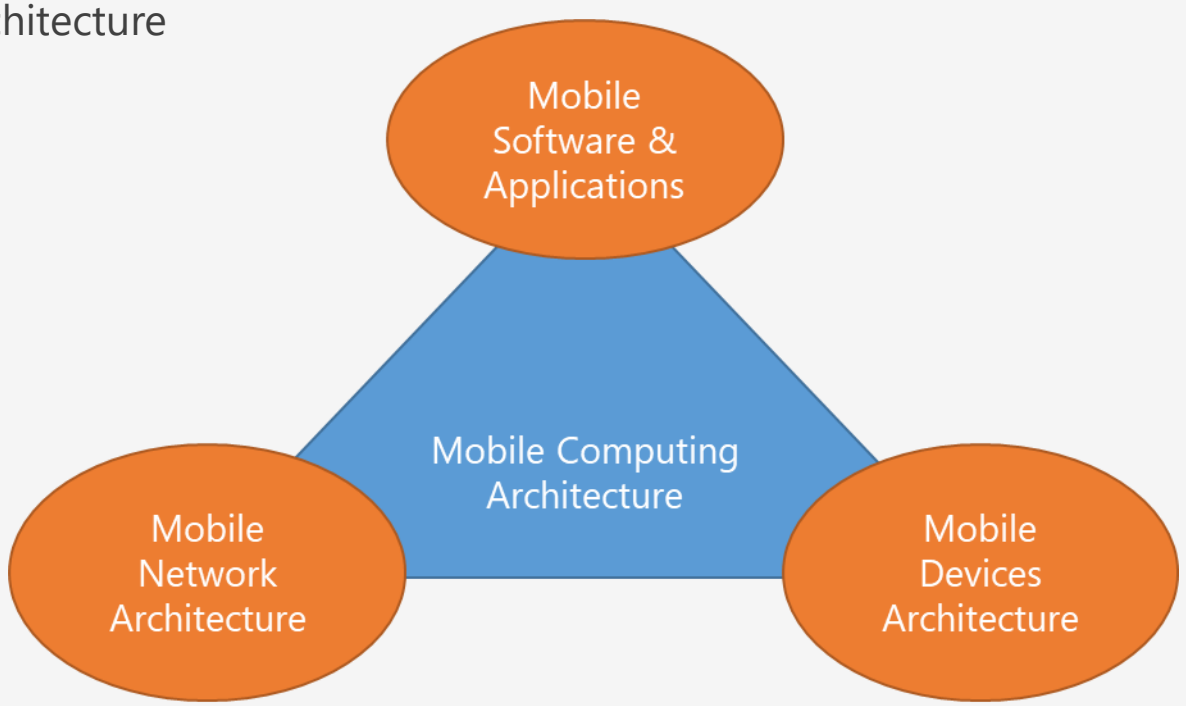
Mobile Computing Architecture

UW Bothell, WA

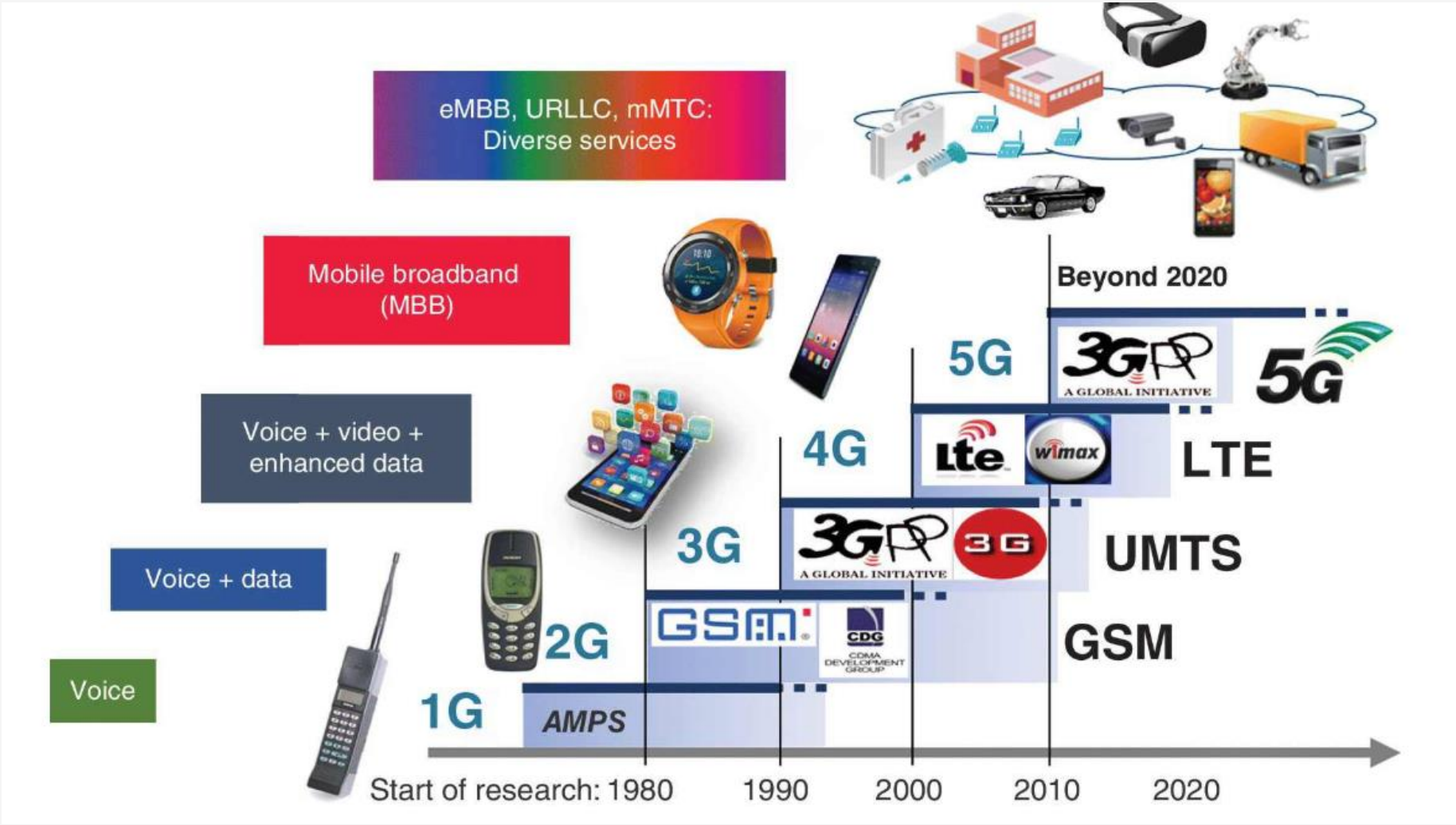
Lecture 3: Evolution to 5G

Mobile Computing Architecture

Focus on Mobile Network Architecture



Mobile Communications Evolution to 5G



eMBB: enhanced Mobile Broadband

URLLC: Ultra-Reliable Low Latency Communication

mMTC: Massive Machine Type Communication

Reference: *5G System Design: Architectural and Functiona...* by *Queseth, Olav, Boldi, Maur*

1G - Advanced Mobile Phone System (AMPS)

- **Voice Only**
- Bell Labs established Mobile Communication department in 1964
- At that time there were no standards. AT&T developed High-Capacity Mobile Telephone System (HCMTS) 1964-1974 and standardized its own standard HCTMS1.
- First ever 2000 phones trial in Chicago in 1977
- The earliest radio standard in North America. Federal Communications Commission (FCC) standardized AMPS in 1979 (Frequency band: 800-900MHz)
- 1st Generation (1G) commercial Analog Cellular System
- Started the Cell Phone era in 80's (~1984)
- AMPS had ~13Million subscribers in ~1995
- Targeted for few subscribers with car phones. High energy consumption, supplied by car
- Frequency Modulation (FM)

1G – Global Deployments

- Japan: Nippon Telephone and Telegraph (NTT)
  - Tokyo 1979
  - High Service Cost (compared to AMPS)
  - Poor Voice Quality (compared to AMPS)
- UK: Total Access Communication System (TACS)
- Scandinavia: Nordic Mobile Telephone (NMT) system
- C450 – West Germany
- AMPS contributed to 2/3rd of the mobile subscribers worldwide

2G

- **Voice, SMS and limited Data service**
- Late 80's AMPS started reaching its capacity limits
- Concurrent developments on 2G in both USA and Europe
- USA: 1989 QUALCOMM started developing Code Division Multiplexing Access (CDMA) – 10 times more capacity than AMPS. CDMA systems were commercialized in Seattle, Hong Kong, Los Angeles, etc
- Europe: Global Systems for Mobile Communication (GSM) was developed by European Telecommunication Standards Institute (ETSI) in the early 90's
- Deployed across globe enabling roaming
- Introduction of SIM Card

