ETSF05 – Internet Protocols

PPP
TDM
Synchronous Optical Networks
xDSL
WLAN

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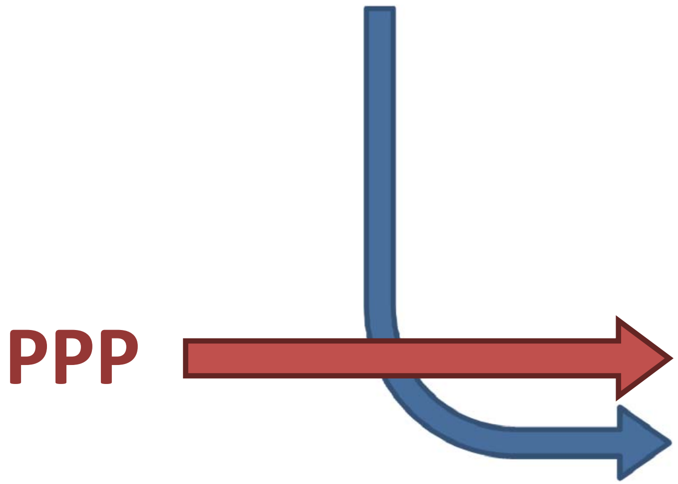
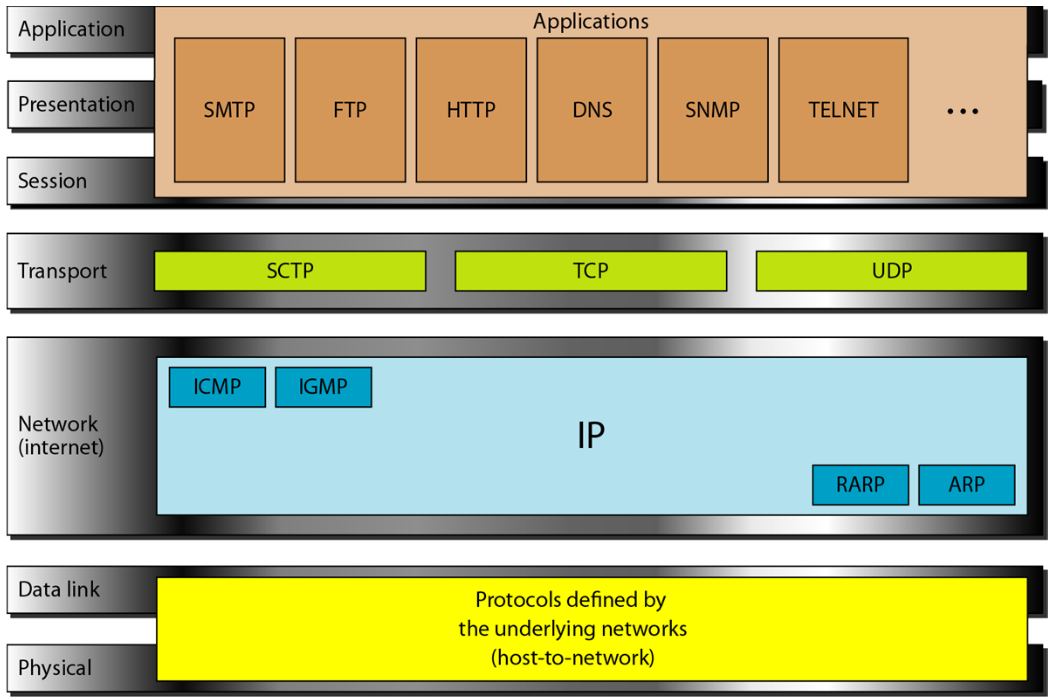
Routing

- Konsten att bygga least-cost trees
    - Från sändare till mottagare
    - Från varje nod till varje annan nod
- Tre principer
    - Distance Vector
    - Link State
    - Path Vector
        - Policy-based routing

Point-to-point protocol (PPP)

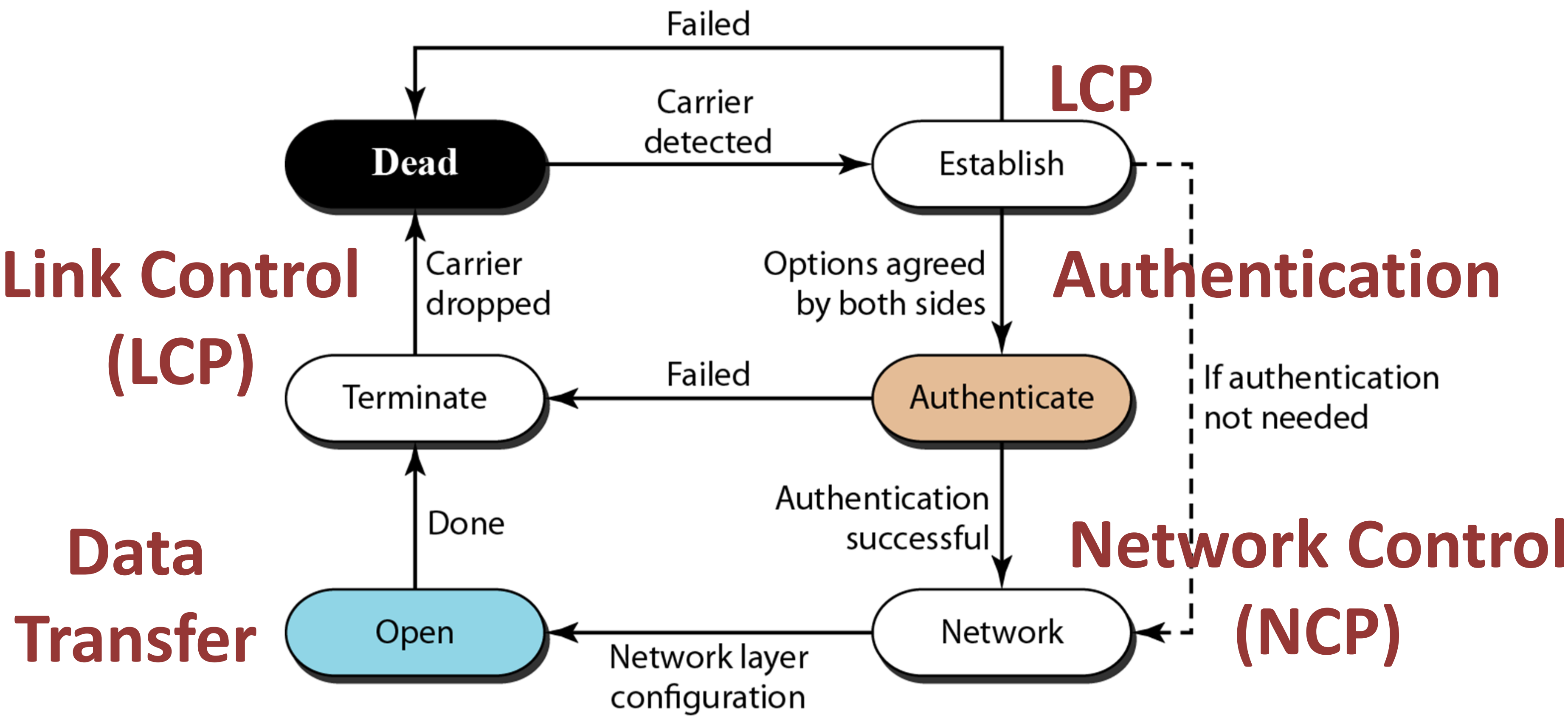
- Direct connection between two nodes
  - Internet access
  - Home user to ISP
    - Telephone line
    - Cable TV





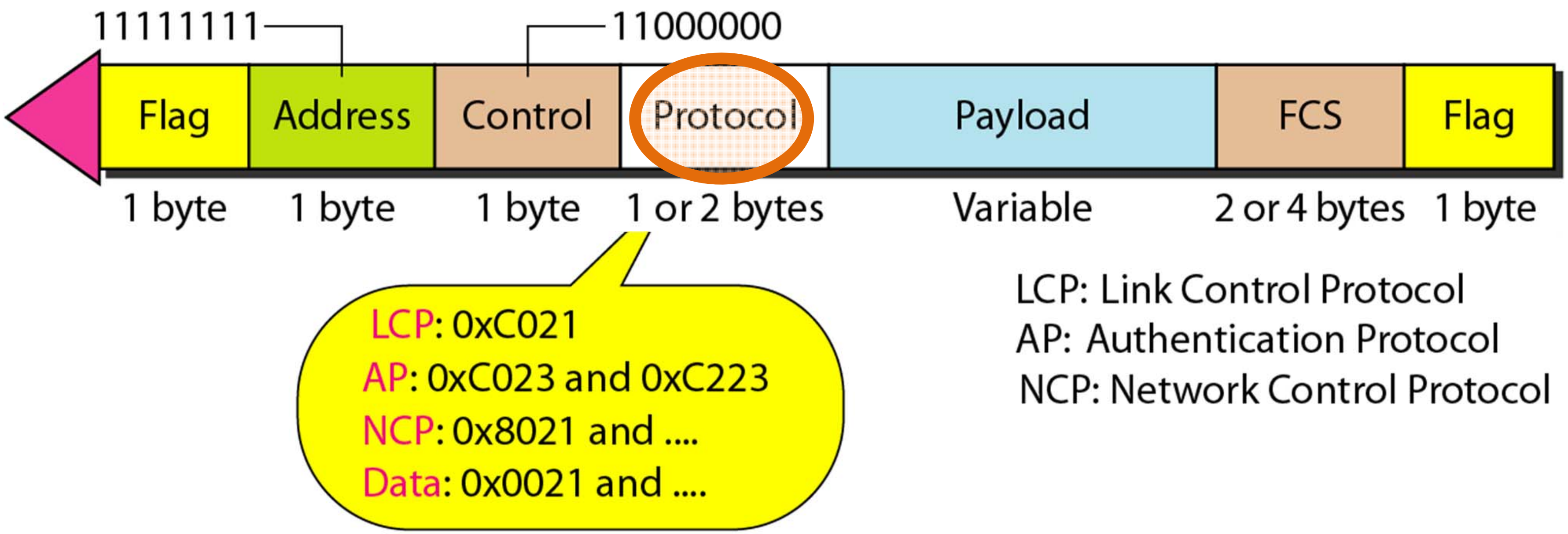
State transitions in PPP

- We need more protocols



PPP frame format

- Support for several (sub)protocols
- Address & control not used
- Maximum payload 1500 bytes

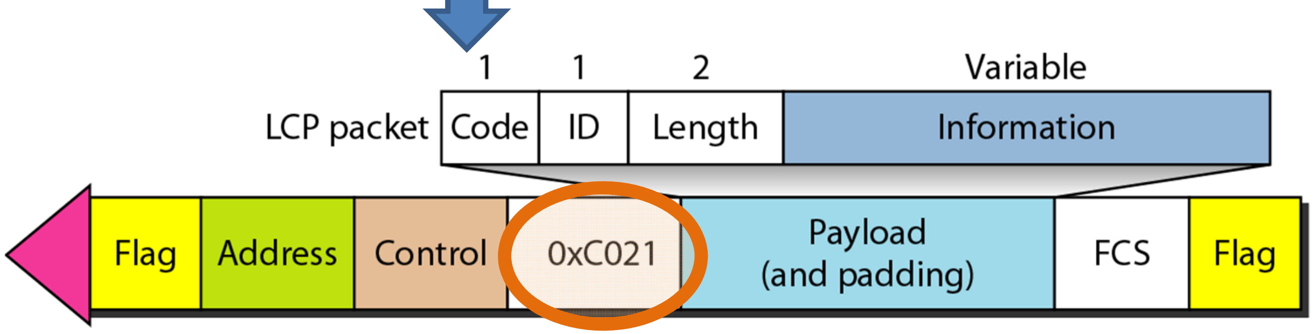


Link control protocol (LCP)

- Establish
- Configure
- Terminate

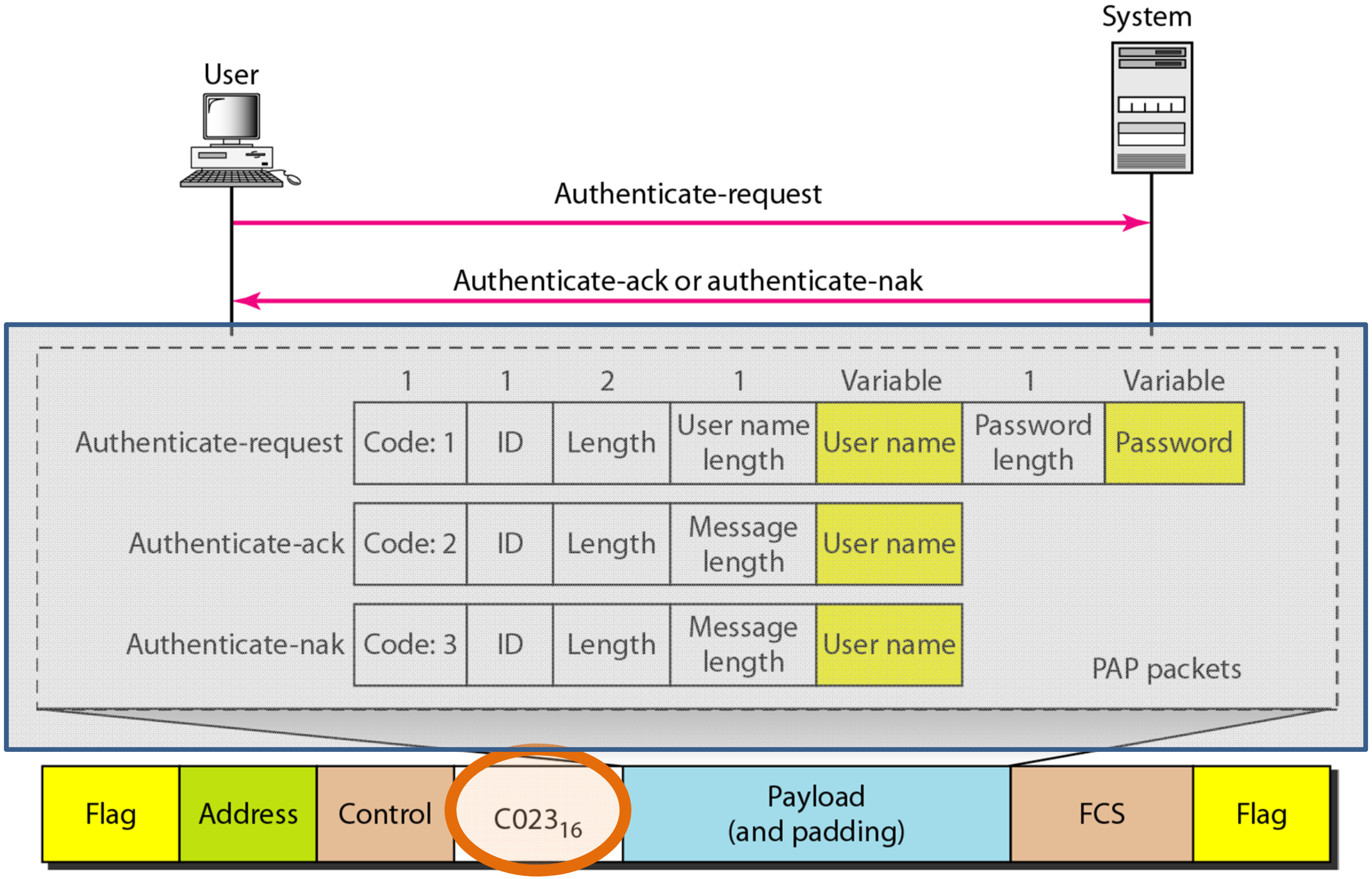
Options
- Maximum receive unit (payload size)
- Authentication protocol (none/PAP/CHAP)
- Protocol field compression (on/off),
- Address and control field compression (on/off)

Code	*Packet Type*	*Description*
0x01	Configure-request	Contains the list of proposed options and their values
0x02	Configure-ack	Accepts all options proposed
0x03	Configure-nak	Announces that some options are not acceptable
0x04	Configure-reject	Announces that some options are not recognized
0x05	Terminate-request	Request to shut down the line
0x06	Terminate-ack	Accept the shutdown request
0x07	Code-reject	Announces an unknown code
0x08	Protocol-reject	Announces an unknown protocol
0x09	Echo-request	A type of hello message to check if the other end is alive
0x0A	Echo-reply	The response to the echo-request message
0x0B	Discard-request	A request to discard the packet



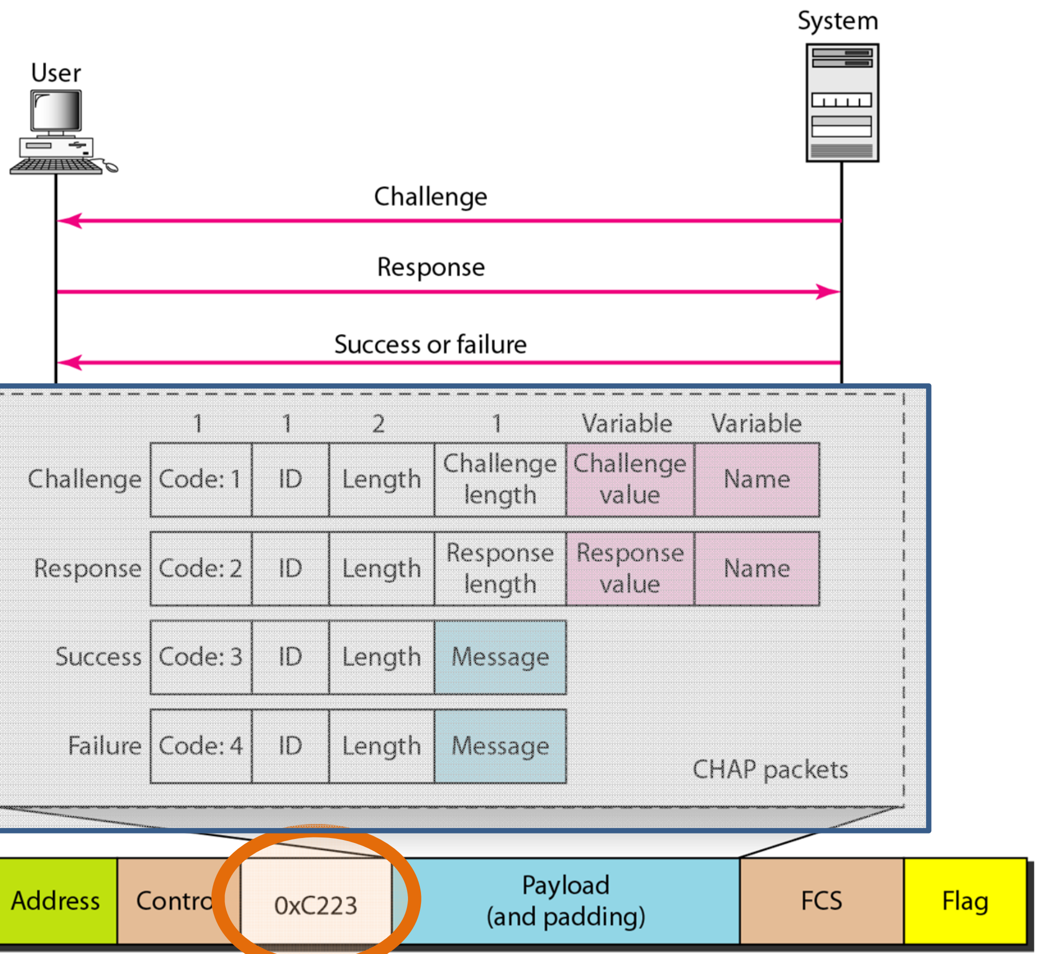
Authentication protocols (AP)

- Password authentication (PAP)



