計算機ネットワーク

開講クォーター: 1-2Q

曜日・時限: 火7-8限

講義室: 1Q @ W834, 2Q @ W931

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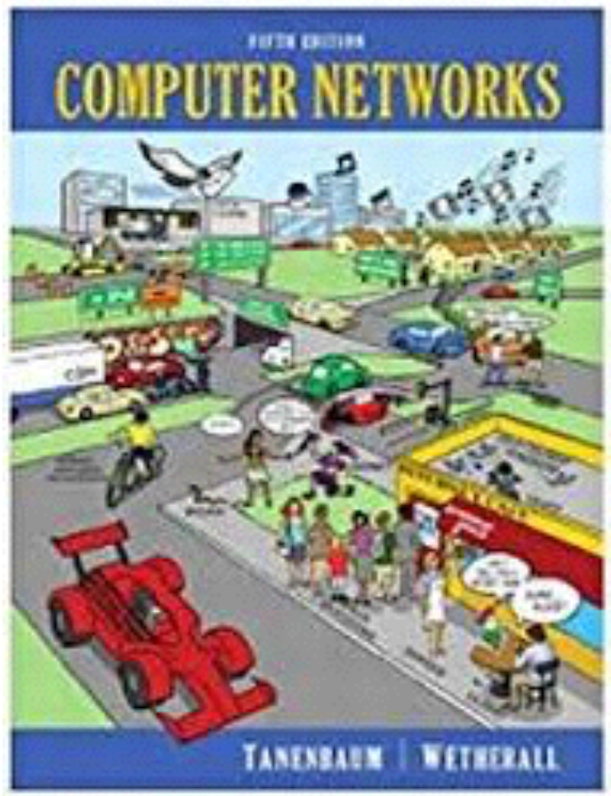
参考書

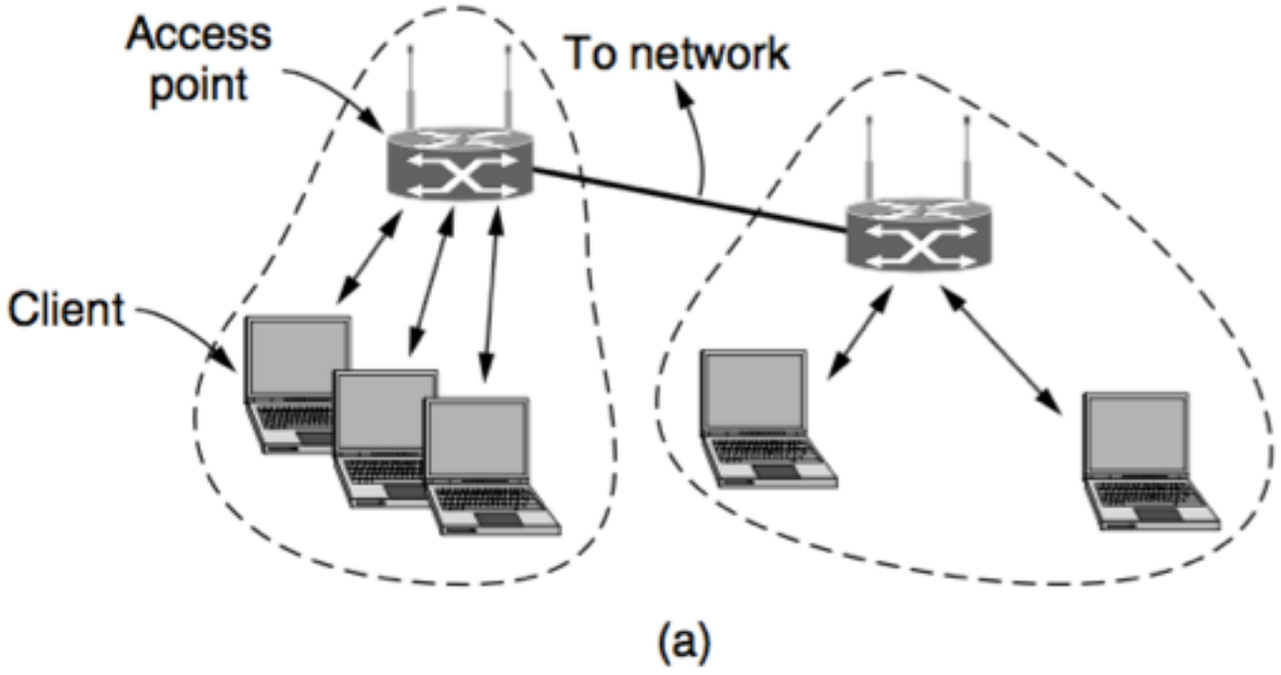


教科書

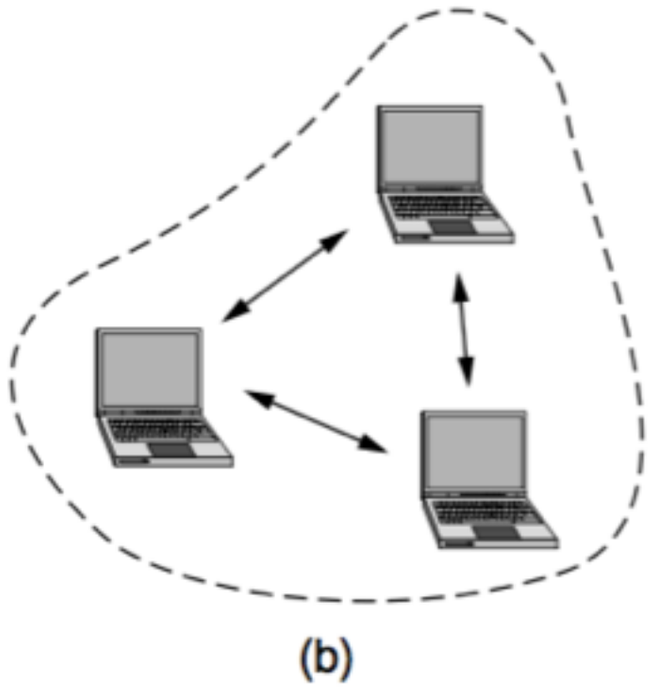
講義日程（1Q）

		授業計画		課題
04/05	第１回	計算機ネットワークの基本概念 ハードウェア・ソフトウェア，参照モデル	１章	ネットワークの種類と参照モデルを理解し プロトコル階層と各層の設計課題
04/12	第２回	物理層１ 有線伝送と無線伝送	２章	物理チャネルの特性を理解し データ通信の理論的基礎を理解
04/19	第３回	物理層２ デジタル変調と多重化	２章	ベースバンド伝送と通過帯域伝送， 電話網，携帯電話システムを説明できる
04/26	第４回	データリンク層１ 誤りの検出・訂正	３章	誤りの検出・訂正のしくみを理解し 検出・訂正符号の計算ができる
05/10	第５回	データリンク層２ データリンク・プロトコル	３章	データリンク・プロトコルの種類， 各プロトコルを定量的に評価できる
05/17	第６回	メディア・アクセス副層１ ブロードキャスト・チャネル	４章	多重アクセス・プロトコルを理解し データ・レートを計算できる
05/24	第７回	メディア・アクセス副層２ 無線 LAN，Bluetooth, RFID	４章	個別のプロトコル・スタックを理解し データリンク層スイッチングを理解
05/31	第８回	理解度確認総合演習 (中間試験) 第１回から第７回までの内容の演習形式による確認		第１回から第７回までの理解度確認と 到達度自己評価

Wireless LANs

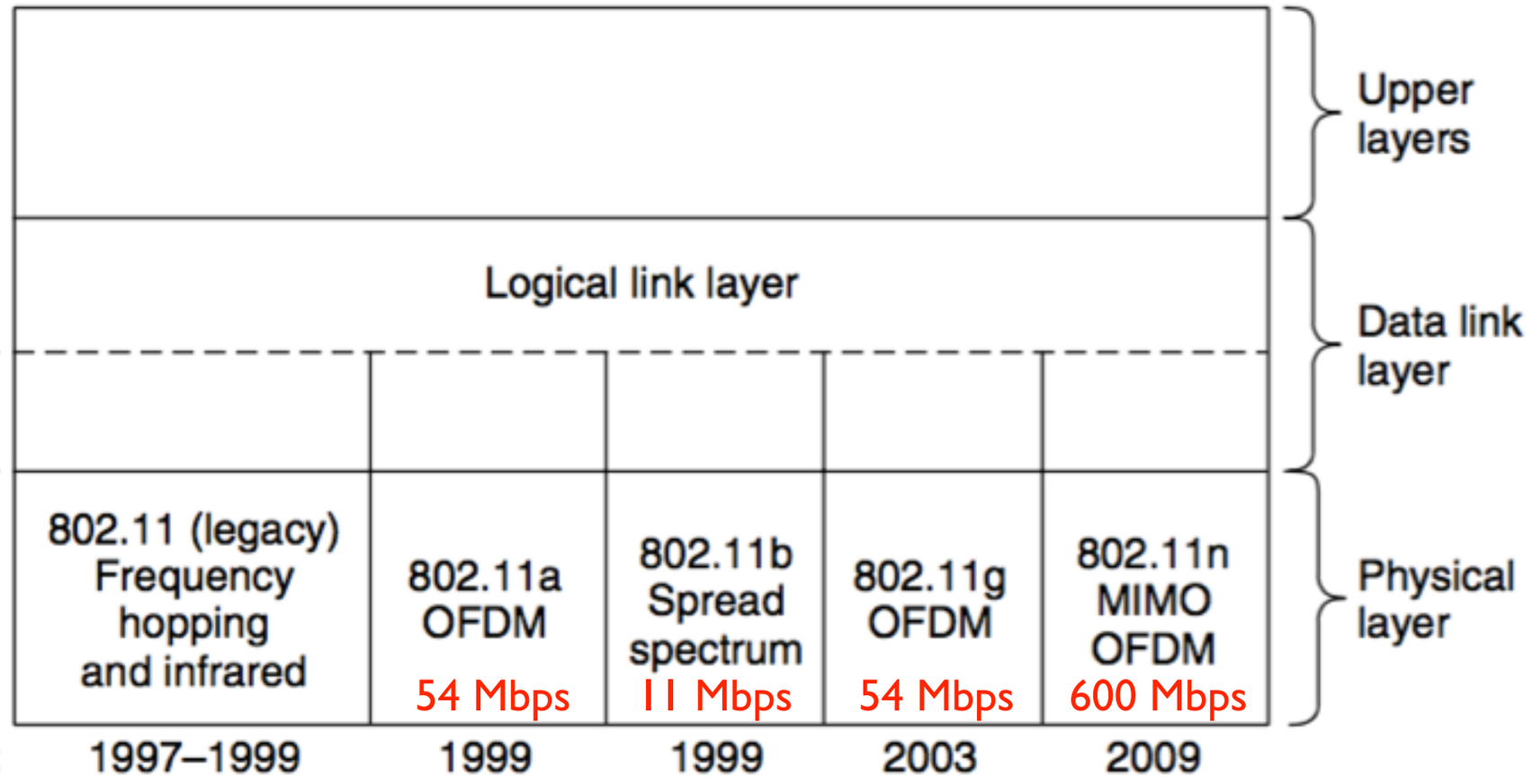


Infrastructure mode

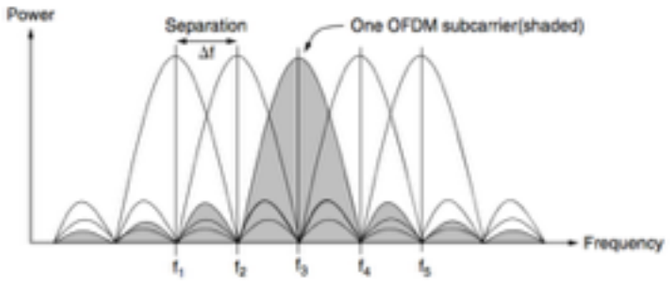


Ad-hoc mode

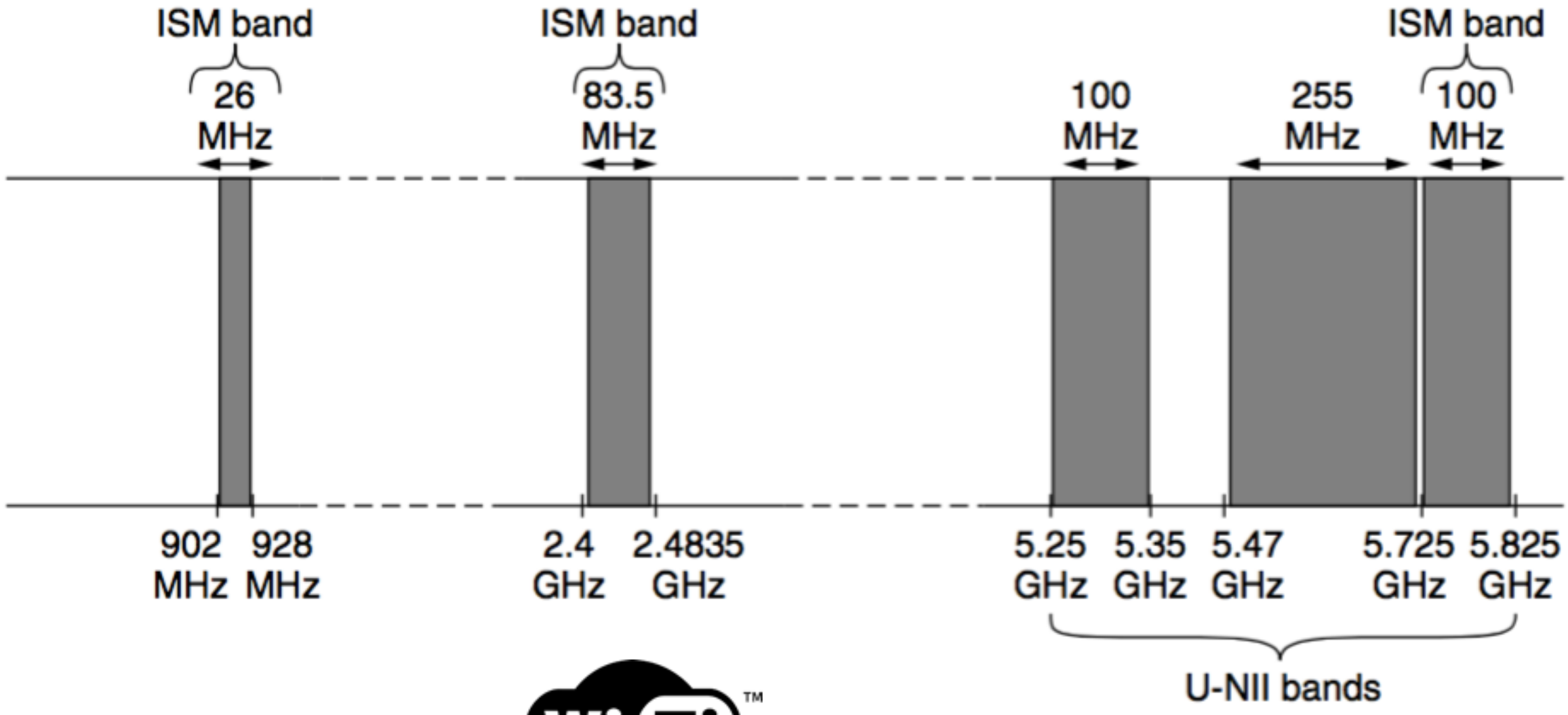
802.11 protocol stack



OFDM



ISM (Industrial, Scientific, Medical)



