

Dator- och telekommunikation

(EITG01)

Höstterminen 2025

”Kort sammanfattning”

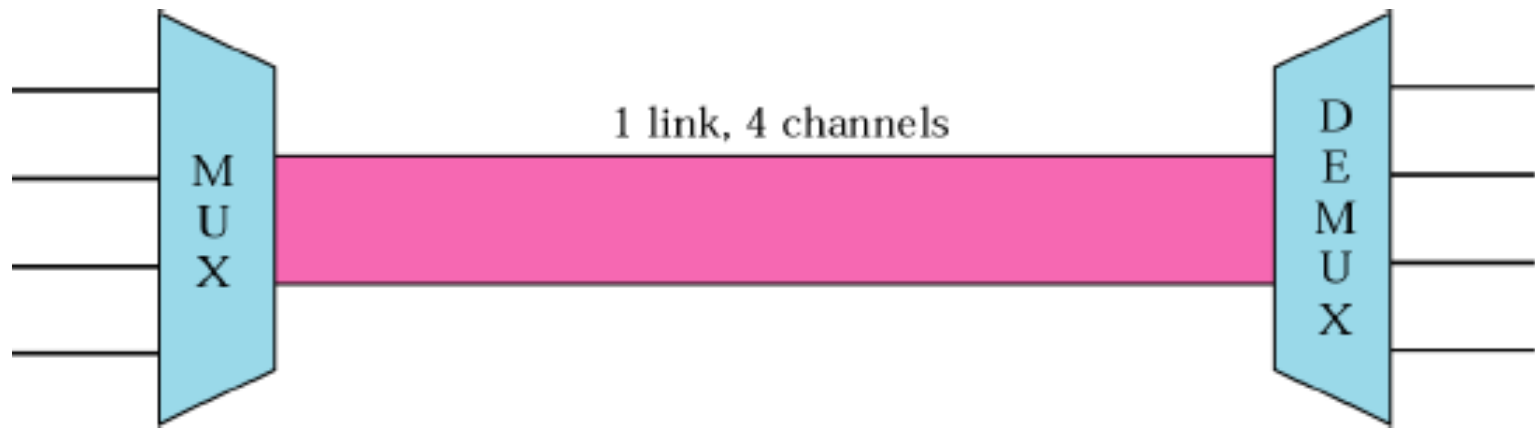
- Föreläsningar
- Övningar
- Laborationer

OSI-modellen

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

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)

