第17章 无线局域网

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参考文献

- 第4章： Fred Halsall, 计算机网络与因特网教程，机械工业出版社，2006年，9月。

Contents

- Wireless LAN Overview
- Wireless Technology
- IEEE 802.11 Architecture
- IEEE 802.11 MAC
- IEEE 802.11 Physical Layer

17.1 Overview

- A wireless LAN uses wireless transmission medium
- Possible problems
  - High prices, low data rates, occupational safety concerns, and licensing requirements
- Problems have been addressed
- Popularity of wireless LANs has grown rapidly

17.1.1 Wireless LAN Applications

- LAN Extension
- Cross-Building Interconnect
- Nomadic Access
- Ad Hoc Networking

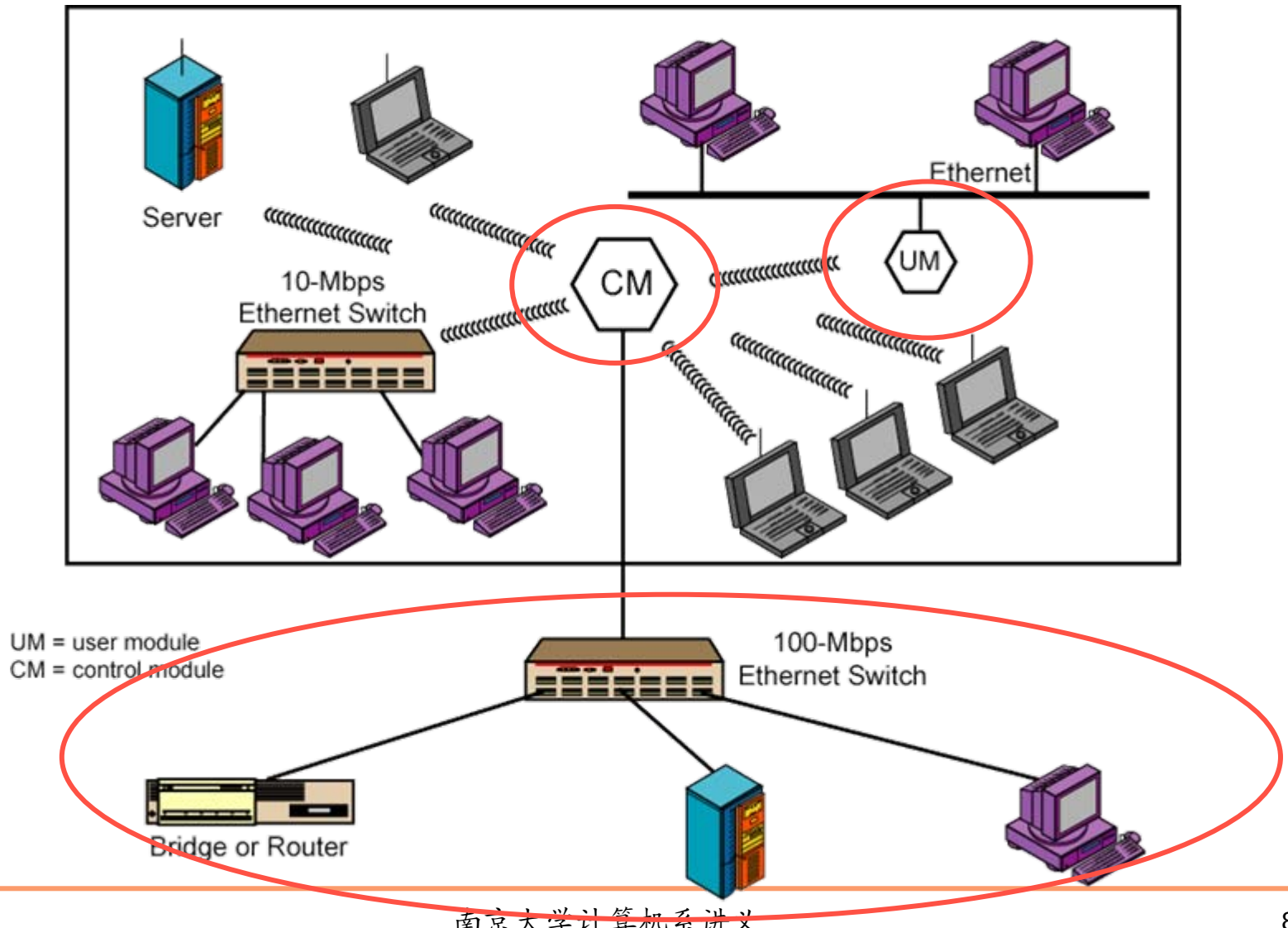
（1）LAN Extension (1)

- Main consideration
  - Saves installation of LAN cabling
  - Eases relocation and other modifications to network structure
- However, increasing reliance on twisted pair cabling for LANs
  - Most older buildings already wired with *Cat. 3 UTP*
  - Newer buildings are pre-wired with *Cat. 5 UTP*
- Wireless LAN to replace wired LANs has not happened

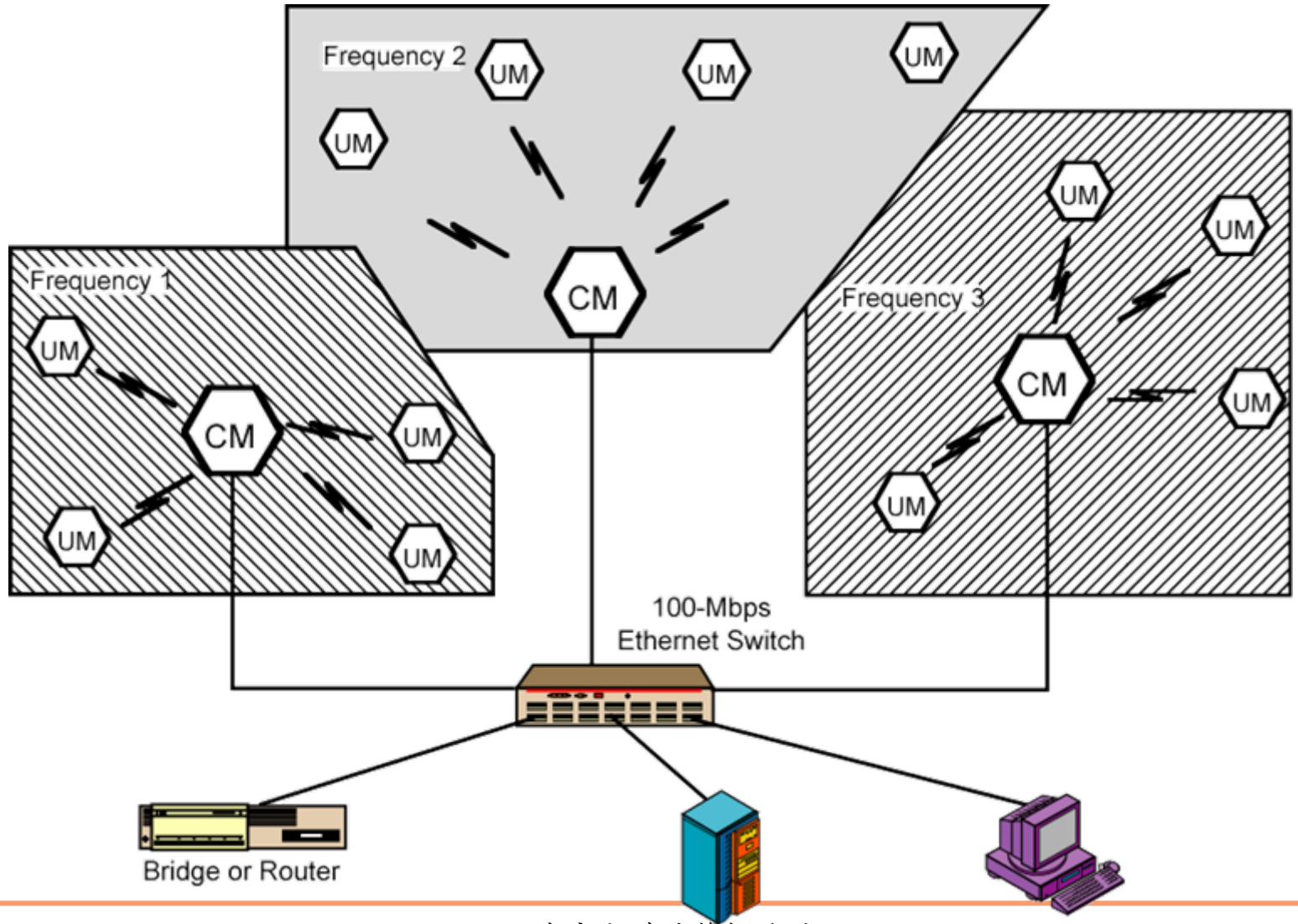
（1） LAN Extension (2)

- In some environments, wireless LAN is better
  - Buildings with large open areas, e.g.
    - Manufacturing plants, stock exchange trading floors, warehouses
  - Historical buildings
  - Small offices where wired LANs not economical
- May works with wired LAN
  - Servers and stationary workstations

