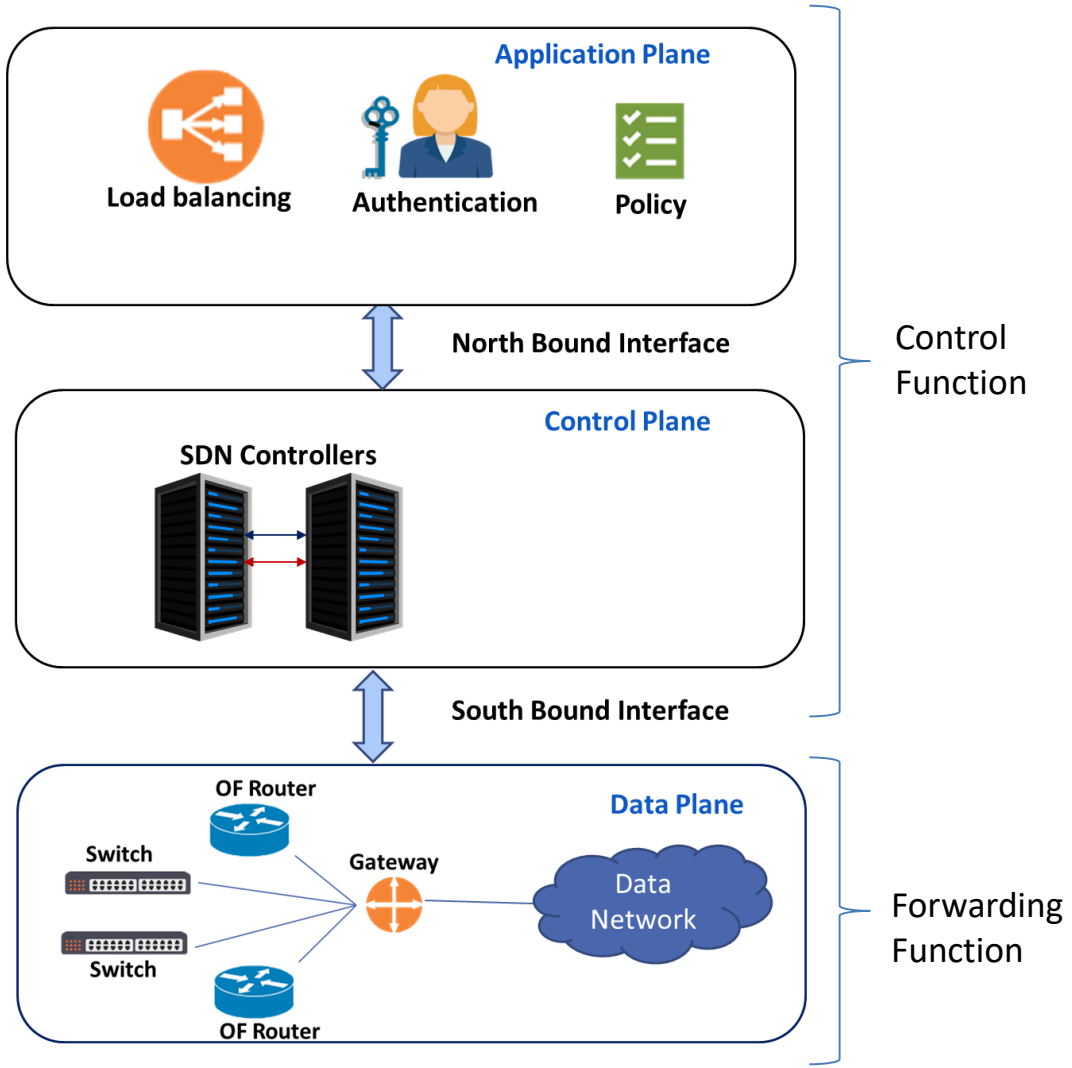
- Fog and Cloud Computing
- Software Defined Networking (SDN)
- Emerging Mobile Network Architecture
  - Impact of SDN and Fog Computing
- Mobile Networks - Use Cases
  - Broadband Public Safety Communication
  - Rural Broadband Communication

