Unit 4. Local Area Networks, LANs

Outline

- Introduction
- IEEE LAN Architecture
- Random MAC Protocols
- Ethernet
- Ethernet Switches
- Wireless LANs

Introduction – WAN and LAN differences

WANs:
- Main goal: scalability.
- Switched network with mesh topology.

LANs:
- Multy-access network with shared media.
- A Medium Access Control (MAC) protocol is needed.

WAN (PSTN)

Switches (Central Office)

Modem

Multiplexed lines

Switched media

LANs

Modem

Shared media

Before 1970's: Sites had only one central computer, with users accessing via computer terminals with proprietary protocols and low speed lines.

During the 1970's, the first LANs were created to connect several large central computers: Ethernet, ARCNET, ALOHAnet, etc.

During the 1980's PCs proliferated and the demand for LAN technologies multiplied. Each vendor typically had its own type of NICs, cabling, and data link and network protocols.

In 1983 Ethernet was standardized as IEEE 802.3 protocol. Many manufacturers started producing devices for this technology.

During the 1990's Ethernet and TCP/IP became the leading LAN technology and network protocols.

In 1999 IEEE 802.11 protocol (wifi) was standardized for Wireless LANs, and it has been an enormous success.
Unit 4. Local Area Networks, LANs

Introduction – Ring Topology

- Stations can be in one of the states:
  - Reception: The repeater decodes the signal and send the bits to the station after some delay $T$. The bits are also encoded and send to the next repeater.
  - Transmission: The same as before, but the bits encoded and send to the next repeater are received from the station.
  - Short circuit: The repeater is in short circuit (e.g. if no station is connected, or a malfunction occurs).

OSI Reference model:

- Logical Link Control (LLC):
  - Common to all 802.x MAC standards.
  - Define the interface with the upper layer and specifies several services (procedural modes):
    - (i) unacknowledged connectionless, (ii) connection oriented, (iii) acknowledged connectionless.

- MAC sublayer:
  - Define the medium access protocol. It is different for each LAN technology.
Unit 4. Local Area Networks, LANs

IEEE LAN Architecture – LAN encapsulation

Higher layer PDU

LLC header

MAC header

CRC

physical layer

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IEEE LAN Architecture – IEEE 802 standards (some)

- 802.1: LAN/MAN architecture.
- 802.2 Logical Link Control (LLC)
- 802.3 Ethernet
- 802.4 Token Bus
- 802.5 Token Ring
- 802.8 FDDI
- 802.11 WiFi: Wireless LANs.
- 802.15 Personal Area Networks or short distance wireless networks (WPAN)
- 802.15.1 Bluetooth
- 802.15.4 low data rate and low cost sensor devices
- 802.16 WiMAX: broadband Wireless Metropolitan Area Networks.

See: http://grouper.ieee.org/groups/802/1, 2, …

Unit 4. Local Area Networks, LANs

IEEE LAN Architecture – LLC header

- 3 / 4 bytes

<table>
<thead>
<tr>
<th>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destination SAP</td>
</tr>
<tr>
<td>==---------------</td>
</tr>
</tbody>
</table>

- Service Access Point (SAP): Identifies the upper layer protocol.
- Control: Identifies the frame type. It can be 8 or 16 bits long, 8 bits for unnumbered frames (used in connectionless modes).

<table>
<thead>
<tr>
<th>SAP hex</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>ARP/ARPv</td>
</tr>
<tr>
<td>02</td>
<td>IP/ICMPv</td>
</tr>
<tr>
<td>04</td>
<td>IP/IDPv</td>
</tr>
<tr>
<td>06</td>
<td>IEEE 802 Bridge Spanning Tree Protocol</td>
</tr>
<tr>
<td>08</td>
<td>IEEE 802.2 Address Resolution Protocol (ARP)</td>
</tr>
<tr>
<td>AA</td>
<td>ISO Network Access Protocol (SNAP)</td>
</tr>
<tr>
<td>90</td>
<td>NOS MIB</td>
</tr>
<tr>
<td>FF</td>
<td>TIP MIB</td>
</tr>
<tr>
<td>00</td>
<td>Null MIB</td>
</tr>
</tbody>
</table>

Example of some IEEE SAP values.
Unit 4. Local Area Networks, LANs
Random MAC Protocols - Aloha

- Developed in 1970 by professor Norm Abramson. The objective was connecting the central computers of the university campus of Hawaii.
- Aloha is the basis of most random MACs protocols. It is interesting evaluate Aloha because is easy to model mathematically, and the main conclusions apply to other random MACs.

