Wireless Networks

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☑ Mid-Review	☐
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⟳ Status	Not started

Lecture 3 - Wireless Networks

Overview

▼ Networking Technologies

    ▼ Circuit Switching(voice)

- physical connection b/t 2 parties; connection cannot used by other parties

- e.g. telephone networks, first generation cellular networks

- Network must have network resource to establish a dedicated communication circuit b/t two devices

- 3 phase

    - Circuit establishment

        - end-to-end circuit established through intermediate switching devices

        - Dedicated network resources allocated to this circuit

    - Information transfer

        - Information can be transmitted through network via the circuit

    - Circuit disconnect

        - Circuit is terminated

        - Each device deallocates dedicated resources to system

- AD:

    - circuit dedicated to the connection

- - guarantee the full bandwidth for the duration of the connection

    - Guarantee quality of service: fixed data rate with only propagation delay

  - DIS:

    - inefficient, need extra delay for establishment b/f transmission

▼ Packet Switching(data)

  - no dedicated connection among all parties; several paties share single connection

  - e.g. computer networks, wireless local area networks

  - sender, message is broken into a series of small packets (msg + header); send all packet 1 by 1

  - router: packet received, stored temp, pass to next router

  - receiver; after receive all packet, remove packet header; reassemble message

  - AD: high link effi.; adapt to diff. data-rate transmission; do not block calls

  - DIS: end-to-end packet delay vary substantially; each packet carries extra header info; more processing required at each node

▼ Network Classification

  Coverage Area

  - Short range wireless networks(limited area)

    - WPAN(Wireless Personal Area Network) - connect various device within close area

    - WLAN(Wireless Local Area Network) - cover corporate building, school campuses, manufacturing plants, homes

    - unlicensed spectrum reserved for industrial, scientific, medical usage

      - no need to obtain a license, free; global availability; common freq. 2.4GHz

  - Long range wireless networks(span large geo. area)

    - provide wide-area coverage; operated by diff company(purchase)

    - WWAN(Wireless wide area network) - city / state / entire country

      - WMAN(Wireless Metropolitan Area network)

    - Satellite Network - connection across world

Infrastructure

- infrastructure-based wireless networks

    - mobile computers/devices connect wired network via hub

    - cellular system / laptop access internet via WLAN access point

- ad hoc wireless networks

    - no infra. temp setup network to meet immediate needs

    - single-hop & multi-hop

Wireless Personal Area Network(WPAN)

- WPAN: PAN- network centered around a person; device connected wireless

- Characteristics:

    - short communication range- personal space

    - low power consumption; low cost; small in size; ad hoc network

- Application

    - wirelessly connecting laptop computer-printer, PDA, wireless mouse, digital cam.; mobile phone - handsfree headset; PC in confined space little bandwidth required; body sensor to mobile phone

- ▼ Standards

    - IrDA(Infrared Data Association)

        - protocol define physical comm. specification for short range exchange of data over infrared links

        - features: comm. range up to 1m; no interfered by radio signal; low power for comm. ; low data transmission rate; low cost; line-of-sight; interference by sunlight, heat sources

- Bluetooth - industrial specification

    - radio interface in 2.4GHz freq. band → e-device to connect and comm. wirelessly via short rang, ad-hoc network

    - interconnected computer & peripheral; handheld devices, PDA, cell phone, headset, remote controls, wireless keyboards

    - features:

        - no line-of-sight; unlicensed ISM band; low cost

        - use FHSS(interf. mitigation) + TDD(transmission sep) + TDMA (multiple device share FH channel in same piconet)

        - provide networking with piconet & scatternet

        - support voice & data with SCO & ACL links

        - standard for interoperability

    - Transmission: freq. hopping + time division duplex

        - 2.4GHz ISM band

        - freq. Hopping(FH) suppress interface(79 channel in freq. band, 1MHz each)
        channel divided into time slot 625us(diff freq.)

        - carrier radio hop from 1 channel to another in pseudo random manner(dictated by FH sequence, hopping rate 1600 hops/s)

        - time division duplex(TDD) b/t sender & receiver: adjacent time slot allocated for comm.