Single Cell Wireless LAN Configuration



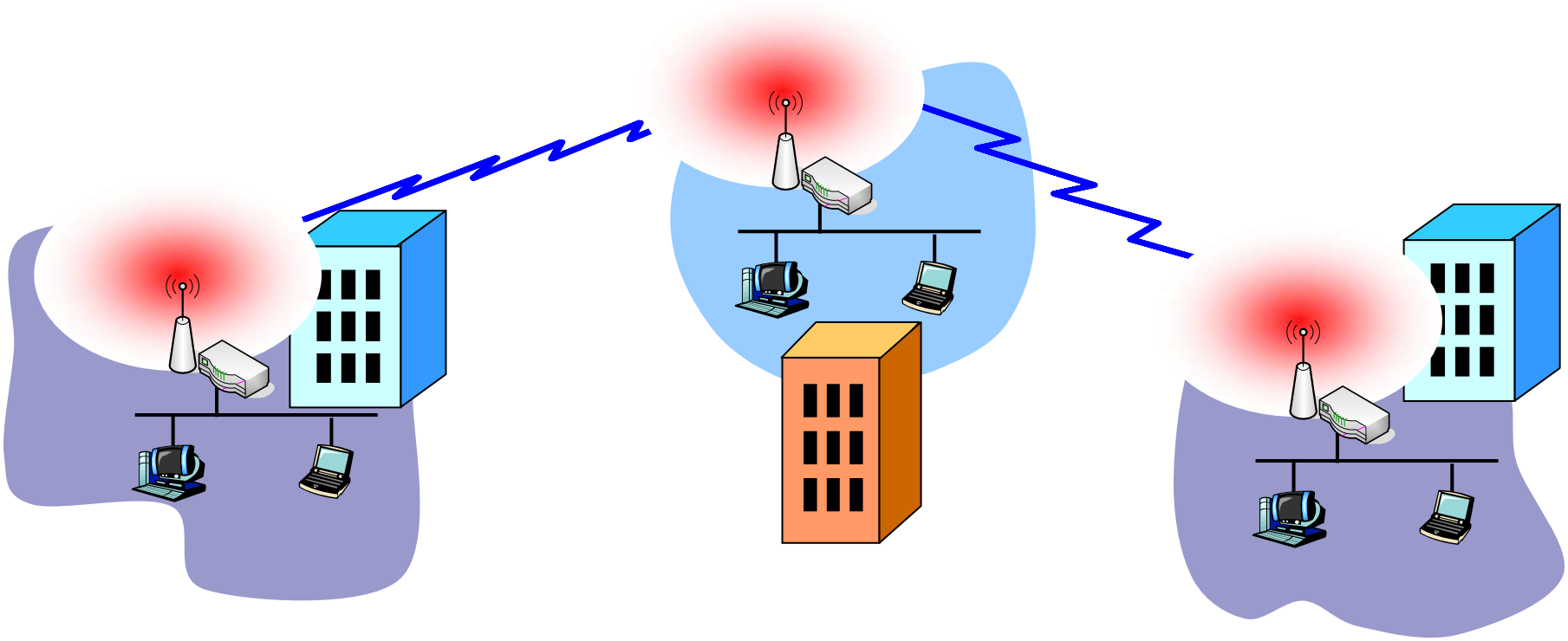
Multi-Cell Wireless LAN Configuration



（2）Cross-Building Interconnect

- Connect LANs in nearby buildings
- Point-to-point wireless link
- Connect bridges or routers
- Not a LAN per se
  - Usual to include this application under heading of wireless LAN

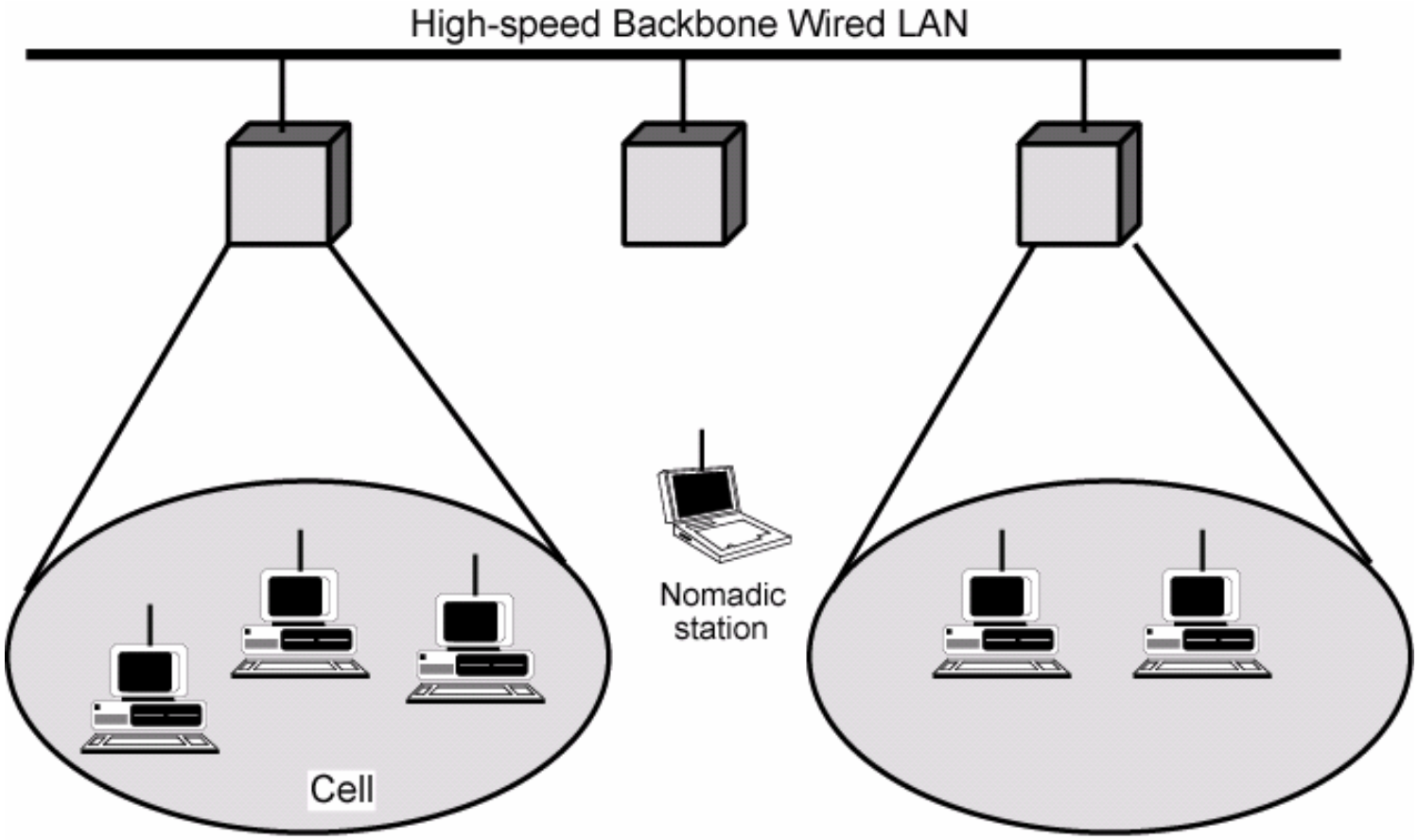
（2） Cross-Building Interconnect



（3）Nomadic Access

- Link between LAN hub and mobile data terminal
  - Laptop, notepad computer, PDA (Personal Digital Assistant)
  - Enable employee returning from trip to transfer data from portable computer to server
- Also useful in extended environment such as campus or cluster of buildings
  - Users move around with portable computers
  - May wish access to servers on wired LAN

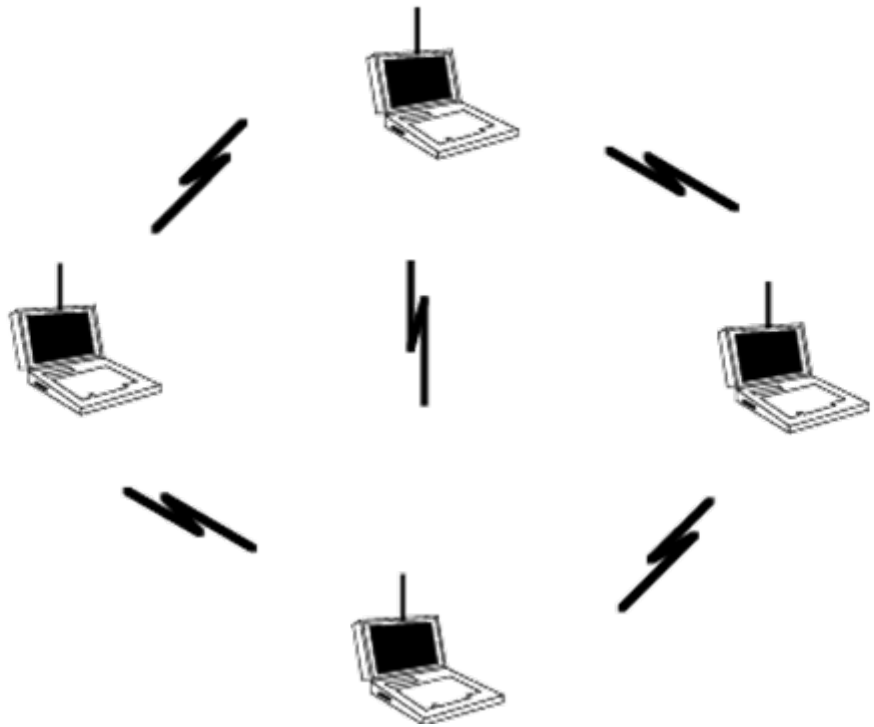
（3） Nomadic Access



（4）Ad Hoc LAN

- Peer-to-peer network
- Set up temporarily to meet some immediate need, e.g.
  - Group of employees, each with laptop or palmtop, in business or classroom meeting
- Network only for duration of meeting

（4）Add Hoc LAN



17.1.2 Wireless LAN Requirements (1)

- Same as any LAN
  - High capacity, short distances, full connectivity, broadcast capability
- Throughput
  - Efficient use of wireless medium
- Number of nodes
  - Hundreds of nodes across multiple cells
- Connection to backbone LAN
  - Use control modules to connect to different LANs
- Service area
  - 100 to 300 m
- Dynamic configuration
  - Addition, deletion, and relocation of end systems without disruption to users

17.1.2 Wireless LAN Requirements (2)

- Low power consumption
  - Need long battery life on mobile stations
  - Mustn't require nodes to monitor access points or frequent handshakes
- Transmission robustness and security
  - Interference prone and easily eavesdropped
- Collocated network operation
  - Two or more wireless LANs in same area
- License-free operation
- Handoff / Roaming
  - Move from one cell to another

17.2 Wireless Technology

- Infrared (IR) LANs
  - IR light does not penetrate opaque walls
  - Individual cell of an IR LAN limited to a single room
- Spread spectrum LANs
  - Mostly operate in ISM (industrial, scientific, and medical) bands
  - No Federal Communications Commission (FCC) licensing is required in USA
- Narrowband microwave
  - Microwave frequencies but not use spread spectrum
  - Some require FCC licensing

Infrared LANs – Features (1)

- Infrared shares some properties of visible light
  - Diffusely reflected by light-colored objects
    - Use ceiling reflection to cover entire room
  - Does not penetrate walls or other opaque objects
    - More easily secured against eavesdropping than microwave
    - Separate installation in every room without interference
- Spectrum virtually unlimited
  - Infrared spectrum is unregulated worldwide
  - Can reach extremely high data rates

Infrared LANs – Features (2)

- Inexpensive and simple
  - Uses intensity modulation, so receivers need to detect only amplitude
- Disturbed by background radiation
  - Sunlight, indoor lighting
  - Noise, requiring higher power and limiting range
  - But power limited by concerns of eye safety and power consumption

Infrared LANs – Transmission Techniques (1)

- Directed-beam IR
  - Point-to-point links
  - Range depends on power and focusing
    - Can be kilometers
  - Indoor use to set up token ring LAN
    - IR transceivers positioned so that data circulate in a ring
  - Outdoor use for building interconnect within line of sight

Infrared LANs – Transmission Techniques (2)

- Omnidirectional
  - Single base station within line of sight of all other stations
    - Typically, mounted on ceiling
  - Acts as a multi-port repeater
  - Other transceivers use directional beam aimed at central unit
- Diffused configuration
  - Transmitters are focused and aimed at diffusely reflecting ceiling

