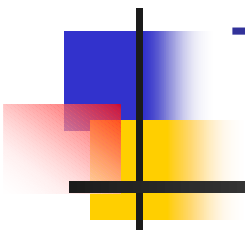
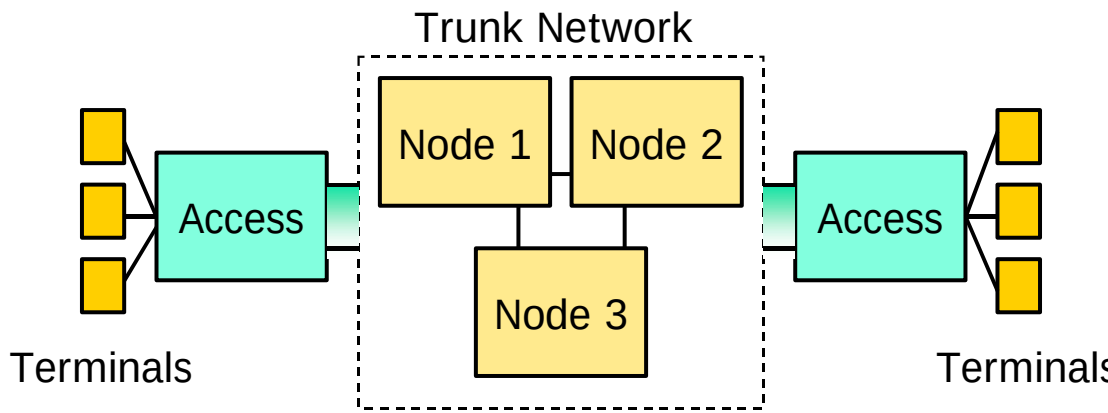


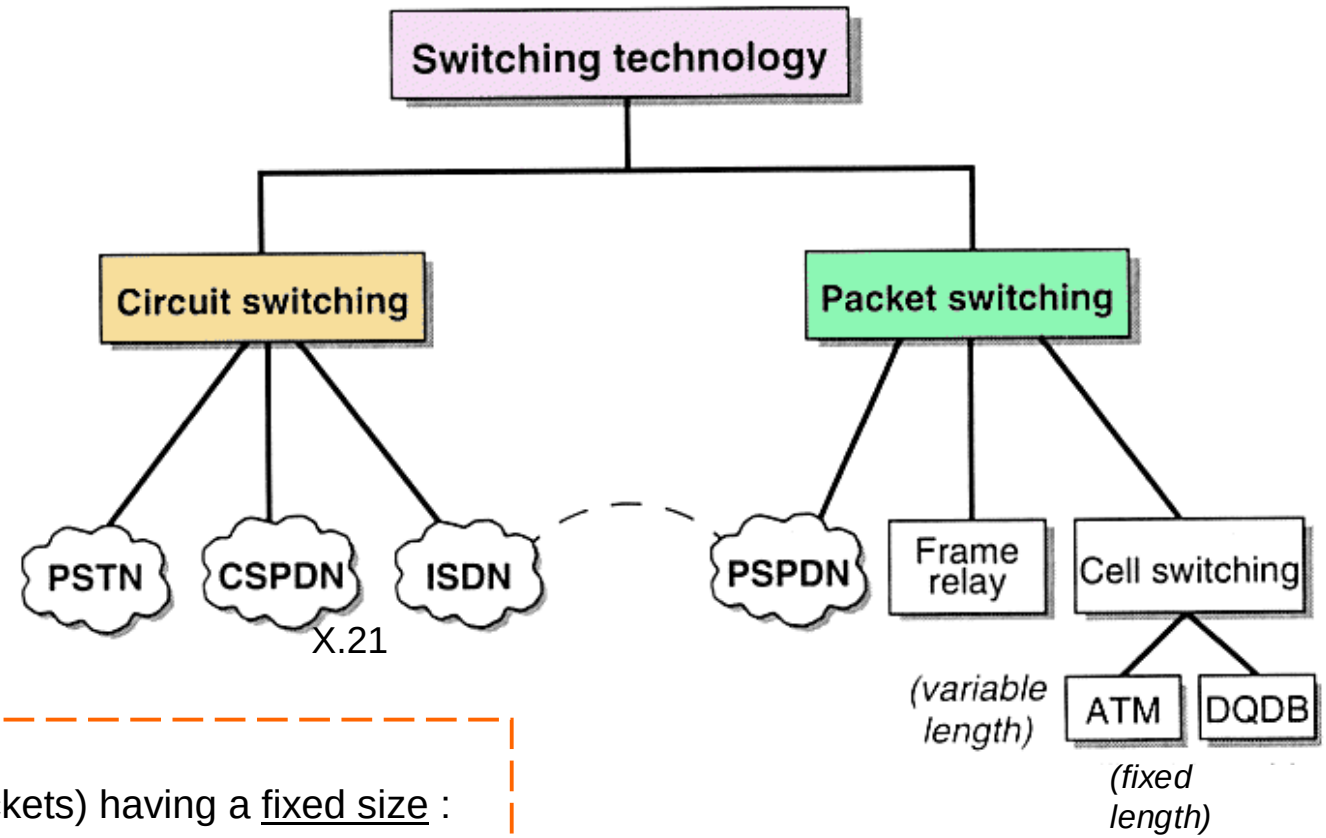
Public Switched Telephone Network (PSTN II/II)

Topics today in PSTN



- A: Switching types
  - Connectionless/ connection oriented
  - Packet/circuit
- B: PSNT exchanges and interfaces
  - interface Q.512
  - using access and trunk networks
  - signaling
  - network management
  - internetworking - Digital Circuit Multiplexing Equipment DCME (G.763)

Switching in public networks



Cell switching

- works with cells (packets) having a fixed size :
  offers bounded delay guarantees
  (QoS compatible, long packets won't stuck cells)

CSPDN: Circuit switched public data net*
PSPDN: Packet switched public data net**
DQDB: Distributed queue dual bus

** Used by European Telecom's that use X.21 in circuit switched nets*
***Used by British Telecom's Packet-switched Service (PSS), Data Pac (Canada) ...*

Circuit switching

Circuit switching

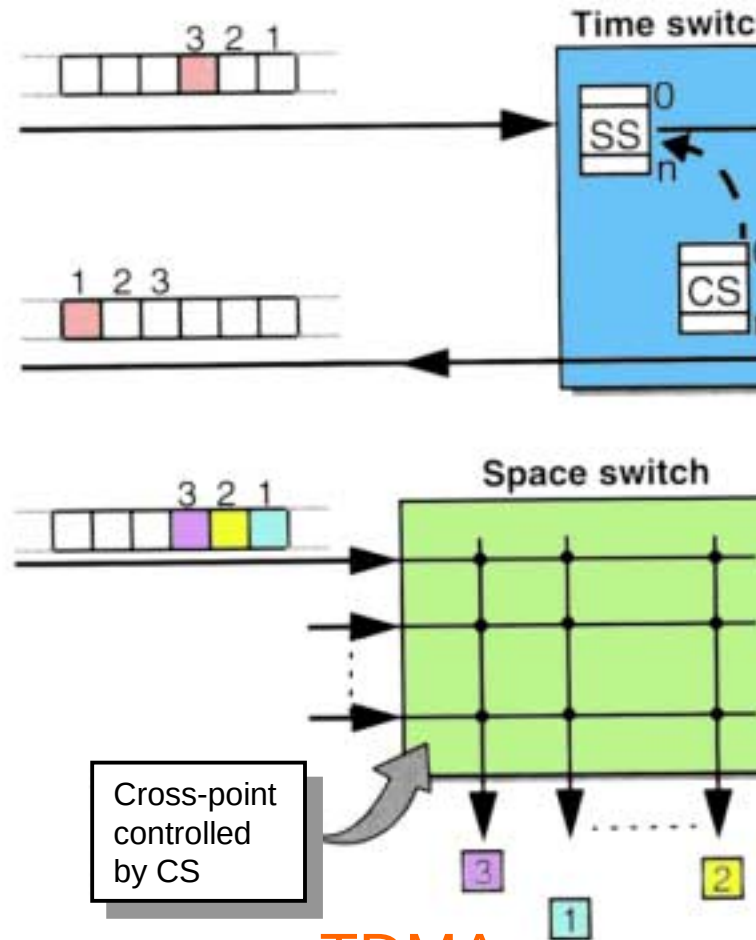
- dedicated path
- constant delay/bandwidth
- voice/data
- paid by time
- examples: PSTN, GSM?

Time switch

- Makes switching between time slots
- In the figure incoming slot 3 is switched to outgoing slot 3 for one voice direction
- Each coming timeslot stored in Speech Store (SS)
- Control store (CS) determines the order the slot are read from SS
- The info in CS is determined during setup phase of the call

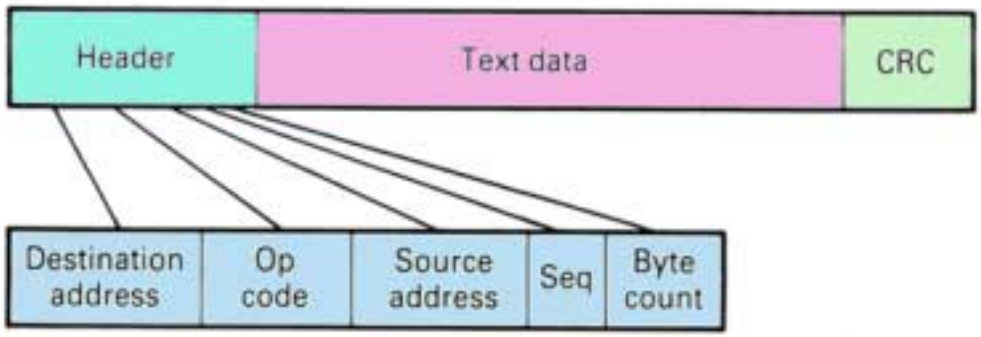
Space switch

- makes switching between PCM lines
- *works with* electronic gates controlled by CS

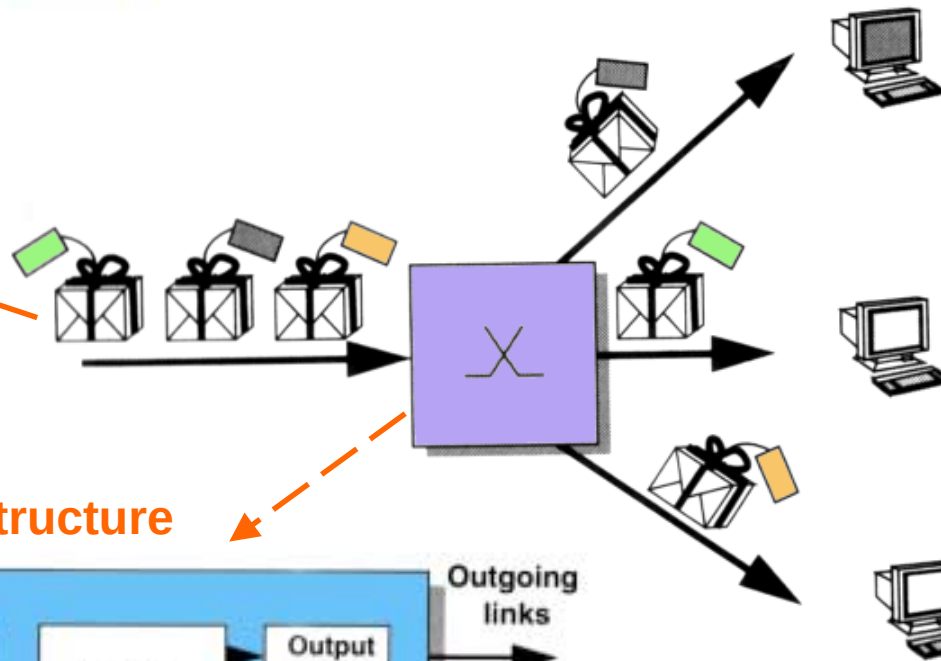


TDMA

Packet switching



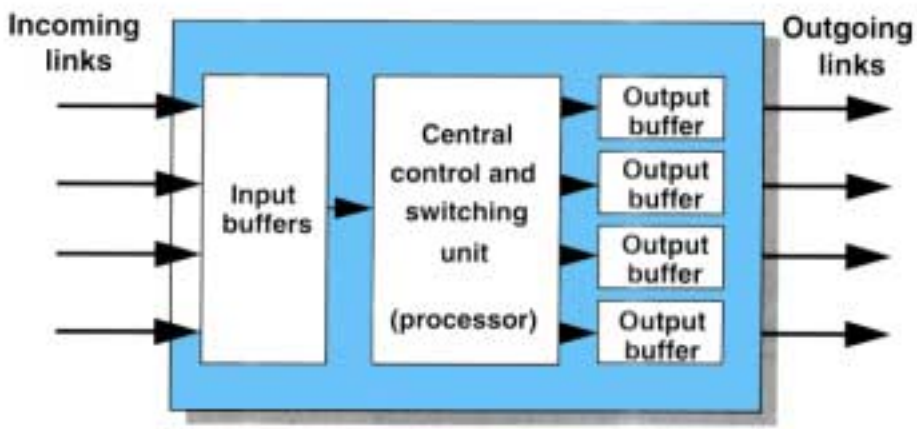
example



Packet structure

Seq: sequence number
Op code: message/control identifier
CRC: Cyclic Redundancy Code