    - Networking: piconet

        - 1 master(determine FH pattern) + 1/7 active slave (synchronize)

        - single channel is shared all device in same piconet that use unique FH pattern

        - parked device: no actively join in piconet(no connection but known & can reactivated; if communicate & already 7 slave, 1 slave switch to parked mode

        - standby device: no join in piconet

        - Form piconet

- all device standby before form

- device 1 initiates piconet become master

- master send device ID(48bits, FH pattern) & clock(phase in FH) to others

- a device adjust internal clock to master to join in piconet as slave(active-3bit active member address; parked device-8bit parked member; standby device no address)

- master and slave comm. by sending message alternatively

- TDMA support multiple slave to communicate with master within the piconet

  - Networking: scatternet

    - multiple piconet form scatternet

      - If piconets are close, they have overlapping areas

      - Some devices may play dual roles same time(master/slave; slave/slave; no master in 2 piconet)

      - comm.: piconet unique FH sequence; S/S device sync. to diff. FH seq. to participate in diff. piconets; M/S device suspend its current piconet & sync. to another piconet

  - SCO and ACL for voice & data

    - Polling-based TDD transm.: master polls slave & slave replies in adj. slots

    - sync connection oriented(SCO) link for voice - symm. 2 consecutive single slots periodically

    - async connection-less(ACL) link for data - use 1/3/5 slot for variable packet sizes, asym BW

  - Bluetooth states

  - Bluetooth Protocol Stack

    - Radio; Baseband; link management protocol; logical link control and adaptation protocol; Service discovery protocol; higher layer protocol

- IEEE 802.15

  - standards for PAN or short distance; similar goals to Bluetooth; aim at standardizing MAC and physical layers of Bluetooth

- standardizing MAC and physical layers of bluetooth

- deal with other issues(coexistence &interoperability within network)

- ▼ standard series

    - 802.15.1 - Based on Bluetooth & defining MAC and PHY layers specifications

    - 802.15.2 - Coexistence of WPAN & WLAN operating in same 2.4 GHz band

    - 802.15.3 - Standard for high rate (≥20Mbps) WPANs; Provide a means of low power & low cost solutions for portable consumer electronics, multimedia applications

    - 802.15.4 - Low data rate (200kbps maximum) solutions with long battery life(months to years) & low complexity; Targeted at sensors, interactive toys, smart badges, controls, etc.

    - 802.15.5 - Standard for mesh networking (partial meshes or full meshes); Range extension, more robustness, longer battery life

    - 802.15.6 - Standard for body area networks, e.g. low power networks for medical / entertainment use; Optimized for low power devices & operations on, in / around human body

    - 802.15.7 - Standard for free space optical comm. using visible light

    - 802.15.8 - Develop a standard for peer aware comm. optimized for P2P & infra-less comm. with fully distributed coordination operating in bands < 11 GHz

    - 802.15.9 - Develop recommended practice for transport of Key Management Protocol (KMP) datagrams

    - 802.15.10 - Develop recommended practice for routing packets in dynamically changing 802.15.4 wireless networks; goal is to extend coverage area as no. of nodes increase

- Other technology

    - Ultra Wideband (UWB)
      Developed for military radar systems; Provide 480 Mbps date rate ranging up to 3m and 11Mbps up to 10m; Use low power source to send out millions of bursts of radio waves each second; 100 times as fast as Bluetooth

- Wireless USB

  USB is the most used interface on PCs; Wireless extension of USB in the short range; Range of 3m and maximum data rate of > 480Mbps

- Z Wave

  A wireless power efficient technology for home automation;
  Build a mesh network using low energy radio waves to support wireless control of residential appliances & other devices;
  Range of 30m and data rate of 127 Kbps

Wireless Local Area Network(WLAN)

- WLAN: local area network which is connected through wireless access

- Characteristics: very flexible; no need wiring; robust; save cost; high-speed internet access

- Infrastructure

  - laptop close to each other , link to access point(AP)

  - AP control access to shared channel(select freq. hopping seq. and wireless device sync to corresponding FH seq.); bridge b/t wireless & wired networking

