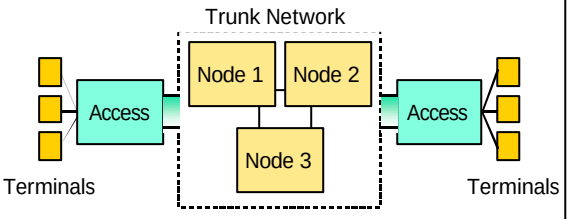
Public Switched Telephone Network (PSTN)

Topics in PSTN

- Introduction
  - review of early exchanges
  - PSTN Standards
- User services & terminals
- Modern exchange technology
  - interface standards
  - access and trunk networks
  - signaling
  - network management
  - internetworking (telecommunications between networks)



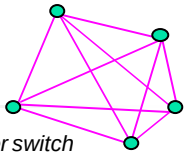
Introduction

- PSTN switching is based on circuit switching by duplex* connections
- Temporary bidirectional connections
- Originally for speech (voice) only at 300-3400 Hz
- Earlier two subscribers connected by purely physical connection (physical switch contacts)
- Nowadays by time slots ~ ISDN is integrated to PSDN
- PCM is the TDMA standard for the digital transmission
- PCM time slots consist of 8 bit samples
- For voice digital exchange sets up 64 kbit/s connections
- Data connections by (1) modems, (2) ISDN interface (3) leased lines via X.25 / Frame relay, or (4) ADSL

**What are semi-duplex and simplex?*

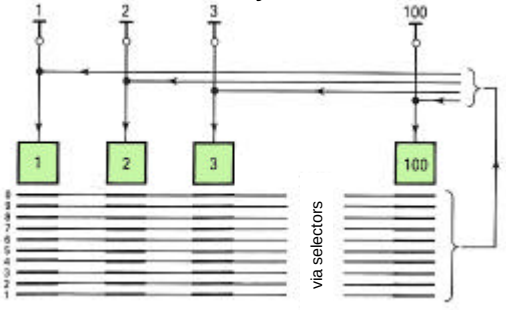
PCM: pulse coded modulation

History

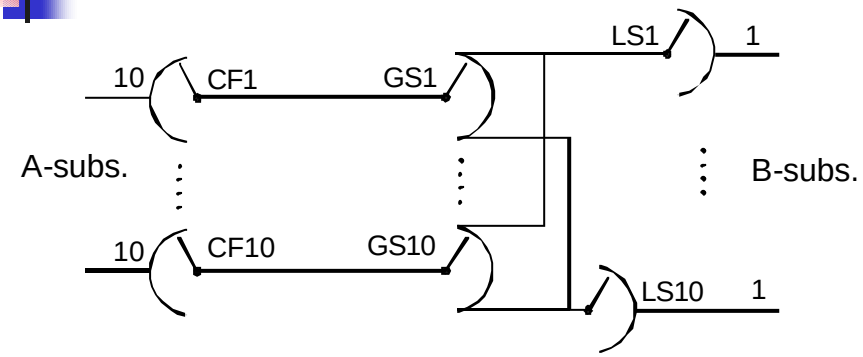


Strowger switch

- 1876 A. G. Bell telephone patent
- 1878 The first exchange constructed in La Porte, the US
  - could connect any two of the 21 subscribers
  - manual switching (!)
- 1891 first automatic exchange: Strowger Switch by Almon B. Strowger: an undertaker in Kansas City
- A 100 line Strowger switch:
  - each user has its own selector
  - no concentrators
  - expensive



An early analog PBX: 100 subscriber exchange (Subscriber controlled call set-up)



MAIN PARTS:
- Call finders (CF)
- Group selectors (GS)
- Line selectors (LS)

Call setup:
1. A-sub. picks up handset (CF detects)
   - exchange sends line available -tone
2. A-sub. Send pulses (GS, LS activated)
   - exchange sends ringing tone