Node structure

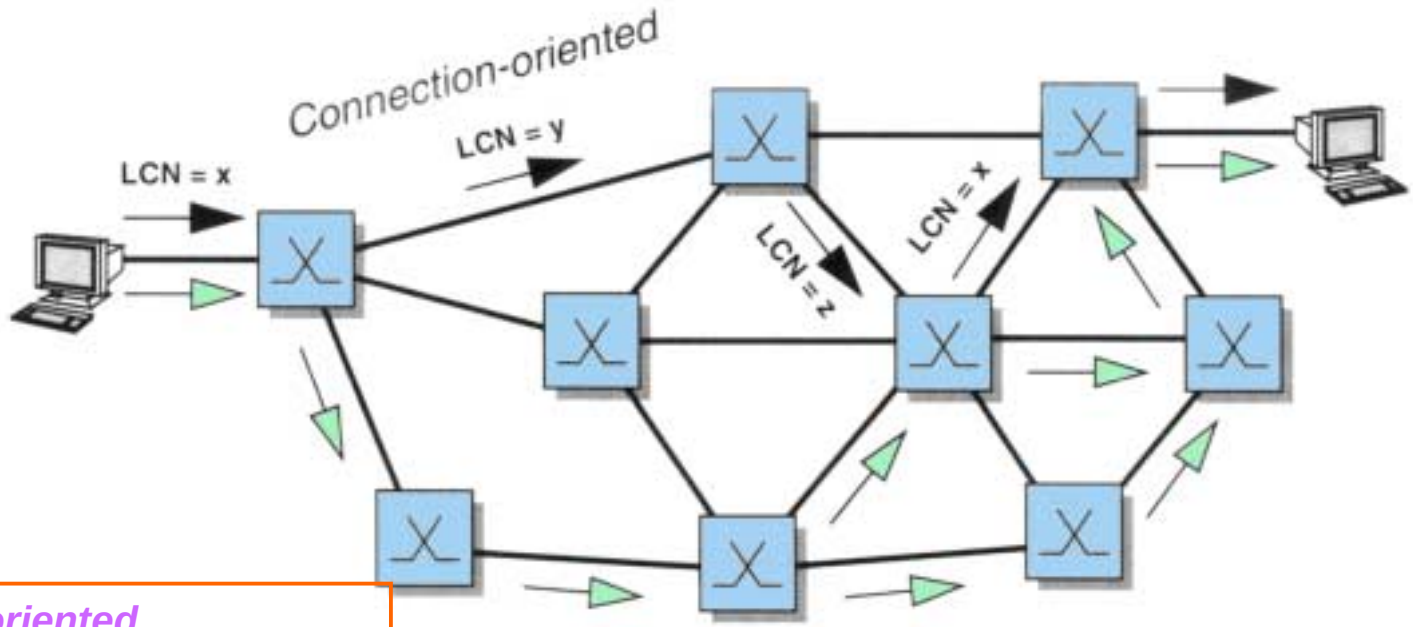


Note:
- source address required for retransmission in ARQ
- byte count could be also an end flag

Packet switching summarized

- General characteristics
  - can use packets of **varying length**
  - packet is assigned an **address** and the necessary **control** information
  - packets are placed in **frames**
- Each sent frame stored in a buffer (**store & forward**) in a receiving node and its information is checked before re-sending -> **delays** but **errorless transmission** possible
- In summary: packet handing by nodes consists of
  - checking the **packet format**
  - checking for **errors** (link level - OSI 2)
  - **waiting** for available outgoing path capacity
- Nodes have routing tables (network level - OSI 3)

Connection-oriented and connectionless switching



Connection oriented

- Applies same route
- QoS well defined

- Phases
  - Connection setup
  - Data transmission
  - Release
- Packets received in same order
- Example: ATM, frame relay, PCM

Connectionless

- Use of different routes for each packet possible
- Each packet has address fields
- QoS not guaranteed

- Packets may come in different order
- Example: IP (Internet Protocol), TCP takes care of cleaning the mess

Transfer modes & connections summarized

Transfer modes

Circuit switching

PSTN
ISDN
PCM

- developed for voice
- nowadays also for data
- well-specified delays
- echo problems

Packet switching

- developed for data
- nowadays also for voice
- statistical multiplexing
- generally variable delays

IP, Frame-relay
ATM

Connection types

Connection oriented

ATM
Frame-relay
X.25

- hand-shaking
- strict error requirements
- for fast data transfer

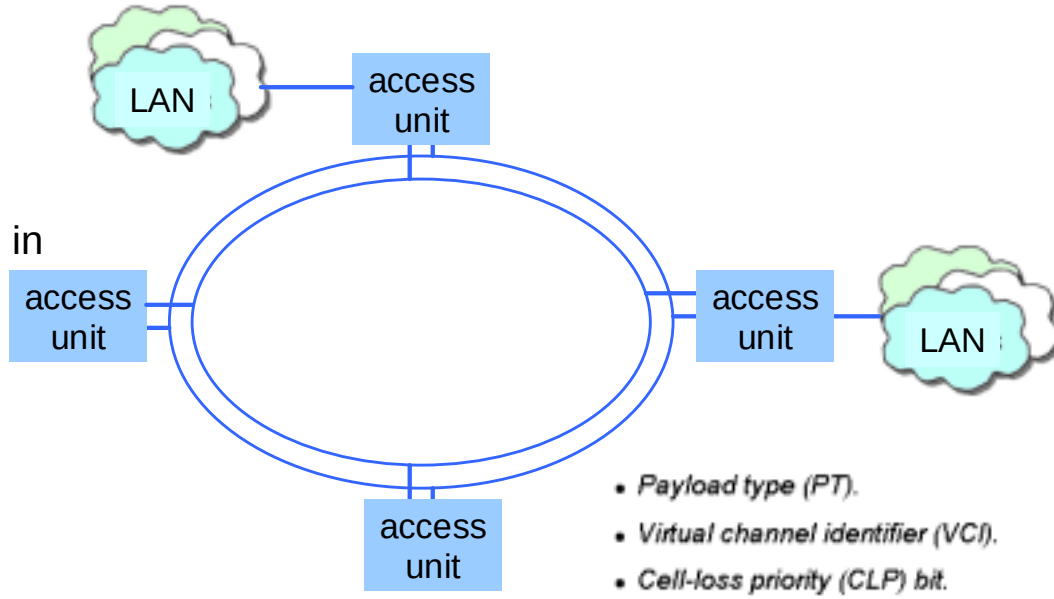
Connectionless

- especially for broadcasting/ streaming
- modest error rates often accepted
- for fast data in good channels

X.25, IP, UDP*

*User Datagram Protoc

Example of cell switching: Distributed queue dual buss (DQDB)



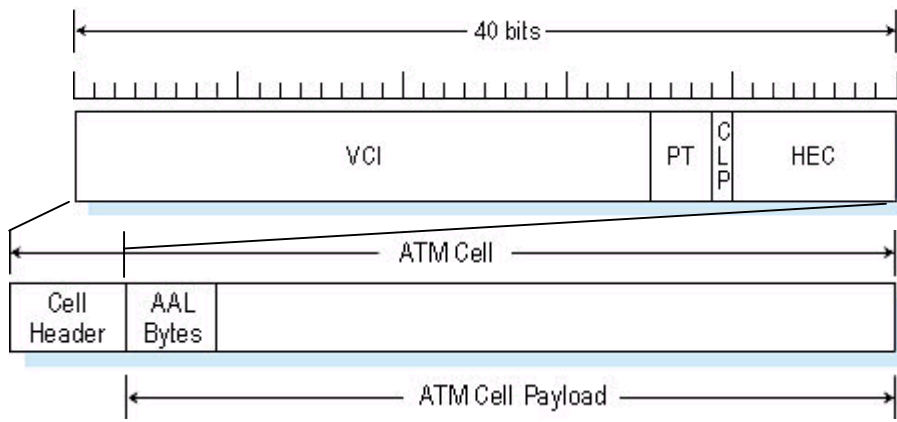
Function

- **transport units** have a constant length
- **access units** access known subscribers in access unit's subnets and route packets for them
- **access protocol** applies token ring

Properties

- distributed switching (see also FDDI*)
- ATM compatible
- rates: 64 kb/s ... 45 Mb/s
- geographical limit up to 200 km

- *Payload type (PT).*
- *Virtual channel identifier (VCI).*
- *Cell-loss priority (CLP) bit.*
- *Header error checksum (HEC) byte*