2G – Data Services

- CDMA1x developed in 1999 with 64Kbps bitrate
  - 2000: Evolution-Data Optimized (EVDO) Rev 0 – 2.4Mbps
- GSM developed General Packet Radio Service (GPRS) in 2000 with 14.4Kbps to 64Kbps
  - Later enhancement: Enhanced Data Rates for GSM Modulation (EDGE) – 384Kbps
  - Simultaneous Voice and Data service
  - IP Packets [later lectures]

3G – 3rd Generation Mobile Communication

Voice, SMS, MMS and Data services [Mobile TV, GPS, Video Conferencing,…]

Two main standards

- **UMTS (Universal Mobile Telecommunications System)** system, first offered in 2001, standardized by 3G Partnership Program (3GPP), used primarily in Europe, Japan, China
  - HSPA+ peak data rates up to 56 Mbps in the downlink and 22 Mbps in the uplink
- **CDMA2000 system**, first offered in 2002, standardized by 3GPP2, used especially in North America and South Korea.
  - EVDO Rev B offers peak rates of 14.7 Mbps
- The sets of technologies and phones existed in parallel

3G – Global Deployments – The Spread of Mobile Communication

- **USA:** The first commercial 3G network was by Monet Mobile Networks. The second was Verizon Wireless in 2002. AT&T Mobility was also upgraded to 3G but to the UMTS standard. Monet and Verizon were both CDMA based.

- **Europe:** The first commercial United Kingdom 3G network was started by Hutchison Telecom which was originally behind Orange. In 2003, it announced first commercial third generation or 3G mobile phone network

- **Asia:** The first network to go commercially live was by SK Telecom in South Korea on the CDMA-based 1xEV-DO technology in January 2002. In India, in 2008, the first 3G mobile and internet services were launched by Mahanagar Telecom Nigam Limited (MTNL) in the cities of Delhi and Mumbai. After MTNL, Bharat Sanchar Nigam Limited (BSNL) started deploying the 3G networks all over the country

- **Australia:** The first pre-commercial demonstration network was built in Adelaide, South Australia by m.Net Corporation in February 2002 using UMTS. This was a demonstration network for the 2002 IT World Congress. The first commercial 3G network was launched by Hutchison Telecommunications branded as Three or "3" in June 2003

- **Africa:** Emtel launched the first 3G network in Africa

4G – Long Term Evolution (LTE)

- Voice, SMS, Over the Top TV services like Netflix, Hulu, Amazon,..; Video conference calls, etc.
- High Data Rates 100Mbps+
- Evolution of GSM. registered trademark owned by ETSI (European Telecommunications Standards Institute) for the wireless data communications technology and a development of the GSM/UMTS standards
- All-IP network
- First used in Scandinavia in 2009
- Improved User-Experience (lower latency)
- Lower Cost of Upgrades, Deployment and Maintenance
- Introduction of Virtual Network Functions (VNFs) [Lecture xx]

4G – LTE – Advantages for Network Operators

- Cost of Upgrade from 3G
- Standardized Interfaces multiple vendors (and competition)
- All-IP
- Global and Roaming
- Availability of competence in the market
- Introduction of Network as a Service
- Cheaper Devices
- Telecom + IT = Information and Communication Technology (ICT)

4G – LTE – Voice

- Introduction of Voice over IP in Mobile Network – only packet switching
- Voice over Long-Term Evolution (VoLTE) is dominantly used for Voice calls in LTE
- VoLTE is based on the IP Multimedia Subsystem (IMS) network. Defined by GSMA in PRD IR.92.
- This approach results in the voice service (control and media planes) being delivered as data flows within the LTE data bearer.
- VoLTE has up to three times more voice and data capacity than older 3G UMTS and up to six times more than 2G GSM.
- Voice quality depends on packet loss, packet delay, jitter, etc. Mean Opinion Score varies greatly because of network congestion, medium access errors, etc. [Lecture xx]

4G – LTE – Global Deployment (Evolving to 5G)

By Q1 2020:

- Globally ~800 operators with LTE networks
- 366 operators investing in either LTE-Advanced or LTE-Advanced Pro technologies.
  - 325 operators have deployed/launched LTE-Advanced or LTE-Advanced Pro technologies
  - 202 operators are investing in one or more LTE-Advanced Pro technologies.
- 5G: About 360 operators are investing in 5G. About 60 operators in 35 countries that have launched one or more 3GPP-compliant commercial 5G services
  - 5G phones
  - 5G routers
  - 5G AR/VR trials

5G - Goals

- Transform the mobile broadband experience: 5G networks will provide an enhanced broadband **experience of up to 1 Gbps**
- With ultra-low latency (1msec) drive growth in new use cases Augmented Reality / Virtual Reality and for critical IoT communications services
- Provide boundless connectivity for all: **5G networks will co-exist with 4G networks** and alternative network technologies to deliver a boundless, highspeed, reliable and secure broadband experience, and support a plethora of use cases for society
- Deliver future networks innovatively and with optimal economics: All stakeholders will strive to cost-effectively deliver better quality networks either independently or through sharing and partnerships. Future networks will rely on a combination of mainstream and alternative technologies, and use both licensed and unlicensed spectrum, across different spectrum bands
- Accelerate the digital transformation of industry verticals: The mobile industry will provide the networks and platforms to drive the digitization and automation of industrial practices and processes (including the fourth industrial revolution)