# Fog and Cloud Computing

- Fog Computing
  - Nearer to the Edge Computation & Communication
  - Lower Latency Applications
  - Reduced Backhaul Bandwidth usage
  - Possibility of a hierarchical organization – Multiple fog levels
- Cloud Computing
  - Centralized Resource Pooling - typically in data centres
  - Efficient Resource Utilization through pooling
  - Management and Control - located in Data Centres
- Not this or that
  - Form a continuum, complement each other

# Software Defined Networking (SDN)

- Network divided into three planes
  - Forwarding/Data Plane
    - Forwarding Elements
  - Control Plane
    - Configures Forwarding Elements
  - Applications Plane
    - Deals with Policies, Algorithms
    - Uniform Policy Enforcement
    - Control over network resources
- Control and Forwarding functions
  - Separated through Open, Standardized interface

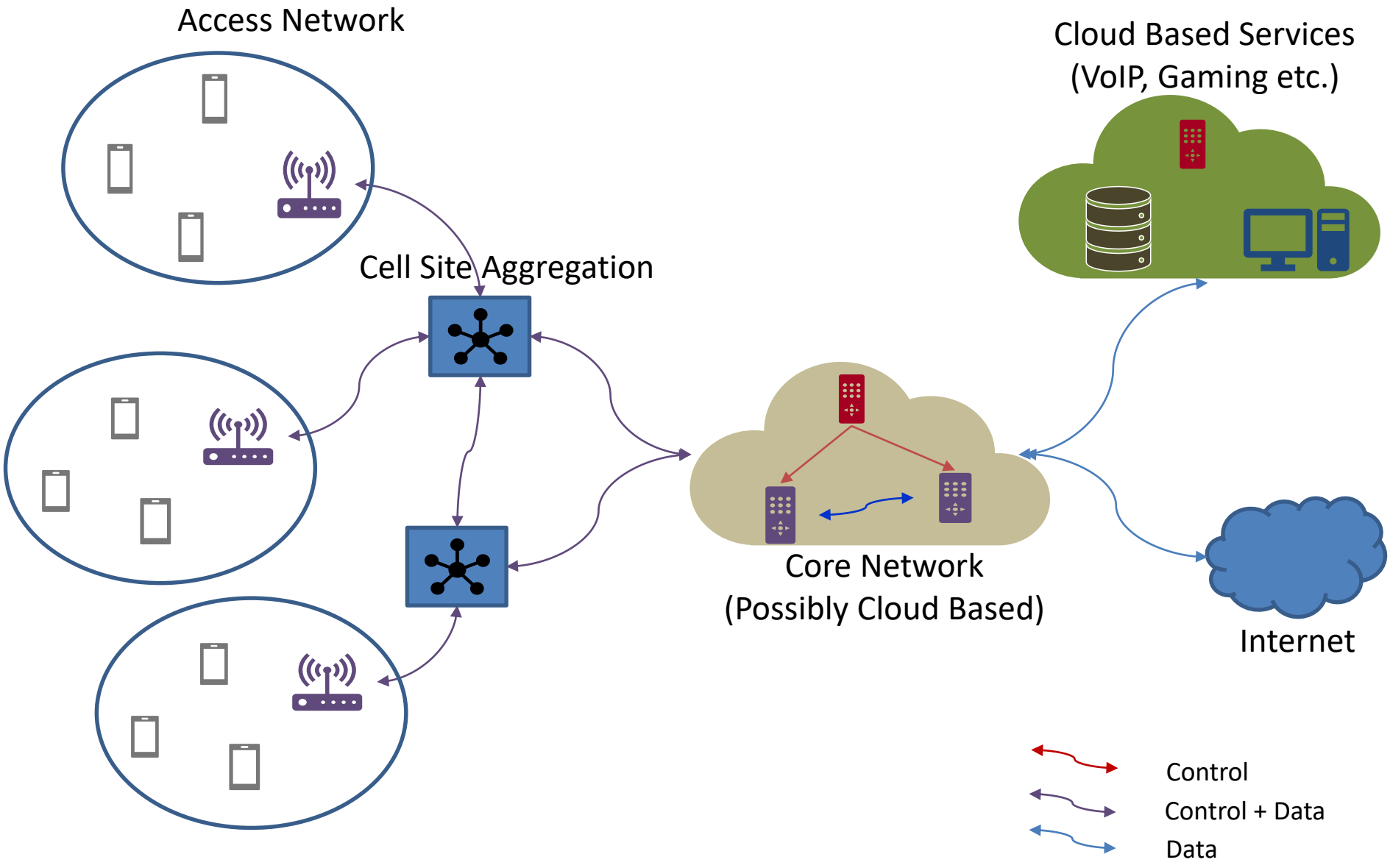



**SDN Architecture**

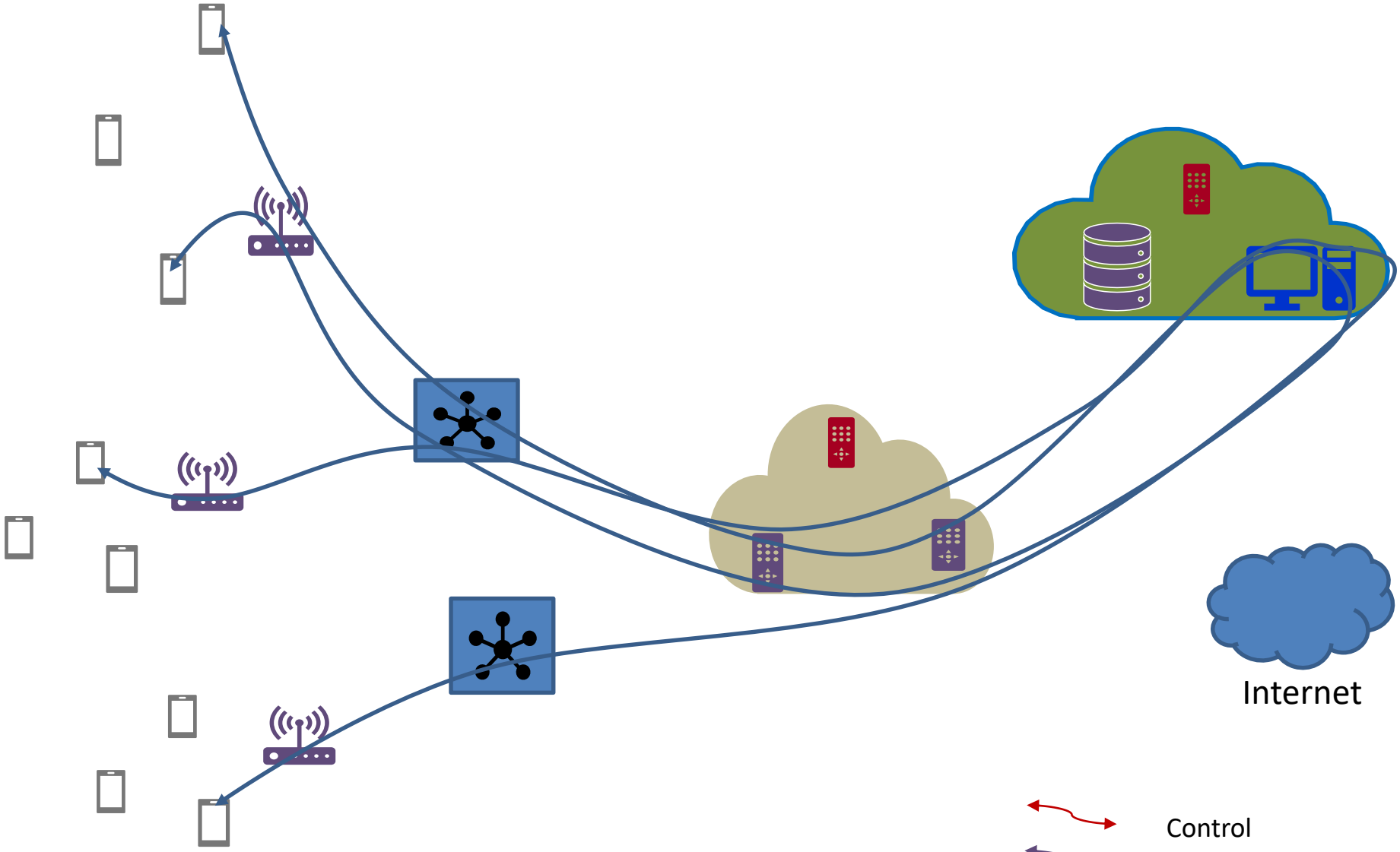
# Software Defined Networking (SDN) Contd.