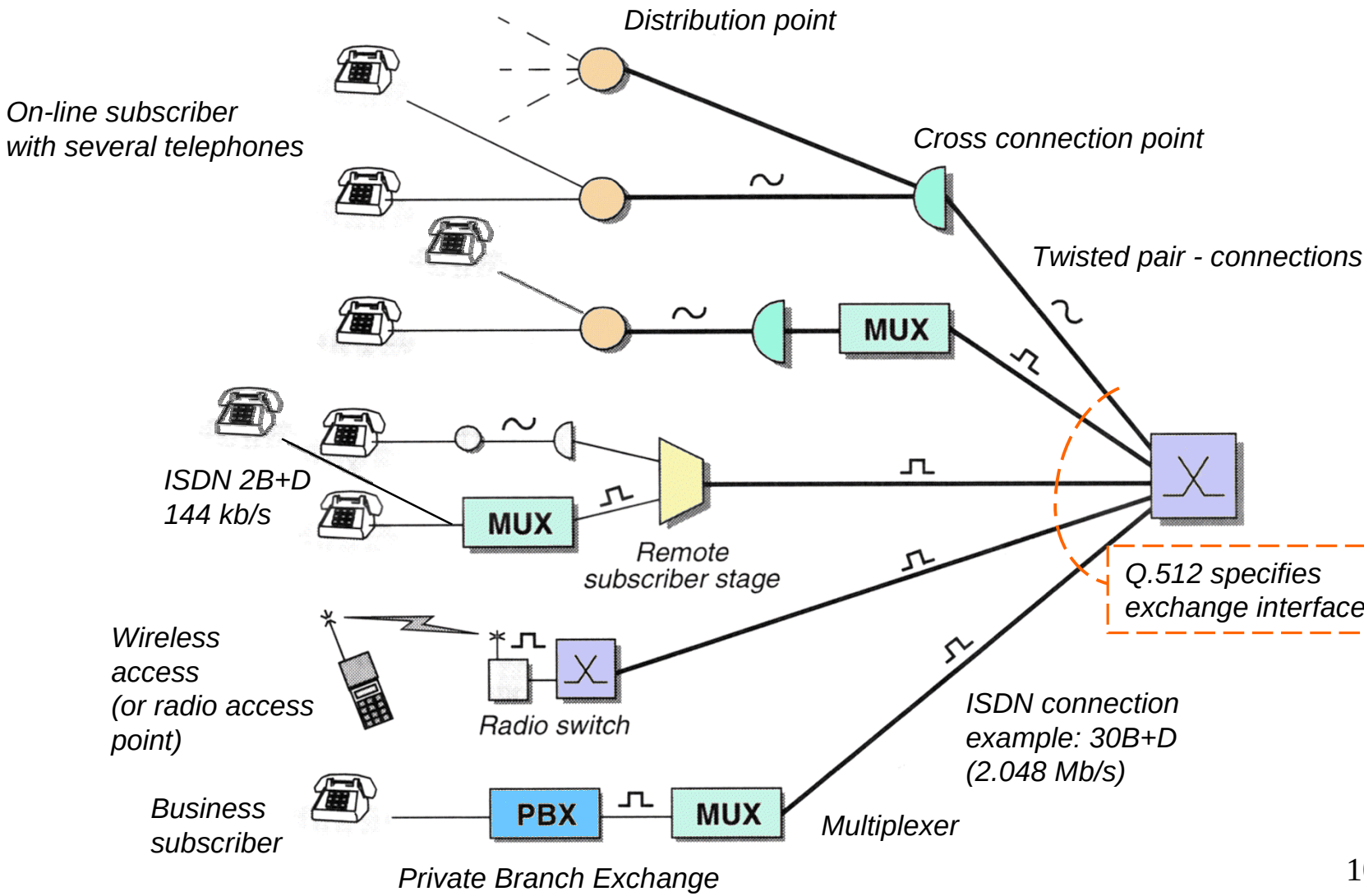


* *FDDI: Fiber Distributed Data Interface*
for description, see the supplementary material of this lecture

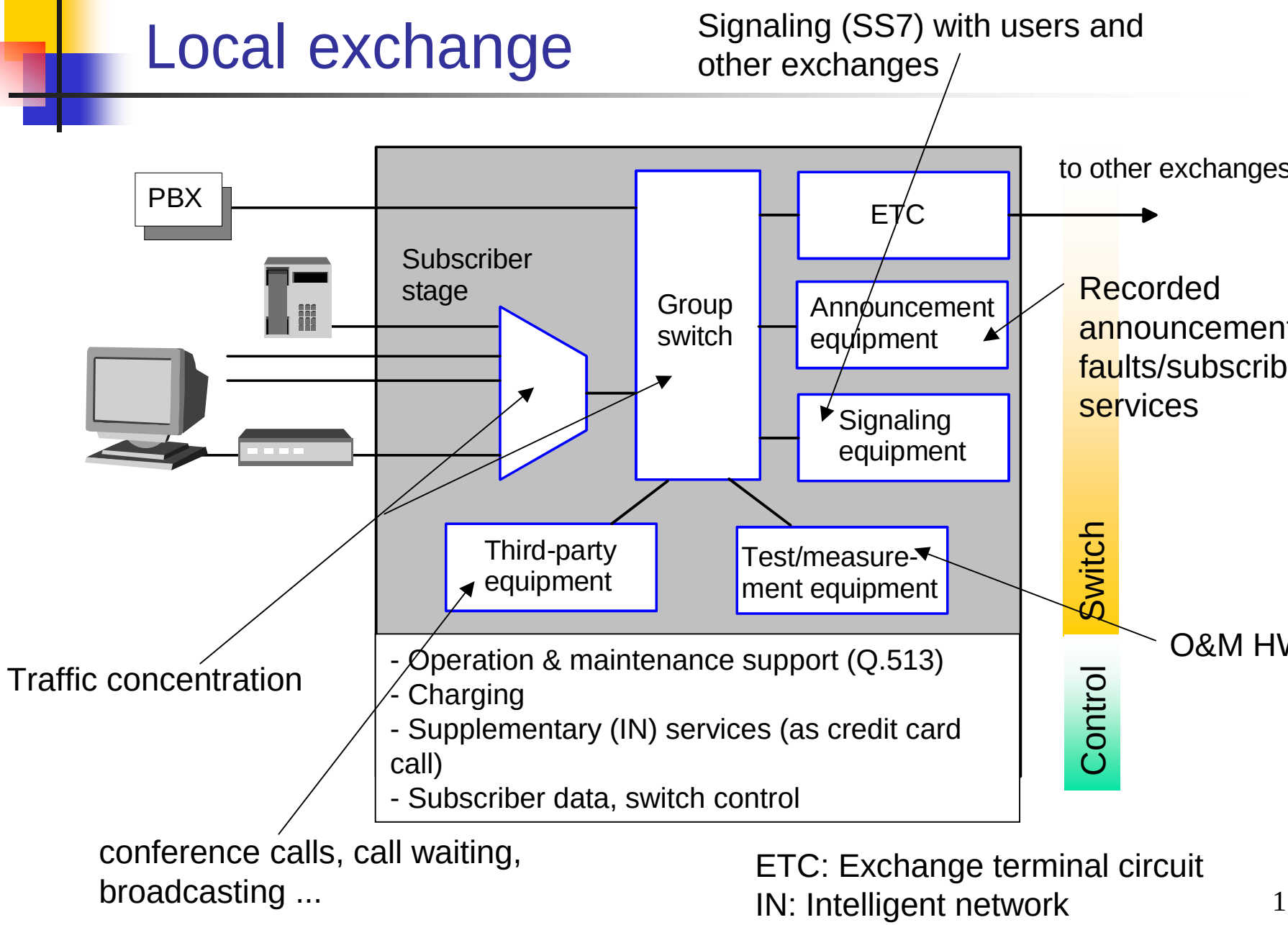
AAL 1: For constant-bit-rate (CBR) services and circuit emulation.
AAL 2: For variable-bit-rate (VBR) services.
AAL 5: For data (for example, IP datagrams)

Transport Unit (same as in ATM)

Connecting into PSTN exchange: Equipment in the access network

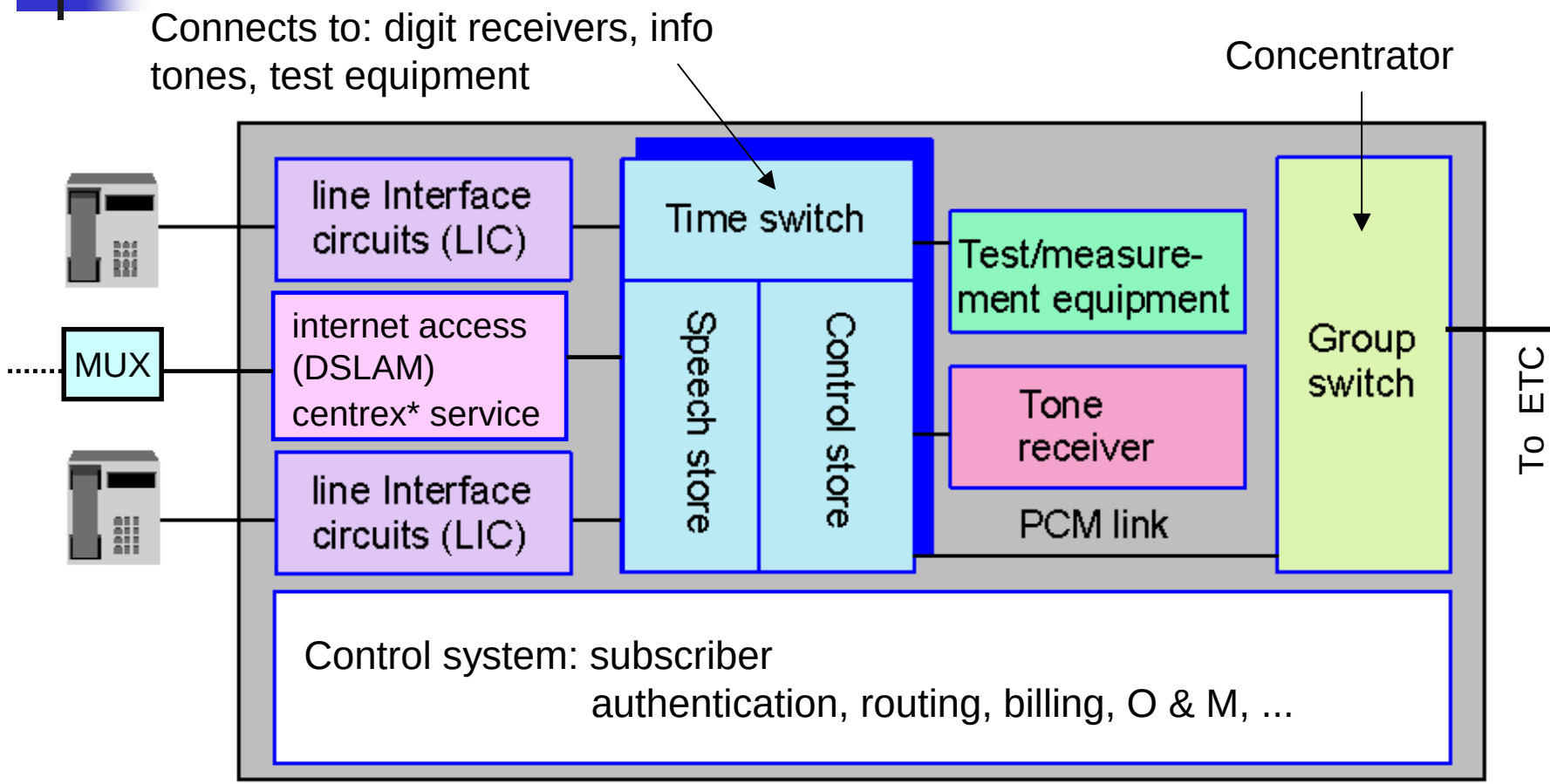


Local exchange



ETC: Exchange terminal circuit
IN: Intelligent network

Subscriber stage



ETC: Exchange terminal circuit
Speech store: shift registers storing bits for time switching
Control store: gates guiding speech store switches
* leased PBX function from local exchange

Exchange control functions

- **Maintenance** functions
  - supervision of subscriber lines and trunk circuits
- **Operational** functions
  - ***administrative*** data as
    - subscriber database
    - routing database
  - ***statistical*** data as
    - from where and whom subscribers call
    - holding times for different equipment types
    - utilization of IN services
- **User services**

Sample of IN services

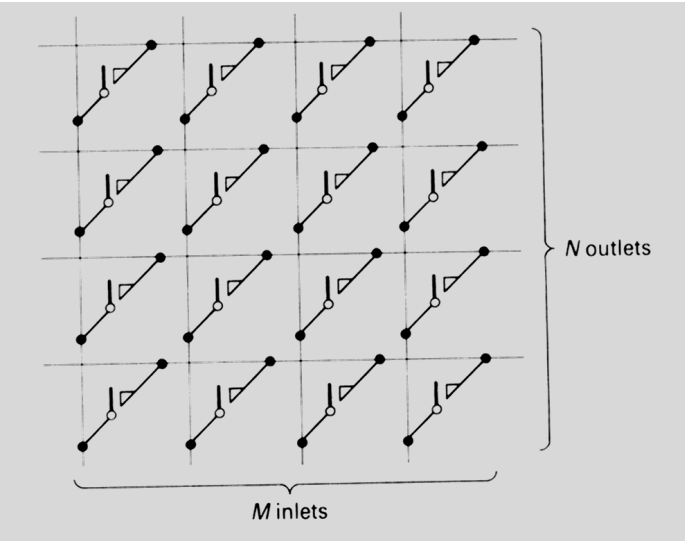
• Pre-Paid	• Calling Card
• Free Phone/Toll-free (NDB 800)	• Single Number Service
• Virtual Private Network	• Number Portability
• Personal Number	• IN based call centers
• Premium Rate	• Call Screening Capabilities