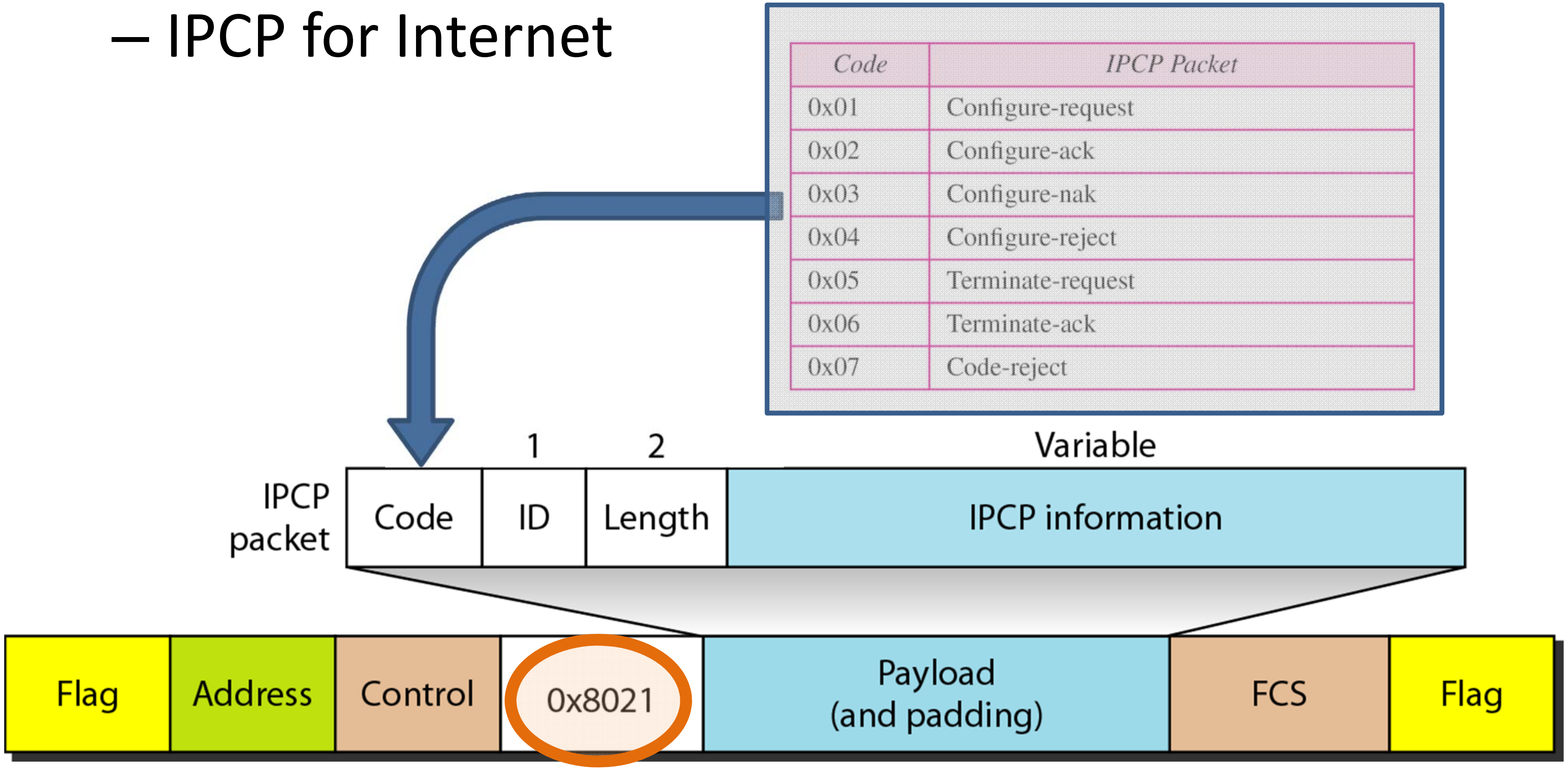
Authentication protocols (AP)

- Challenge handshake authentication (CHAP)

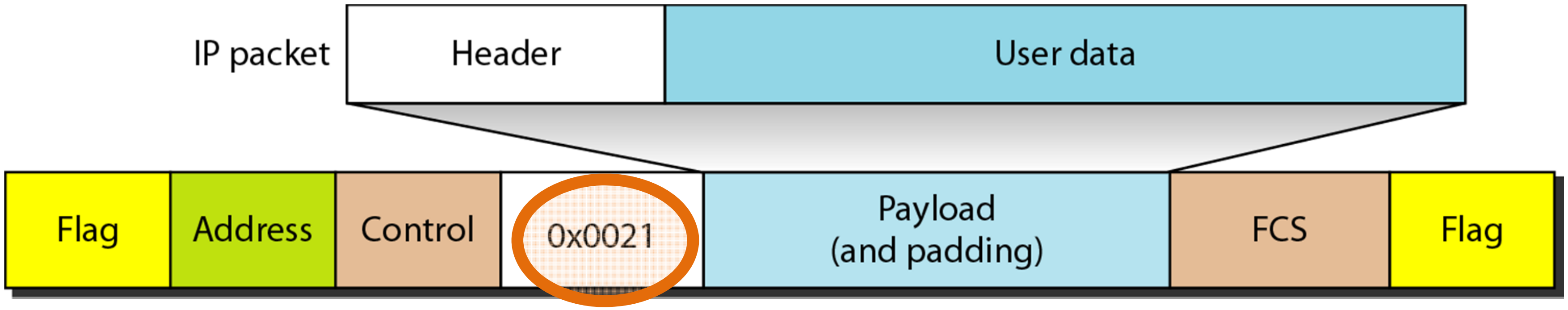


Network control protocols (NCP)

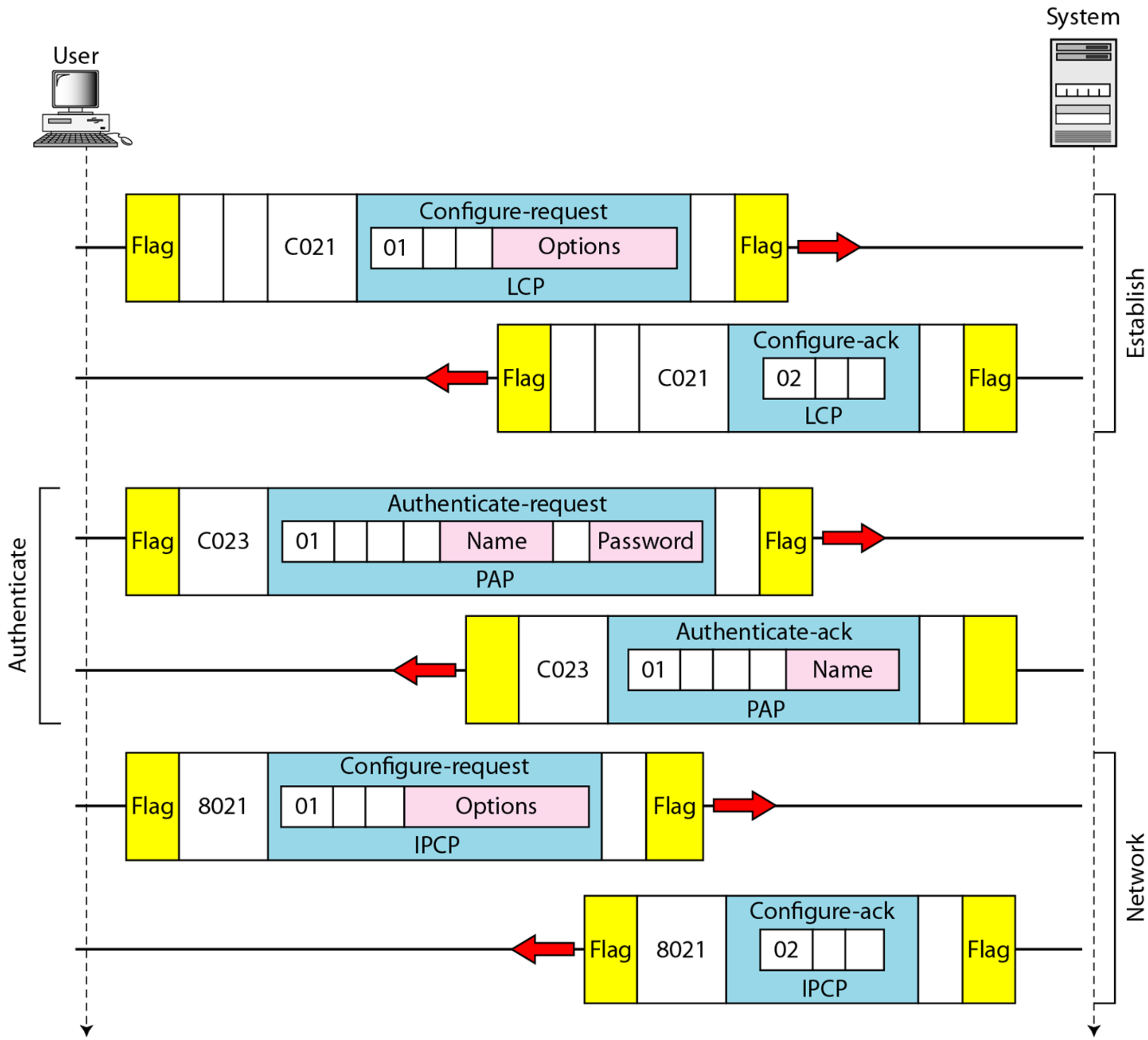
- Preparations for the network layer
  - IPCP for Internet



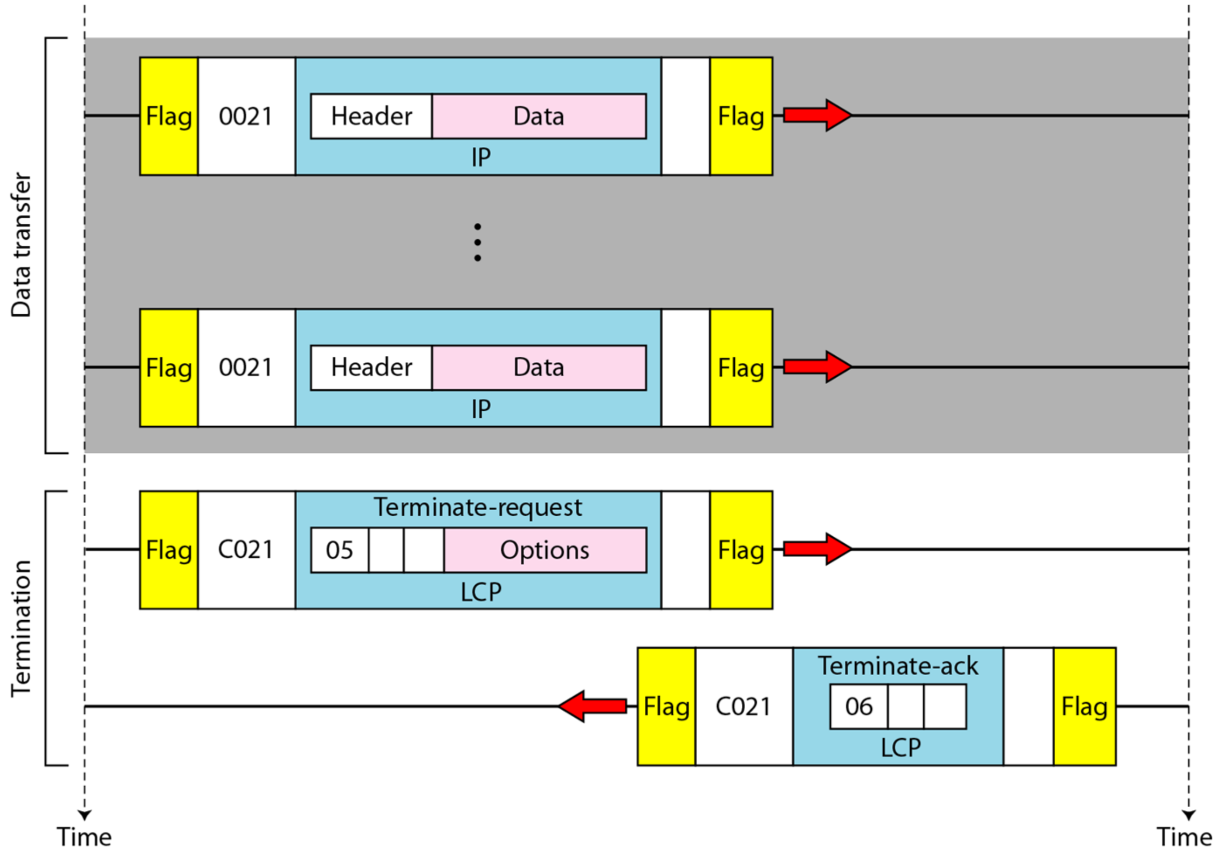
IP datagram encapsulation in PPP



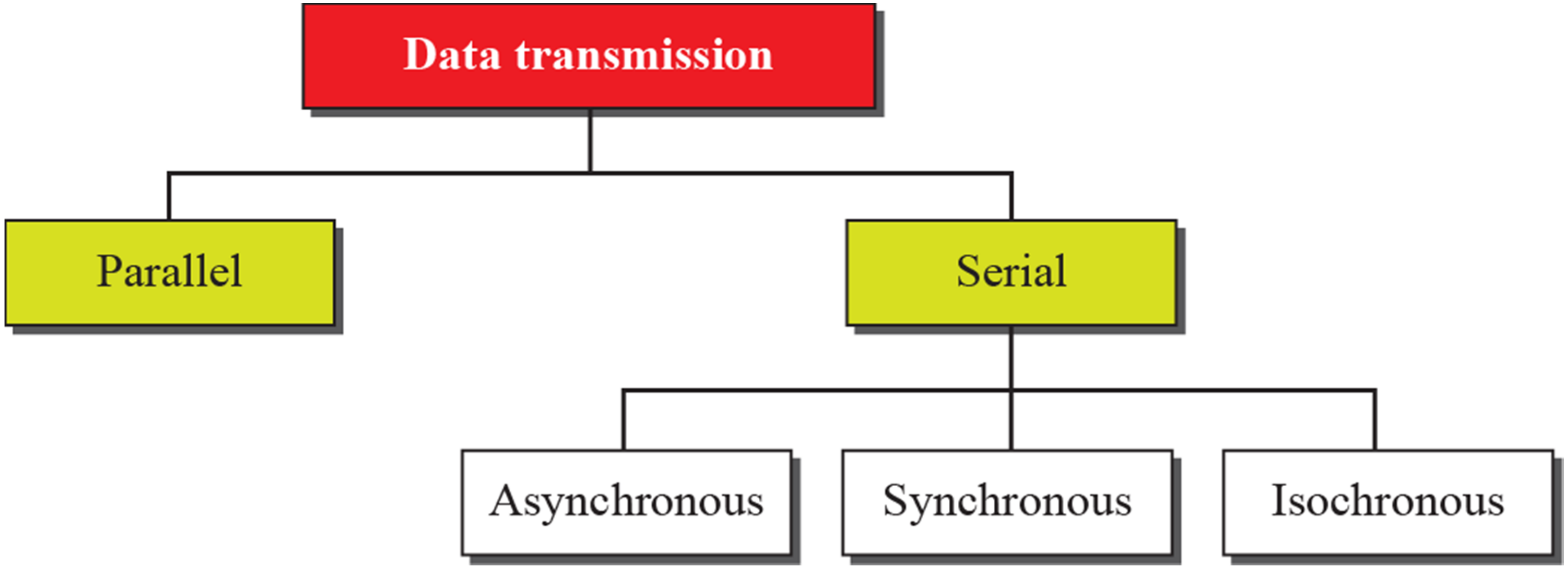
PPP session example



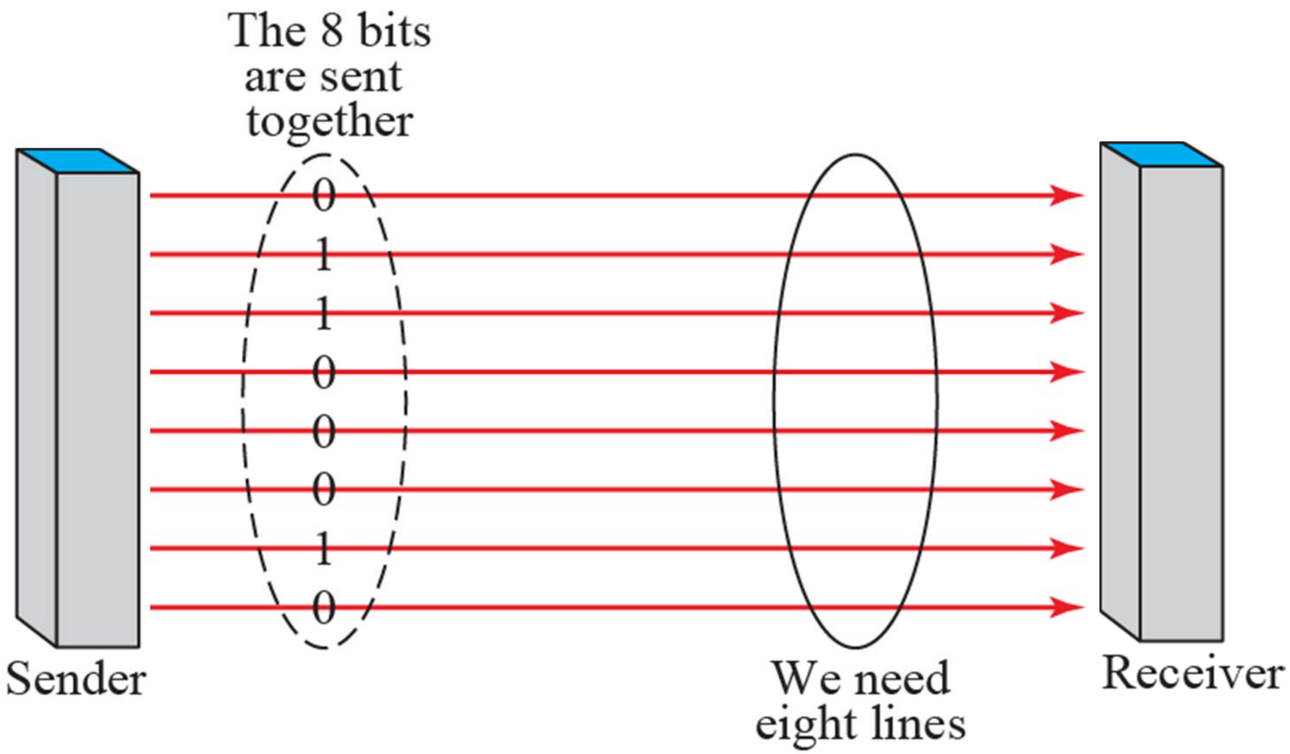
PPP session example (cont.)



