Computer Networks

Lecture on

Other LANs

Plan of This Lecture

- Mechanisms for accessing transmission media
- Token Bus
- Token Ring
- Wi-Fi

Transmission Medium Access

Medium Access Control algorithms

- Stochastic
  - Frames are sent in a random way
  - Collisions can occur
  - Efficient while transmission load is low
- Deterministic
  - Frames are sent while control mechanism allows
  - No collisions
  - Efficient while transmission load is high
- Adaptive
  - If transmission load is low a stochastic mechanism works
  - If transmission load is high a deterministic mechanism works

Stochastic MAC Algorithms

- Pure Aloha
  - A frame can be sent at any moment
  - If no ACK frame, then retransmission after a random delay
  - Efficiency of medium usage = 18%
- Slotted Aloha
  - A frame can be sent at the beginning of a time slot
  - Efficiency of medium usage = 37%
- CSMA
  - A frame can be sent at random delay after previous frame
  - Senders should hear each other
- CSMA/CD
  - e.g. Ethernet
- …

Deterministic MAC Algorithms

- Master-slave
  - One master controls some slave nodes
    - Are you ready to send?
    - Are you ready to receive?
  - Any topology

- Token-Bus
  - The owner of the token is a master
  - The token circulates between selected nodes

- Token-Ring
  - The token circulates in the ring
  - A node stops the token to send its frame
  - The retransmission delay (input to output interface) can be 1 bit
  - The frame can be removed by the addressee or by the sender
- Slotted-Ring
  - Empty frames (slots) circulate in the ring
  - The slots can be filled with data frames
  - The retransmission delay can be 1 bit
- Register-Insertion-Ring
  - A node can insert its frame to the ring
    if enough “empty bits” enter its input interface
  - The retransmission delay must be >= destination address header field

A monitor node can be elected

- to be the only one that generates clock signal – then the network works faster
- to monitor the network health
  - e.g. to remove lost frames

Token Bus

- The signal propagates over a bus topology
- Initialisation mechanism
  - A logical ring of nodes is built – interface addresses are used
  - Selected node creates the token
- The token circulates in the ring
- The holder of the token is a master
  - It can communicate with any node – belonging or not to the ring
- Attaching a node to the ring mechanism
- Detaching mechanism

Example networks

- ARCNet 1977
- IEEE 802.4 1984
- Thomas Conrad Networking System 1992

Token Ring

- The signal propagates over a ring topology
- Token it is a short frame carrying some management data
  - e.g. priority reservation, monitor stamp
- A node can intercept the token if its data frame priority is not lower than the reservation
- The node holding the token can send its data frames for a limited time period
- There can be one or more tokens circulating in the network

Example networks

• IBM Token Ring	1984	later IEEE 802.5	LAN
• Fiber Distributed Data Interface (FDDI)	1986		MAN

In 80's IBM Token Ring was

- technically better than Ethernet
  - no network congestions
  - bigger throughput
  - longer distance
  - higher reliability
- more expensive than Ethernet ⇒ Ethernet was widely used and evolved rapidly

Wi-Fi The Standard for Wireless Fidelity

Dominant radio technology for access networks

Network types

- Ad hoc – direct communication between connected terminals
- With an access point – e.g. for Internet access
- With many access points – e.g. a campus or city-wide network
  roaming between APs while the terminal moves

Works in non-licensed radio bands

Frame priorities are possible 802.11e

SSID – Service Set Identifier is a name of a given network

- Several independent networks can work in the same area

Communication Range

Strongly depends on

- transmission power – hence local regulations
- antenna size and shape – can be directional or omnidirectional
  – 802.11n/ac allow for multiple antennas
  MIMO *Multiple-Input and Multiple-Output*
- environment – outdoor, indoor, physical obstacles (e.g. motor lorry, aquarium)
- number of active terminals in the area
- radio noises
- expected transmission speed