Exchange user services (examples)

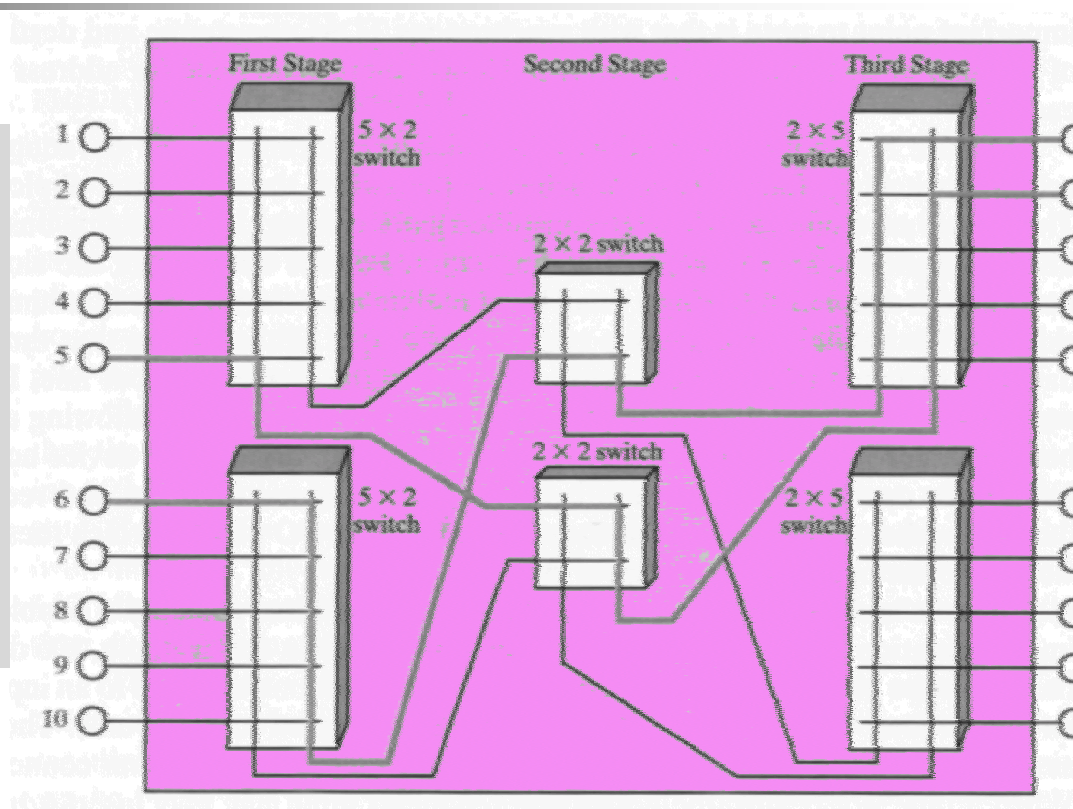
- **Absent-subscriber** services as the answering machine
- **Call booking**: connection at the desired time
- **Person-to-person call**: ensures that call goes to a right person
- **Serial call**: setting up several calls
- **Telephone conferencing**: several persons participate to call in real-time (compare: tele-conferencing)
- **Directory inquiries**: also speech recognition, recorded messages

(many of these nowadays available in terminals)

The space-switch (used as a cross-switch and concentrator)

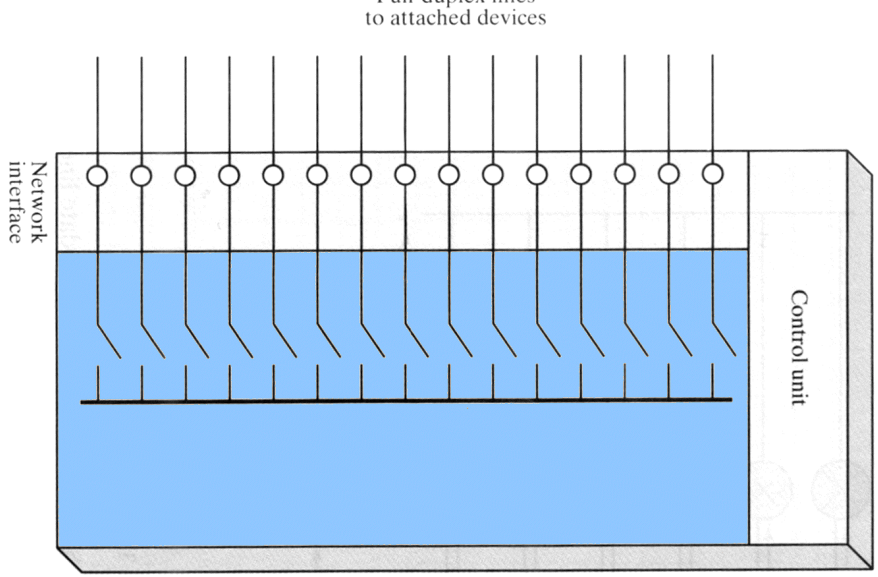


Cross-bar switch
(space division matrix)



- Number of cross-connections reduced compared if a simple space division matrix of NxM (input x output) would be used
- Usually performs concentration: Blocking possible
- Same signal can be routed via different paths: increased reliability
- application: connects physically separate PCM-lines

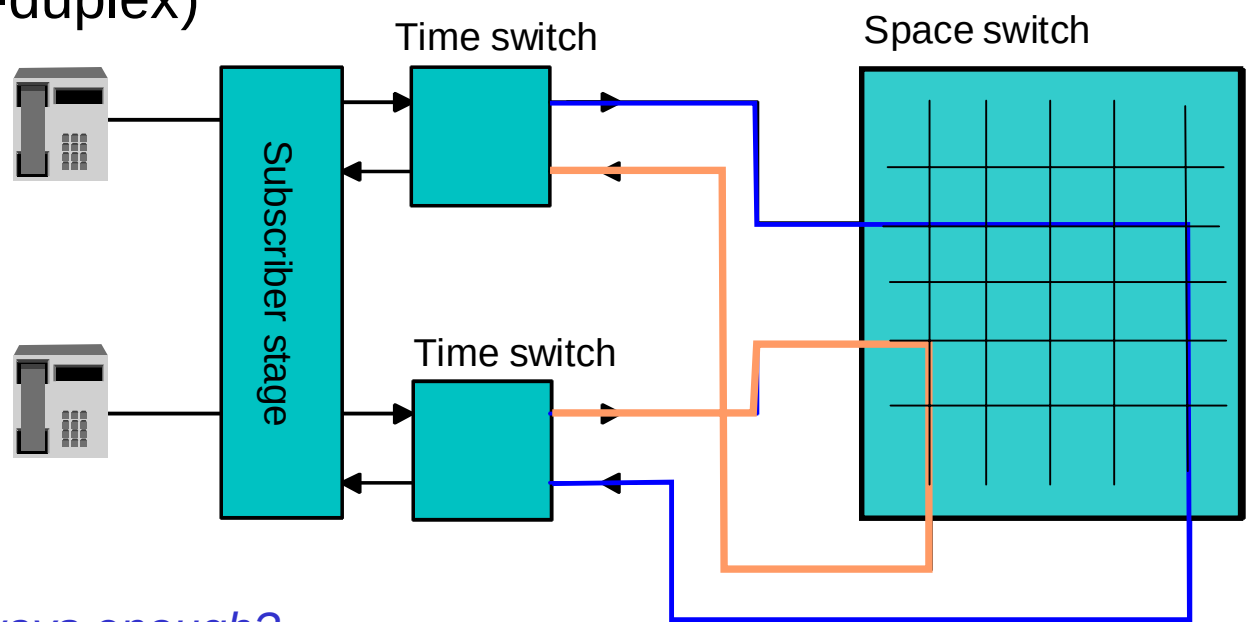
The time-switch



- One of the time slots of any **full-duplex** lines is connected to some other line (at a time)
- Thus two switches / time slot connect a line
- For 100 full-duplex lines at 19.6 kbps a 1.92 Mbps bus is thus required for no blocking
- If no fixed assignment of input lines to time slot but on demand allocation -> blocking switch that reduces number of switches and switch clock frequency. For instance 200 lines of 19.6 kbps with bus of 1.92 Mbps
  -> about half of the devices can connect at any time, eg concentration is 2:1

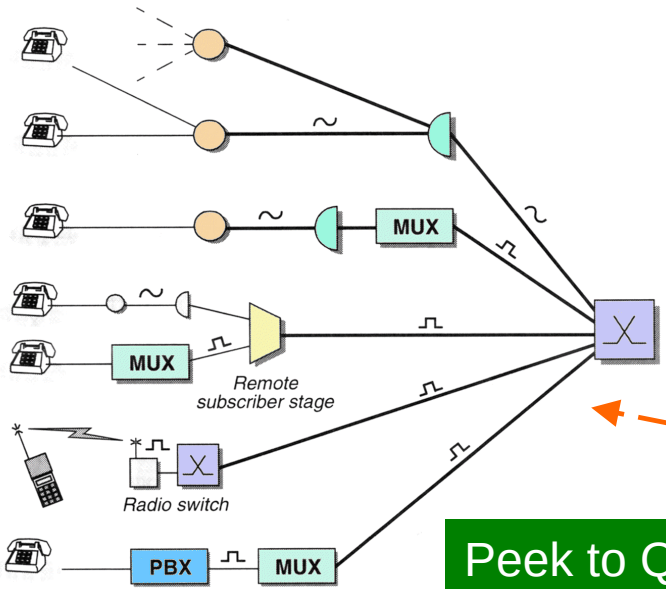
The time-space-time (TST) switch

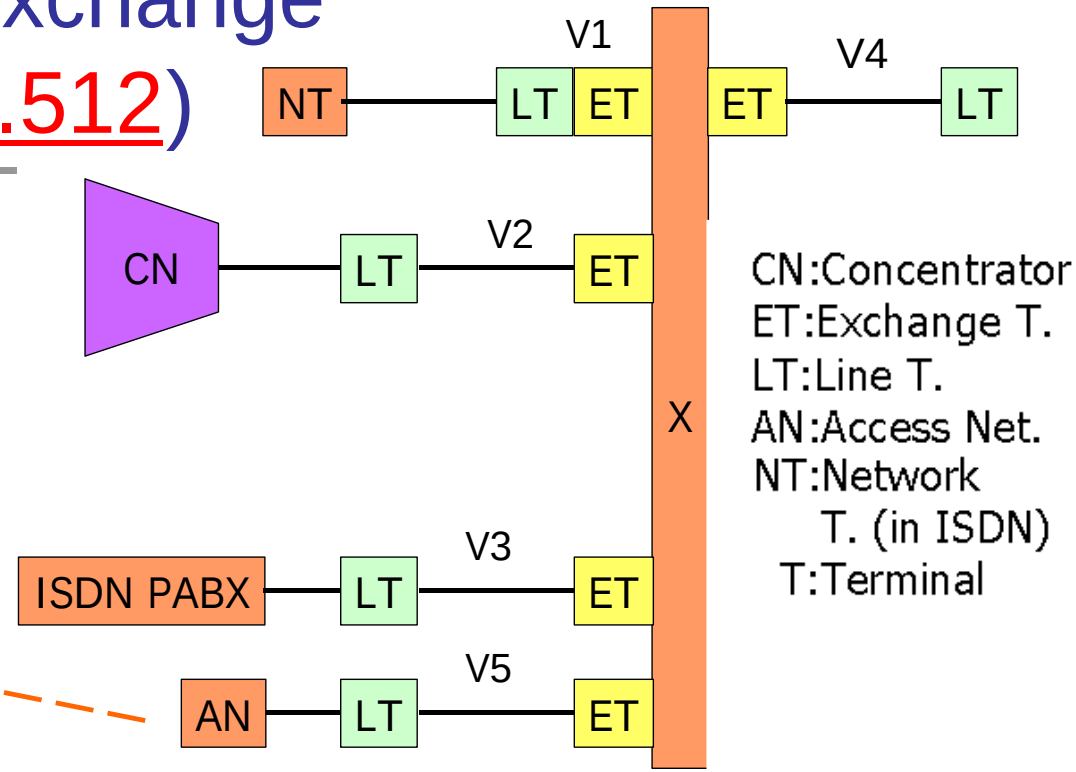
- Works in local exchange and subscriber stage
- Performs PCM concentration, usually 10:1 ... 3:1
- Connects subscribers also to information tones and test equipment
- Time switch contains one bus for incoming and outgoing calls (full-duplex)



Question: Why time or space switch is not always enough?