Spread Spectrum LANs – Hub Configuration

- Usually use multiple-cell arrangement
  - Adjacent cells use different center frequencies
- Hub is typically mounted on ceiling
  - Connected to wired LAN
  - Connect to stations attached to wired LAN and in other cells
  - May also control access
    - IEEE 802.11 point coordination function
  - May also act as multiport repeater
    - Stations transmit to hub and receive from hub
  - Stations may broadcast using an omnidirectional antenna
    - Logical bus configuration
- Hub may do automatic handoff
  - Weakening signal, hand off

Spread Spectrum LANs – Peer-to-Peer Configuration

- No hub
- MAC algorithm such as *CSMA* used to control access
- For ad hoc LANs

Spread Spectrum LANs – Transmission Issues (1)

- Licensing regulations differ from one country to another
- USA FCC authorized two unlicensed applications within the ISM band
  - Spread spectrum: up to 1 watt
  - Very low power systems: up to 0.5 watts
- Other unlicensed band for spread spectrum in USA
  - 902 ~ 928 MHz (915 MHz band)
  - 2.4 ~ 2.4835 GHz (2.4 GHz band)
  - 5.725 ~ 5.825 GHz (5.8 GHz band)
  - 2.4 GHz also in Europe and Japan
  - Higher frequency means higher potential bandwidth

Spread Spectrum LANs – Transmission Issues (2)

- Interference
  - Devices at 900 MHz: cordless telephones, wireless microphones, and amateur radio
  - Fewer devices at 2.4 GHz, e.g. microwave oven
  - Little competition at 5.8 GHz
  - Higher frequency band, more expensive equipment

Narrow Band Microwave LANs

- Just wide enough to accommodate signal
- Until recently, all products used licensed band

Licensed Narrowband RF

- Microwave frequencies licensed within specific geographic areas to avoid interference
  - Usable for voice, data, and video
  - Per radium 28 km, can contain 5 licenses, each covering 2 frequencies
  - Motorola holds 600 licenses (1200 frequencies) in the 18-GHz range
  - Cover all metropolitan areas with populations of 30,000 or more in USA
- Use cell configuration
  - Adjacent cells use non-overlapping frequency bands
- Motorola controls frequency band
  - Can assure nearby independent LANs do not interfere
- All transmissions are encrypted
- Licensed narrowband LAN guarantees interference-free communication
  - License holder has legal right to interference-free data channel

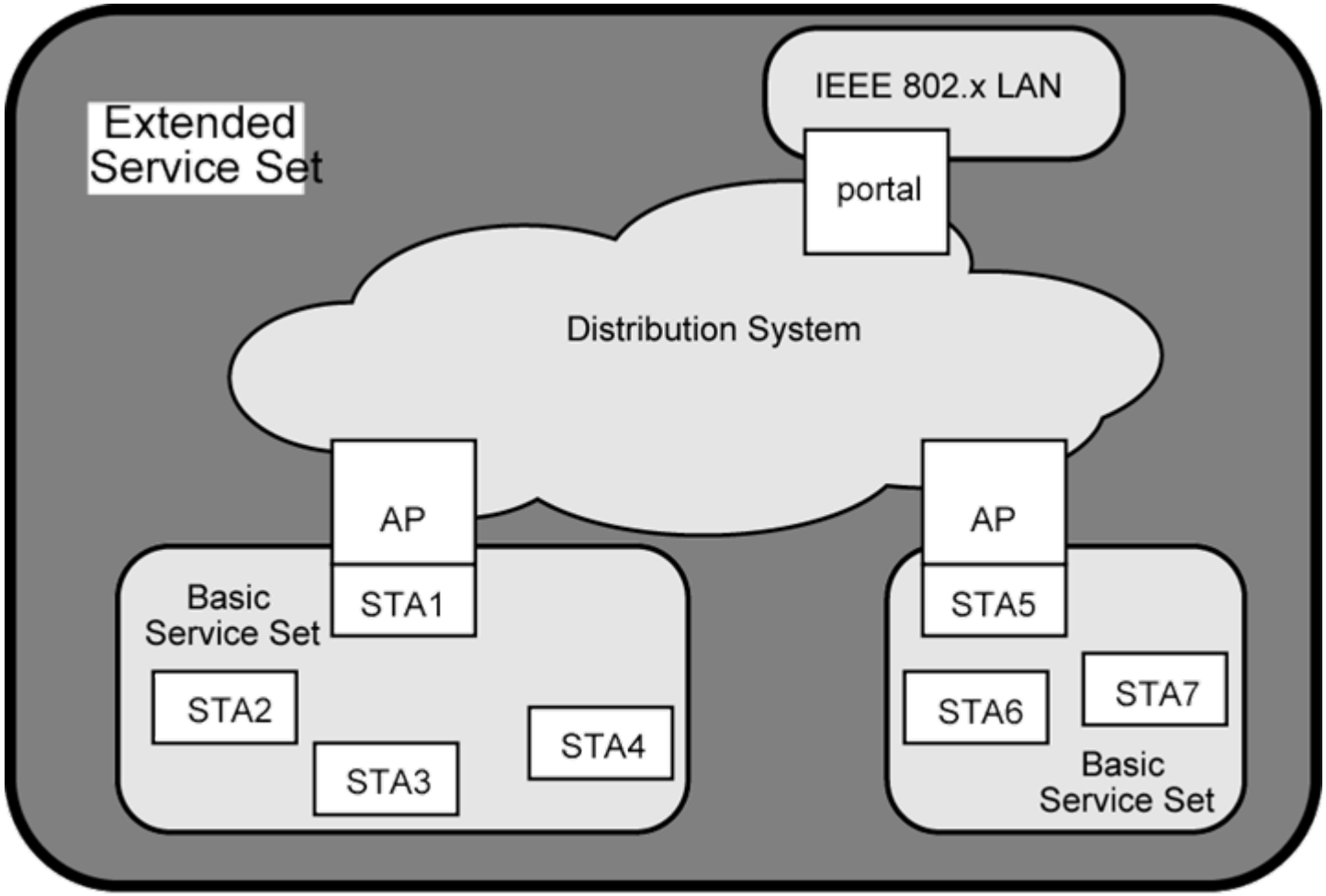
Unlicensed Narrowband RF

- 1995, RadioLAN introduced narrowband wireless LAN using unlicensed ISM spectrum
  - Used for narrowband transmission at low power, <0.5 watts
  - Use 5.8-GHz band, operates at 10 Mbps
  - 50m in semi-open office and 100m in open office
- Peer-to-peer configuration
- Elects one node as dynamic master
  - Based on location, interference, and signal strength
  - Master can change automatically as conditions change
- Includes dynamic relay function
  - Stations can act as repeater to move data between stations that are out of range of each other

17.3 802.11 Architecture and Services

- Definitions
  - Basic Service Set (BSS)
    - Group of stations that coordinate their access using a given instance of *MAC*
    - Located in a Basic Service Area (BSA)
    - Distinct collocated BSS's can coexist
  - Extended Service Set (ESS)
    - Multiple BSSs interconnected by Distribution System (DS)
    - Portals attached to DS provide access to Internet

IEEE 802.11 Architecture



STA = station
AP = access point

BSS – Basic Service Set

- MAC protocol and physical medium specification defined
- BSS is the smallest building block
  - Number of stations use same MAC protocol
  - Competing for access to same shared wireless medium
- May be isolated or connect to backbone DS through AP
  - AP functions as bridge
- MAC protocol may be distributed or controlled by central coordination function in AP
- BSS generally corresponds to cell
- DS can be a switch, wired network, or wireless network

BSS Configuration

- Simplest
  - Each station belongs to a single BSS
  - Within one BSS range only, and stay still
- Can have 2 BSSs overlap
  - Station could participate in more than one BSS
- Dynamic association between station and BSS
  - Stations may turn off, come within range, and go out of range

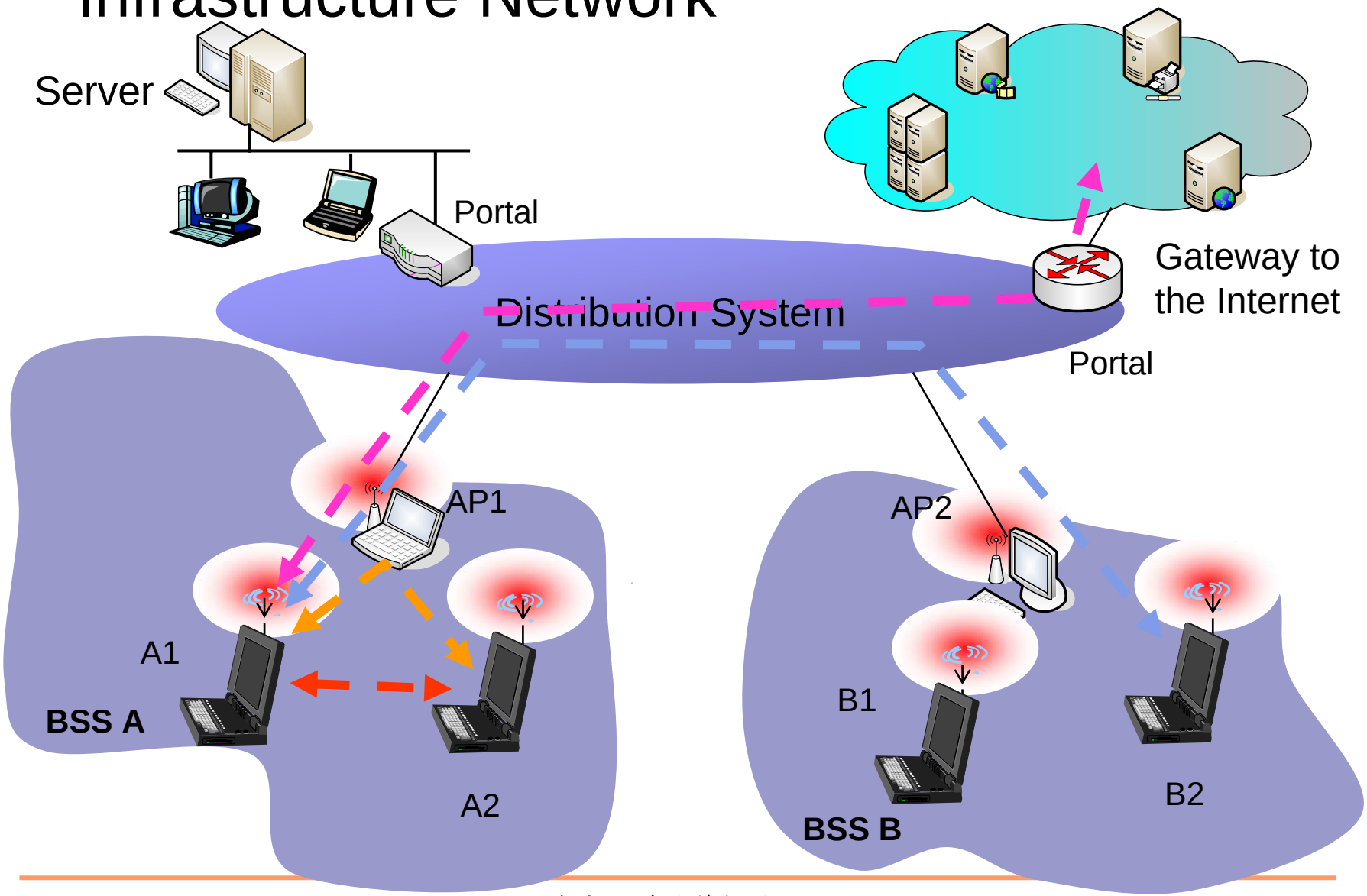
Extended Service Set (ESS)