Unit 4. Local Area Networks, LANs
Random MAC Protocols - Type of MACs

- Token Passing:
  - Only the station having the token can transmit. After transmission the token is passed to another station.
  - Examples: FDDI and Token-Ring
- Random:
  - There is no token. Instead, there is a non null collision probability. In case of collision, the frame is retransmitted after a random backoff time.
  - We shall only study random MACs.
  - Example: Ethernet

If only one station transmits:

\[ E = \frac{T_f}{T_c} \approx 100\% \]
Unit 4. Local Area Networks, LANs
Random MAC Protocols – Aloha efficiency

- Many stations transmit. Define:
  - \( N(T) \): Number of successful Tx during \( T \).
  - \( C(T) \): Number of collisions during \( T \).
  - \( T_r \): Tx time of a frame.

Efficiency: \( E = \frac{N(T)}{T} \)

Offered load: \( G = \frac{[N(T) + C(T)]}{T} \)

Hypothesis: Poisson arrivals

\[
P(n \text{ frames arrive in a time } t/T_r) = \frac{(GT_r/T)^n}{n!} e^{-\frac{GT_r}{T}}
\]

\[
E = \lim_{T \to \infty} \frac{N(T)}{T} = \lim_{T \to \infty} \frac{(N(T) + C(T))}{T} = G P_{\text{ave}}
\]

Conclusions:
- The maximum load is only 18%.
- After the maximum load is reached the protocol becomes unstable: The higher is the offered load (\( G \)), the lower is the efficiency (\( E \)).

Efficiency: \( E = \frac{N(T)}{T} \)

Offered load: \( G = \frac{[N(T) + C(T)]}{T} \)

Hypothesis: Poisson arrivals

\[
P(n \text{ frames arrive in a time } t/T_r) = \frac{(GT_r/T)^n}{n!} e^{-\frac{GT_r}{T}}
\]

\[
E = \lim_{T \to \infty} \frac{N(T)}{T} = \lim_{T \to \infty} \frac{(N(T) + C(T))}{T} = G P_{\text{ave}}
\]

- If a packet is scheduled for Tx at time \( t \), the success probability is the probability of no other Tx occur in the vulnerable interval \([t-T_r, t+T_r]\):

\[
P_{\text{ave}} = P[0 \text{ packet is Tx in } 2T_r] = \frac{(GT_r/T)^n}{n!} e^{-\frac{GT_r}{T}} = e^{-2G}
\]
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Unit 4. Local Area Networks, LANs
Random MAC Protocols – Carrier Sense Multiple Access (CSMA)
- If the transmission time is small compared with the delay, the aloha efficiency can be increased if the stations “listen” the medium (carrier sense) before transmission.
- When the medium is becomes free:
  - 1 persistent-CSMA: Transmit immediately. E.g. Ethernet.
  - non persistent CSMA: Wait for an additional random time and listen again before transmission. E.g. Wifi.

Unit 4. Local Area Networks, LANs
Ethernet – Frames
- Ethernet II (DIX):

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Destination</th>
<th>Source MAC</th>
<th>Frame type</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8 bytes)</td>
<td>(6 bytes)</td>
<td>(6 bytes)</td>
<td>(4 bytes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6 bytes)</td>
<td>(6 bytes)</td>
<td>(1500 bytes)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- IEEE 802.3

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Destination</th>
<th>Source MAC</th>
<th>Length of</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8 bytes)</td>
<td>(6 bytes)</td>
<td>(6 bytes)</td>
<td>(2 bytes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6 bytes)</td>
<td>(6 bytes)</td>
<td>(1500 bytes)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Type: Give time to detect, synchronize and start reception.
- Type: Identifies the upper layer protocol (IP, ARP, etc. RFC 1700, Assigned numbers). This value is always > 1500.
- Length: Payload size (0–1500).
The binary representation of an address is formed by taking each octet in order and expressing it as a sequence of eight bits, least significant bit (lsb) to most significant bit (msb), left to right.

The order is changed because each octet is transmitted in the order lsb...msb, but it is written (and seen at in a PC console) in the reverse order (msb...lsb). IP addresses are written in the Tx order, and htonl() is used to convert to network bit order.

