Fog Computing in 5G & Beyond

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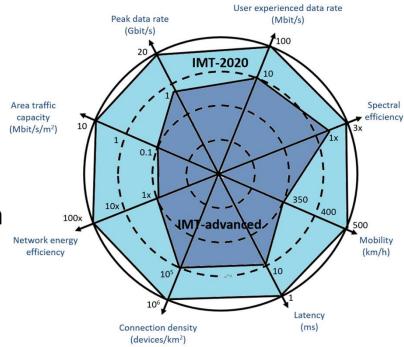
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Dec 29-30, 2020

Winter Fog School

Introduction to 5G

- Next generation of Mobile Communication System- IMT 2020
  - Enhanced capabilities over 4G
- Enhanced Mobile Broadband (eMBB)
  - Enhanced Mobility Support – 500 Km/h
  - Very High Peak Data Rate - 20 Gbps
  - High Spectral Efficiency – 30 bps/Hz
- Massive Machine-to-Machine Communication (MMTC)
  - Large no of devices in a small area – 10^6/km^2
- Ultra Reliable Low Latency Communication (URLLC)
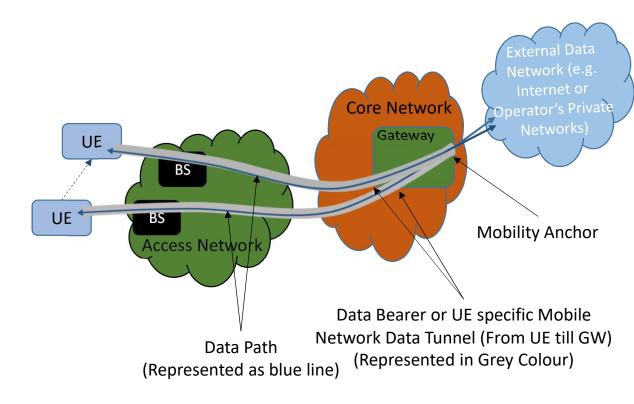 - Extremely low Latency - ~ 1 ms latency over the air

Enhancement of key capabilities from IMT-Advanced to IMT 2020

Courtesy – International Telecommunication Union

Typical Mobile Network Architecture

- **Two Major Parts**
  - Distributed Access Network
  - A Centralized Core Network

- **Mobility- a key aspect**
  - How to handle Mobility?
    - Data Tunnel between UE & Gateway in CN
    - CN Gateway - "Mobility Anchor" for UE
  - When a UE moves
    - Its point of attachment (BS) in the network may change
    - But its "Mobility Anchor" does not change
  - Packets from/to external network routed through the same Gateway for a UE even while it moves

External Data Network (e.g. Internet or Operator's Private Networks)

Core Network

Gateway

UE

BS

UE

BS

Access Network

Mobility Anchor

Data Path (Represented as blue line)

Data Bearer or UE specific Mobile Network Data Tunnel (From UE till GW) (Represented in Grey Colour)

5G Mobile Network Architecture

- Similar to the one Shown in the Previous slide

- Comprising of a Distributed Access & a Centralized Core Network

- Usage of Data Tunnel to Manage Mobility

- UPF - Mobility Anchor in the Core

Cloud Infrastructure

Core Network

SMF

AMF

UPF

Access Network

gNB

UE

gNB

UE

gNB

UE

External Data Network (e.g. Internet or Operator's Private Networks)

Data Path

Data Tunnel (Bearer/PDU Session) (From UE till anchor UPF)

Mobile Core typically deployed using a centralized cloud based infrastructure

Characteristics of Emerging Mobile Communication (1/2)

- Massive IoT
  - A key 5G use case

- Use Cases fuelling the growth of IoT
  - Smart Homes
  - Smart Cities & Villages
  - Smart Workplaces/Factories
  - Increased Automation Everywhere

- Most IoT Devices use Wireless Connectivity
  - Wi-Fi, Bluetooth, 4G and (5G in near future)
  - But Mobility not Important
  - Most IoT Devices - Stationary

Characteristics of Emerging Mobile Communication (2/2)

- Increased Importance of Low Latency Communication
    - Mission Critical Communication
    - Industrial Control Systems
    - Mobile Health Care
    - V2X Communication etc.