- Two or more BSS interconnected by DS
  - Typically, DS is wired backbone but can be any network
- An ESS appears as single logical LAN to LLC

Access Point and Portal

- Logic within station that provides access to DS
  - Provides DS services in addition to acting as a station
- To integrate IEEE 802.11 architecture with wired LAN, portals are used
- Portal logic implemented in device that is both part of wired LAN and attached to DS
  - i.e. a bridge or router

Infrastructure Network



IEEE 802.11 Services

- Station services
  - 4 services implemented in every 802.11 station, including AP stations
- Distribution services
  - 5 services provided between BSSs
  - May be implemented in AP or special-purpose device
- Control access and confidentiality
  - 3 services defined
- Delivery of MAC service data units (MSDUs) between stations
  - 6 services defined, typically for LLC PDU
  - Block of data passed down from MAC user to MAC layer
  - If MSDU too large for MAC frame, fragment and transmit in series of frames

Categorizing Services

Service	Provider	Support
Authentication	Station	LAN access and security
Deauthentication	Station	LAN access and security
MSDU send/receive	Station	MSDU delivery
Privacy	Station	LAN access and security
Association	Distribution system	MSDU delivery
Disassociation	Distribution system	MSDU delivery
Reassociation	Distribution system	MSDU delivery
Distribution	Distribution system	MSDU delivery
Integration	Distribution system	MSDU delivery

Distribution of Messages Within a DS

- Distribution service used by stations to exchange MAC frames that must traverse DS
  - From station in one BSS to station in another BSS
  - Transport of frame through DS is beyond scope of 802.11
  - If stations within same BSS, distribution service logically goes through single AP of that BSS
- Integration service enables transfer of data between station on 802.11 LAN and one on integrated 802.x LAN
  - Integration refers to wired LAN physically connected to DS
  - Stations may be logically connected to 802.11 LAN via integration service
  - Integration service takes care of address translation and media conversion

Association Related Services

- Distribution service transfers MSDUs between MAC entities
- DS requires information about stations within ESS
  - Provided by association related services
  - Station must be associated before communicating
- 3 transition types based on mobility
  - No transition: Stationary or moves within range of single BSS
  - BSS transition: From one BSS to another within same ESS
    - Requires addressing capability to be able to recognize new location
  - ESS transition: From BSS in one ESS to BSS in another ESS
    - Only supported in sense that the station can move in such a way
    - Maintenance of upper-layer connections not guaranteed
    - Disruption of service likely

Station Location

- DS needs to know where destination station is
  - Identity of AP to which frame should be delivered
  - Station must maintain association with AP within current BSS
- 3 services relate to this requirement
  - Association: establishes initial association between station and AP
    - To make identity and address known
    - AP can communicate information to other APs within ESS
  - Reassociation: Transfer established association to another AP
    - Allows station to move from one BSS to another
  - Disassociation: From either station or AP that association is terminated
    - Given before station leaves ESS or shuts
    - MAC management facility protects itself against stations that disappear without notification

Authentication

- Wired LANs assume access to physical connection conveys authority to each other
  - Not a valid assumption for wireless LANs
  - Connectivity achieved by having properly tuned antenna
  - Any station within radio range of other devices can transmit and receive
- Authentication: Used to establish identity of stations to each other
  - 802.11 supports several authentication schemes
  - Range from relatively insecure handshaking to public-key encryption schemes
  - Does not mandate any particular scheme, and allows expansion
  - 802.11 requires mutually acceptable, successful authentication before association

Deauthentication and Privacy

- Deauthentication
  - Invoked whenever an existing authentication is to be terminated
- Privacy
  - Used to prevent messages being read by others
  - 802.11 provides for optional use of encryption

17.4 IEEE 802.11 Medium Access Control

- MAC layer covers 3 functional areas
  - Reliable data delivery
  - Access control
  - Security (beyond the scope)

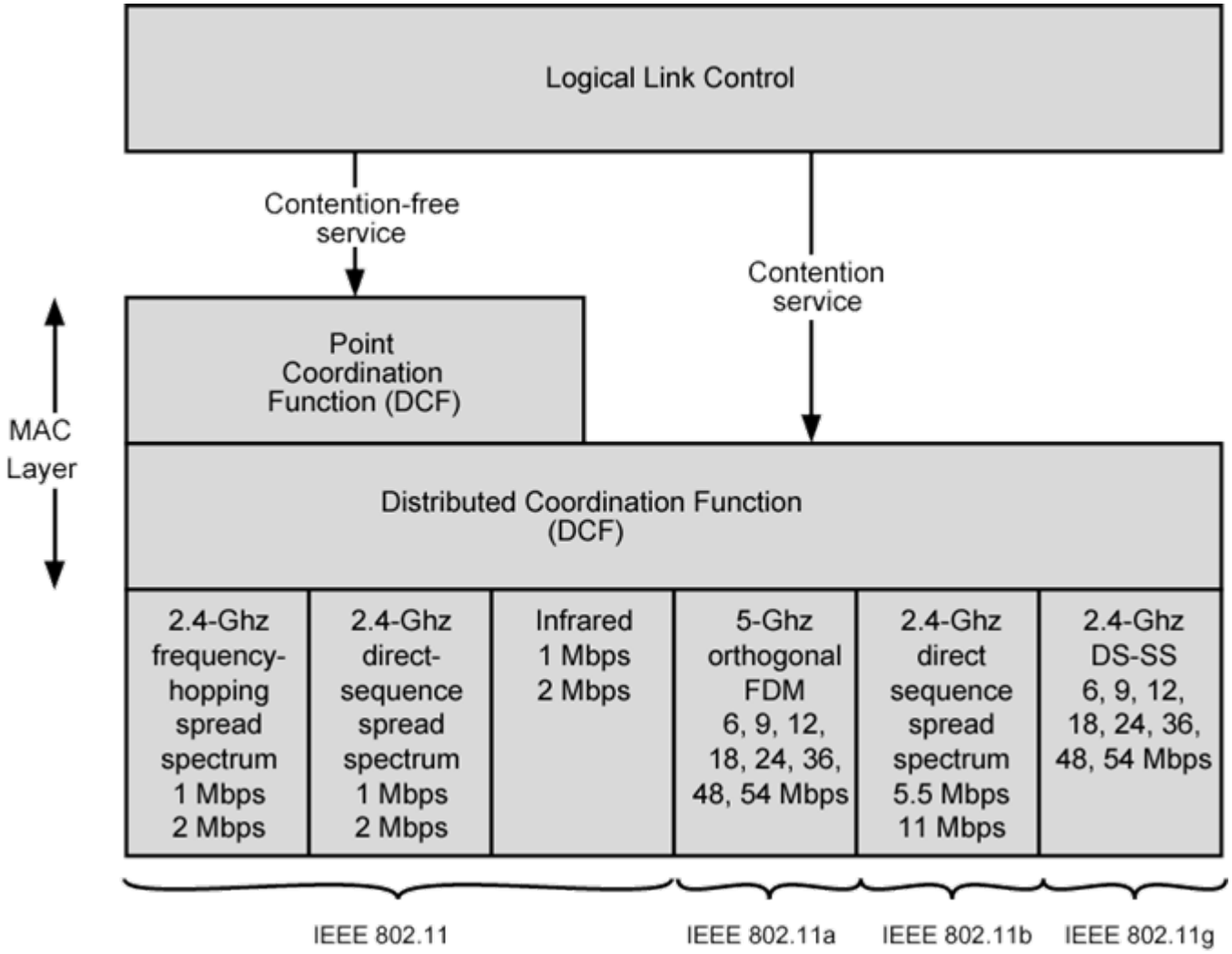
Reliable Data Delivery

- 802.11 physical and MAC layers subject to unreliability
  - Noise, interference, and other propagation effects result in loss of frames
  - Even with error-correction codes, frames may not be successfully received
- Can be dealt with at a higher layer, such as TCP
  - However, retransmission timers at higher layers are typically order of seconds
  - More efficient to deal with errors at the MAC level
- 802.11 includes frame exchange protocol
  - Station receiving frame returns acknowledgment (ACK) frame
  - Exchange must be treated as atomic unit, i.e. not interrupted by any other station
  - If no ACK within defined period of time, retransmit

Media Access Control

- Distributed wireless foundation MAC (DWFMAC)
  - Distributed access control mechanism
  - Optional centralized control on top
- The lower sub-layer is distributed coordination function (DCF)
  - Contention algorithm to provide access to all traffic
  - Asynchronous traffic
- The upper is point coordination function (PCF)
  - Centralized MAC algorithm
  - Contention free
  - Built on top of DCF

IEEE 802.11 Protocol Architecture



Distributed Coordination Function

- The DCF sub-layer uses CSMA/CA
  - If station has frame to transmit, it listens to medium
  - If medium idle, station may transmit
  - Otherwise must wait until current transmission complete
- No collision detection
  - Not practical on wireless network, since range of signals varies largely
  - Transmitting station cannot distinguish incoming weak signals from noise and effects of own transmission
- DCF includes delays
  - Means inter-frame space
  - Accounts to priority scheme