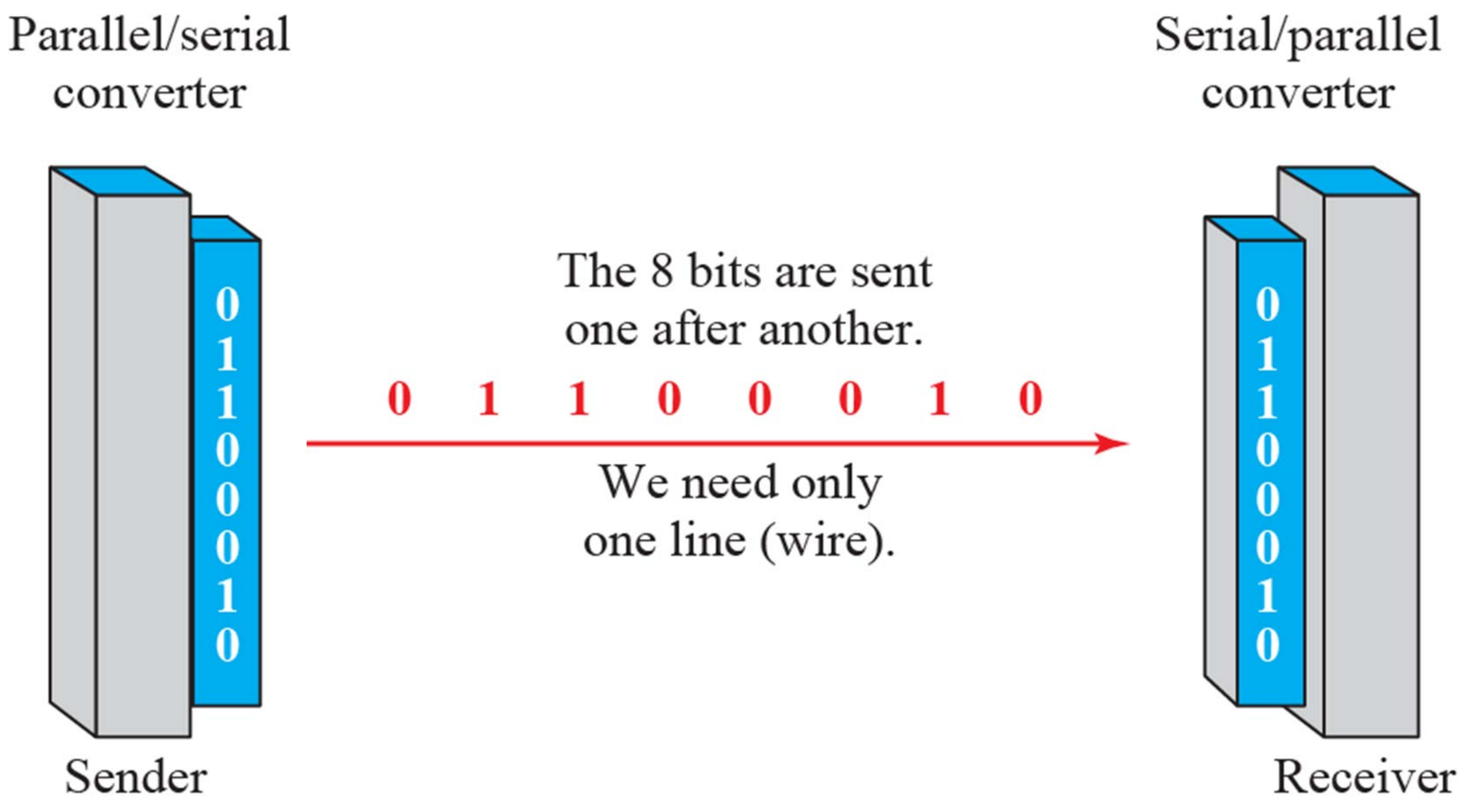
Transmission modes



Parallell transmission

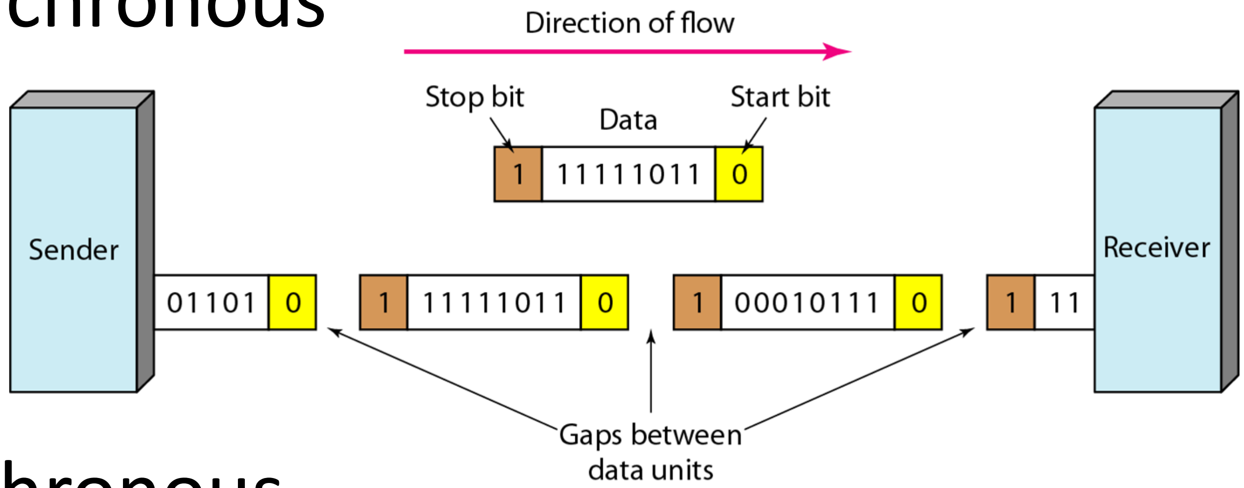


Serial transmission

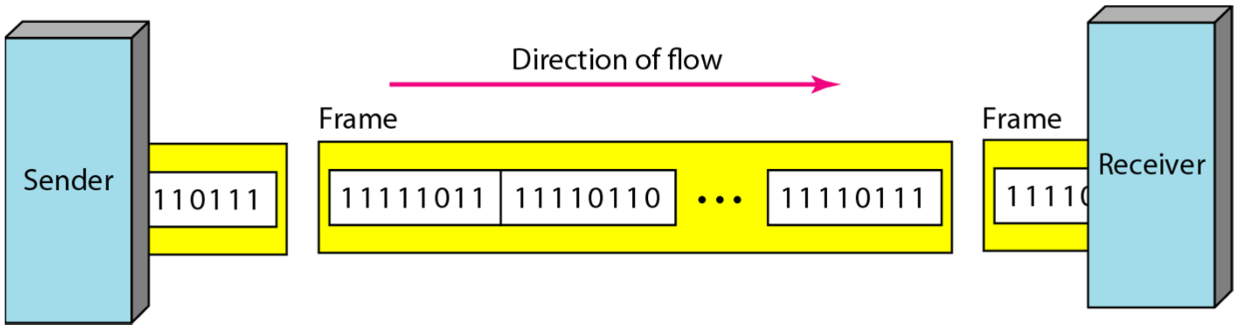


Transmission modes

- Asynchronous



- Synchronous



Multiplexing, princip

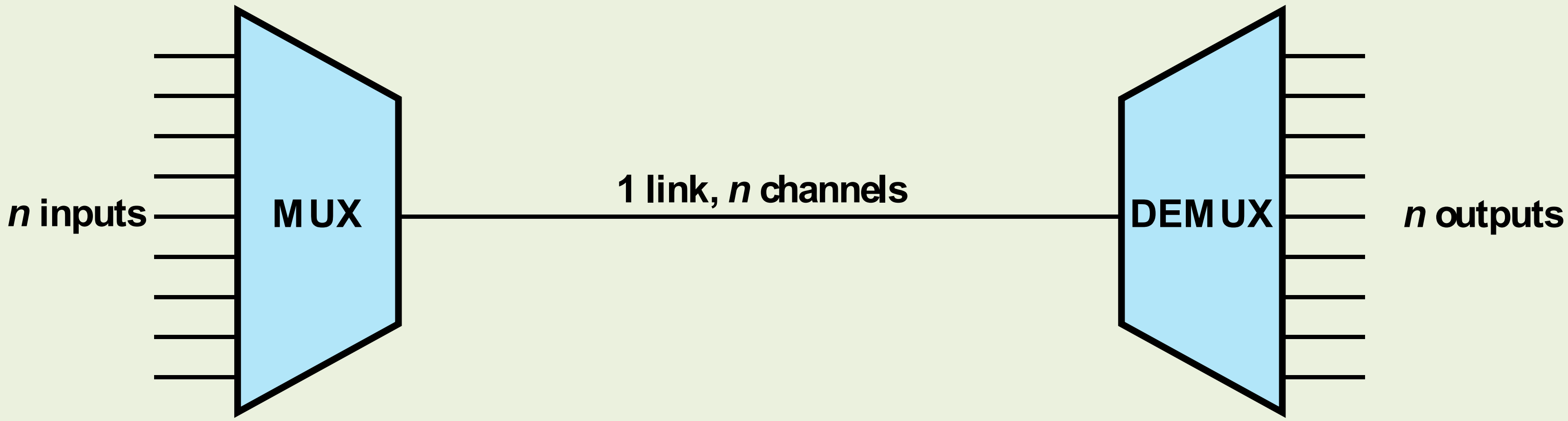
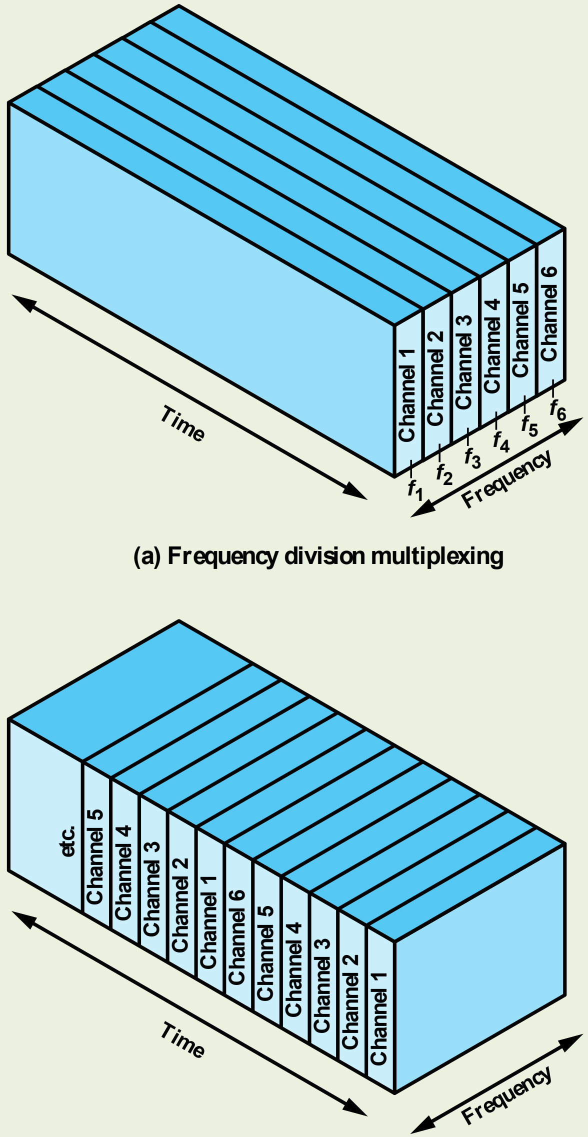


Figure 8.1 Multiplexing

FDM vs TDM



(a) Frequency division multiplexing

(b) Time division multiplexing

Figure 8.2 FDM and TDM

Synkron TDM

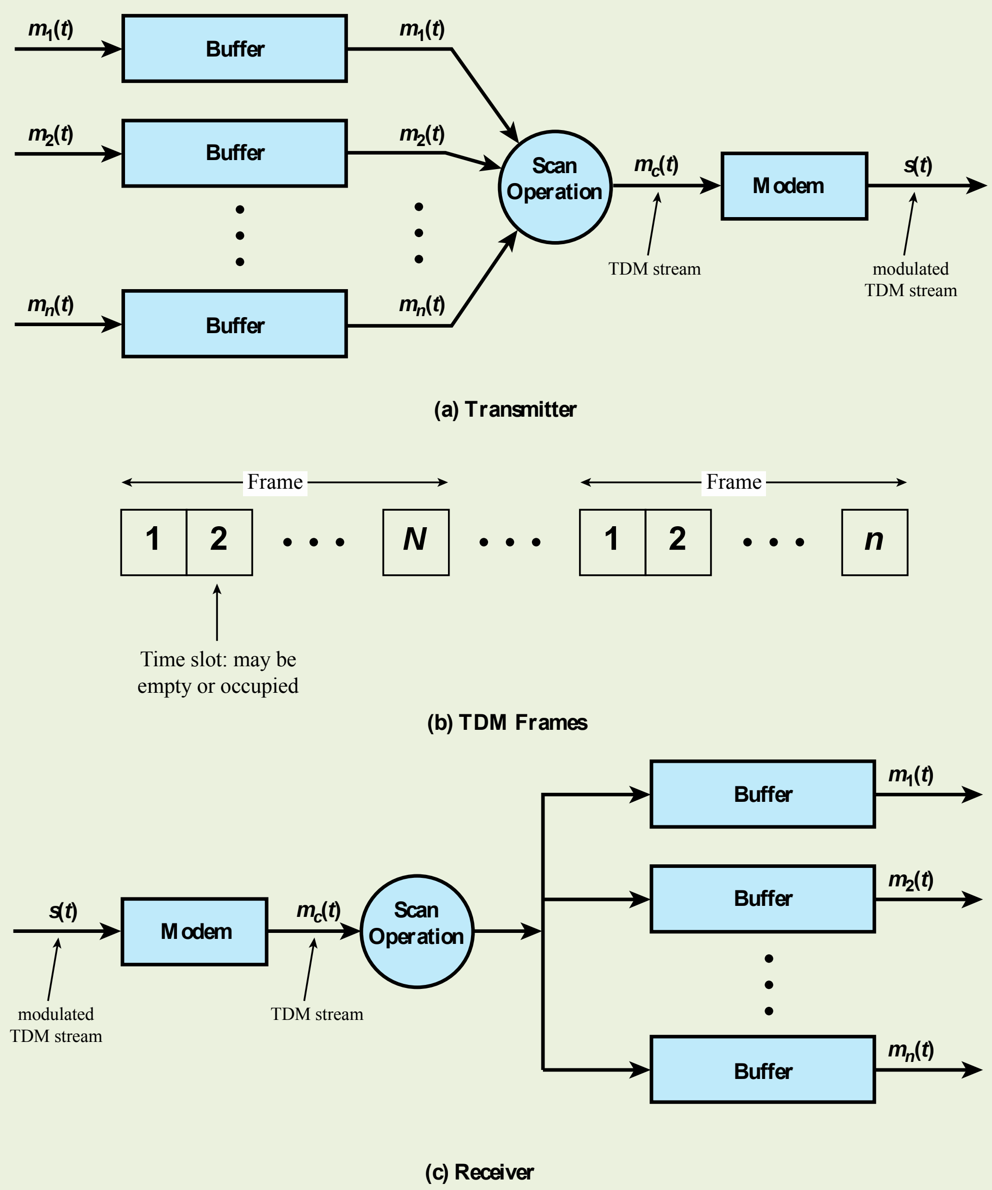
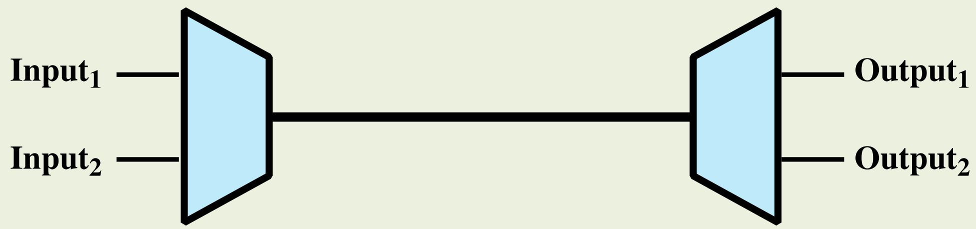


Figure 8.6 Synchronous TDM System

TDM Link Control

- No headers and trailers
- Data link control protocols not needed
- Flow control
  - Data rate of multiplexed line is fixed
  - If one channel receiver can not receive data, the others must carry on
  - Corresponding source must be quenched
  - Leaving empty slots
- Error control
  - Errors detected and handled on individual channel



(a) Configuration

Input$_1$ • • • • • • • • • • • F$_1$ f$_1$ f$_1$ d$_1$ d$_1$ d$_1$ C$_1$ A$_1$ F$_1$ f$_1$ f$_1$ d$_1$ d$_1$ d$_1$ C$_1$ A$_1$ F$_1$

Input$_2$ • • • F$_2$ f$_2$ f$_2$ d$_2$ d$_2$ d$_2$ d$_2$ C$_2$ A$_2$ F$_2$ f$_2$ f$_2$ d$_2$ d$_2$ d$_2$ d$_2$ C$_2$ A$_2$ F$_2$

(b) Input data streams

• • • f$_2$ F$_1$ d$_2$ f$_1$ d$_2$ f$_1$ d$_2$ d$_1$ d$_2$ d$_1$ C$_2$ d$_1$ A$_2$ C$_1$ F$_2$ A$_1$ f$_2$ F$_1$ f$_2$ f$_1$ d$_2$ f$_1$ d$_2$ d$_1$ d$_2$ d$_1$ d$_2$ d$_1$ C$_2$ C$_1$ A$_2$ A$_1$ F$_2$ F$_1$

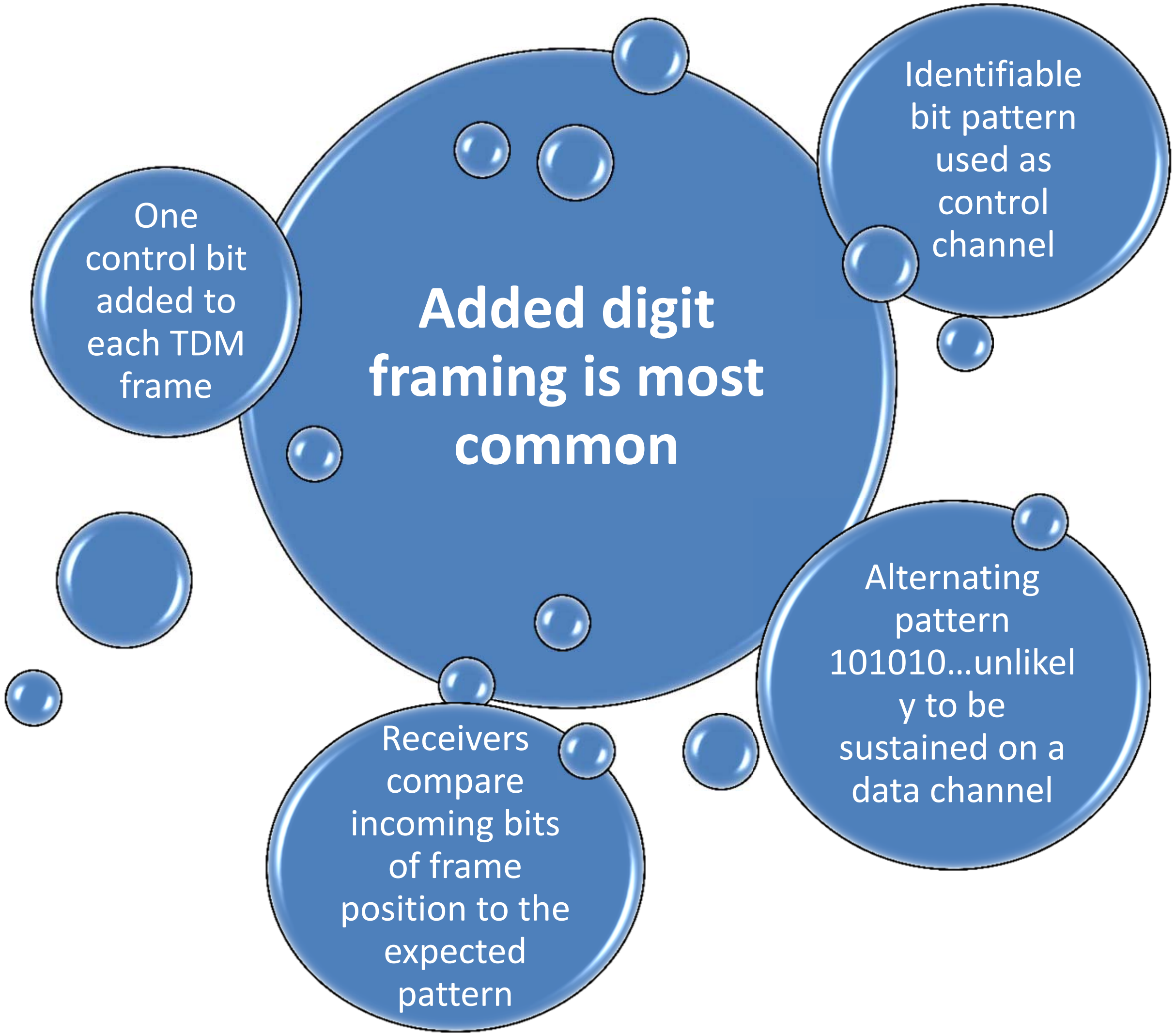
(c) Multiplexed data stream

Legend: F = flag field; A = address field; C = control field; d = one octet of data field; f = one octet of FCS field

Figure 8.7 Use of Data Link Control on TDM Channels

Framing

- No flag or SYNC characters bracketing TDM frames
- Must still provide synchronizing mechanism between source and destination clocks



Pulse Stuffing is a common solution

Have outgoing data rate (excluding framing bits) higher than sum of incoming rates	**Stuff extra dummy bits or pulses into each incoming signal until it matches local clock**	**Stuffed pulses inserted at fixed locations in frame and removed at demultiplexer**

- Problem of synchronizing various data sources
- Variation among clocks could cause loss of synchronization
- Issue of data rates from different sources not related by a simple rational number