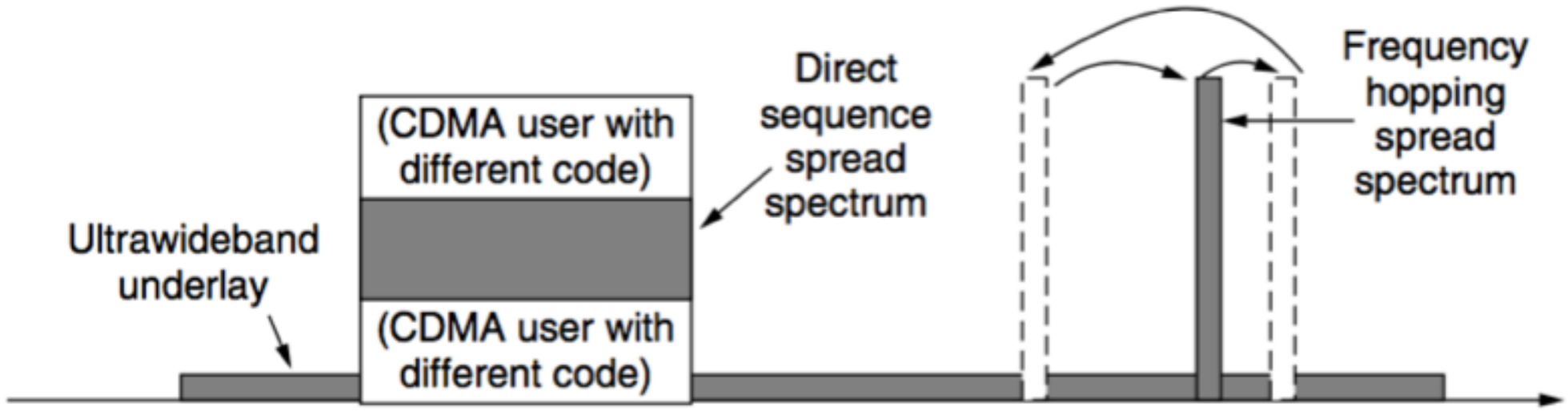
WiFi (802.11)

Bluetooth

< 1 Watt

802.11b

Spread-spectrum method @ 2.4 GHz
Similar to CDMA but with only one spreading code (Barker code)

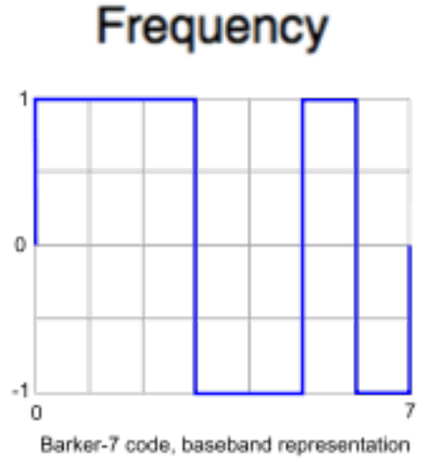


Barker code

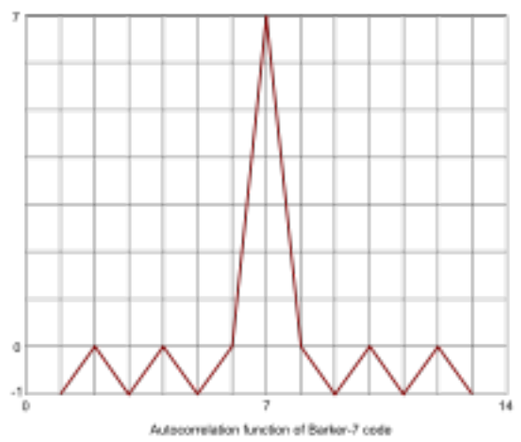
Autocorrelation is low except when the sequences are aligned
This allows a receiver to lock onto the start of a transmission

Known Barker codes

Length	Codes		Sidelobe level ratio[8][9]
2	**+1 −1**	+1 +1	−6 dB
3	**+1 +1 −1**		−9.5 dB
4	+1 +1 −1 +1	+1 +1 +1 −1	−12 dB
5	+1 +1 +1 −1 +1		−14 dB
7	**+1 +1 +1 −1 −1 +1 −1**		−16.9 dB
11	**+1 +1 +1 −1 −1 −1 +1 −1 −1 +1 −1**		−20.8 dB
13	+1 +1 +1 +1 +1 −1 −1 +1 +1 −1 +1 −1 +1		−22.3 dB



Barker-7 code, baseband representation

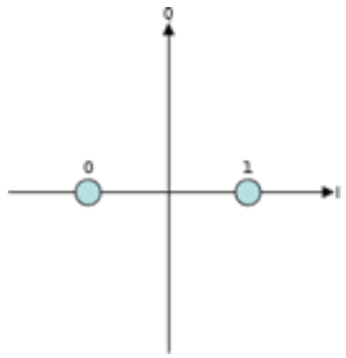


Autocorrelation function of Barker-7 code

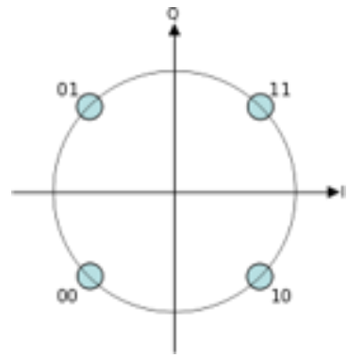
https://en.wikipedia.org/wiki/Barker_code

802.11b

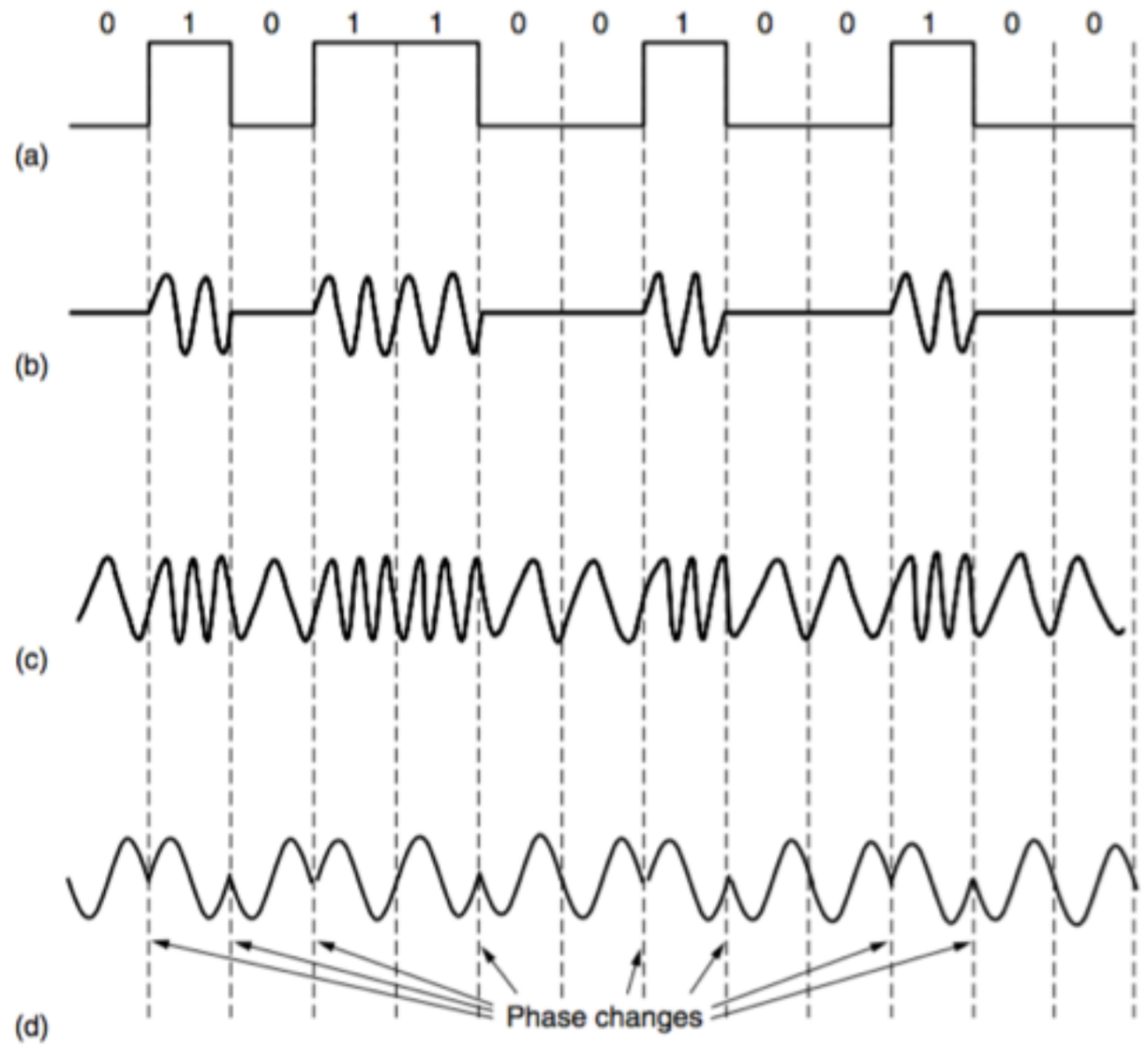
BPSK : 1 Mbps
QPSK : 2 Mbps
CCK(0.5 bit/chip) : 5.5 Mbps
CCK(1 bit/chip) : 11 Mbps



BPSK



QPSK



ASK (Amplitude Shift Keying)
振幅

FSK (Frequency Shift Keying)
周波数

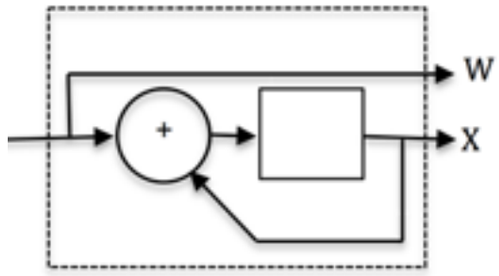
PSK (Phase Shift Keying)
位相

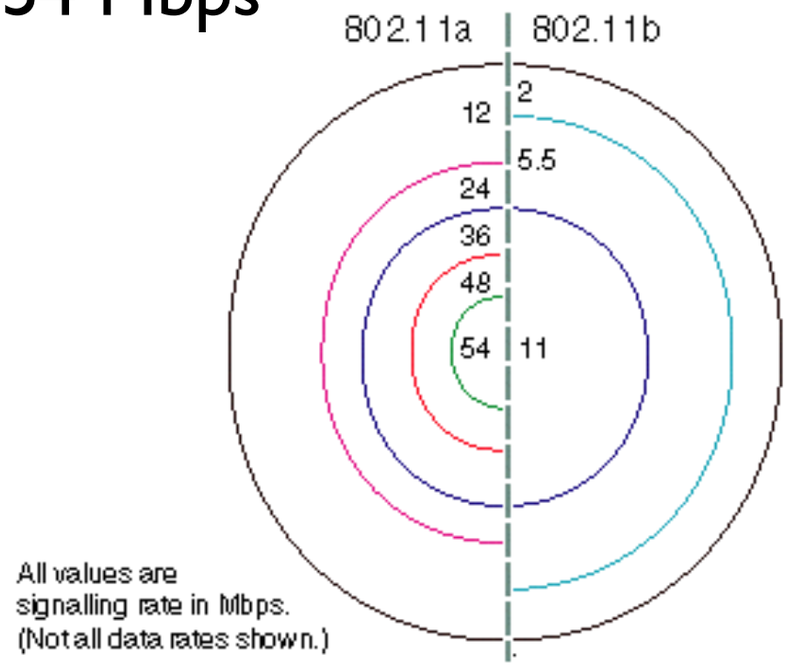
<u>Barker code</u>
11 bit chipping sequence

<u>CCK (Complementary code keying)</u>
8 bit chipping sequence

802.11a

OFDM (Orthogonal Frequency Division Multiplexing) @ 5 GHz
Bits are sent over 52 subcarriers, 48 for data and 4 for synchronization
Binary convolutional code
54 Mbps

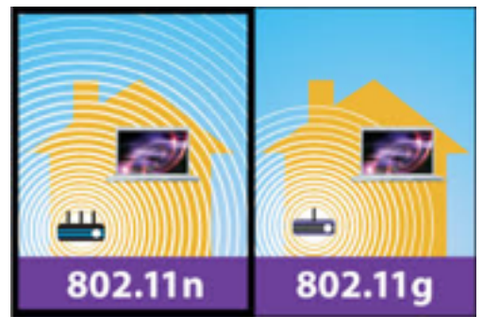




May 2002 FCC changed its regulations

802.11g

OFDM (Orthogonal Frequency Division Multiplexing) @ 2.4 GHz
54 Mbps

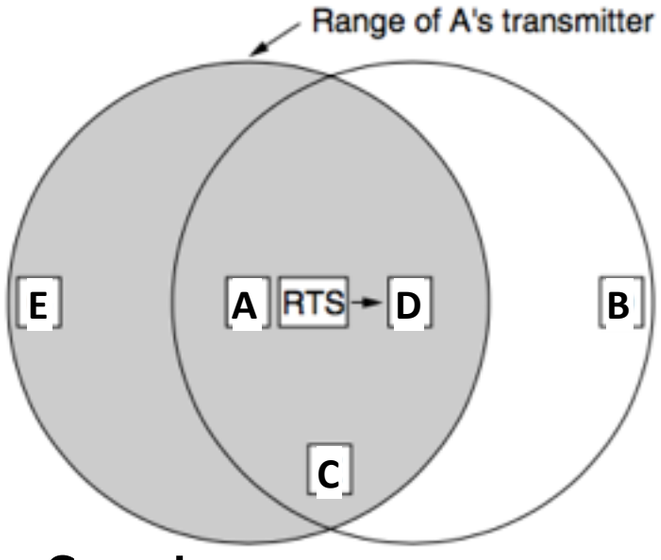


802.11n

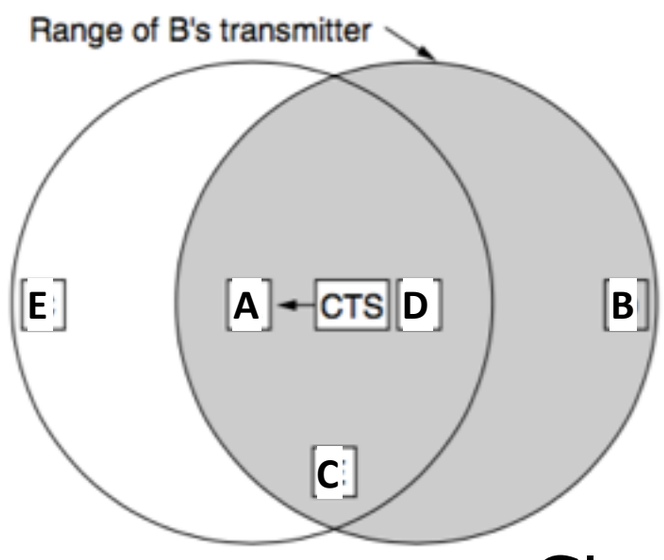
OFDM (Orthogonal Frequency Division Multiplexing) @ 2.4/5 GHz
MIMO (multiple-input multiple-output)
600 Mbps