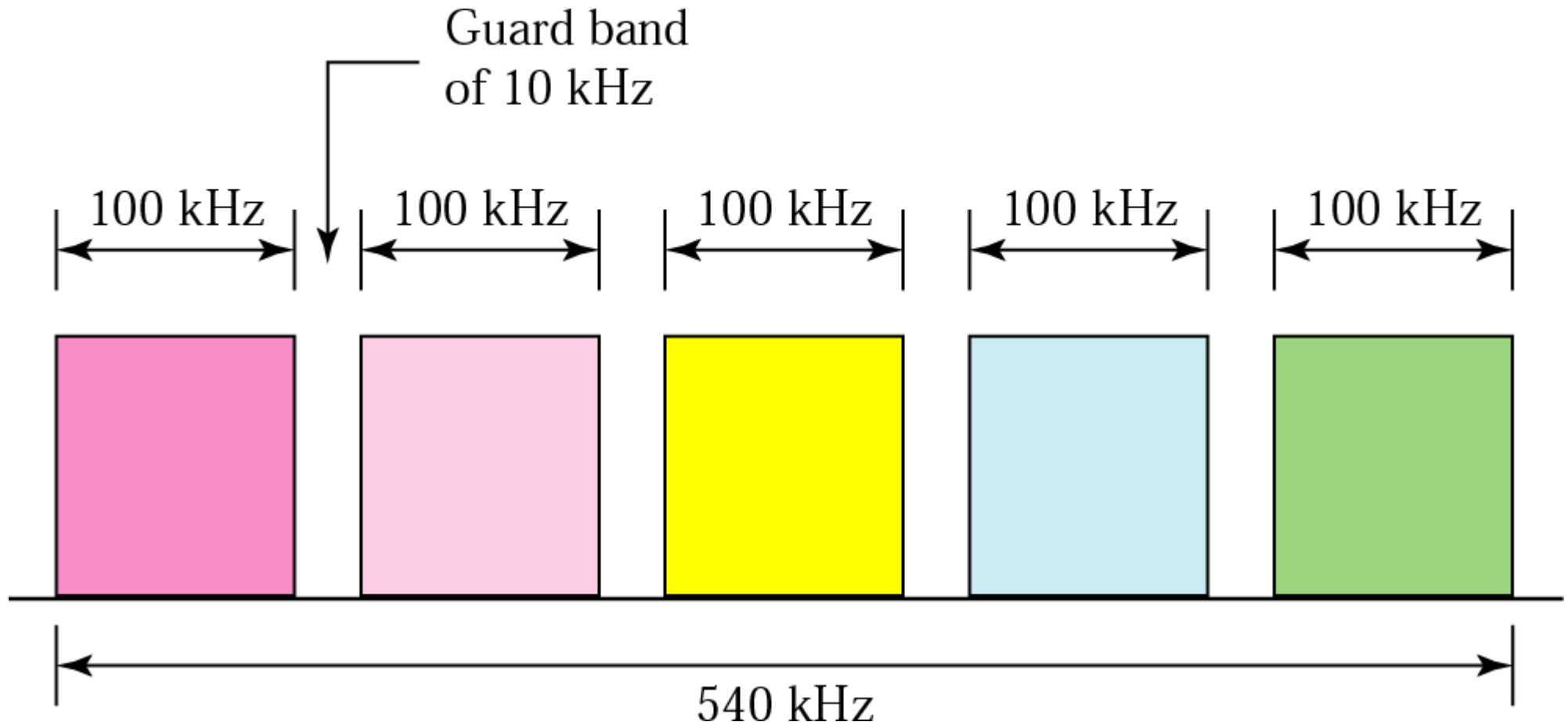
Multiplexering FDM

- Kombination av signaler med olika frekvens



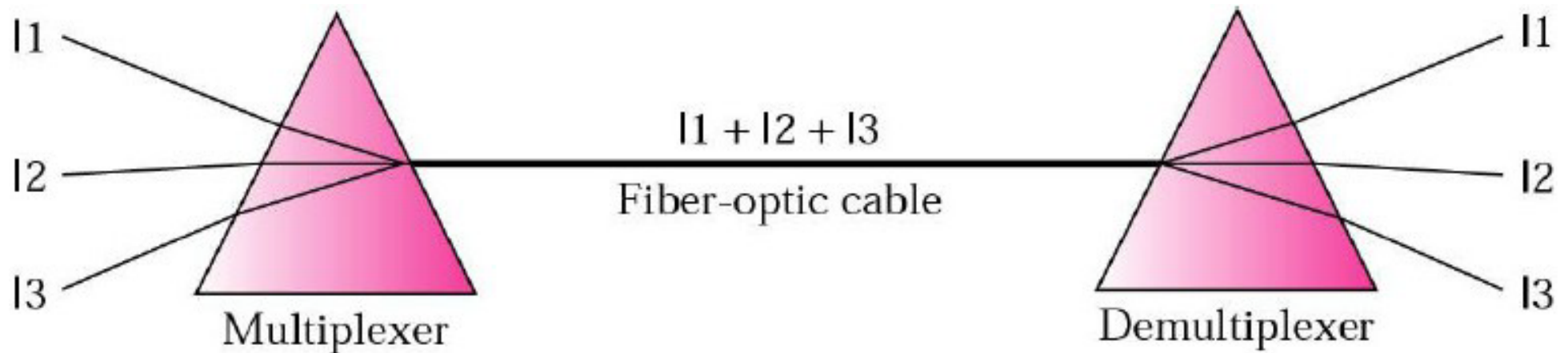
Multiplexering, FDM

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



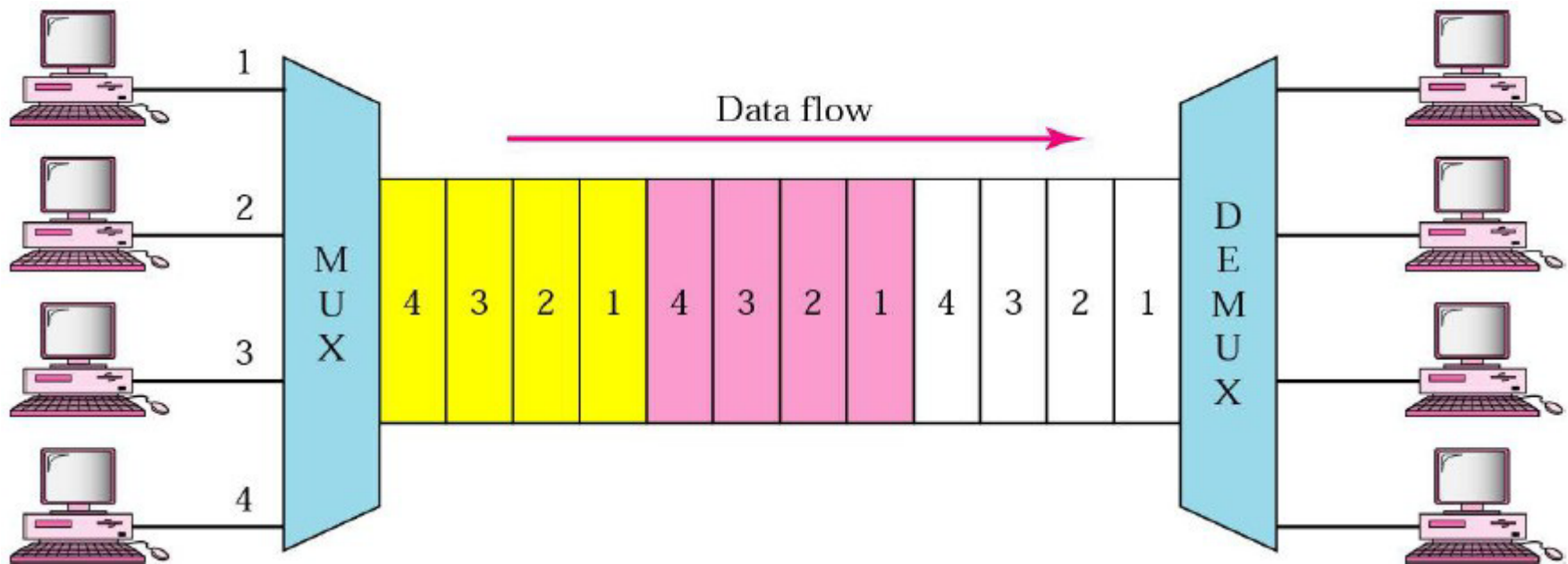
Multiplexing, WDM

- Användning av prismor för WDM



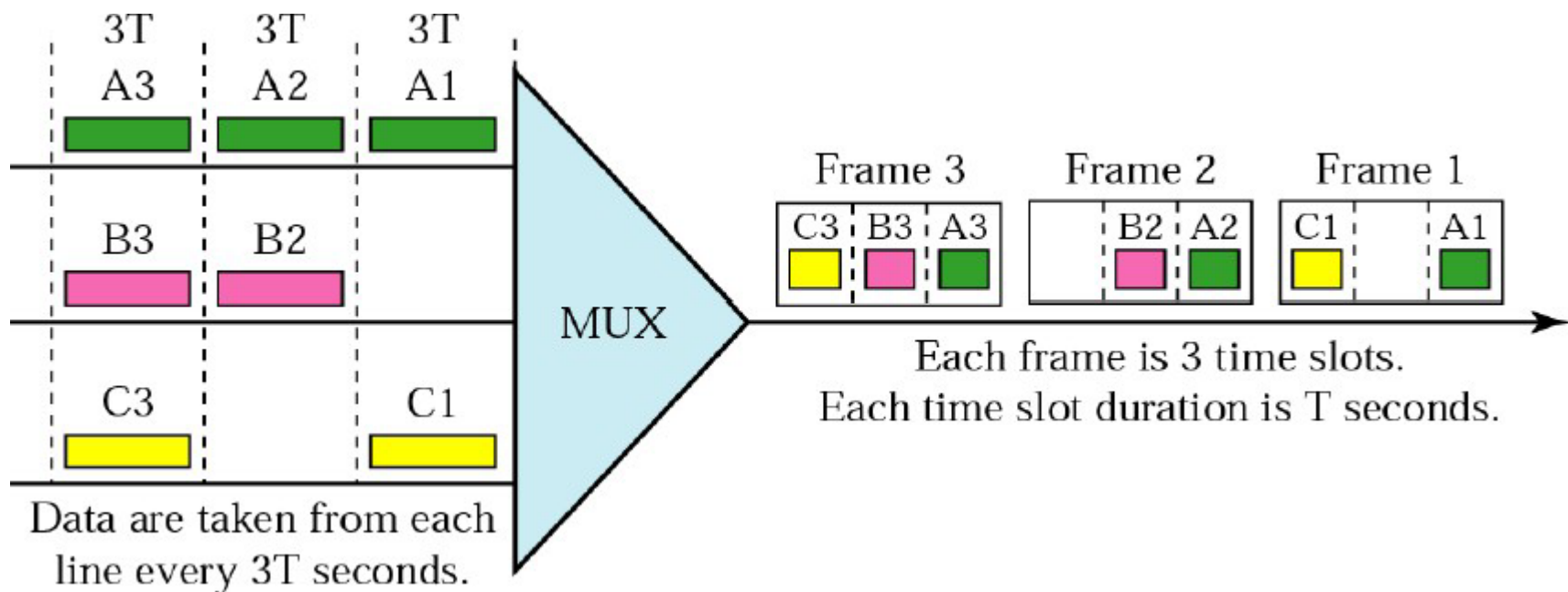
Multiplexing, TDM

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



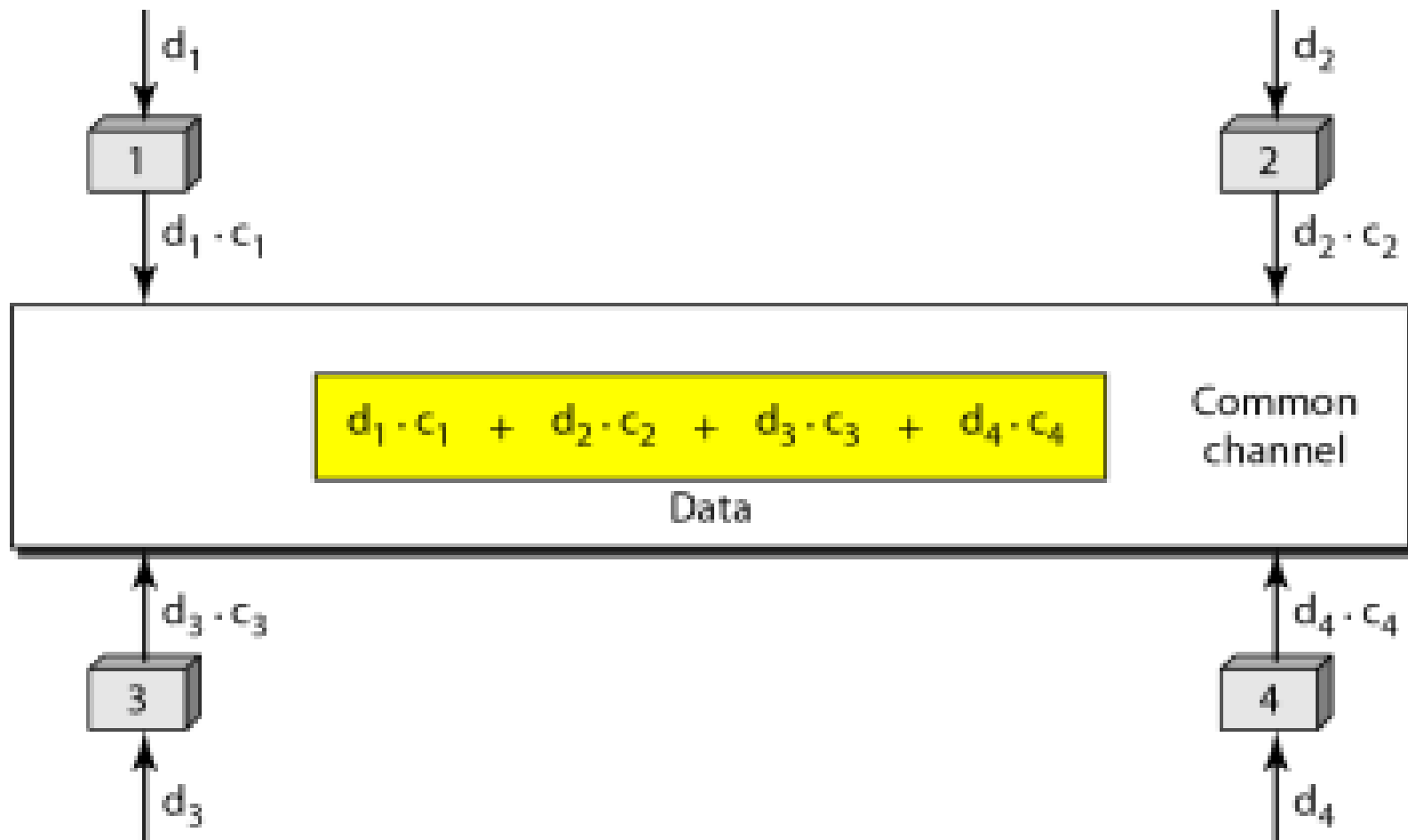
Multiplexing, TDM

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

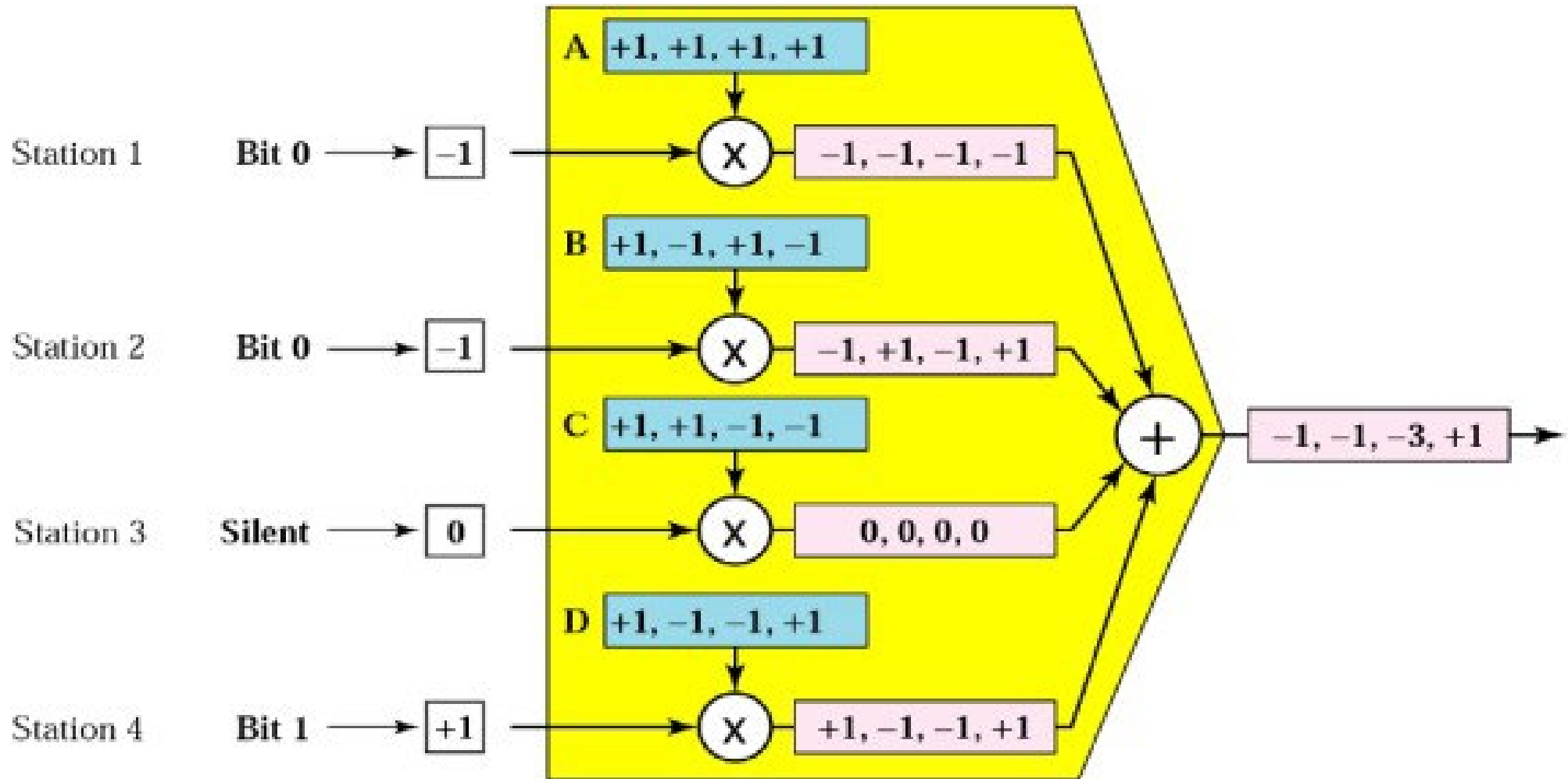


Multiplexering, CDM

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



Multiplexing, CDM



Multiplexing, CDM

- Raderna i en Walsh-matris är ortogonala mot varandra

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

a. Two basic rules

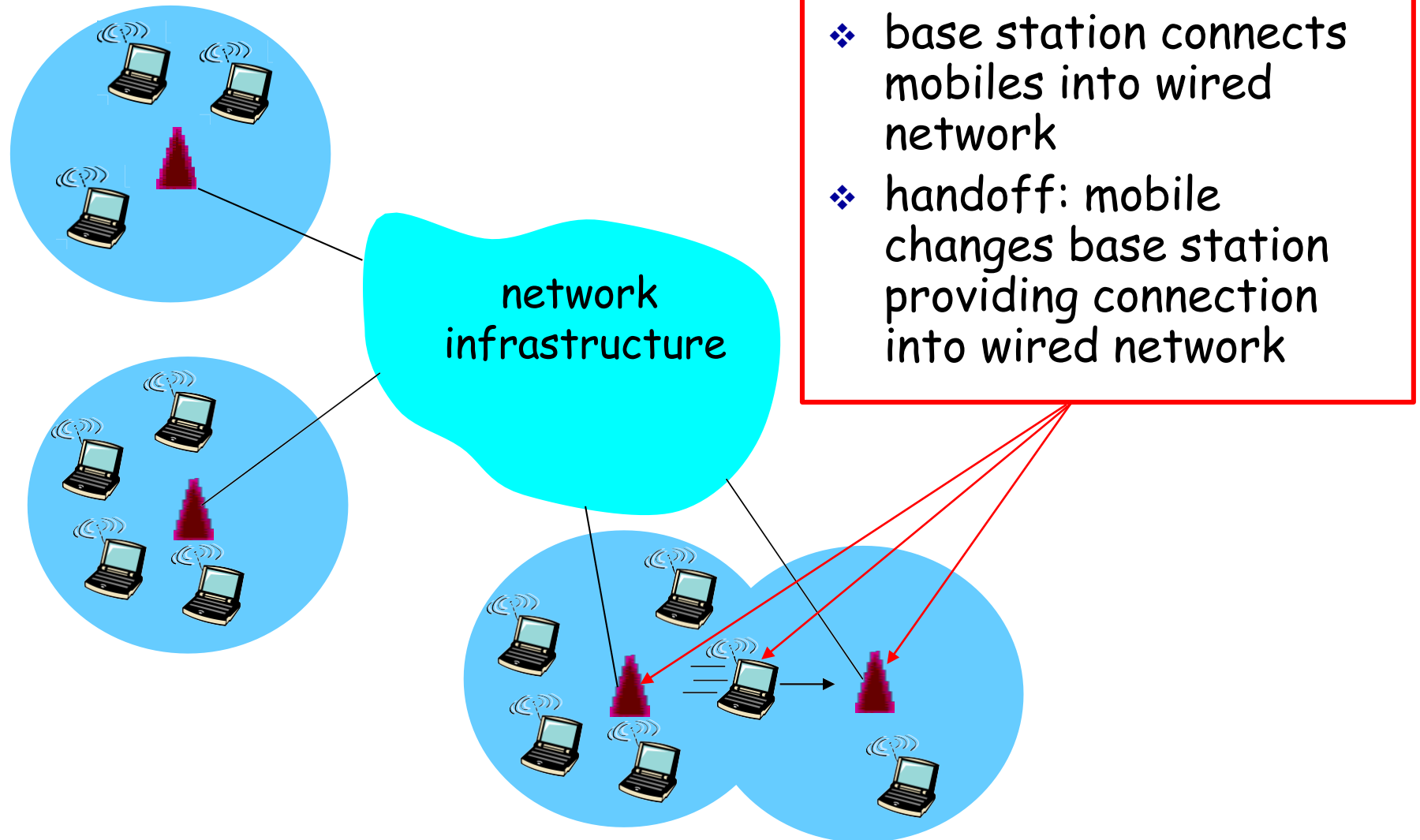