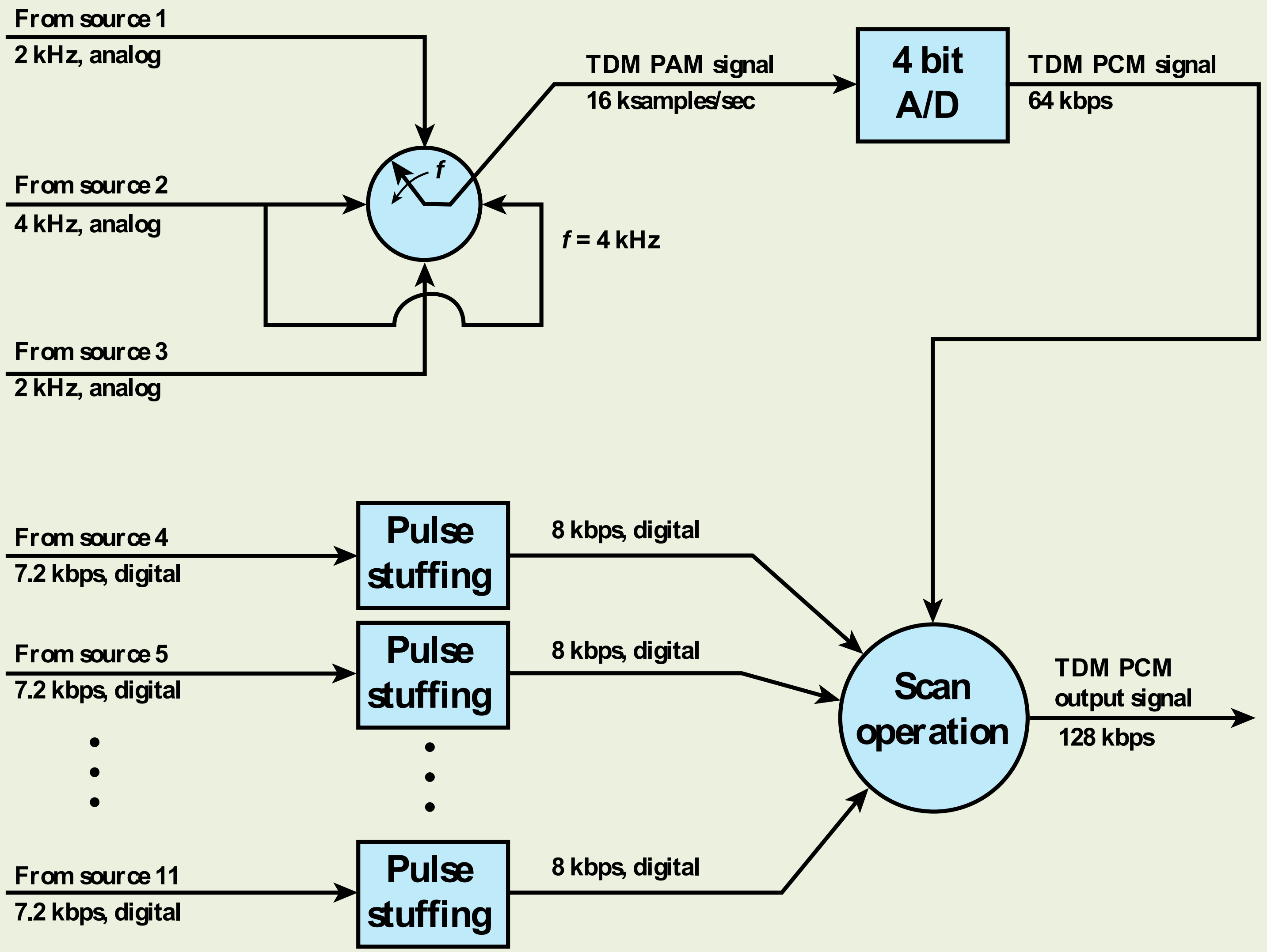


Figure 8.8 TDM of Analog and Digital Sources

Table 8.3

North American and International TDM Carrier Standards

North American			International (ITU-T)		
Designation	Number of Voice Channels	Data Rate (Mbps)	Level	Number of Voice Channels	Data Rate (Mbps)
DS-1	24	1.544	1	30	2.048
DS-1C	48	3.152	2	120	8.448
DS-2	96	6.312	3	480	34.368
DS-3	672	44.736	4	1920	139.264
DS-4	4032	274.176	5	7680	565.148

Synchronous Optical Networks

- SONET, developed by ANSI

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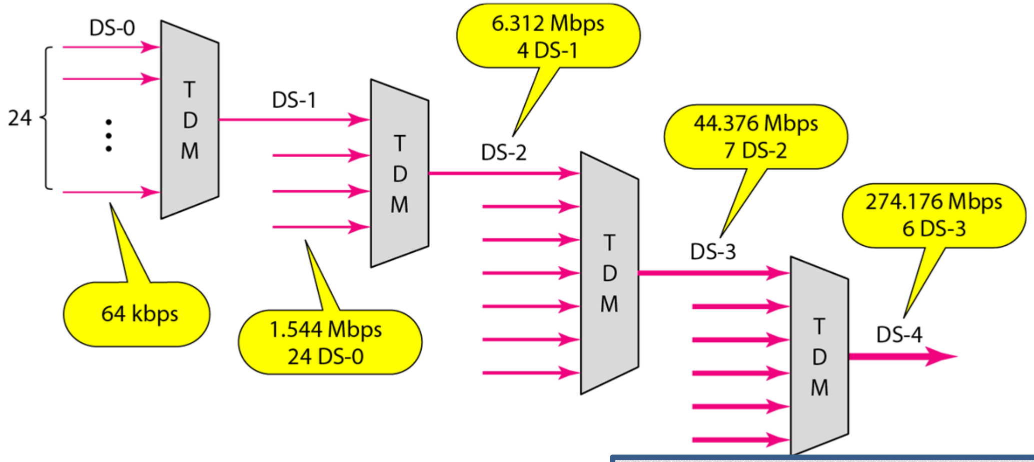
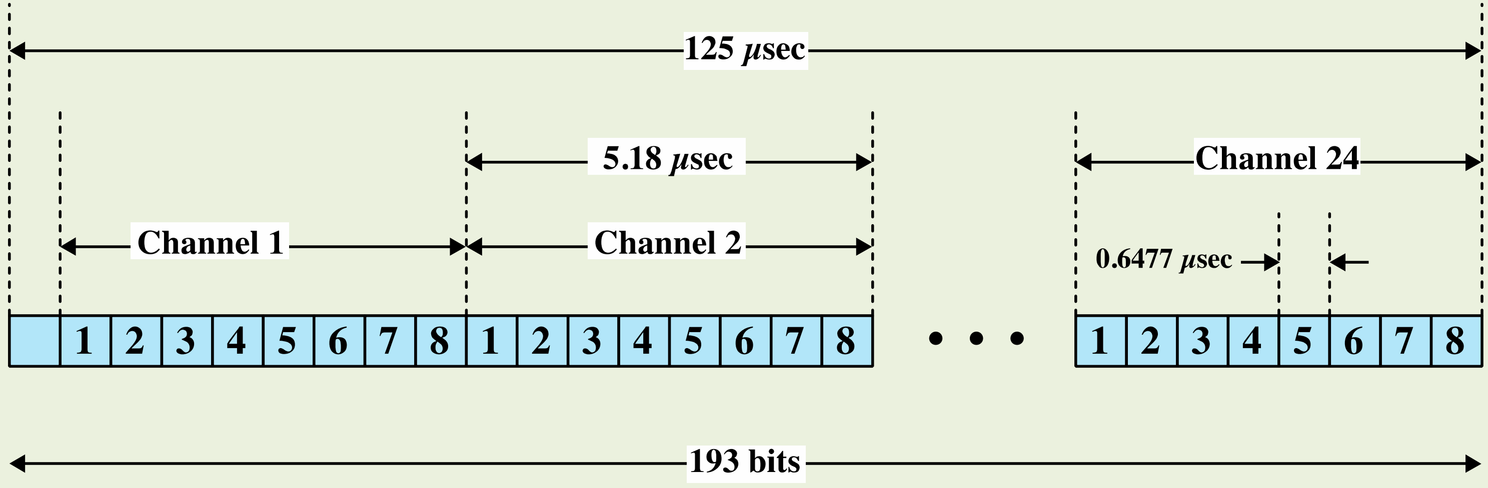
Synchronous Digital Hierarchy

- SDH, developed by ITU-T

Digital hierarchy on optical links



STS	*OC*	*Rate (Mbps)*	*STM*
STS-1	OC-1	51.840	
STS-3	OC-3	155.520	**STM-1**
STS-9	OC-9	466.560	**STM-3**
STS-12	OC-12	622.080	**STM-4**
STS-18	OC-18	933.120	**STM-6**
STS-24	OC-24	1244.160	**STM-8**
STS-36	OC-36	1866.230	**STM-12**
STS-48	OC-48	2488.320	**STM-16**
STS-96	OC-96	4976.640	**STM-32**
STS-192	OC-192	9953.280	**STM-64**



Notes:

1. The first bit is a framing bit, used for synchronization.
2. Voice channels:
   - 8-bit PCM used on five of six frames.
   - 7-bit PCM used on every sixth frame; bit 8 of each channel is a signaling bit.
3. Data channels:
   - Channel 24 is used for signaling only in some schemes.
   - Bits 1-7 used for 56 kbps service
   - Bits 2-7 used for 9.6, 4.8, and 2.4 kbps service.

Figure 8.9 DS-1 Transmission Format

Network architecture

- Devices and connections

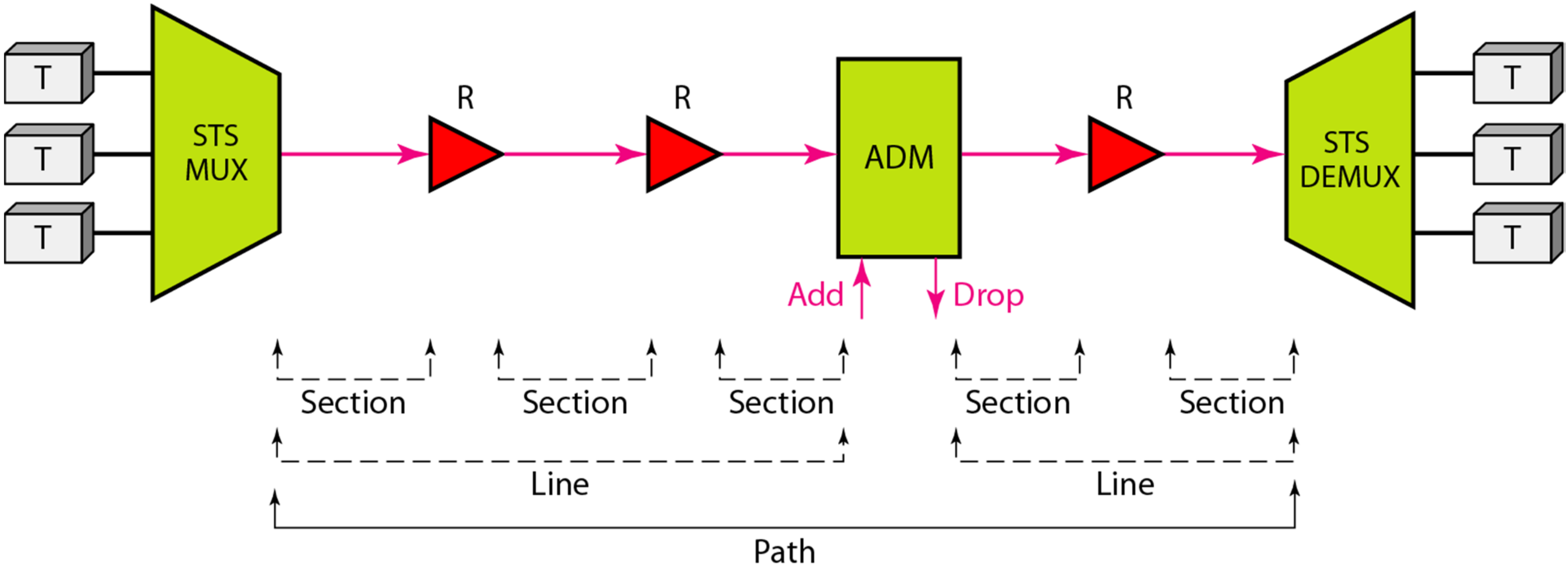
ADM: Add/drop multiplexer

STS MUX: Synchronous transport signal multiplexer

STS DEMUX: Synchronous transport signal demultiplexer

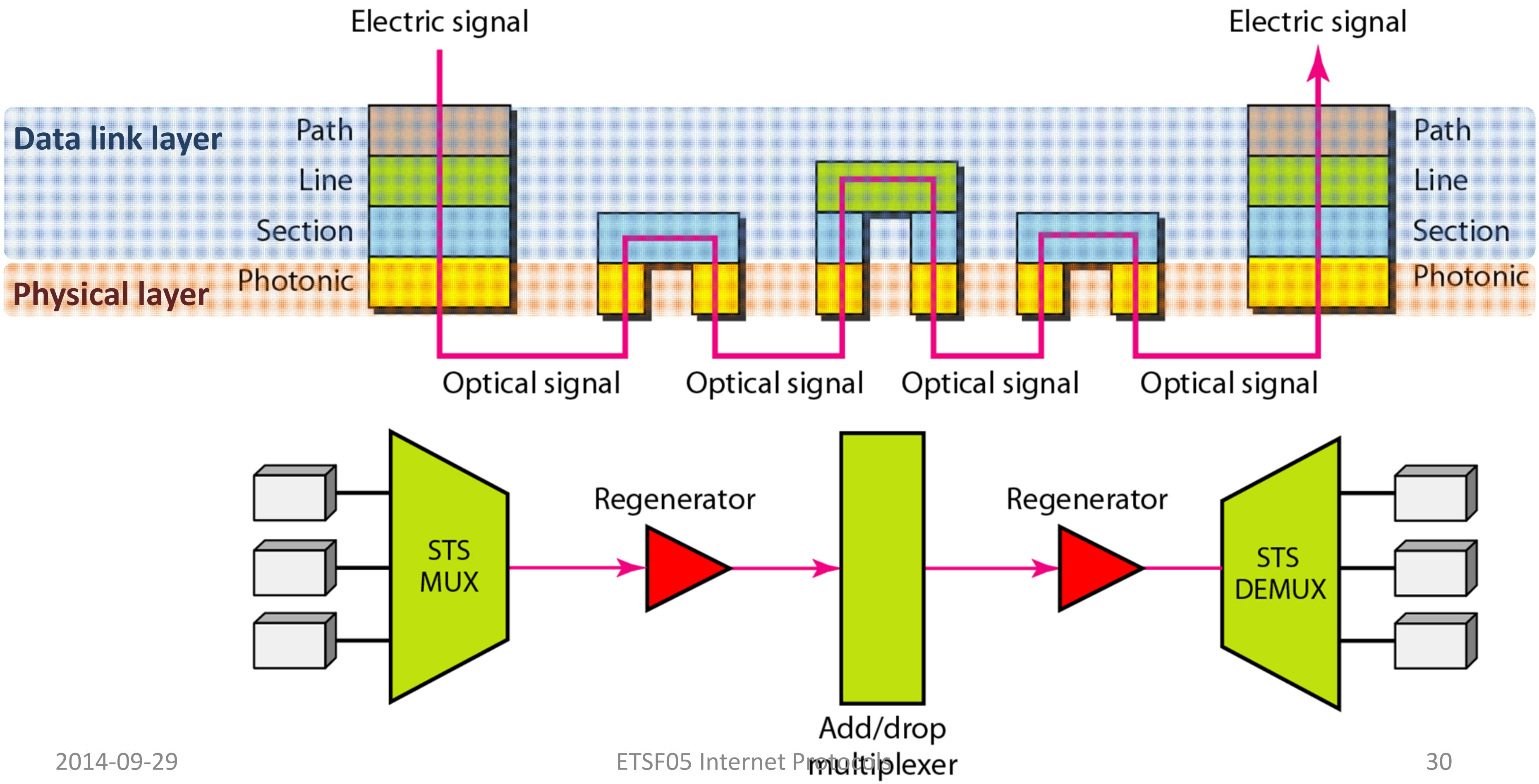
R: Regenerator

T: Terminal



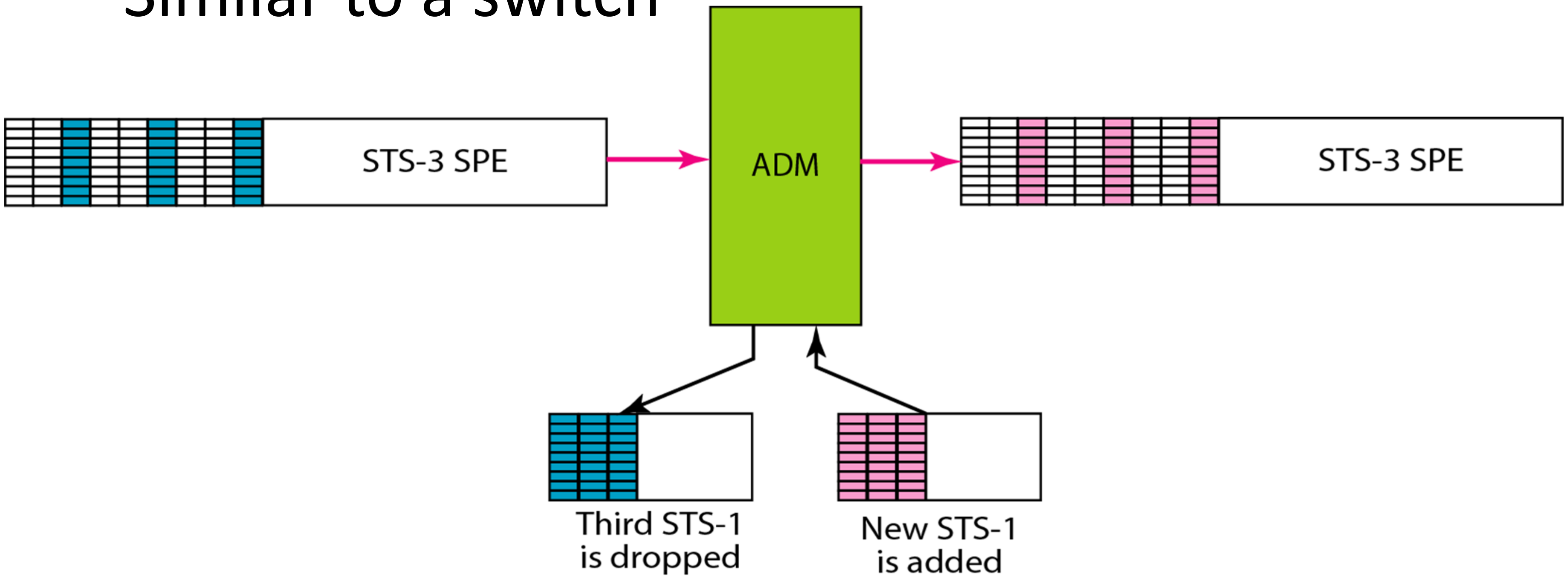
Network architecture

- Devices and layers



SONET add/drop multiplexer

- Replaces a signal with another one
- Operates at line layer
- Similar to a switch



SONET/SDH

- Synchronous Optical Network (ANSI)
- Synchronous Digital Hierarchy (ITU-T)
- High speed capability of optical fiber
- Defines hierarchy of signal rates
    - Synchronous Transport Signal level 1 (STS-1) or Optical Carrier level 1 (OC-1) is 51.84Mbps
    - Carries one DS-3 or multiple (DS1 DS1C DS2) plus ITU-T rates (e.g., 2.048Mbps)
    - Multiple STS-1 combine into STS-N signal
    - ITU-T lowest rate is 155.52Mbps (STM-1)

Table 8.4
SONET/SDH Signal Hierarchy

SONET Designation	ITU-T Designation	Data Rate	Payload Rate (Mbps)
STS-1/OC-1		51.84 Mbps	50.112 Mbps
STS-3/OC-3	STM-1	155.52 Mbps	150.336 Mbps
STS-12/OC-12	STM-4	622.08 Mbps	601.344 Mbps
STS-48/OC-48	STM-16	2.48832 Gbps	2.405376 Gbps
STS-192/OC-192	STM-64	9.95328 Gbps	9.621504 Gbps
STS-768	STM-256	39.81312 Gbps	38.486016 Gbps
STS-3072		159.25248 Gbps	153.944064 Gbps