802.11 MAC Sublayer Protocol

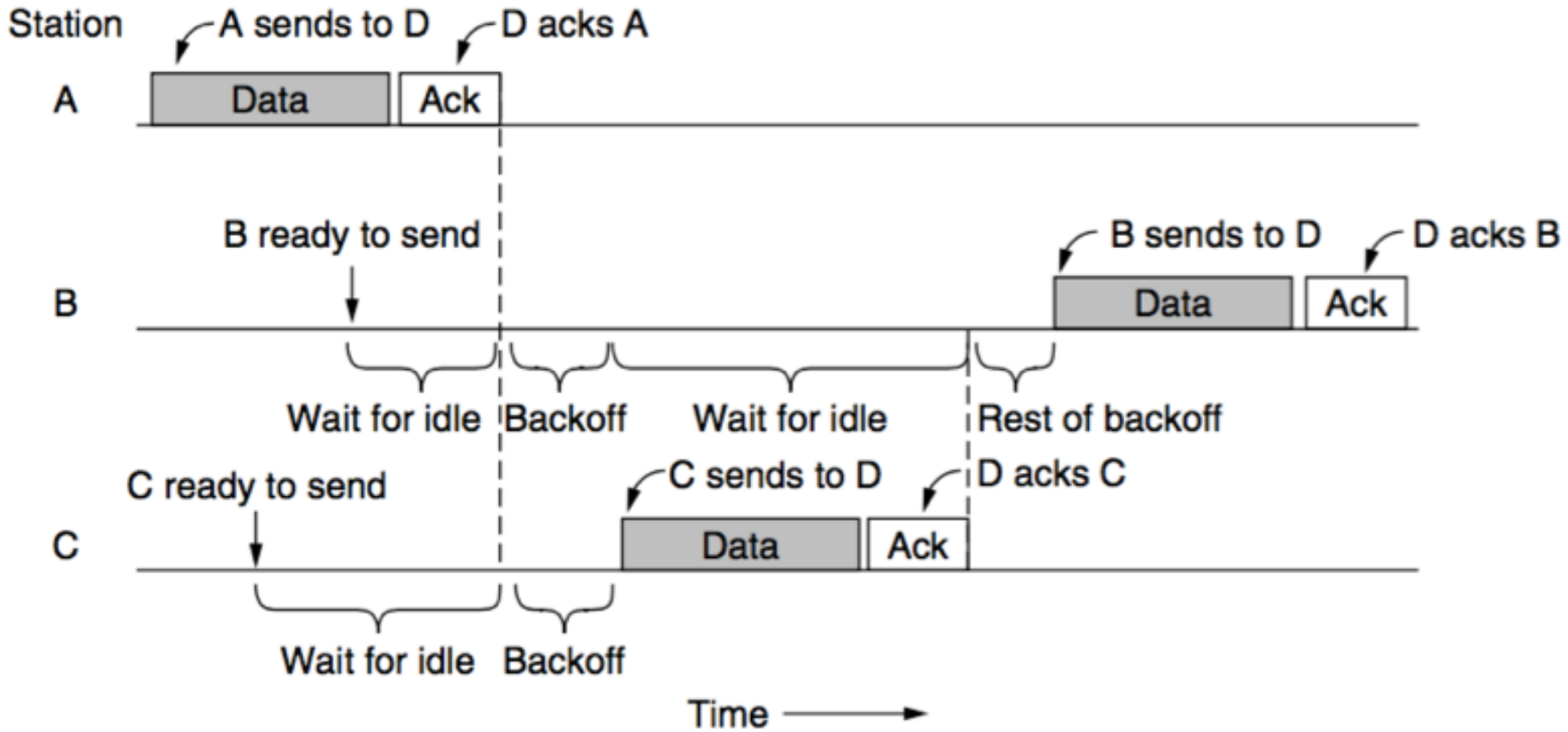
CSMA/CA (CSMA with Collision Avoidance)



Request to Send

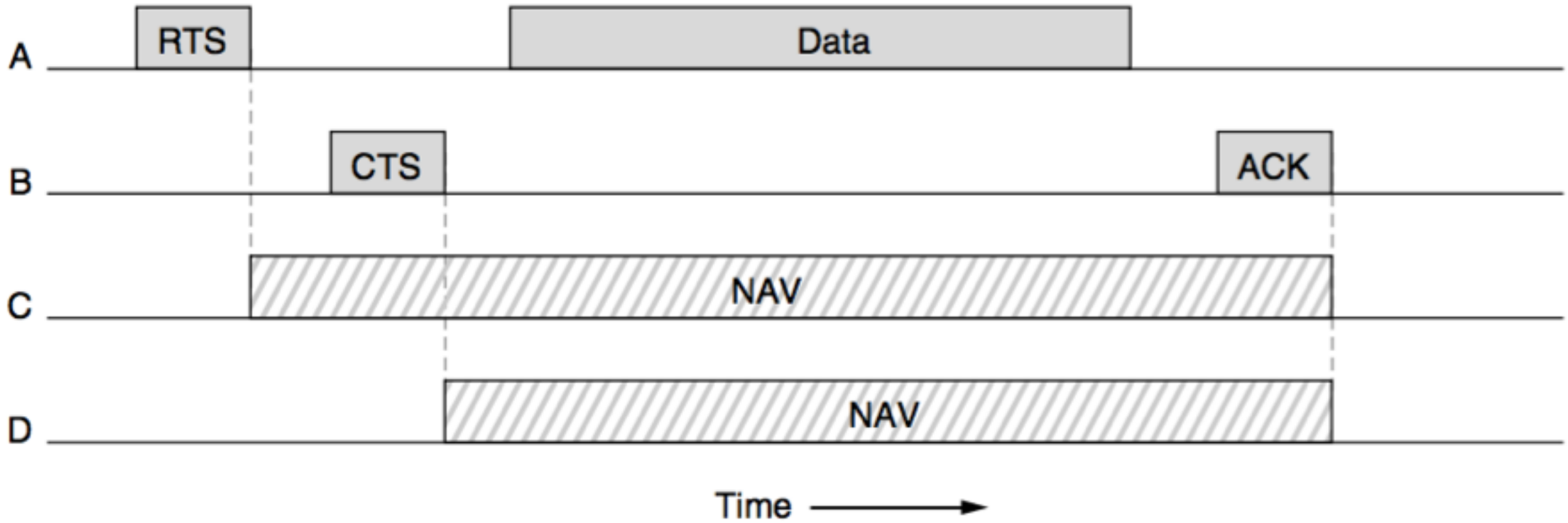


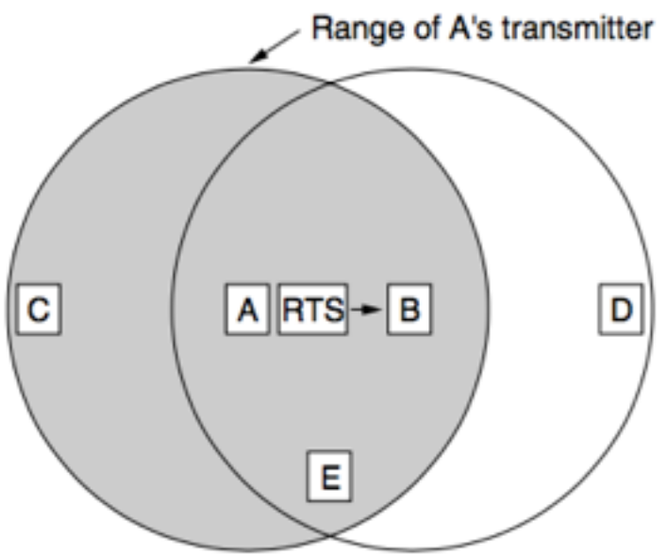
Clear to Send

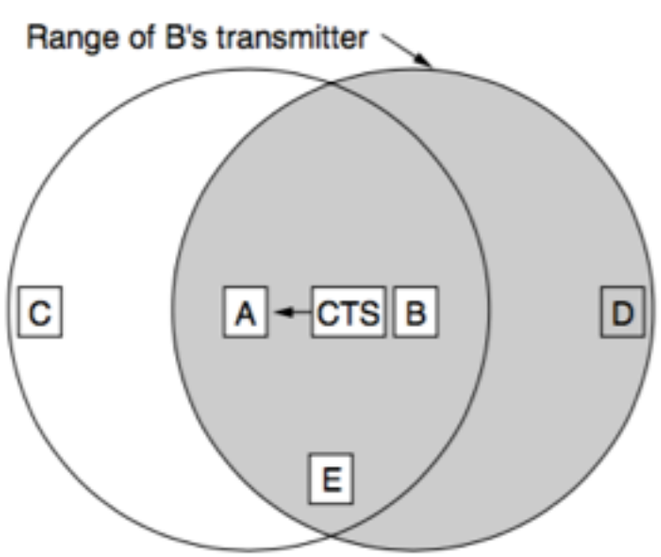


(NAV) Network Allocation Vector

Each frame carries a NAV field that says how long the current sequence of frames will take to complete the transmission







Does not help for short frames
Slows down operation
Does not help for exposed terminals
There are few hidden terminals

How to increase reliability

1. Send shorter frames (fragments)
   - Fragments are individually numbered and acknowledged using a stop-and-wait protocol
   - Once the channel has been acquired, multiple fragments are sent as a burst with an acknowledgement in between
   - The NAV mechanism keeps other stations quiet only until the next acknowledgement

2. Beacon frames
   - Periodic broadcasts by the AP (e.g., every 100 msec)
   - Contains identifier of the AP, the time, how long until the next beacon, and security settings

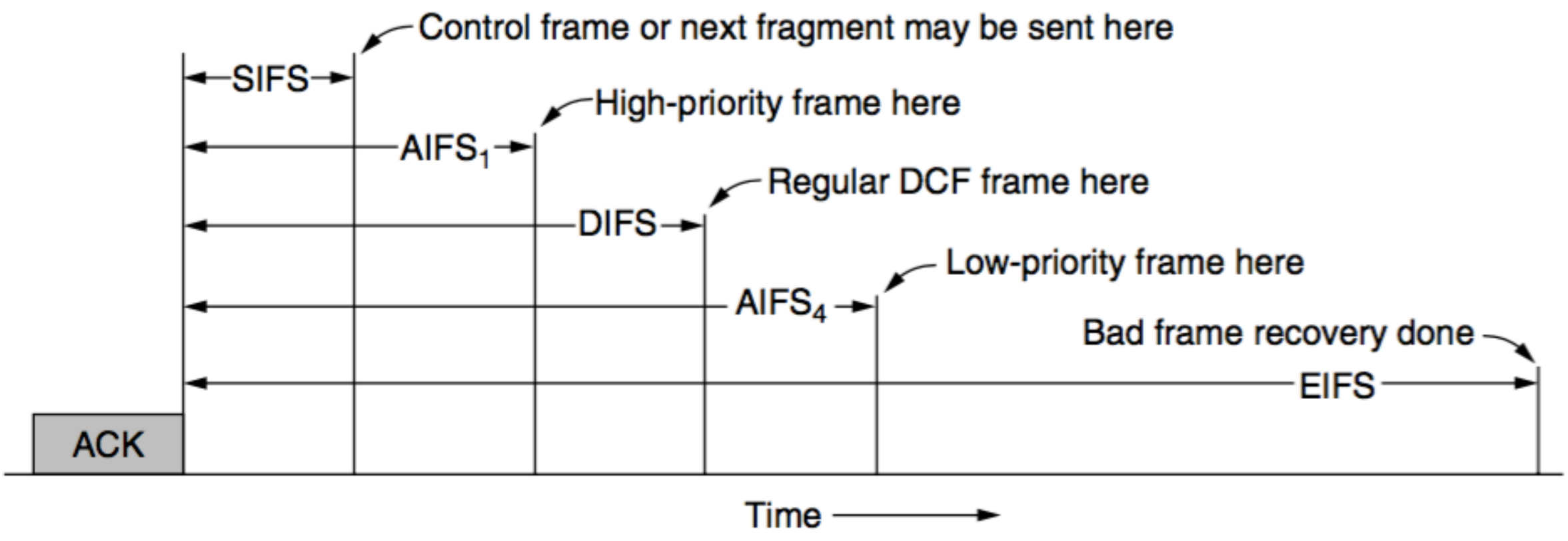
3. Carefully defined intervals between frames
   - DIFS (DCF InterFrame Spacing)
   - SIFS (Short InterFrame Spacing)
   - AIFS (Arbitration InterFrame Space)
   - EIFS (Extended InterFrame Spacing)

InterFrame spacing

SIFS (Short InterFrame Spacing)
 - ACK, RTS, CTS, burst of fragments
DIFS (DCF InterFrame Spacing)
 - Any station may attempt to acquire the channel to send a new frame

DCF (Distributed Coordination Function)

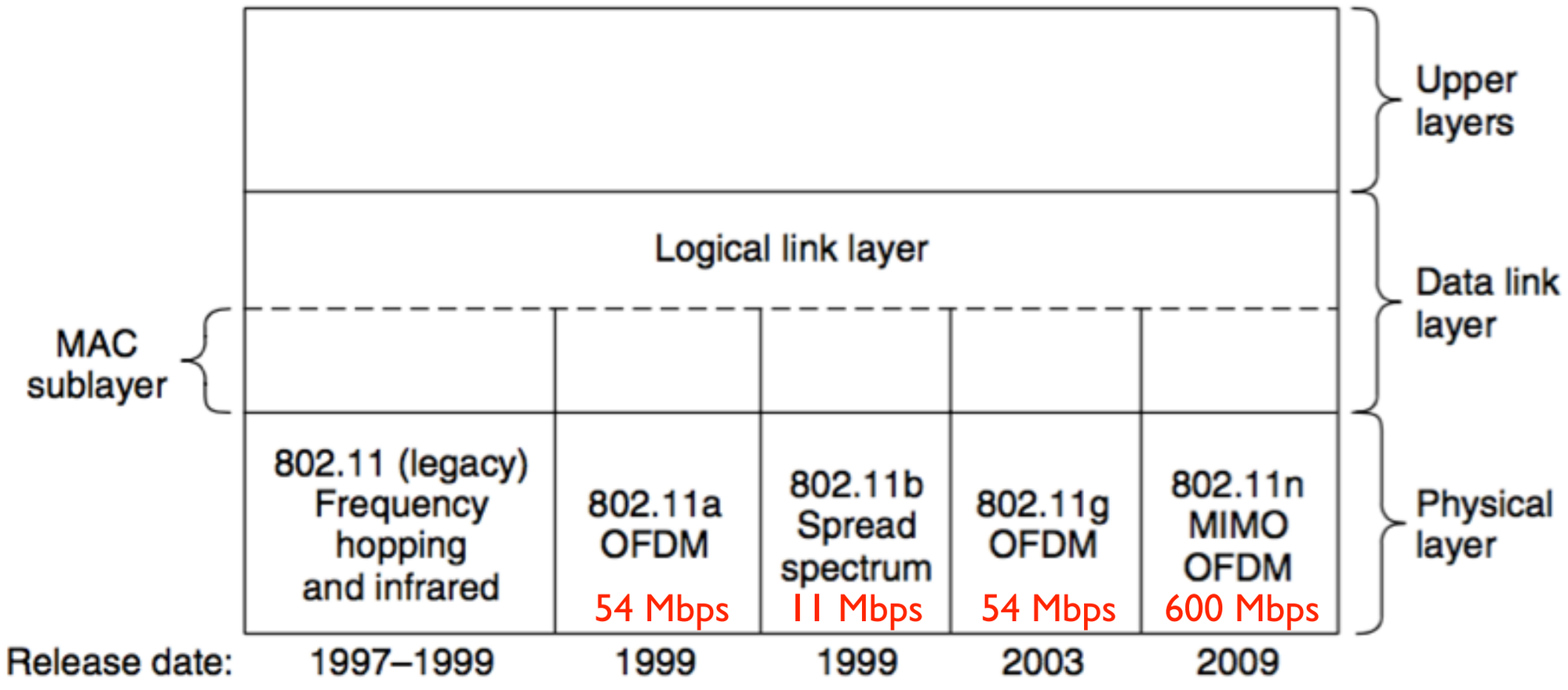
EIFS (Extended InterFrame Spacing)
 - used only by a station that has just received a bad or unknown frame, to report the problem
AIFS (Arbitration InterFrame Space)
- $AIFS_1$: Voice, $AIFS_4$: Background traffic