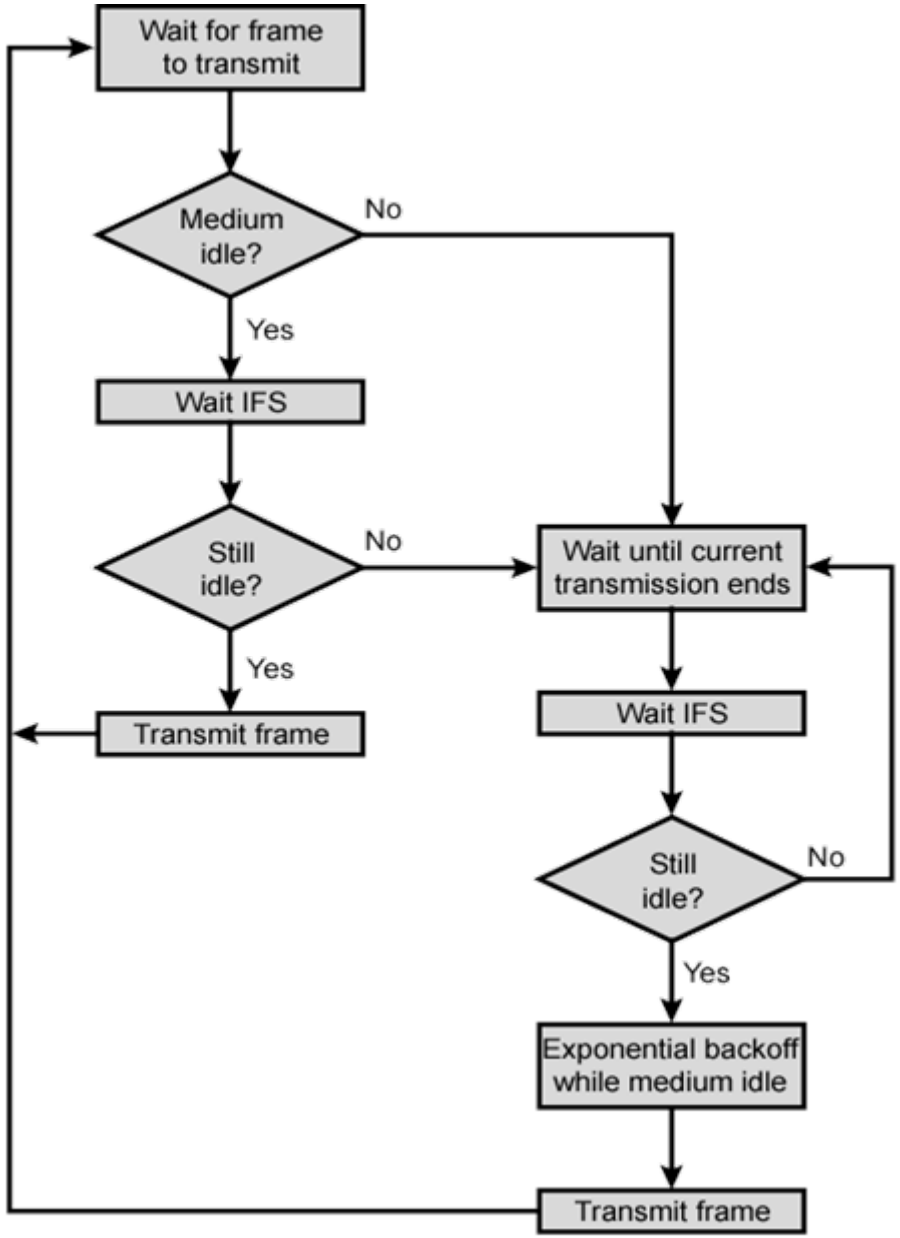
Inter-Frame Space

- Single delay known as inter-frame space (IFS)

IFS rules for CSMA

1. Station with frame senses medium
   - If idle, wait to see if remains idle for 1 IFS. If so, may transmit immediately
   - If busy (either initially or becomes busy during IFS) station defers transmission
   - Continue to monitor until current transmission is over
2. Once current transmission over, delay another IFS
   - If remains idle, backoff random time and again sense
   - If medium idle, station may transmit
   - During backoff time, if becomes busy, backoff timer is halted and resumes when medium becomes idle
3. To ensure stability, binary exponential backoff used

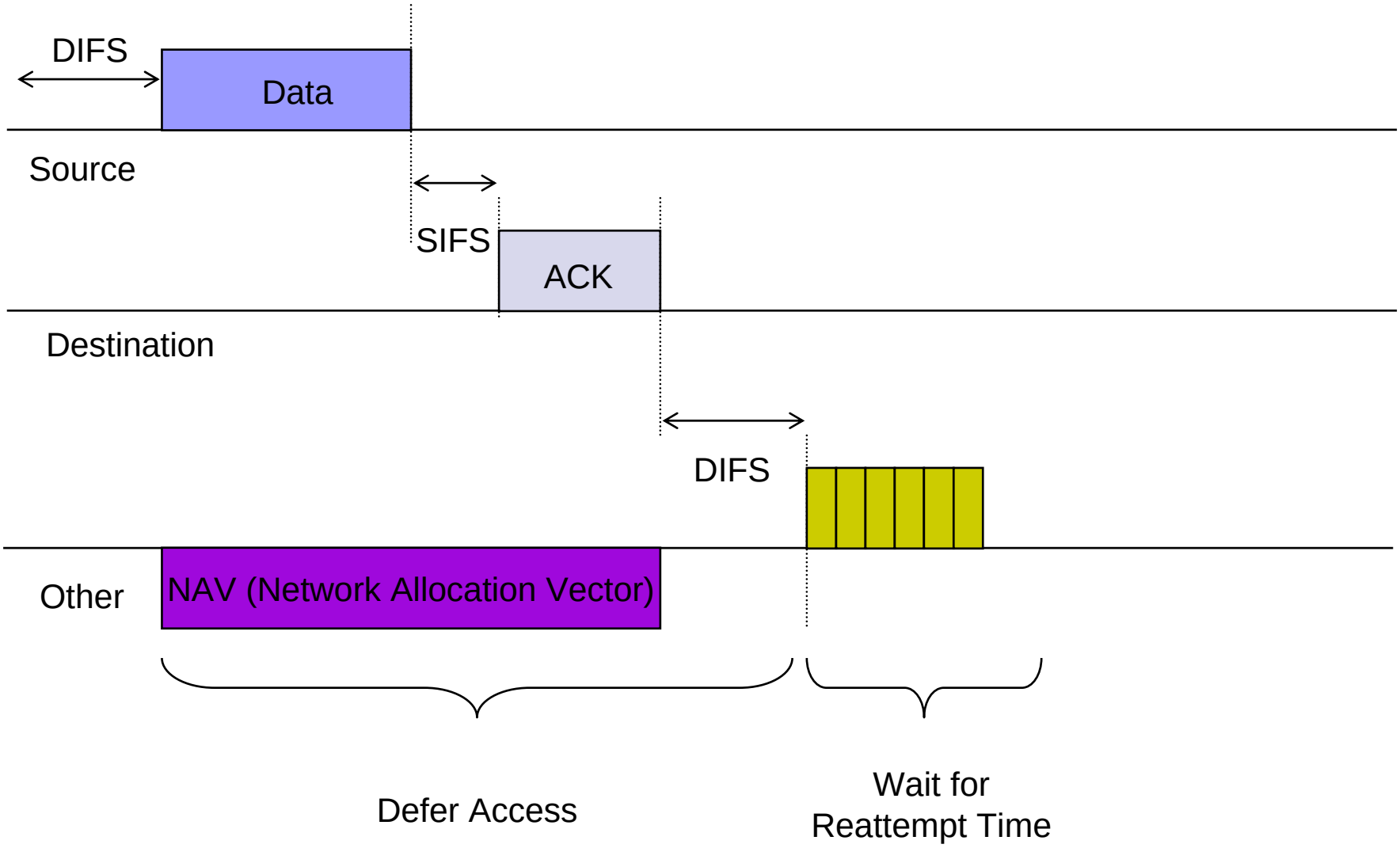
IEEE 802.11 Medium Access Control Logic



Priority

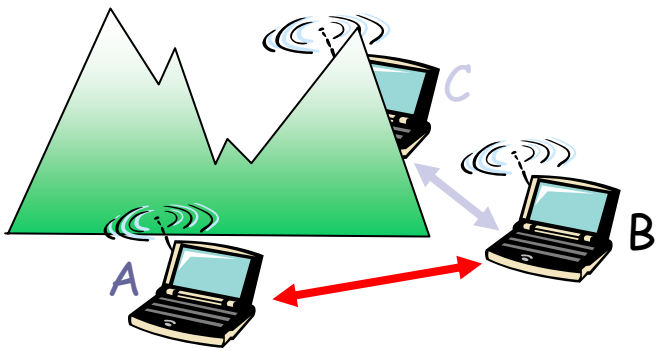
- Use 3 values for IFS
- SIFS (short IFS)
  - Shortest IFS
  - For all immediate response actions
- PIFS (point coordination function IFS)
  - Mid-length IFS
  - Used by the centralized controller in PCF scheme when issuing polls
- DIFS (distributed coordination function IFS)
  - Longest IFS
  - Used as minimum delay for asynchronous frames contending for access

Transmission of MPDU without RTS/CTS



Wireless Communication

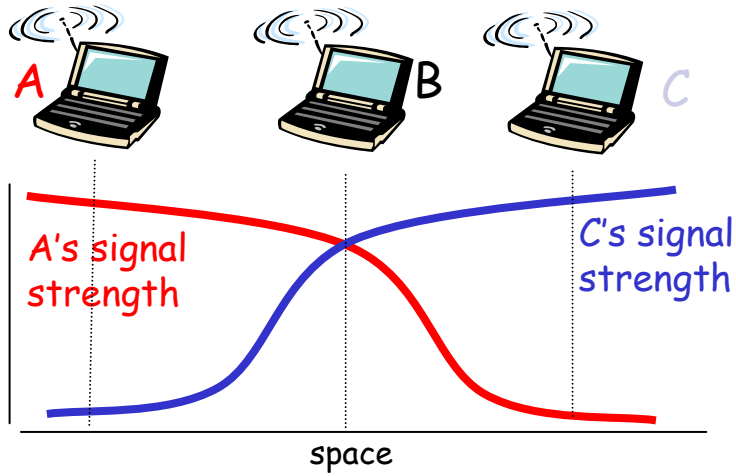
- Multiple wireless senders and receivers create additional problems (beyond multiple access)