SONET frames

- Proportional to data rates

STS	*OC*	*Rate (Mbps)*	*STM*
STS-1	OC-1	51.840	
STS-3	OC-3	155.520	**STM-1**
STS-9	OC-9	466.560	**STM-3**
STS-12	OC-12	622.080	**STM-4**
STS-18	OC-18	933.120	**STM-6**
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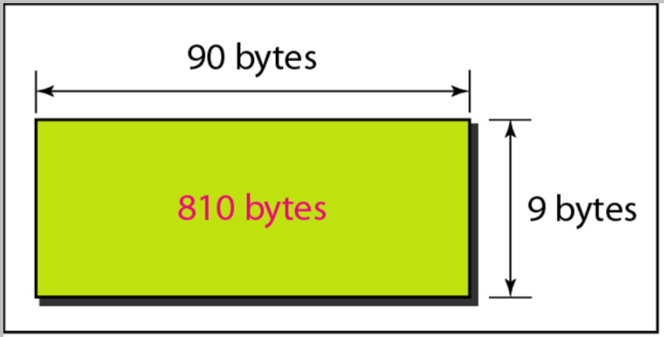
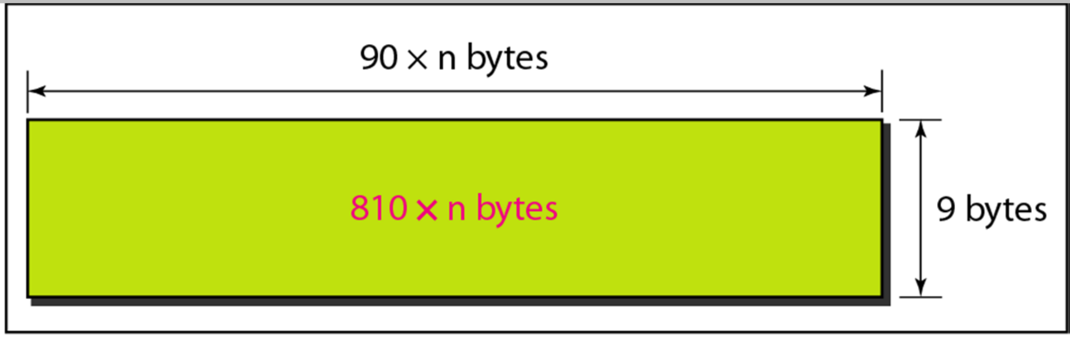
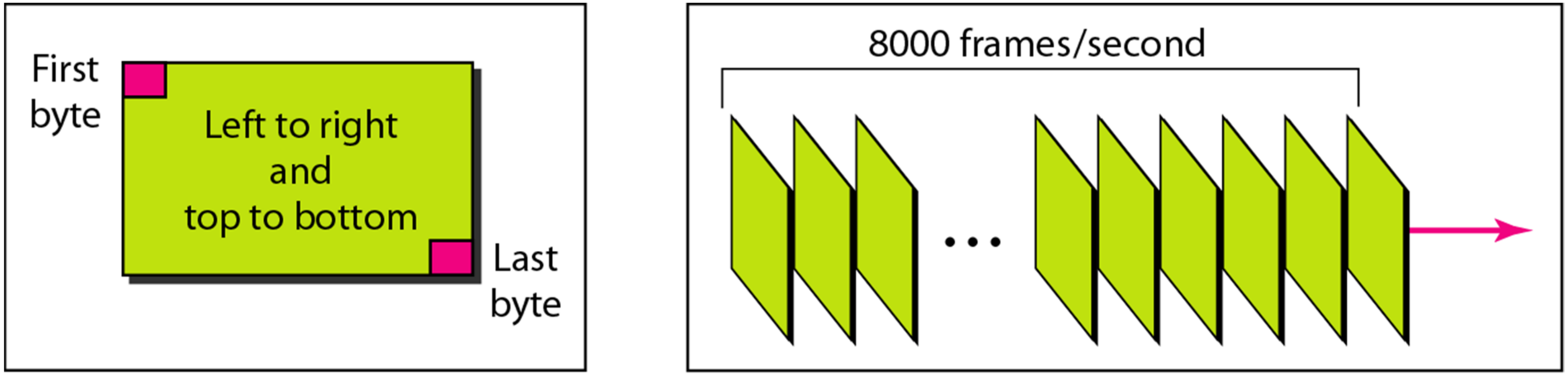


a. STS-1 frame



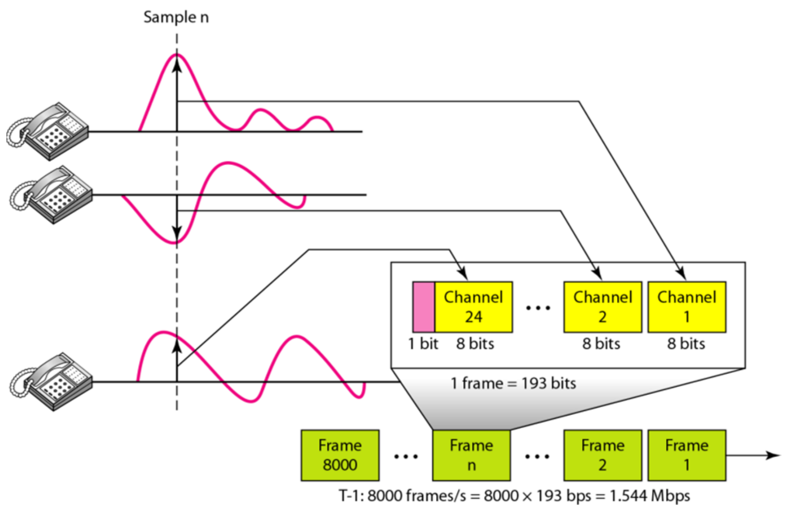
b. STS-n frame

SONET frames in transmission



a. Byte transmission

b. Frame transmission



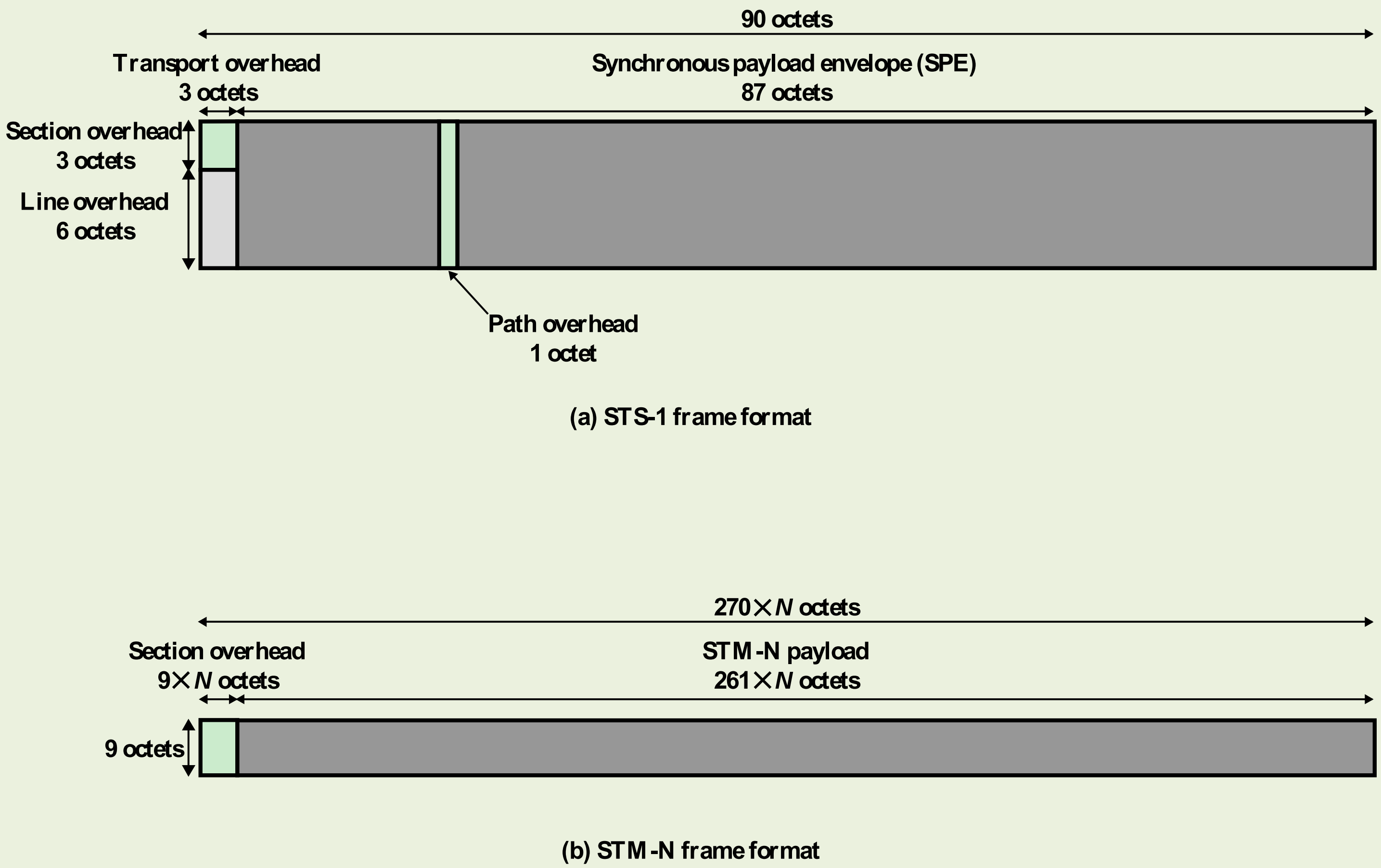
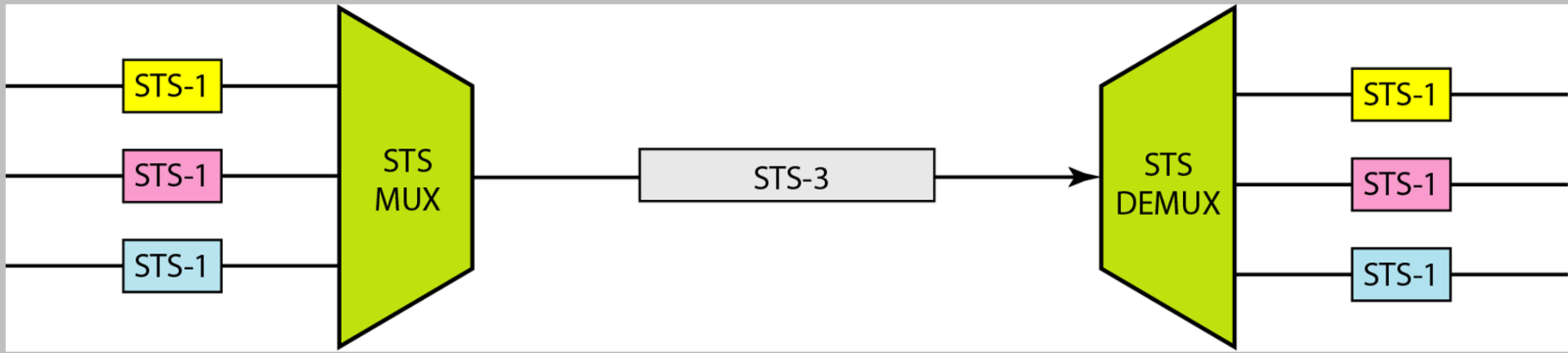
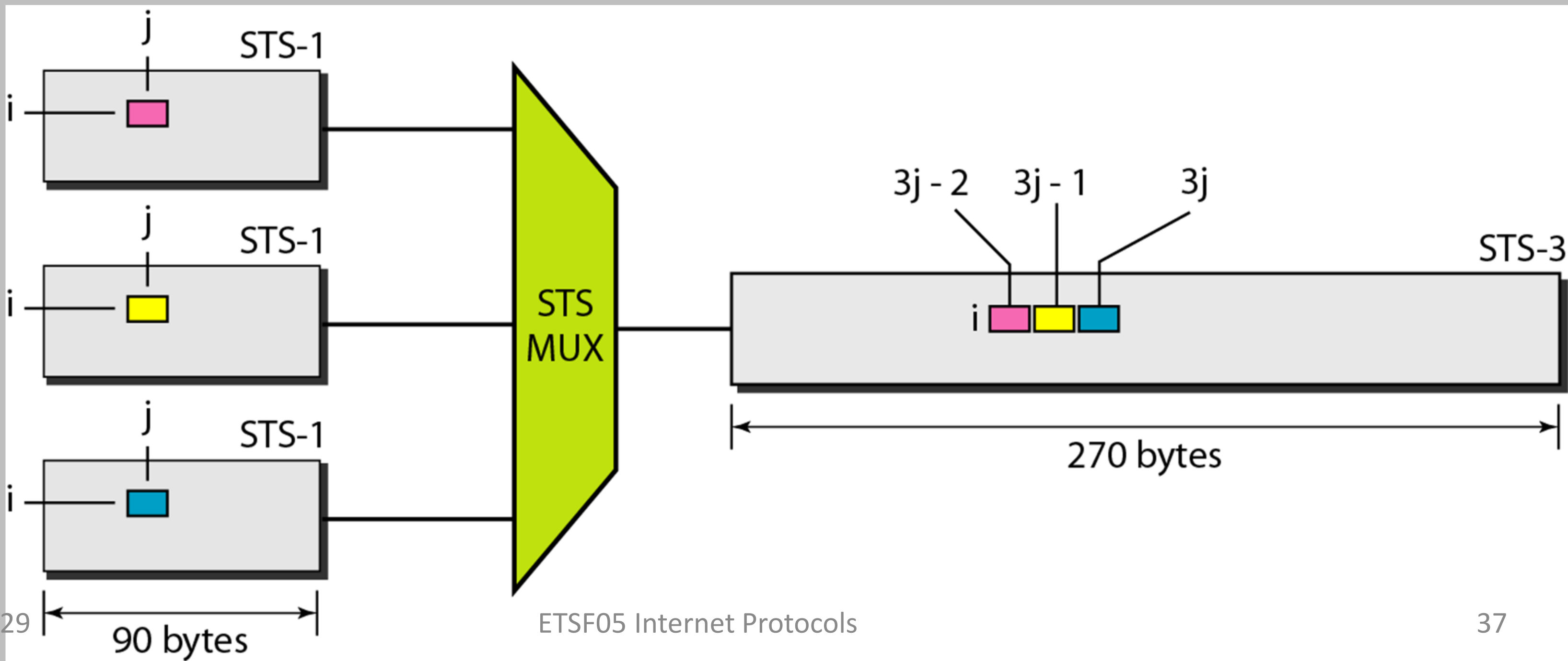


Figure 8.10 SONET/SDH Frame Formats

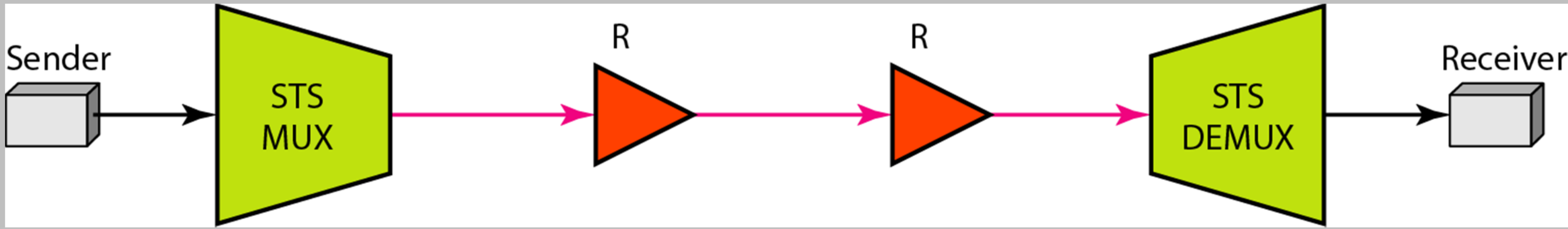
Multiplexing and byte interleaving



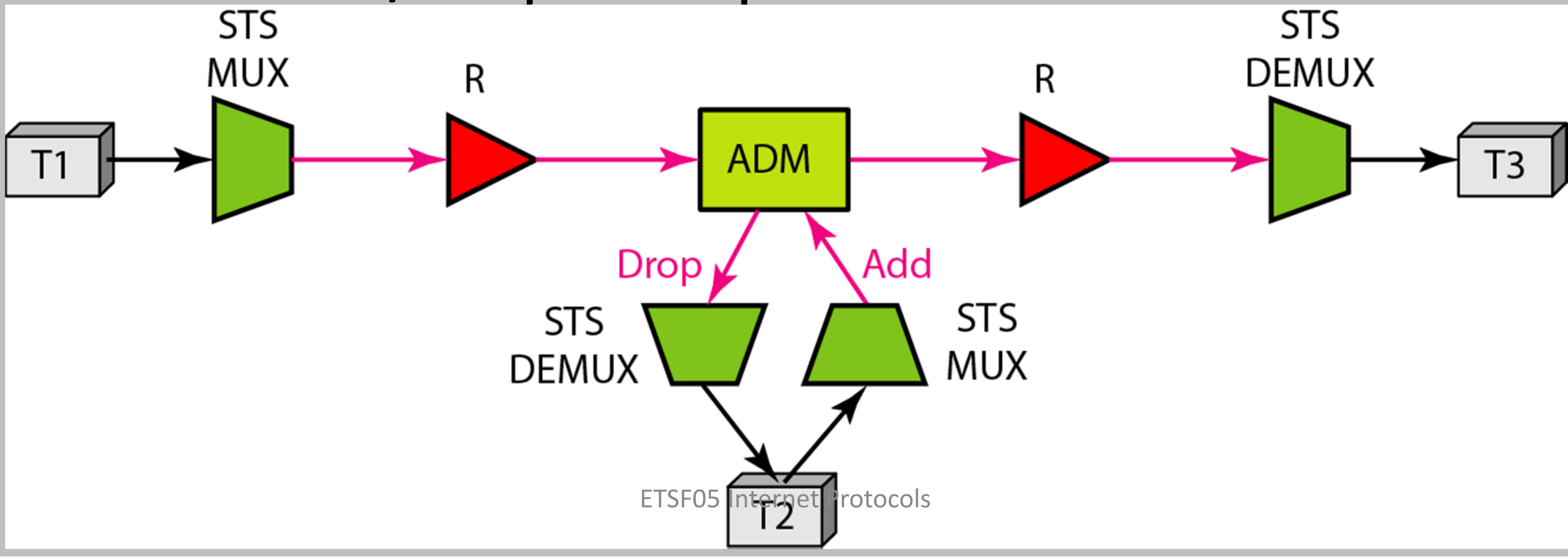


Linear SONET topology

- Without add/drop multiplexer

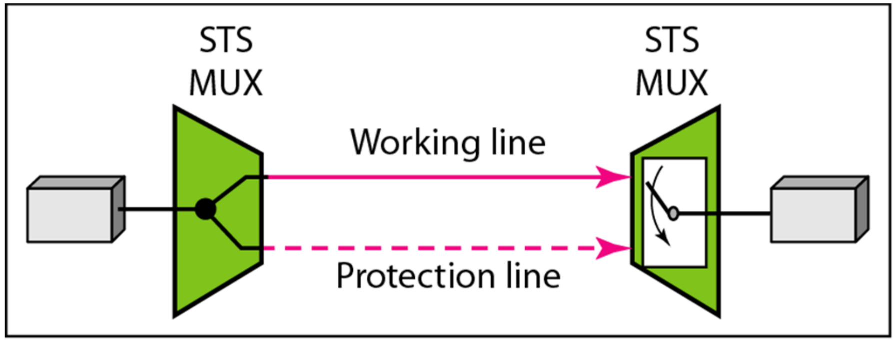


- With add/drop multiplexer

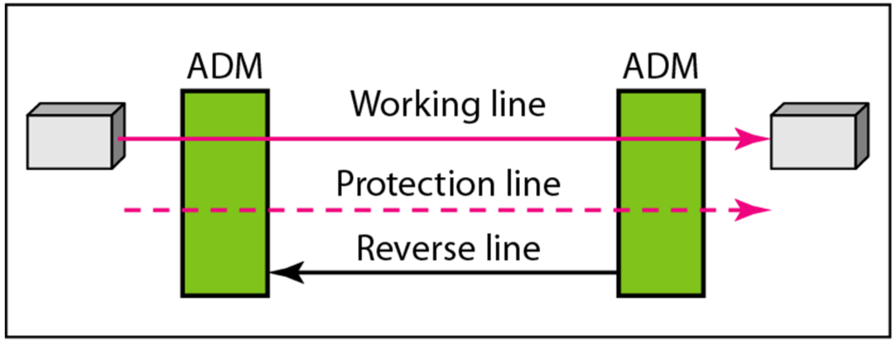


Automatic protection switching

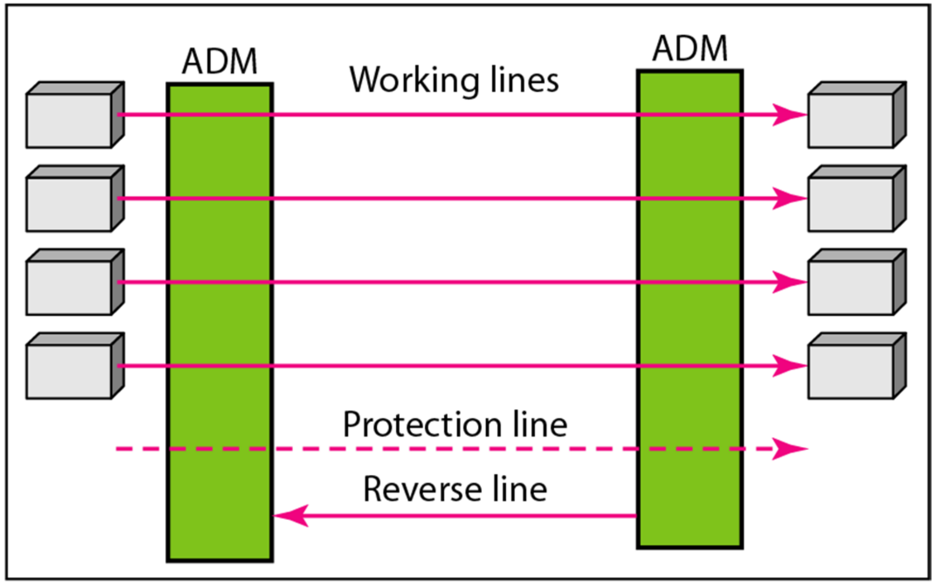
- Failure protection through line redundancy