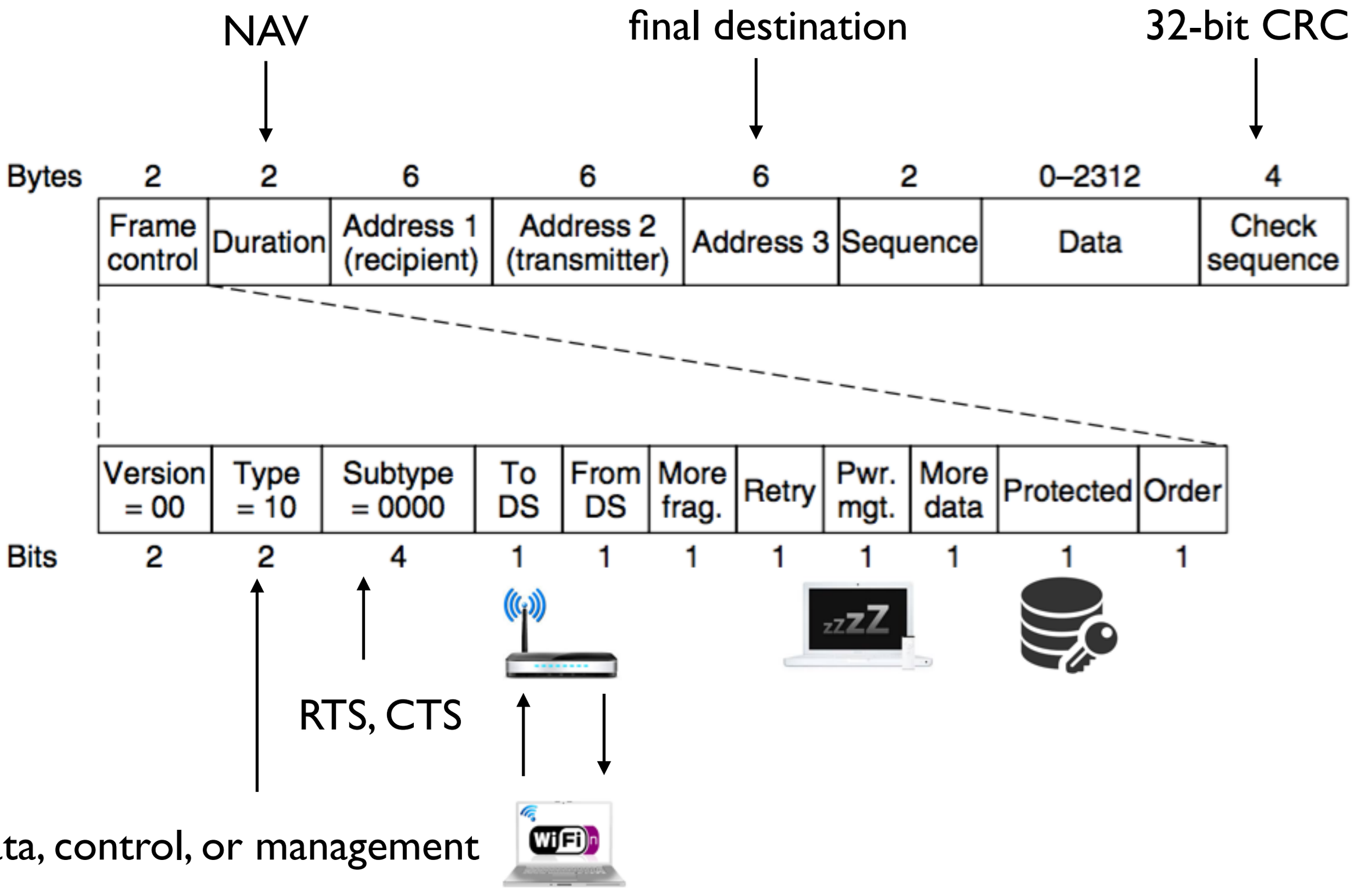
TXOP (Transmission Opportunity)

With transmission opportunities, each station gets an equal amount of airtime, not an equal number of frames

Stations that send at a higher rate for their airtime will get higher throughput



802.11 Frame Structure

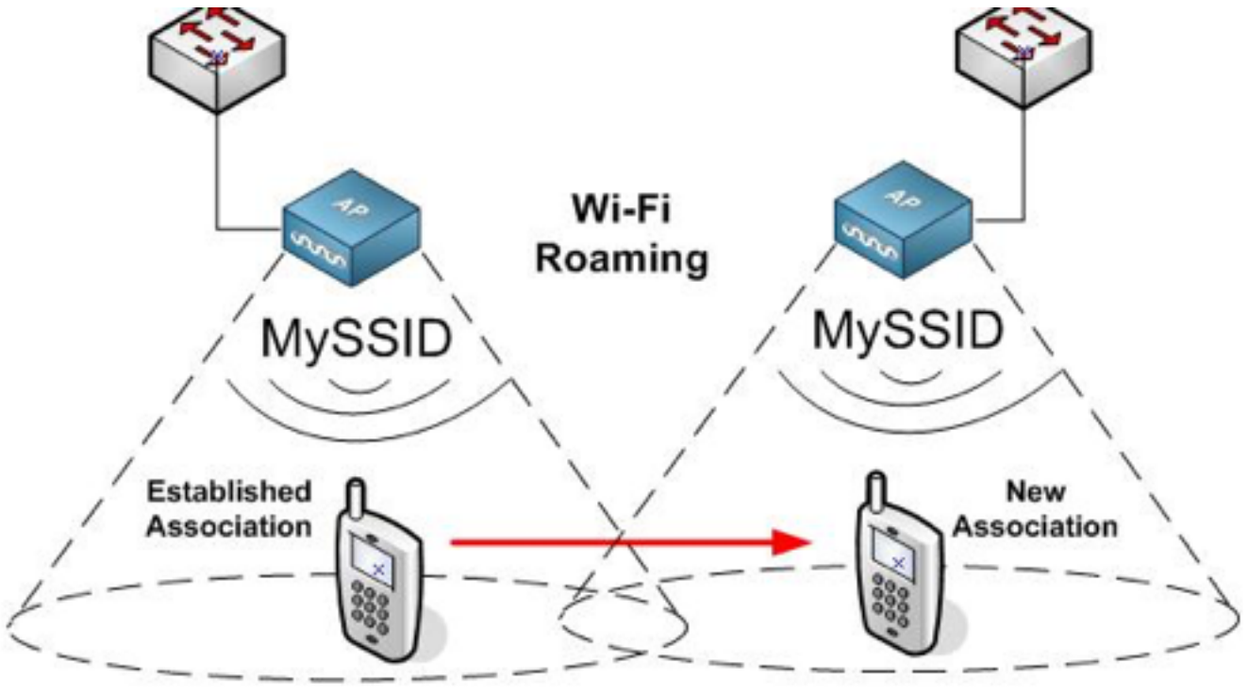


802.11 Services

Association

Reassociation

Disassociation



Authentication

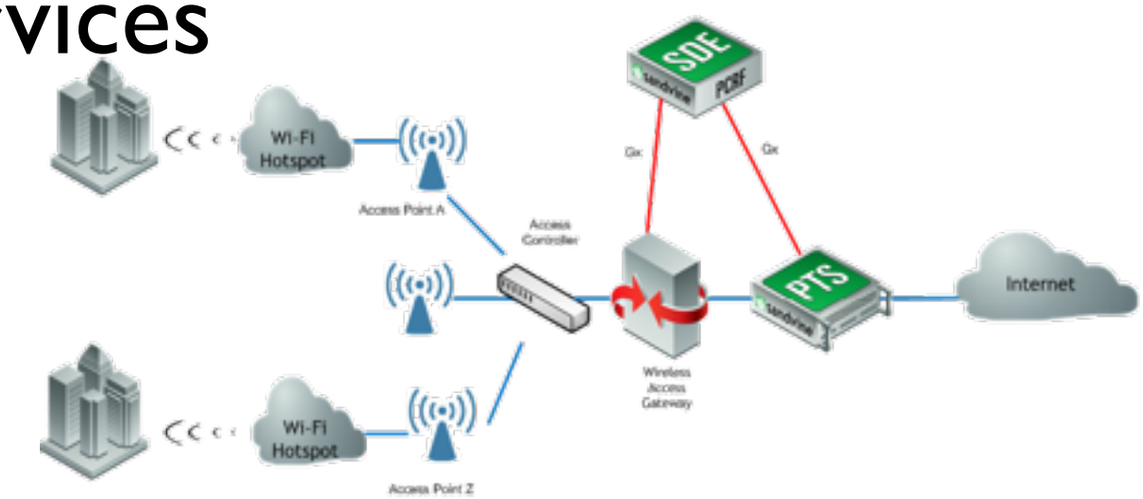
WEP (Wired Equivalent Privacy)

- Authentication with a preshared key happens before association

WPA2 (WiFi Protected Access 2)

- AP can talk to an authentication server that has a username and password database to determine if the station is allowed to access the network. This exchange hap- pens after association.

802.11 Services



Distribution
Determines how to route frames

Integration
Handles any translation that is needed for a frame to be sent outside the 802.11 LAN, or to arrive from outside the 802.11 LAN

Data delivery
Lets stations transmit and receive data using the protocols described earlier

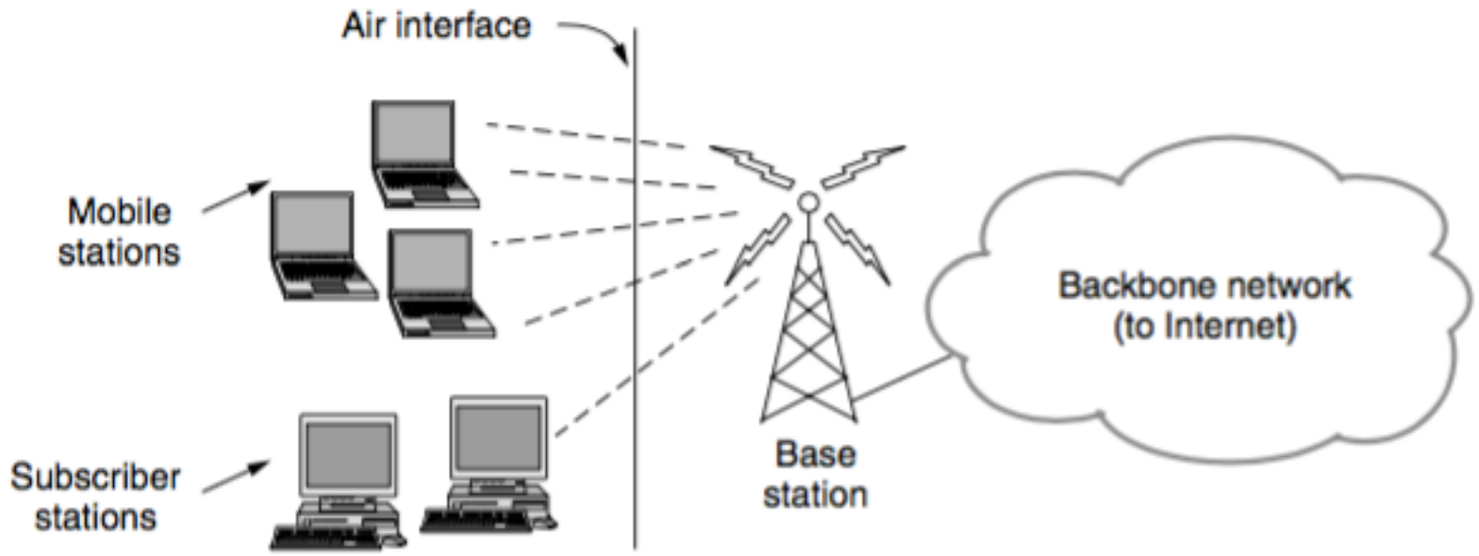
Privacy
AES (Advanced Encryption Standard)

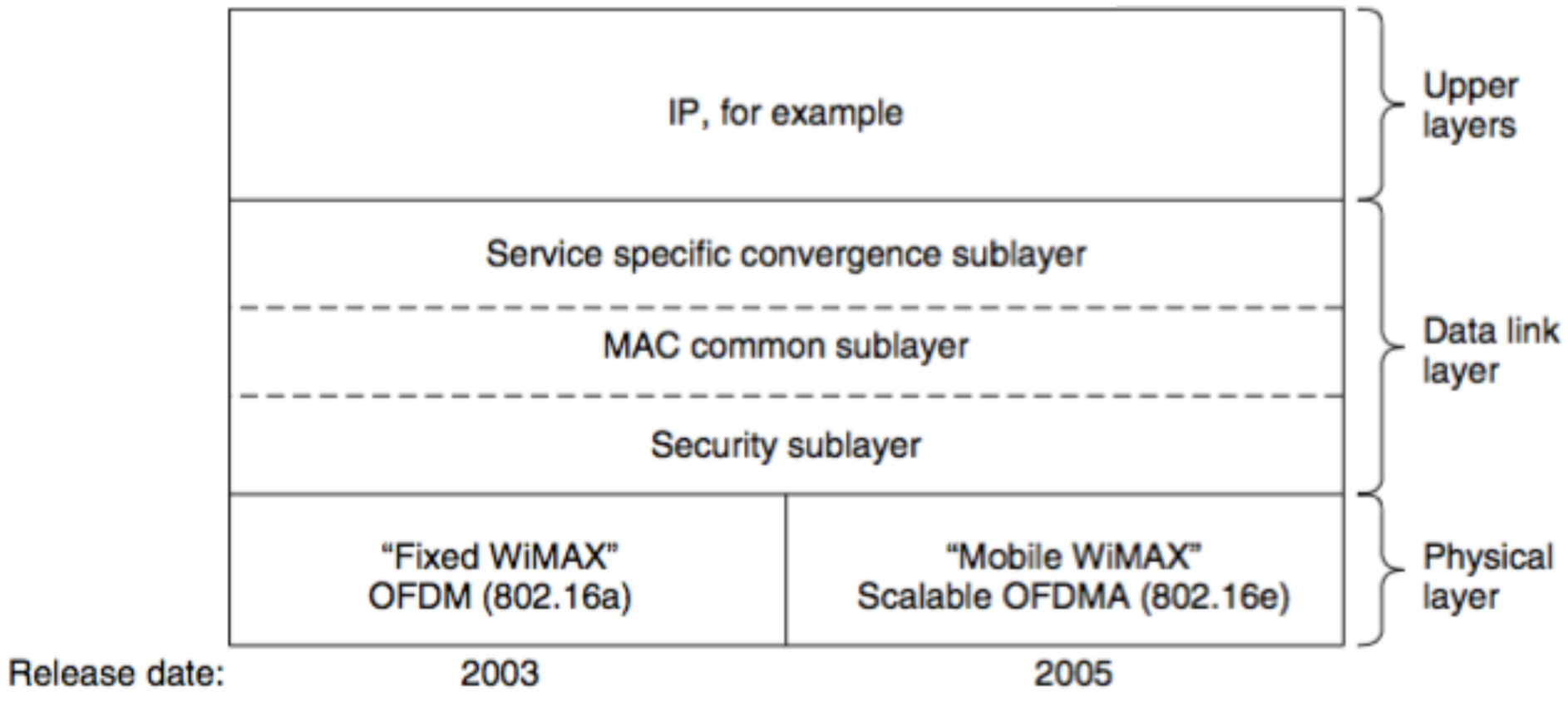
QOS traffic scheduling
Give voice and video traffic preferential treatment compared to best-effort and background traffic