$$W_1 = \begin{bmatrix} +1 \end{bmatrix}$$

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

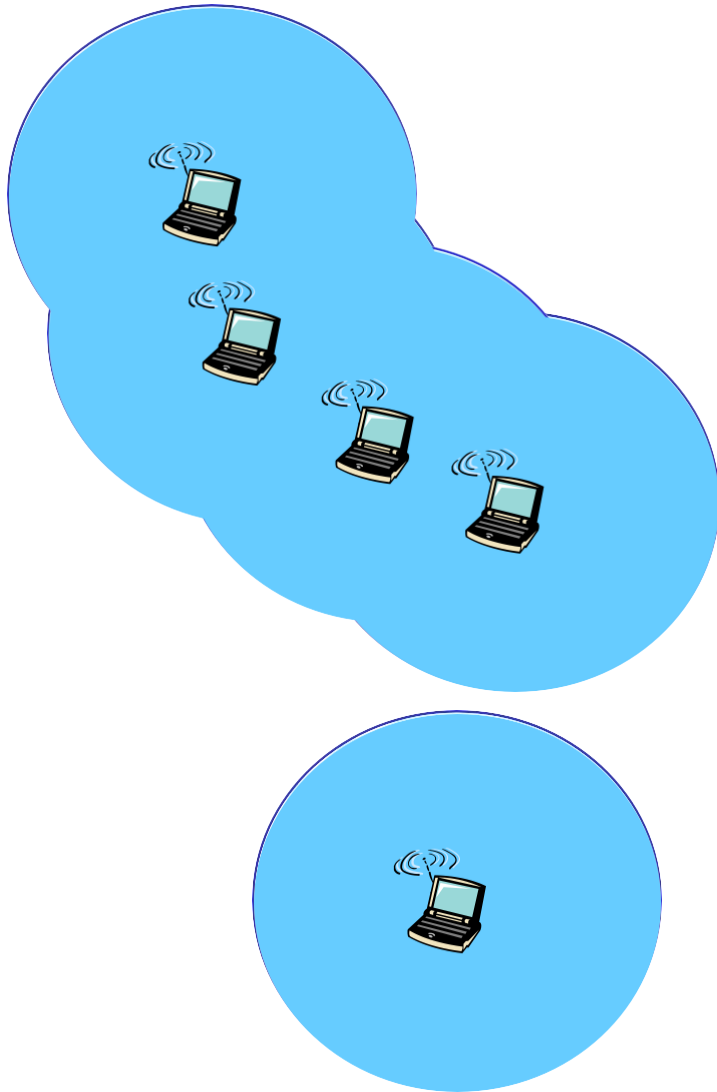
$$W_4 = \begin{bmatrix} \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} & \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \\ \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} & \begin{bmatrix} -1 & -1 \\ -1 & +1 \end{bmatrix} \end{bmatrix}$$

b. Generation of W_1 , W_2 , and W_4

Elements of a wireless 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

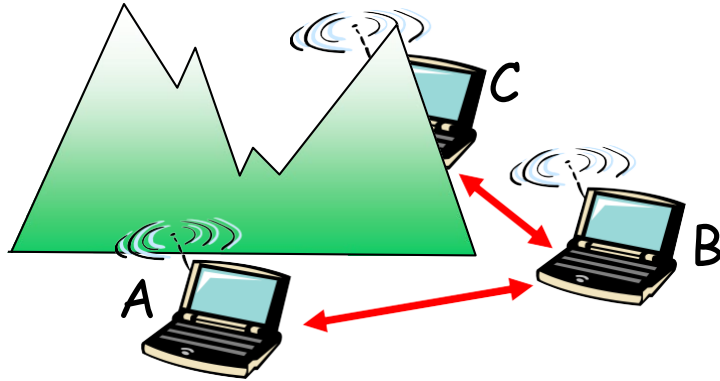
Wireless Link Characteristics

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

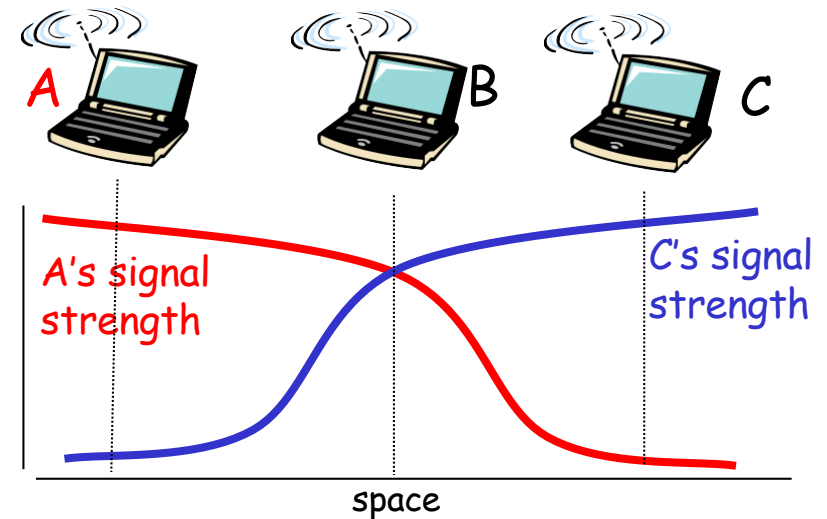
Wireless network characteristics

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

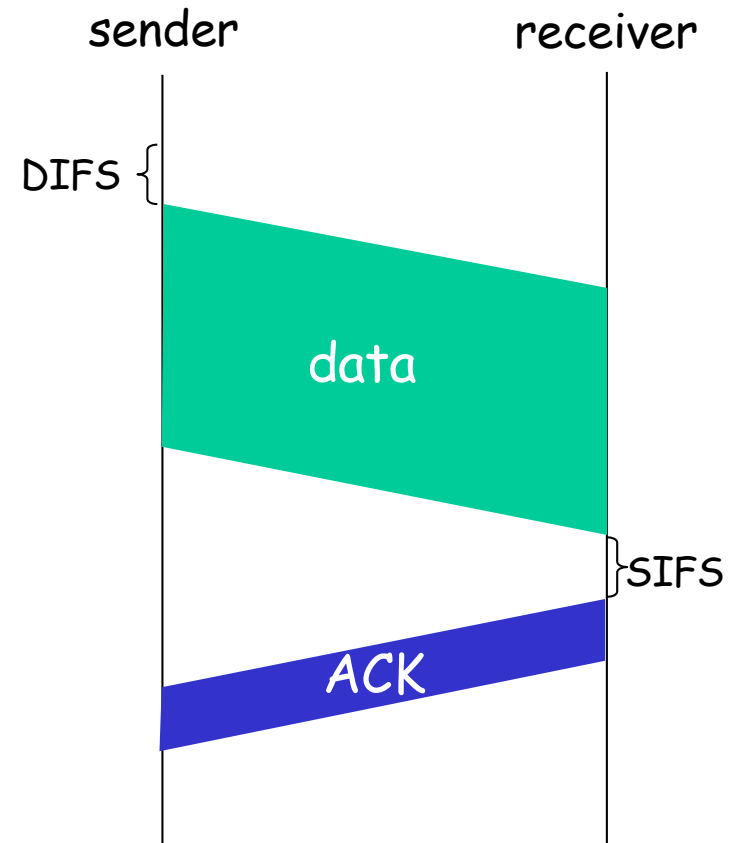
IEEE 802.11 MAC Protocol: CSMA/CA

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)



