Dator- och telekommunikation

(ETS601)

Höstterminen 2023

”*Kort sammanfattning*”

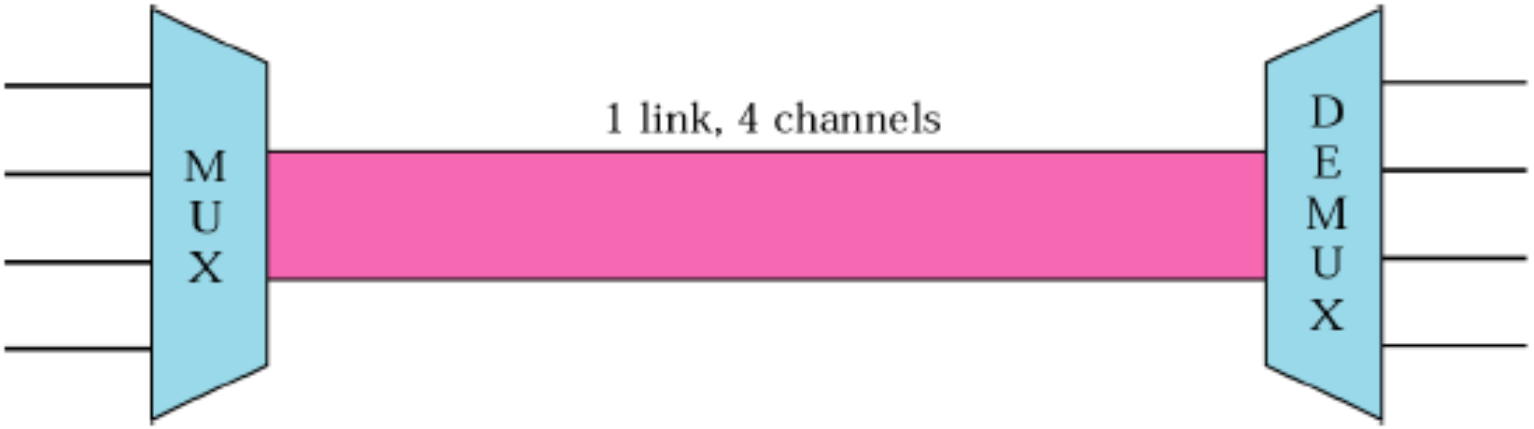
- Föreläsningar
- Övningar
- Laborationer

OSI-modellen

Applikation	Program som interagera med användaren; epost, www
Presentation	Kryptering, komprimering, teckensnitt, färger
Session	Kommunikationssamordning Sessioner ~ uppkoppling
Transport	TCP, UDP Ankomstkontroll *(segment)*
Nätverk	Vägval, virtuella vägar, IP *(paket)*
(Data)Länk	Fel- och flödeskontroll på länknivå, MAC, LLC, PPP *(ramar)*
Fysisk	Kodning, signalnivåer *(bitar)*

Multiplexering allmän princip

- Flera signaler sänds samtidigt över samma länk



Multiplexering allmän princip

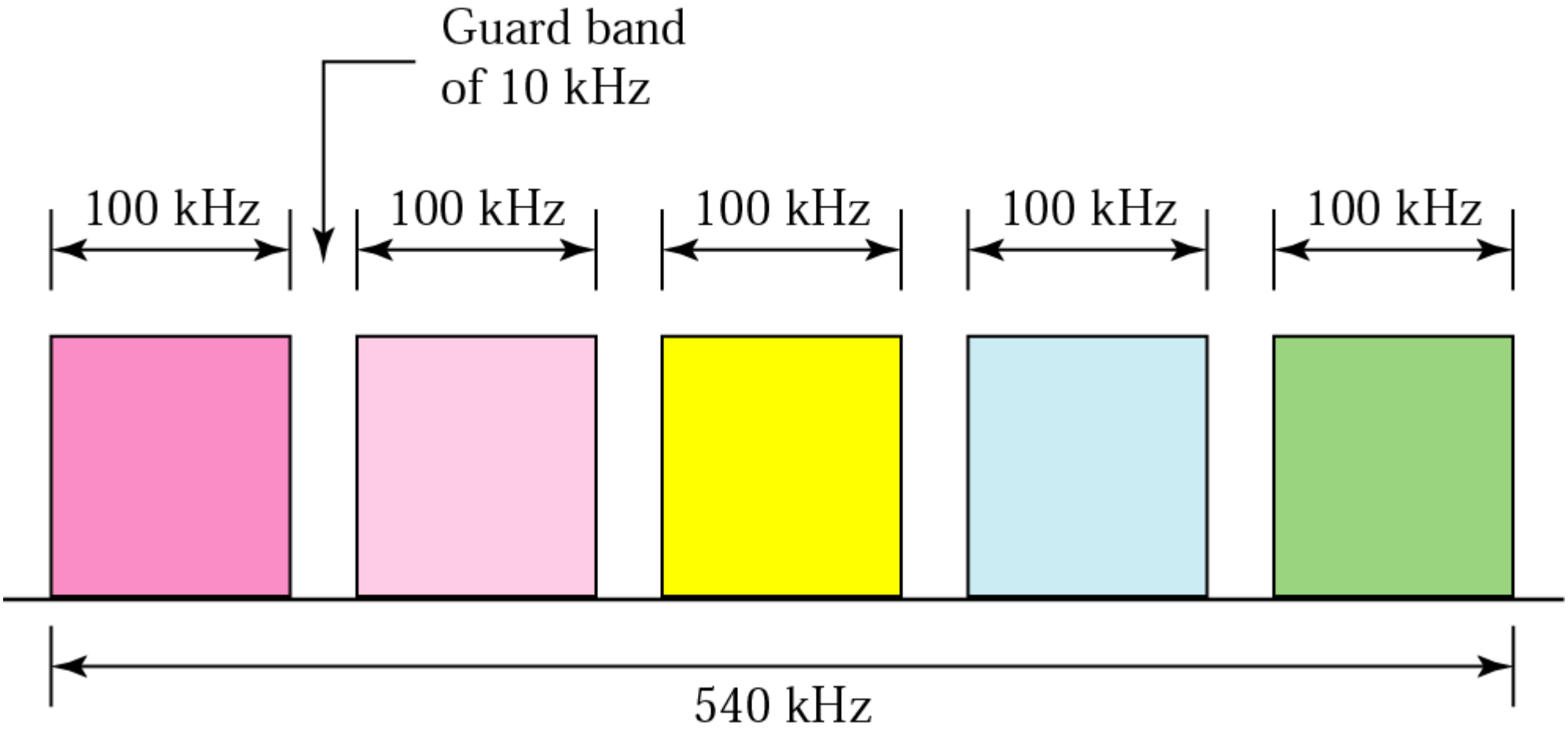
- En gemensam kanal delas på något av följande sätt
  - FDM (Frequency Division Multiplexing)
  - WDM (Wavelength Division Multiplexing)
  - TDM (Time Division Multiplexing)
  - CDM (Code Division Multiple Access)

Multiplexering FDM

- Kombination av signaler med olika frekvens

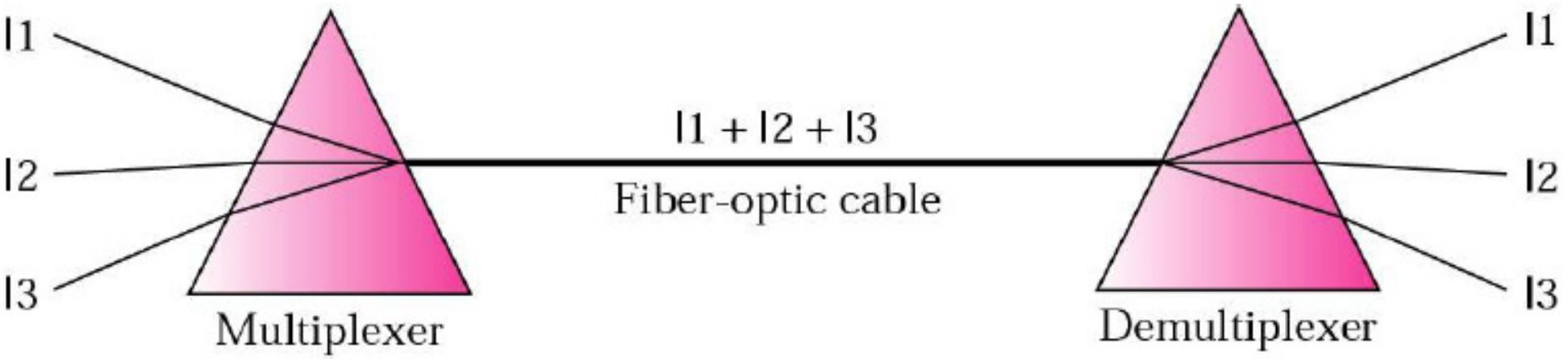
Multiplexering, FDM

- Exempel: Multiplexering av 5 signaler (bandbredd 100 kHz) med ”lucka” (guard band) på 10 kHz