Transmit power control, Dynamic frequency selection

Broadband Wireless

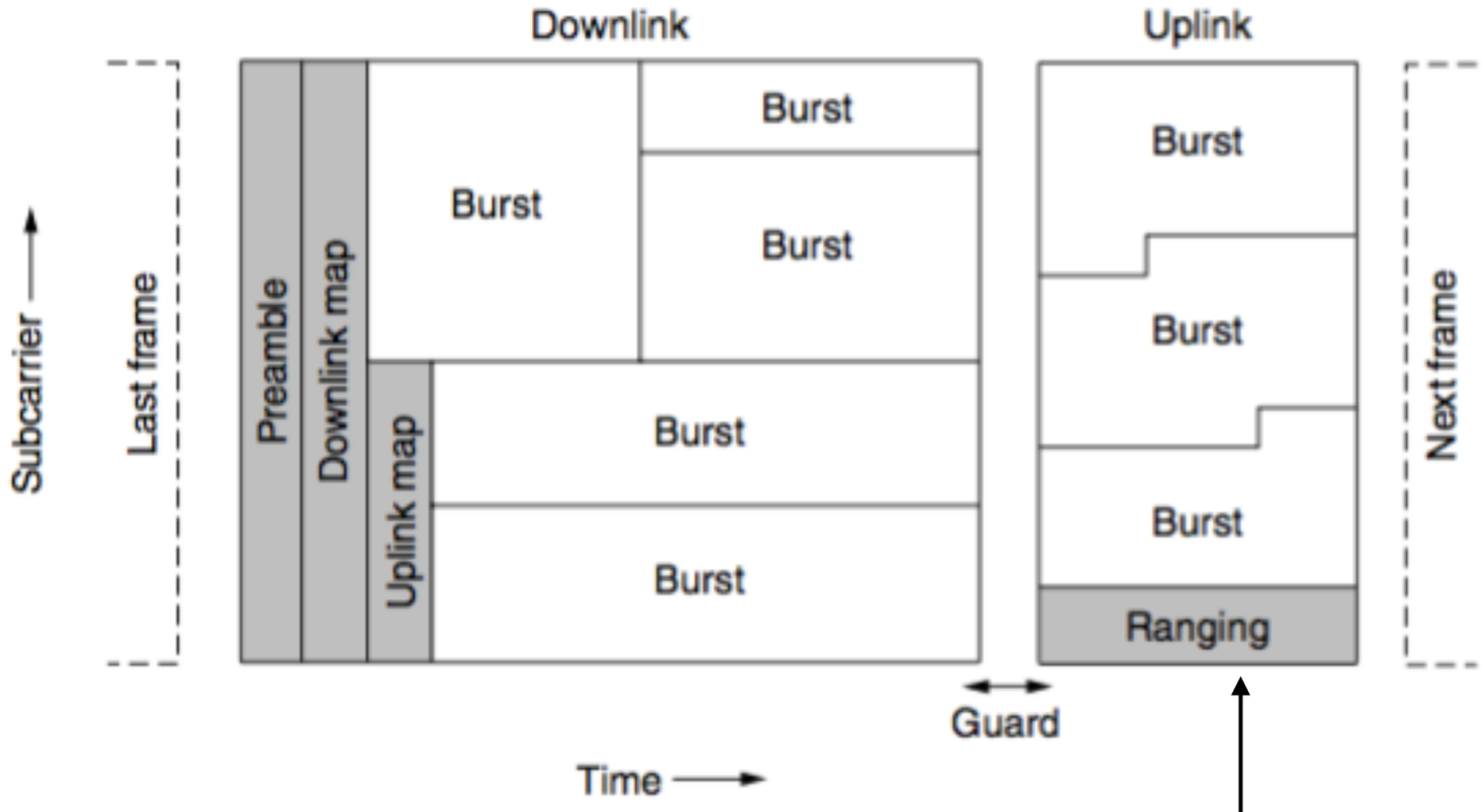
WiMAX (Worldwide Interoperability for Microwave Access) 802.16





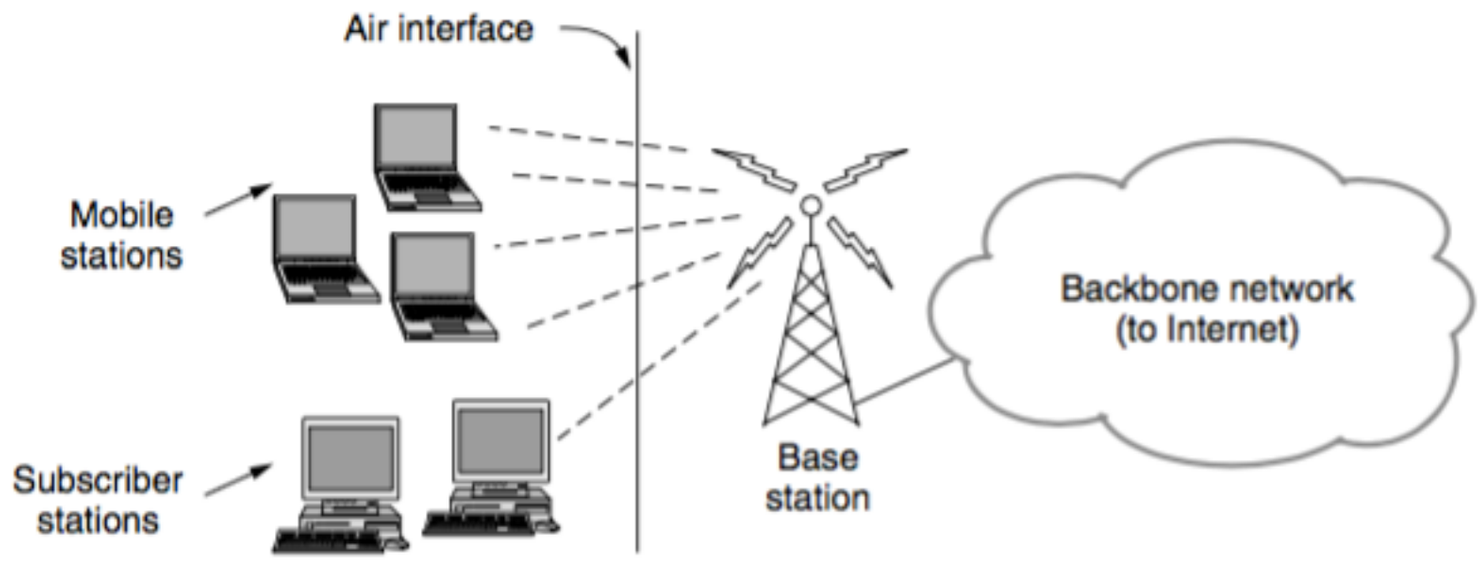
802.16 Physical Layer

OFDMA (Orthogonal Frequency Division Multiple Access)
Different sets of subcarriers can be assigned to different stations, so that more than one station can send or receive at once



Process by which new stations adjust their timing and request initial bandwidth to connect

802.16 MAC Sublayer Protocol



- Base Station sends out frames
- Each frame includes a number of subframes, which include a number of time slots
- The first two subframes are the downstream and upstream maps, which tell what is in which time slot
- Downstream subframes (channels) are straightforward. The base station decides what to send
- Upstream channel is more complex, due to competition

Uplink channel QoS

Constant bit rate service
For transmitting uncompressed voice. This service needs to send a predetermined amount of data at predetermined time intervals.

Real-time variable bit rate service
For compressed multimedia and other soft real-time applications. It is accommodated by the base station polling the subscriber at a fixed interval to ask how much bandwidth is needed this time.

Non-real-time variable bit rate service
For heavy transmissions that are not real time, such as large file transfers. For this service, the base station polls the subscriber often, but not at rigidly prescribed time intervals.

Best-effort service
No polling is done and the subscriber must contend for bandwidth with other best-effort subscribers.

802.16 Frame Structure

whether the payload is encrypted

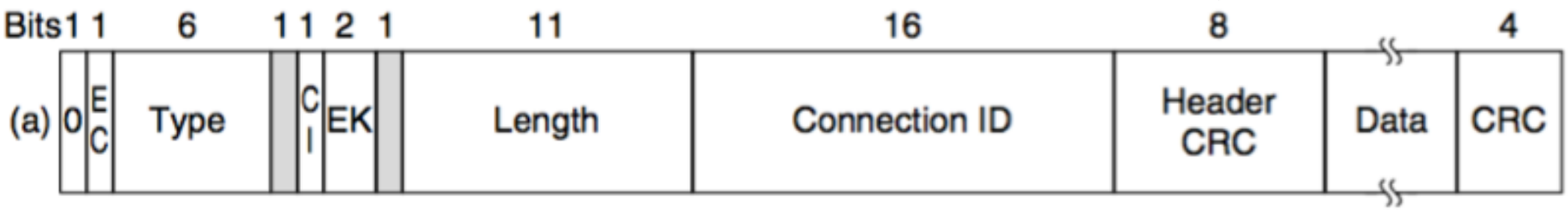
the presence of the final checksum

which encryption key is being used

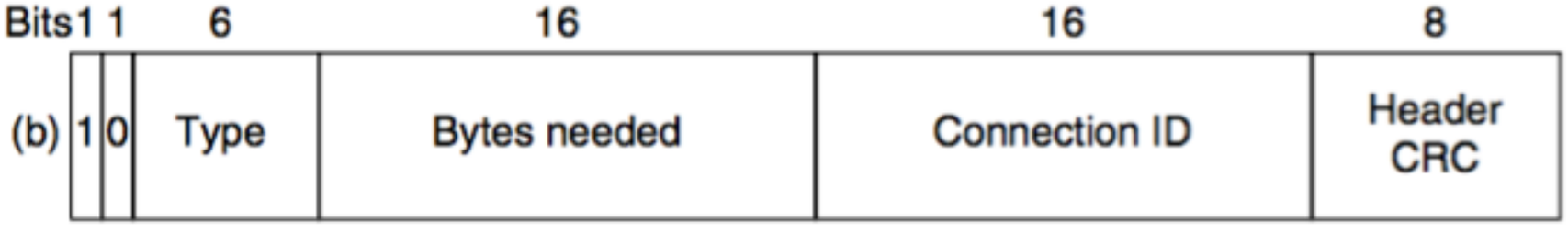
which connection this frame belongs to

$x^8 + x^2 + x + 1$

Generic frame



Bandwidth request frame

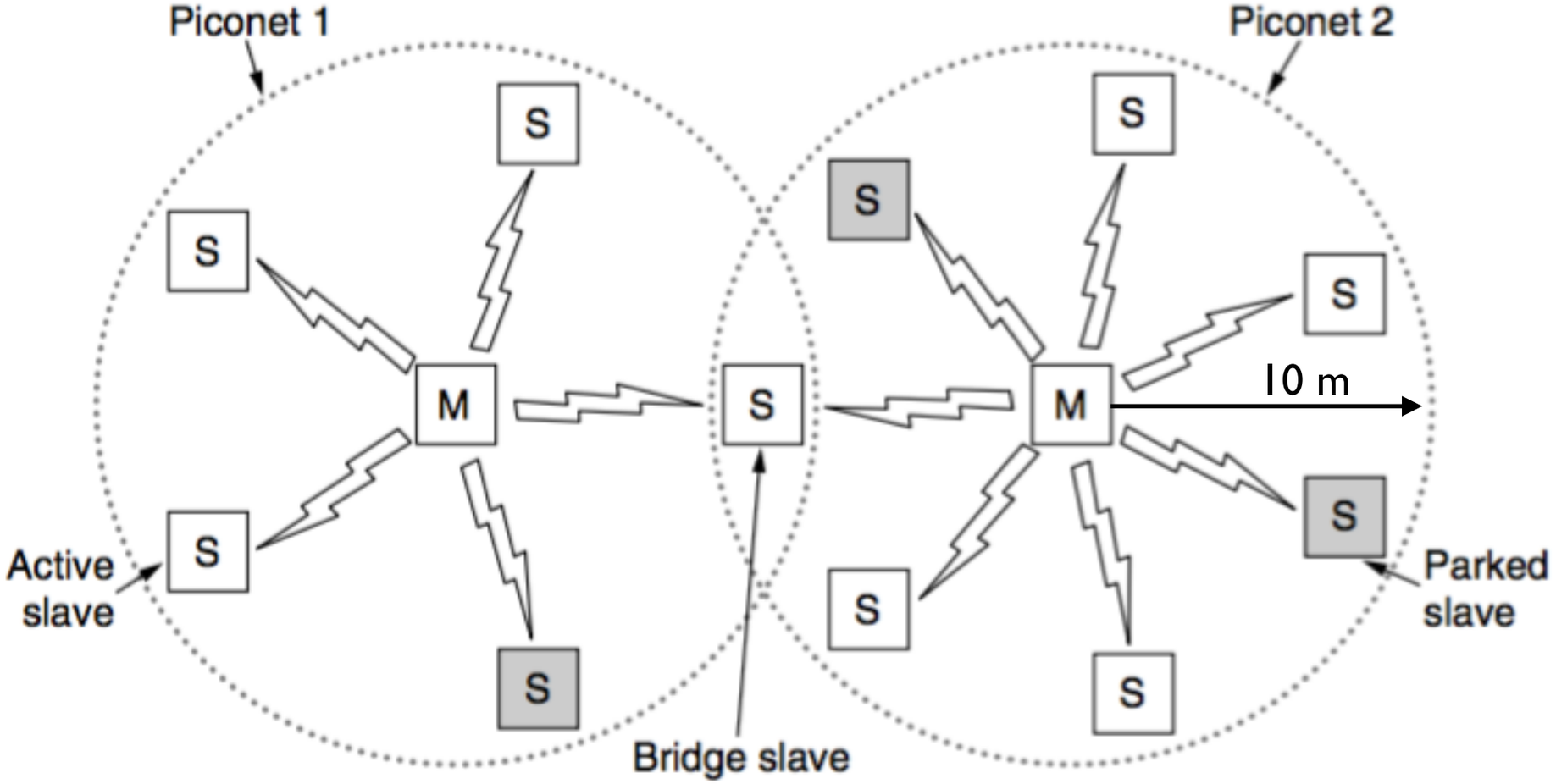


Bluetooth

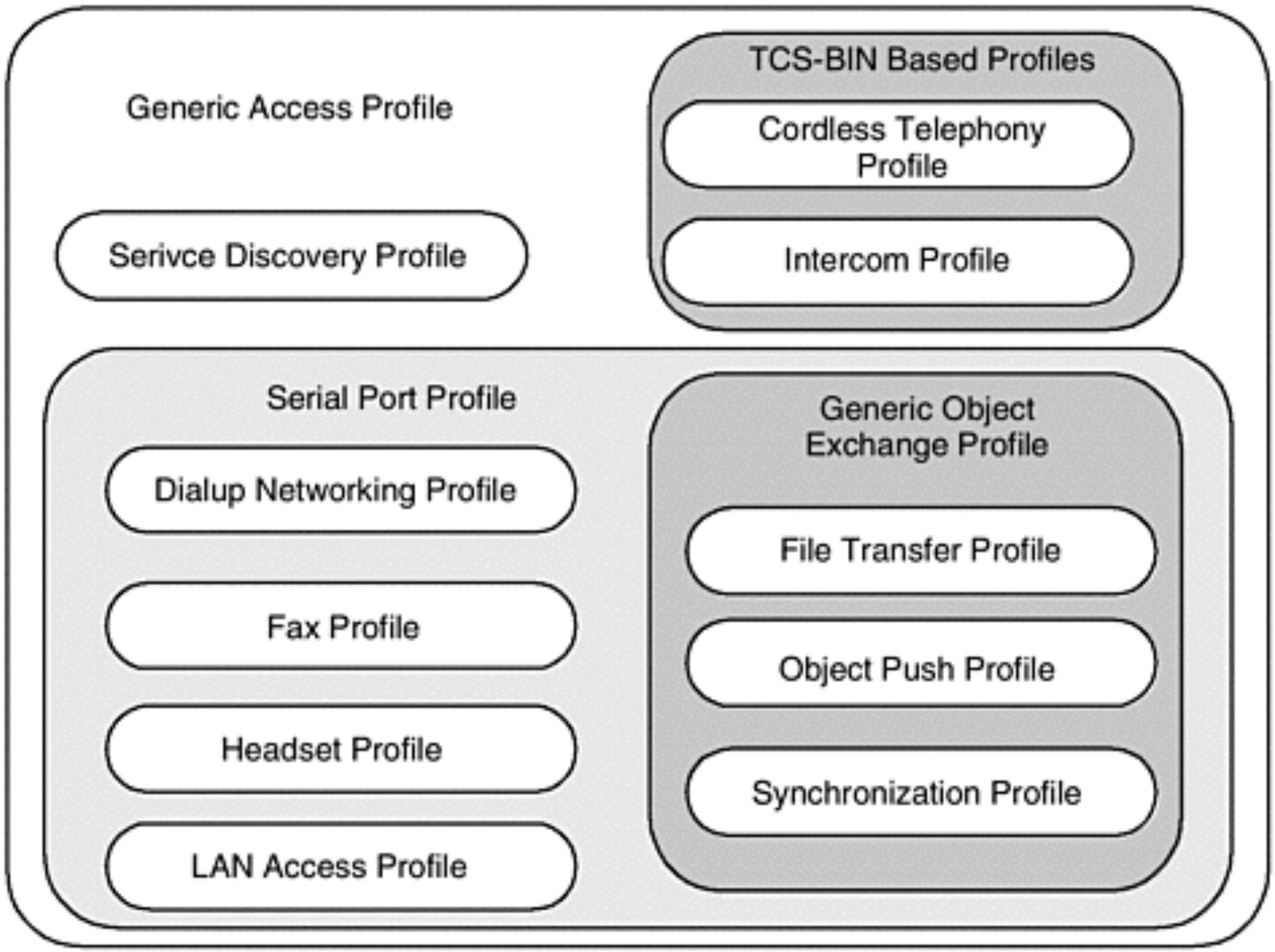
1998 SIG (Special Interest Group)

