Wireless Networks

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- Wireless and Mobile Networks: Context
  - More wireless (mobile) phone subscribers than fixed (wired) phone subscribers (10-to-1 in 2029)
  - More mobile-broadband connected devices than fixed-broadband connected devices (5-1 in 2019)
    - 4G/5G cellular networks now embracing Internet protocol stack, including SDN
  - Two important (but different) challenges
    - Wireless: communication over wireless link
    - Mobility: handling the mobile user who changes point of attachment to network
- Wireless Hosts
  - Laptop, smartphone, IoT device, etc.
  - Run applications
  - May be stationary (non-mobile) or mobile
    - Wireless does not always mean mobility
- Base Station
  - Key element that connects the wireless network to wired networks through the backbone link
  - Relay — responsible for sending packets between wired networks and wireless host(s) in its "area"
    - For examples, cell towers, IEEE 802.11, access points
- Network Infrastructure

  - Larger network with which a wireless host may wish to communicate
  - Backbone link: connects base station to network infrastructure

- Infrastructure Mode
  - Each node is associated to the base station
  - Base station connects wireless hosts into the wired network
  - Handoff or handover: mobile node changes base station providing connection into wired network (without losing connectivity)

- Operating Modes of a Wireless Network
  - Ad Hoc Mode
    * No base stations
    * No larger network infrastructure to connect
    * Nodes can only transmit to other nodes within link coverage
    * Nodes organize themselves into a network: route among themselves
    * Development of protocols is challenging

- Wireless Link Characteristics
  - Decreased signal strength: radio signal attenuates as it propagates through matter (path loss)
  - Interference from other sources: some wireless network frequencies (like 2.4 GHz) are shared by many devices (like WiFi, Bluetooth, garage openers, motors, etc), which cause interference
  - Multipath propagation: radio signal reflects off objects and ground, arriving at destination may create different copies of the signal at slightly different times (multipath fading)
  - Moreover, nodes in the wireless link (broadcast link) do not receive the same signal

- WiFi: IEEE 802.11 Wireless LAN
  - Many different 802.11 Standards:
    * Link layer and physical layer
    * Most of the IEEE 802.11 standards have infrastructure mode and ad hoc mode network versions
    * Common MAC protocol
    * Common frame format
    * All offer connectionless reliable service with positive ACK and stop and wait at the link layer

        * Different data rates
        * All (but one) operate in unlicensed spectrum → ISM bands (Industrial, Scientific, and Medical bands)
            · Open frequency bands for non-exclusive usage (no license required)

- Infrastructure Mode
    - Base station is the access point (AP)
    - Wireless host communicates with AP
    - Service set identifier (SSID): AP identifier
    - Basic Service Set (BSS) contains:
        * Wireless hosts
        * AP

- IEEE 802.11 MAC Protocol: CSMA/CA
    - IEEE 802.11 Sender
        1. If sense channel idle for DIFs, then:
            * Transmit entire frame (no CD)
        2. If sense channel is busy, then:
            * Wait until channel is idle for DIFS
            * Start random backoff time using binary exponential backoff
            * Timer counts down only when channel idle
        3. Transmit when timer expires (only occurs when channel idle)
            * Wait for ACK
        4. If ACK received and another frame to send, begin CSMA/CA in step 2
        5. If no ACK, increase random backoff interval, repeat step 2
    - IEEE 802.11 Receiver
        * If frame received OK (no collision and no errors detected)
            · Return ACK after SIFS
    - Inter-frame spaces
        * Used to give access priority to different transmissions:
            · SIFS (Short Inter-Frame Space)
            · DIFS (Distributed Inter-Frame Space)
        * The smaller interface space, the higher priority

- IEEE 802.11: RTS/CTS
    - IEEE 802.11 MAC protocol includes an optionalreservation scheme to deal with hidden terminal problem

- Idea: sender "reserves" channel for data frames using small reservation packets
    - Using CSMA/CA, sender transmits a short RTS (Request-To-Send) frame to receiver indicating the total time required to transmit the data frame
    - After SIFS, receiver broadcasts CTS (Clear-To-Send) in response to RTS, including the reserved time
        - After receiving the CTS, sender waits SIFS and transmits data frame
        - Nodes that create collisions in receiver hear CTS and defer transmissions for the reserved time
- RTS may still collide with other RTS, but RTS are short frames
    - RTS/CTS only worth it for transmission of long data frames
    - Each node sets an RTS threshold → If frame is longer than threshold, then use RTS/CTS

- IEEE 802.11: Reliable, Connectionless
    - MAC Protocol: CSMA/CA
    - Error Detection in link layer: CRC
    - Connectionless: no handshaking between sending and receiving NICs
    - Reliable: receiving NIC sends positive ACKs to sending NIC if frame is received correctly
        - Implements stop and wait
        - CSMA/CA: collisions can still happen and can not be detected
            - Transmitter needs acknowledgements to know if frame was received without collisions
        - Error detection in link layer to detect bit errors introduced by the physical medium and physical layer
            - Transmitter needs acknowledgements to know if frame was received correctly or otherwise recover from the error in the link

- Wireless, Mobility: Impact on Higher Layer Protocols
    - Logically, impact on higher layers should be minimal
        - Best effort service model remains unchanges
        - TCP and UDP can (and do) run over wireless, mobile
    - Performance-wise:
        - Packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handover loss
            - TCP interprets loss as congestion, will decrease congestion window unnecessarily
            - Delay impairments for real-time traffic
        - Link capacity is a scarce resource for wireless links