5G – New Realtime Mobile Applications

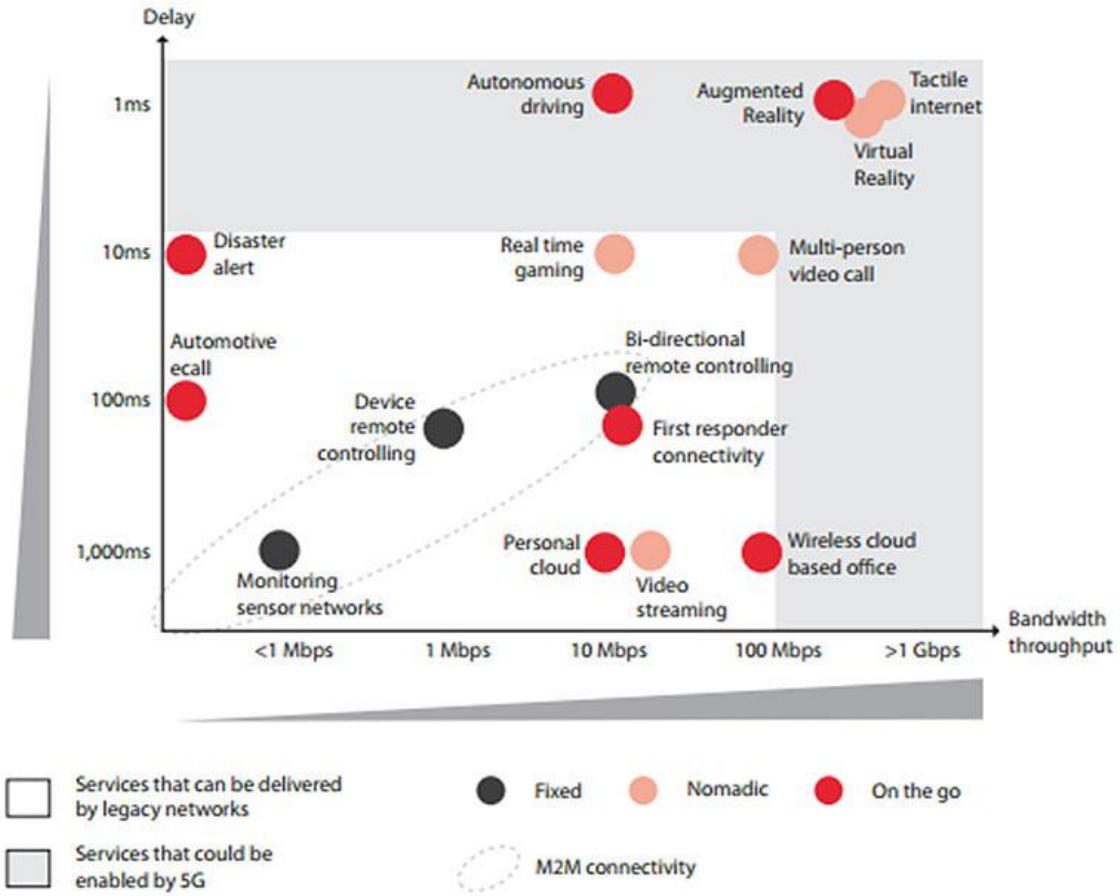


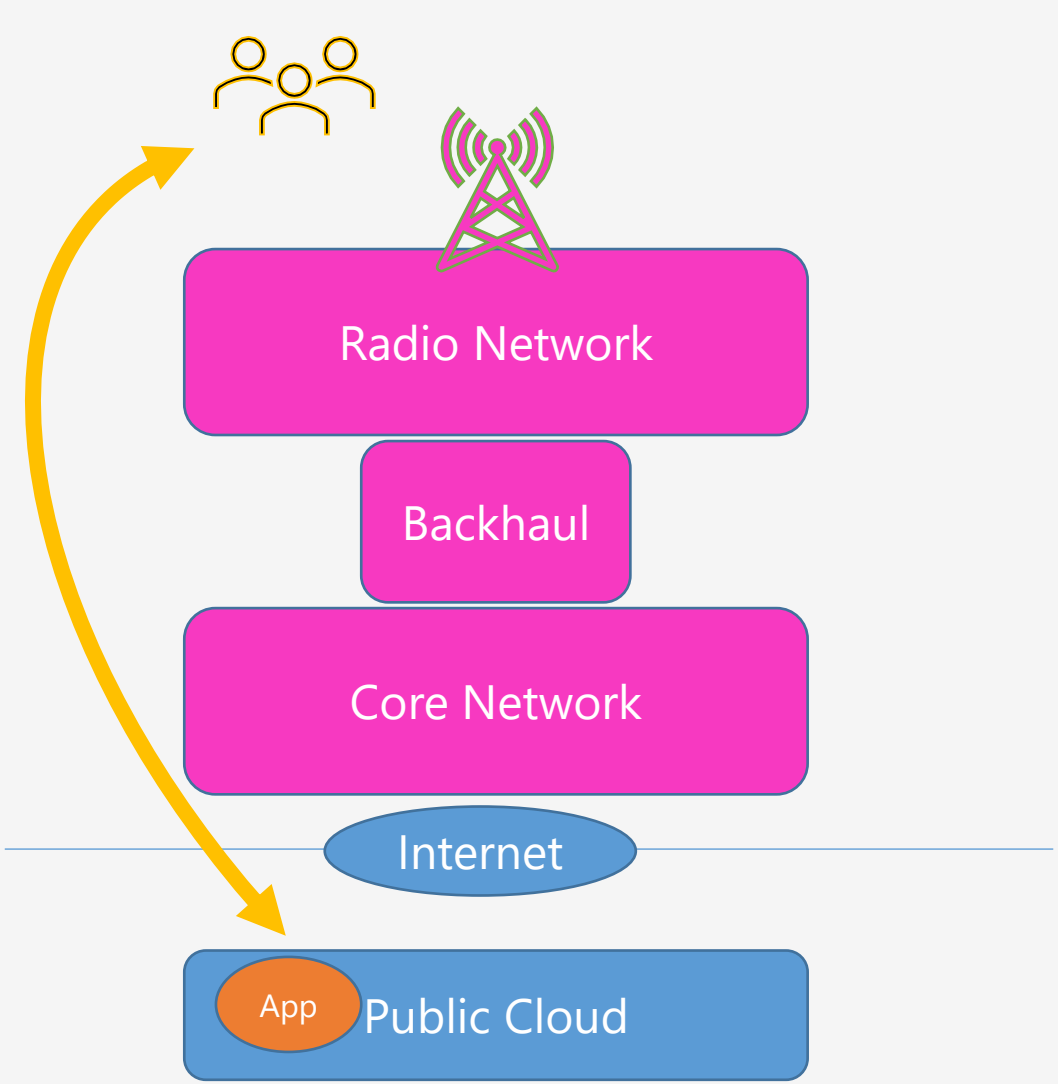
Figure 1: Bandwidth and latency requirements of potential 5G use cases