Example:

Transmitted bits: 0011 0111 1101 0010 0010 0000 0000 0000 0000 0000 0000 0001
Binary Representation (msb-lsb): 1010 1110 1101 1000 0100 0000 0000 0000 1000 0000 0000 0001
Hexadecimal representation: ACD 4 0 0 0 0 0 0 0 0 0 0 0
Notations: AC-DE-48-00-00-80, AC:DE:48:00:00:80, ACDE:4800:0080

The station which Tx the frame has to LLC header (3 bytes) SNAP header (5 bytes)

<table>
<thead>
<tr>
<th>MAC</th>
<th>DSAP</th>
<th>SSAP</th>
<th>Contr.</th>
<th>OUI</th>
<th>Type</th>
<th>upper layer</th>
<th>CRC</th>
<th>802.3</th>
<th>0xAA</th>
<th>0xAA</th>
<th>0x03</th>
<th>0x000000</th>
<th>2bytes</th>
<th>PDU</th>
<th>(4 bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLC header (3 bytes)</td>
<td>SNAP header (5 bytes)</td>
<td>≤ 1492</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unit 4. Local Area Networks, LANs
Ethernet – IEEE Sub-Network Access Protocol (SNAP)
- Allows the specification of protocols, and vendor-private identifiers, not supported by the 8-bit 802.2 Service Access Point (SAP) field.
- It is used to encapsulate TCP/IP protocols over IEEE 802.2 with OUI=0x000000 and Type equal to the RFC 1700 (used for DIX).

802.3 SNAP Frame

Note: The MSS indicated by TCP would be of 1460 if DIX, and 1452 if IEEE encapsulation is used.
Unit 4. Local Area Networks, LANs

Ethernet – Minimum Frame Size

- Example of a “too small frame”

A does not detect the collision!

Legend:
- preamble
- Jam
- frame i
- collision detection
- τ latency

The preamble is not interrupted in case of collision, and the JAM is Tx immediately after.

512 bits slot time is too restrictive for Gigabit Ethernet (10^9 bps).

Example, assume v_p = 2 10^8 m/s and consider only propagation delay:

\[ T_{\text{SL}} > 2 \tau + T_{\text{jam}} \Rightarrow 512/10^9 > 2 \frac{D}{(2\times10^8)} + 32/10^9 \Rightarrow D < 48 \text{ m} \]

48 m is too short (we shall see that 100 m is used as maximum Ethernet segment)

To cope with this, Gigabit Ethernet uses an “extension field”, such that the minimum Gigabit Ethernet size is 512 bytes (instead of bits).

The extension field uses special symbols for its detection and removal.

The Ethernet payload has to be \( \geq 46 \) bytes, for the ethernet frame size without the preamble to be \( \geq 64 \) bytes (512 bits)

IEEE standard: The slot time shall be larger than the sum of the Physical Layer round-trip propagation time and the Media Access Layer maximum jam time:

\[ T_{\text{SL}} > 2 \tau + T_j \]

Justification:
If the previous relation holds, station A has time to detect the collision and send the JAM before the end of the frame Tx.
### Unit 4. Local Area Networks, LANs

#### Ethernet – Different Ethernet Standards (some)

<table>
<thead>
<tr>
<th>Commercial name</th>
<th>type</th>
<th>Standard year</th>
<th>Name</th>
<th>Cabling</th>
<th>UPOF Pins</th>
<th>Connector</th>
<th>Codification</th>
<th>segment distance*</th>
<th>Half duplex</th>
<th>Full duplex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet</td>
<td>10/100BaseT</td>
<td>1985</td>
<td>10BaseT</td>
<td>CCA/UTP</td>
<td>1R45, 1R45</td>
<td>RJ45</td>
<td>100m</td>
<td>100m</td>
<td>100m</td>
<td>100m</td>
</tr>
<tr>
<td>Fast Ethernet</td>
<td>10/100BaseTX 100BaseT</td>
<td>1995</td>
<td>10BaseTX UTPcable</td>
<td>2R45, 2R45</td>
<td>RJ45</td>
<td>RJ45</td>
<td>100m</td>
<td>100m</td>
<td>100m</td>
<td>100m</td>
</tr>
<tr>
<td>Gigabit/10GBaseT</td>
<td>10/100BaseT</td>
<td>1985</td>
<td>10BaseT</td>
<td>CCA/UTP</td>
<td>1R45, 1R45</td>
<td>RJ45</td>
<td>1000m</td>
<td>1000m</td>
<td>1000m</td>
<td>1000m</td>
</tr>
<tr>
<td>40GBaseT</td>
<td>10/100BaseT</td>
<td>2008</td>
<td>10BaseT</td>
<td>CCA/UTP</td>
<td>1R45, 1R45</td>
<td>RJ45</td>
<td>4000m</td>
<td>4000m</td>
<td>4000m</td>
<td>4000m</td>
</tr>
</tbody>
</table>

*With OF the distance depends on the OF type.