- Programmable Network
  - Application Provides policies, decisions to the Controller
    - Thru North bound interface
      - e.g., REST based interface
  - Controller configures Forwarding Elements
    - Thru South bound interface
      - e.g., OpenFlow, NETCONF
- Intelligence - logically centralized
  - Optimal decisions due to global view
- Independent Innovation possible for all three planes

# Existing Mobile Network Architecture



# Existing Mobile Network Architecture - VoIP Data Flow Example



# Existing Mobile Network Architecture – Salient Points

- A data pipe between a User and the Cloud is created
  - Data Bearer - to handle User Mobility
- Data Flow always routed via the Cloud
  - Higher Latency
  - Higher Backhaul Utilization
- Service deployments in cloud only
  - Application Servers in Cloud, e.g., IMS based services
  - No service deployments near the user (edge)
- Tightly Coupled Control and Data Plane
- Distributed Intelligence and State in RAN
  - Suboptimal decisions due to fragmented view

Architecture may not be suitable for certain Use Cases!!!

# Mobile Networks – Let us see some use cases

- Broadband Public Safety Communication
- Rural Broadband Communication

# Public Safety Communication

- Communication used by Law enforcement agencies, Fire Brigade, Medical Emergency teams etc.
- Emergency Warning or Public Warning Systems
- Communication to support
  - Public Safety and Disaster Recovery
- Critical Communication

# Broadband Public Safety Communication - Uniqueness

- Mission Critical
- Low Latency Communication
- Group Communication
- Direct mode (peer-to-peer) communication
- Public Safety operation typically localized in a small geographical area
- Real-time voice, data and video communication
- Rapidly Deployable System

Is the existing Mobile Network Architecture an appropriate one for this use case?

# Another Use Case - Rural Broadband Connectivity

- India suffers from low Rural Tele-density
- One-fourth of the unconnected population globally, lives in India
- Rural Broadband Connectivity
  - Abysmally low in India

# Challenges in Connecting Rural India

Low Average Revenue Per User

Unavailability of Fiber Backhaul

Intermitant Availability of Electricity

# Rural Broadband Connectivity - Requirements

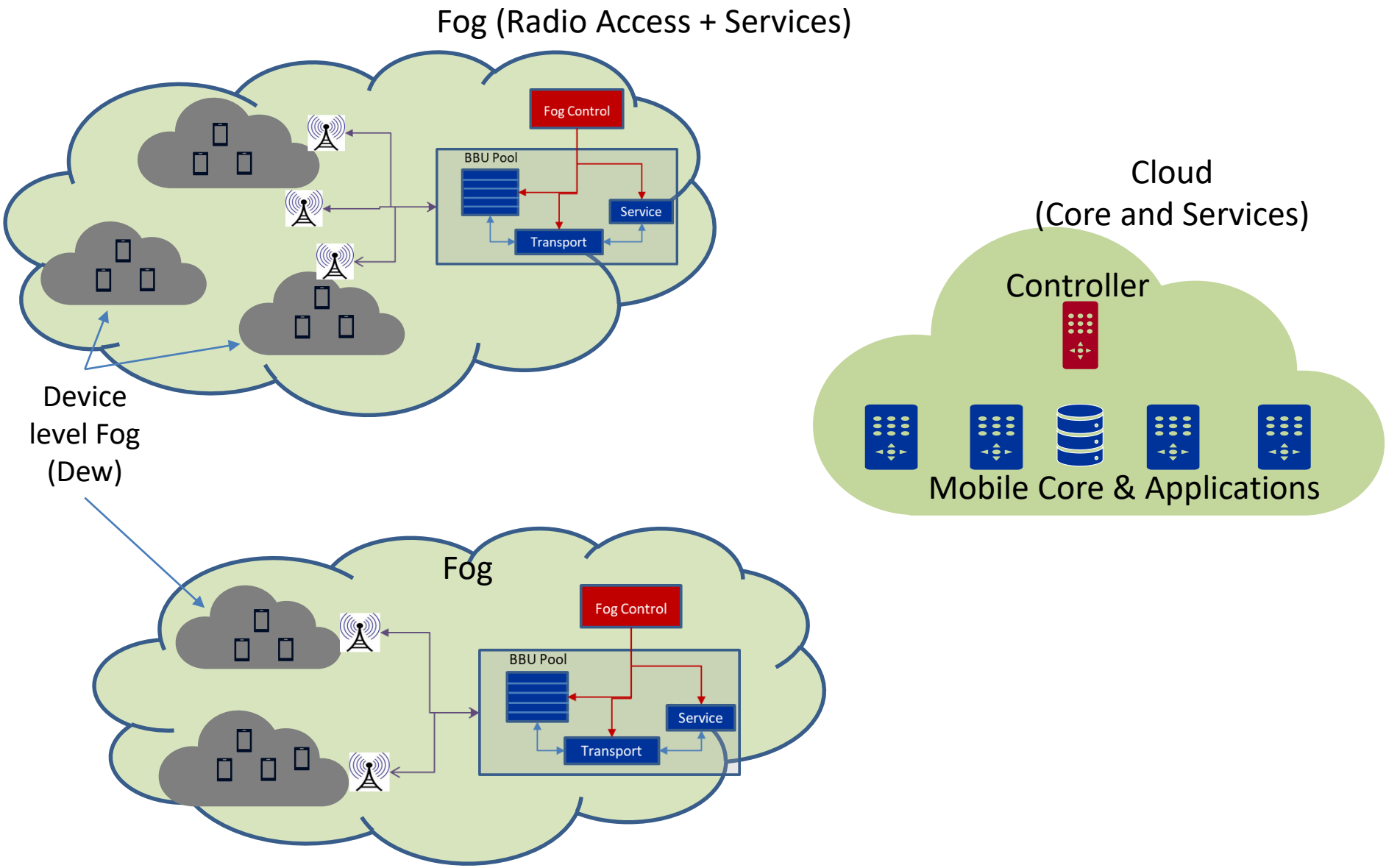
- Low cost solution
  - Low Device cost
    - Simpler Hardware and RF Design reducing the device costs
  - Low cost Connectivity/backhaul solution
    - Using wireless backhaul/middle mile instead of fiber
  - Lower spectrum cost
    - Efficient usage of spectrum
      - For Access as well as Middle Mile Network
- Limited mobility support
  - Fixed primary access is the key