  - n *AP work together to provide wider wireless coverage

  - ad hoc network: no central controller, use MAC protocol

- ▼ Standards

  - 802.11 System Architecture(CSMA/CA)

    - Architecture

      - Station (STA)
        Terminal with access mechanisms to wireless medium & radio contact to AP

      - Access Point (AP)
        Device connects to distribution system & provides wireless conn. to stations

      - Basic Service Set (BSS)
        A group of stations & AP using same radio freq. channel

      - Extended Service Set (ESS)
        A set of BSSs integrated together; ESS appears same to LLC layer as

independent BSS; Mobile stations can move from one BSS to another transparently to LLC

- Distribution System (DS)
Connect APs in an ESS to form one logical network

- Portal
Bridge to other (wired) networks

- Ad hoc WLAN

    - independent Basic Service Set

        - Independent Basic Service Set (IBSS): Group of stations using same radio freq

▼ Protocol: specifies Physical layer & MAC standards

- Layer & Function

    - PMD(Physical Medium Dependent): Modulation, coding

    - PLCP (Physical Layer Convergence Protocol): Clear channel assessment (carrier sense)

    - PHY Manag: Channel selection, MIB

    - MAC: Access mechanisms, fragmentation, encryption

    - MAC Manag: Sync, roaming, MIB, power manag

    - Station Manag: Coordination of all manag func

- Physical Layer: distinct freq. rang

    - 2.4GHz: 14channel range spaced 5MHz apart; adj. channel overlap; will interf.(FHSS/DSSS/OFDM for coexis)

    - 5.0GHz: sep

▼ MAC layer

- Distributed Coordination Function (DCF): asynchronous data service; data packets based on a "best effort" strategy

- Point Coordination Function (PCF): time-bounded service; periodic polling strategy

    ▼ **3 inter frame space** to prioritize medium access

- SIFS (Short Inter Frame Space) - highest priority, used for ACK, CTS, polling response packets

- PIFS (PCF IFS) - medium priority, used for PCF

- DIFS (DCF IFS) - lowest priority, used for DCF

▼ 3 access methods

- DCF CSMA/CA: Collision avoidance via randomized back off mecha; ACK packet for reception

  - Broadcast:

    - Station ready to send starts sensing medium Carrier Sense

    - If medium is free for duration of an DIFS, station can start sending data

    - If the medium is busy, the station wait s for a free DIFS, then station must additionally wait random back off time (multiple timeslots) collision avoidance

    - If another station occupies medium during back off time, back off timer stops & station waits for another chance

  - Unicast:

    - Sender wait s for DIFS before sending data

    - If the packet was received correctly receiver sends ACK after waiting for SIFS

    - If transmission has error, sender retransmits packet later

- DCF with RTS/CTS: RTS/CTS avoids hidden terminals

  - Unicast:

    - Sender sends RTS with reservation parameter after waiting for DIFS: Reservation determines amount of time data packet needs medium - net allocation vector (NAV)

    - Receiver responses CTS after SIFS if ready receive

    - Sender sends data after SIFS, receiver sends ACK after SIFS

   - Other stations defer to access reserved medium for time period defined by NAV

- PCF: AP polls terminals according to a list

▼ MAC management

- Sync: Find a LAN, stay within a LAN, timer, etc

- Power management: Power saving mode without miss msg - Periodic sleep, frame buffering

- Association / Reassociation **(station no/bad connection)**
  New station integrates into LAN;
  Roaming , i.e. change networks by changing access points;
  Scanning , i.e. active search for a network;

  - scanning - environment

  - association / reassociation request

  - Association / reassociation response

  - AP accepts (re)association request

- MIB Management Information Base: Managing read, write operations

▼ Power Management

- Continuous aware mode: radio transceiver always on awake state for packet transmission, packet reception and idle listening

- Power saving mode (PSM): radio transceiver switched off to sleep state **if no need** to save power; AP has to keep in its buffer data for stations in PSM and sends wake-up signal