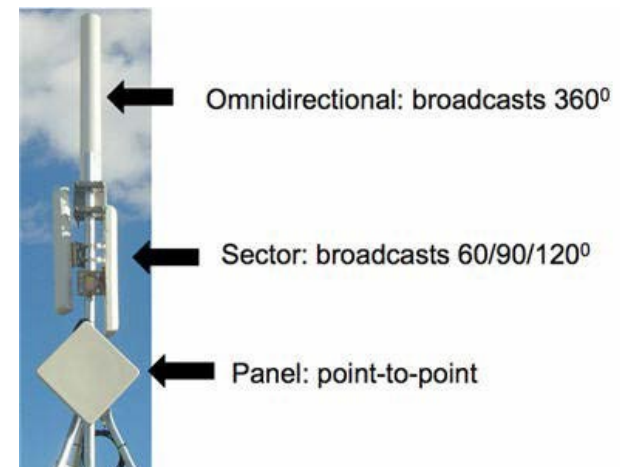
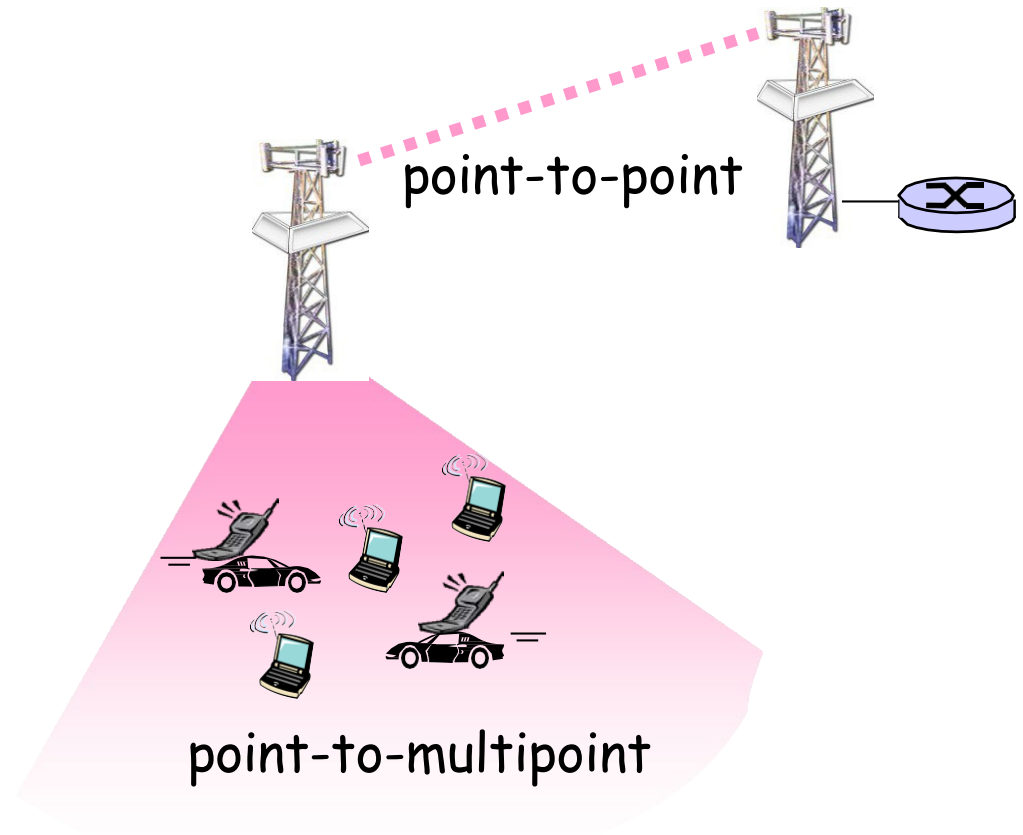
802.16: WiMAX

❖ like 802.11 & cellular: base station model

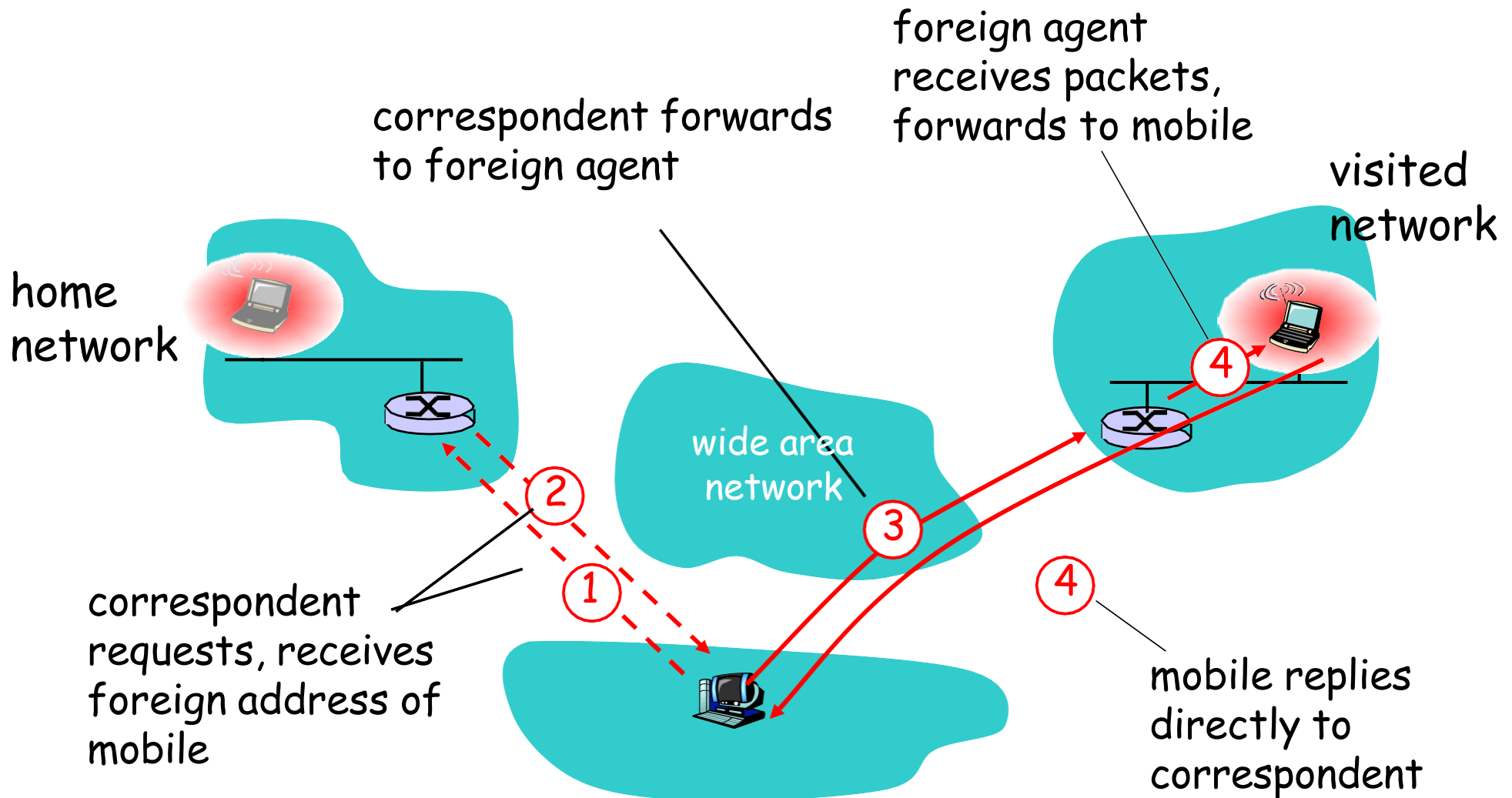
- transmissions to/from base station by hosts with omnidirectional antenna
- base station-to-base station backhaul with point-to-point antenna

❖ unlike 802.11:

- range ~ 6 miles ("city rather than coffee shop")
- ~14 Mbps



Mobility via Direct Routing



Mobile IP

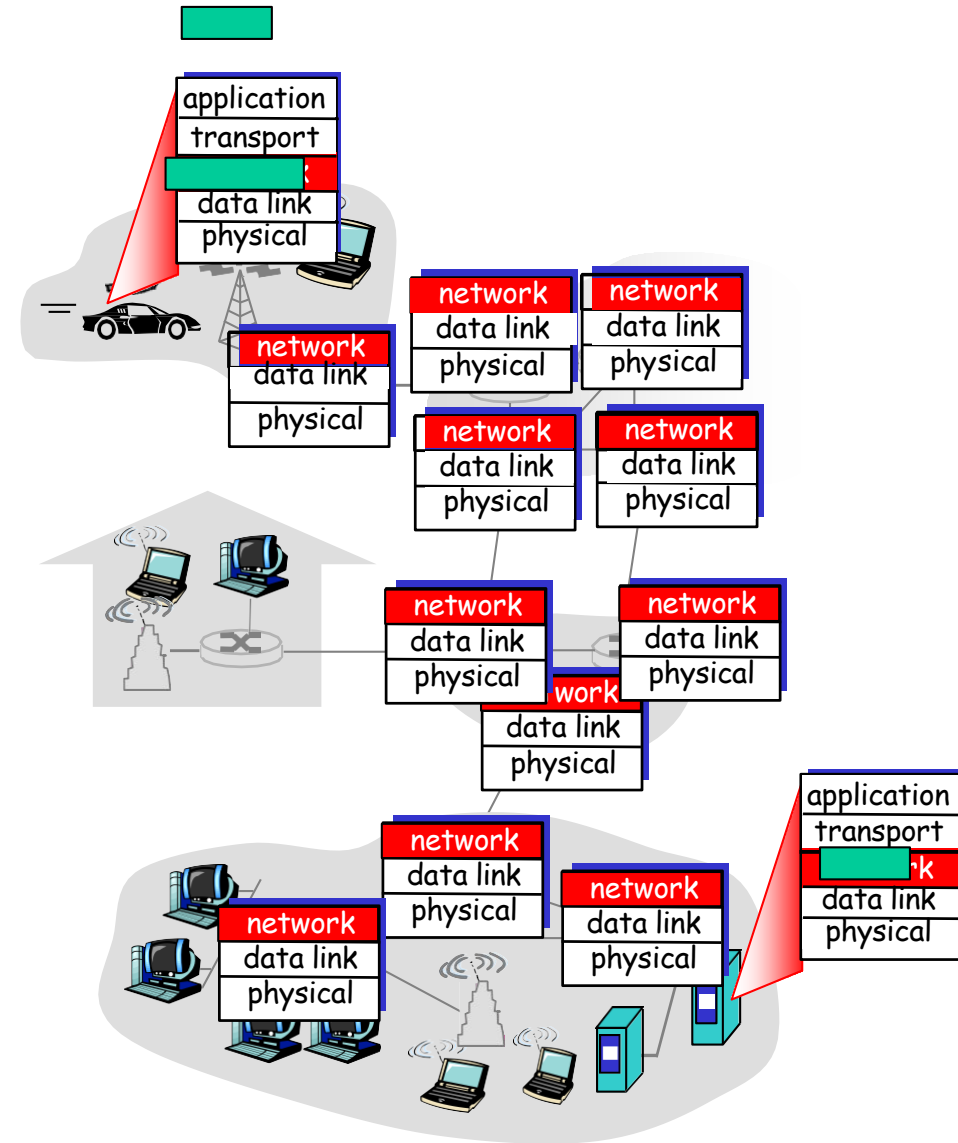
- ❖ RFC 3344
- ❖ has many features we've seen:
 - home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)
- ❖ three components to standard:
 - indirect routing of datagrams
 - agent discovery
 - registration with home agent