Harald Bluetooth
958-986

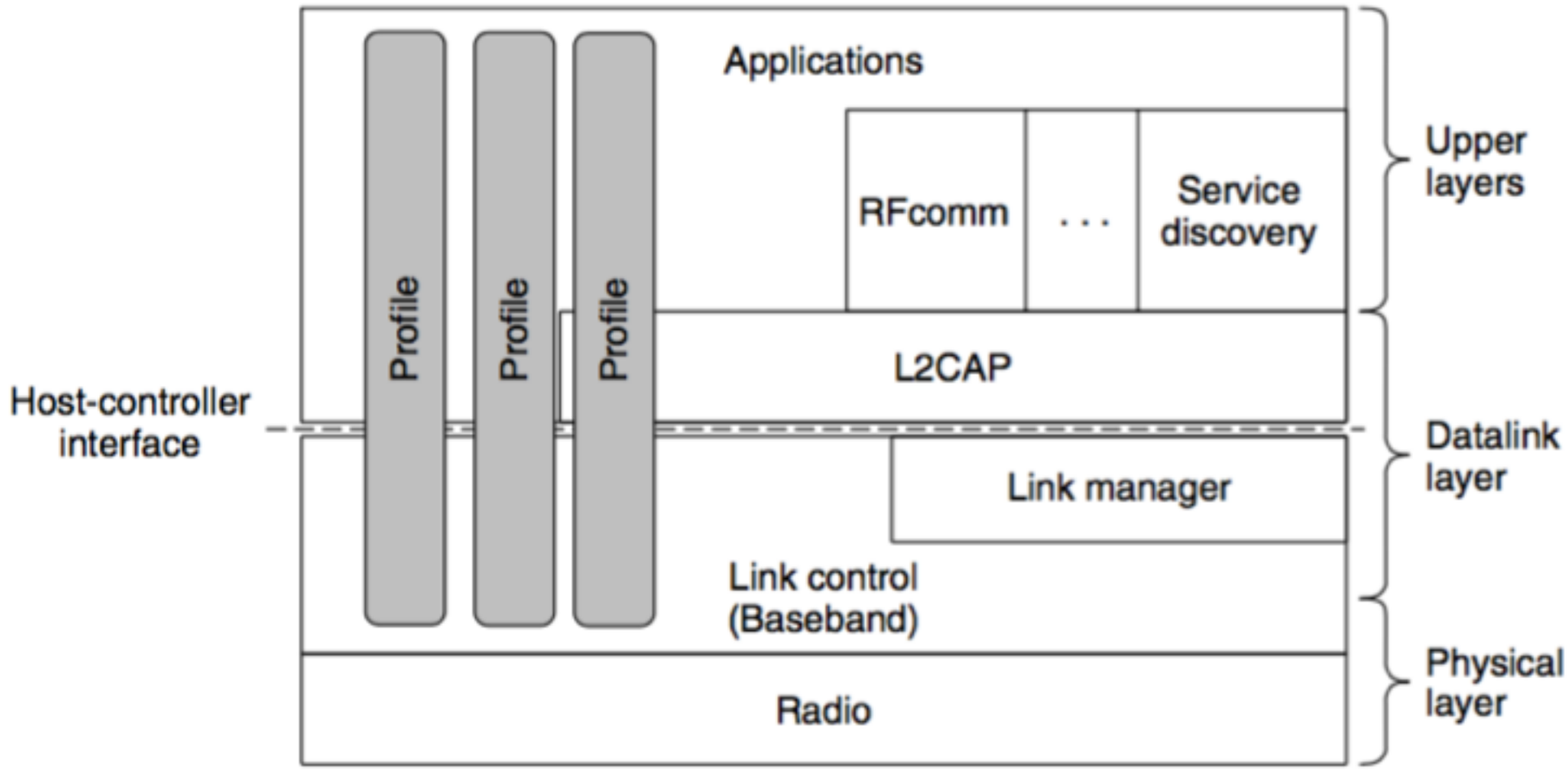
Bluetooth protocols let devices find and connect to each other through an act called **pairing**



Bluetooth Applications (Profiles)



Bluetooth Protocol Stack



<u>L2CAP (Logical Link Control Adaptation Protocol)</u>

Frames variable-length messages and provides reliability if needed

<u>Bluetooth Link Layer</u>

The link manager protocol sets up logical channels, called **links:**

SCO (Synchronous Connection Oriented) link : Used for real-time data

ACL (Asynchronous ConnectionLess) link : Used for packet-switched data

<u>Bluetooth Radio Layer</u>

2.4-GHz ISM divided into 79 channels of 1 MHz each + adaptive frequency hopping

Bluetooth Frame Structure

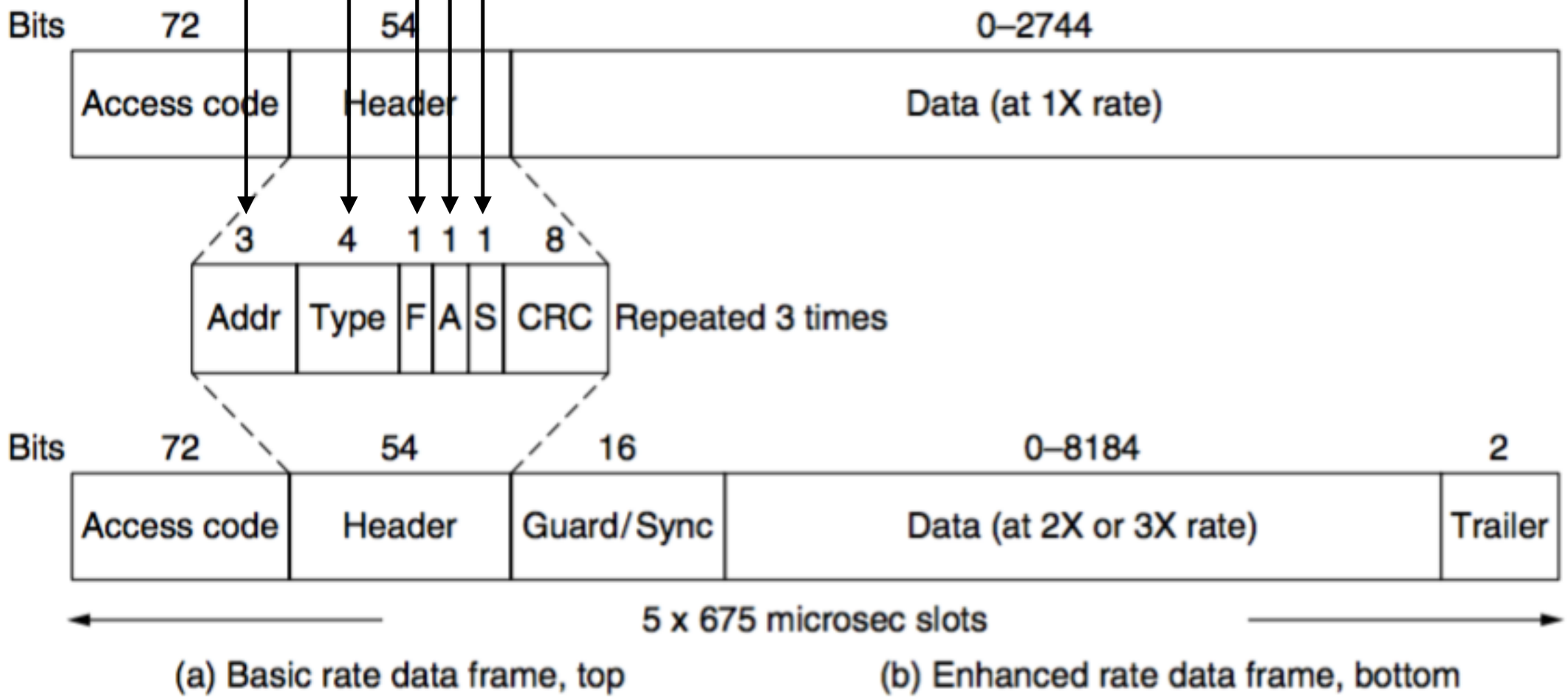
Identifies which of the eight active devices the frame is intended for

Identifies the frame type (ACL, SCO, poll, or null)

Flow bit : Indicates when a buffer is full

Acknowledgement bit (ACK)

Sequence bit



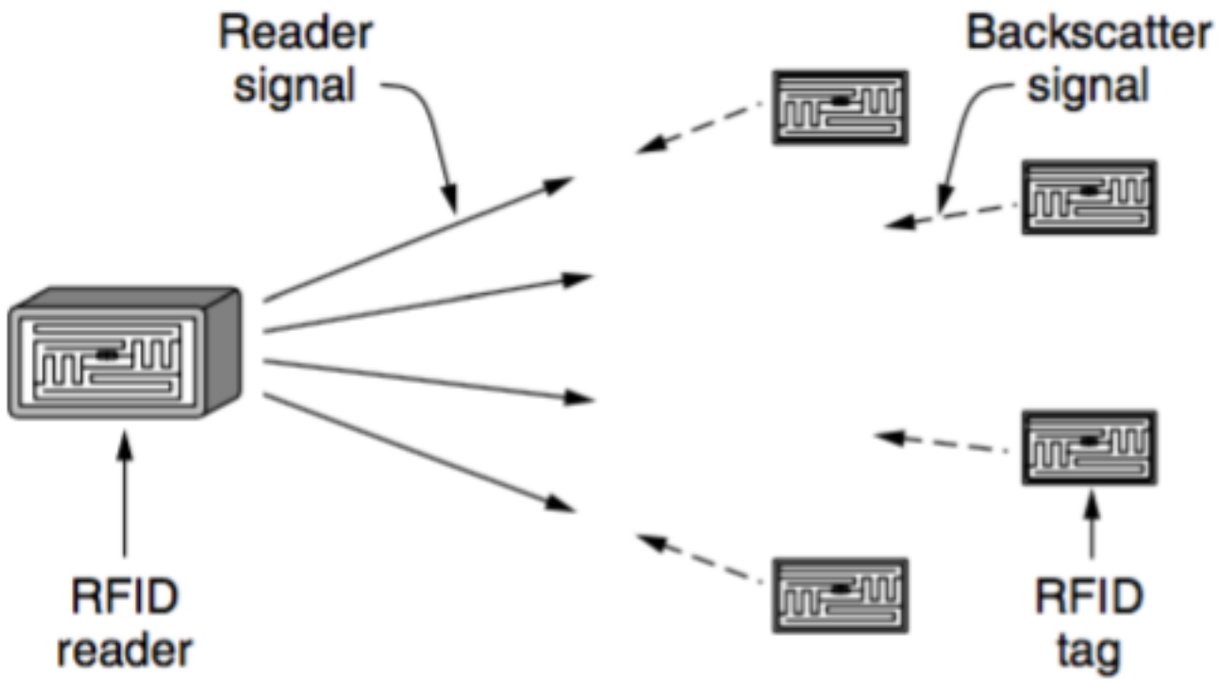
(a) Basic rate data frame, top

(b) Enhanced rate data frame, bottom

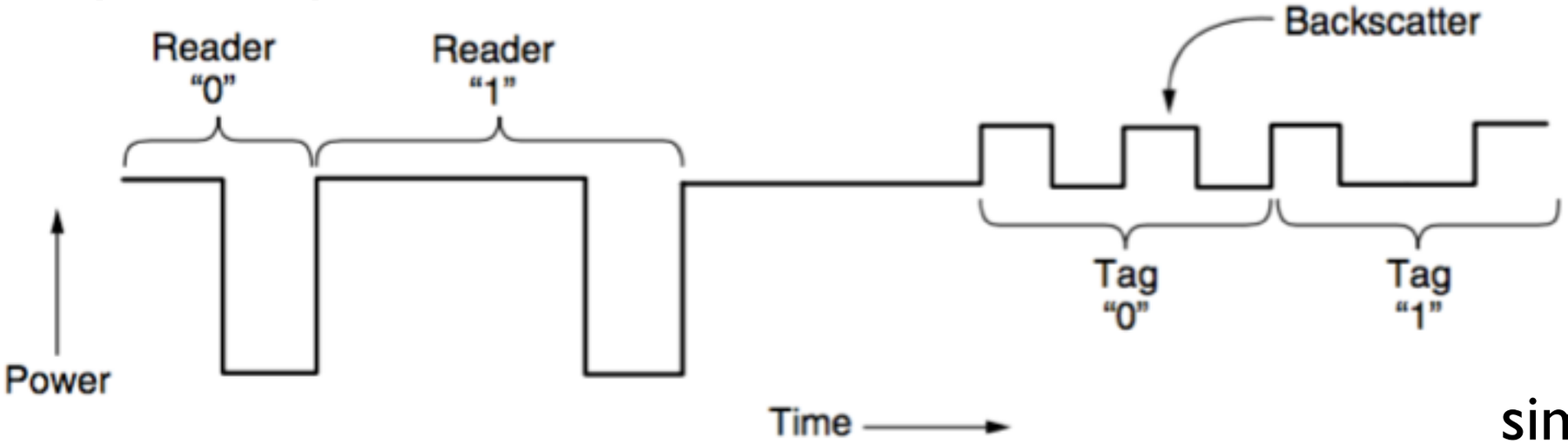
RFID (Radio Frequency IDentification)

<u>History</u>
1999 EPC (Electronic Product Code) at MIT
2003 EPCglobal
2005 Walmart equips all shipments with RFID
2008 EPC Gen 2

<u>Features</u>
96-bit identifier
Placed on stickers
Integrated in a card
Tag has no battery
 - Power is gathered from readers