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#### Unit 4. Local Area Networks, LANs

#### Ethernet – Minimum Frame and full-duplex Ethernet

- As we shall see, some Ethernet standards allow a full-duplex Tx, when Ethernet NICs are connected point-to-point.
- Ethernet NICs have an auto-negotiation mechanism to detect the full-duplex availability.
- In full-duplex mode Ethernet NICs deactivate CSMA/CD (no collisions can occur).
- Therefore, with full-duplex mode, a minimum frame size is not needed, and Gigabit Ethernet does not add the extension field.

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### Unit 4. Local Area Networks, LANs

#### Ethernet – Different Ethernet Standards: 10Base5

First IEEE Ethernet standard (1983). Now a days is obsolete.

- **Transceiver (MAU):**
  - DB15 female
  - DB15 male
  - Thick coaxial

- **Terminator:**
  - 10Base5 segment 500 m maximum

- **AUI Cable:**
  - Thick coaxial with N type connectors

- **Transceiver (MAU):**
  - AUI cable with MAU connector

- **Taps:**
  - AUI cable with N type connector

#### Denomination:

- **Baseband Signal:**
  - Broad: translated band signal.

#### Various meanings:
- **Number:** Maximum segment distant in hundreds of m.
- **Reference to the medium type:**
  - T: UTP
  - F: Fiber Optic
- **Other:**
  - T4: Uses 4 UTP pairs.
  - TX: Full Duplex
  - ...
Unit 4. Local Area Networks, LANs

Ethernet – Different Ethernet Standards: 10BaseT


- Hub: Is a multi-port repeater (layer 1).
- The signal received in 1 port is retransmitted by all the others.

10BaseT segments
UTP cable, RJ45 connection
100 m maximum

NIC “combo”: Supports 10Base5, 10Base2, 10BaseT

NIC 10/100 – RJ45
10BaseT-100BaseTX
$11.99

NIC 10/100/1000 - SC
10BaseFL, 100BaseFX-1000Base-SX
$151

NIC 10Gbps – CX4
10BaseCX4
$795

Infiniband cable with CX4 connectors

Thin coaxial with BNC connectors

BNC in T

Unit 4. Local Area Networks, LANs

Ethernet – Different Ethernet Standards: 10Base2


NIC
Terminator
10Base2 segment, 185 m maximum

All standards use UTP or OF (except 10GBaseCX4):
- 10Gigabit Ethernet (2002). Now the only copper standard is Infiniband with segment size ≤ 15m. It is foreseen a UTP standard-cat.6 – cat.7.

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Ethernet Switches - Switch Architecture

How the switch works:
- It is equivalent to a “multiport bridge”.
- When a frame is received with a source address not in the table, it is added.
- If a frame is received with a destination address: (i) not in the table, (ii) broadcast or multicast: copy the frame in all transmission buffer of the other ports (flooding).
- If a frame is received with the address from another port: It is switched as fast as possible the the transmission buffer of that port.
- If receives a frame addressed to another station from the same port, it is discarded (filtering).
Unit 4. Local Area Networks, LANs
 Ethernet Switches – Flux Control

- Switch Flux Control: Consists of adapting the rate at which the switch receives the frames, and the rate at which the switch can send them.

- Examples:
  - If no flux control is used, frames could be lost by buffer overflow.

- Flux control techniques (back pressure):
  - Jabber signal (half duplex): The switch sends a signal into the port which need to be throttled down, such that CSMA see the medium busy.
  - Pause frames (full duplex): The switch send special pause frames. These frames have an integer (2 bytes) indicating the number of slot-times (512 bits) that the NICs receiving the frame must be silent.

Other problems:
- Reception of duplicated frames
- MAC Tables instability

Solution: IEEE 802.1D Spanning Tree Protocol (STP)

Unit 4. Local Area Networks, LANs
 Ethernet Switches – Broadcast and Collision Domains

- Broadcast Domain: Set of stations that will received a broadcast frame sent by any of them.
- Unless Virtual LANs are used, a switch does not segment the broadcast domain.
- A router segment the broadcast domain.
- The broadcast reachability is important because allows reaching stations having one hop connectivity (with ARP).