Hidden terminal problem

- B, A hear each other
- B, C hear each other
- A, C can not hear each other

A, C unaware of their interference at B



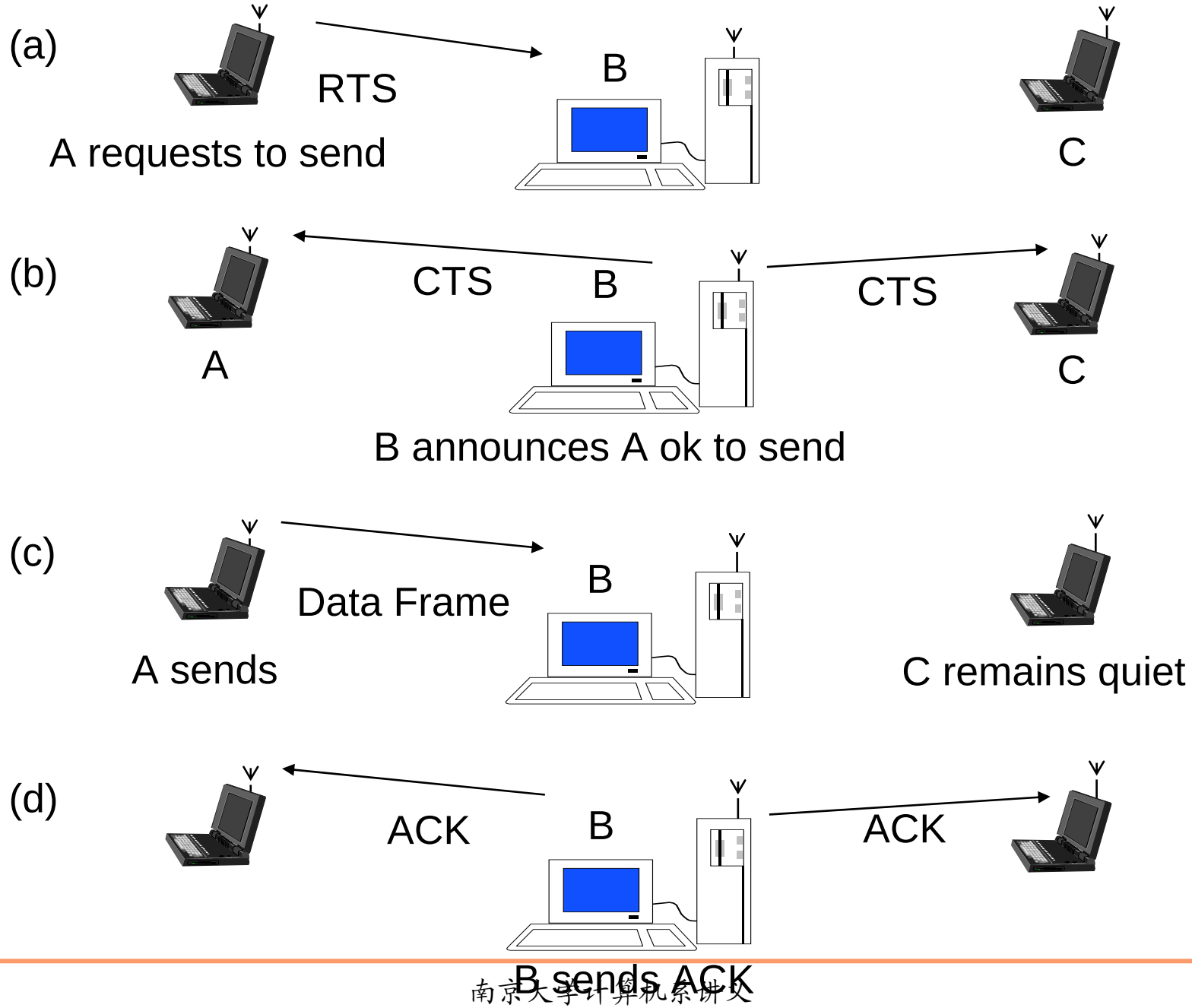
Signal fading problem

- B, A hear each other
- B, C hear each other

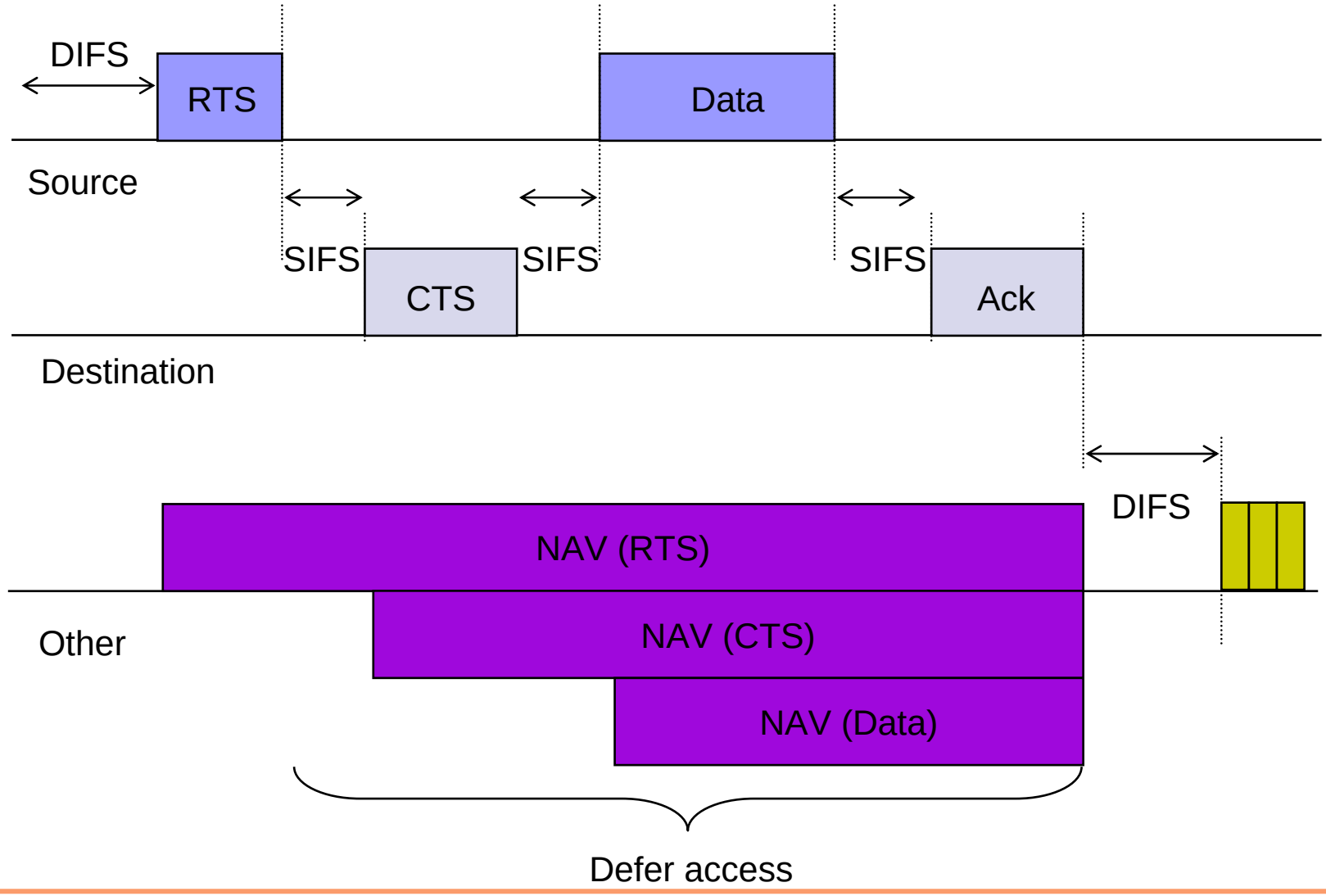
A, C can not hear each other interferring at B

4 Frame Exchange

- Basic data transfer involves exchange of 2 frames
- To further enhance reliability, 4-frame exchange may be used
  - Source issues a Request to Send (RTS) frame to destination
  - Destination responds with Clear to Send (CTS)
  - After receiving CTS, source transmits data
  - Destination responds with ACK
- Stations refrain from transmission to avoid collision
  - RTS alerts all stations within range of source that exchange is under way
  - CTS alerts all stations within range of destination
- RTS/CTS exchange is required function of MAC but may be disabled


(a)
RTS
B
A requests to send
C
(b)
CTS
B
CTS
A
C
B announces A ok to send
(c)
Data Frame
B
A sends
C remains quiet
(d)
ACK
B
ACK
B sends ACK

Transmission of MPDU with RTS/CTS



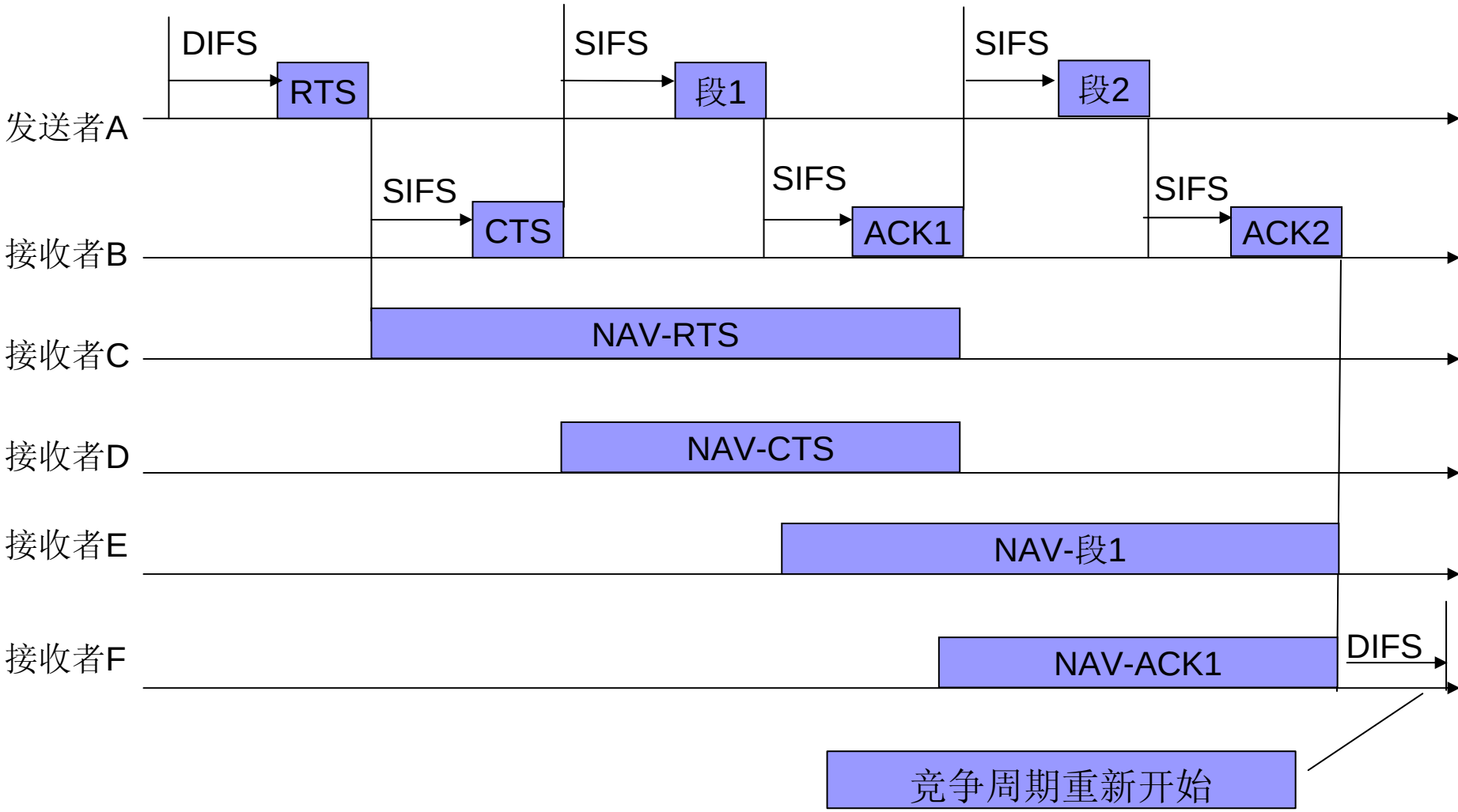
Point Coordination Function (PCF)