It is assumed

- 20 m indoor
- up to 30 terminals per access point

Wi-Fi Generations

Year	Standard	Bandwidth	Max. Link-rate	Generation
1997	802.11	2.4 GHz	2 Mb/s	
1999	802.11a	5 GHz	54 Mb/s	
1999	802.11b	2.4 GHz	11 Mb/s	
2003	802.11g	2.4 GHz	54 Mb/s	
2009	802.11n	2.4/5 GHz	72–600 Mb/s	Wi-Fi 4
2012	802.11ac	5 GHz	433–6933 Mb/s	Wi-Fi 5
2014	802.11ad	2.4/5/60 GHz	6912 Mb/s	
2019	802.11ax	1–7/2.4/5 GHz	600–9608 Mbit/s	Wi-Fi 6

Throughput varies due to:

- protocol overheads
- channel sharing
- adaptive modulations – function of distance and radio noises
- number of terminals

Modulation Techniques

- FHSS *Frequency Hopping Spread Spectrum*
  pseudorandom rapid switching a carrier among many frequency channels

- DSSS *Direct Sequence Spread Spectrum*
  modulation by a pseudorandom keying signal

$$s(t) = d(t) \oplus k(t) * \cos 2\pi f\, t + i(t)$$ – received signal

$\oplus$ – exor operator

data, keying signal, noise

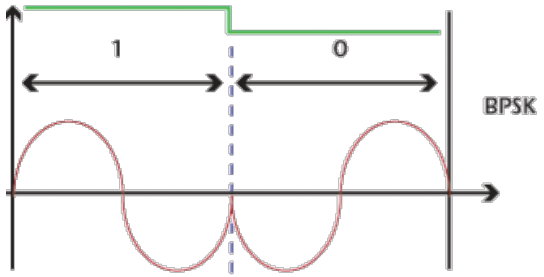
$$[d(t) \oplus k(t) + i'(t)] \oplus k(t) = d(t) + i'(t) \oplus k(t)$$ – decoded signal

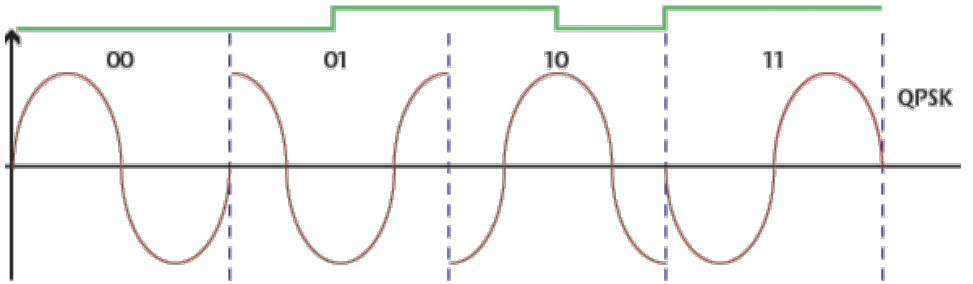
high frequency part to be filtered

- OFDM *Orthogonal Frequency Division Multiplexing*
  encoding digital data on multiple carrier frequencies

Modulation examples

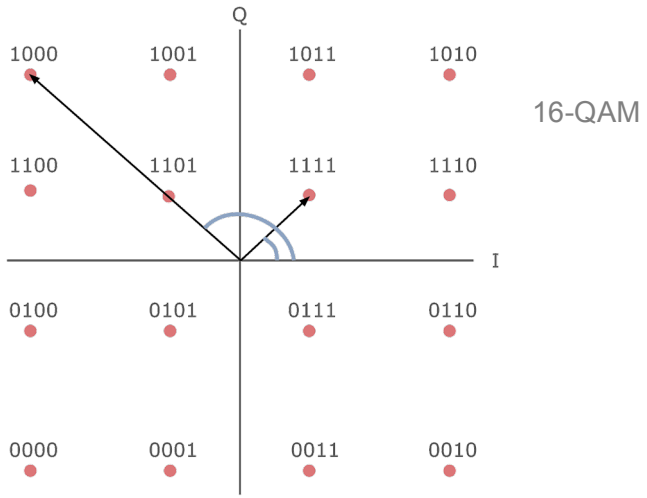
- BPSK *Binary Phase-Shift Keying*
- QPSK *Quadrature PSK*
- 16-QAM, 64-QAM, 256-QAM
  Quadrature Amplitude Modulation