  - PSM infrastructure based WLAN
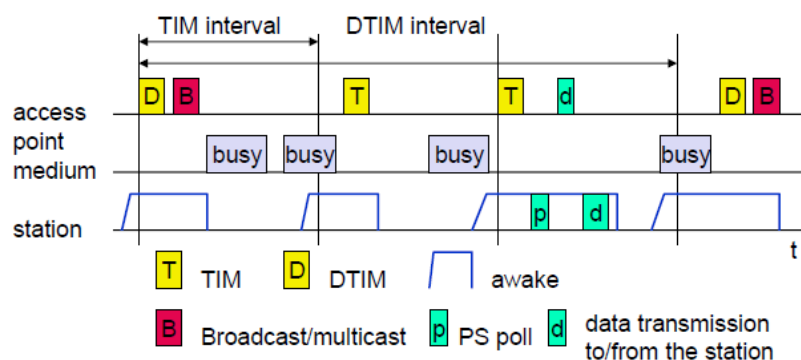
  - Traffic Indication Map (TIM)
    AP announces a list of unicast receivers

- Delivery Traffic Indication Map (DTIM)
    AP announces a list of broadcast/multicast receivers

  - PSM for ad hoc based WLAN
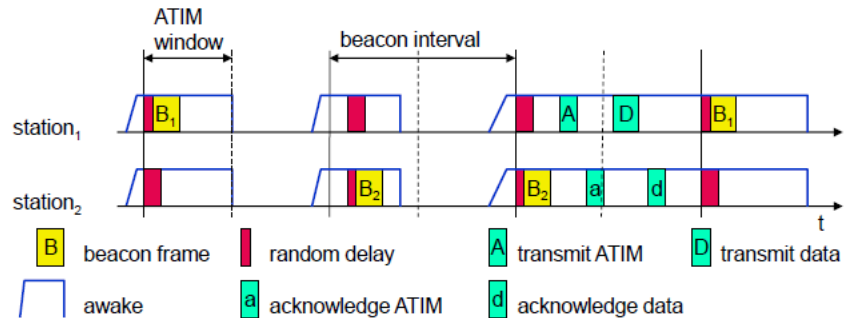
    - Ad hoc Traffic Indication Map (ATIM)
      no central AP; station with buffering frames announces
      receivers in ATIM

  ▼ Wi-Fi: Wireless Fidelity, a family of wireless network protocol

  Wi-Fi Alliance company certificate products for interoperability and backward
  compatibility, promote WLAN tech based on 802.11


- ETSI HiperLAN

  - High Performance Radio Local Area Network)

    - standard for Radio LANs developed in Europe

    - standard specifies common air interface for MAC & PHY layers

    - Operate in 5.15 GHz and 17.1 GHz bands; Cover 50 m

    - Specially designed for ad hoc computing

  - Family of standards

    - HiperLAN/1 Indoor LAN (~20 Mbps) for business workspace

    - HiperLAN/2 Indoor broadband multimedia (~50 Mbps) for indoor
      broadband multimedia

Wireless Wide Area Network(WWAN)

- WWAN (cellular network)

- divides the space into cells(region covered by base station) r=300m-40km(signal frequency, signal power, network protocols)

- microcell: highly populated area, w/ base station positioned closer to one another

- cell partition into several sector

- Freq. reuse:
  - increase sys capacity & spectrum utilization
  - each cell's base station is allocated a group of radio channels
  - neighboring cell are assigned diff. channel groups
  - reuse channel groups by diff. cells if interference lv. below tolerable thresholds