# Rural Broadband Connectivity – Requirements contd.

- Energy efficient solution
  - Lower system energy consumption
  - Support for operation in power saving mode
  - Usage of non-conventional energy sources
- Large coverage area support
  - Support for large cells to reduce CAPEX and OPEX
- Our study also shows
  - Significant % of Communication Needs – Local
    - Peer-to-peer communication
    - People who know each other typically live in a small geographical area

Is the existing Mobile Network Architecture an appropriate one for this use case?

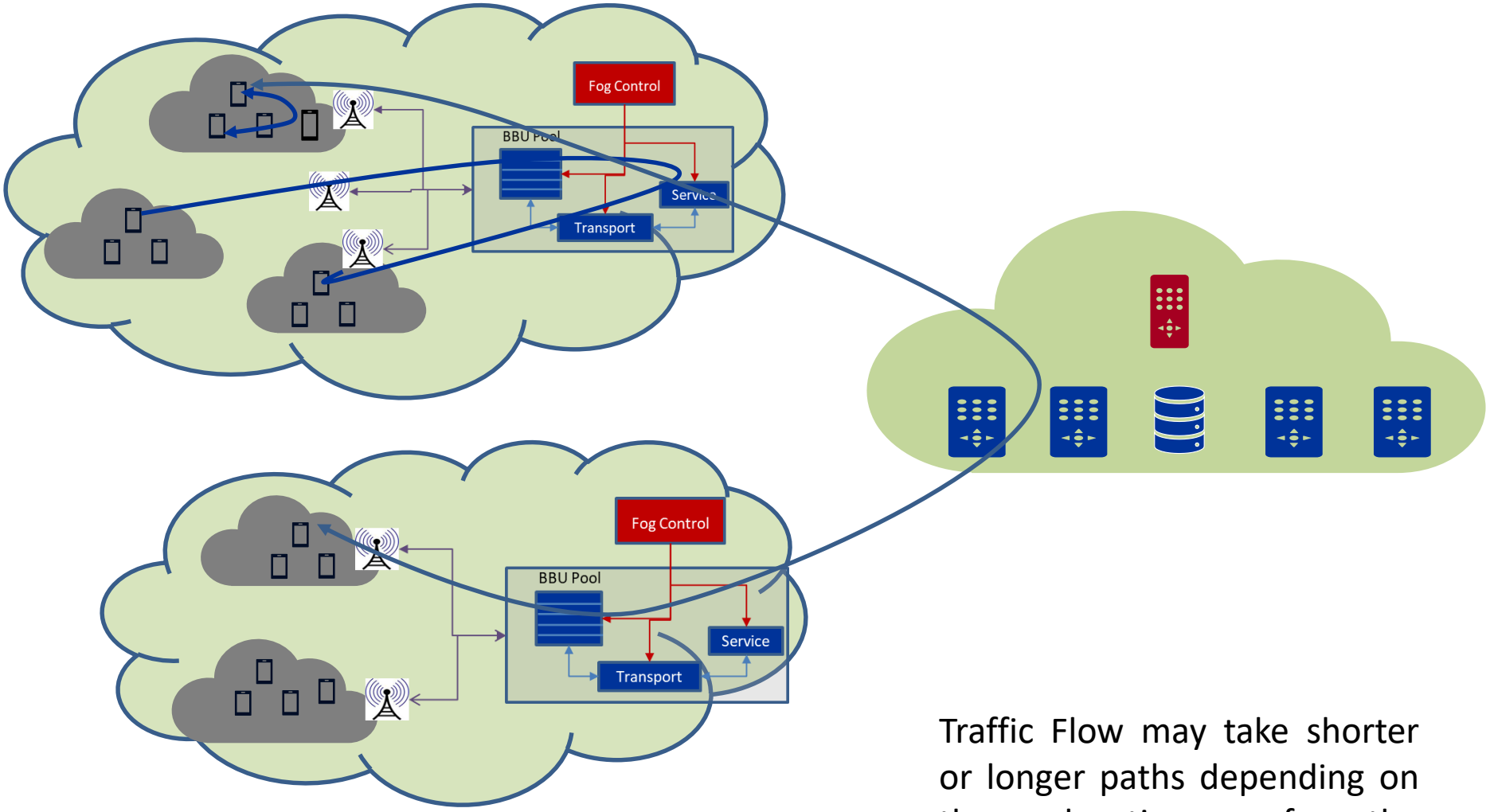