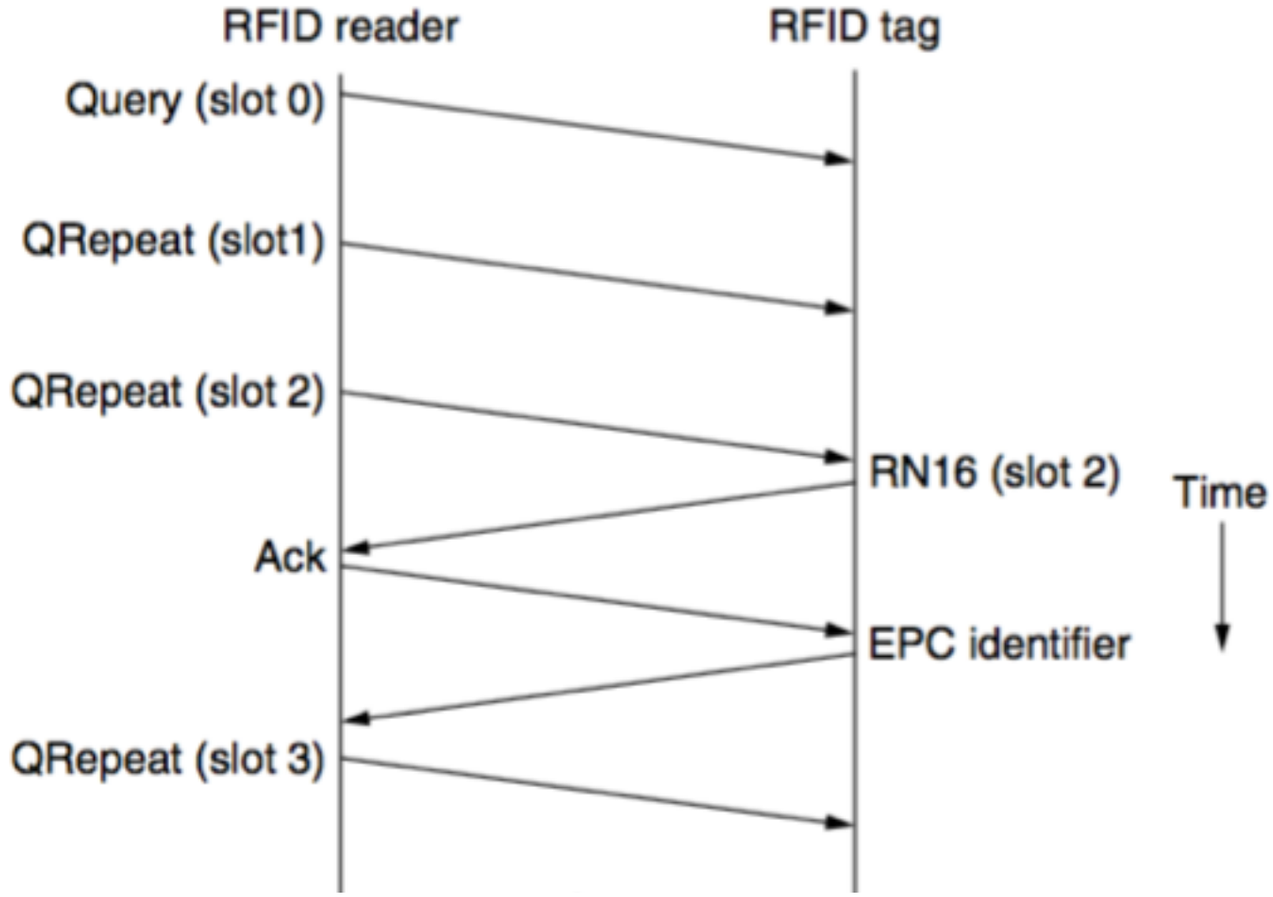
Physical Layer

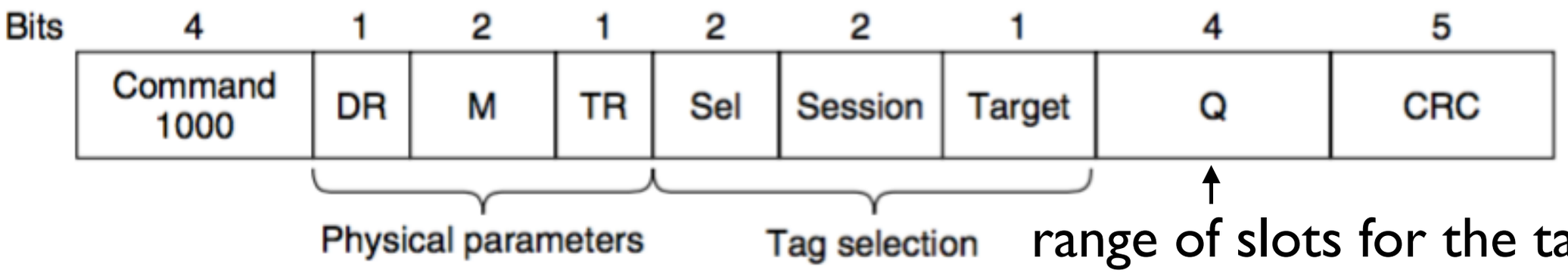


Backscatter is a low-energy way for the tag to create a weak signal of its own that shows up at the reader

Tag Identification Layer

similar to slotted ALOHA



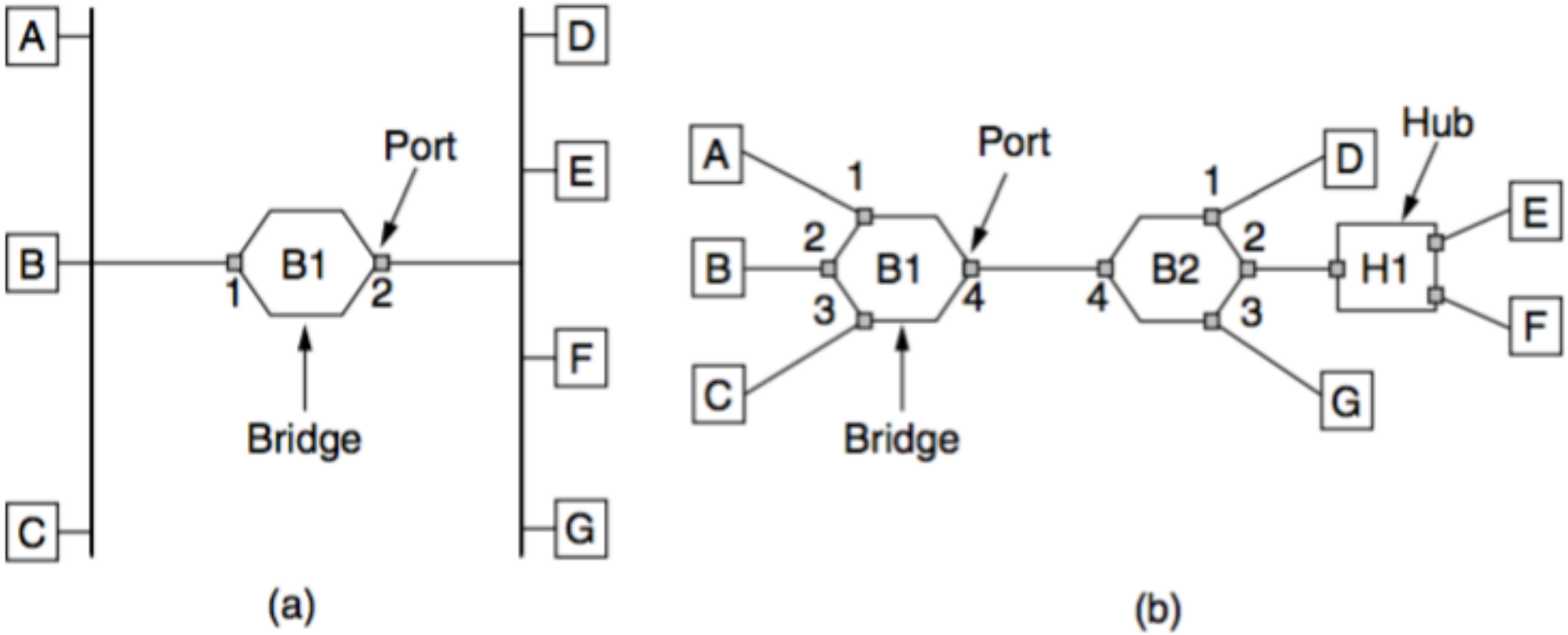


range of slots for the tag to respond

Data Link Layer Switching

Use of bridges

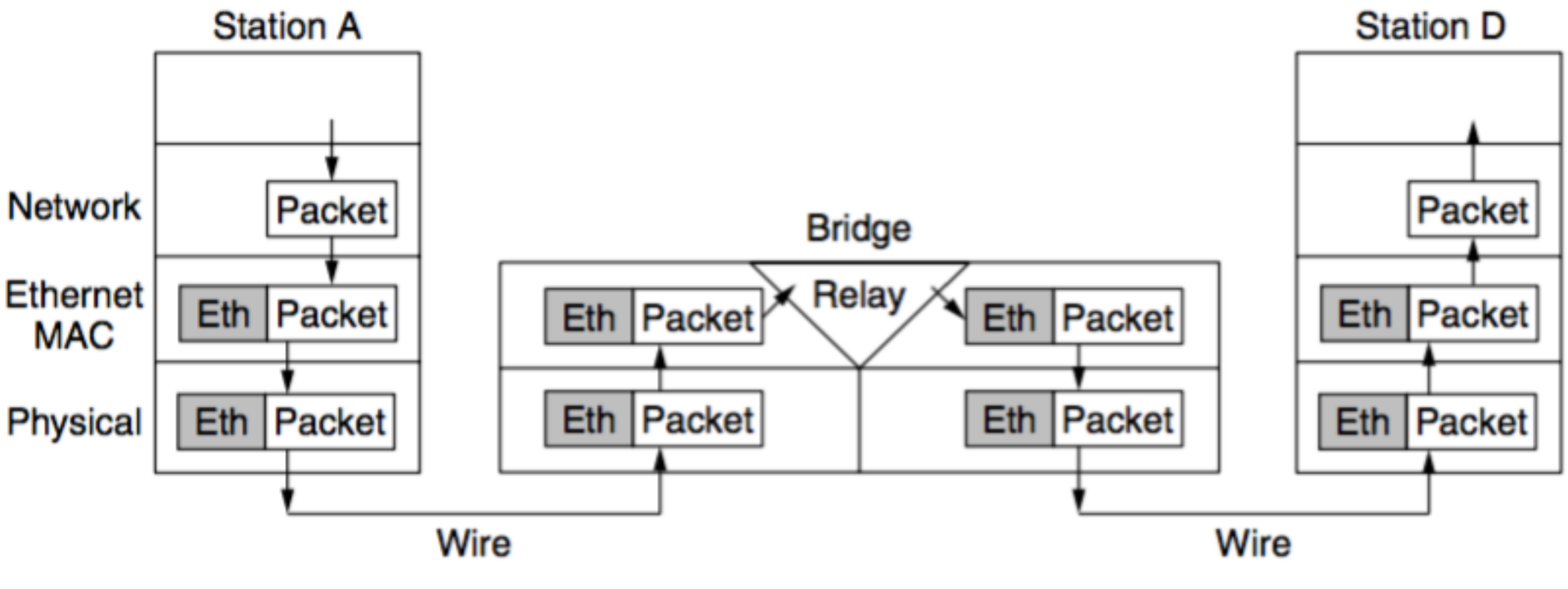
- Learning bridges
- Spanning tree bridges

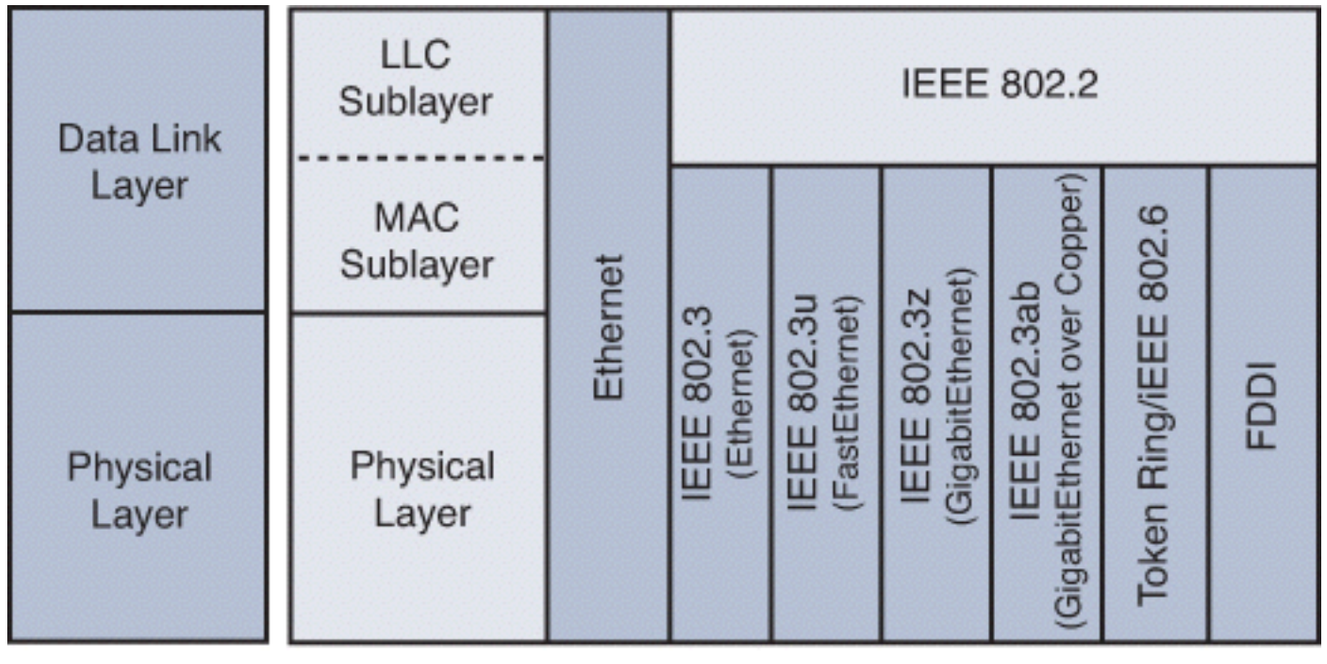


Learning procedures

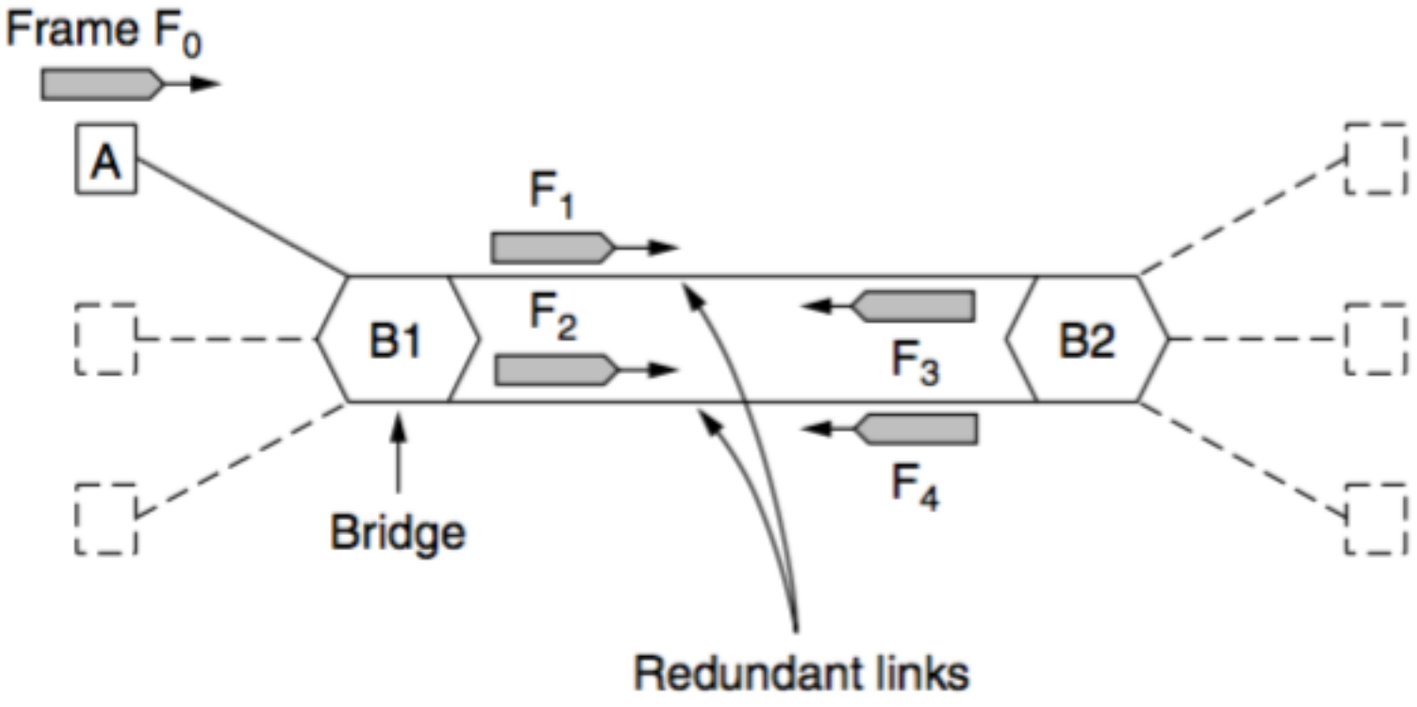
1. If the port for the destination address is the same as the source port, discard the frame.
2. If the port for the destination address and the source port are different, forward the frame on to the destination port.
3. If the destination port is unknown, use flooding and send the frame on all ports except the source port.