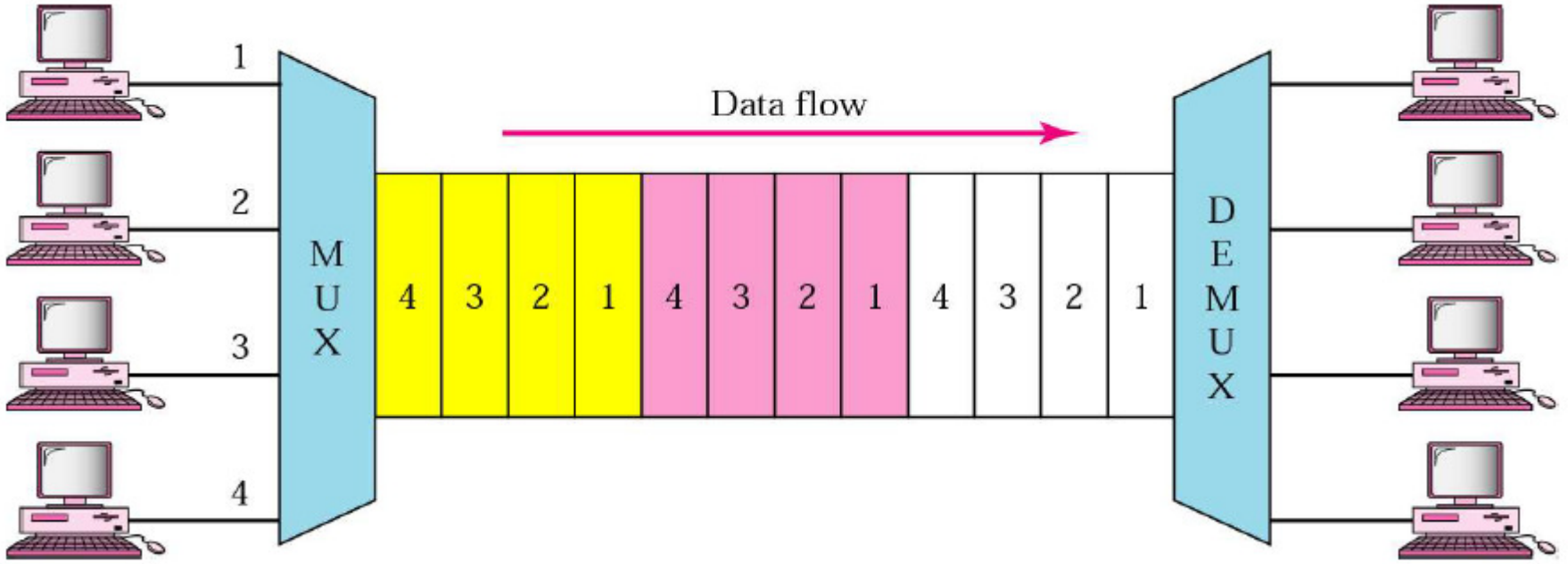
Multiplexing, WDM

- Användning av prismor för WDM



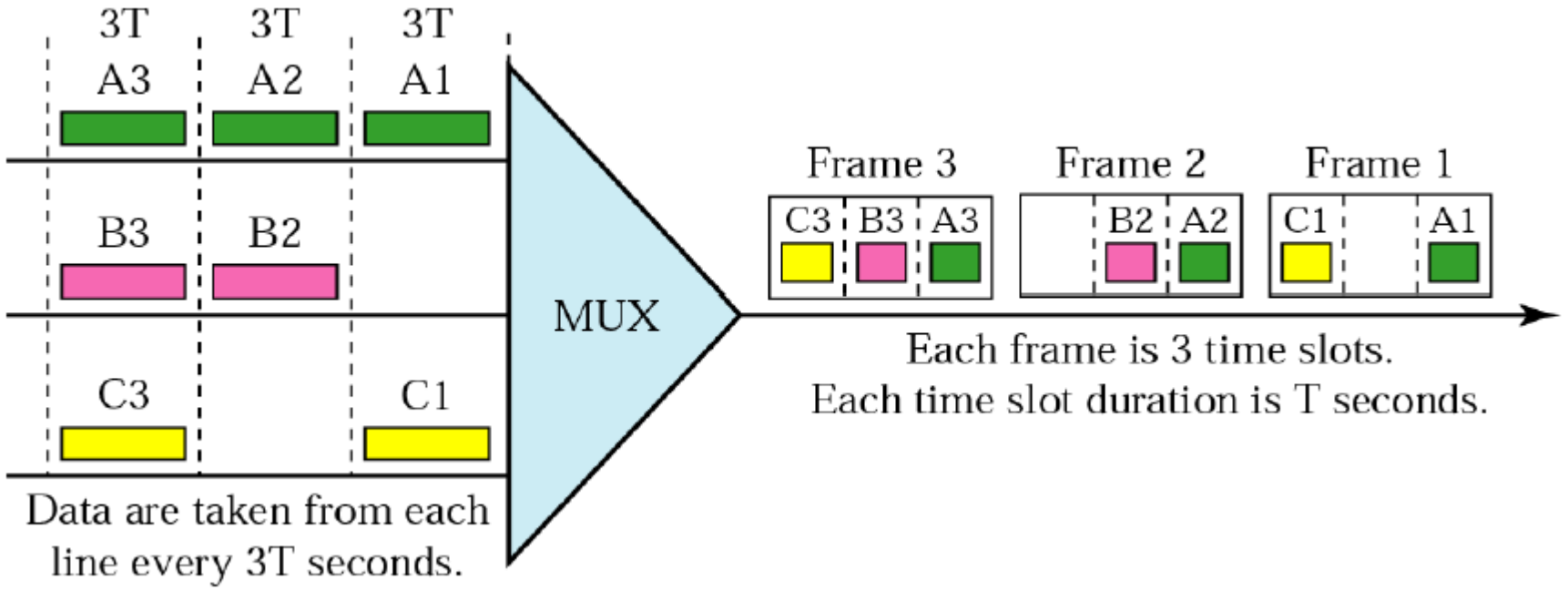
Multiplexing, TDM

- Time-Division Multiplexing (TDM) kombinerar flera digitala signaler så att de skickas tillsammans i snabb takt



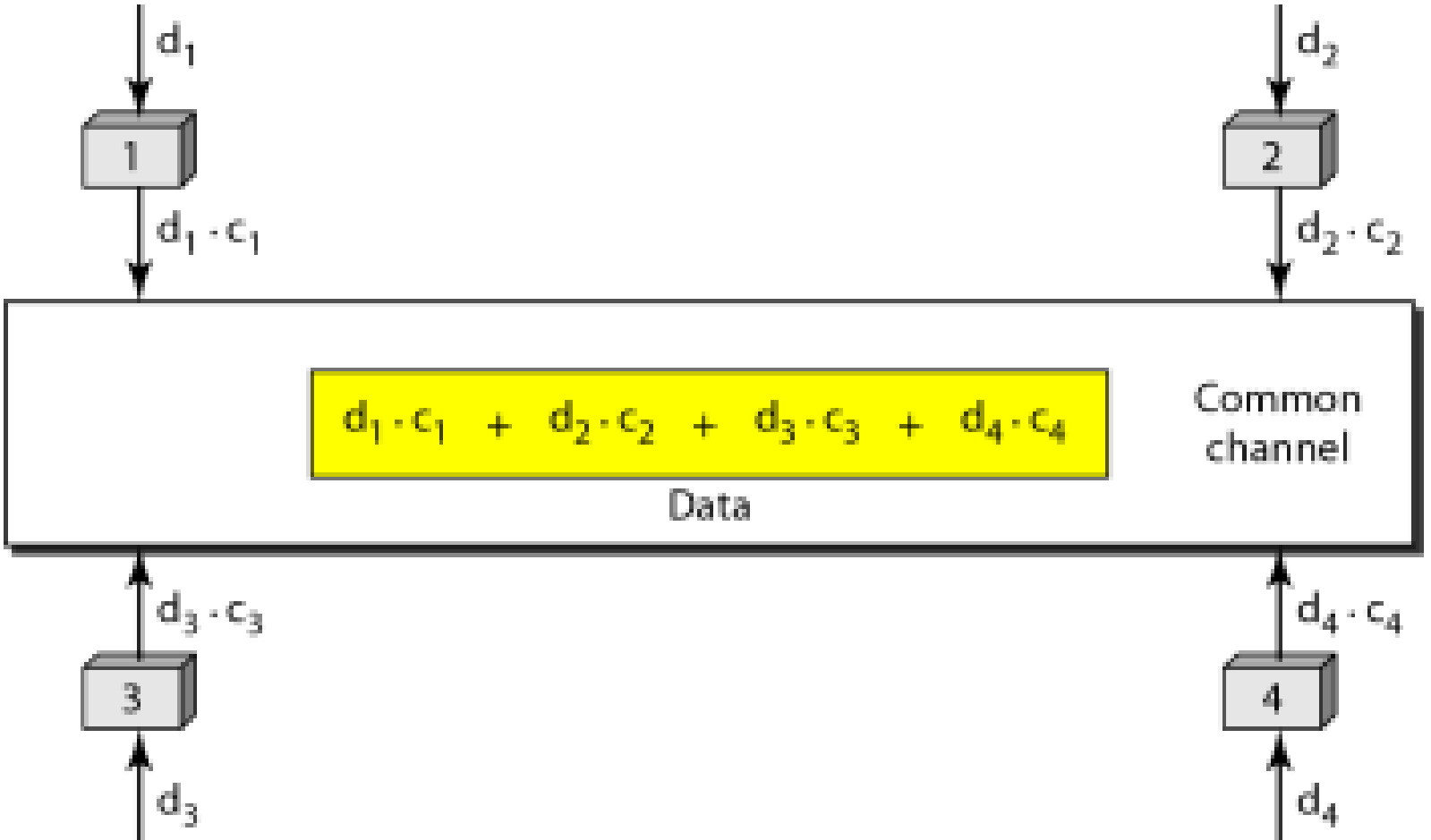
Multiplexing, TDM

- Varje ”tvärsnitt” skickas som en ram över länken fast *N* ggr så snabbt

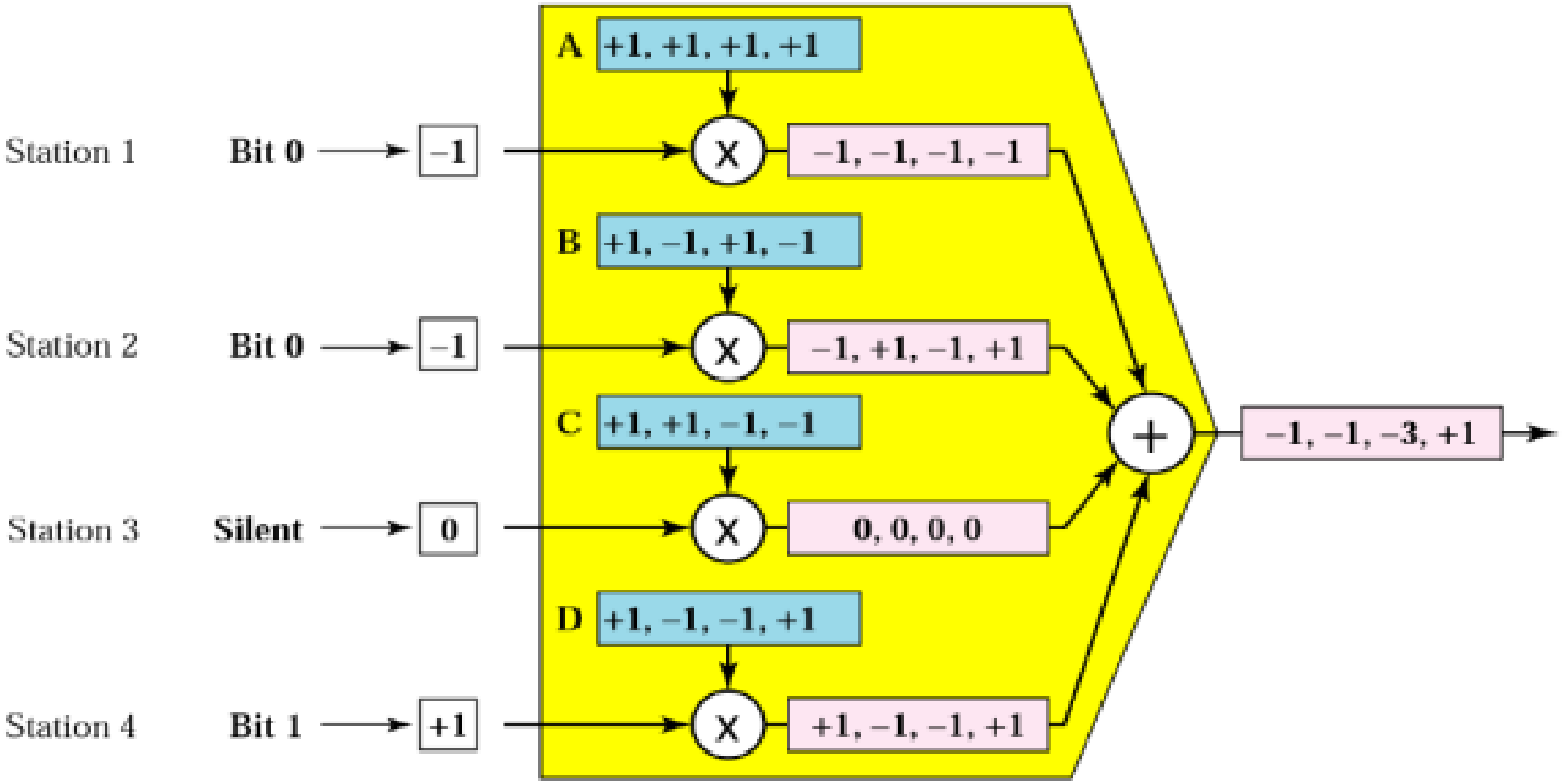


Multiplexering, CDM

- Varje sändare har en vektor c_i som är ortogonal mot alla andra sändares vektorer:
  Om $i \neq j$ så är $c_i \cdot c_j = 0$
  Dessutom gäller $c_i \cdot c_i = 1$
- Data som ska skickas av sändare i kallas d_i