▼ Cellular Network Architecture
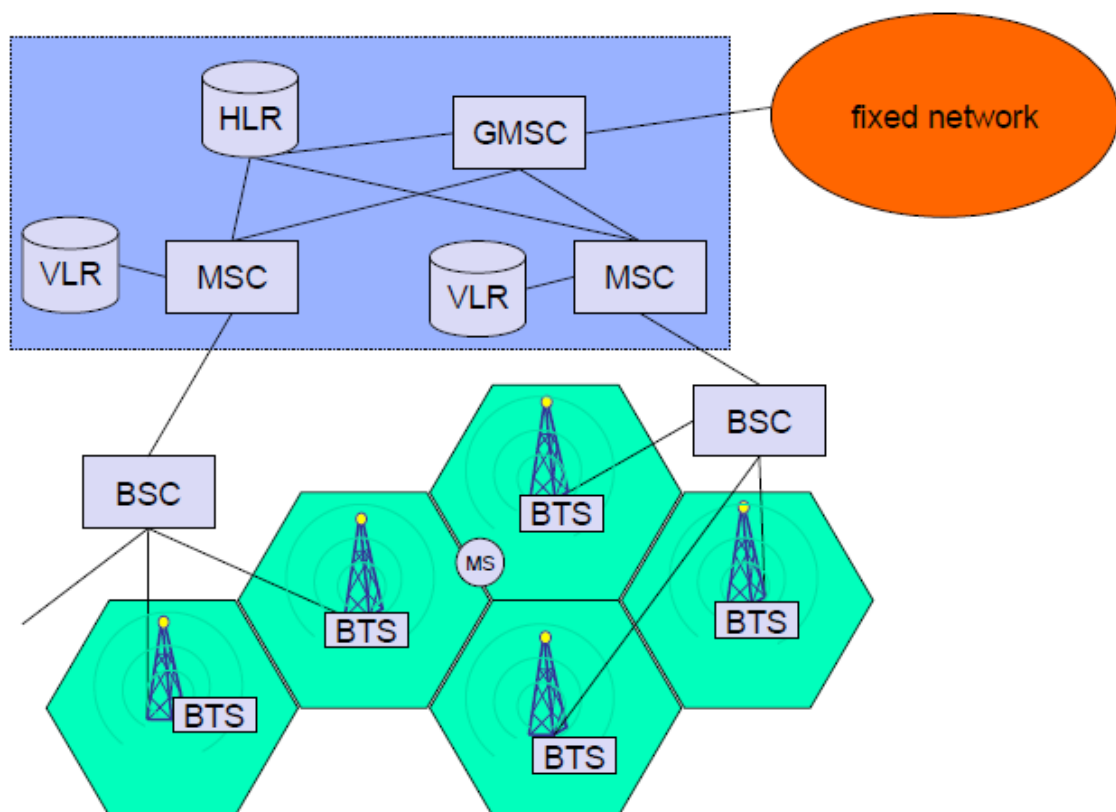
▼ Cellular Network Components

- **Mobile station(MS)**
  Consist of hardware, software, subscriber identity module (SIM)(stores user profile); Movable among cells & served by BS via radio interface

- **Base station (BS)**

- Include base transceiver station (BTS) and base station controller (BSC)

    - BTS: radio components including sender, receiver, antennas

    - BSC: switching between BTSs, controlling BTSs, managing radio channels

- Provide MS the network access within a cell via two types of channels

    - Control channels used to exchange control information that deals with setting up and maintaining user calls

    - Traffic channels used to deliver voice or data signals between user

- **Mobile switching center(MSC)**

    - manage group of BSs, control all connections within its domain

    - set up conn, route traffic, serve as a gateway to external networks

- **Location register (LR)**

    - location database consists of **home location register(HLR) and visitor location register (VLR)**

    - Two databases communicate with each other to authenticate MS and manage location information of MS

        - HLR central master database: Every MS permanently associated with HLR; Keep MS's user profile, including mobile device ID, authentication keys, location;

        - VLR local database: Keep subset of MS' user profile in its service area

- 2 techniques for sharing MS2BS radio spectrum

    - Combined FDMA/TDMA: divide spectrum channels, divide each channel into time slots

    - CDMA: code division multiple access

- Phone call operation

    - MS initialization: MS scan BS signal in setup control channel, select BS with strongest signal; MS registers to MSC via selected BS; MS periodically update its location info to HLR/VLR

    - Outgoing call: MS send phone no. of receiver when setup channel is idle; BS send request to MSC; call is blocked if free channel not available

- Paging: MSC send paging msg to certain BS; each BS send paging signal within its cell