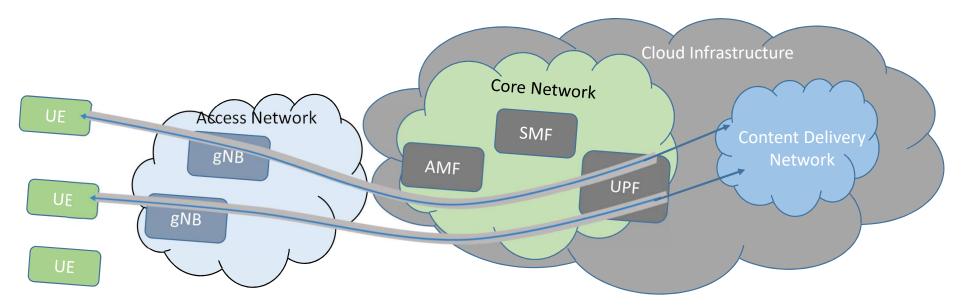- Need to Reduce Cost & Resource Consumption

Cloud Computing

- Remote Delivery of Compute/Storage Services (say over Internet)
  - Computation
    - Program Execution, Analytics, Intelligence etc.
  - Storage
    - Database etc.

- Virtually Unlimited Storage Capacity and Processing Power

- Scalability

- Business Continuity
  - Location Independence - Work from Anywhere/Anytime

- Economies of Scale & Cost Efficiency
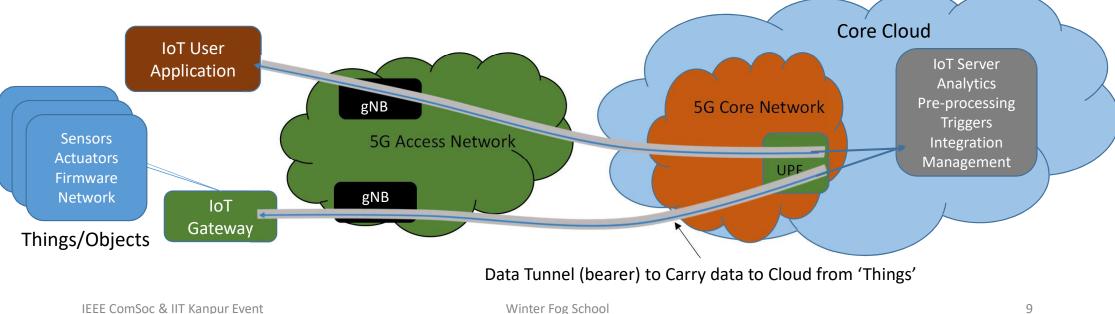
Cloud & 5G Use case – Content (Video) Delivery

- Content Delivery Network (CDN)
  - Delivery of Content to Users via Mobile Network
- CDN along with Mobile Core typically a part of Cloud based Infrastructure
- UE specific Data tunnel- CDN can only exist beyond the CN, i.e., beyond the UPFs (Gateways/Mobility Anchors)

IoT Integration with 5G – An Architecture

- **IoT Server placed in Cloud along with 5G Core**

- **IoT Gateway acts as a UE**
  - Data Tunnel via 5G Network to 'IoT Server…' in Cloud
  - Exchanges Information with IoT Server via Data Tunnel

- **IoT User Application also acts as a UE**
  - Separate Data Tunnel via 5G Network to 'IoT Server…'
  - Controls 'Things' via Cloud (via IoT Server)

IoT User Application

Sensors Actuators Firmware Network

Things/Objects

IoT Gateway

gNB

gNB

5G Access Network

5G Core Network

UPF

Core Cloud

IoT Server Analytics Pre-processing Triggers Integration Management

Data Tunnel (bearer) to Carry data to Cloud from 'Things'