Other problems:
- Turning indefinitely in the loop!
- ARP cannot solve an @IP out of the broadcast domain. To leave the broadcast domain a router is required.

Example:

If A, B and C simultaneously transmit to S:
throughput C = 100 Mbps / 2 = 50 Mbps
throughput A = throughput B = (100 Mbps / 2) / 2 = 25 Mbps
Unit 4. Local Area Networks, LANs
Ethernet Switches – Virtual LANs, VLANs

- Motivation:
  - Grouping related servers and hosts in different broadcast domains.
- How VLANs work:
  - Each switch port belongs to a VLAN.
  - The switch isolates different VLANs: The switch flooding is done only towards the ports of the same VLAN. Each VLAN is equivalent to a different physical switch.
  - A router is needed to send traffic to a different VLAN.

Unit 4. Local Area Networks, LANs
Ethernet Switches – Virtual LANs, VLANs

- Problem:
  - Why connecting several ports between the same devices?
- Trunking:
  - The port configured as trunk belongs to several VLANs (maybe all).
  - The traffic sent in one VLAN is also sent to the trunk the VLAN belongs to.
  - A tagging mechanism is used in the trunk to discriminate the traffic from different VLANs.

Unit 4. Local Area Networks, LANs
Ethernet Switches – Spanning Tree Protocol (STP)

- STP goal: Build a loop free topology (STP-tree) with optimal paths. The ports that do not belong to the STP tree are blocked.
- The switches send 802.1D messages to their neighbors to build up the STP-tree. If the topology changes (e.g. due to a link failure), a new STP-tree is setup.

Unit 4. Local Area Networks, LANs
Ethernet Switches – Virtual LANs, VLANs

- Advantages:
  - Flexibility of the physical placement of the devices.
  - Facilitates the network grow.
  - Facilitates the network management: Changing the topology, adding new subnetworks, moving ports from one network to another.
- NOTE: Since each VLAN is a different broadcast domain, usually a different STP instantiation is used for each VLAN. Thus, a different STP-tree is build in each VLAN.
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IEEE-802.3 frame with the 802.1Q tag:

- **Tag Control Information (TCI):** Contains several fields. The most important is the VLAN ID (12 bits), which identify the VLAN.

Tag Protocol Identifier (TPID): Field with the hex. value 8100 for an Ethernet frame.

IEEE-802.3 frame with the 802.1Q tag:

---

Unit 4. Local Area Networks, LANs

Wireless LANs (WLANs) – 802.11

- **802.11 (MAC)**
- **802.11a**
- **802.11b**
- **802.11g**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Bitrate</th>
<th>ISM band</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11</td>
<td>1, 2 Mbps</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>802.11b</td>
<td>up to 11 Mbps</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>802.11a</td>
<td>up to 54 Mbps</td>
<td>5 GHz</td>
</tr>
<tr>
<td>802.11g</td>
<td>up to 54 Mbps</td>
<td>2.4 GHz</td>
</tr>
</tbody>
</table>

ISM: Industrial Scientific and Medical. Free band for non commercial usage.

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Unit 4. Local Area Networks, LANs

Ethernet Switches – VLAN Trunking

- Trunking Protocols:
  - Inter-Switch Link (ISL). CISCO proprietary protocol.
  - IEEE-802.1Q.

<table>
<thead>
<tr>
<th>Frame</th>
<th>Destination MAC</th>
<th>Source MAC</th>
<th>TPID</th>
<th>TCI</th>
<th>Length of Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 bytes</td>
<td>6 bytes</td>
<td>6 bytes</td>
<td>2 bytes</td>
<td>12 bytes</td>
<td>12 bytes</td>
<td>55 bytes</td>
</tr>
</tbody>
</table>

Home made antenna

- **802.11 APs**
- **802.11 NICs**
- **802.11 Antennas**
Unit 4. Local Area Networks, LANs

Wireless LANs (WLANs) – 802.11 Components

- Basic Service Set (BSS)
  - Set of stations communicating with each other.
  - Are identified by: (i) a Service Set identifier (SSID), or Network name: String with <32 characters; and (ii) a BSS Identifier (BSSID): 48 bits number.
  - If the network is composed of more than 1 BSS it is called Extended Service Set (ESS).