Multiplexering, CDM



Multiplexering, CDM

- Raderna i en Walsh-matris är ortogonala mot varandra

$$W_1 = [+1] \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

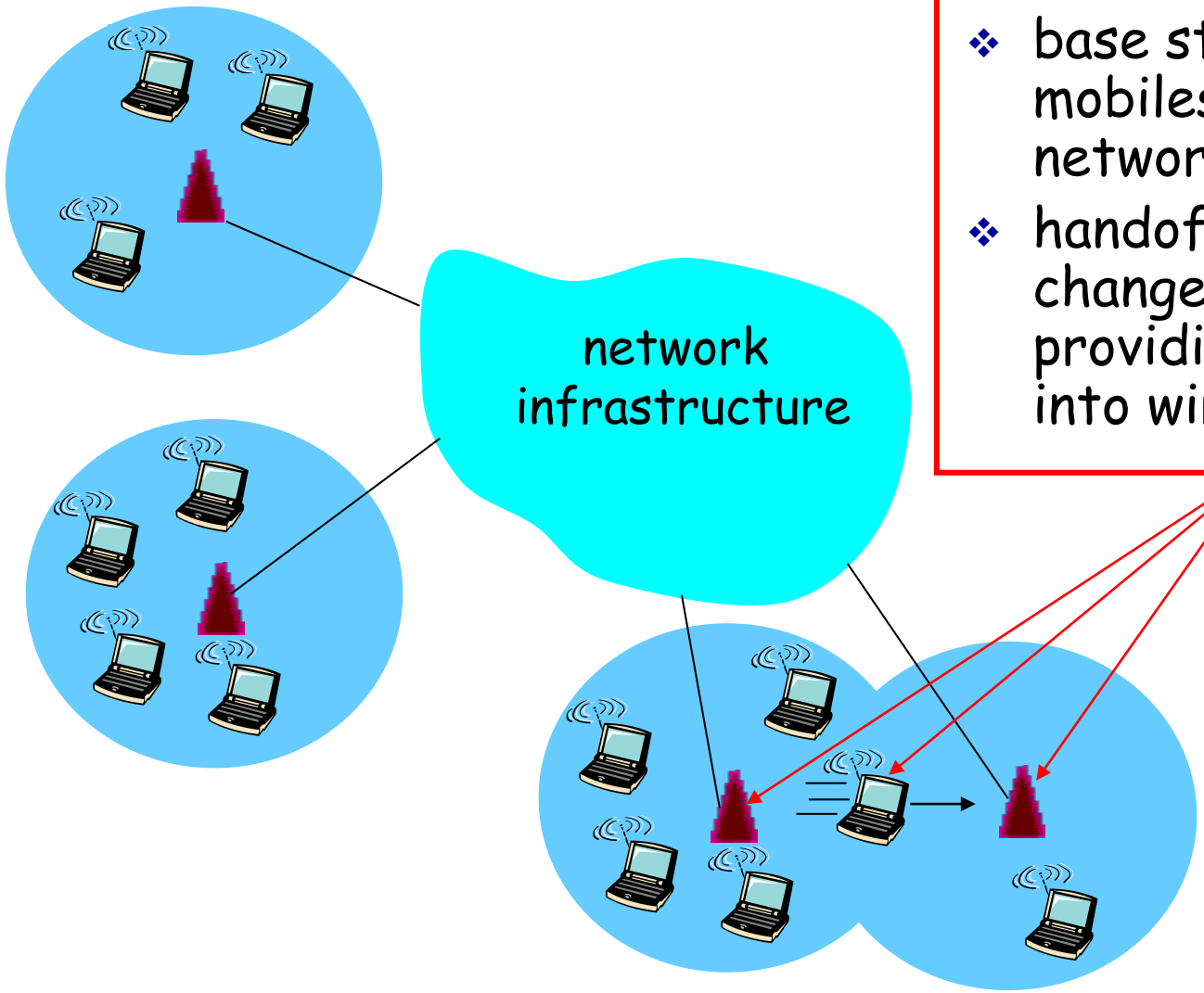
$$W_1 = [+1]$$

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_1, W_2, and W_4

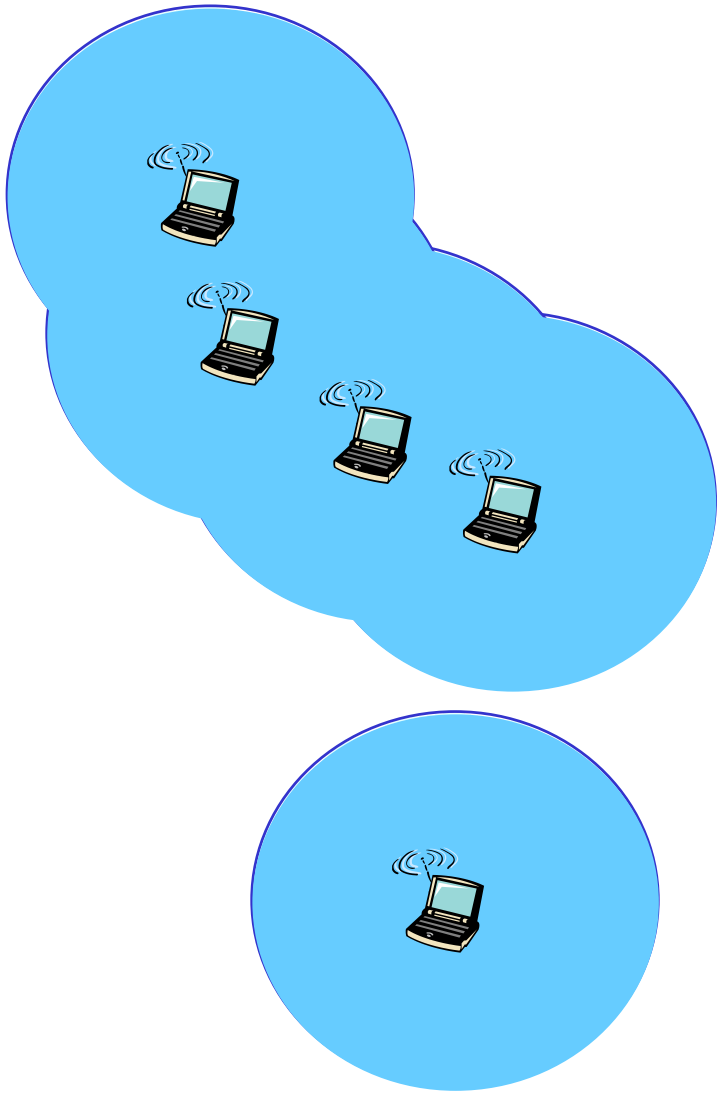
Elements of a wireless network



infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

Elements of a wireless network



ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

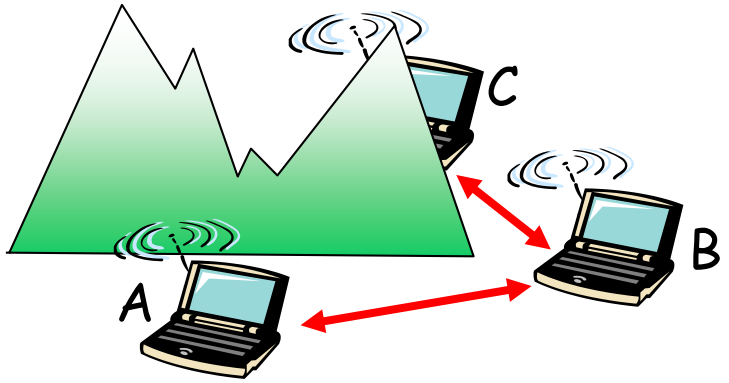
Wireless Link Characteristics

Differences from wired link ….

- decreased signal strength: radio signal attenuates fast
- interference from other sources: wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
- multipath propagation: radio signal reflects off objects ground, arriving to a destination at slightly different times

Wireless network characteristics

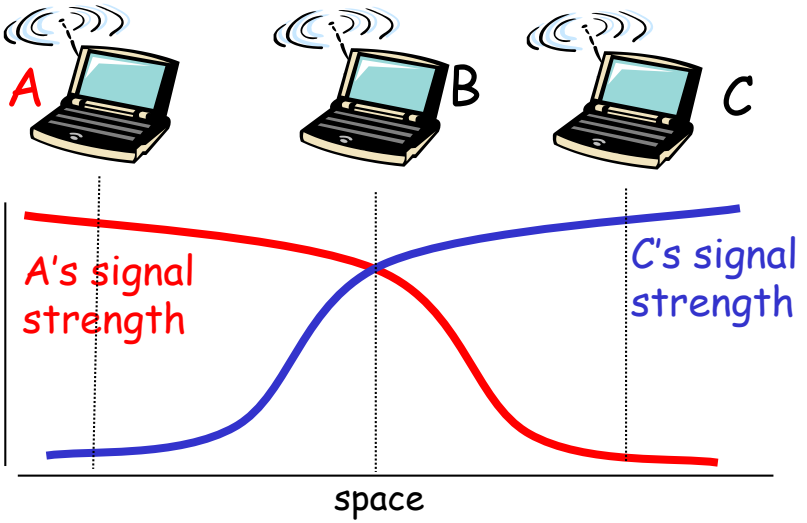
Additional problems:



Hidden terminal problem

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

means A, C unaware of their interference at B



Signal attenuation:

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

IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** then

transmit entire frame (no CD)

