CS698T
Wireless Networks: Principles and Practice

Topic 16
IEEE 802.11 (WLAN/WiFi)

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http://www.cse.iitk.ac.in/users/braman/courses/wless-spring2007/
IEEE 802.11 (WiFi)

- Part of 802.x series
  - 802.3 is Ethernet
- 802.11a, 802.11b, 802.11g specify three different PHY layers
  - MAC is the same
- 802.11a: 5.2 to 5.7GHz
- 802.11b/g: 2.4 to 2.4835GHz
802.11: What does it specify?

Figure 11—Portion of the ISO/IEC basic reference model covered in this standard

Source: IEEE 802.11 specification
802.11: What does it Specify?

- PHY sub-layer
  - 802.11a, 802.11b, 802.11g

- MAC sub-layer
  - Independent of the PHY
  - DCF (Distributed Coordination Function)
    - CSMA/CA
  - PCF (Point Coordination Function)

- MAC management
802.11 PHY

• 802.11b data-rates (modulation schemes):
  – 1Mbps (BPSK), 2Mbps (QPSK), 5.5Mbps (CCK), 11Mbps (CCK)

• 802.11a and 802.11g data-rates:
  – 6, 9, 12, 18, 24, 36, 48, 54 Mbps
  – OFDM + BPSK/QPSK/16QAM/64QAM
  – 802.11g also supports 802.11b data-rates and modulations (backwards compatible)
802.11b Channels

- Each channel is 22MHz wide
- Adjacent channels overlap
- Non-overlapping channels: 1, 6, 11
- Band recently delicensed in India for indoor, outdoor usage
802.11a Channels

- Each channel is 20MHz wide
- As of now, band is not free in India for outdoor use

Source: Cisco presentation
802.11 Service Sets

IBSS: Independent Basic Service Set

Basic Service Set: set of STAs in a region

Infrastructure Basic Service Set
802.11 Extended Service Set (ESS)

Wired LAN (ethernet), or Wireless (WDS)
MAC Classification

• Based on what dimension is used for multiplexing:
  - SDMA, TDMA, FDMA, CDMA

• Based on how control is achieved:
  - Central
    • (+) Easy to design/implement
    • (-) Single point of failure, bottleneck
  - Distributed
    • (+) Natural when there is no central information

• 802.11 specifies DCF (Distributed Coordination Function), PCF (Point Coordination Function)
  - PCF uses central control
Ethernet CSMA/CD: Prelude to 802.11 CSMA/CA

- CSMA/CD: Carrier-Sense Multiple Access with Collision Detection
  - Listen before transmit (CS)
  - Tx when (as soon as) medium is free (1-persistent)
  - Collision Detection (CD)
  - Backoff (exponential) on collision
802.11 CSMA/CA

• Collision detection impossible in wireless
  – Tx power is relatively very high near the transmitter

• Conceptual name is CSMA/CA: Carrier-Sense Multiple Access with Collision Avoidance
  – 802.11 calls it DCF (Distributed Coordination Function)

• Collision Avoidance:
  – Back-off before tx (even when no collision)
  – Contention Window (CW) in terms of number slots
The Backoff Procedure

Contestation window:
Num slots = Random[0, CW)
CW = 32, 64, 128, 256, 512, 1024
Double CW on collision

Question: Why DIFS?
CSMA/CA + ACK

- ACK missing ==> Deduce collision
  - Retransmit (have to content anew)
- SIFS should be < DIFS
  - Else, ACK timeout may occur unnecessarily
DCF Timing Relations

Figure 58—DCF timing relationships

Source: IEEE 802.11 Specifications
Propagation Time is Important

1. A finishes tx at time $t$
2. B senses the channel to be free at $t$, C senses the channel to be free at $t+d$
3. C starts sending at $t+d+\text{DIFS}$, this reaches B at $t+d+\text{DIFS}+d$
4. B should not have started tx by then $\implies$ slot-time should be $< 2d$

- Ignore delay between A & B
- One-way delay = $d$

- Node A
- Node B
- Node C

$r=0$

$r=1$
802.11 PCF Mode of Operation

Source: IEEE 802.11 Specification
IFS Relations

aSIFSTime and aSlotTime are fixed per PHY.

aSIFSTime is:  
\[ \text{aSIFSTime} = \text{aRxDelay} + \text{aRxPLCPDelay} + \text{aMACProcessingDelay} + \text{aRxTxTurnaroundTime} \]

aSlotTime is:  
\[ \text{aSlotTime} = \text{aCCATime} + \text{aRxTxTurnaroundTime} + \text{AirPropagationTime} + \text{aMACProcessingDelay} \]

The PIFS and DIFS are derived by the following equations, as illustrated in Figure 58.

\[ \text{PIFS} = \text{aSIFSTime} + \text{aSlotTime} \]

\[ \text{DIFS} = \text{aSIFSTime} + 2 \times \text{aSlotTime} \]

Source: IEEE 802.11 Specification
The Hidden Node Problem

Medium is free DOES NOT IMPLY ok-to-transmit
The Exposed Node Problem

Medium is busy DOES NOT IMPLY not-ok-to-transmit
Hidden Node Solution: RTS/CTS
RTS/CTS Exchange Example

Source: IEEE 802.11 Specification
Beacons and Probes

- A client may be in the coverage area of many APs
- APs send periodic beacons
- Client may passively scan these
- Or, probe-response for active scanning

Beacon has: AP capabilities, beacon period, SSID, Traffic Indication Map (TIM)
Authentication and Association

- A client has to
  - Authenticate itself to an AP
  - Then Associate itself
- A client may authenticate itself to many APs to speed-up roaming
802.11 Frame Format

Source: IEEE 802.11 Specification
Throughput estimation in 802.11

- PLCP preamble + header: 24 bytes
- RTS: 20 bytes, CTS: 14 bytes
- MAC header: 28 or 34 bytes
- IP header: 20 bytes
- TCP header: 20 bytes
- UDP header: 8 bytes
- Bottomline: too much per-packet overhead!
## 802.11 Alphabet Soup

### WLAN “Alphabet Soup”:
IEEE 802.11 Standards Activities

- **802.11a**: 5 GHz, 54 Mbps
- **802.11b**: 2.4 GHz, 11 Mbps
- **802.11d**: Multiple regulatory domains
- **802.11e**: Quality of Service (QoS)
- **802.11f**: Inter-Access Point Protocol (IAPP)
- **802.11g**: 2.4 GHz, 54 Mbps
- **802.11h**: Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC)
- **802.11i**: Security
- **802.11j**: Japan 5 GHz Channels (4.9-5.1 GHz)
- **802.11k**: Measurement
- **802.11m**: Maintenance
- **802.11n**: High-Speed

Source: Cisco presentation
802.11 Enterprise Deployment
Community Networks

Source:
Roofnet SIGCOMM’04 paper

Figure 2: A map of Roofnet, with a black dot for each of the 38 nodes that participated in the experiments presented in this paper.
Long-Dist.: Digital Gangetic Plains

End to end distance ~80 Km

802.11 for last-hop access within a village

Land-line access point (close to high-population density area)

Not to scale

River Ganges
The Ashwini Network
## Wireless Technologies

### Network Types

- **WAN**: Wide Area Network
- **MAN**: Metropolitan Area Network
- **LAN**: Local Area Network
- **PAN**: Personal Area Network

### Technologies Comparison

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<td>11 to 100+ Mbps</td>
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Source: Cisco presentation