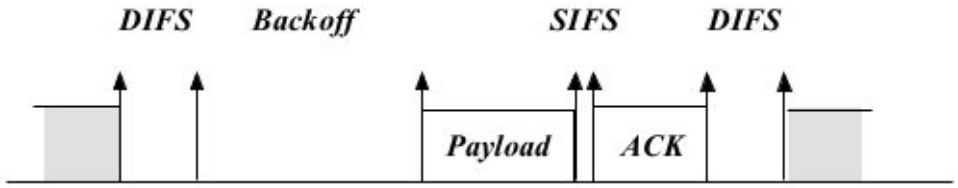
Adaptive channel modulation and coding

- Depends on received signal strength and packet error rate
- Link-rate lowers with distance
- Link-rate lowers with radio noises



CSMA/CA *Carrier-Sense Multiple Access with Collision Avoidance*

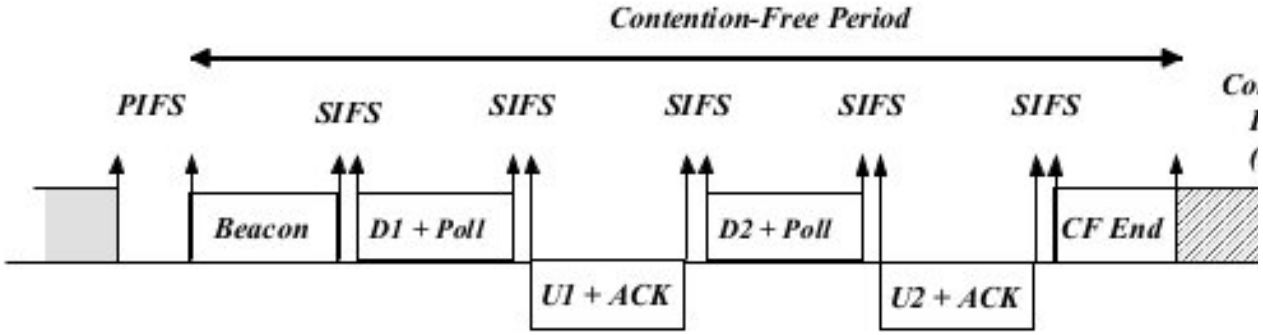
Distributed Coordination Function



DIFS – *distributed CF* interframe space
SIFS – short interframe space
Backoff – random delay in a given time slot
RTS – request to send
CTS – clear to send