# Emerging Mobile Network Architecture



# Emerging Mobile Network Architecture

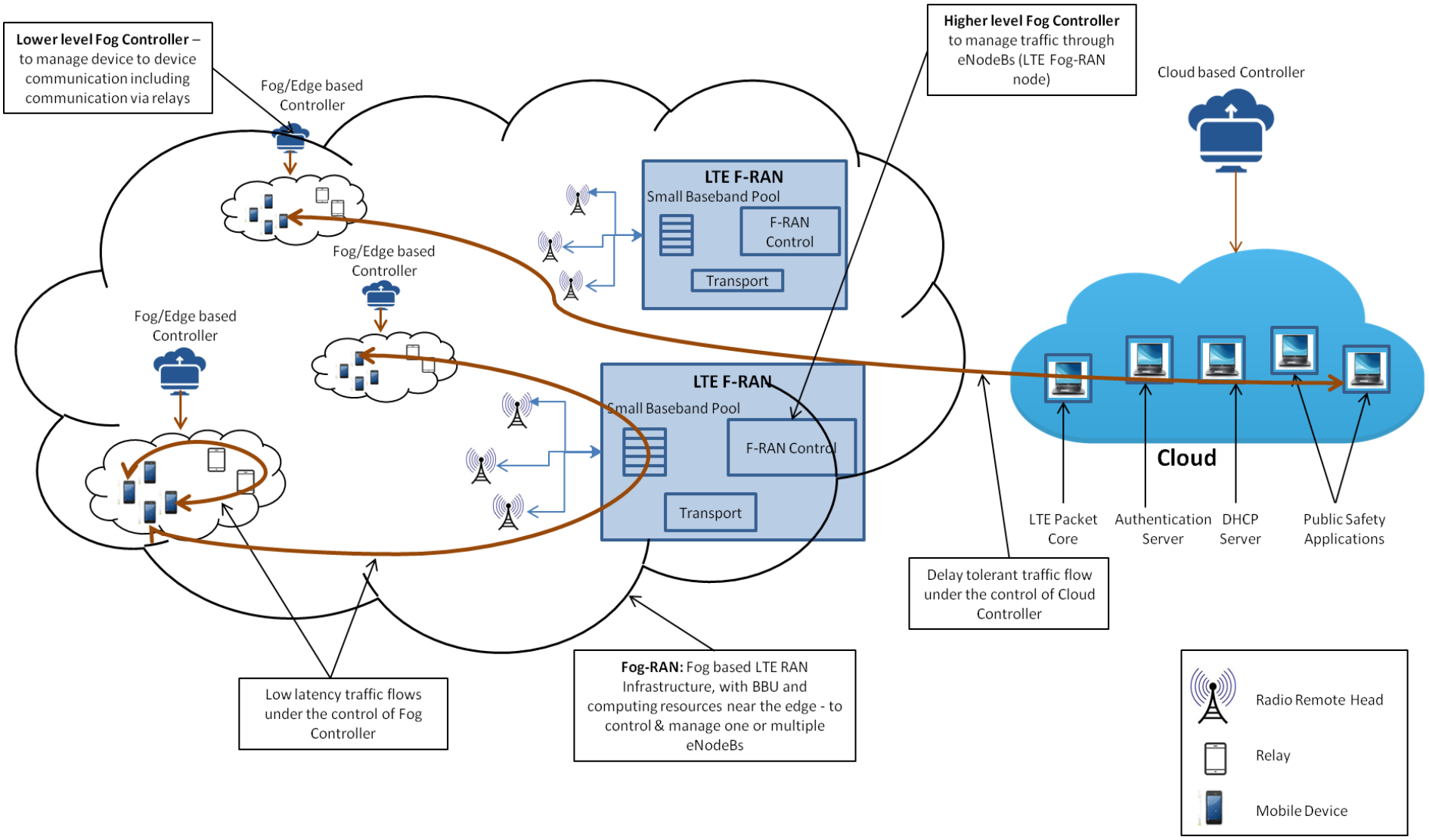
- Network Split into Fog and Cloud Components
- Hierarchical Structure
  - Multiple Levels of Fog Components
- Components typically follow SDN paradigm
- Each Fog/Cloud Component may have
  - Control Function
    - Controller
    - Control Applications
  - Forwarding Function
    - Forwarding Elements
    - Services – Application Servers, e.g., VoIP
- Migration of Application level Intelligence from Cloud to Fog and vice versa

# Emerging Mobile Network Architecture
# Data Flow Paths




Traffic Flow may take shorter or longer paths depending on the location of the communication end points