- Alternative access method implemented on top of DCF
- Polling by centralized polling master (point coordinator)
  - Uses PIFS (<DIFS) when issuing polls
  - Can seize medium and lock out all asynchronous traffic while it issues polls and receives responses
- Wireless network configured so number of stations with time-sensitive traffic are controlled by point coordinator
  - Point coordinator polls in round-robin to stations configured for polling
  - When poll issued, polled station may respond using SIFS
  - If point coordinator receives response, it issues another poll using PIFS
  - If no response during expected turnaround time, coordinator issues another poll
  - Remaining traffic contends for access using CSMA

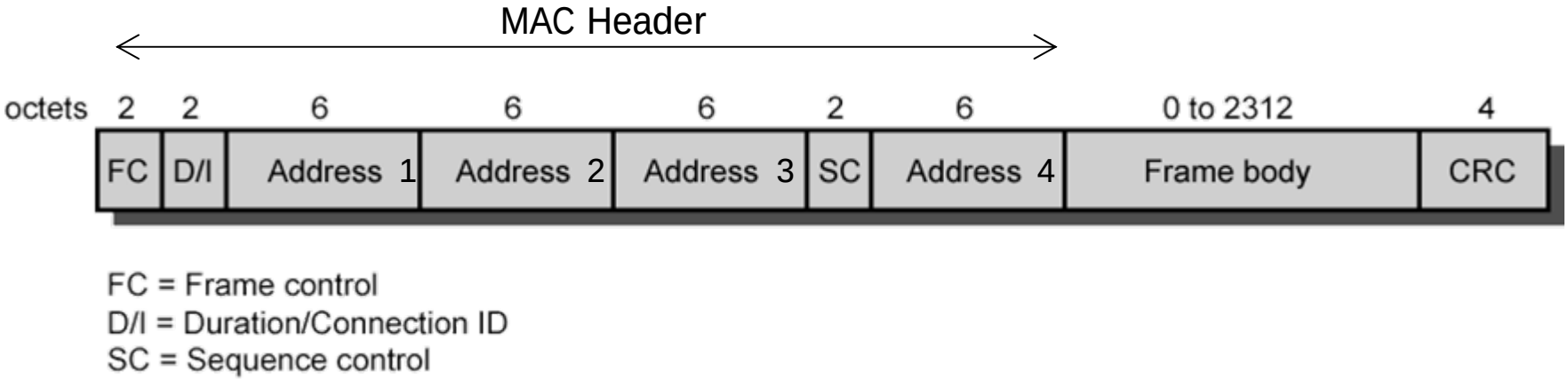
Super-frame

- Super-frame interval defined for PCF
  - During first part of super-frame interval, point coordinator polls round-robin to all stations configured for polling
  - Point coordinator then idles for remainder of super-frame
  - Allowing contention period for asynchronous access
- At beginning of super-frame, point coordinator creates a contention-free period
  - Time varies because of variable frame size issued by responding stations
  - Rest of super-frame available for contention-based access
- At end of super-frame interval, point coordinator contends for access using PIFS
  - If idle, point coordinator gains immediate access, and full super-frame period follows
  - If busy, point coordinator must wait for idle to gain access
  - Results in foreshortened super-frame period for next cycle

PCF Frame Transfer



17.4.3 IEEE 802.11 MAC Frame Format



- MAC Header: 30 octets
- Frame Body: 0~2312 octets
- CRC: CCITT-32 4 octets CRC over MAC header & frame body

Frame Types

- Management frames
- Control frames
- Data frames

Management Frames

- Manage communications between stations and APs
  - Station association & disassociation with AP
  - Authentication & deauthentication
  - Timing & synchronization

Control Frames

- Assist in reliable data delivery
- Power Save-Poll (PS-Poll)
  - Sent by any station to AP
  - Request AP transmission frame buffered for this station while station in power-saving mode
- Request to Send (RTS)
- Clear to Send (CTS)
- Acknowledgment (ACK)
- Contention-Free-End (CF-End)
  - Announces end of contention-free period part of PCF
- CF-End + CF-Ack:
  - Acknowledges CF-End
  - Ends contention-free period and releases stations from associated restrictions

Data Frames – Data Carrying

- 8 data frame subtypes, in two groups

First 4 carry upper-level data from source station to destination station

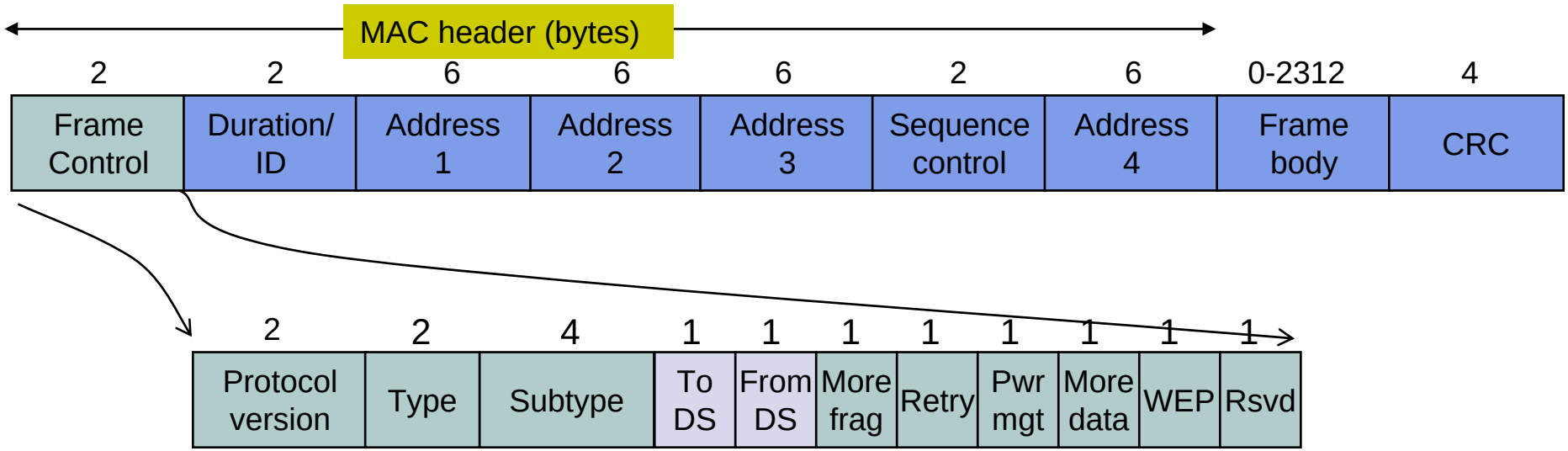
- Data
  - Simplest data frame
  - May be used in contention or contention-free period
- Data + CF-Ack
  - Only sent during contention-free period
  - Carries data and acknowledges previously received data
- Data + CF-Poll
  - Used by point coordinator to deliver data
  - Also to request station send data frame it may have buffered
- Data + CF-Ack + CF-Poll
  - Combines Data + CF-Ack and Data + CF-Poll

Data Frames – No Data Carrying

Last 4 data frames do not carry user data

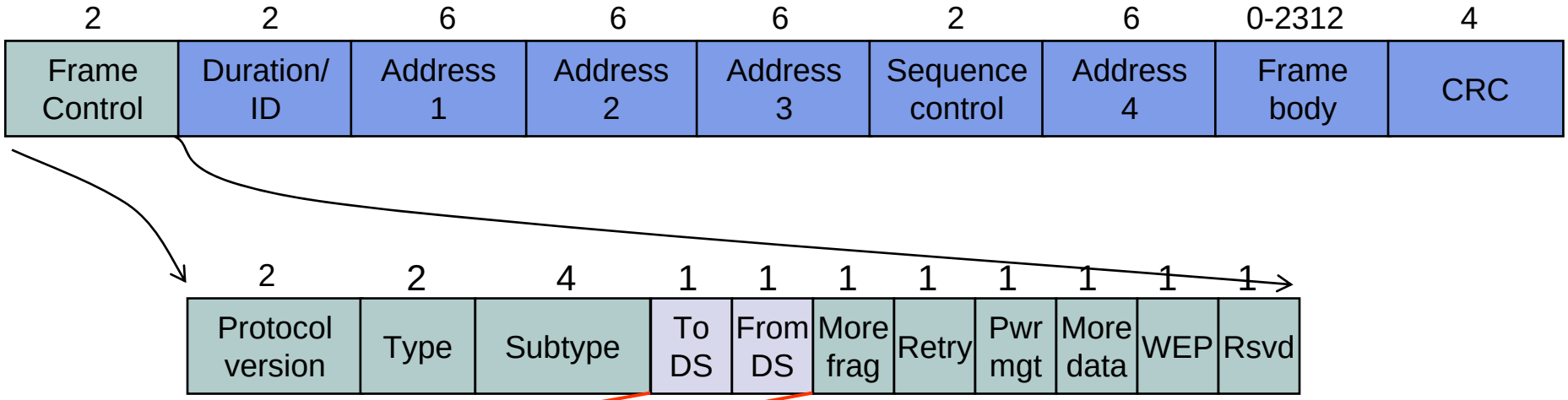
- Null Function
  - Carries no data, polls, or acknowledgments
  - Carries power management bit in frame control field to AP
  - Indicates station is changing to low-power state
- Other 3 frames
  - CF-Ack, CF-Poll, CF-Ack + CF-Poll
  - Same as corresponding frame in preceding list but without data

Frame Control Field (1)



- Protocol version = 0
- Type: Management (00), Control (01), Data (10)
- Subtype within frame type, e.g.
  - Type=00, subtype=association; Type=01, subtype=ACK
- MoreFrag=1 if another fragment of MSDU to follow

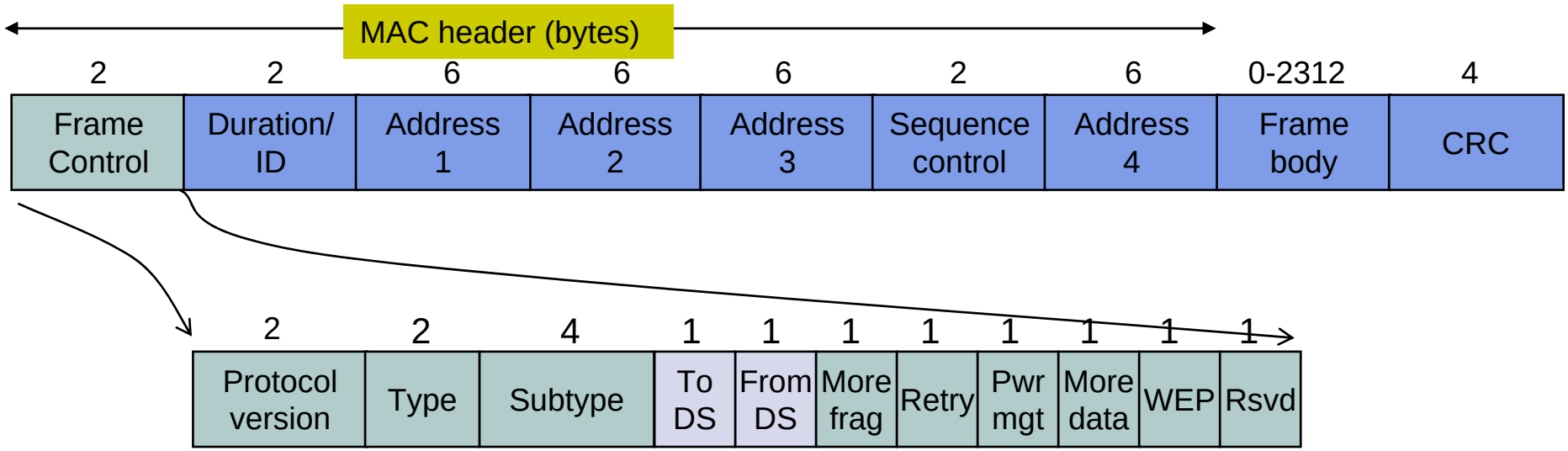
Frame Control Field (2)