RTS and CTS frames can be used before long payload

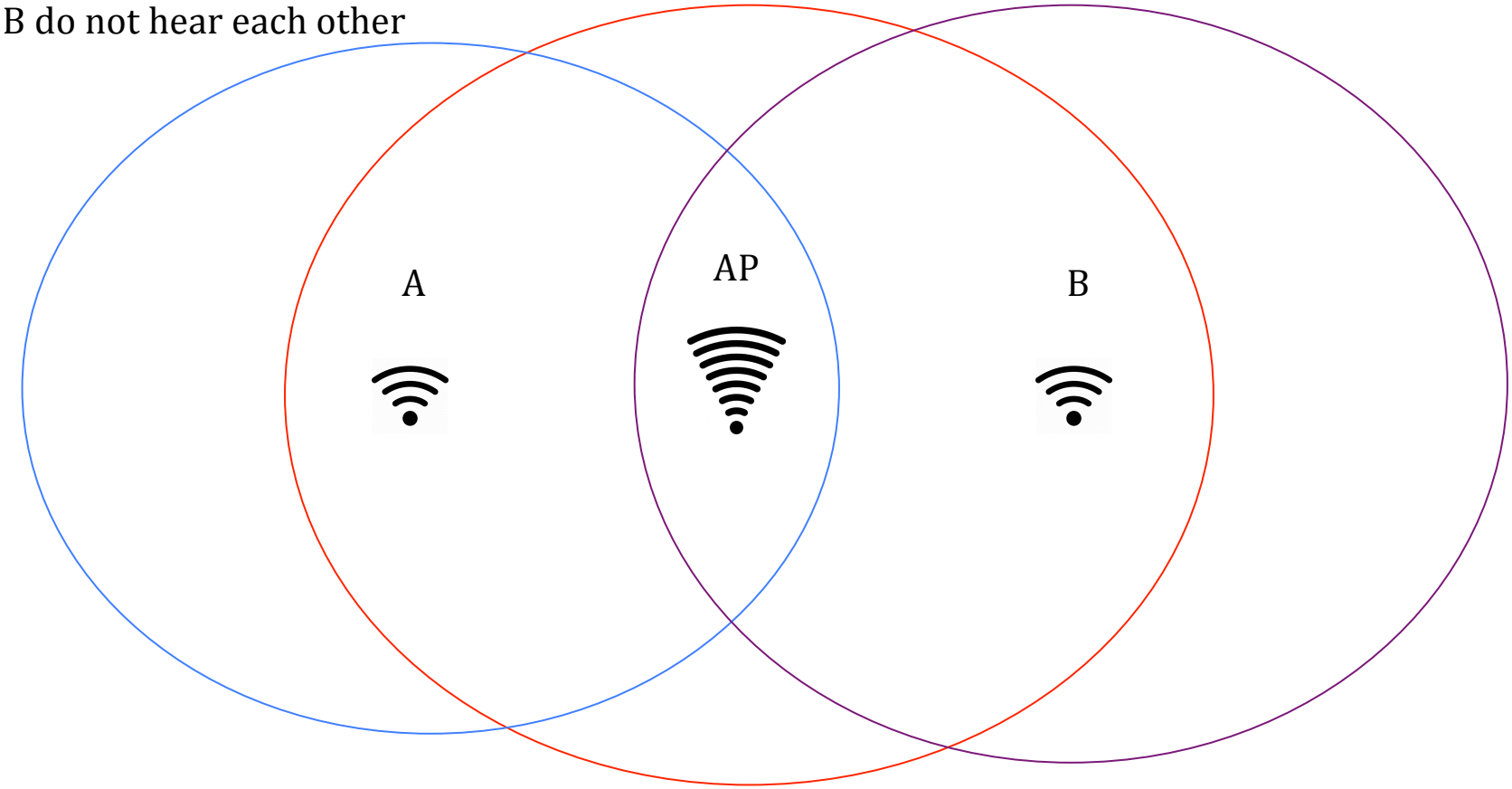
Point Coordination Function – only in network with an access point