PSTN ISDN exchange interfaces (Q.512)





Peek to Q-recommendations

Q.511	Exchange interfaces towards other exchanges
Q.512	Digital exchange interfaces for subscriber access
Q.513	Digital exchange interfaces for operations, administration and maintenance
Q.521	Digital exchange functions
Q.522	Digital exchange connections, signalling and ancillary functions
Q.541	Digital exchange design objectives - General
Q.542	Digital exchange design objectives - Operations and maintenance
Q.543	Digital exchange performance design objectives
Q.544	Digital exchange measurements

Exchange interfaces and tasks, V1

- Purpose of exchange is to organizes connection between exchange terminators!
- V1: Access to basic ISDN (This is user's ISDN-u interface that can be used to connect small PBX also)
- Basic ISDN V1-functions:
  - 2 B + D (2x64 kbps + 16 kbps) channeling structure
  - timing and frame synchronization
  - activate and deactivate terminator
  - operation and maintenance
  - feeding power supply
  - ISDN basic access parameters defined in G.961

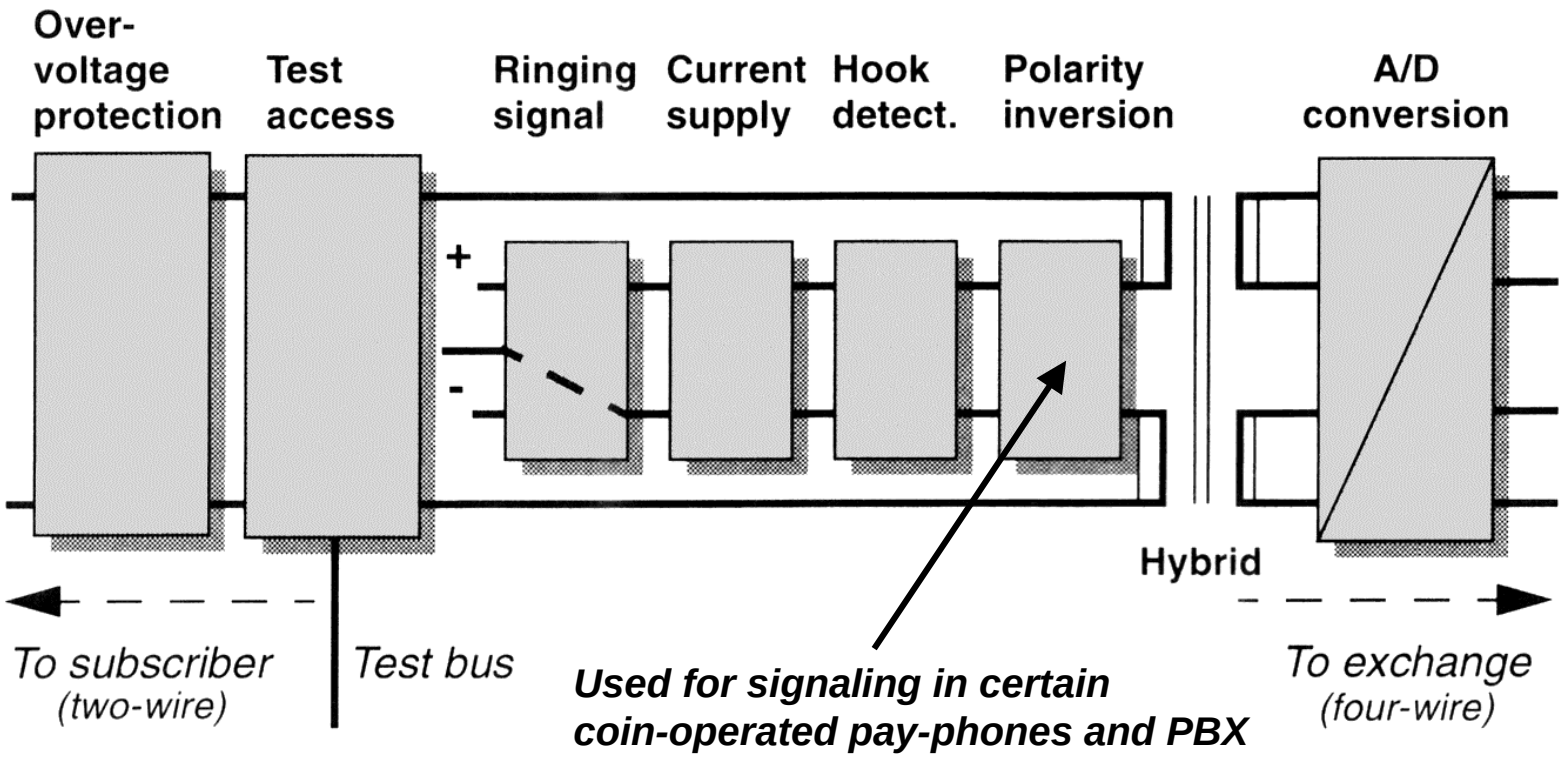
Exchange interfaces and tasks, V2-V4

- V2: Interface serves typically concentrators
  - 2048 kbit/s eg
  - 30 B + D
  - Electrical standard G.704
- V3: Resembles V2 but intended for interface other exchanges (PABX)
  - Electrical standard G.703
  - 30 B + D at 2048 kb/s (SDH E-1, Europe)
  - also 23 B +D at 1544 kb/s (I.431) (SDH T-1, US)
- V4:Interface to private networks (as such not ITU-T specified), for instance DSLAM (ADSL-interface specified by ADSL-forum - ANSI T1.413 , ITU-T: G.992)

Exchange interfaces and tasks, V5

- Between access network and exchange
- 2048 kbit/s basic rate
- Specifies basic interfaces for
  - Analog access
  - ISDN-access
- Electrical interface G.703
- Channel control and signaling
- V5 supports interface rates 2048 kbit/s ... 8448 kbit/s

Connecting the local loop: Line interface circuit (LIC)

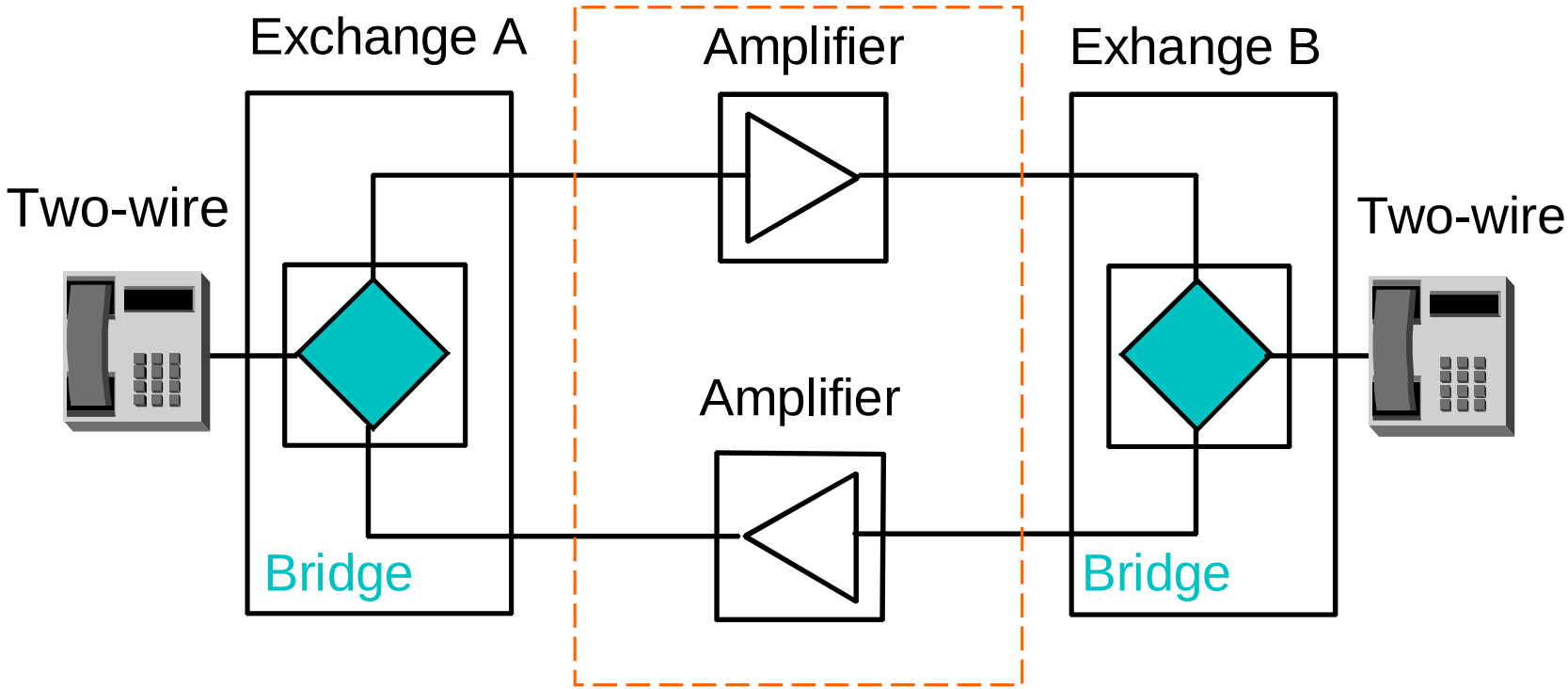


Line interface circuit components

- Over-voltage protection
- Test equipment to connect to monitor the line condition faults
- Voltage feed
  - ringing
  - telephone current supply
- Detection of
  - hook stage, pulse generated, or dual-tone receiver
- The hybrid junction (2 wire - 4 wire interface)
- An A/D converter (uses PCM techniques at 64 kbps)