2 if sense channel busy then

start random backoff time

timer counts down while channel idle

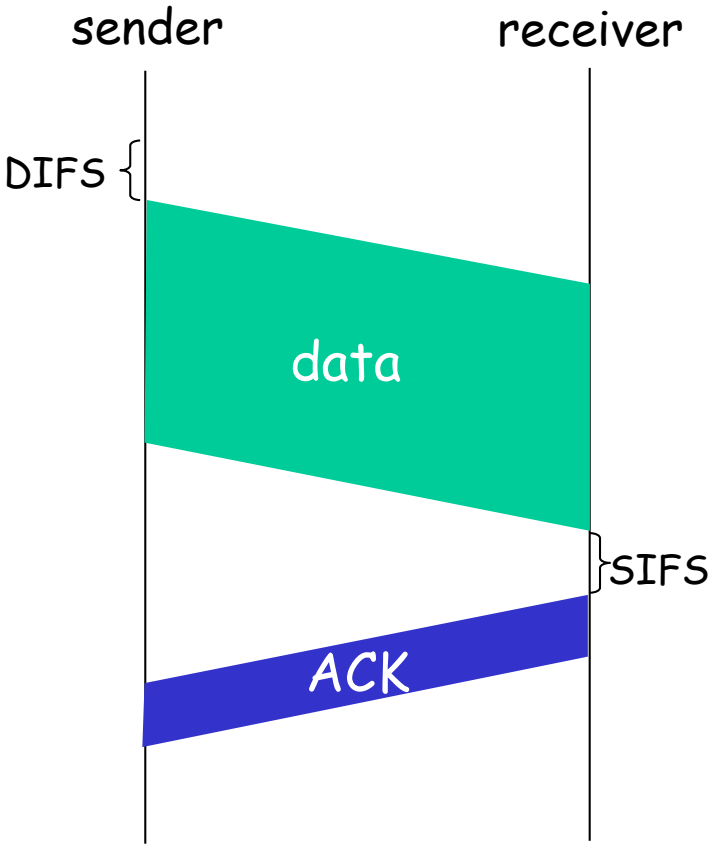
transmit when timer expires

if no ACK, increase random backoff interval, repeat 2

802.11 receiver

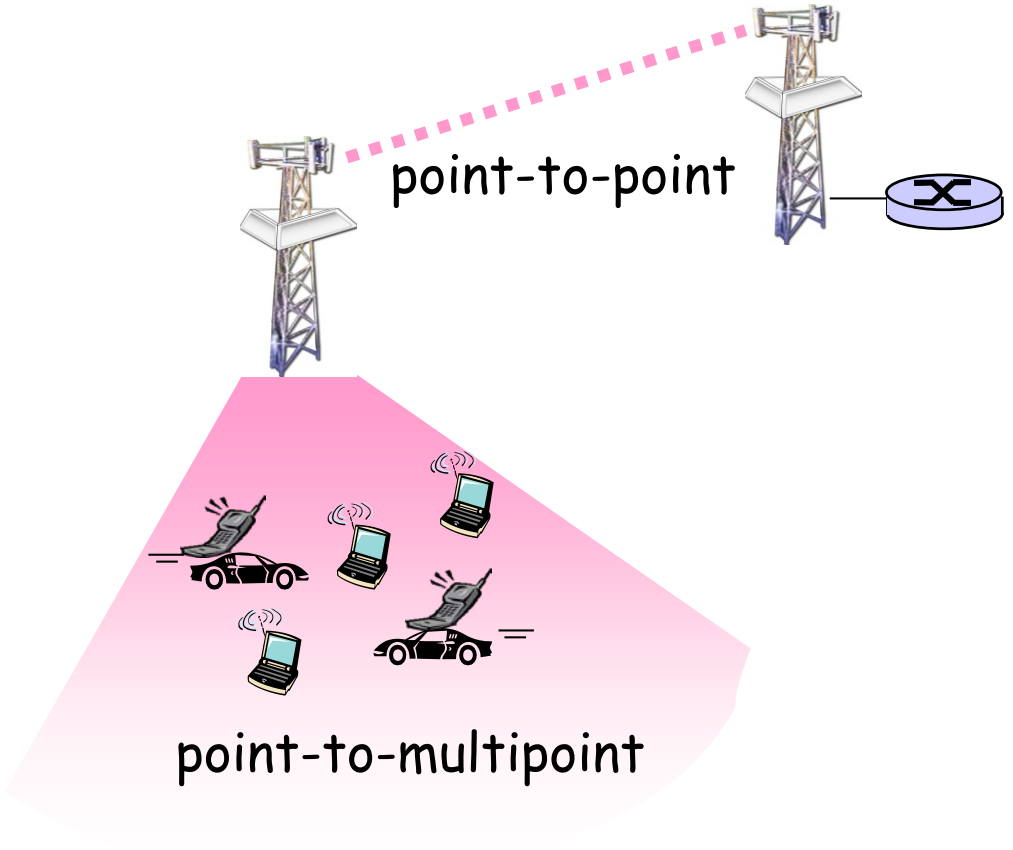
- if frame received OK

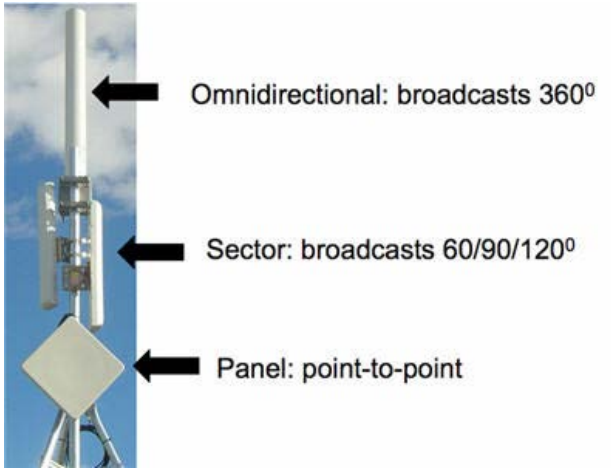
return ACK after **SIFS** (ACK needed due to hidden terminal problem)



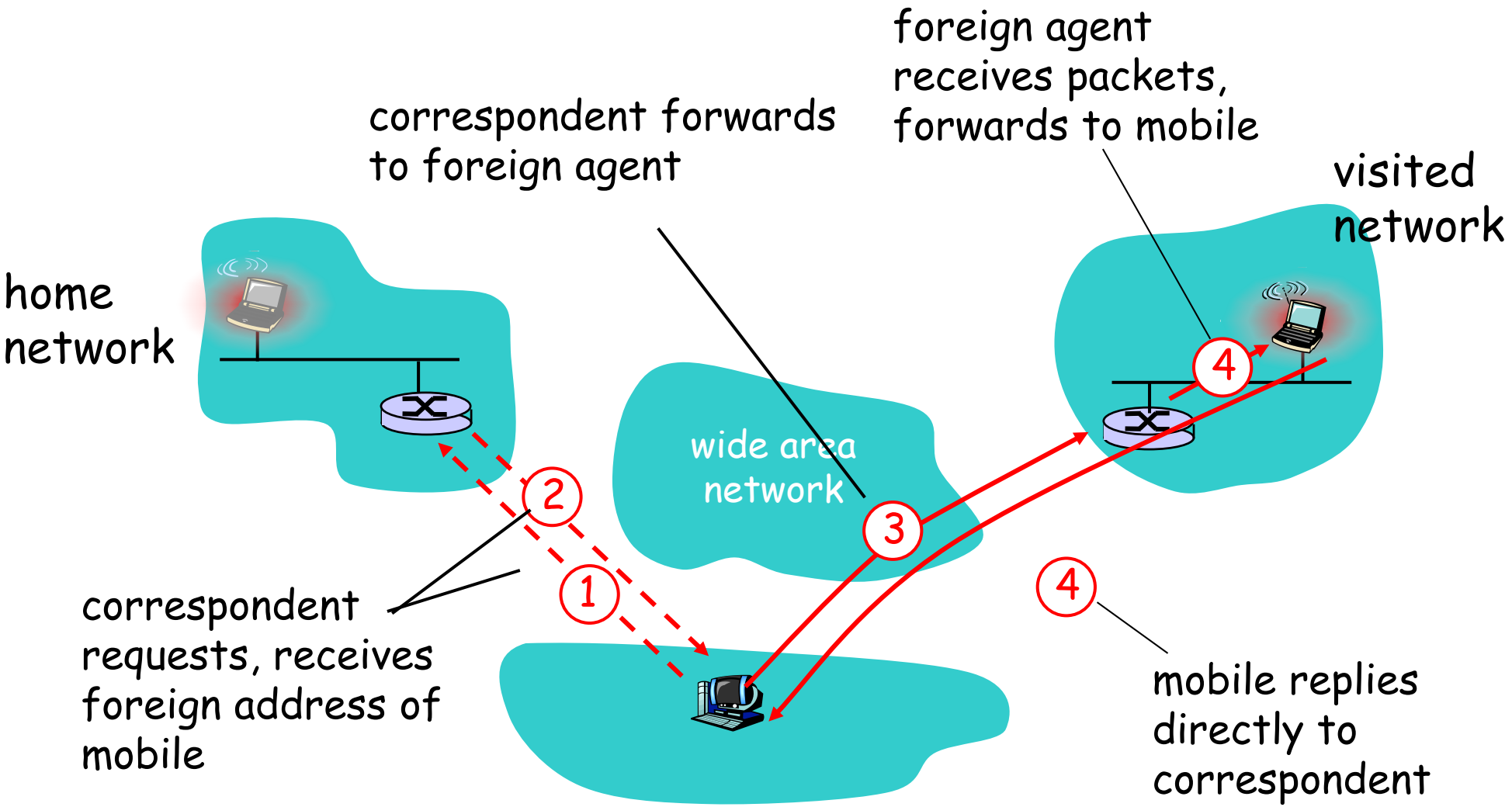
802.16: WiMAX

- like 802.11 & cellular: base station model
  - transmissions to/from base station by hosts with omnidirectional antenna
  - base station-to-base station backhaul with point-to-point antenna
- unlike 802.11:
  - range ~ 6 miles ("city rather than coffee shop")
  - ~14 Mbps