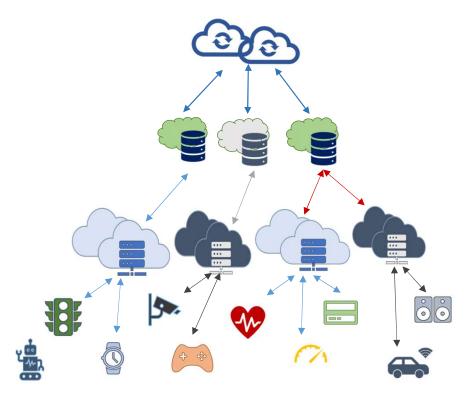# IoT with a Centralized Cloud via 5G - Issues

- **Limitations of Cloud Computing**
  - 'Low Latency Communication' Difficult to Achieve
  - Increased Resource Usage

- **Push the Computing near 'Things' (Fog)**
  - Computation/Storage near 'Things'
  - Shorter Communication Paths
    - Improved Time Responsiveness
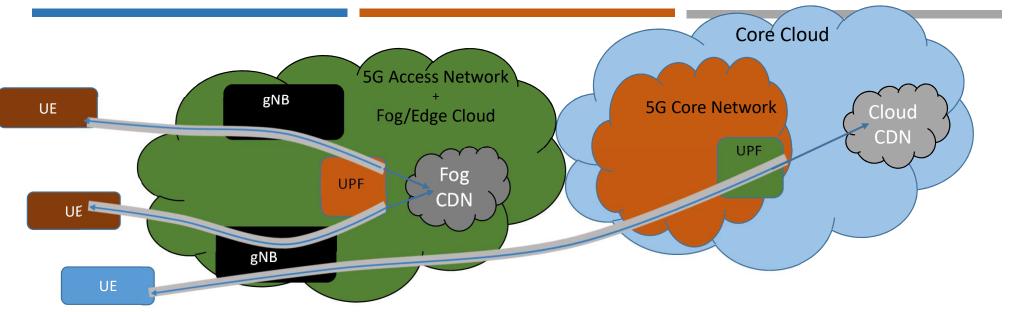   - Reduced Resource Utilization

What is Fog Computing?

- Fog - **F**rom c**O**re to ed**G**e

- Support for Lower Latency Applications

- Location Awareness

- Reduced Network Bandwidth Usage

- However, there is an Issue
  - Can't handle Mobility of Devices
  - Need to form Continuum with Cloud
    - Fog for Stationary Devices, Cloud for Mobile ones
  - Fog and Cloud Complement each other

Core Cloud

Fog Level 'n'

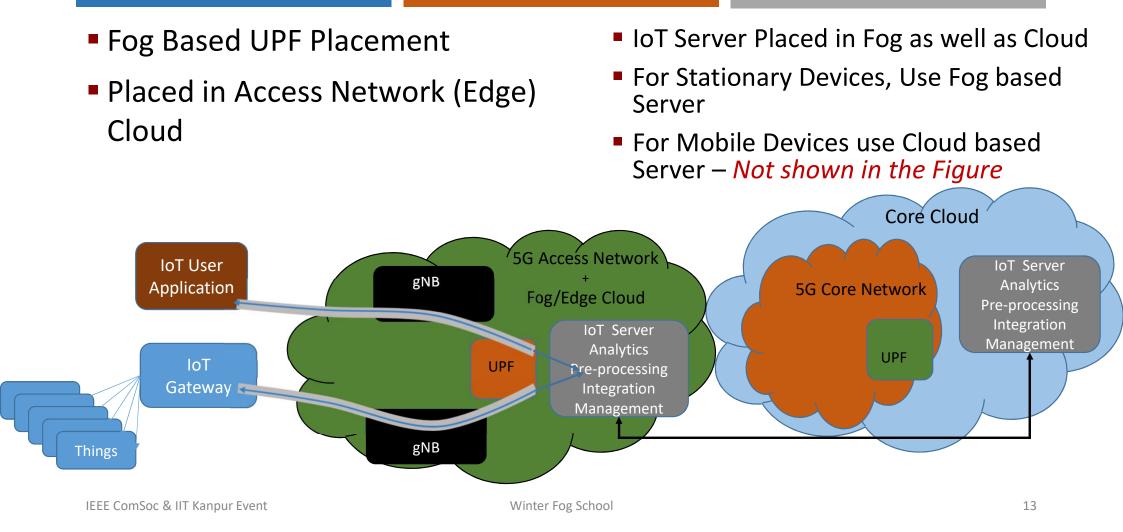Fog Level '0'

