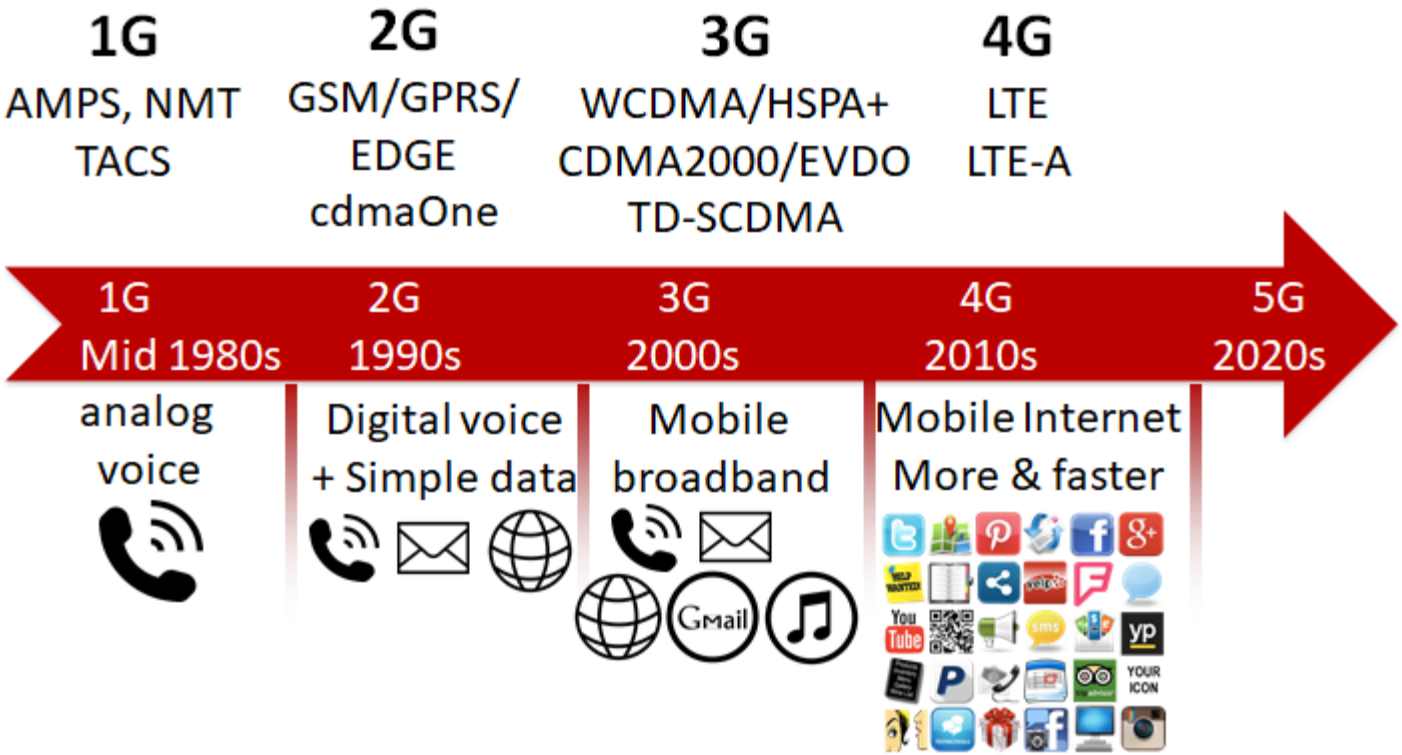
4G and 5G Technology

Lecture 5

Mobile Network Evolution



4G Networks

- All IP based secured packet switched network
- Voice also transmitted over IP
- Supports IPv6
- Access schemes – OFDMA, SC-FDMA
- Supports up to 100mbps downlink and 50mbps uplink.
- Using MIMO, speed can be increased

4G Networks

- Technologies – LTE, WiMAX, Wi-Fi metro, HSPA+.
- No formal specification – Operators making their own choices.
  - Verizon, Sprint, ATT, T-Mobile (and various other carries offer 4G networks).

