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

**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

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

**TDMA**
Packet switching

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

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**
- 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

**Connection types**

**Connection oriented**
- 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

**Connection types**

- ATM
- Frame-relay
- X.25
- IP, Frame-relay
- ATM
- X.25, IP, UDP*

*User Datagram Protocol*
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

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

Transport Unit (same as in ATM)
Connecting into PSTN exchange: Equipment in the access network

1. **ISDN connection**
   - Example: 30B+D (2.048 Mb/s)

2. **Twisted pair - connections**

3. **Private Branch Exchange (PBX)**
4. **Multiplexer (MUX)**
5. **Cross connection point**
6. **Distribution point**
7. **On-line subscriber with several telephones**
8. **Business subscriber**
9. **Wireless access (or radio access point)**

Q.512 specifies exchange interfaces
Local exchange

PBX

Subscriber stage

Group switch

ETC

Announcement equipment

Signaling equipment

Third-party equipment

Test/measurement equipment

Switch

O&M HW

Signedaling (SS7) with users and other exchanges

to other exchanges

Recorded announcements: faults/subscriber services

Traffic concentration

- Conference calls, call waiting, broadcasting ...

- Operation & maintenance support (Q.513)
- Charging
- Supplementary (IN) services (as credit card call)
- Subscriber data, switch control

ETC: Exchange terminal circuit
IN: Intelligent network
Subscriber stage

Connects to: digit receivers, info tones, test equipment

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

<table>
<thead>
<tr>
<th>Pre-Paid</th>
<th>Calling Card</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Phone/Toll-free (NDB 800)</td>
<td>Single Number Service</td>
</tr>
<tr>
<td>Virtual Private Network</td>
<td>Number Portability</td>
</tr>
<tr>
<td>Personal Number</td>
<td>IN based call centers</td>
</tr>
<tr>
<td>Premium Rate</td>
<td>Call Screening Capabilities</td>
</tr>
</tbody>
</table>
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)

- Number of cross-connections reduced compared if a simple space division matrix of N x M (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

Cross-bar switch (space division matrix)
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)

CN: Concentrator
LT: Line T.
NT: Network
AN: Access Net.
ET: Exchange T.

V1 V2 V3 V4

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)

Used for signaling in certain coin-operated pay-phones and PBX
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.

Diagram:
- **Voice direction**: From exchange to local loop.
- **Local loop**: From local loop to exchange.
- **Line balance**: Balancing the signal.
- **Z_b**: Impedance at the hybrid circuit.
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.

[Diagram showing the process of echo cancelling with a microphone, subtractor, echo calculator, clipping circuit, and waveform suppression.]
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:

**International trunk circuits**
- Signal level
- Signal-to-noise ratio
- Bit error ratio
- Echo

**National trunk circuits**
- Extremely few or extremely many calls
- Synchronisation problems
- Line breakdown
- Number of faults per hour

**Subscriber line**
- Unintentional off-hook state
- Extremely long or extremely short calls
- Line breakdown
- Impedance balancing
Modern PSTN hierarchy

- Access transport level
- Local exchange
- Local transport level
- Regional transport level
- Transit exchange
- to international level
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

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**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

1. Set-up phase
   - Off hook
   - Dial tone
   - B-number "1234...
   - Ringing tone
   - Ringing signal
   - B-answer

2. Conversation

3. Clearing
   - On hook

(the connection is cleared)
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.)

Diagram:

- **Ringing tone**
- **Routing information** (Register signal)
- **B-answer** (Line signal)
- **B-answer**
- **Conversation**
- **Clear forward** (Line signal)
- **Release guard** (Line signal)
- **On hook**
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
\[=\text{SS7 bearer part: network service part (NSP)}\]
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 and traffic measurements.