# Modified Mobile Network Architecture for Public safety Communication (LTE Based)



# Fog and SDN based Architecture for Public safety Communication - Salient Features

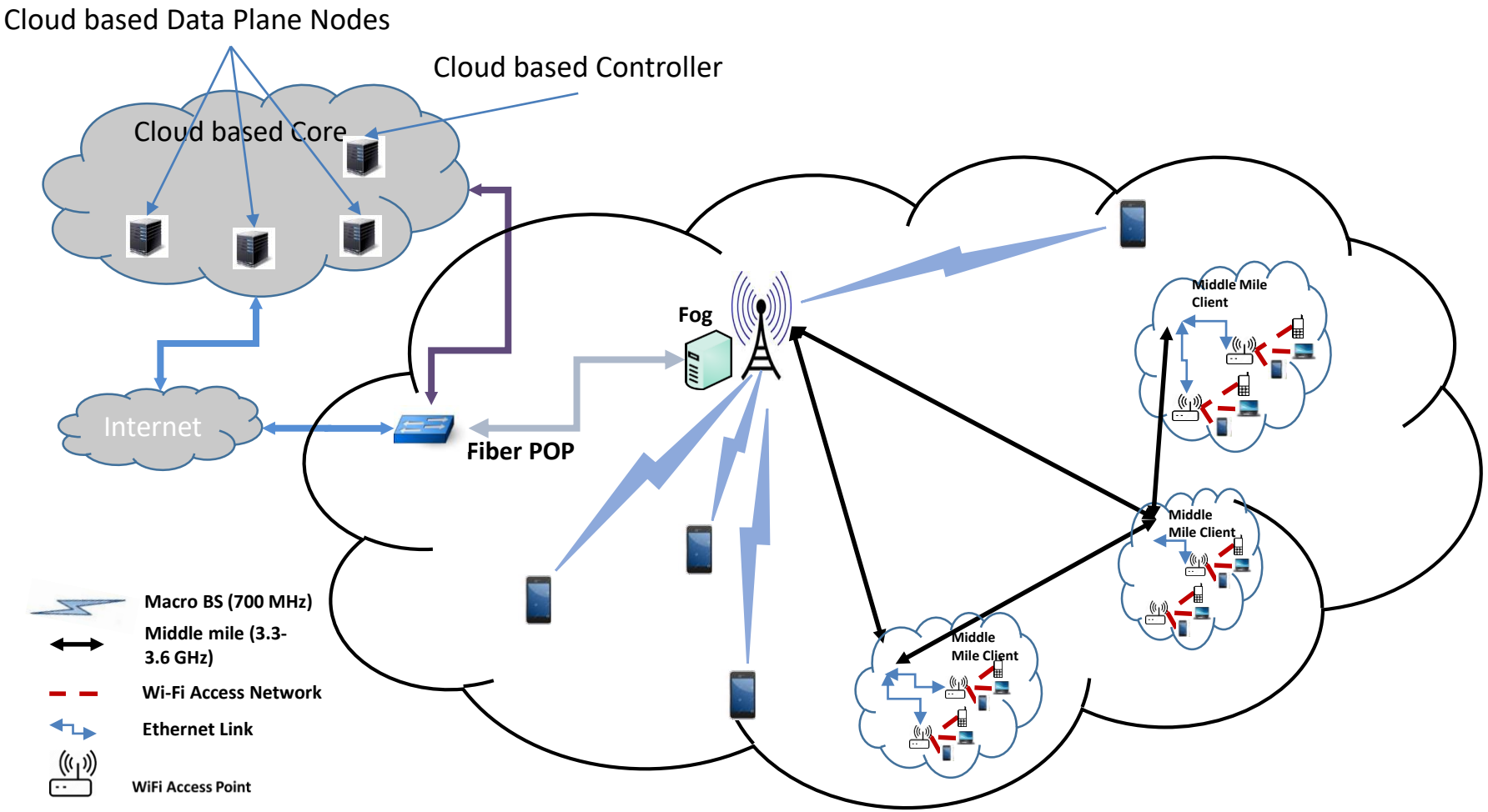
- Fog/Edge SDN Controllers
  - Hierarchical Fog Controllers
  - Low Latency traffic flow paths
  - Immediate Connectivity and Communication within a group
  - Rapidly Deployable System
- Cloud based SDN Controller
  - Traffic flows routed through the Core Network, if needed
    - Between Users & Application Servers
  - User Authentication
  - Migration of Application Servers and Authentication Function to Fog, if needed

Better suited than the existing Mobile Network Architecture

# SDN and Fog based Mobile Network for Rural Connectivity – Frugal 5G

- Large Coverage Area Cells to provide ubiquitous connectivity
- Small Cells (WiFi Hotspots) as access points for high speed data connectivity
  - WiFi devices are very low cost devices
- Wireless Middle Mile Network to backhaul the data from WiFi Hotspots to Fiber POP
- Point to point wireless links to connect the nodes in villages
- Usage of Fog and Cloud Computing/Networking Paradigm
- SDN based control and management of the network
  - Local (Fog/Edge) as well as Global (Cloud-based) Controllers
  - Multi-RAT Control

# Frugal 5G - System Architecture



# Frugal 5G System Architecture – Cloud Components

- Cloud based SDN controller
  - User Authentication
  - Control and Management of Complete Network
  - Mobility Management
  - Control of Data traffic routed via cloud
- Forwarding Plane Entities
- Application Servers
- Optimization Functions
  - Caching and TCP Optimization

# Frugal 5G System Architecture – Fog Components

- Fog/Edge based SDN Controller
  - Macro Cell (BS) Control
  - Control and Management of Middle Mile Network
    - Efficient allocation of spectrum resources
  - Small Cell (WLAN) Control
  - Energy Efficient Operation
- Backhaul Optimization Functions
  - Support for Peer-to-peer communication
    - Traffic flows inside a village cluster routed locally
  - Content & Application Servers
    - Serving locally stored data, when possible

Better support for Frugal 5G Requirements

# Thank you