a. One-plus-one APS

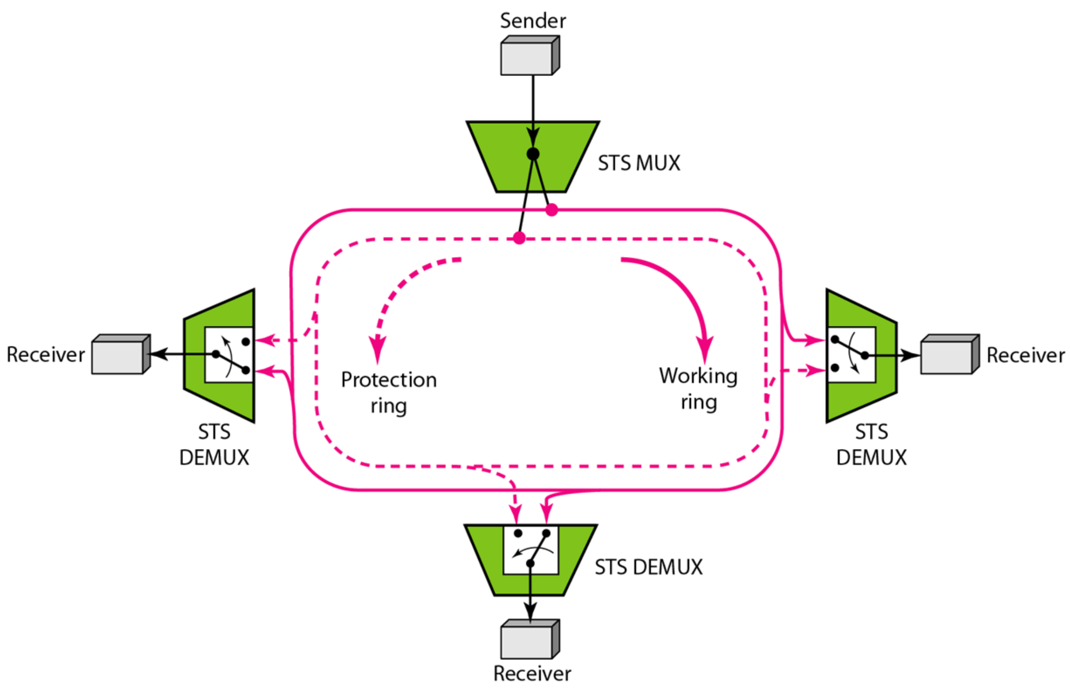


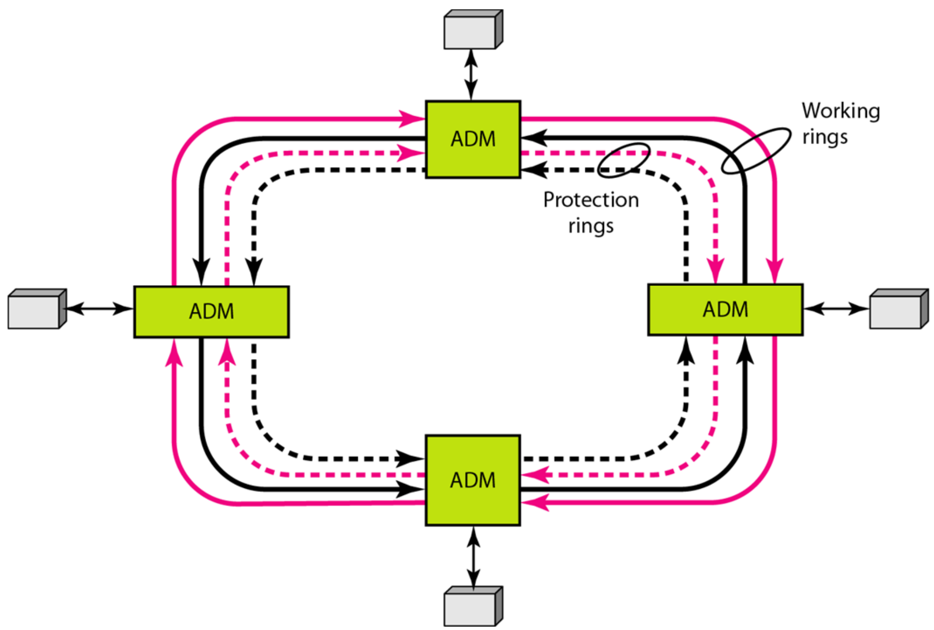
b. One-to-one APS



c. One-to-many APS

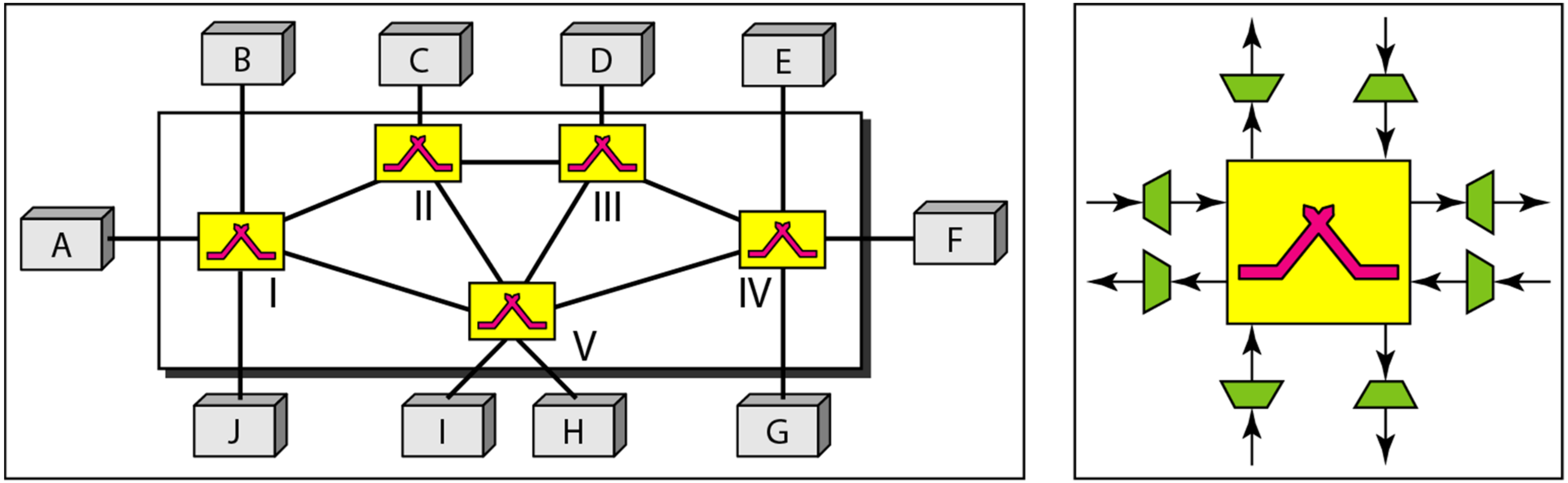
Ring SONET topology





Mesh SONET topology

- Better scalability
  - – Multiplexing/demultiplexing at switches



a. SONET mesh network   b. Cross-connect switch

Asymmetrical Digital Subscriber Line (ADSL)

- Link between subscriber and network
- Uses currently installed twisted pair cable
- Is Asymmetric - bigger downstream than up
- Uses Frequency Division Multiplexing
  - Reserve lowest 25kHz for voice (POTS)
  - Uses echo cancellation or FDM to give two bands
- Has a range of up to 5.5km

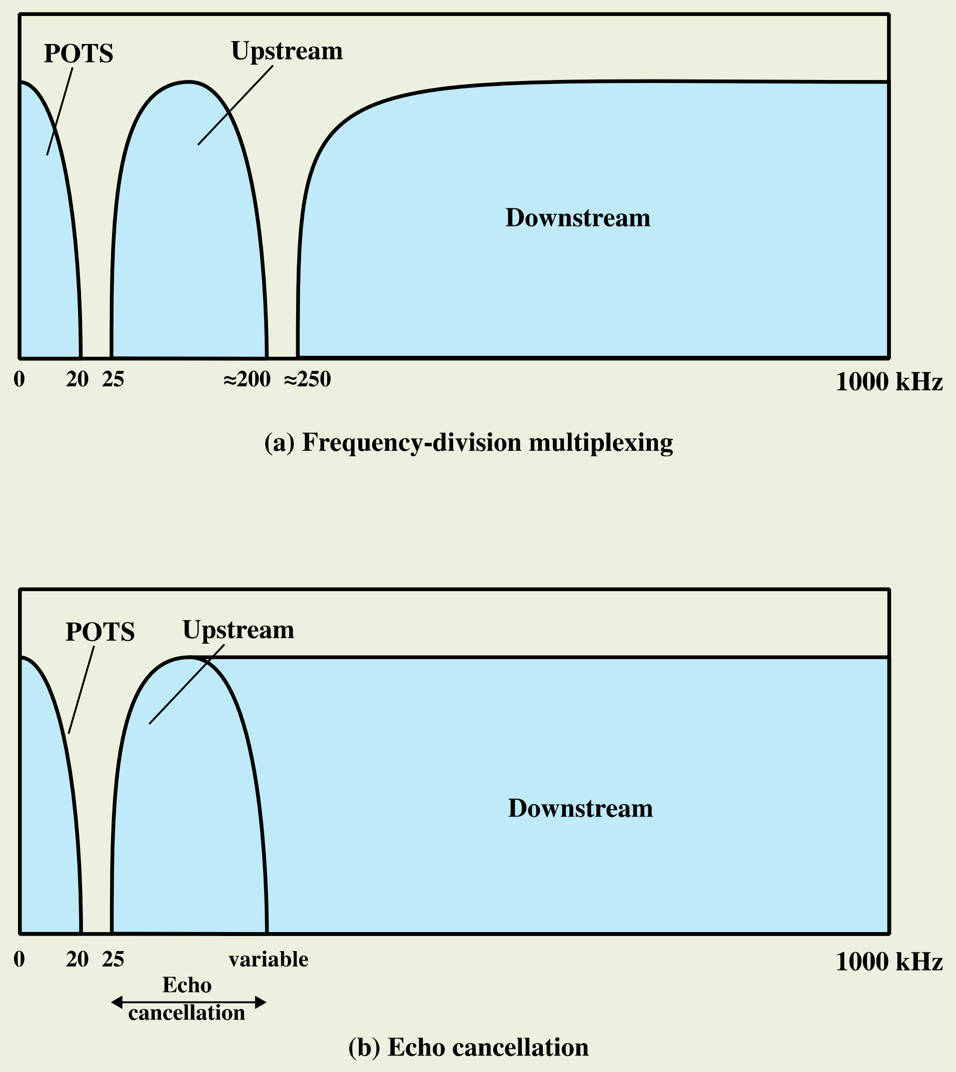


Figure 8.14 ADSL Channel Configuration

Discrete Multitone (DMT)

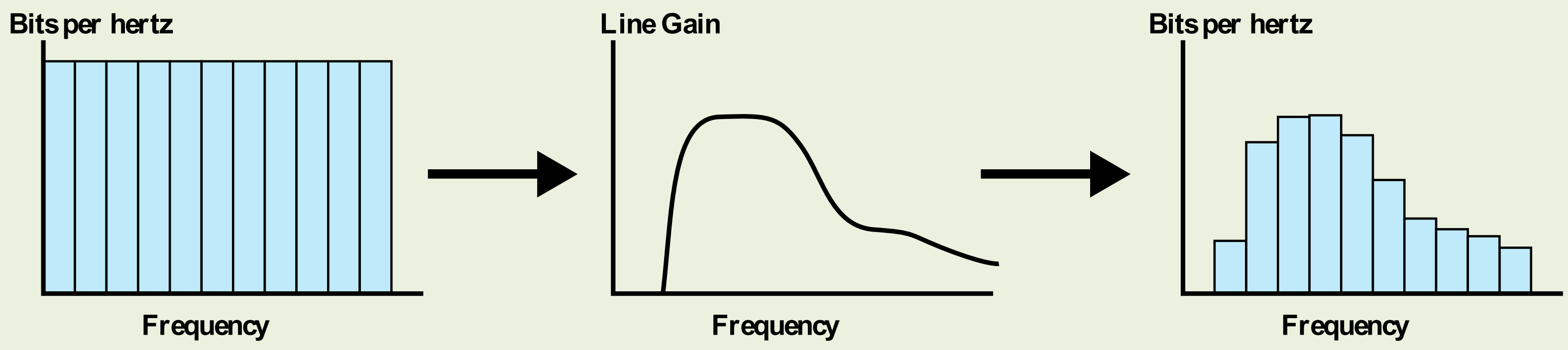


Figure 8.15 DMT Bits per Channel Allocation

- Multiple carrier signals at different frequencies
- Divide into 4kHz subchannels
- Test and use subchannels with better SNR
- 256 downstream subchannels at 4kHz (60kbps)
  – In theory 15.36Mbps, in practice 1.5-9Mbps

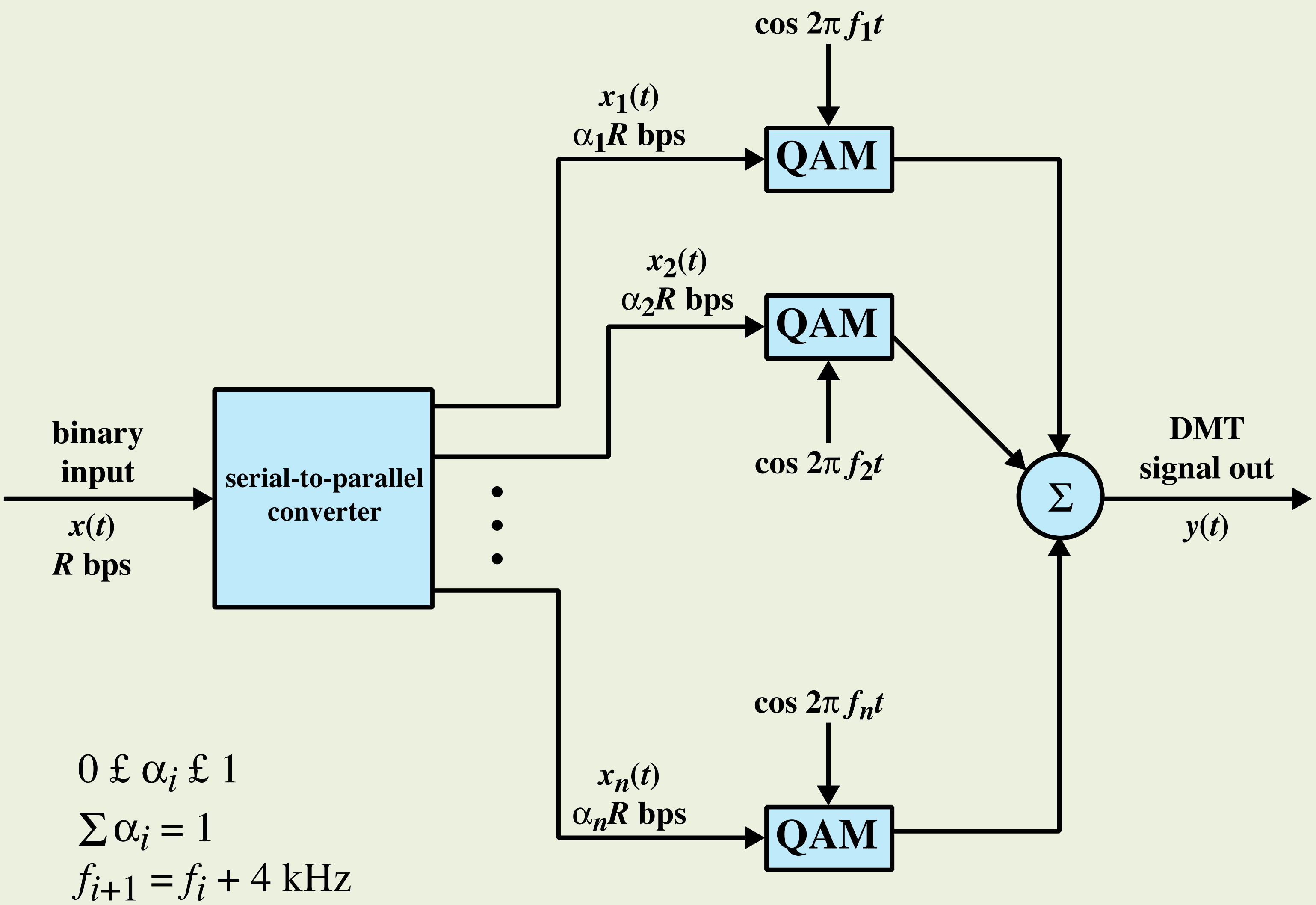
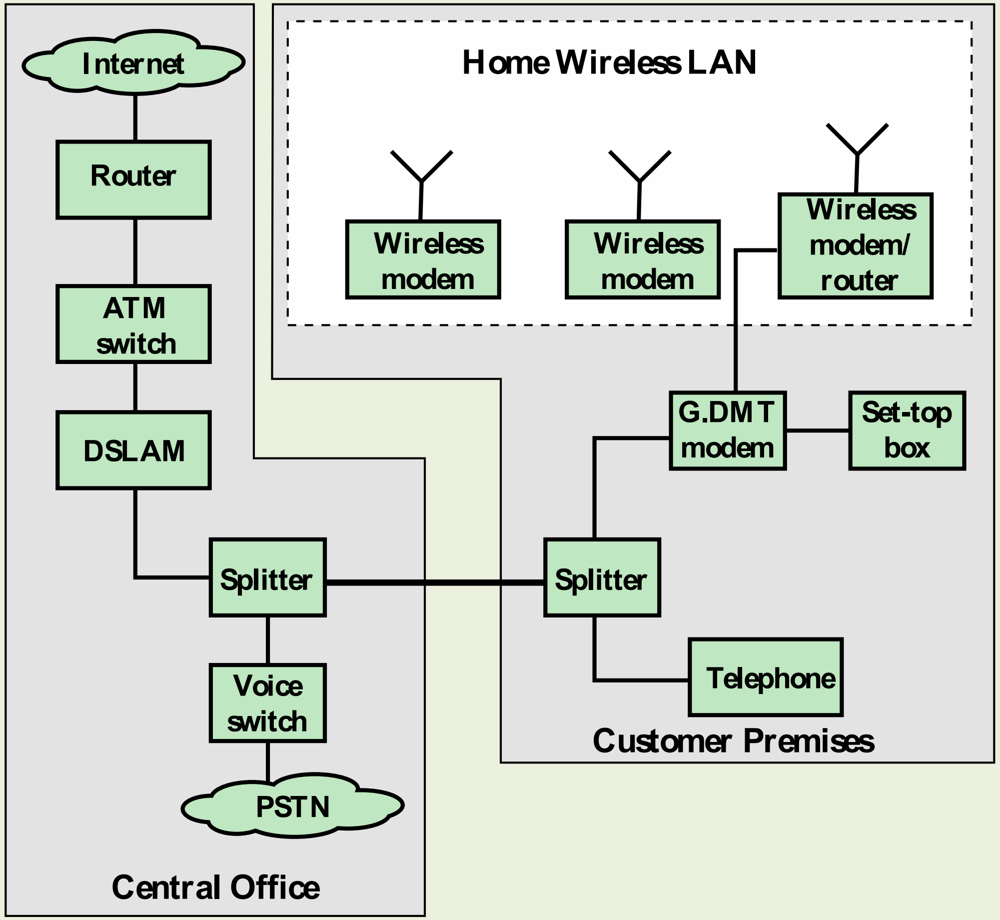


Figure 8.16 DMT Transmitter



ATM = Asynchronous Transfer Mode
DSLAM = Digital Subscriber Line Access Multiplexer
PSTN = Public Switched Telephone Network
G.DMT = G.992.1 Discrete Multitone

Figure 8.17 DSL Broadband Access

Table 8.6
Comparison of xDSL Alternatives

	ADSL	HDSL	SDSL	VDSL
Data rate	1.5 to 9 Mbps downstream 16 to 640 kbps upstream	1.544 or 2.048 Mbps	1.544 or 2.048 Mbps	13 to 52 Mbps downstream 1.5 to 2.3 Mbps upstream
Mode	Asymmetric	Symmetric	Symmetric	Asymmetric
Copper pairs	1	2	1	1
Range (24-gauge UTP)	3.7 to 5.5 km	3.7 km	3.0 km	1.4 km
Signaling	Analog	Digital	Digital	Analog
Line code	CAP/DMT	2B1Q	2B1Q	DMT
Frequency	1 to 5 MHz	196 kHz	196 kHz	$\geq$ 10 MHz
Bits/cycle	Varies	4	4	Varies