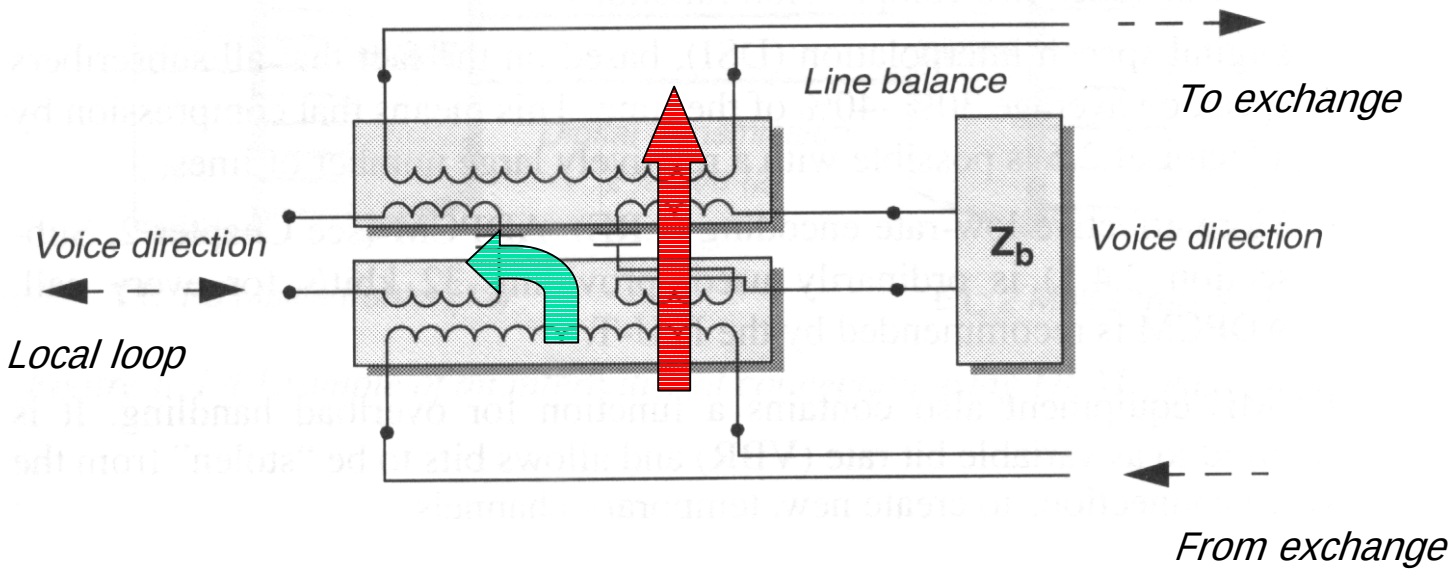
The hybrid circuit

- 4-wire connection is used between exchanges and 2-wire connections from exchange to subscribers



The hybrid-circuit

If the impedance Z_b equals the line impedance no incoming voice (down right) leaks to outgoing voice (up right) but the signal goes via the two wire connection on the left

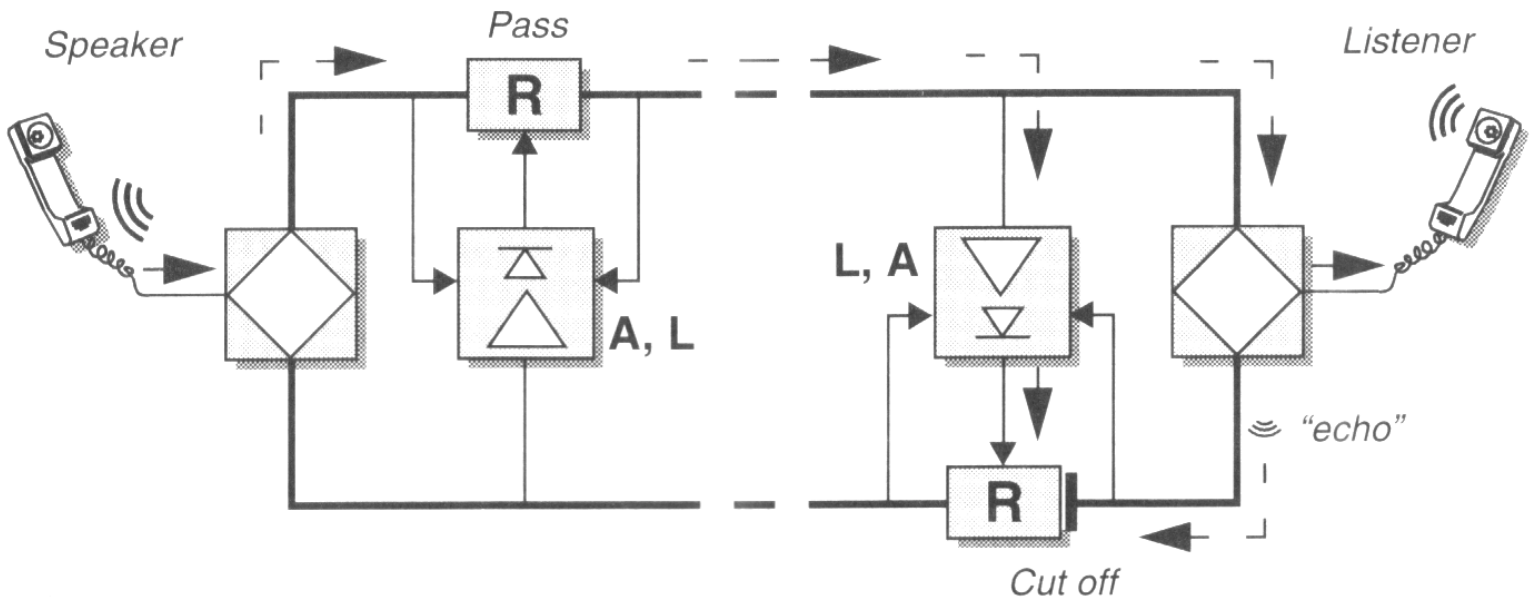


The hybrid circuit summarized

- The hybrid circuit **transforms** two-wire connection into 4-wire connection.
- If the hybrid is unbalanced **echo** will result
  - Hybrid is **balanced** when no own voice is leaked into own loudspeaker
- Hybrid unbalance can result from **line impedance** changes due to weather conditions
- Unbalance results **echo**
- Echo **cancellation** circuits are harmful in data connections
- Nowadays realized by **operational amplifier** based circuitry that automatically monitors line impedance changes

Network echo suppressor (NES)

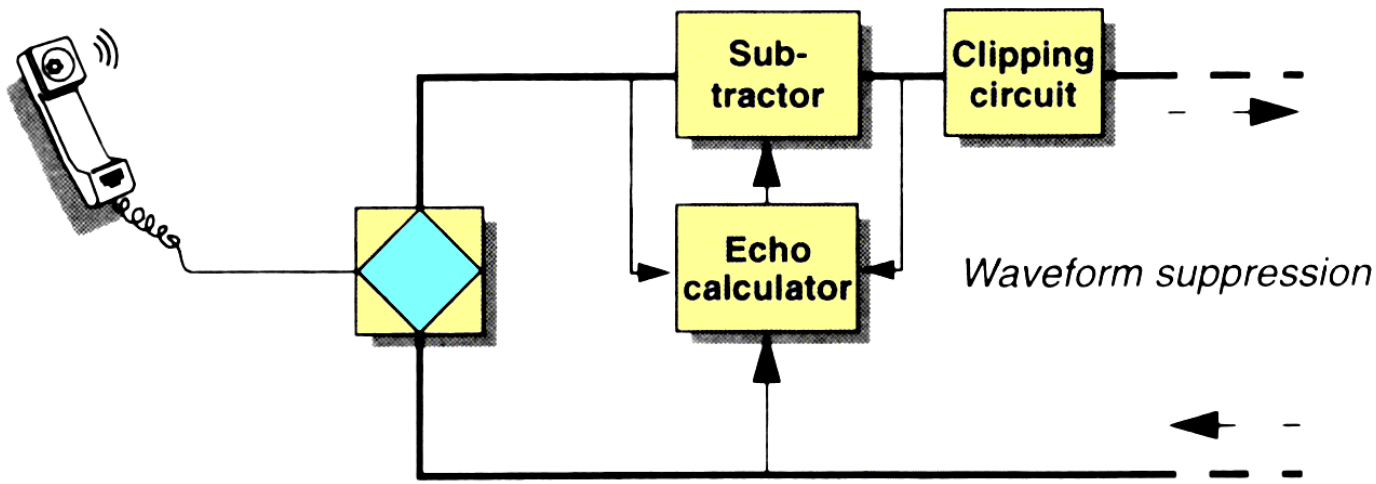
- R: transmission gate, A: attenuator, L: logic circuit
- When the signal is present on the receiving line the transmitting line is **cut-off**



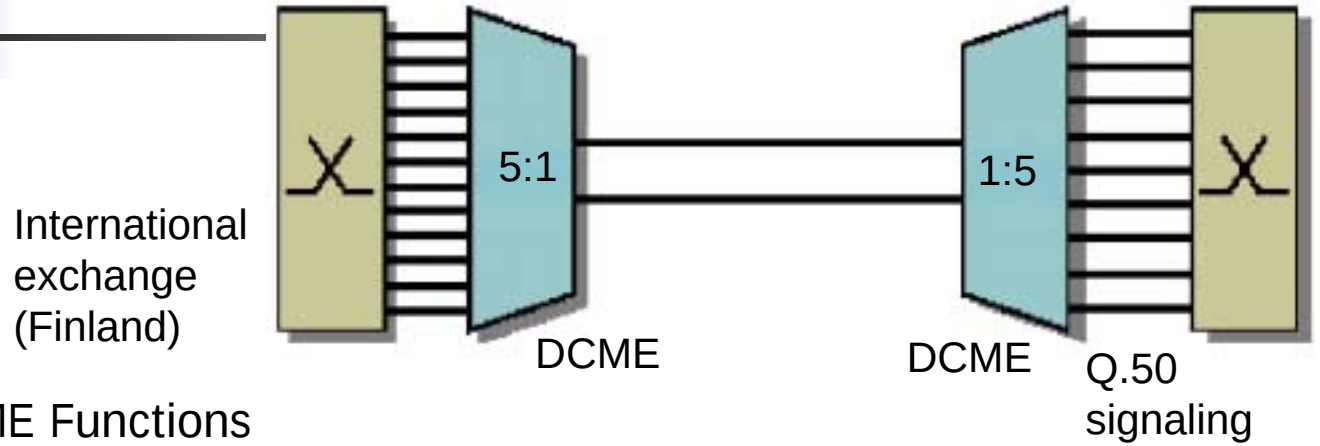
- A kind of semi-duplex approach to solve the echo problem

Network echo canceller (NEC)

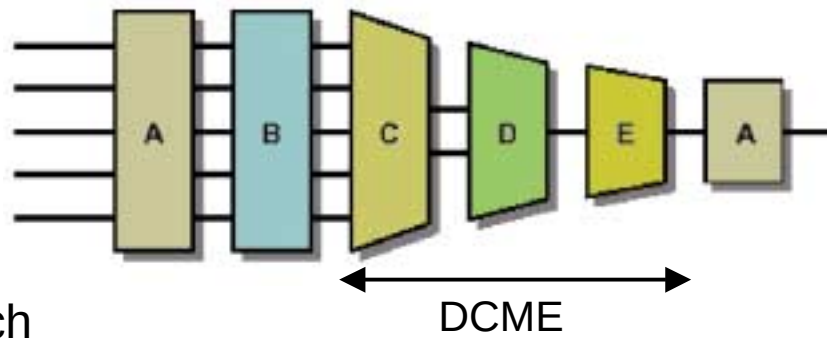
- Signal echo is extracted and **subtracted** from the received signal
- More effective than echo suppressor. Often NEC and NES are however both used



Digital Circuit Multiplexing Equipment DCME (G.763)



- DCME Functions
  - Digital speech interpolation (**DSI**) 2.5:1 + **ADPCM** of 32 kb/s
  - Overload handling: Extra system capacity can be allowed to variable bit rate (**VBR**) channels (capacity taken from unused compressed speech channels)
  - Option to **make conversions**
    - between T1 (1.5 Mb/s, US) and E1 (European 2 Mb/s) connections
    - between μ- and A-law compressions