- Distribution System (DS)
  - Used by APs to exchange frames with one another and with wired networks. (e.g. an ethernet switch).

- Access Point (AP)
  - Simplify communication between stations.
  - All transmissions go through the AP.
  - APs are bridges and may have a collocated router.

Wireless medium

Station

Distribution System (DS)

IP address

ADSL

Wireless medium

Station

Association request

AP

Probe request

Authentication

Probe response

Association response

Independent BSS, IBSS (ad-hoc mode)

Infrastructure BSS (infrastructure mode)

An station must associate with an AP.

All transmissions go through the APs.

Extended Service Set (ESS)
Unit 4. Local Area Networks, LANs

802.11: Protocol description - Frames

- Data frames
- Control frames: handle reliable transmission of data frames
  - ACK, RTS, CTS and polling
- Typical time scales: Frame transmission time (<1ms)
- Management frames: communication between stations and APs
  - Beacons, association, Probe and authentication.
- Typical time scales: 100 ms, minutes, hours,...

Unit 4. Local Area Networks, LANs

Wireless LANs (WLANs) – 802.11 Addresses

Example: M# ping S

Legend, frames 802.11:
MESSAGE-TYPE(to-DS, from-DS, Address1, Address2, Address3)
Legend, frames ethernet:
MESSAGE-TYPE(destination address, source address)
FF is the broadcast address

Unit 4. Local Area Networks, LANs

802.11: Protocol description - Features

- Fragmentation
  - Optional mechanism to reduce the effect of Tx errors. If the frame size is larger than the threshold, it is fragmented into multiple frames.
- Power-saving mechanism
  - Optional mechanism to save battery: The AP sends periodically a TIM (Traffic Information MAP), informing which stations have buffered traffic. The stations wake up at the TIM Tx periods, and request the frames, if any.
- WEP (Wired Equivalent Privacy):
  - Frame payload is encrypted using a 64/128 key.

Unit 4. Local Area Networks, LANs

Wireless LANs (WLANs) – 802.11 Addresses

- Designed to be compatible with ethernet.
- 48 bits (6 bytes).
- Use non overlapping ranges with ethernet.
  - The frame may have up to 4 addresses. The meaning of the addresses is specified by the bits to-DS and from-DS of the control.
  - The BSSID is always present to identify frames belonging to the BSS.
  - When a station is searching for the BSS it uses the broadcast BSSID: FF:FF:FF:FF:FF:FF

<table>
<thead>
<tr>
<th>Frame Control</th>
<th>Address 1</th>
<th>Address 2</th>
<th>Address 3</th>
<th>BSSID</th>
<th>Address 4</th>
<th>Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sender Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generic frame format</td>
<td></td>
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</tr>
</tbody>
</table>
Unit 4. Local Area Networks, LANs

Wireless LANs (WLANs) – 802.11 MAC

Two Coordination Functions (CF) are defined:
- Distributed CF (DCF):
  - Contention MAC.
  - Best effort service
  - Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

- Optional Point CF (PCF):
  - Contention free MAC built on top of DCF.
  - Centralized polling scheme. The AP poll each PCF station for Tx.
  - A contention free period (CFP) using PCF and a contention period (CP) using DCF follow each beacon.

Legend:短时访问域时间
- DCF: Distributed Coordination Function
- PCF: Point Coordination Function

**Partial Diagram**

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Legend: 802.11:
- Frame (to-DS, from-DS, Address1, Address2, Address3, Address4)
- Frame (destination address, source address)

**Legend:**
- Short InterFrame Space (SIFS): Minimum time for highest priority transmissions: CTS, ACKs, and fragments.
- DCF InterFrame Space (DIFS): e.g. Data frames, RTS, etc.
Optional mechanism to solve the hidden node problem.

- RTS is sent using the basic access mechanism.
- Upon receiving a RTS/CTS, the station sets the Network Allocation Vector (NAV) to the indicated duration. While the NAV is non-zero, the virtual carrier sensing indicates that the medium is busy.
- RTS/CTS is only used for unicast Tx.
- There is a threshold indicating the minimum frame size for using RTS/CTS.

Wireless LANs (WLANs) – 802.11 RTS/CTS

- Node A is in coverage with AP and C
- A and B cannot hear each other
- When A transmits to AP, B cannot detect the transmission using the carrier sense mechanism
- If B transmits, a collision will occur at AP