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



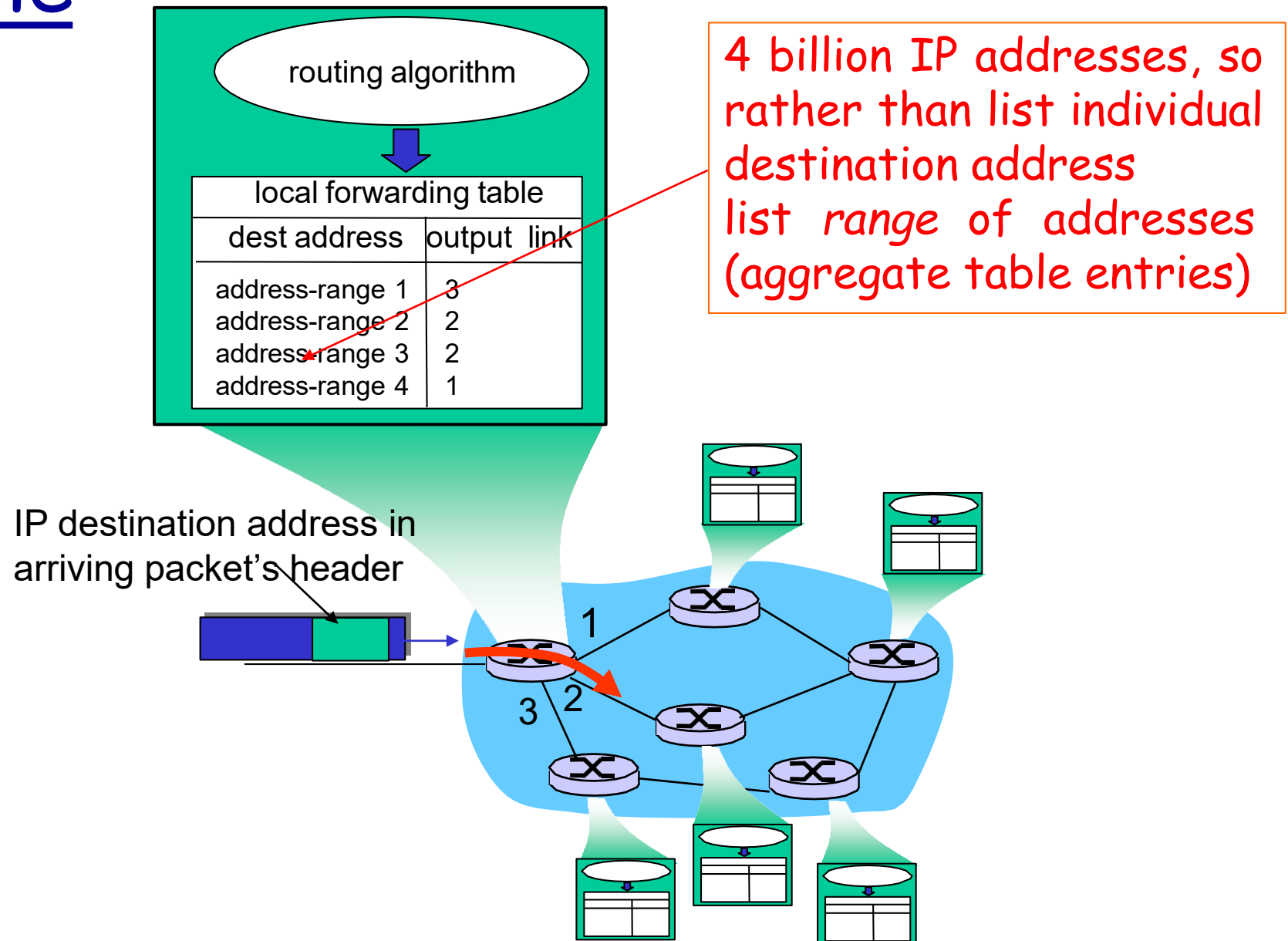
Two Key Network-Layer Functions

- ❖ *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 destination
- ❖ *forwarding*: process of getting through single interchange

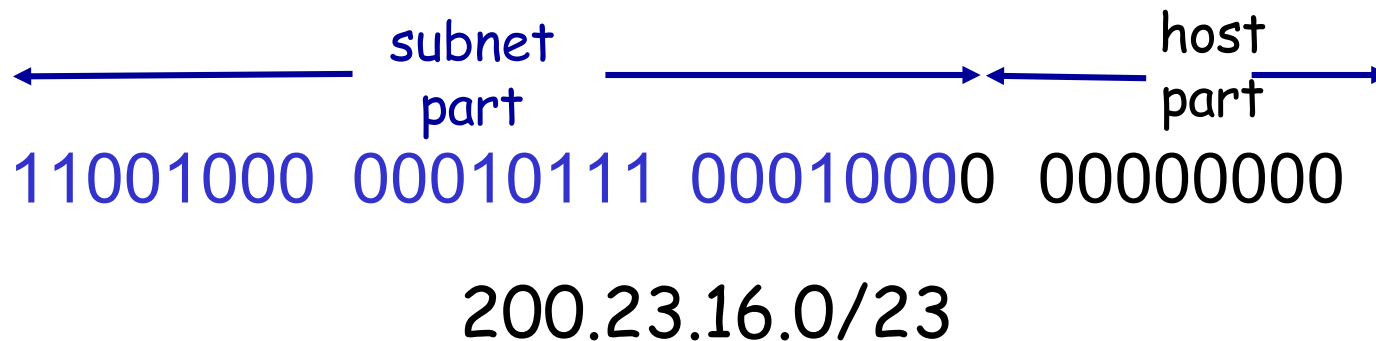
Datagram Forwarding table



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



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 ; $= \infty$ 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

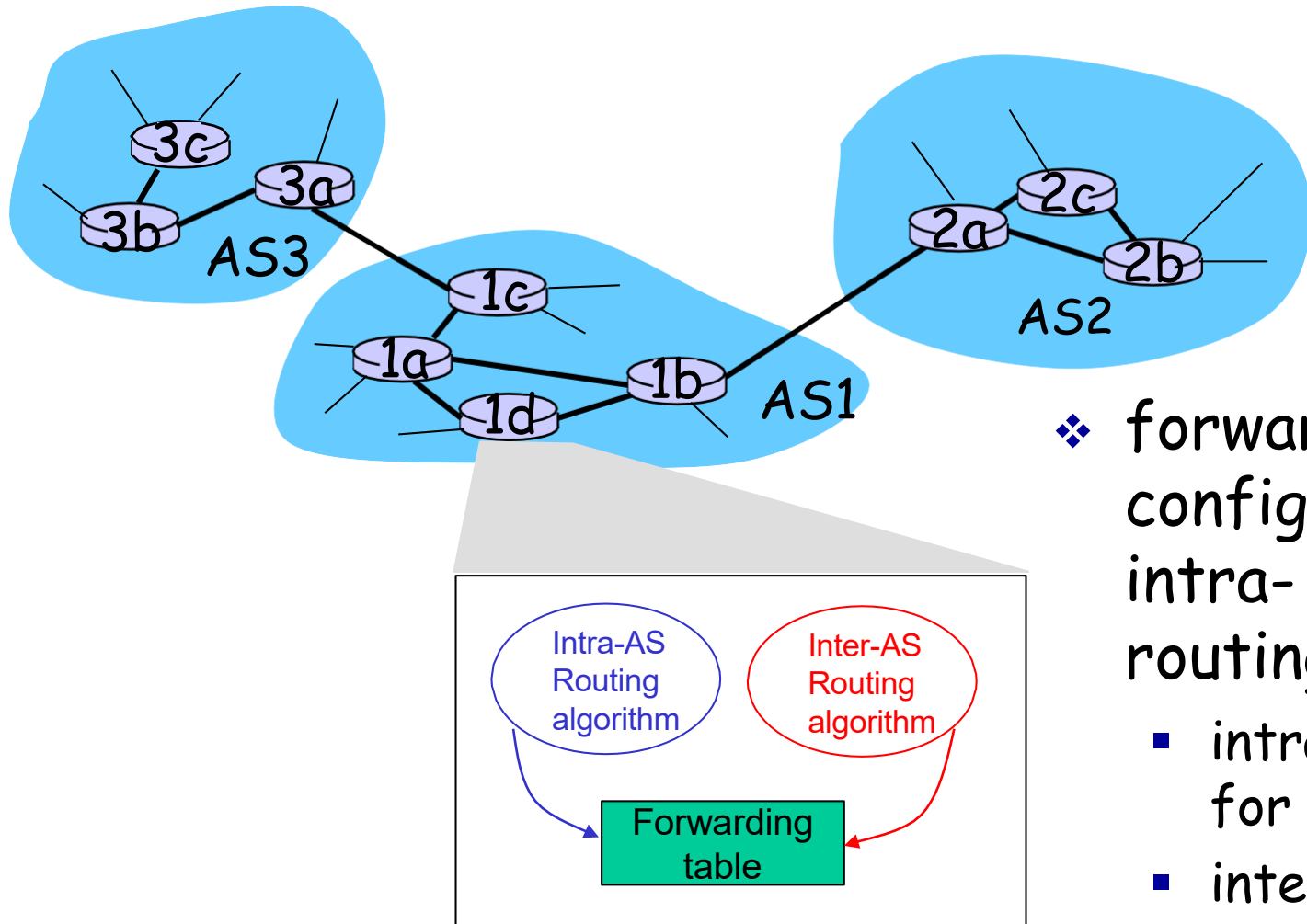
$d_x(y) :=$ cost of least-cost path from x to y