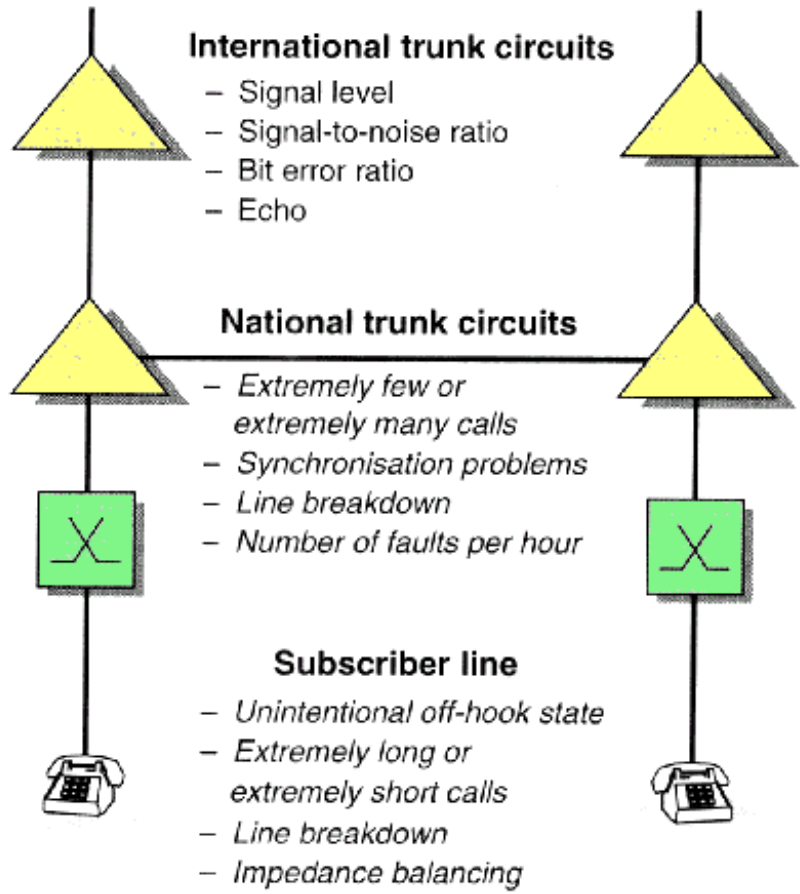


A: Digital line interface
B: Time-slot switching
C: Voice interpolation (DSI)
D: ADPCM
E: Variable bit rate (for overload)

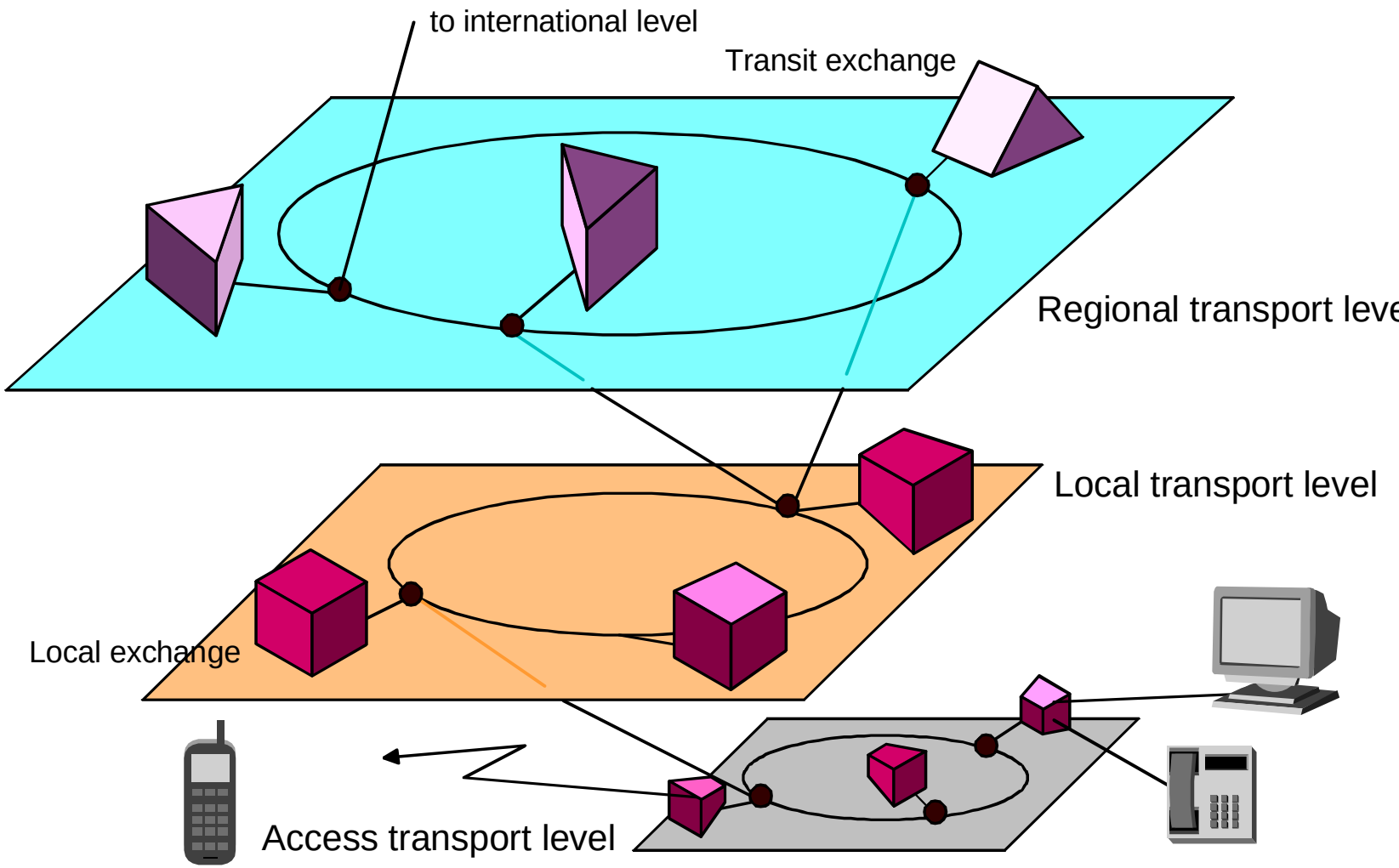
PSTN operation and maintenance (Q.513)

- Different alarm classes
- Vital functions and circuits (as SS7 and group switch) use secured paths and backups
  Procedures provided for:
  - troubleshooting
  - fault diagnostics
    - hardware faults can be isolated
- Supervision is realized also by connecting maintenance units to the network
- Important switches have extensive backup equipment

A supervision plan by network levels:



Modern PSTN hierarchy



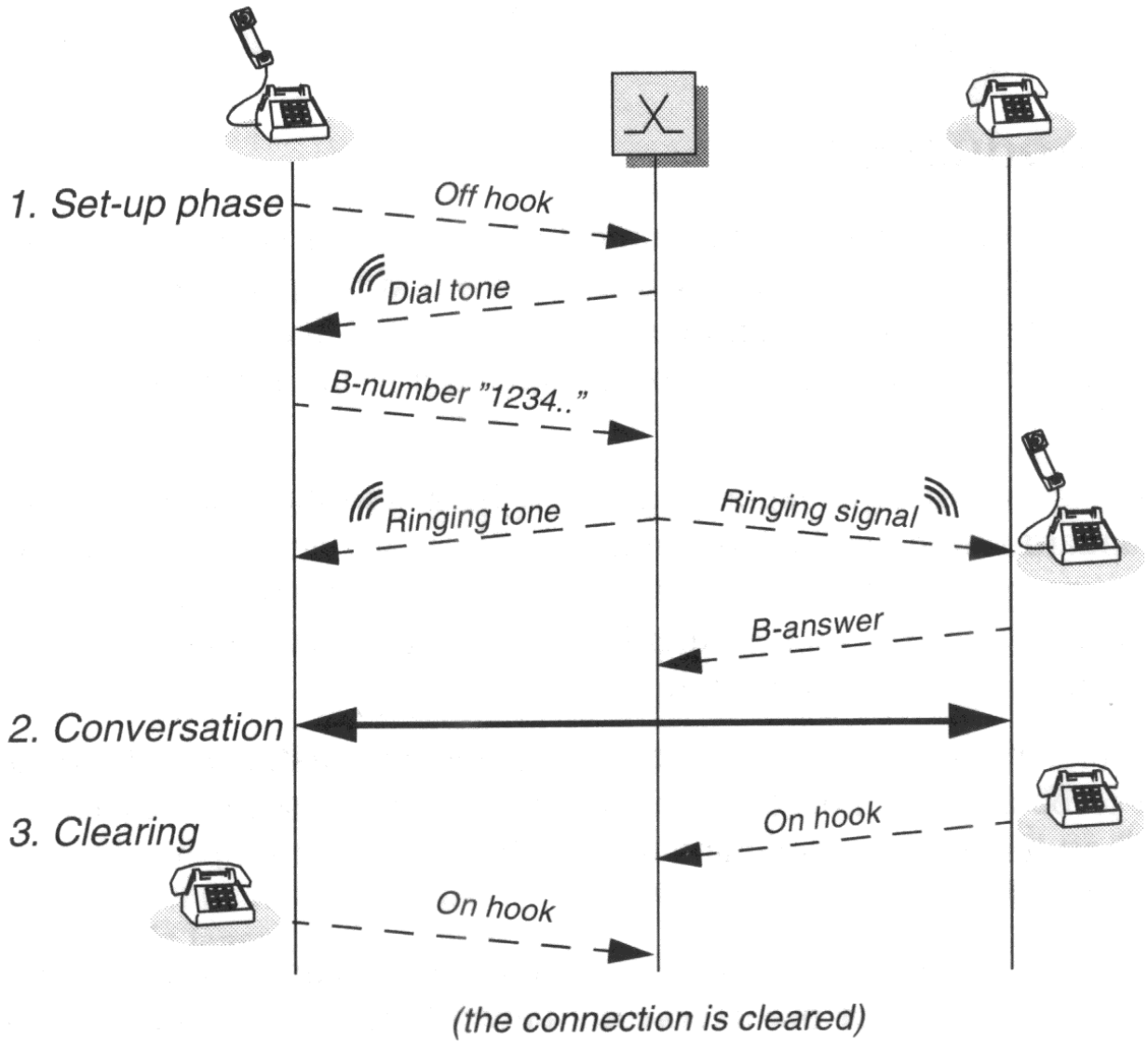
PSTN Hierarchy cont.