Mobility via Direct Routing



Mobile IP

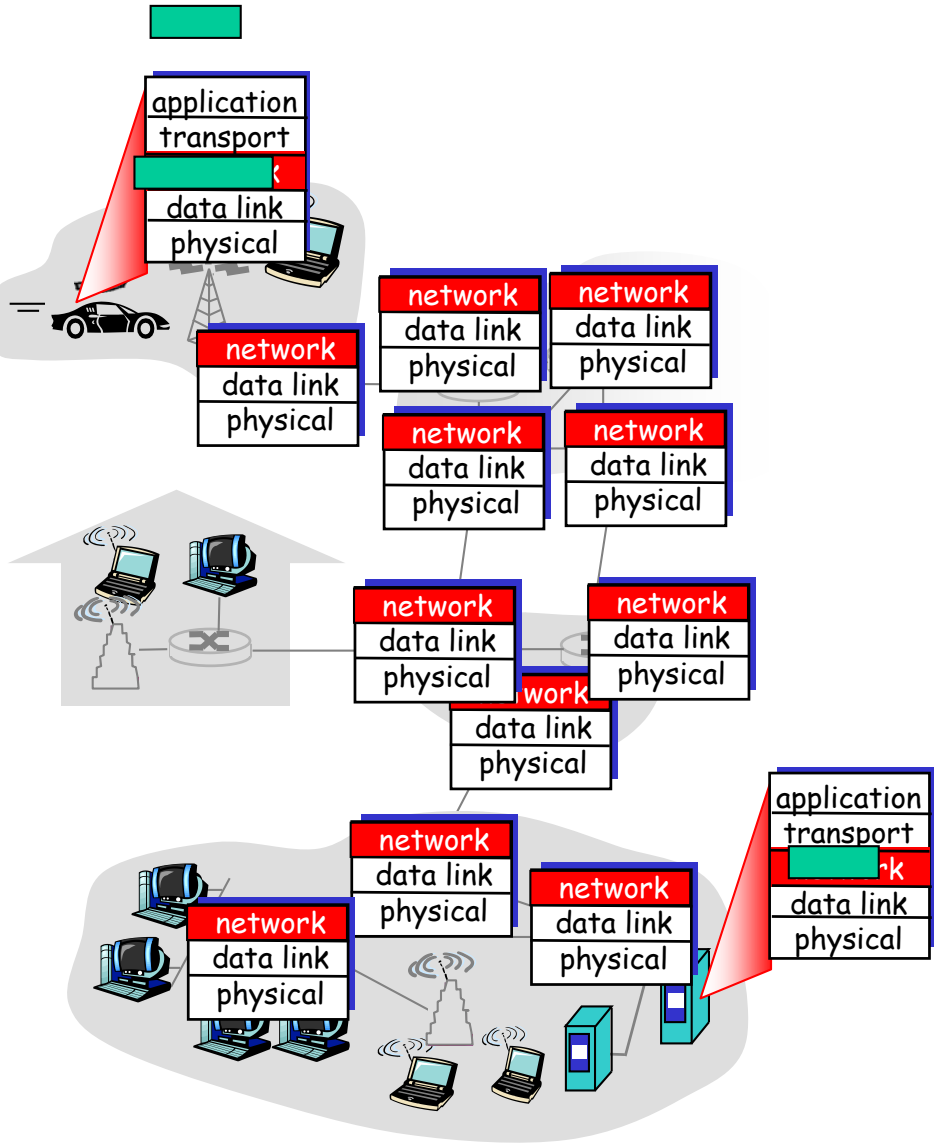
- RFC 3344
- has many features we've seen:
  - home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)
- three components to standard:
  - indirect routing of datagrams
  - agent discovery
  - registration with home agent

Handling mobility in cellular networks

- *home network:* network of cellular provider you subscribe to (e.g., Telia, Telenor)
  - *home location register (HLR):* database in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- *visited network:* network in which mobile currently resides
  - *visitor location register (VLR):* database with entry for each user currently in network
  - could be home network

Network layer

- transport segment from sending to receiving host
- on sending side encapsulates segments into datagrams
- on receiving side, delivers segments to transport layer
- network layer protocols in *every* host, router
- router examines header fields in all IP datagrams



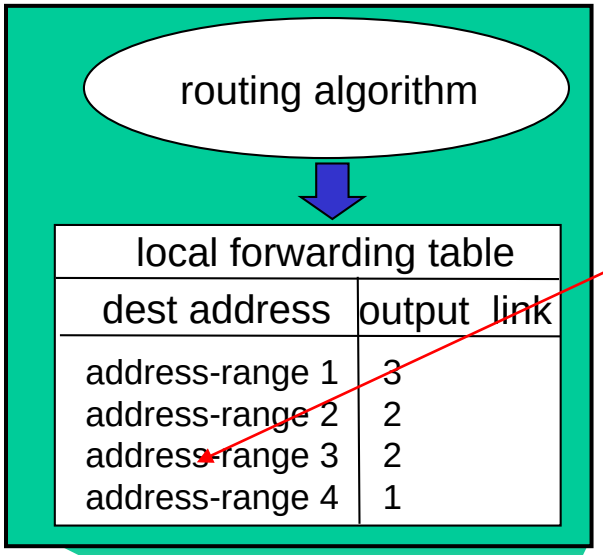
Two Key Network-Layer Functions

- *forwarding:* move packets from router's input to appropriate router output
- *routing:* determine route taken by packets from source to destination
  - *routing algorithms*

Analogy (driving):

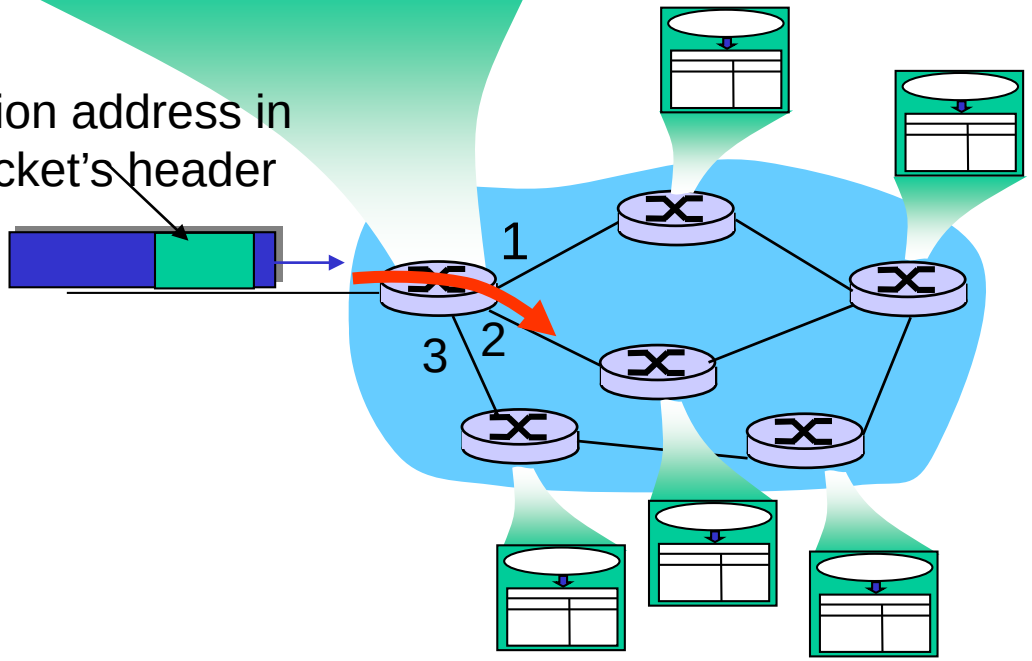
- routing: process of planning trip from source to destimation
- forwarding: process of getting through single interchange

Datagram Forwarding table



4 billion IP addresses, so rather than list individual destination address list *range* of addresses (aggregate table entries)

IP destination address in arriving packet's header



IP addressing: CIDR

CIDR: Classless InterDomain Routing

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address

200.23.16.0/23

IPv6

- Initial motivation: 32-bit address space soon to be completely allocated.
- Additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS

  IPv6 datagram format:
  - fixed-length 40 byte header
  - no fragmentation allowed

Transition From IPv4 To IPv6

- Not all routers can be upgraded simultaneous
  - How will the network operate with mixed IPv4 and IPv6 routers?

- *Tunneling:* IPv6 carried as payload in IPv4 datagram among IPv4 routers
- *Dual stack:* Both IPv4 and IPv6 protocol implemented in the routers
- *Translation:* When transiting, translate between protocols (information lost)

A Link-State Routing Algorithm

Dijkstra's algorithm

- net topology, link costs known to all nodes
  - accomplished via "link state broadcast"
  - all nodes have same info
- computes least cost paths from one node ("source") to all other nodes
  - gives *forwarding table* for that node
- iterative: after *k* iterations, know least cost path to *k* destinations

Notation:

- $c(x,y)$: link cost from node *x* to *y*; = ∞ if not direct neighbors
- $D(v)$: current value of cost of path from source to destination *v*
- $p(v)$: predecessor node along path from source to *v*
- N': set of nodes whose least cost path definitively known

Distance Vector Algorithm

Bellman-Ford Equation (dynamic programming)

Define

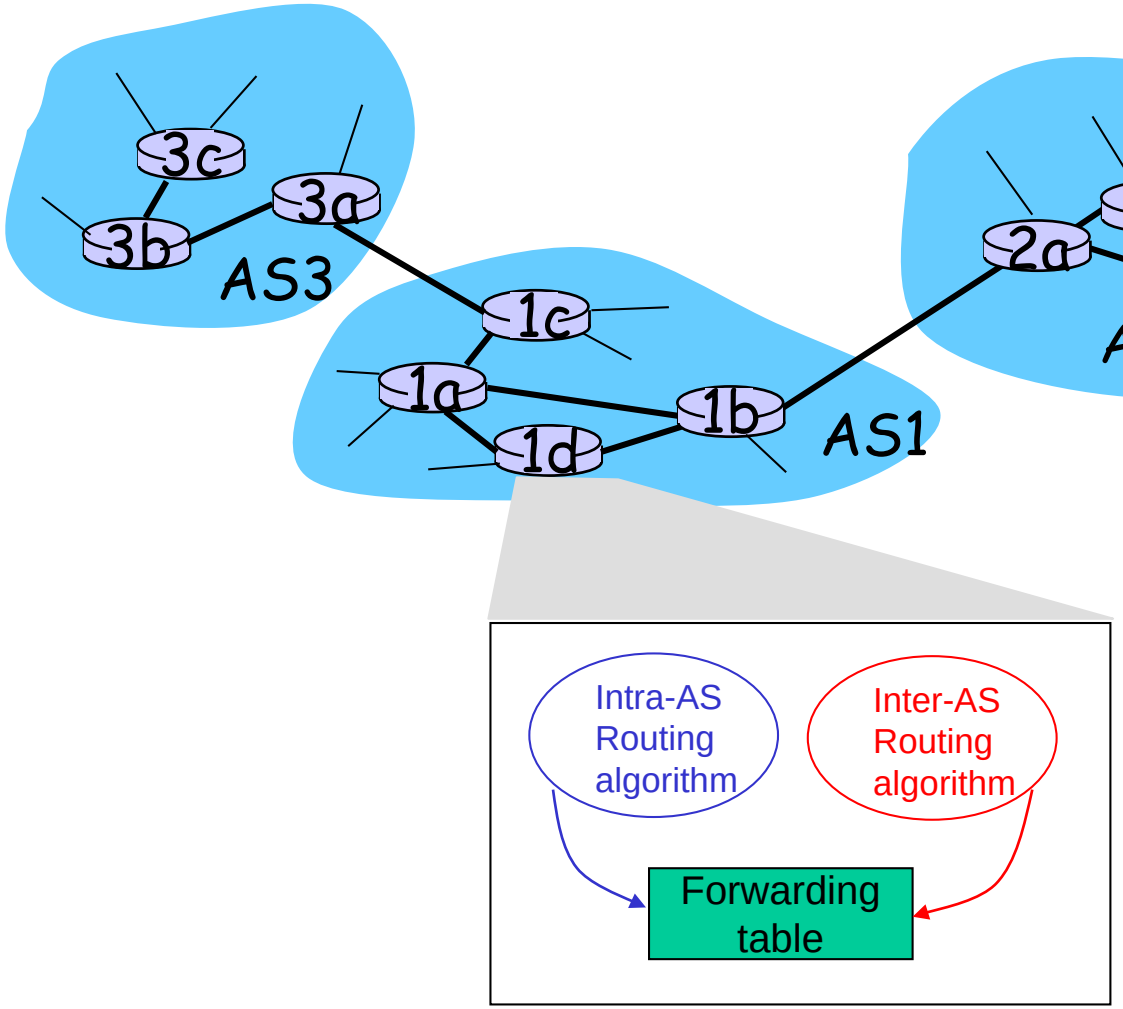
$d_x(y)$:= cost of least-cost path from *x* to *y*