UTP = unshielded twisted pair

WLAN

- IEEE 802.11
- ”Trådlöst Ethernet”
- Tre konfigurationsprinciper

System med en accesspunkt

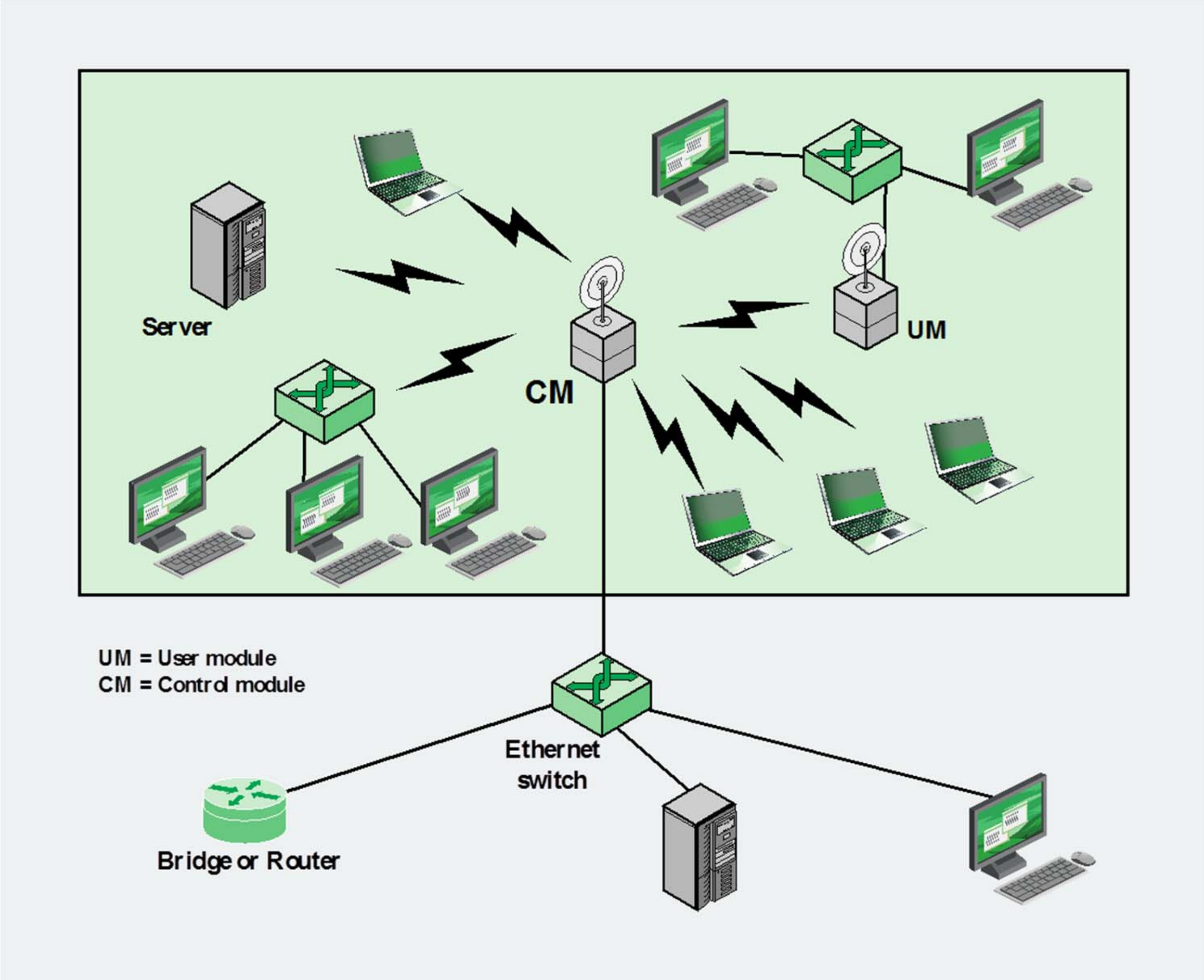


Figure 13.1 Example Single-Cell Wireless LAN Configuration

System med flera accesspunkter

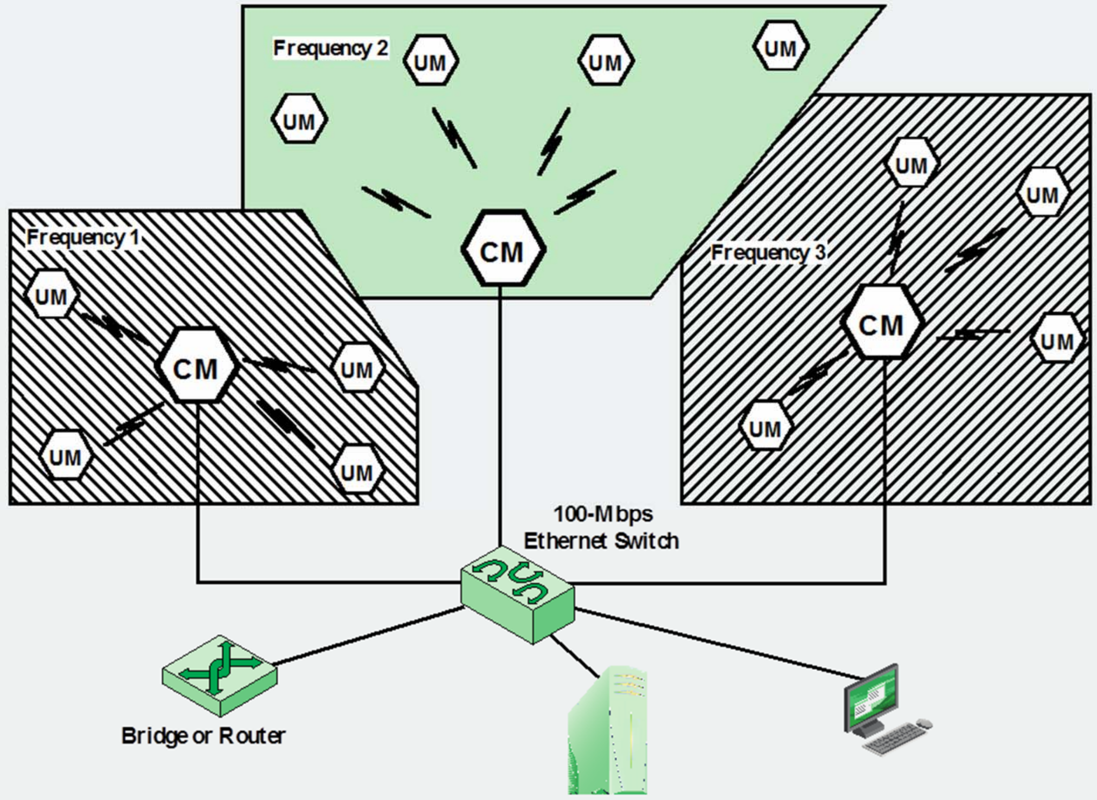


Figure 13.2 Example Multiple-Cell Wireless LAN Configuration

Ad Hoc (ingen accesspunkt)

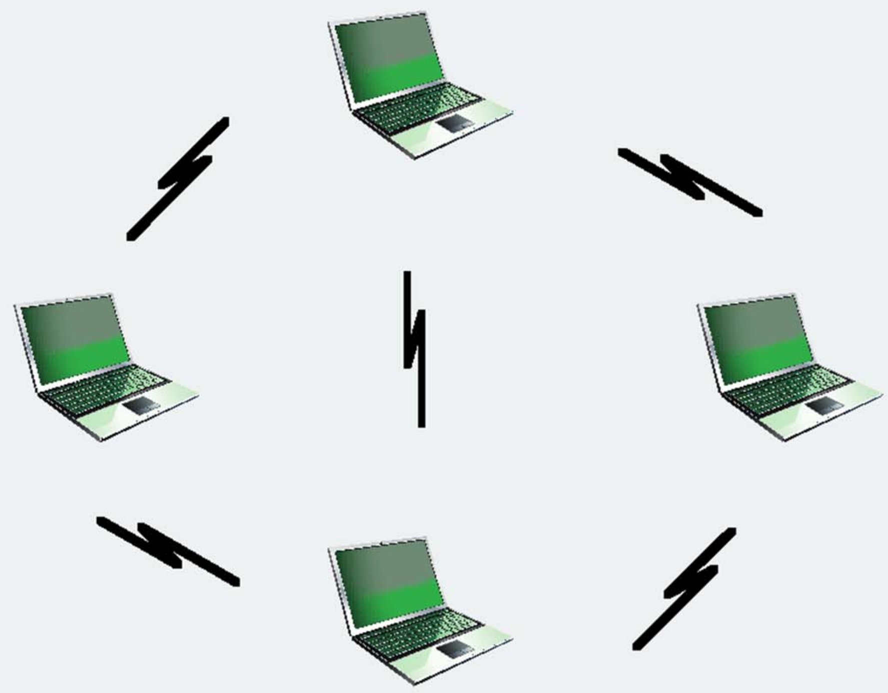


Figure 13.3 Ad Hoc Wireless LAN Configuration

Wireless LAN Requirements

- Throughput
- Number of nodes
- Connection to backbone LAN
- Service area
- Battery power consumption
- Transmission robustness and security
- Collocated network operation
- License-free operation
- Handoff/roaming
- Dynamic configuration

Wi-Fi Alliance

- There is always a concern whether products from different vendors will successfully interoperate
- Wireless Ethernet Compatibility Alliance (WECA)
  - Industry consortium formed in 1999
- Renamed the Wi-Fi (Wireless Fidelity) Alliance
  - Created a test suite to certify interoperability for 802.11 products

Table 13.1
Key IEEE 802.11 Standards

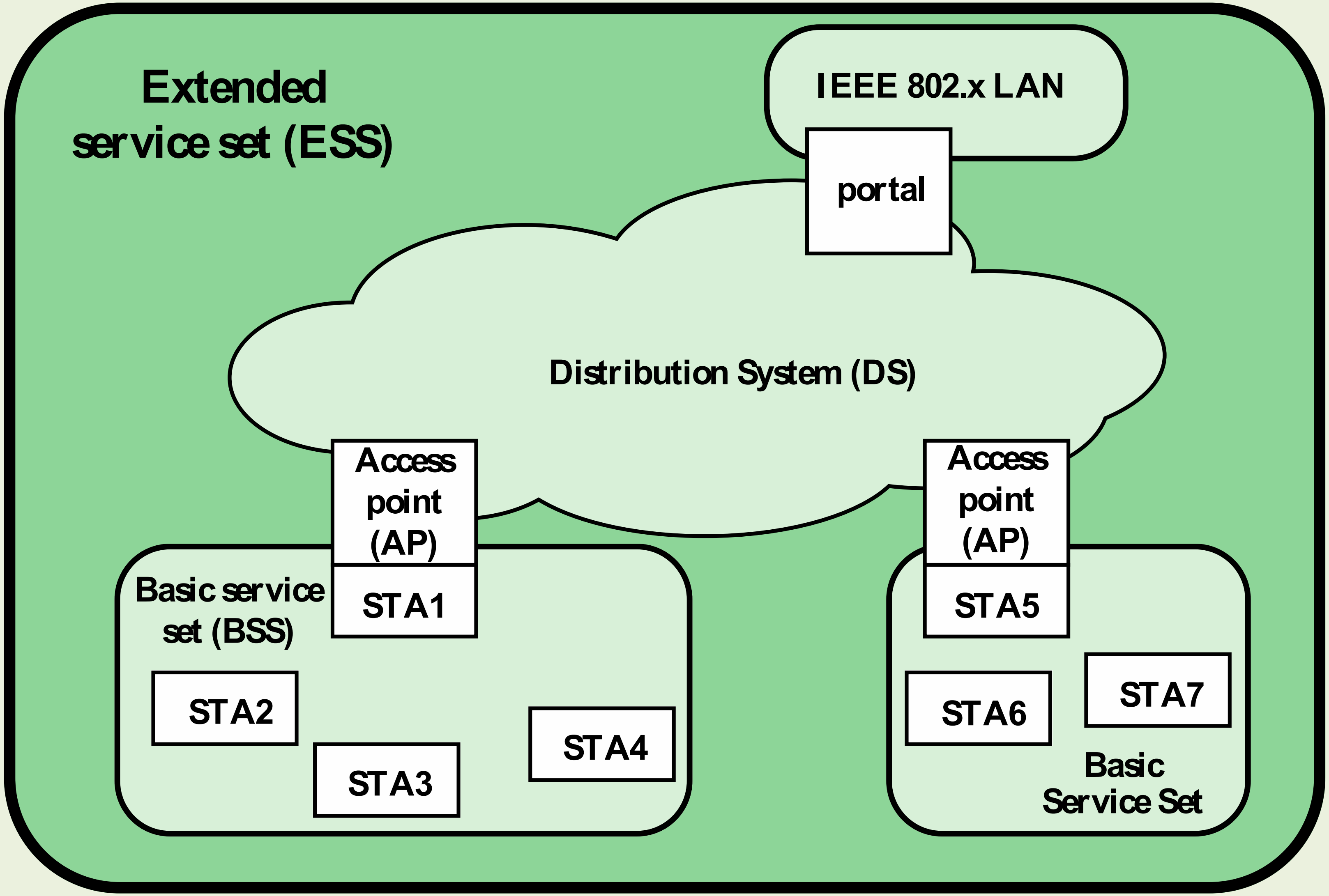
Standard	Scope
IEEE 802.11a	Physical layer: 5-GHz OFDM at rates from 6 to 54 Mbps
IEEE 802.11b	Physical layer: 2.4-GHz DSSS at 5.5 and 11 Mbps
IEEE 802.11c	Bridge operation at 802.11 MAC layer
IEEE 802.11d	Physical layer: Extend operation of 802.11 WLANs to new regulatory domains (countries)
IEEE 802.11e	MAC: Enhance to improve quality of service and enhance security mechanisms
IEEE 802.11g	Physical layer: Extend 802.11b to data rates >20 Mbps
IEEE 802.11i	MAC: Enhance security and authentication mechanisms
IEEE 802.11n	Physical/MAC: Enhancements to enable higher throughput
IEEE 802.11T	Recommended practice for the evaluation of 802.11 wireless performance
IEEE 802.11ac	Physical/MAC: Enhancements to support 0.5-1 Gbps in 5-GHz band
IEEE 802.11ad	Physical/MAC: Enhancements to support ≥ 1 Gbps in the 60-GHz band

(Table can be found on page 424 in the textbook)

Table 13.2
IEEE 802.11 Terminology

Access point (AP)	Any entity that has station functionality and provides access to the distribution system via the wireless medium for associated stations
Basic service set (BSS)	A set of stations controlled by a single coordination function
Coordination function	The logical function that determines when a station operating within a BSS is permitted to transmit and may be able to receive PDUs
Distribution system (DS)	A system used to interconnect a set of BSSs and integrated LANs to create an ESS
Extended service set (ESS)	A set of one or more interconnected BSSs and integrated LANs that appear as a single BSS to the LLC layer at any station associated with one of these BSSs
Frame	Synonym for MAC protocol data unit
MAC protocol data unit (MPDU)	The unit of data exchanged between two peer MAC entities using the services of the physical layer
MAC service data unit (MSDU)	Information that is delivered as a unit between MAC users
Station	Any device that contains an IEEE 802.11 conformant MAC and physical layer

(Table can be found on page 424 in the textbook)



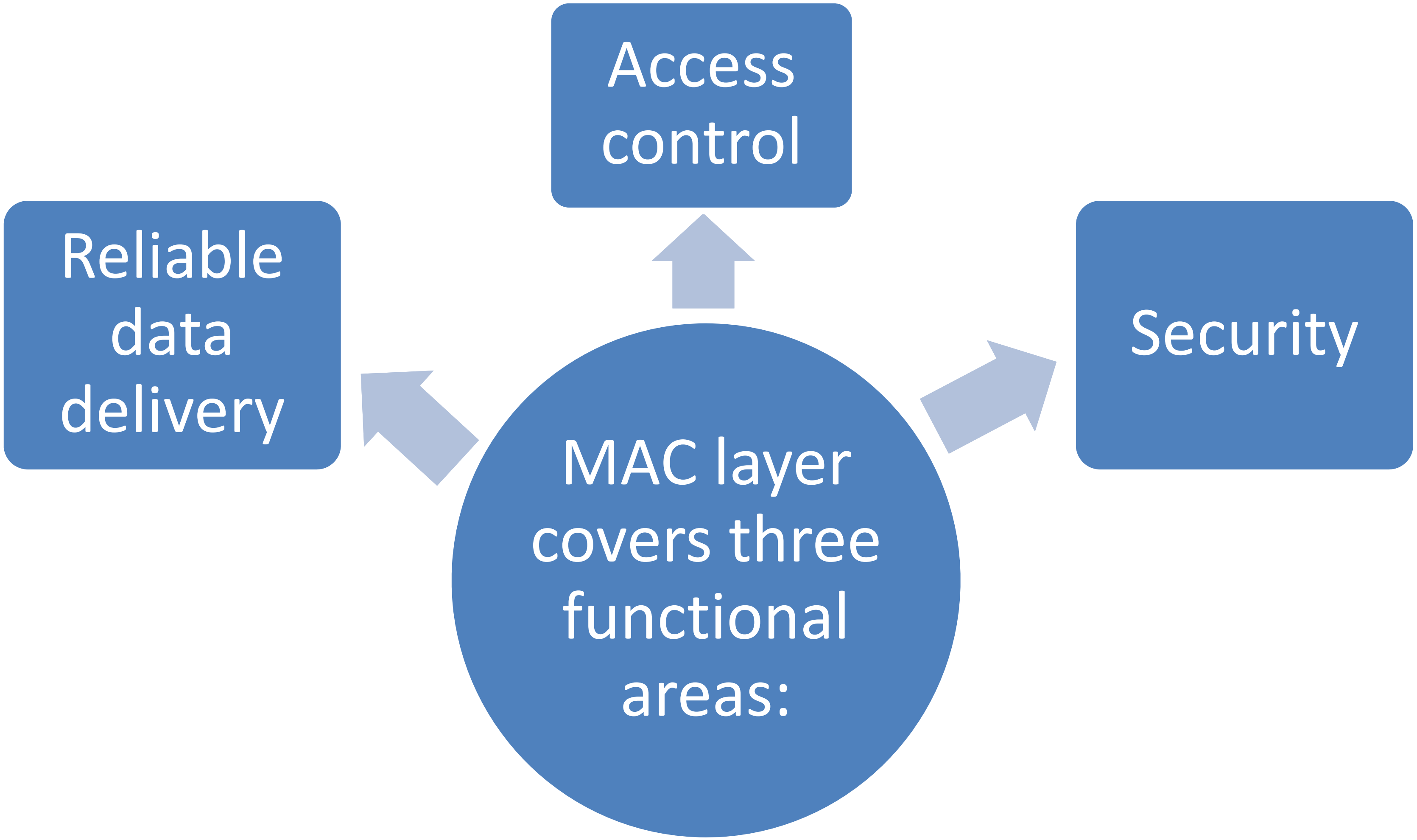
STA = station

Figure 13.4 IEEE 802.11 Architecture

Table 13.3
IEEE 802.11 Services

Service	Provider	Used to support
Association	Distribution system	MSDU delivery
Authentication	Station	LAN access and security
Deauthentication	Station	LAN access and security
Dissassociation	Distribution system	MSDU delivery
Distribution	Distribution system	MSDU delivery
Integration	Distribution system	MSDU delivery
MSDU delivery	Station	MSDU delivery
Privacy	Station	LAN access and security
Reassocation	Distribution system	MSDU delivery

Medium Access Control

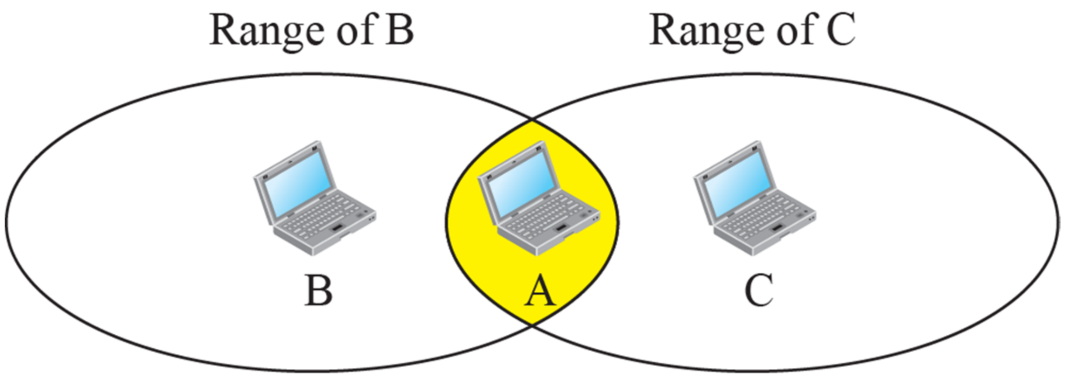


Reliable Data Delivery

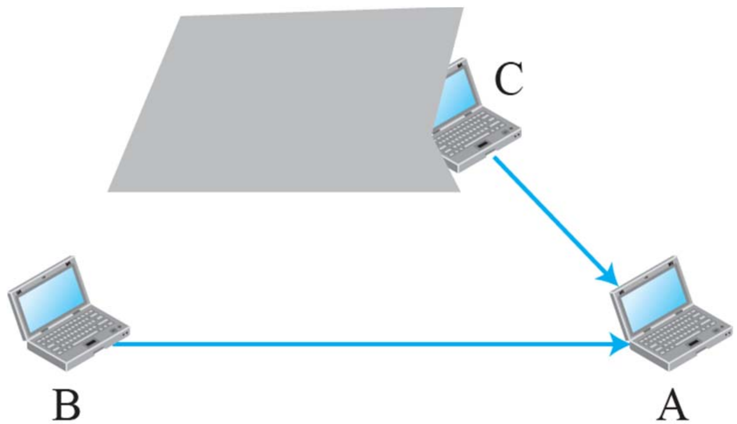
- Can be dealt with at a higher layer
- More efficient to deal with errors at MAC level
- 802.11 includes frame exchange protocol
  - Station receiving frame returns acknowledgment (ACK) frame
  - Exchangetreated as atomic unit
  - If no ACK within short period of time, retransmit

- 802.11 physical and MAC layers unreliable
  - Noise, interference, and other propagation effects result in loss of frames
  - Even with error-correction codes, frames may not successfully be received

Hidden Node/Station Problem



a. Stations B and C are not in each other's range.