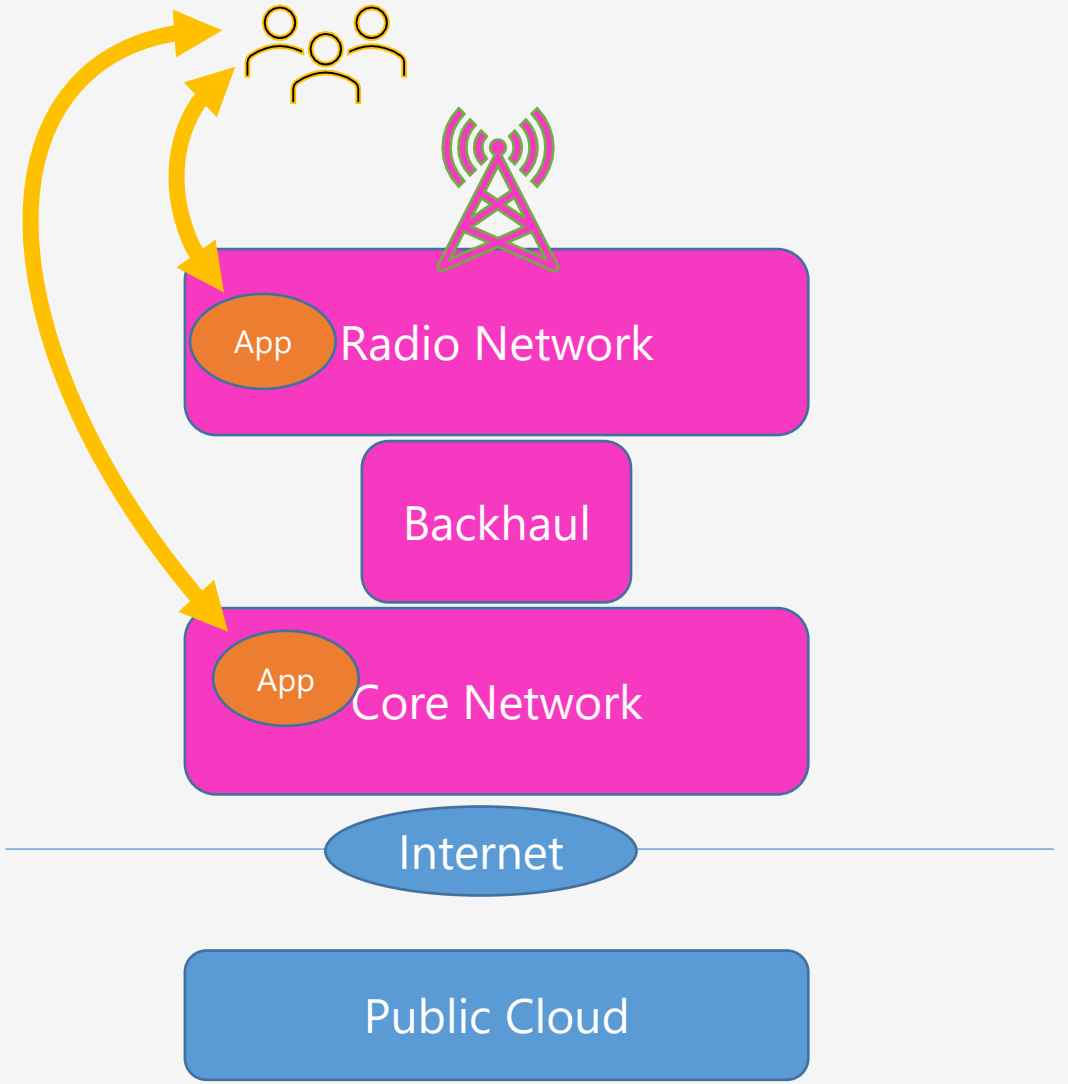
Source: GSMA Intelligence

5G – Enablers – Network Telco Cloud

- Adoption of virtualization in the telecommunications industry is evolving towards a cloud-native paradigm, where network functions are realized as cloud-native VNFs hosted by cloud infrastructures
- This approach of Platform-as-a-Service (PaaS) is being built on top of Infrastructure-as-a-Service (IaaS environments already deployed in teleco data centers
- The telco cloud spans all the layers of MNO networks, from central data centers to the edge of the network in order to support edge computing services
- An autonomic framework cooperates with the telco cloud from a system wide perspective to facilitate optimized system performance and end-user experience

5G – Edge Computing Intro [Latency]





5G – Technology Shifts

Fundamental Technology shift:

- **Decomposition of software and hardware**, separation of control plane and user plane, **virtualization**, **distribution, and decentralization**. Virtualization of the network through the use of **cloud native models** in a **service-based architectural framework** is an integral aspect of advances in the 5G system
- Flexible provisioning of **network slices** is necessary for delivering service value at the **edges** of the network through multiaccess **edge computing**

We will cover all above in the coming lectures….