Then

$$d_x(y) = \min_v \{c(x,v) + d_v(y)\}$$

where *min* is taken over all neighbors *v* of *x*

Interconnected ASes



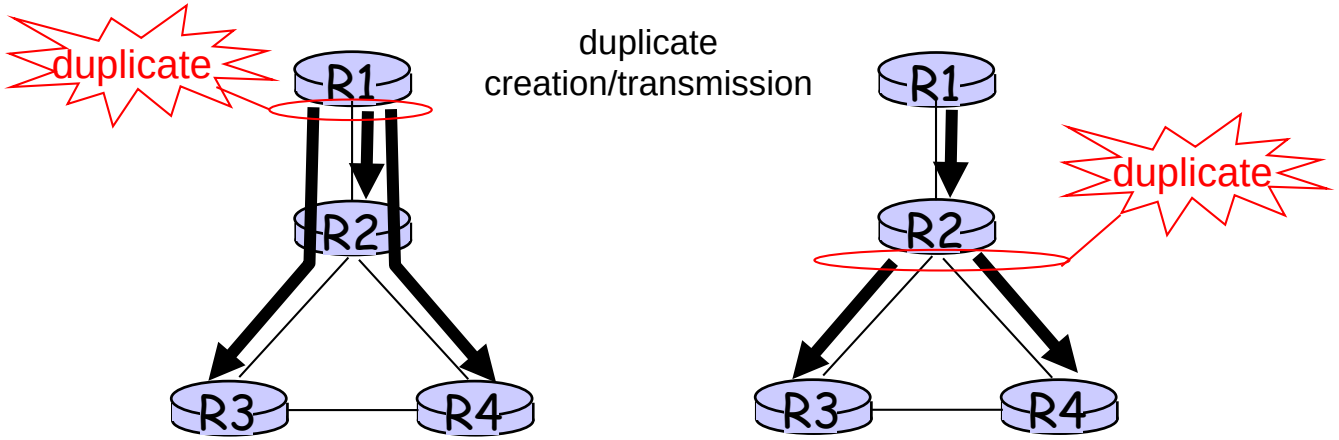
- forwarding table configured by both intra- and inter-AS routing algorithm
  - intra-AS sets entries for internal dests
  - inter-AS & intra-As sets entries for external dests

Intra-AS Routing

- also known as Interior Gateway Protocols (IGP)
- most common Intra-AS routing protocols:
  - RIP: Routing Information Protocol
  - OSPF: Open Shortest Path First
  - IGRP: Interior Gateway Routing Protocol (Cisco proprietary)

Broadcast Routing

- deliver packets from source to all other nodes
- source duplication is inefficient:



source duplication

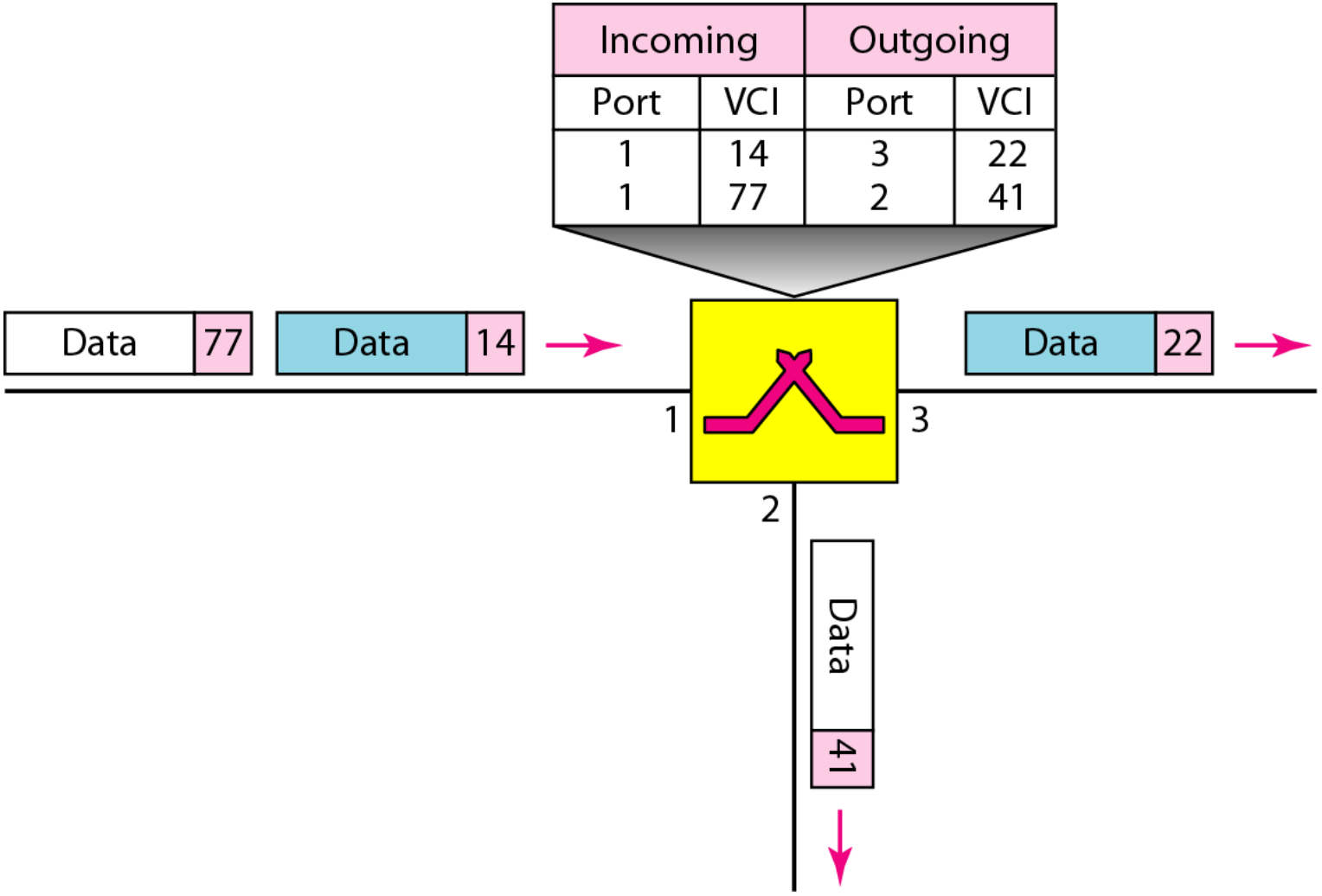
in-network duplication

Virtuella kretskopplade nät
virtual circuit networks

- Blandning mellan kretskoppling och datagram
- Förbindelser har tre faser:
  - Initiering
  - Dataöverföring
  - Nerkoppling
- Data skickas i paket med adress
- Alla paket i en förbindelse går samma väg

Virtuella kretskopplade nät

- En växel, observera att VCI byts vid passagen



What is simulation?

- Simple synonym: imitation
- We are interested in studying a system
- Instead of experimenting with the system itself we experiment with a model of the system

Two approaches to simulation

- Event-scheduling method
- Process-interaction method

Event scheduling approach

What is needed:

- A state description
- Events
- Rules telling what will happen when an event occurs
- Parameters

Processes in simulation

- In simulation a *process* is something that does something
- A process has some *internal state*
- Processes communicate by sending *signals* to each other
- Signals have a name and can carry information
- When a signal arrives to a process some *activity* is trigged
- During an activity the state of the receiving process might be changed and signals may be sent
- When a signal is sent the sender assigns it an *arrival time*

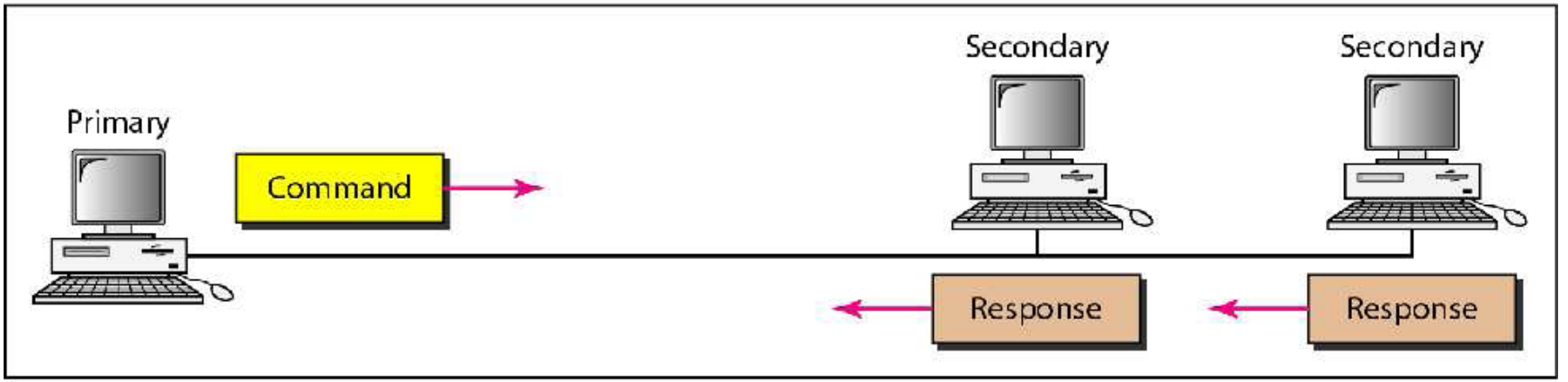
Punkt-till-punkt-access

- HDLC
  (High-level Data Link Control)
- PPP
  (Point-to-Point Protocol)