- **Local** (example, within a city)
  - Subscriber connections
  - Switching within the local exchange
  - Switching to other exchanges
- **Transit** (county level, say between Tampere and Helsinki)
  - Switching traffic between different geographical areas within one country
- **International**
  - Gateway-type traffic between
    - different countries
    - DWDM (Dense Wavelength Division Multiplexing) routes
- Rates can follow SONET or SDH standard

SDH

- transport of 1.5/2/6/34/45/140 Mbps within a transmission rate of 155.52 Mbps
- carries for instance ATM and IP within rates that are integer multiples of 155.52 Mbps

Subscriber signaling for local calls



Inter-exchange signaling

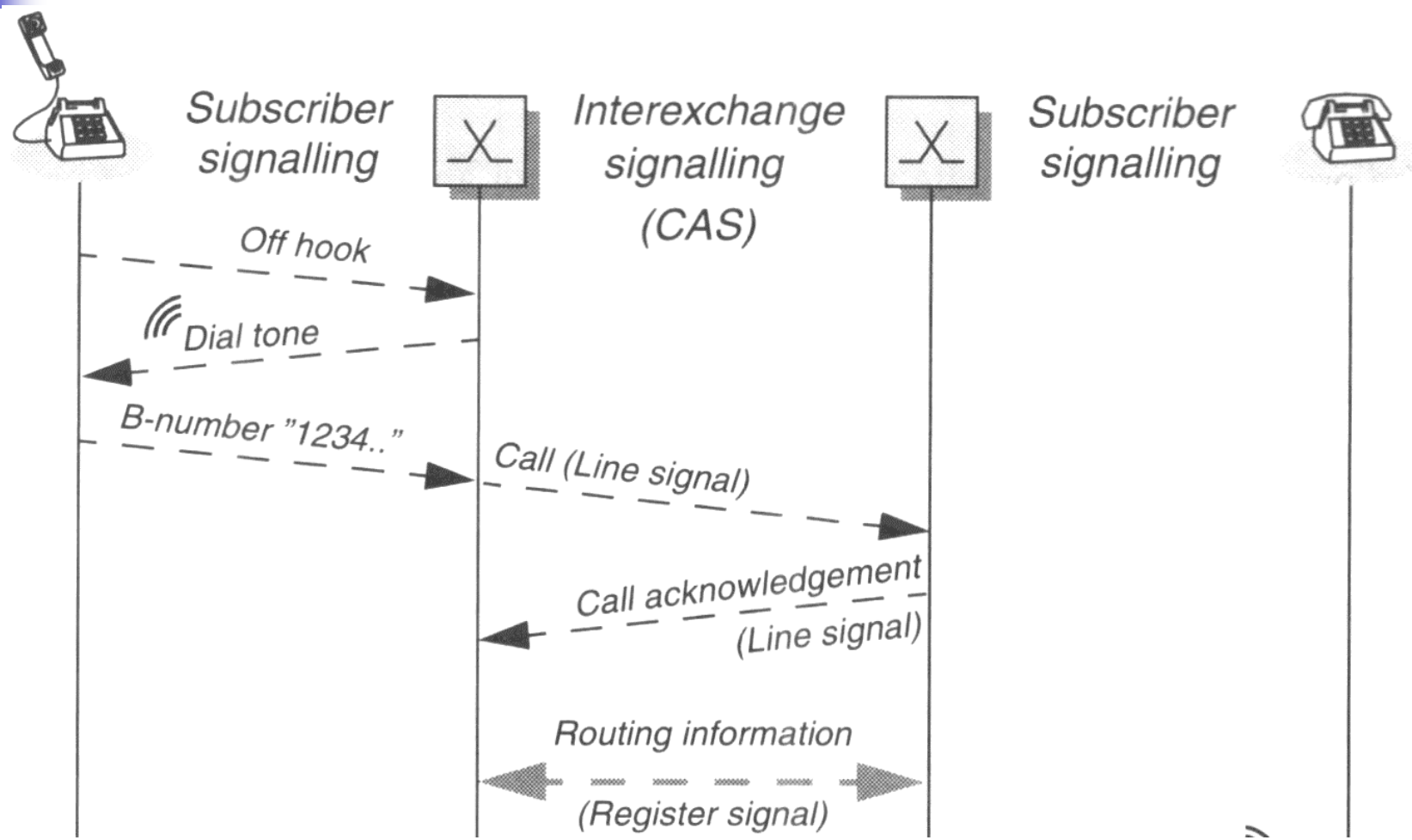
- Channel associated signaling (**CAS**) as No.5, R1, R2
  - analog and digital connections
- Modern ISDN exchanges apply SS7(digital), that is a common channel signaling method (**CSS**) that is discussed later in its own lecture
- **CAS** is divided into line and register signaling:
  - **Line** signaling:
    - line state between the trunk-links as
      - answer, clear-forward*, clear-back
  - **Register** signaling:
    - routing information as
      - B-number, A-category, B-status

*A-subscriber's on-hook message transmitted to B exchange

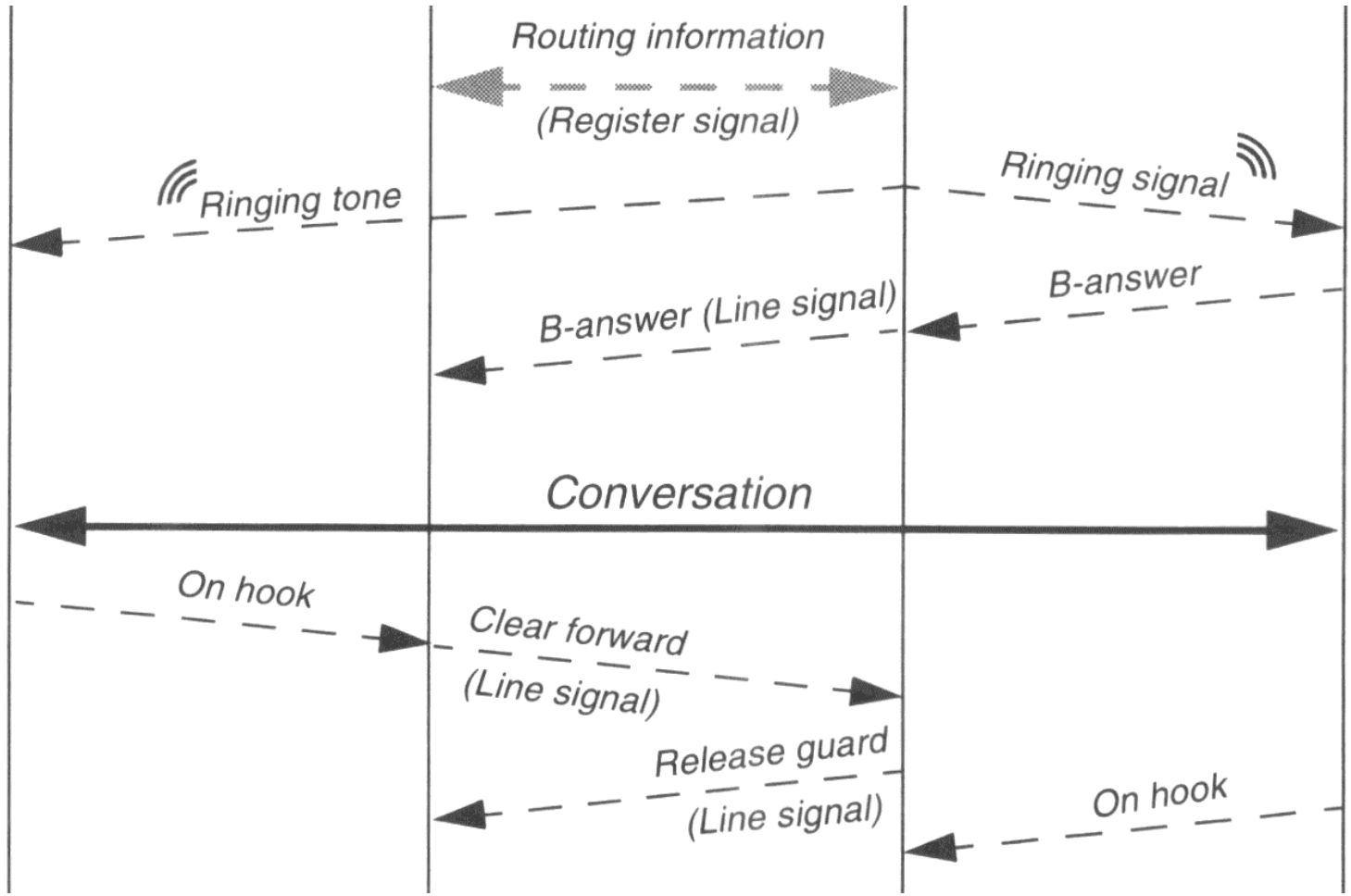
Inter exchange signaling (cont.)

- Three categories of information is transmitted:
  - **setup**, supervision clearing
  - **service** related information as
    - forwarding, callback, charging
  - **status** change information
    - transmission network congestion
    - neighborhood exchange congestion

Example of inter-exchange signaling

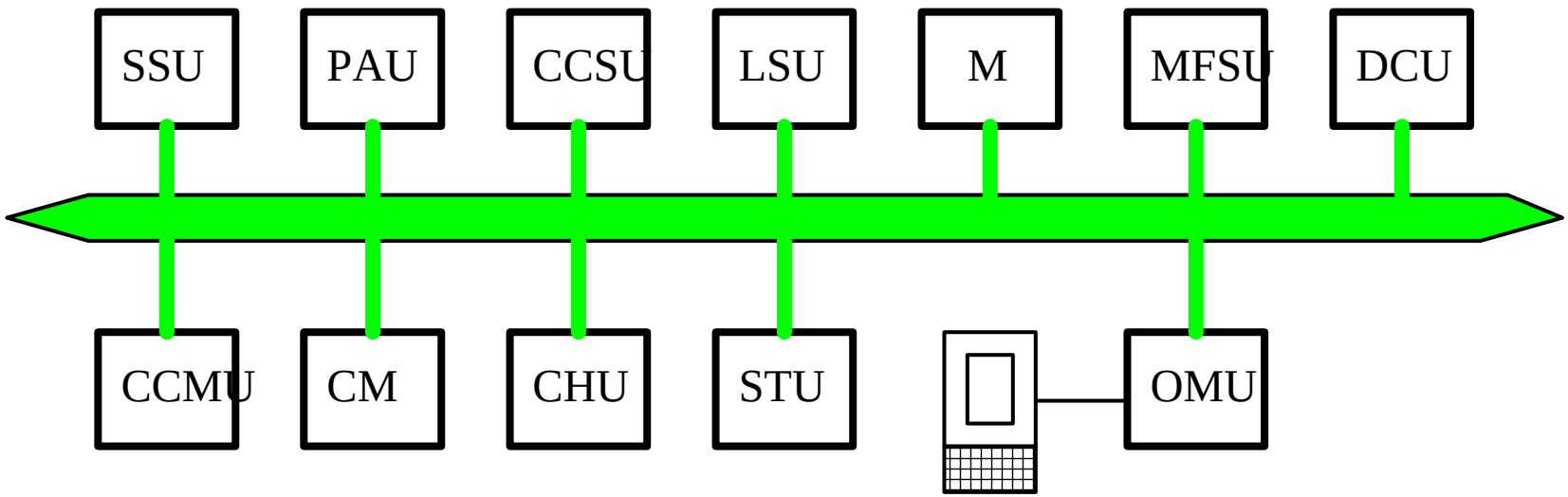


Inter-exchange signaling (cont.)



A case study: DX 200 Exchange

- Various control units apply common busses to control the exchange



A case study: DX 200 Exchange

- SSU: Subscriber Signaling Unit: controls access network
- CCSU:Common Channel Signaling Unit (SS7).
- CCMU: Common Channel Signaling Management Unit: (as MTP, SCCP)
- PAU: Primary Rate Access Unit: controls basic (64 kbit/s) system interfaces
- LSU: Line Signaling Unit: takes care of signaling between transit exchanges and access networks
- MFSU: Multi-Frequency Service Unit: Takes care of signaling when multiple frequency signals are used

MTP: Message transfer part of SS7
SCCP: Signaling connection control part
} =SS7 bearer part: network service part (NSP)

A case study: DX 200 Exchange (cont.)

- BCDU:Basic Data Communication Unit: Serves various data services to OMU as access to X.25 and LANs
- M: Marker Unit: Controls concentrators / space switches
- CM: Central Memory: Contains user database, charging, signalling, routing and exchange ensemble.
- STU: Statistical Unit: Collects statistical information on traffic and charging.
- CHU:Charging Unit: Maintains charging database obtained from signalling units.
- OMU:Operation and Maintenance Unit: Allows personnel access to exchange memory, perform tests an traffic measurements.