Protocol Processing at a bridge

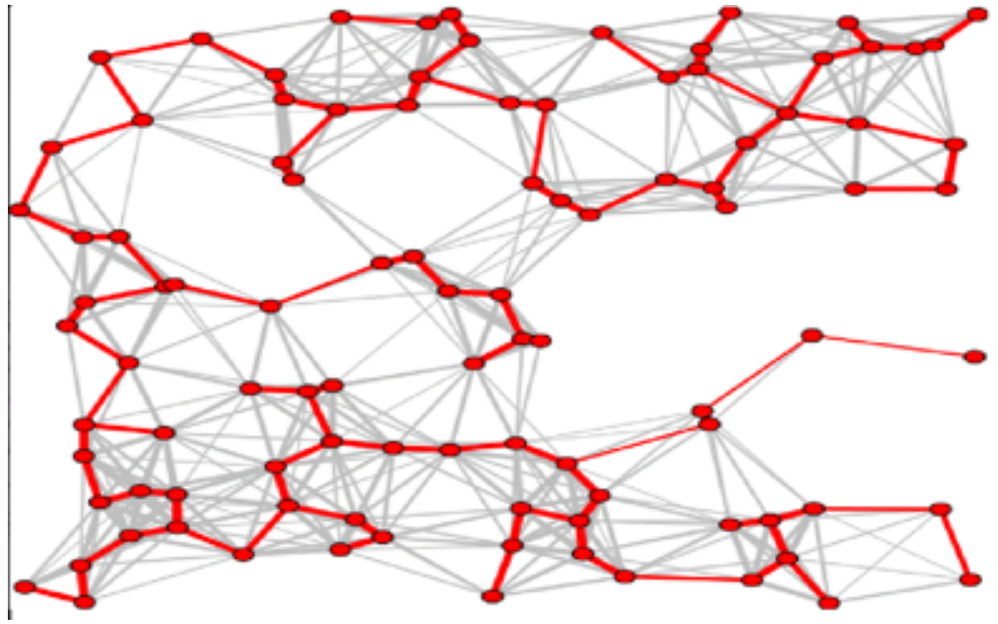


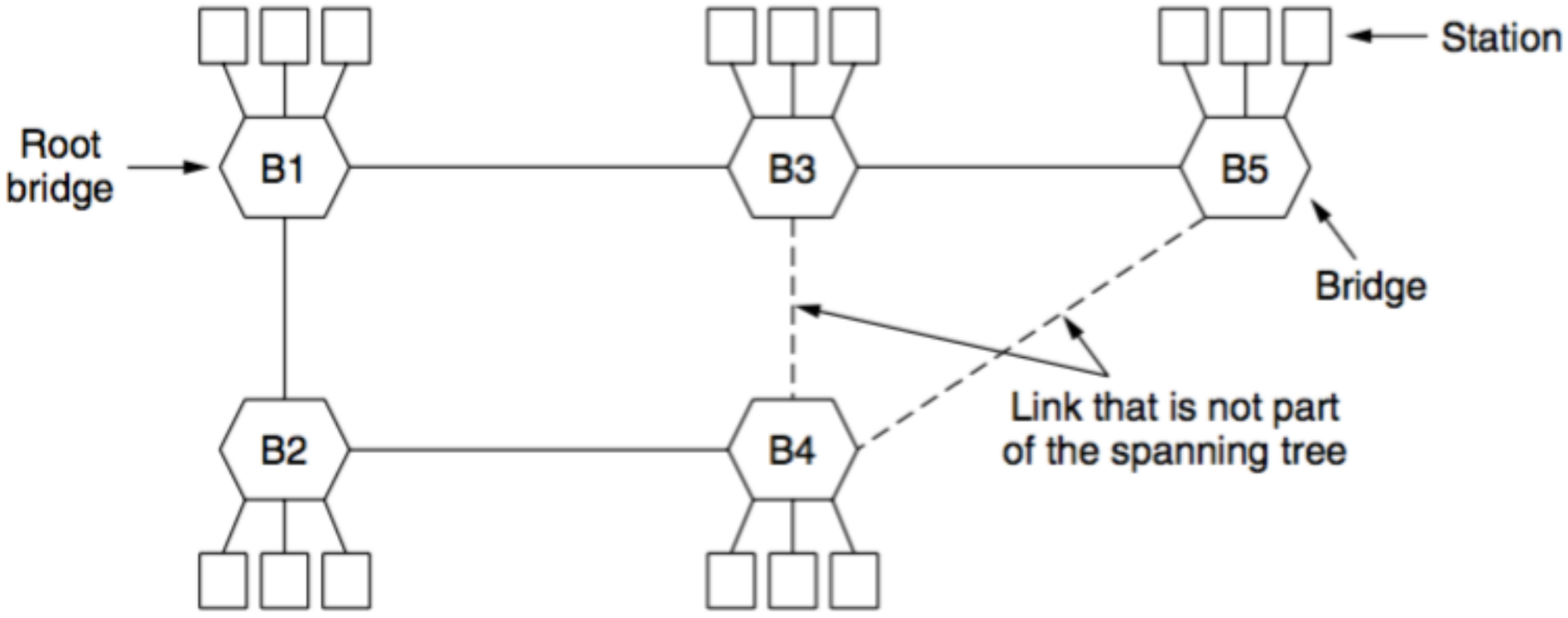


Spanning Tree Bridges



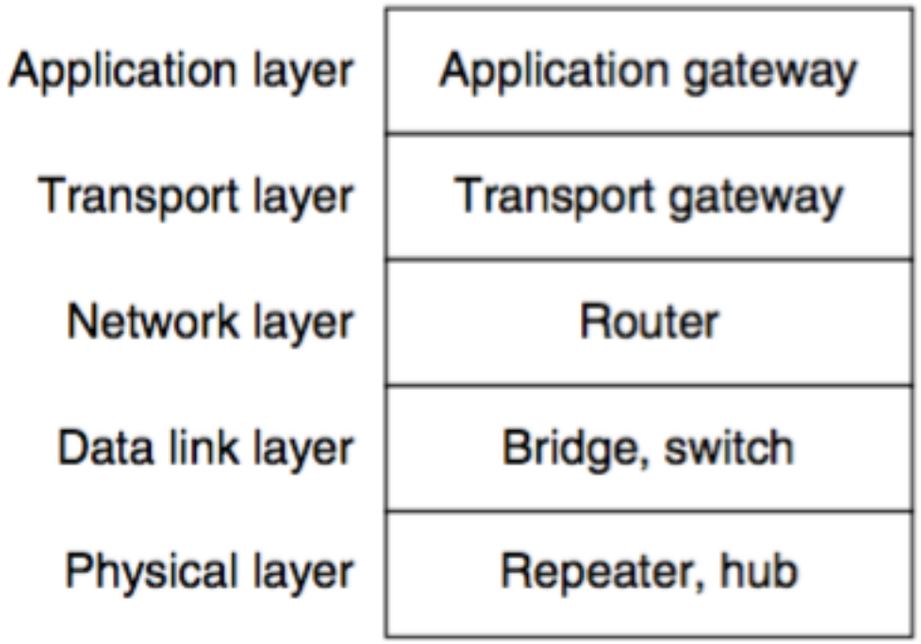
Spanning tree



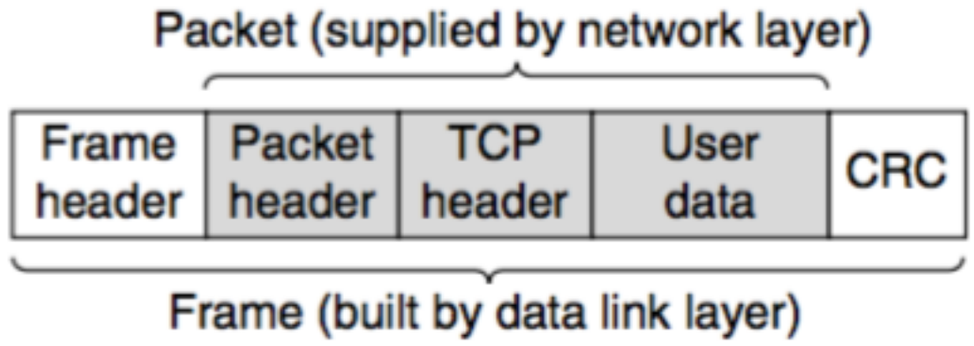


Repeaters, Hubs, Bridges, Switches, Routers, and Gateways

Repeater: Physical layer connection to the network
Hub: Multiport repeater
Bridge: Datalink level connection of two networks
Switch: Multiport bridge
Router: Transport level connection of two networks
Gateway: Router between two individual networks

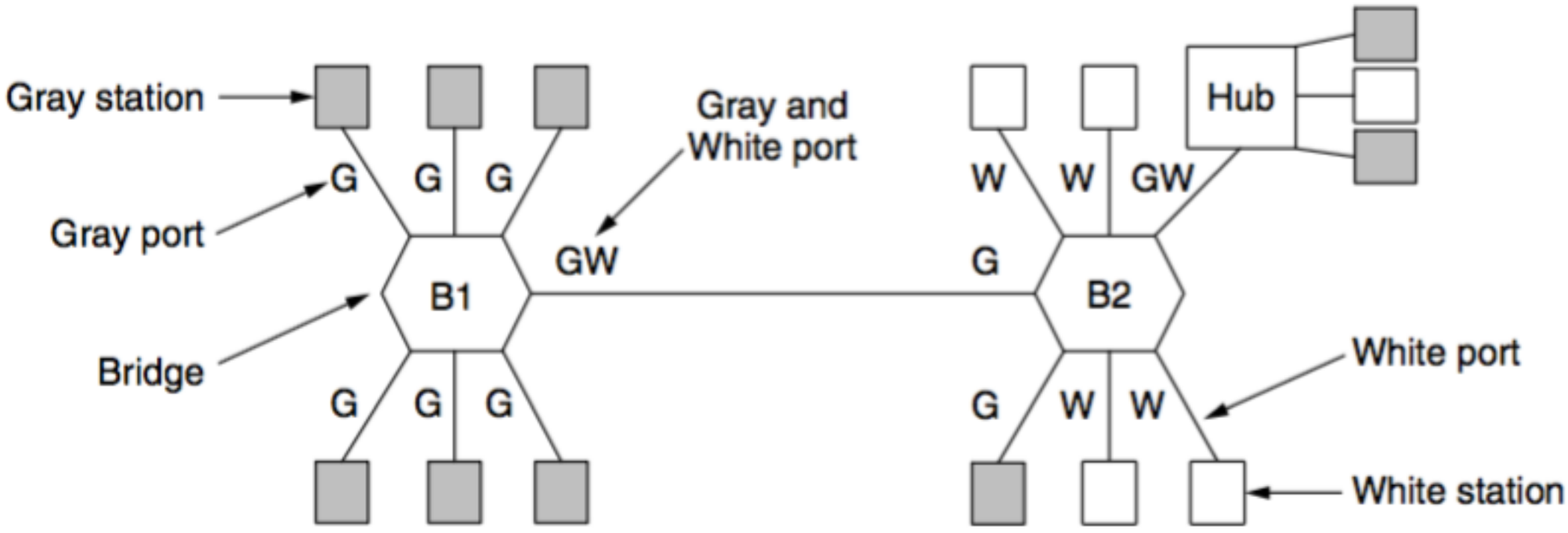


(a)



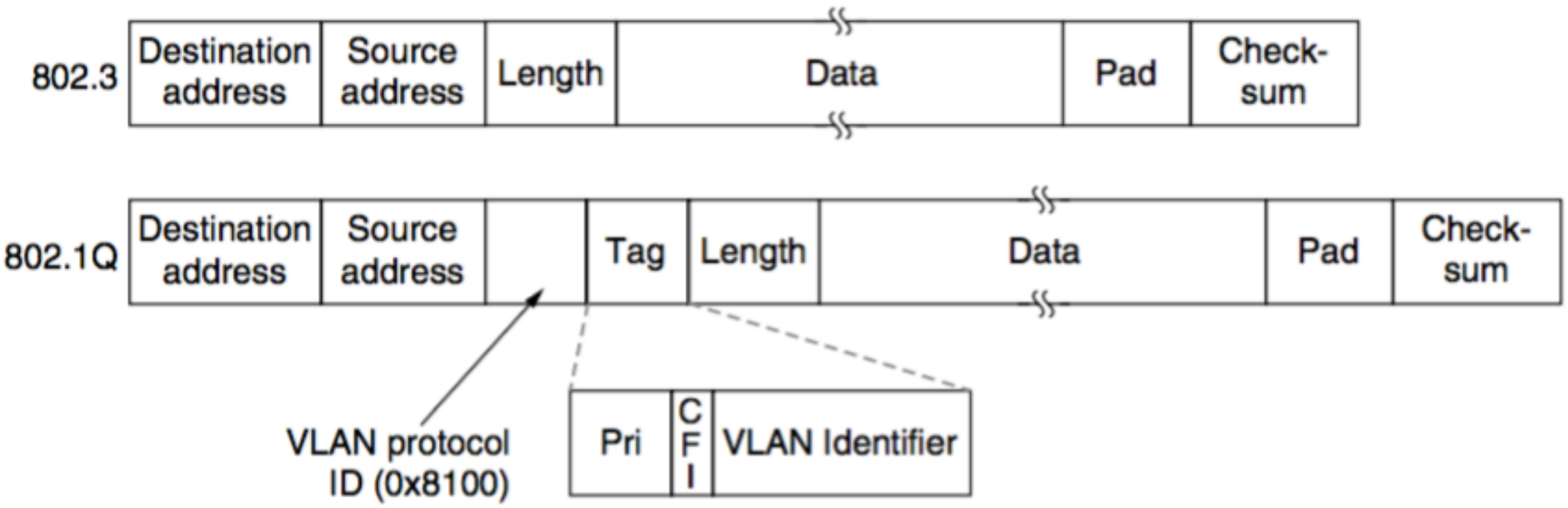
(b)

VLAN (Virtual Local Area Network)



802.1Q

Add VLAN tag to Ethernet standard



講義日程（1Q）

		授業計画		課題
04/05	第１回	計算機ネットワークの基本概念 ハードウェア・ソフトウェア，参照モデル	１章	ネットワークの種類と参照モデルを理解し プロトコル階層と各層の設計課題
04/12	第２回	物理層１ 有線伝送と無線伝送	２章	物理チャネルの特性を理解し データ通信の理論的基礎を理解
04/19	第３回	物理層２ デジタル変調と多重化	２章	ベースバンド伝送と通過帯域伝送， 電話網，携帯電話システムを説明できる
04/26	第４回	データリンク層１ 誤りの検出・訂正	３章	誤りの検出・訂正のしくみを理解し 検出・訂正符号の計算ができる
05/10	第５回	データリンク層２ データリンク・プロトコル	３章	データリンク・プロトコルの種類， 各プロトコルを定量的に評価できる
05/17	第６回	メディア・アクセス副層１ ブロードキャスト・チャネル	４章	多重アクセス・プロトコルを理解し データ・レートを計算できる
05/24	第７回	メディア・アクセス副層２ 無線 LAN，Bluetooth, RFID	４章	個別のプロトコル・スタックを理解し データリンク層スイッチングを理解
05/31	第８回	理解度確認総合演習 (中間試験) 第１回から第７回までの内容の演習形式による確認		第１回から第７回までの理解度確認と 到達度自己評価