CHAPTER 1
Introduction to Wireless Telecommunication Systems and Networks

1. Introduction to Wireless Communication Systems

Wireless Communication is a method of transmitting information from one point to other/others without using any physical connections like wires or cables.

2. Brief History of Wireless Communication

- Pre-Historic Period 150BC – The use of (Semaphore) smoke/fire signals, flags and flashing mirrors for communication. Since then wireless communication has been a part of human life and it is continuously evolving.
- 1794, optical telegraph by Claude Chappe
- Here electromagnetic waves of special importance.
- 1831, Faraday demonstrates electromagnetic induction
- 1864, J Maxwell: theory of electromagnetic Fields, wave equations.

- 1888, H. Hertz demonstrates with an experiment the wave character of electrical transmission through space
- 1896, Guglielmo Marconi: First demonstration if wireless telegraphy (digital!)
  : Long wave transmission, high transmission power is necessary (>200kW)
- 1915, Wireless voice transmission New York – San Francisco, 3500 Miles, Its first transcontinental telephone call
- 1920, Discovery of short waves(radio wave of a wavelength between about 10 and 100m, frequency 3 to 30 MHz) by Marconi, reflection at ionosphere, smaller sender and receiver, possible due to the invention of the vacuum tube in 1906
- 1928, many TV broadcast trials (across Atlantic, color TV, news)
- 1933 Frequency modulation (E.H Armstrong)
- 1958 A-Netz, first telecom company in Germany : analog, 160MHz, connection setup only from the mobile station, no handover, 80% coverage, by 1971 11000 customers,
- 1979 NMT (Nordic Mobile Telephone) at 450 MHz in Sweden, Denmark and Norway.
- 1982, start of GSM – specification.
- 1983, Start of the American AMPS (Advanced Mobile Phone System, Analog)
- 1986, C-Netz in Germany
  - Analog voice transmission, 450MHz, handover possible, digital signaling, automatic location of mobile device
- 1991 specification of DECT
  - Digital European Cordless Telephone
  - 1880-1999 MHz ~ 100-500m range, 120 duplex channels, 1.2 Mbps transmission, voice encryption, and used in more than 50 country
- 1992 start of GSM
  - Fully digital 900MHz, 124 channels,

    - Automatic location, handover, cellelur
    - Roaming in Europe – now worldwide in more than 2000 countries
    - Services: data with 9.6 Kbps, Fax, voice etc.
- 1994, E-Netx in Germany
    - GSM with 1800, smaller cells
- 1996, HiperLAN (High Performance Radio Local Area Network)
    - Is a wireless LAN standard which is European alternative for the IEEE 802.11
- 1997, Wireless LAN – IEEE802.11
- 1998, Specification of GSM successors
    - For UMTS (Universal Mobile Telecommunications System) as European proposals for IMT-2000
- 1999, Standardization of additional wireless LANs
    - IEEE standard 802.111b 2.4-2.5 GHz, 11 Mbps
- 2000 GSM with higher data rates
    - First GPRS trials with upto 50 kbps
- 2001 start of 3G systems
    - CDMA 2000 in Korea, UMTS tests in Europe and Japan
- 2003, UMTS starts in Germany
- 2005, WiMax starts as DSL alternative (for internet)
- 2006,
    - HSDPA starts in Germany as fast UMTS DL Speed >3 Mbps
    - WLAN draft for 250 Mbps 802.11n using MIMO
    - WPA2 mandatory for Wi-Fi WLAN devices
- 2007, Ericsson demonstrated for the first time in the world, LTE with bit rates upto 144 Mbps
- 2010, LTE- Advanced, 3GPP Release 10
- 2018, 5G NR NSA – Non-Stand Alone
- 2019, 5G NR SA – Stand Alone

Types of Wireless Communication Systems

- Television and Radio Broadcasting
- Satellite Communication
- Radar
- Mobile Telephone System (Cellular Communication)
- Global Positioning System (GPS)
- Infrared Communication
- WLAN (Wi-Fi)
- Bluetooth (IEEE 802.15.1)
- ZigBee (International standard: IEEE 802.15.4, physical range : 10 to 100m)
- Paging
- Cordless Phones
- Radio Frequency Identification (RFID)

Generations of Wireless Communications

1G: First Generations

- This is the first generation of wireless telephone technology, mobile telecommunications, which was launched in Japan by NTT in 1979.
- It uses analog signals.
- It supports only voice calls.
- It allows the voice calls in one country.
- Maximum speed 2.4 kbps.
- Data transmission at 150MHz.

Disadvantages

- Poor quality of voice
- Poor life of Battery
- Size of phone was very large
- No security
- Capacity was limited

2G: Second Generations

- This is the second generation of mobile telecommunication was lunched in Finland in 1991.
- It was based on GSM standard.
- Digital Modulation – TDMA and CDMA- 900MHz.
- Maximum speed 14.4 Kbps DL/UL, circuit switched transport.
- It supports voice call and SMS.
- Smaller and more secure mobile phones as compared to 1G.
- **2.5G, GPRS General Packet Radio Service**
    - It was first standardized and released by ETSI 1993.
    - It is Packet Switched Technologies.
    - The information to be sent to destination is divided into packets and all packets could be sent in parallel.
    - Maximum speed reached 53.6 Kbps Downlink
      26.8 Kbps Uplink
    - Introduced MMS – Multimedia Message Service
    - Supports IP to connect to internet.