- Call accepted: the receiver recognizes phone no. & responses to BS, BS response to MSC; MSC setup connection b/t 2 BS, find free tranffic channel within each BS, and notifies each BS, BS notifies MS; end-to-end connection b/t MS is established

- ongoing call: 2 MS exchange voice signals via established conn. through BS & MSC

- call completed: 1 MS terminates the call; MSC informed the call completion; assign traffic channel is released

▼ Evolution

- 1G Network

    - analog network based on FDMA; they only provide voice comm. service

    - drawbacks: low voice quality, poor battery life, poor handoff reliability, often resulting in disconnection, low capacity, no security, large phone size

- 2G Network

    - Digital AMPS(TDMA in US); GSM(global system for mobile comm.); CDMA(quality); PDC(personal digital cellular, TDMA in Japan)

    - better voice quality; more service(voicemail, call waiting, 3-way calling); basic data service(SMS, MMS); increase capacity; provide security support

    - feature

        - 1G&2G: circuit-switching tech for voice/data service: ineffi. & expensive / provide very limited data transfer rate

        - 2G has packet-switching option for data service

        - drawback: require strong digital signal; capacity not adequate for data-driven app

- 2.5G/2.75G Networks

    - system b/t 2G & 3G: 2.5G (GPRS - general packet radio service / CDMA2000), 2.75G(EDGE - enhanced data rate for GSM evolution)

    - feature: channel bandwidth(data rate) up to 144kbps; multiplexing CDMA, SMS/MMS service, high capacity packetized data; packet switching; PSTN Core network

- 3G Networks

- - CDMA 1x EVDO & EVDV in US / UMTS in EU

  - feature: channel bandwidth: 144Kbps - 2Mbps; CDMA multiplexing; enhanced quality of service audio/video/data; packet switching; packet network

- 3.5G Networks

  - high speed packet access

  - feature: channel bandwidth: > 2Mbps; CDMA multiplexing; integrated high quality audio/video/data; all packet switching; internet network

- 4G Networks

  - tech 1: LTE(long term evolution) advanced standardized by 3GPP; surpass/reach 1Gbps for stationary reception & 100 Mbps for mobile reception

  - tech 2: 802.16m - mobile WiMAX(e), peak rate no reach 4G requirement; 802.16m(WirelessMAN-advanced) evolution of e, fulfill 4G

  - all IP core: IP packet tunneled from base station to gateway; no sep b/t data & voice

  - feature: all-IP packet switched network; provide wide bandwidth for high data rate multimedia service; guaranteed QoS, suitable for high quality multimedia; ubiquitous connection and seamless handover among diff. network; provide customized service

  - key techn

    - advanced multiplexing & access scheme: orthogonal FDMA, single-carrier FDMA; multi-carrier CDMA(effic)

    - advanced modulation techn

    - smart antenna(Multiple input & multiple output)MIMO, multi-user MIMO high rate, high reliability

    - support IPv6: packet switching only

    - Open-wireless architecture(OWA)

- 5G Network(wireless world wide web)

  - service

    - enhanced mobile broadband(eMBB): immersive experience - VR & AR

    - ultra-reliable low-latency comm.(URLLC) for mission-critical applications, such as remote device; surveillance cam & sensor for public safety &

infras; Vehicle2V comm. among autonomous C; remote therapy

- Massive machine-type comm.(mMTC) seamlessly interconnect large no. embedded sensors & smart devices

  - requirement(IMT-2020)

    - peak data rate: 20Gbps downlink & 10Gbps uplink; real-word data rate(100Mbps-50Mbps); latency<4ms; spectral effi: 30bits/Hz - 15bits/Hz; movement 0-310mph; 1million connected devices per km^2

  - feature: unified platform; wide use spectrum; faster; more capacity; low latency

  - new tech: new radio freq.; massive MIMO; edge comp.; small cell; beamforming

Satellite System

- Wireless network with coverage for entire planet; no roam; transponder for data transfer

- overtaken by cellular network for tele comm.

- not cover/destroyed; radio & TV broadcast/weather satellite; navigation

Types of Satellite

- Geostationary Earth Orbit; medium/low Earth Orbit