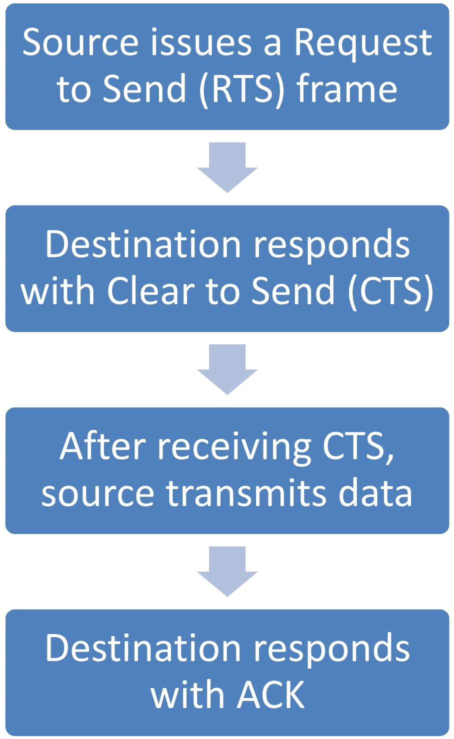


b. Stations B and C are hidden from each other.

Four Frame Exchange

- RTS alerts all stations within range of source that exchange is under way
- CTS alerts all stations within range of destination
- Other stations don't transmit to avoid collision
- RTS/CTS exchange is a required function of MAC but may be disabled

- Can use four-frame exchange for better reliability



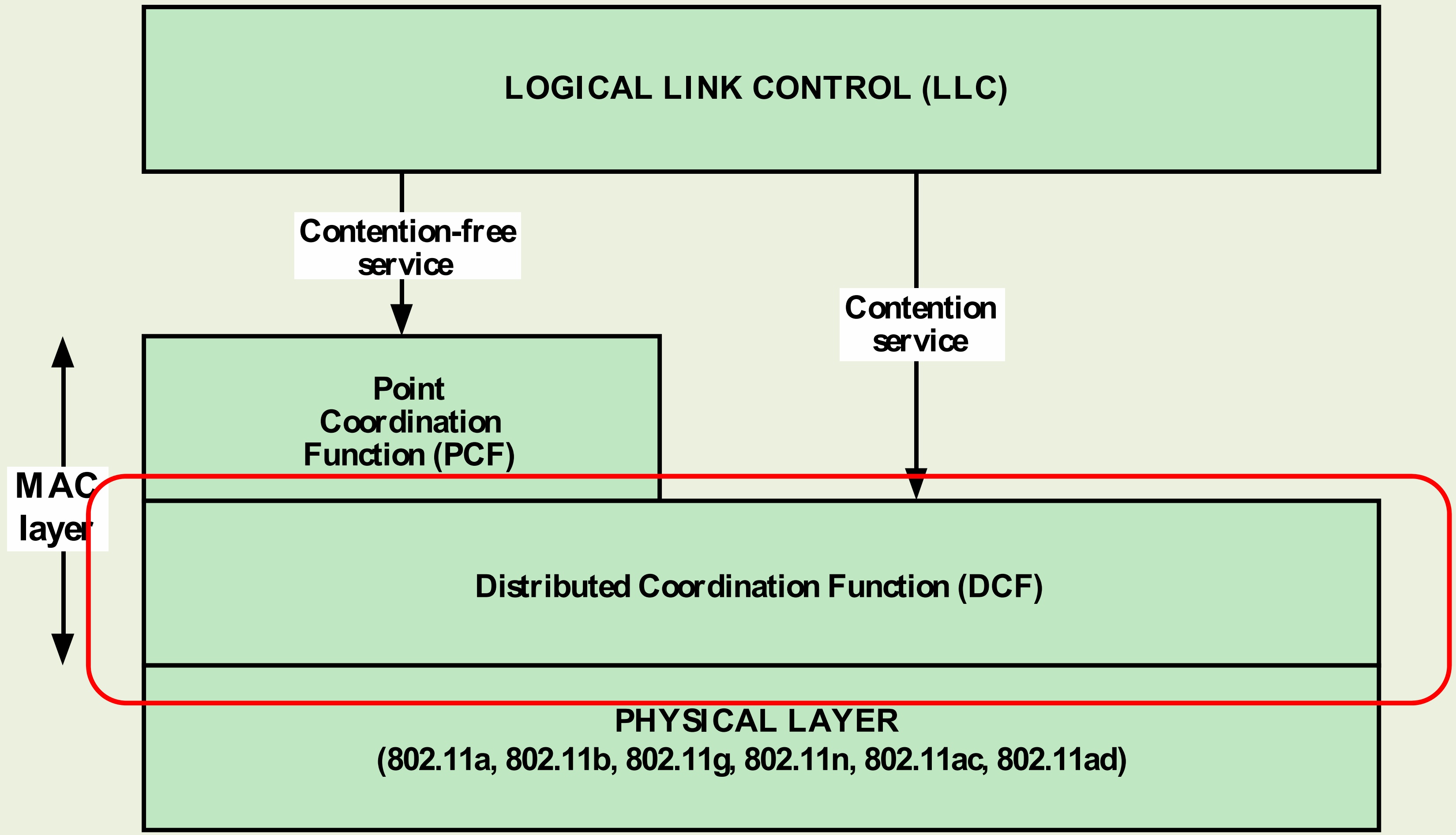
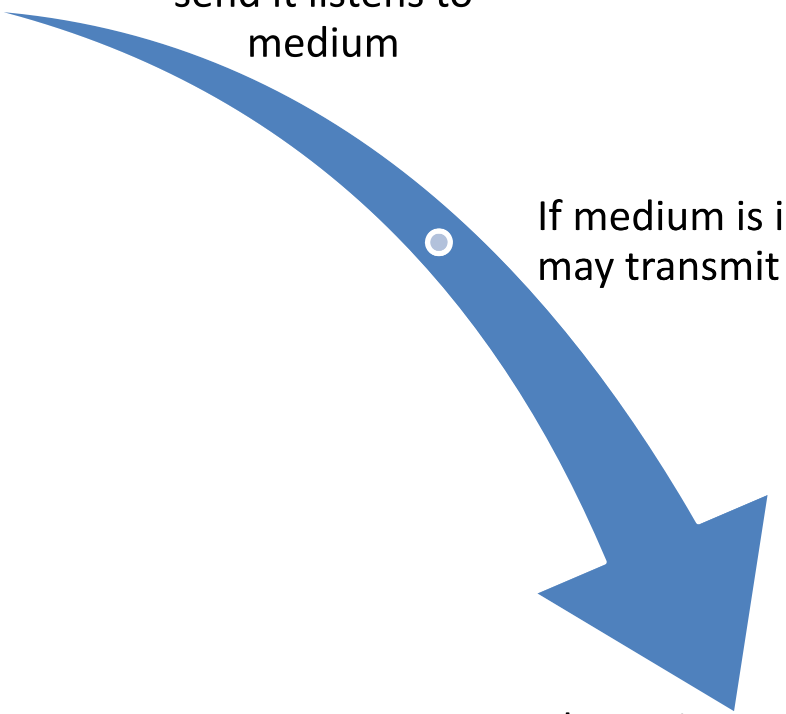


Figure 13.5 IEEE 802.11 Protocol Architecture

Distributed Coordination Function (DCF)

- DCF sublayer uses CSMA algorithm
- Does not include a collision detection function because it is not practical on a wireless network
- Includes a set of delays that amounts as a priority scheme



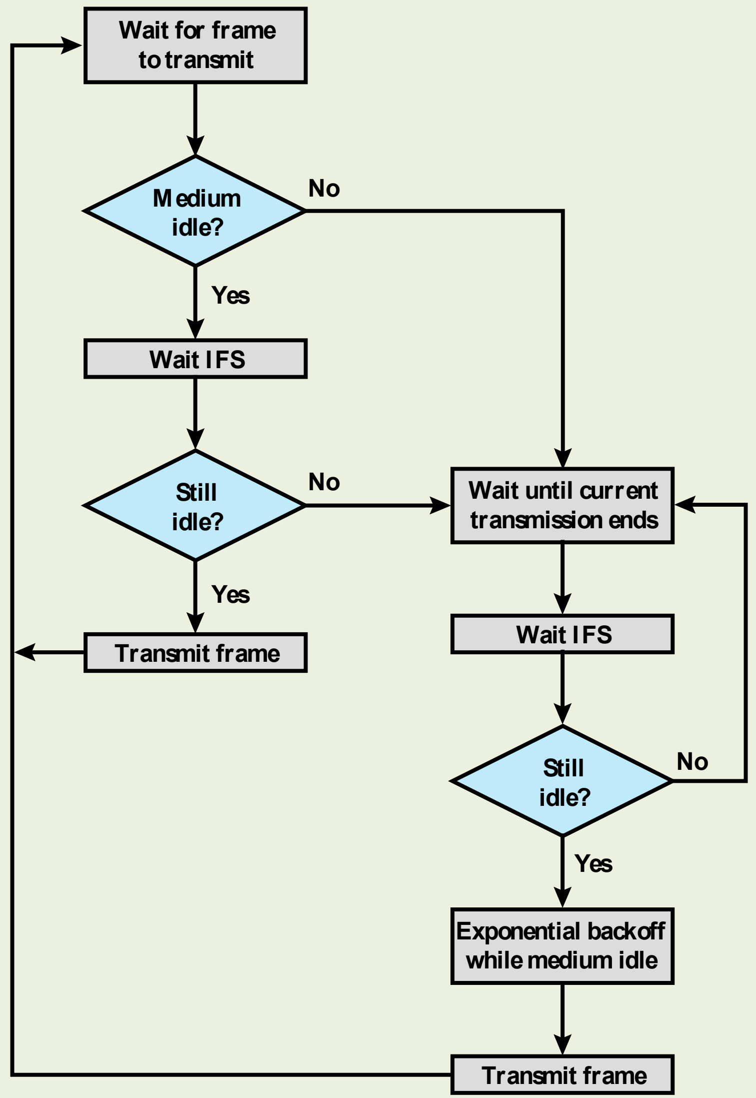


Figure 13.6 IEEE 802.11 Medium Access Control Logic

Priority IFS Values

SIFS
(short IFS)

For all immediate response actions

PIFS
(point coordination function IFS)

Used by the centralized controller in PCF scheme when issuing polls

DIFS
(distributed coordination function IFS)

Used as minimum delay for asynchronous frames contending for access

Point Coordination Function (PCF)

Alternative access method implemented on top of DCF

Polling by centralized polling master (point coordinator)

Uses PIFS when issuing polls

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 poll

Coordinator could lock out asynchronous traffic by issuing polls

Have a superframe interval defined

802.11 MAC ramformat

Två ramtyper

- Kontroll
- Data
- *Management*

Notera fyra adressfält!

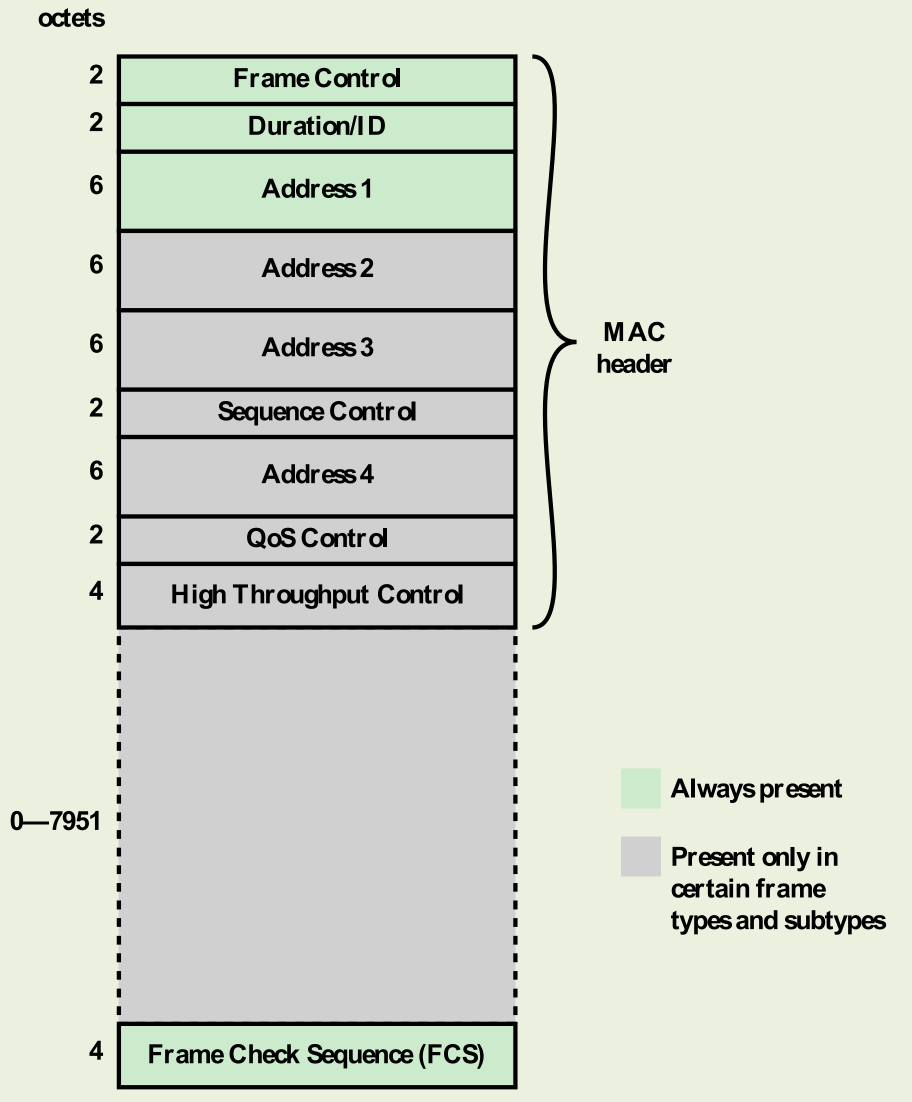


Figure 13.8 IEEE 802.11 MAC Frame Format

Table 13.4
IEEE 802.11 Physical Layer Standards

Standard	802.11a	802.11b	802.11g	802.11n	802.11ac	802.11ad
Year introduced	1999	1999	2003	2000	2012	2014
Maximum data transfer speed	54 Mbps	11 Mbps	54 Mbps	65 to 600 Mbps	78 Mbps to 3.2 Gbps	6.76 Gbps
Frequency band	5 GHz	2.4 GHz	2.4 GHz	2.4 or 5 GHz	5 GHz	60 GHz
Channel bandwidth	20 MHz	20 MHz	20 MHz	20, 40 MHz	40, 80, 160 MHz	2160 MHz
Highest order modulation	64 QAM	11 CCK	64 QAM	64 QAM	256 QAM	64 QAM
Spectrum usage	DSSS	OFDM	DSSS, OFDM	OFDM	SC-OFDM	SC, OFDM
Antenna configuration	1×1 SISO	1×1 SISO	1×1 SISO	Up to 4×4 MIMO	Up to 8×8 MIMO, MU-MIMO	1×1 SISO

(Table is on page 436 in textbook)

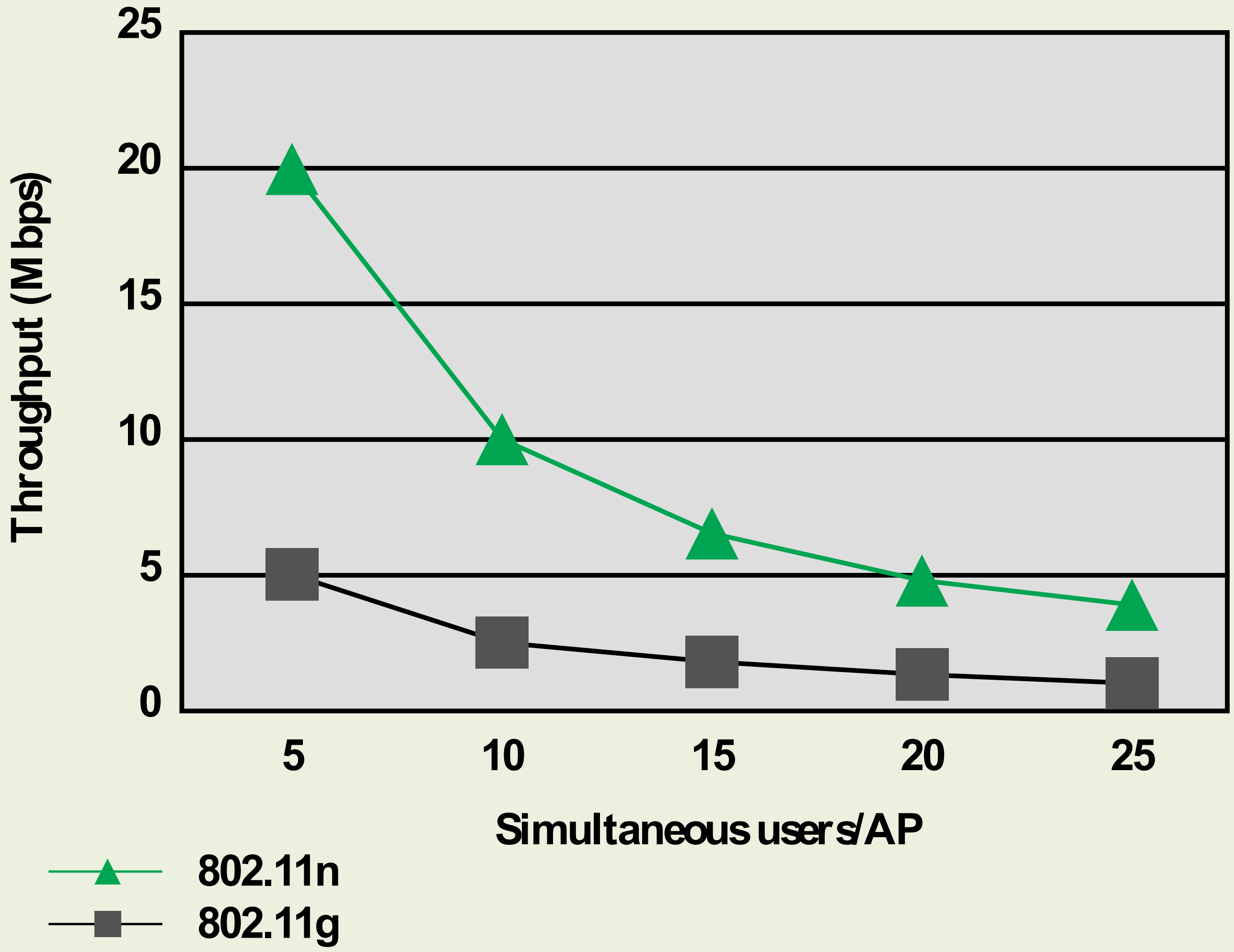


Figure 13.12 Average Throughput per User

Access and Privacy Services Deauthentication and Privacy

- Privacy
  - Used to prevent messages being read by others
  - 802.11 allows optional use of encryption
- Original WEP security features were weak
- Subsequently 802.11i and WPA alternatives evolved giving better security
- Deauthentication
  - Invoked whenever an existing authentication is to be terminated