Comparison of Generations 1G, 2G, 3G, 4G

Generation	Definition	Throughput	Technologies
1G	Analog	14.4 kbps (peak)	AMPS,NMT,TACS
2G	Digital (Narrow band Circuit Data)	9.6/14.4 kbps(peak)	TDMA, GSM, CDMA
2G plus	Packet Data	114/236.8 kbps(peak) 20-40 kbps	HSCSD, GPRS, EDGE
3G	Digital broadband packet data	3.1 mbps (peak) 500-700 kbps	UTMS, CDMA2000 1XRTT

Comparison of Generations 1G, 2G, 3G, 4G

Generation	Definition	Throughput	Technologies
3G plus	Digital broadband packet data. >2mbps	3.6/7.2/14.4 mbps$_{(peak)}$ 1-3 mbps	HSPA, CDMA2000 EV-DO
4G	Digital broadband packet based All IP (VOIP)	100 – 300 mbps $_{(peak)}$ 3-12 mbps	LTE Advanced WiMax Advanced

Cellular Network Standards

Generation	3GPP Circuit Switched	3GPP Packet Switched	3GPP2	Wimax Forum
2G	GSM		cdmaOne	
2.5G		GPRS		
2.75G		EDGE		
3G	UMTS		CDMA2000	
3.5G		HSPA/+	CDMA EV-DO	
4G		**LTE**	~~UMB~~	WiMAX

Note our focus will be on the 3GPP standards

LTE

- **Long Term Evolution (LTE)**
  - Fourth-generation (4G) cellular technology from 3GPP
  - Deployed worldwide

  - Increased data speed
  - IP-based network (No circuit-based network used)
  - New air interface:
    - OFDMA (Orthogonal Frequency-Division Multiple Access)
    - MIMO (Multiple Input Multiple Output technology)

LTE

- LTE is always evolving and 3GPP often has new “releases”
- The 1st 4G standard (3GPP Rel.8) was finalized in 2008
- Ever since, multiple upgrades in the standard (Rel. 9 onwards) have been released, including:
  - LTE-A (Rel.10), finalized in 2010.
  - LTE-A Pro (Rel.13), finalized in March 2016.

LTE

- The first 4G commercial network operated in Stockholm in 2009.
- 4G LTE networks now available in various countries:
  - 644 LTE commercial networks in more than 200 countries worldwide.
  - 100 LTE-A commercial networks in more than 50 countries worldwide

LTE

- OFDM/OFDMA techniques in down-link (downloading data)

- SC-FDMA technology in the up-link (uploading data).

LTE

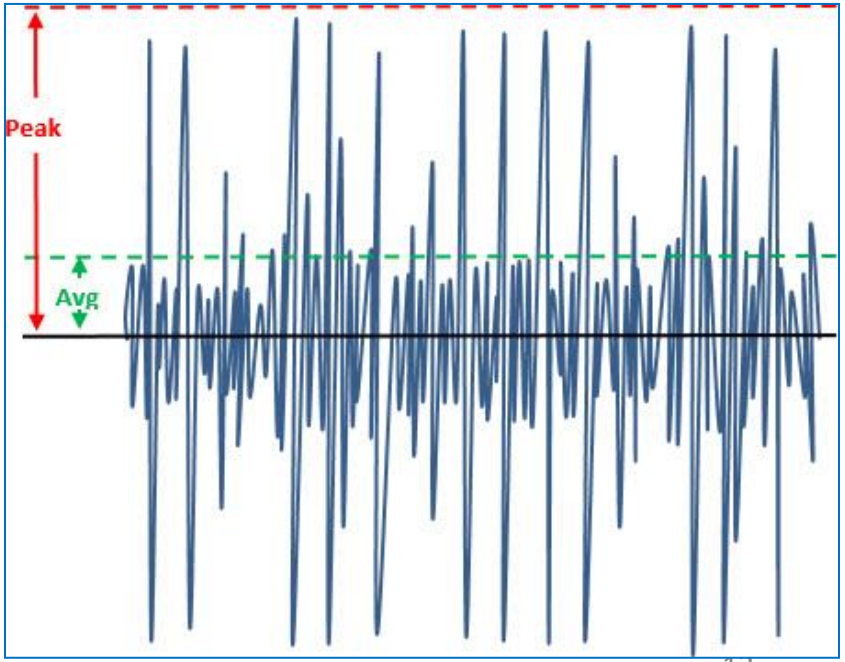
- Orthogonal frequency-division multiple access (OFDMA)
  - Allows access points to serve multiple clients at the same time
  - an updated version of frequency-division multiplexing (FDM) technology used to divide packets of information into separate bands that are carried by separate signals
  - OFDMA is used for achieving high spectral efficiency in the 4G communication system