PIFS – *point CF* interframe space

Hidden Node Problem

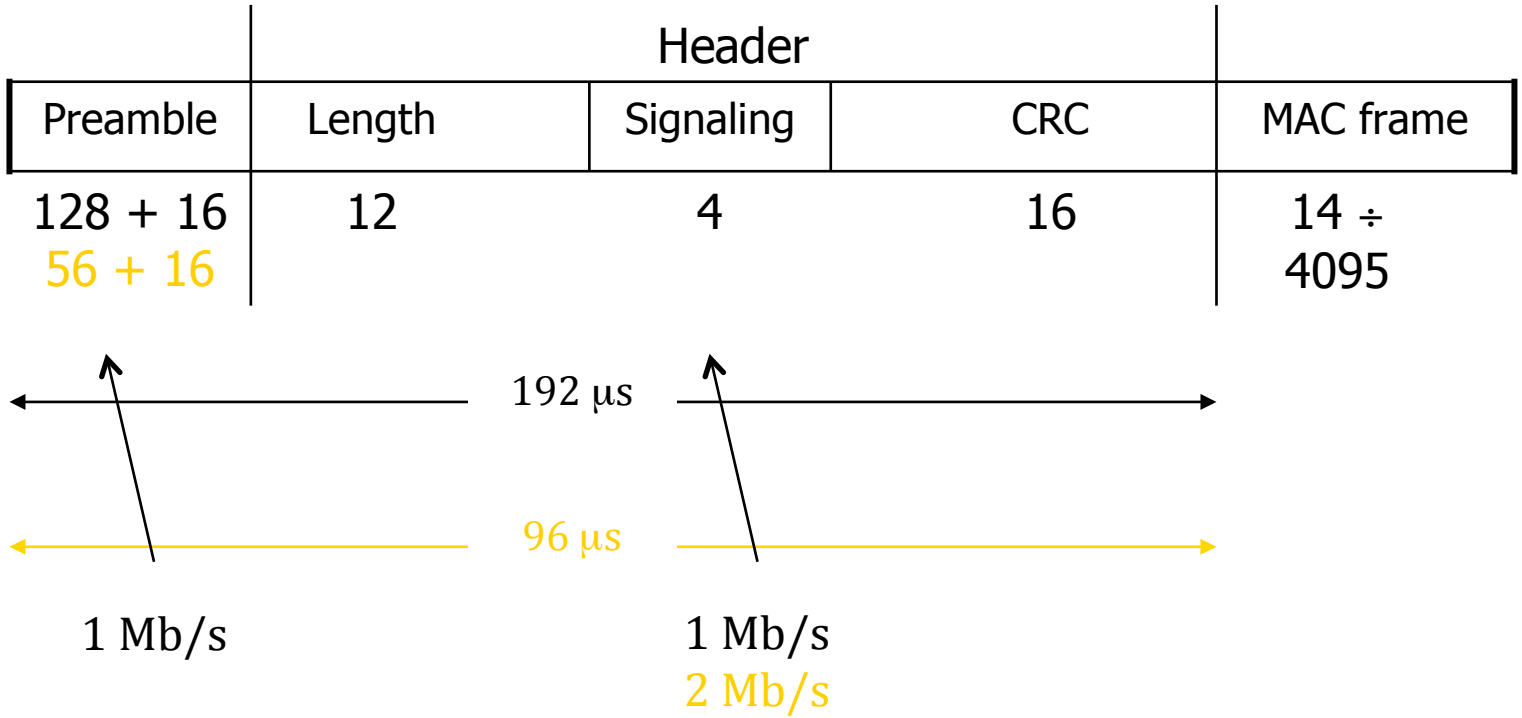
A & B do not hear each other



A broadcasts RTS(reservation_time)
⇒ AP broadcast CTS(reservation_time)
⇒ B remains silent for the time

PLCP Header

Physical Layer Convergence Protocol



MAC Frame

2	2	6	6	6	2	6	2	0 - 2312	4
control	duration/ID	address 1	address 2	address 3	sequence control	address 4	QoS control	payload	CRC

Control bits allow for:

- fragmentation
- retransmission
- sleeping mode terminals
  power management

Addresses:

- source
- destination
- sender
- next hope receiver
- network segment

802.11 Security

Protection against

- eavesdropping the radio channel
- connection of unauthorised devices

WEP *Wireless Equivalent Privacy* — insecure!

MAC address filtering — insecure!

WPA *Wi-Fi Protected Access*

WPA2

} pre-shared key or enterprise AAA servers (e.g. RADIUS or DIAMETER)

Authentication, Authorization and Accounting

WPA & WPA2 use temporal ciphering keys

Summary

- Mechanisms for accessing transmission media
  - Stochastic MAC algorithms
  - Deterministic MAC algorithms
- Token Bus
- Token Ring
- Wi-Fi
  - Network types
  - Communication range
  - Versions and generations
  - Modulation techniques
  - Collision avoidance
  - Physical and MAC headers
  - Security mechanisms

Questions

1. When stochastic access to a shared medium is more efficient than any deterministic one?
2. When deterministic access to a shared medium is more efficient than any stochastic one?
3. Why the slotted Aloha algorithm is more efficient than the pure Aloha algorithm?
4. In which way a master node controls access to a shared medium?
5. What is the principle of the Token-Bus?
6. What is the principle of the Token-Ring?
7. What is the principle of the Slotted-Bus?
8. What is the principle of the Register-Insertion-Bus?
9. What are the main functions of the monitor node in ring-based networks?
10. What are the Wi-Fi network types?
11. What are limitations for the Wi-Fi communication range?
12. Why is the Wi-Fi transmission throughput below 50% of maximum link-rate?
13. What is the principle of Direct Sequence Spread Spectrum?
14. What is the aim of the adaptive channel modulation and coding?
15. What is the principle of CSMA/CA?
16. What information is carried by the header of Physical Layer Convergence Protocol?
17. What is the aim of having 4 address fields in the MAC header?
18. What security methods should be used in Wi-Fi networks?

Questions for curious minds

1. How does one frame can get priority over another in 802.11e network?
2. What are advantages of having the duration field in the MAC header?