- **2.75G, EDGE Enhanced Data Rates for GSM Evolution**
    - It was introduced by AT&T in 2003
    - Maximum Speed 236.8 Kbps DL
- It provides better quality and capacity

Disadvantages

- Unable to handle complex data such as Video
- Requires strong digital signals

3G: Third Generations

- The first standard of 4G is WCDMA (Wideband Code Division Multiple Access) and UMTS (Universal Mobile Telecommunications Systems)
- 3G was first released by Japan NTT in 1998, but it was not a commercial release.
- The first commercial release of 3G was in 2001 by SK Telecom South Korea.
- It used CDMA (Code Division Multiple Access) Technology for multiplexing and followed packet switching paradigm. Used three main frequencies band 2100/1900/850 MHz.
- Speed 384 Kpbs – 2 Mbps from moving to non-moving devices.
- Supported Video Calling, Mobile Internet and Streaming, 3G gaming, video conferencing, Mobile TV etc.
- **3.5G HSPA – High Speed Packet Access**
    - Enhanced version of WCDMA technology
    - Theoretical DL Speed: 14.4 Mbps, UL Speed: 5.76 Mbps
    - Symbol : H
- **3.75G HSPA+**
    - Evolved version of HSPA which used MIMO (Multiple Input Multiple Output) Antenna technology
    - Theoretical DL Speed: 168 Mbps, UL Speed: 22 Mbps
    - Symbol : H^+

Disadvantages

- Costly
- Requirement of high bandwidth
- Expensive 3G phones

4G: Fourth Generations

- LTE standardization started by ITU in 2004
- In 2005 LTE specification was released and deployment plan was started.
- In 2009 first commercially deployment available in Norway and Sweden.

- 4G is not only LTE, it also included another standard name WiMax which was standardized by IEEE and standard was called IEEE 802.16
- Wi-Max was released in 2006 by South Korea. However, LTE is the winning technology.
- Speed LTE: Downlink- 326 Mbps, Uplink - 50 Mbps
  (Recent LTE Throughput: DL:2.5 Gbps UL: 500 Mbps – Practically achieved values)

  Wi-Max: Downlink – 128 Mbps, Uplink – 56 Mbps

- High QoS (Quality of Service) and high security
- Low latency of about 30 ms
- Supports IP Telephony VoIP, 3D Television, Video Conferencing, Mobile Web, HD Mobile TV, Gaming, cloud computing
- LTE- Advanced – More advanced version of LTE.
  - It is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard.
  - It was standardized by 3GPP in 2011 as 3GPP release 10.
  - Increased peak data rate: Downlink 3Gpbs and Uplink 1.5 Gbps
  - Spectrum efficiency: 3 times greater than LTE.
  - Carrier Aggregation of contiguous and non-contiguous frequencies.
  - Self-Organizing networks.
  - Coverage enhancements
  - Improved MIMO schemes i.e. Massive MIMO (mMIMO) 8T8R, 32T32R, 64T64R
  - Heterogeneous Networks: Using a mix of macro, pico, femto and relay base station, heterogeneous network enable flexible and low-cost deployments and provide a uniform broadband experience to users anywhere in the network.

5G: Fifth Generations

- Started deployed worldwide commercially in 2019.
- 5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. 5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices.
- 5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, ultra low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users. Higher performance and improved efficiency empower new user experiences and connects new industries.
- Where 5G is being using:

- **Enhanced mobile broadband**
  In addition to making our smartphones better, 5G mobile technology can usher in new immersive experiences such as VR and AR with faster, more uniform data rates, lower latency, and lower cost-per-bit.

- **Mission-critical communications**
  5G can enable new services that can transform industries with ultra-reliable, available,

low-latency links like remote control of critical infrastructure, vehicles, and medical procedures.

- **Massive IoT**
  5G is meant to seamlessly connect a massive number of embedded sensors in virtually everything through the ability to scale down in data rates, power, and mobility — providing extremely lean and low-cost connectivity solutions.

- **URLCC :** Ultra Reliable low latency communications

- **5G Features:**
  - Higher Tput : Downlink – 20 Gbps(current QCOMM chipset X65 available in market supports up to 10 Gpbs)
    Uplink - 10 Mbps (current QCOMM chipset X65 available in market supports up to 5 Gpbs)
  - Very low latency <10 ms (upto 1 ms)
  - High motion mobility – Ability to support users on rapidly moving modes of transportation
  - New Spectrum: Utilization of millimeter – wave bands, radio carrier aggregation
  - Very high capacity
  - Wide range of applications
  - It used beamforming for transmission
  - Wide frequency range
    - FR1 →410 MHz to 7125 MHz
    - FR2 → 24.250 GHz to 52.600 GHz

5G Deployment Scenarios:

1. 5G NR NSA – Non Stand Alone
   The "Non-Stand Alone" (NSA) architecture, where the 5G Radio Access Network (AN) and its New Radio (NR) interface is used in conjunction with the existing LTE and EPC infrastructure Core Network (respectively 4G Radio and 4G Core), thus making the NR technology available without network replacement. In this configuration, only the 4G services are supported, but enjoying the capacities offered by the 5G New Radio (lower latency, etc). The NSA is also known as "E-UTRA-NR Dual Connectivity (EN-DC)"
2. **5G NR SA – Stand Alone**
   The "Stand-Alone" (SA) architecture, where the NR is connected to the 5G CN. 5G SA does not need 4G or LTE support.