Then

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

where $\min$ is taken over all neighbors v of x

Interconnected ASes



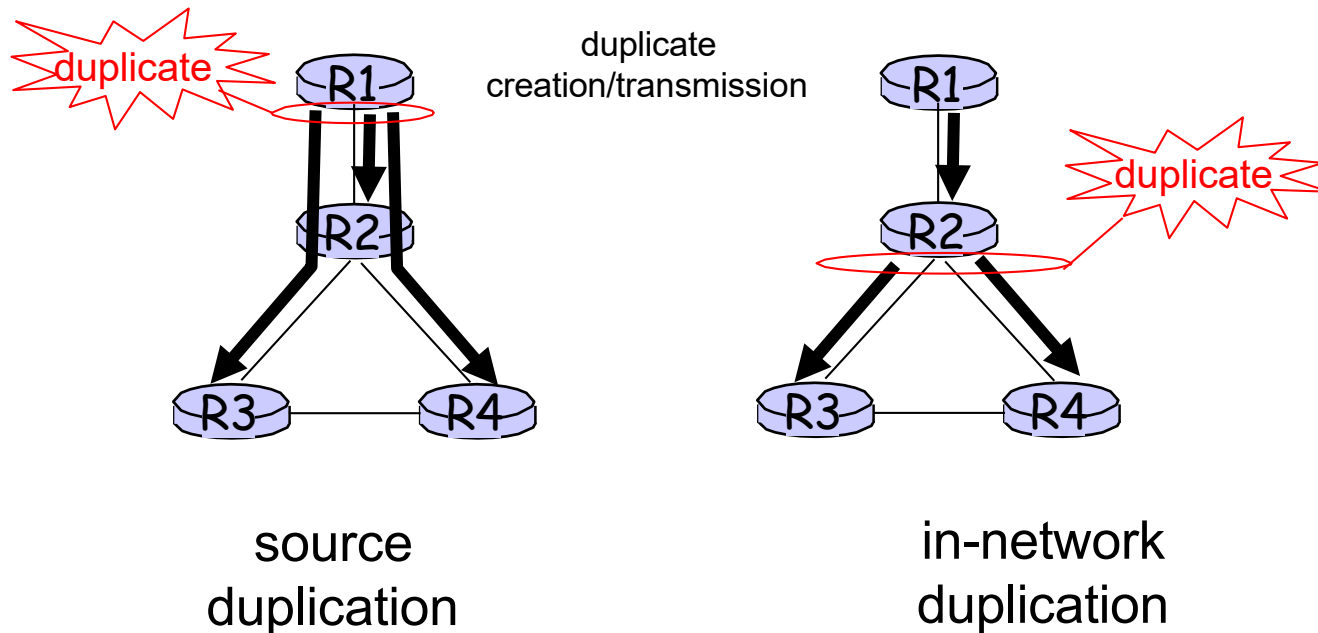
- ❖ forwarding table configured by both intra- and inter-AS routing algorithm
 - intra-AS sets entries for internal dests
 - inter-AS & intra-AS sets entries for external dests

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:



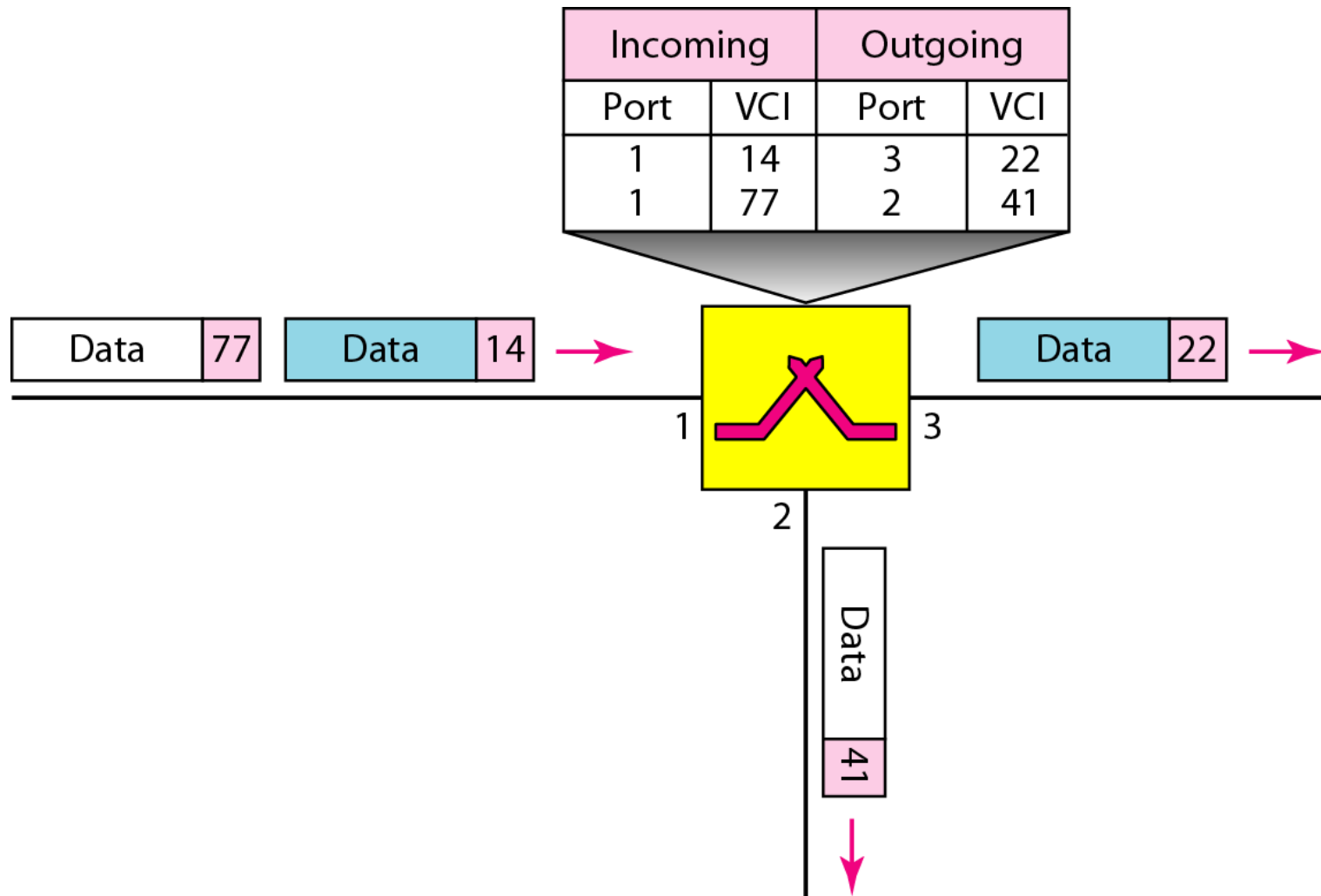
Virtuella kretskopplade nät

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

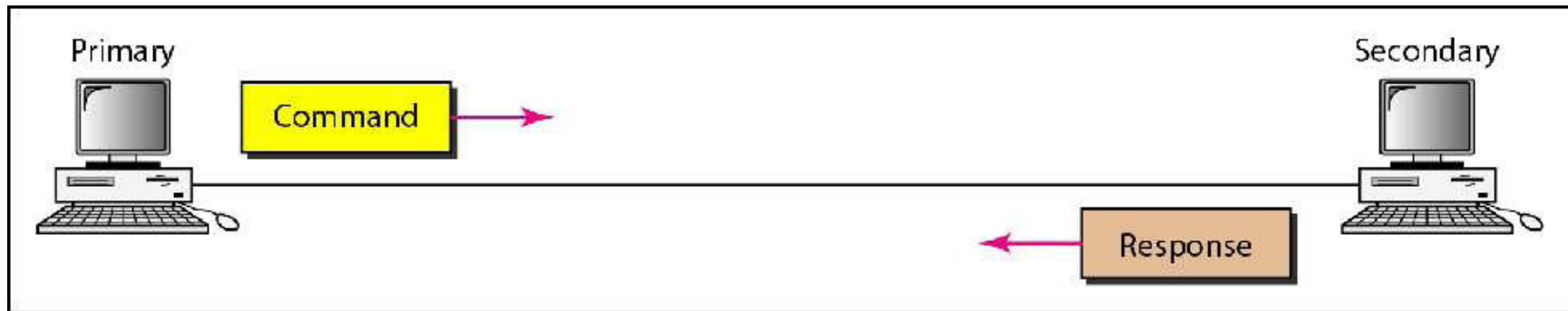
- In simulation a *process* is something that does something
- A process has some *internal state*
- Processes communicate by sending *signals* to each other
- Signals have a name and can carry information
- When a signal arrives to a process some *activity* is triggered
- During an activity the state 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

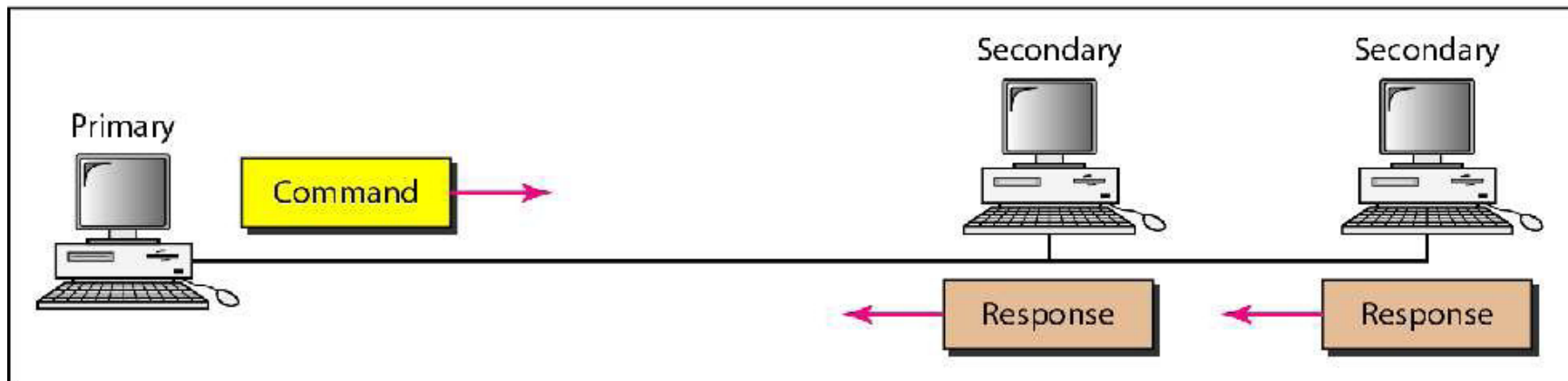
- HDLC
(High-level Data Link Control)
- PPP
(Point-to-Point Protocol)