LTE

- Why OFDMA is not used for both downlink and uplink:
  - Unfortunately OFDMA has a **high peak to average ratio**

  - **Every signal has an average power**: a high peak to average ratio indicates signals which require more power to be processed

  - This is not a problem for the base station where power is not a problem, however it is unacceptable for the mobile devices with limited power capabilities



LTE

- Single-carrier frequency-division multiple access **(SC-FDMA)**
  - ➢ Multiplexing technique which has a lower Peak-to-average Power Ratio (than OFDMA)
    - hence used for 4G uplink (upload) while OFDMA is used for 4G downlink (download)

LTE

- Duplex method
  - FDD, half duplex FDD, TDD
- Maximum mobile speed
  - 350 km/h
- Multiple access method
  - Upload: SC-FDMA (>50Mbps @ 20MHz)
  - Download: OFDMA (>100Mbps+ @ 20MHz)

LTE

- Data Transmission Speeds
  - Upload: 150 Mbps (LTE-Advanced)
  - Download: 300 Mbps (LTE-Advanced)
    - 100 Mbps (real-world usage)
    - Theoretical maximum 4G speeds reach 300Mbps, although such speeds are only achievable in controlled laboratory environments

3G and 4G

3G
Mobile
Broadband
42+ Mbps

4G
Faster and Better
Mobile broadband
300+ Mbps

4G WiMax and LTE

- **WiMAX**
  - Conceived as TDD
  - Internet compatible technology
  - More economical
  - Better specifications

- **LTE**
  - Conceived as FDD
  - Better marketing
  - Supported by 2G European vendors
  - 2G compatible technology
  - More expensive
  - Flawed specifications being fixed
  - **Prevailed with support from traditional operators**

WiMax and LTE

- WiMax Advanced
  - Proposed by IEEE based on WiMAX
  - OFDMA used for downlink and SC-FDMA for uplink
  - Requires completely different network architecture
    - Compared to GSM, WCDMA and LTE
  - Backward compatible (with WiMax)
  - Bit rates up to 40 Mbps.
    - Up to 110 Mbps with WiMax2+