HDLC

- NRM (Normal Response Mode)

a. Point-to-point



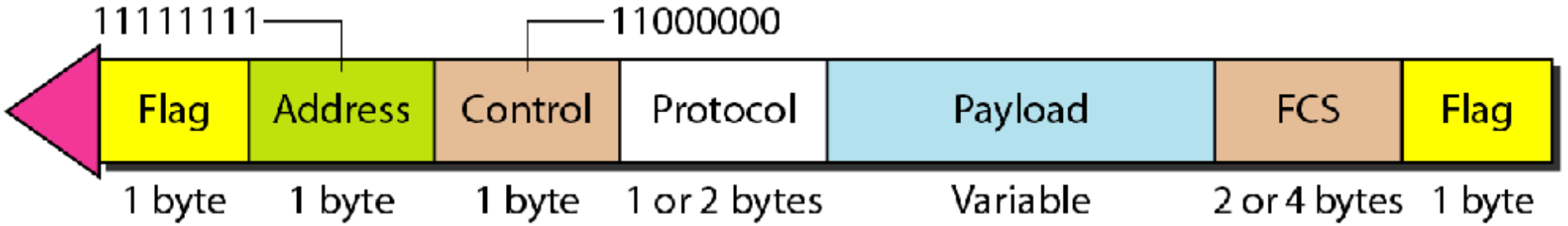
b. Multipoint

PPP

- PPP (Point-to-Point Protocol)
  - Vanligaste protokollet för punkt-till-punkt-förbindelser
  - Används för kontakt mellan användare och internetleverantör
  - Använder en variant av HDLC