HDLC

- NRM (Normal Response Mode)



a. Point-to-point



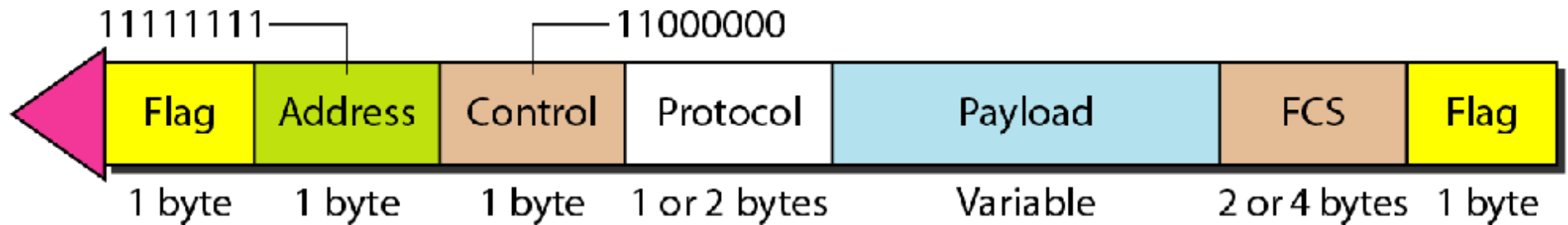
b. Multipoint

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

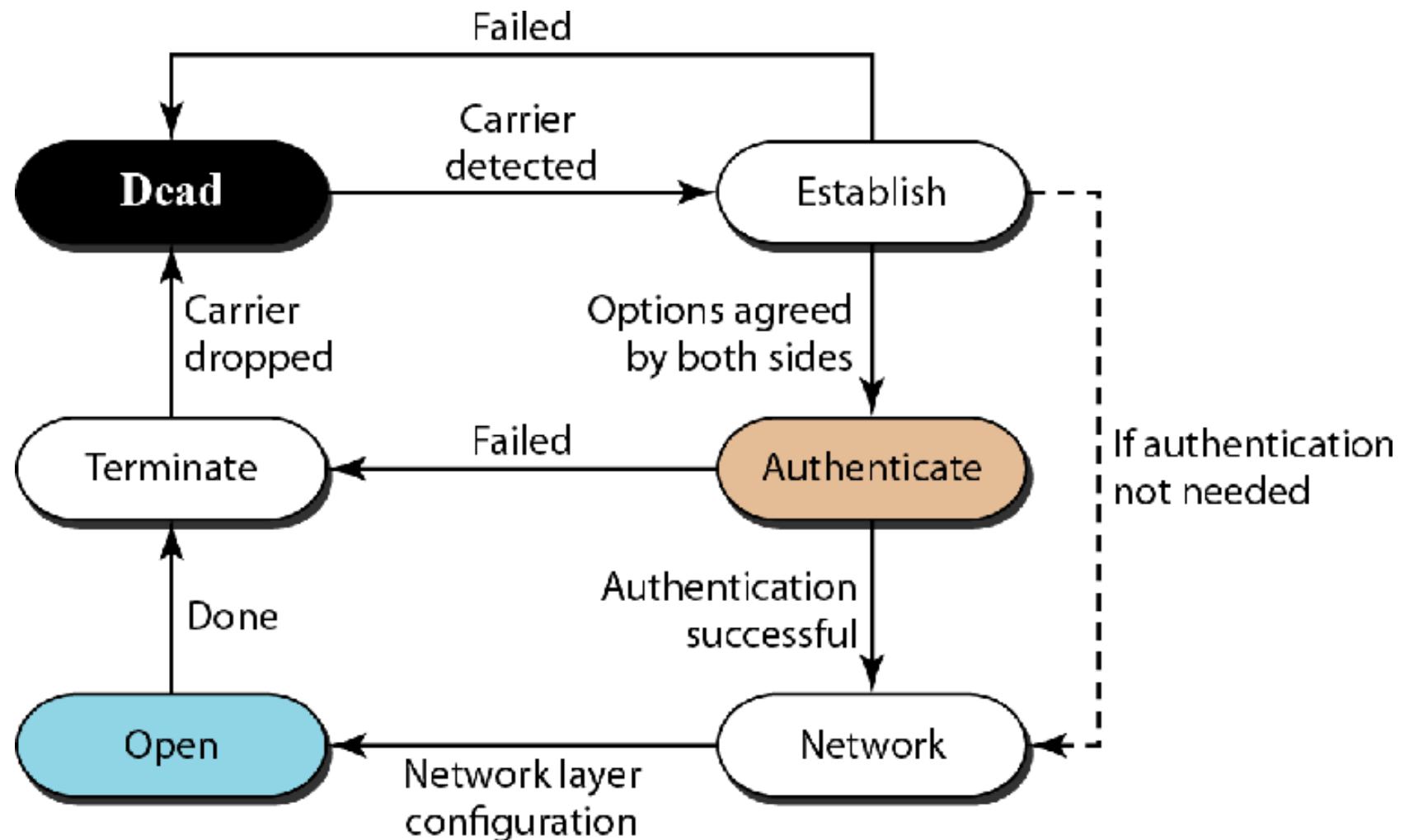
PPP

- Formatet på en PPP-ram

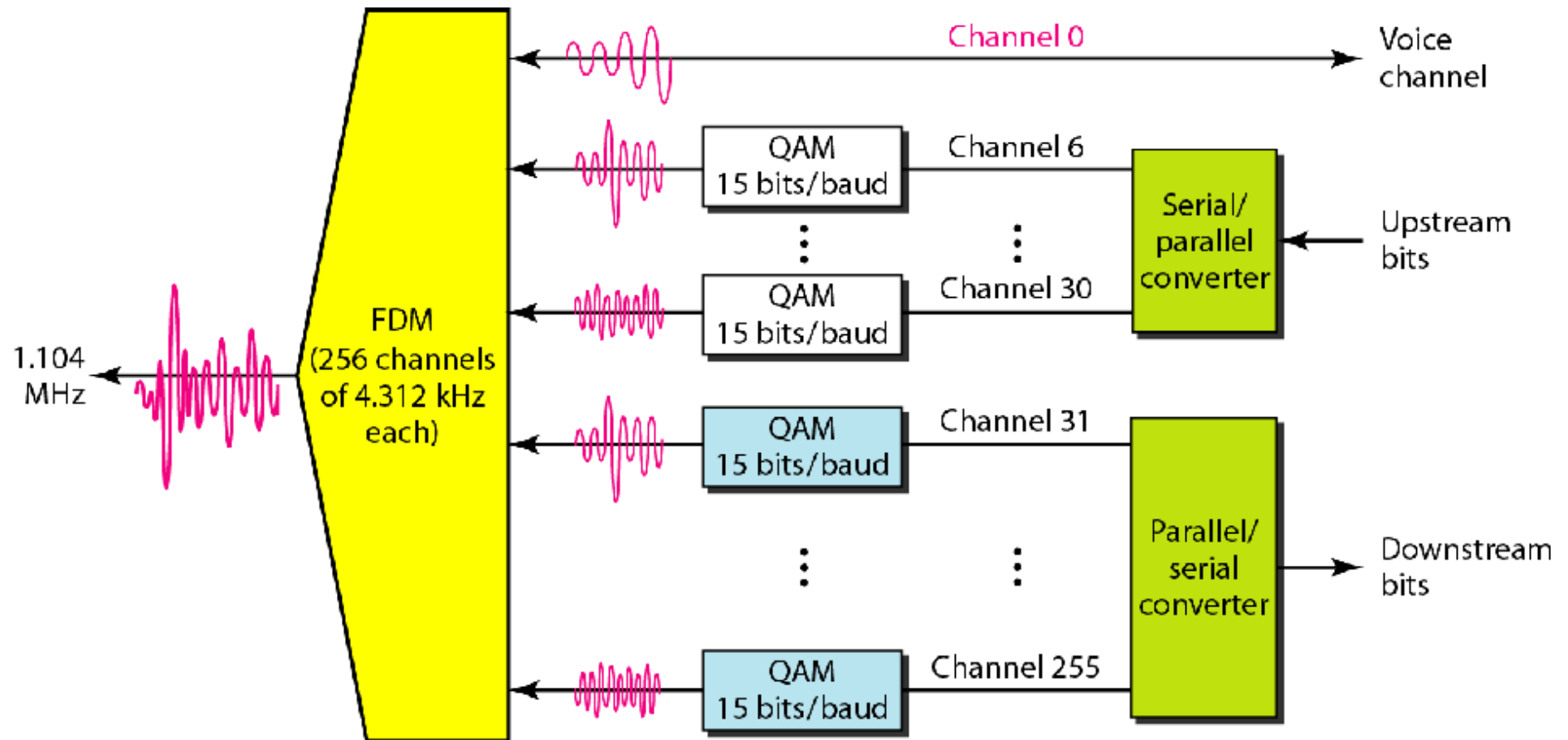


PPP

- Tillståndsgraf för PPP

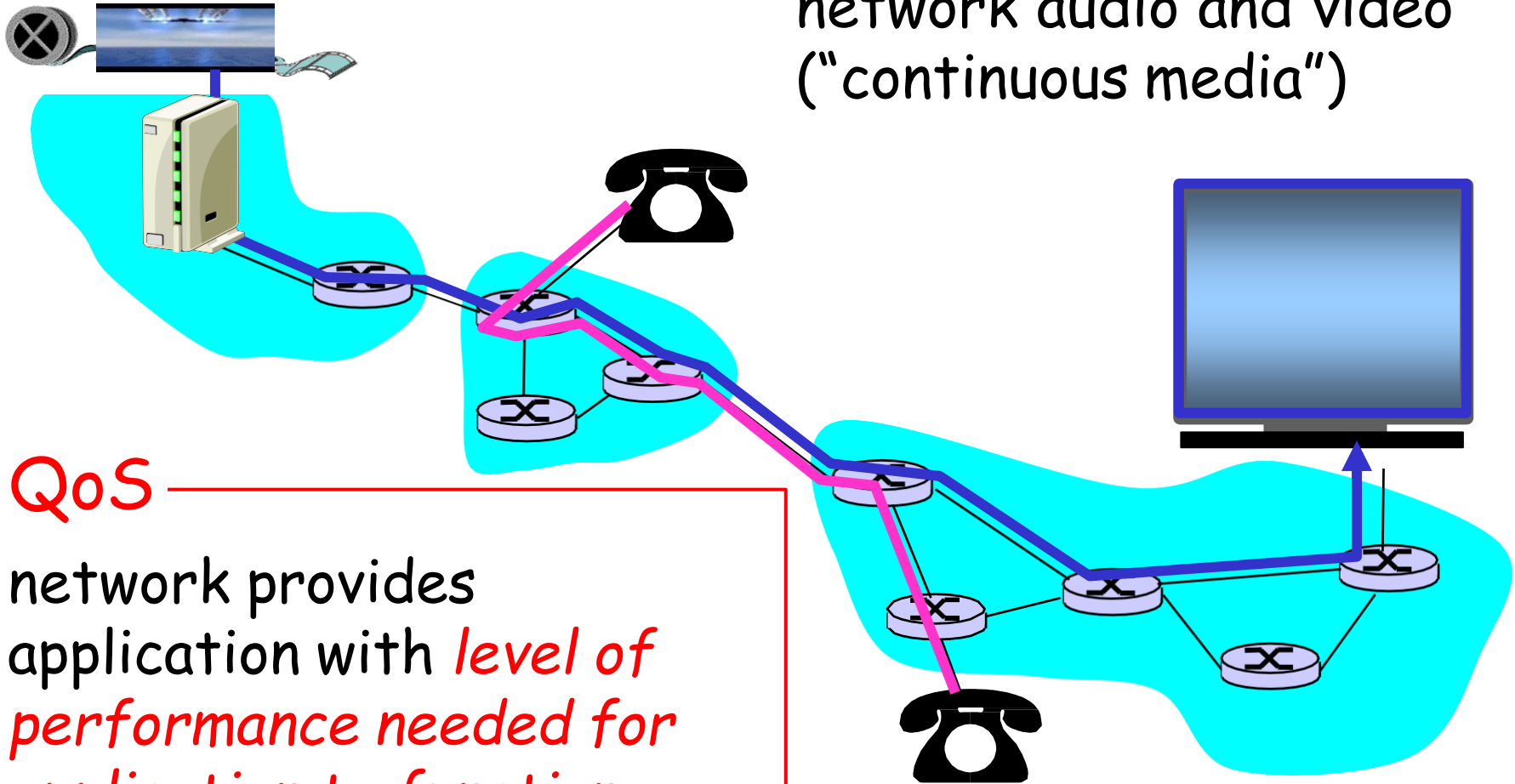


ADSL



Multimedia and Quality of Service: What is it?

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