To DS	From DS	Address 1	Address 2	Address 3	Address 4	Meaning
0	0	Destination address	Source address	BSS ID	N/A	Data frame from station to station within a BSS
0	1	Destination address	BSS ID	Source address	N/A	Data frame exiting the DS
1	0	BSS ID	Source address	Destination address	N/A	Data frame destined for the DS
1	1	Receiver address	Transmitter address	Destination address	Source address	WDS frame being distributed from AP to AP

To DS = 1 if frame goes to DS; From DS = 1 if frame exiting DS

Frame Control Field (3)



- Retry =1 if mgmt/control frame is a retransmission
- Power Management used to put station in/out of sleep mode
- More Data =1 to tell station in power-save mode more data buffered for it at AP
- WEP =1 if frame body encrypted

Other MAC Frame Fields (1)

- Duration/Connection ID
  - If used as duration, indicates time (in μs) channel will be allocated for successful transmission of MAC frame
  - In some management frames, contains association or connection identifier
- Addresses
  - Number and meaning of address fields depend on context
  - Types include source, destination, transmitting station, and receiving station

Other MAC Frame Fields (2)

- Sequence Control
  - 4-bit fragment number subfield
    - For fragmentation and reassembly
  - 12-bit sequence number
  - Number frames between given transmitter and receiver
- Frame Body
  - MSDU, or a fragment of MSDU
  - LLC PDU or MAC control information
- Frame Check Sequence
  - 32-bit cyclic redundancy check

17.5 802.11 Physical Layer

- Issued in four stages
- First part in 1997
  - IEEE 802.11, includes MAC layer and 3 physical layer specifications
  - Two in 2.4-GHz band and one infrared
  - All operating at 1 and 2 Mbps
- Two additional parts in 1999
  - IEEE 802.11a, 5-GHz band up to 54 Mbps
  - IEEE 802.11b, 2.4-GHz band at 5.5 and 11 Mbps
- Most recent in 2002
  - IEEE 802.g extends IEEE 802.11b to higher data rates

802.11 Physical Layer – DSSS

- Direct-sequence spread spectrum
- 2.4 GHz ISM band at 1 Mbps and 2 Mbps
  - Up to 7 channels can be used, each 1 Mbps or 2 Mbps
  - Each channel has bandwidth 5 MHz
  - Encoding scheme: DBPSK for 1 Mbps and DQPSK for 2 Mbps
- Depends on bandwidth allocated by various national regulations
  - 13 in most European countries
  - 1 in Japan

802.11 Physical Layer – FHSS

- Frequency-hopping spread spectrum
  - 2.4 GHz ISM band, uses multiple channels, each has bandwidth 1 MHz
  - Signal hopping from one channel to another based on a pseudo-noise sequence
  - Minimum 23 channels in Japan, 70 in USA
- Hopping scheme adjustable, e.g.
  - Minimum hop rate for USA is 2.5 hops per second
  - Minimum hop distance: 6 MHz in North America and most of Europe, 5 MHz in Japan
- 2-level Gaussian FSK modulation for 1 Mbps
  - Bits encoded as deviations from current carrier frequency
- For 2 Mbps, 4-level GFSK used
  - 4 different deviations from center frequency define four 2-bits combinations

802.11 Physical Layer – Infrared

- Omnidirectional defined, range up to 20 m
- Intensity modulation
  - Presence of signal corresponds to 1
- 1 Mbps uses 16-PPM (pulse position modulation)
  - Each group of 4 data bits mapped into one of 16-PPM symbols
  - Each 16-PPM symbol is a string of 16-bits
  - Each 16-bits string consists of fifteen 0s and one binary 1
- For 2 Mbps, 4-PPM used
  - Each group of 2 data bits mapped into one of four 4-bits strings
  - Each 4-bits string consists of three 0s and one binary 1

802.11a – OFDM

- 5-GHz band, uses orthogonal frequency division multiplexing
  - Not spread spectrum, also called multi-carrier modulation
  - Multiple carrier signals at different frequencies
- Some bits on each channel
  - Similar to FDM but all sub-channels dedicated to single source
- Data rates: 6, 9, 12, 18, 24, 36, 48, and 54 Mbps
- Up to 52 sub-carriers modulated using BPSK, QPSK, 16-QAM, or 64-QAM
  - Depending on rate
  - Sub-carrier frequency spacing 0.3125 MHz
  - Convolutional code at rate of 1/2, 2/3, or 3/4 provides forward error correction

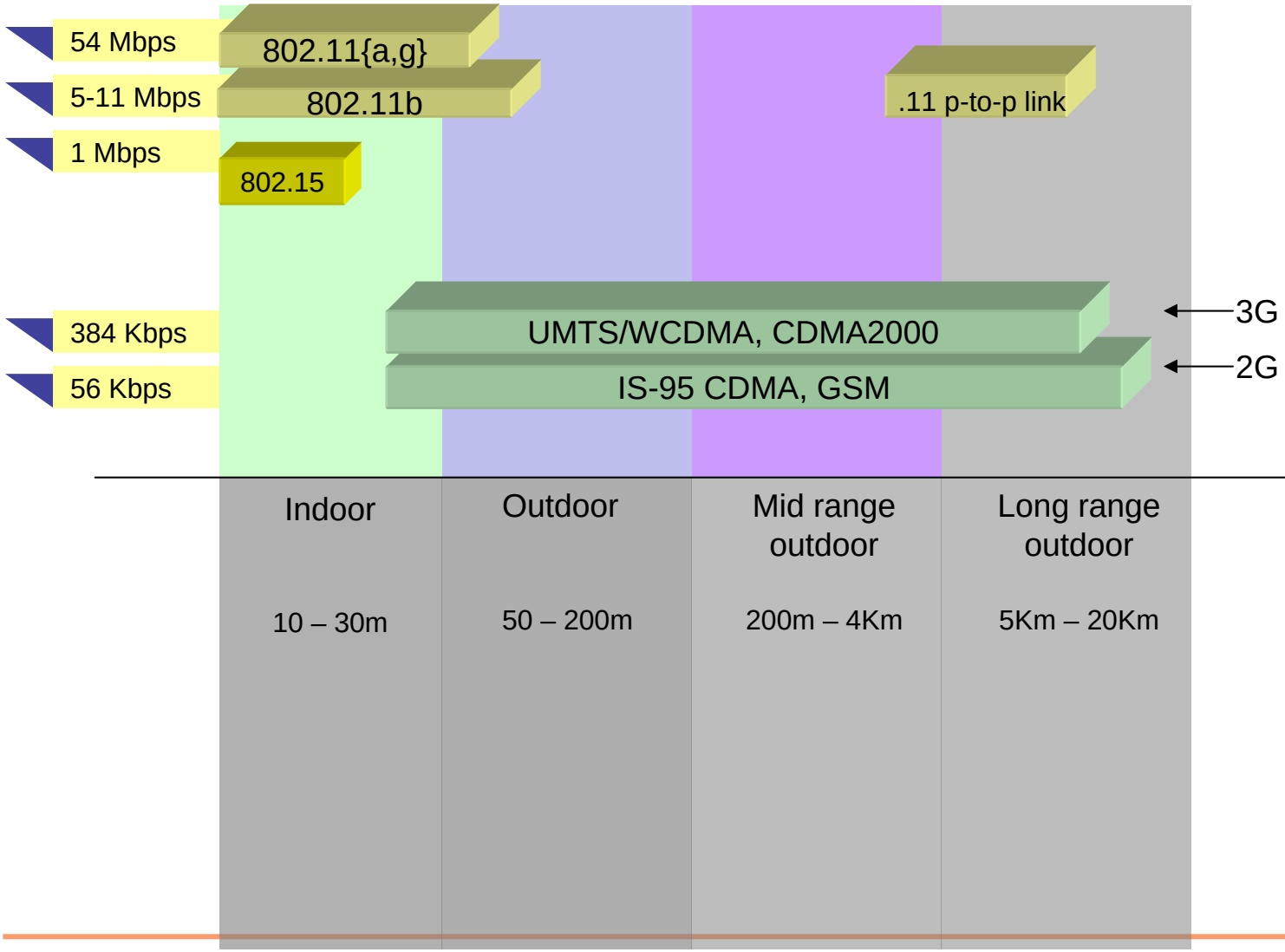
802.11b

- Extension of 802.11 DSSS scheme
  - 5.5 and 11 Mbps
- Chipping rate 11 MHz
  - Same as original DSSS scheme, same occupied bandwidth
  - Complementary code keying (CCK) modulation to achieve higher data rate
- CCK modulation
  - Input data treated in blocks of 8 bits at 1.375 MHz
    - 8 bits/symbol × 1.375 MHz = 11 Mbps
  - 6 of these bits mapped into one of 64 code sequences
  - Output of mapping, plus 2 additional bits, forms input to QPSK modulator

802.11g

- Higher-speed extension to 802.11b
- Combines physical layer encoding techniques used in 802.11a & 802.11b
- Provides service at a variety of data rates

Characteristics of 802.11 Physical Media



Summary

- Wireless LAN Overview
  - The Applications: LAN Extension, Cross-Building Interconnect, Nomadic Access, Ad Hoc Networking
  - Wireless LAN Requirements
- Wireless Technology
  - Infrared (IR) LANs, Spread spectrum LANs, Narrowband microwave
- IEEE 802.11 Architecture
  - Basic Service Set & Extended Service Set, Access Point, Distribution System
  - 802.11 Services
- IEEE 802.11 MAC
  - Reliable Data Delivery, Media Access Control
  - DCF & PCF, SIFS & PIFS & DIFS; MAC Frame Format
- IEEE 802.11 Physical Layer
  - IEEE 802.11, 802.11a, 802.11b, 802.11g; Physical Media Characteristics