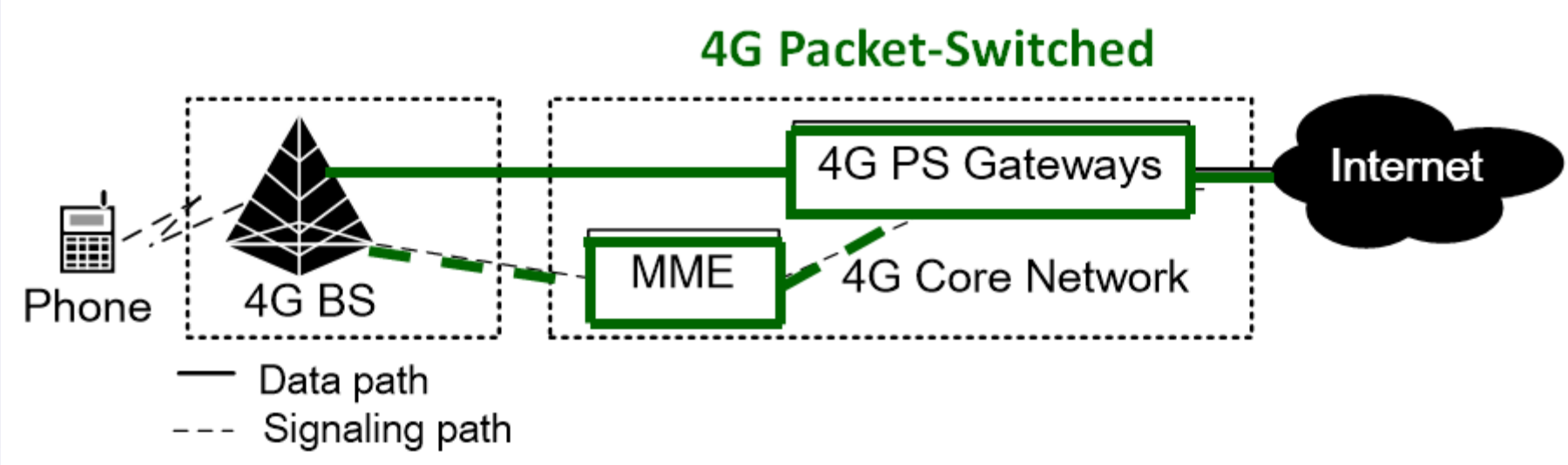
WiMax and LTE

- LTE Advanced
  - Proposed by 3GPP based on UMTS/HSPA.
  - OFDMA used for downlink and SC-FDMA for uplink
  - Can be constructed using existing 3G network
    - WCDMA to LTE network
    - LTE is anl upgrade to GSM/WCDMA networks, can be used by CDMA networks also.
  - Backward compatible (3G 3GPP networks)
  - Downlink up to 300 mbps and uplink up to 150 Mbps.

Long Term Evolution Advanced

- Increased downlink and uplink peak data rates.
- Improved spectral efficiency
- All IP network
- LTE network intended to bridge
  - very high data rate **fixed** wireless Local Area Networks (LAN)
  - and very high **mobility** cellular networks.