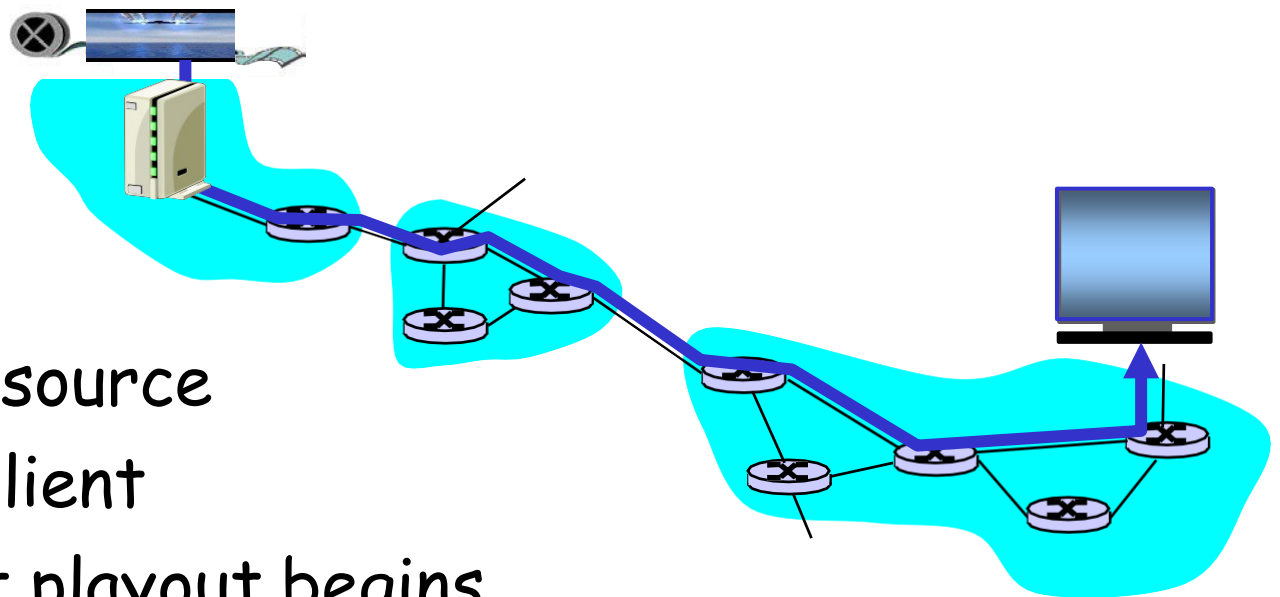
QoS

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

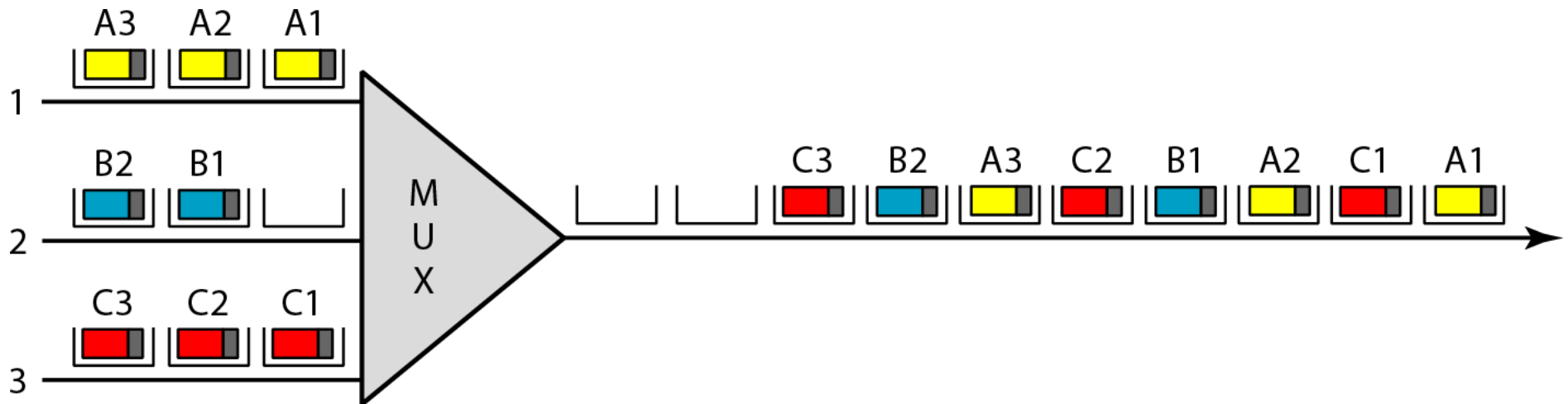


ATM

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

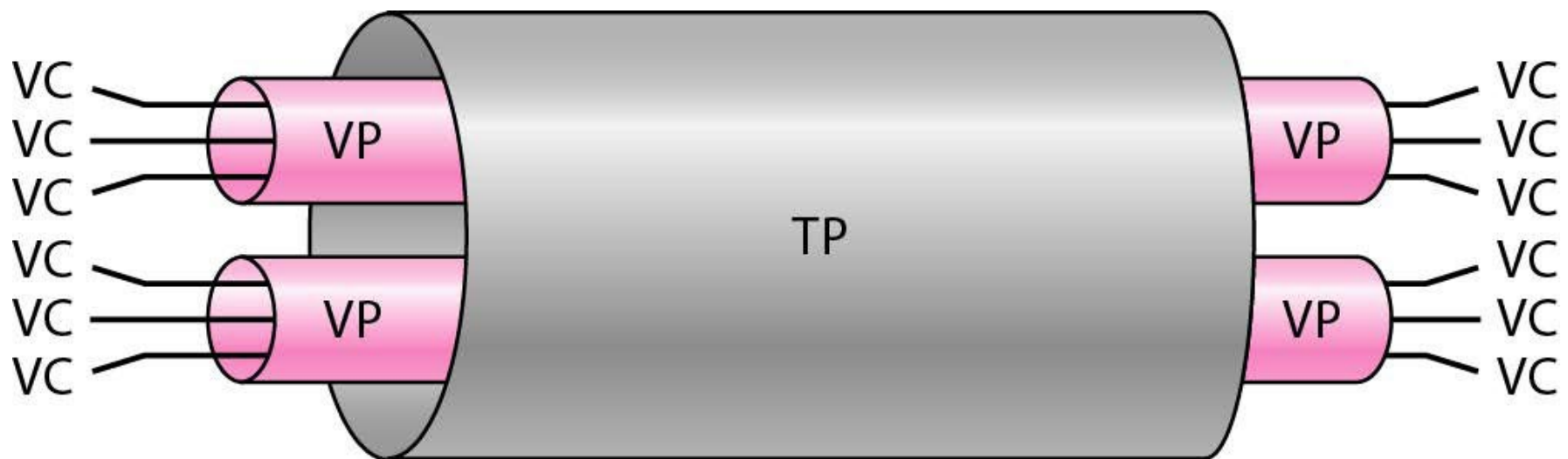
ATM

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

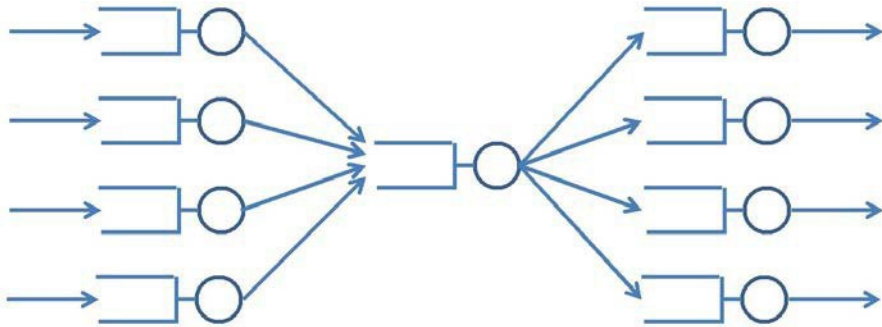


ATM

- 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
-

$P(\text{spärr})=?$

Little's sats
 $E(N) = E(T) \cdot \lambda_{eff}$