Devices

Fog/Edge Computing and 5G – CDN

- Existence of a Content Delivery Network (CDN) in Fog as well as Cloud

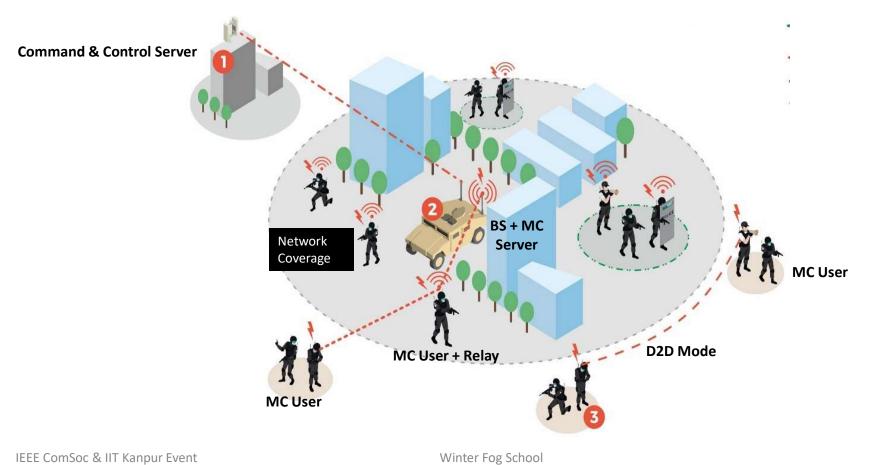- Mobile UEs served from Cloud CDN

- Stationary UEs served from Fog CDN

Fog/Edge Computing and 5G – IoT Use case

- Fog Based UPF Placement

- Placed in Access Network (Edge) Cloud

- IoT Server Placed in Fog as well as Cloud

- For Stationary Devices, Use Fog based Server

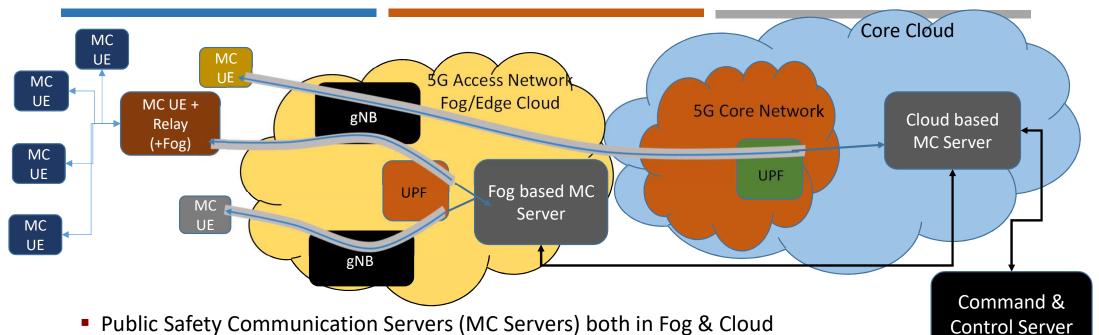- For Mobile Devices use Cloud based Server – *Not shown in the Figure*

Public Safety Communication

- A Rapidly Deployable Mission Critical System

Fog Computing & 5G – Public Safety Communication

- Public Safety Communication Servers (MC Servers) both in Fog & Cloud
- Localized Communication between Devices facilitated by Fog Servers
  - Relay based Fog Element between a set of UEs
  - Fog Element in the vicinity of gNB too (in Access Fog)
- UE can communicate via Core Cloud also, if needed
- Command & Control Server Communication directly to Cloud (can use 5G network also for comm)

Summary

- Fog/Edge Computing together with 5G
  - Enables Many Use Cases

- Fog/Edge Computing
  - Easy to Integrate with the 5G Network
  - Lower Latency – Better Performance
  - Improved Resource Utilization
  - Addresses Certain Limitations of Cloud

- User/Device Mobility a key factor in the usage of Fog in 5G Network

THANK YOU