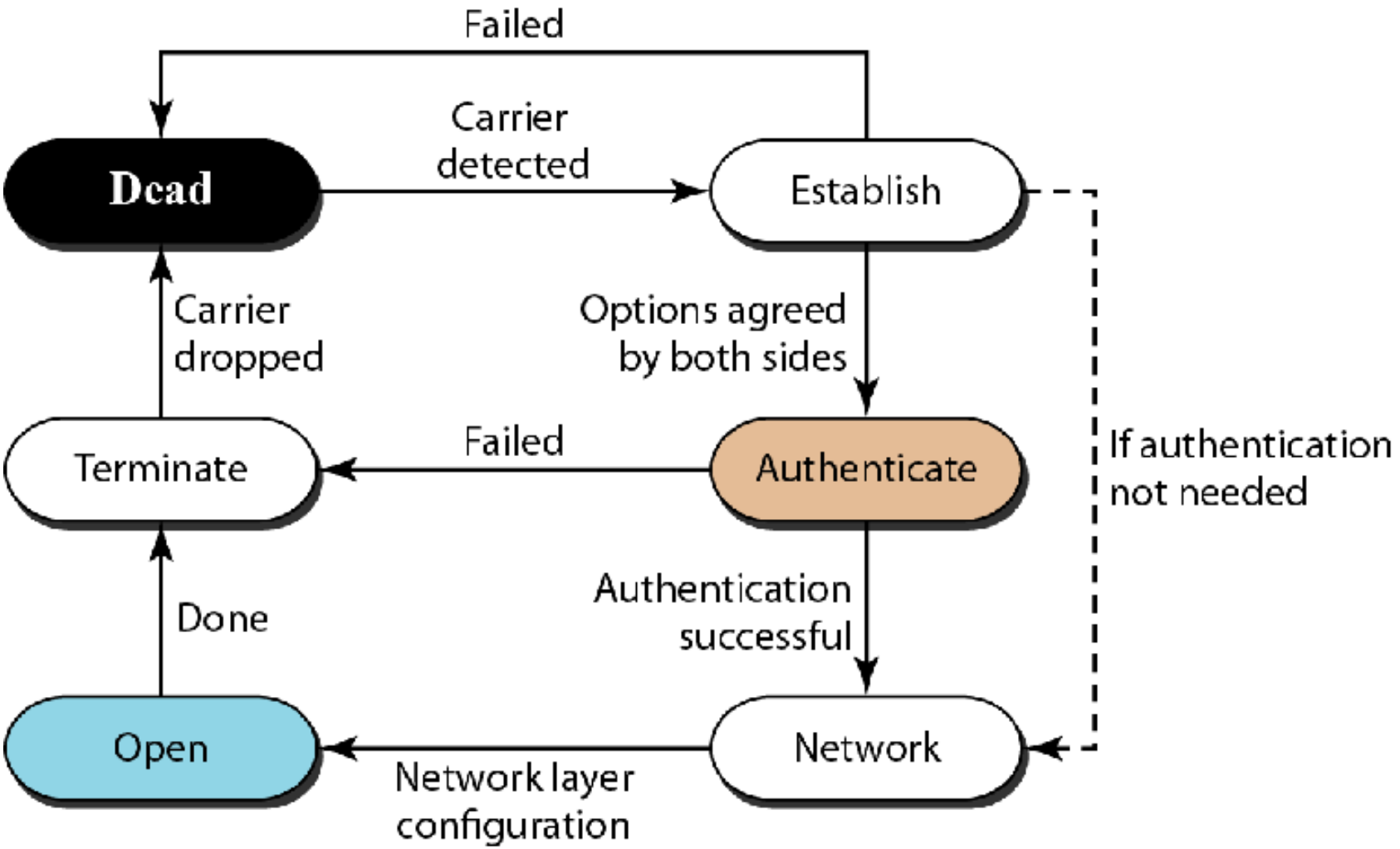
PPP

- Formatet på en PPP-ram

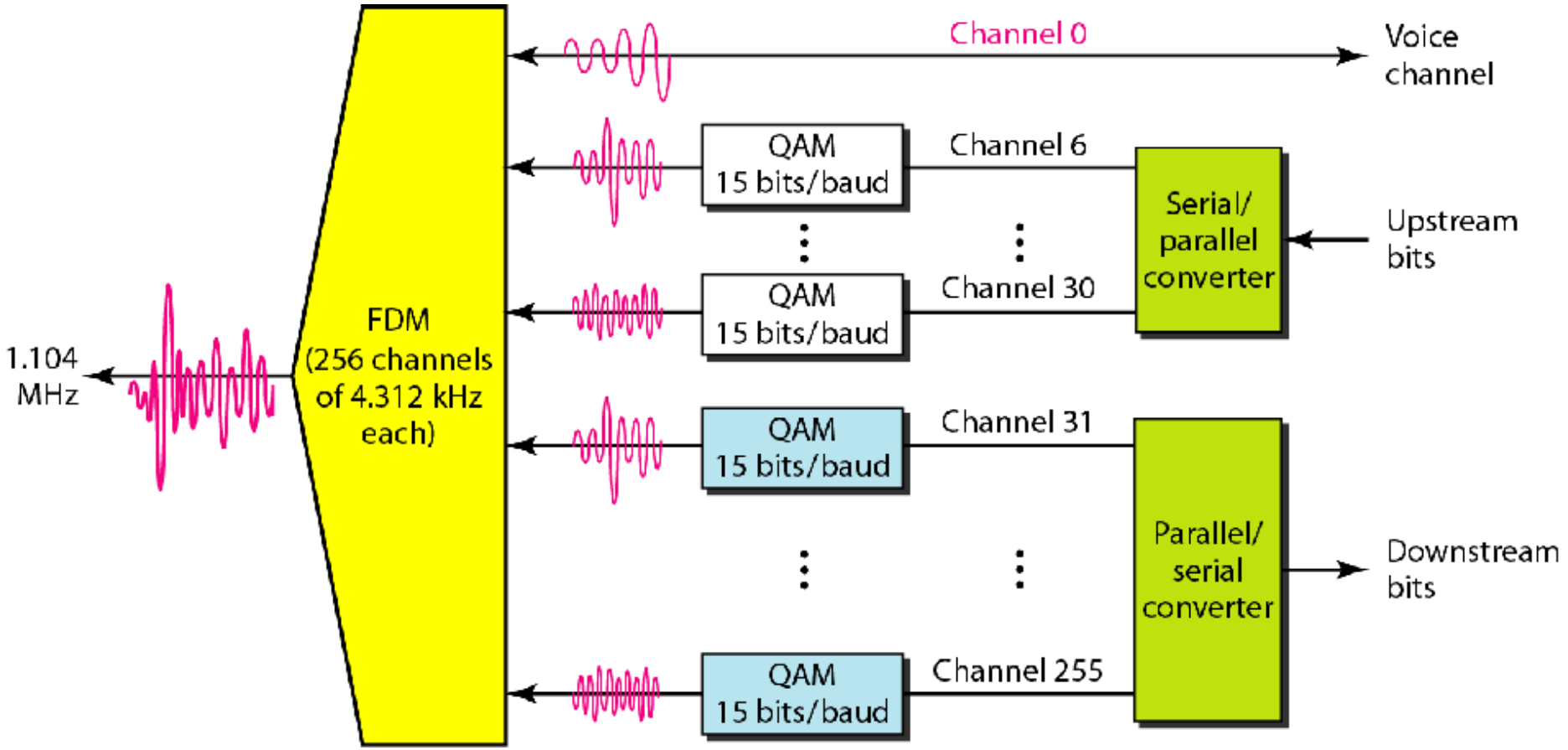


PPP

- Tillståndsgraf för PPP

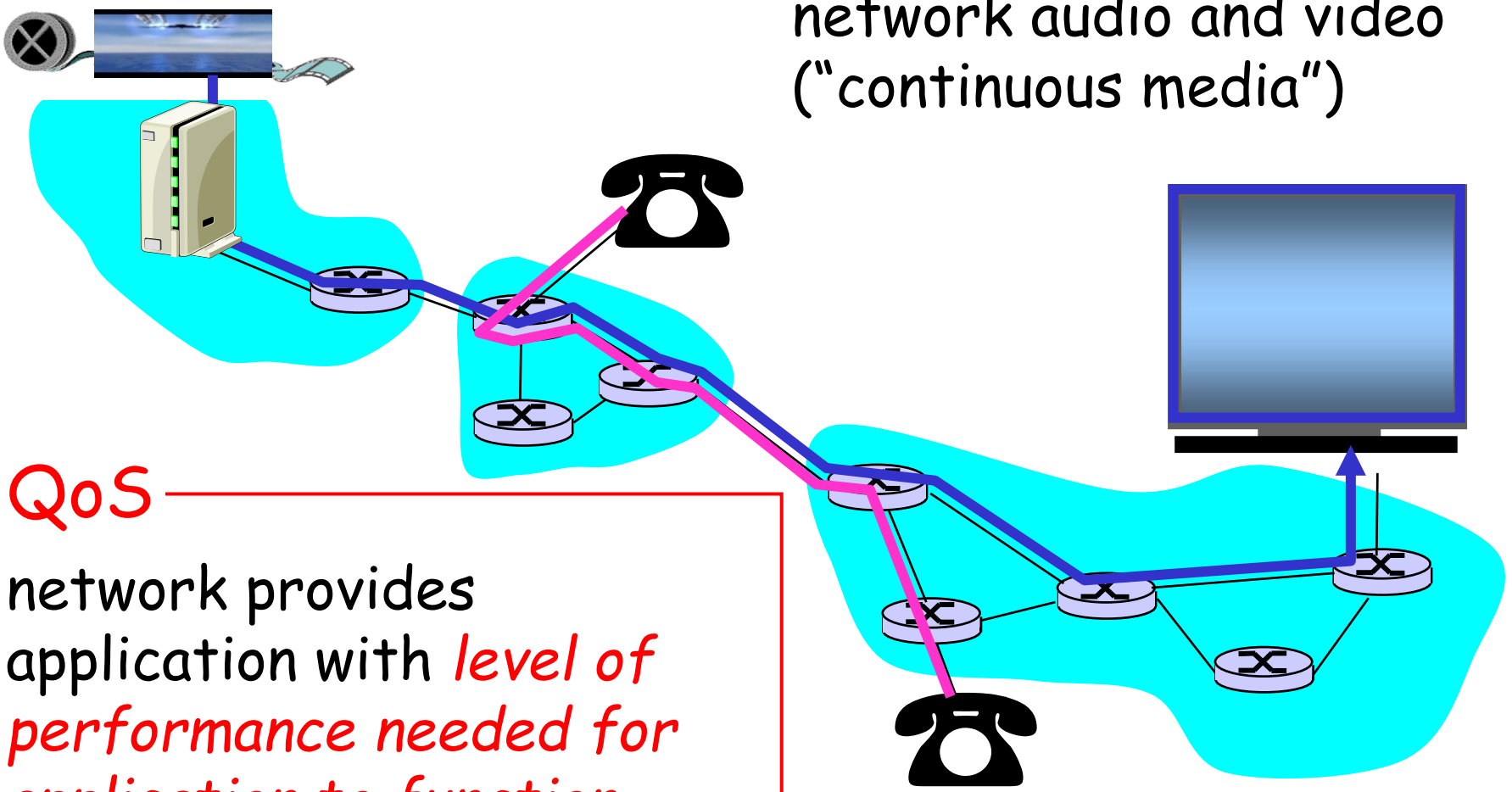


ADSL


1.104
MHz
FDM
(256 channels
of 4.312 kHz
each)
Channel 0
Voice
channel
QAM
15 bits/baud
Channel 6
Serial/
parallel
converter
Upstream
bits
QAM
15 bits/baud
Channel 30
QAM
15 bits/baud
Channel 31
Parallel/
serial
converter
Downstream
bits
QAM
15 bits/baud
Channel 255

Multimedia and Quality of Service: What is it?

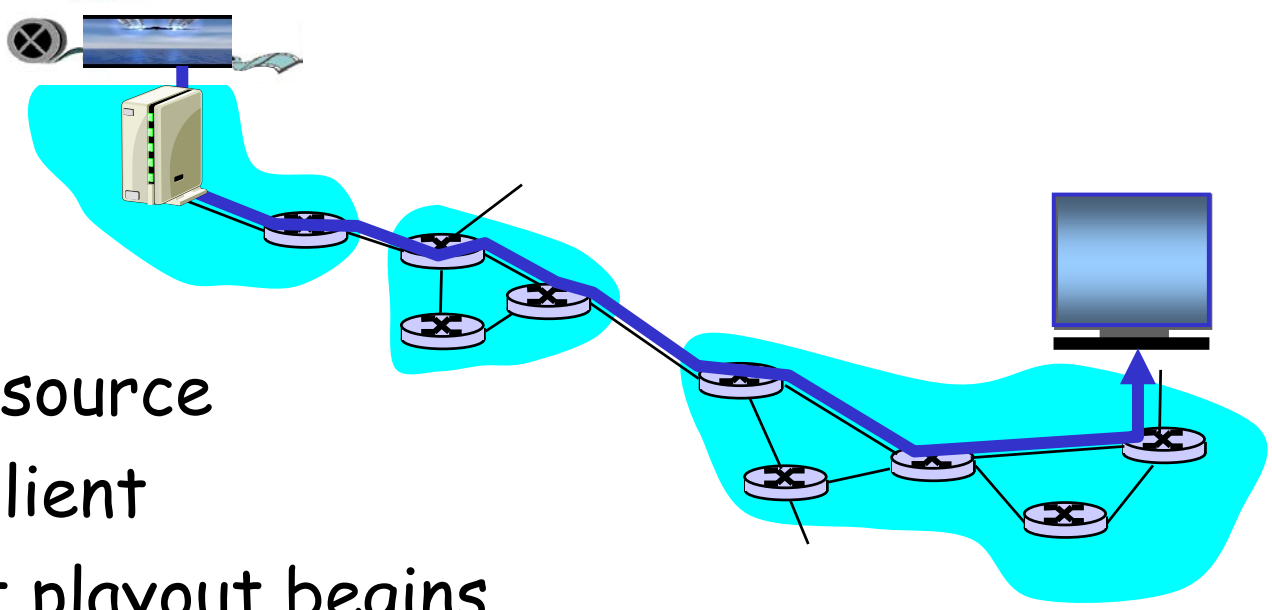
multimedia applications:
network audio and video
("continuous media")



QoS

network provides application with *level of performance needed for application to function.*

Streaming Stored Multimedia



Stored streaming:

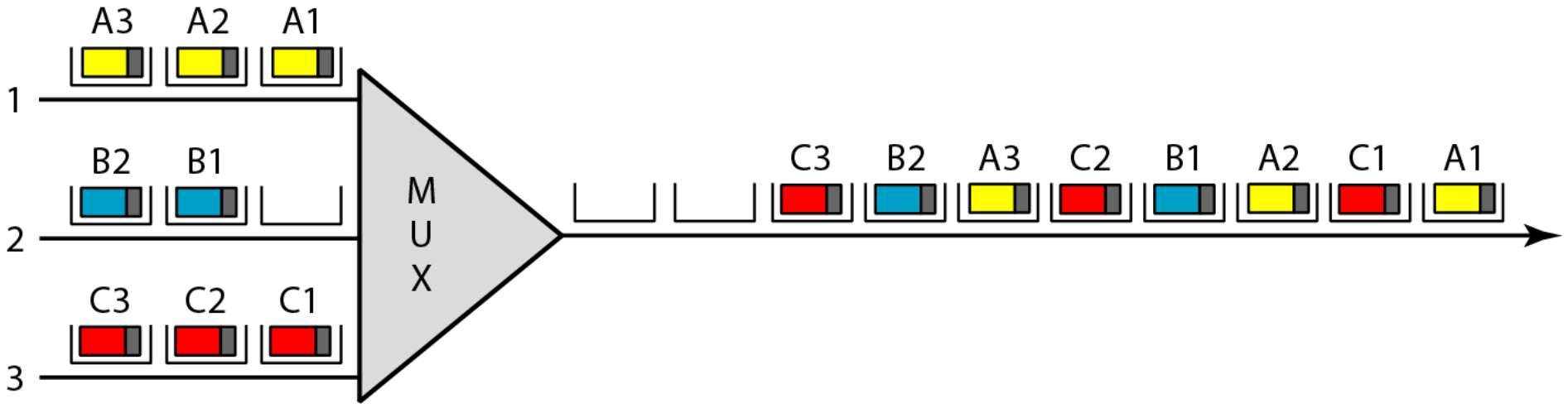
- media stored at source
- transmitted to client
- *streaming:* client playout begins *before* all data has arrived
  - timing constraint for still-to-be transmitted data: in time for playout

ATM

- Asynchronous Transfer Mode (ATM)
  - Kan fungera som ”informationsmotorväg”
  - I stället för ramar har man små paket (s.k. celler) med fix längd

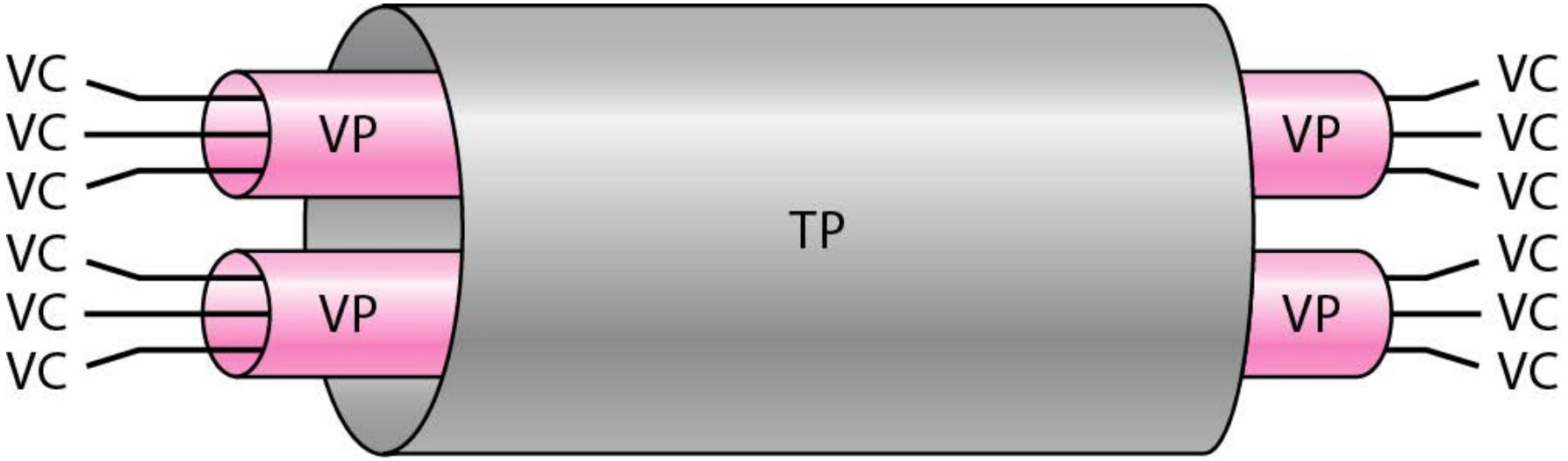
ATM

- Multiplexering med ATM
  - Cellerna har fix storlek
  - Varje lucka (slot) behöver inte fyllas

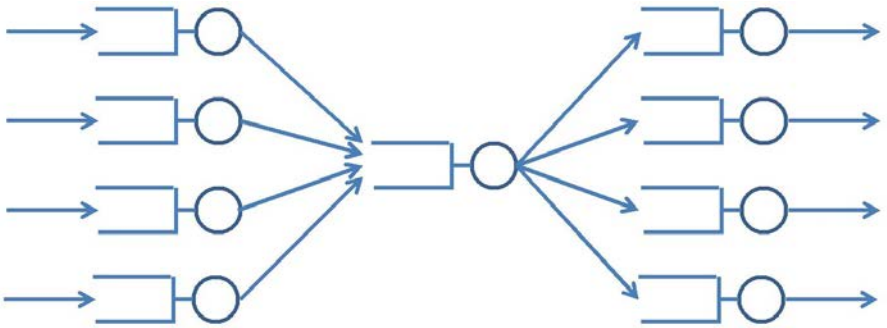


ATM

- Indelning av förbindelser
  - TP (Transmission Path): Fysisk förbindelse
  - VP (Virtual Path): Logisk förbindelse mellan två växlar, vilken ingår som en del av en TP
  - VC (Virtual Circuit): Delar av en VP där varje VC utgör en väg mellan de två växlarna



Köteori



- Ankomstintensitet
- Genomströmning
- Betjäningstid
- ….

Little's sats

$E(N) = E(T) \cdot \lambda_{eff}$

P(spärr)=?