4G Architecture

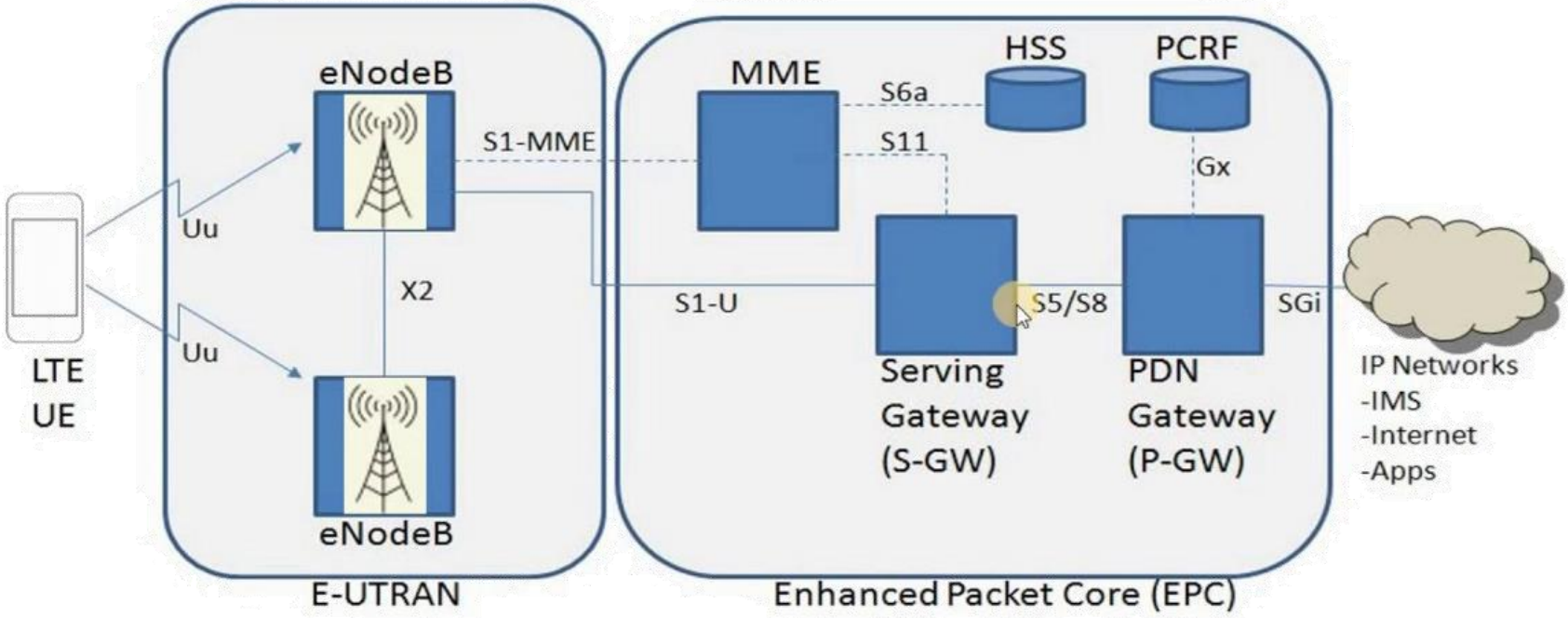


PS – Packet Switched Gateways, multiple gateways which connect the 4G network to other networks such as the Internet

4G Architecture

- Mobility Management Entity (MME)
  - plays an important role in LTE architecture.
  - LTE MME is responsible for initiating paging and authentication of the mobile device.
  - MME retains location information for each user and then selects the appropriate gateway during the initial registration process.
  - MME connects to the evolved Node B (eNode B, 4G Base station) through the S1-MME interface
  - Multiple MMEs can be grouped together to meet increasing signaling load in the network.
  - MME also plays a vital part in handover signaling between LTE and 2G/3G networks.

4G Core Network



4G Core Network (EPC) includes: MME, HSS, PCRF, S-GW, P-GW

(Exercise: find out more about the HSS, PCRF, S-GW & P-HW)

Next Generation (5G)

- Next generation (**5G**) has already taken its first steps
  - March 2017, 3GPP published the first studies for Release 14, the first version referring to 5G.
  - 4G LTE (Long Term Evolution) technology is only capable of using lower frequency bands, operating up to 6GHz, whereas the radio bands that 5G will be able to handle will be anywhere between 30GHz and 300GHz.
    - Since 5G can operate at such a high frequency, it includes speed increases supporting massive data transfers

5G

Generation	Theoretical Speed	Technology	Features
4G	100-300Mbps	WiMax LTE	Incredibly fast download speeds, paved the way for HD Streaming.
5G	10-30Gbps	Developing	Ultra-fast internet, low-latency and improved reliability.

Three Types of 5G (as of 2021)

- **mmWave high-band 5G**:
  - Operators: T-Mobile, AT&T and Verizon (USA).
  - About 10x faster than LTE with extremely low latency
  - however the user needs to be standing really close to a 5G tower or transmitter to get those speeds.
- **Mid-band 5G**:
  - Operator: Sprint (USA).
  - About 6x faster than LTE
- **Low-band 5G**:
  - Operators: T-Mobile and AT&T (USA)
  - About 20 percent faster than 4G LTE.

5G

- Millimeter wave high-band 5G is the fastest 5G.
  - For example: if a user downloads a 4GB file
    - This might take roughly 5 minutes and 19 seconds on today's fastest 4G LTE networks *(assuming a 100Mbps connection)*
    - On a mmWave high-band 5G connection, that same file download would take only 32 seconds *(assuming 1000Mbps).* However the user has to stay within 24 meters of a tower or transmitter to get those speeds

5G Cell Towers

- 5G cell towers are telecommunications sites that could boost wireless signals by ten times the current speed of 4G.
- 5G operates in a high-frequency band of the wireless spectrum.
  - Because high frequency waves have a harder time traveling over distance & through objects, the 5G network will be built on small cell site technology with antennas as close as 152 meters apart.
  - Cell tower leases are being established

5G Devices

- As of March 2021:
  - The number of announced 5G devices continues to rise with over 620 announced 5G devices
  - More than 404 commercially available 5G devices
  - A 5G SIM is required for secure 5G network access