An early exchange, call setup

- One of the 100 subscribers lifts his handset -> Call finder is activated to search the line.
- After the line is located other relays connect the dial-tone generator.
- The subscriber selects two digits.
- The first digit selects the subscriber group by using the group selector.
- The second digit selects the line selector.
- Selection is done by sending pulses that move the selectors stepwise.
- When connection is established a ringing tone is sent.
- Note that only 10 subscribers of 100 can call at the same time to different numbers! (why?) (concentration is 1:10)

PSTN exchange development

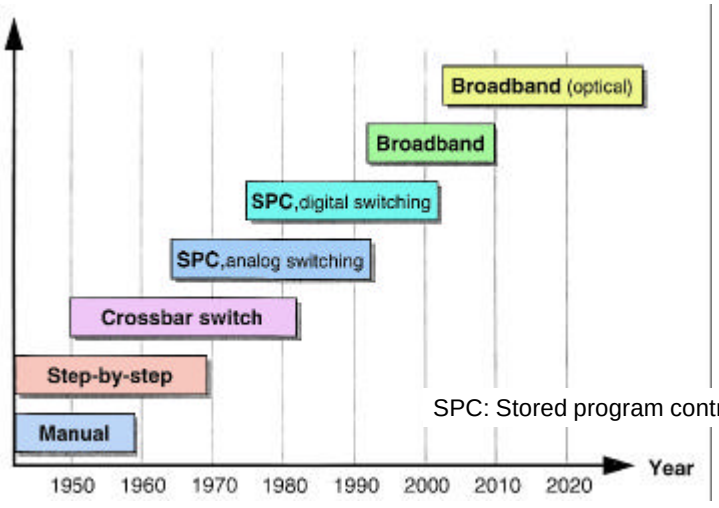
Efficient use of switches

More flexibility & services

- Register-controlled setup (1920 -)
  - B-subscriber number receiver by a **register**
  - register controls all the remaining call setup stages
- Distributed control
  - **Markers** indicate idle switches
  - Thus markers control path routing
- Stored program control, 1960s and 1970s (SPC)
  - New services
    - supervision (operation & maintenance O&M)
    - integrated charging
    - gathering statistics
  - IN services
  - Easier updating and maintenance

S P C 1960

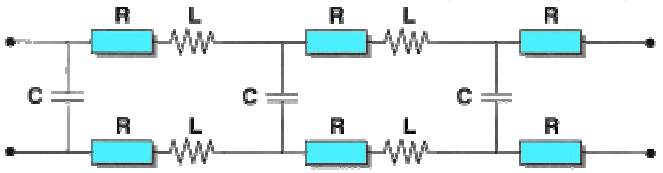
Categorizing switching



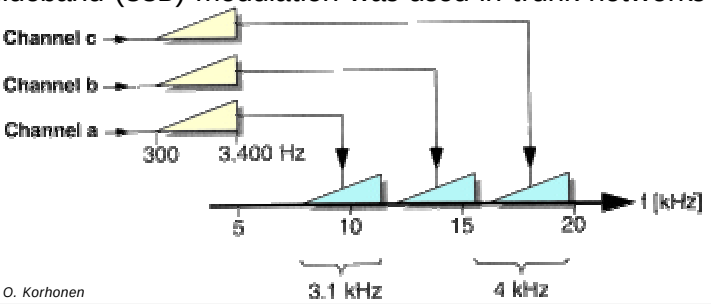
SPC: Stored program control

Some features in PSTN of ´60

- Coil loading was used to enhance higher frequency range



- Frequency division multiplexing (FDM) with single sideband (SSB) modulation was used in trunk networks



Some features of PSTN of ´60 (cont.)

- Network **intelligence** and **value-added services**
  - not supported as such
  - operators were anyhow intelligent :)
    - value added services by tracking what happens in the area!
- Inter-exchange **signaling**
  - call setup took about 15 seconds
  - **channel-associated** signaling (CAS: No.5, R1,R2*)
  - about 10% of trunk line capacity was taken by signaling
- Operation and maintenance
  - using local info-bases and local workforce
  - network maintenance was based on on-field check-ups

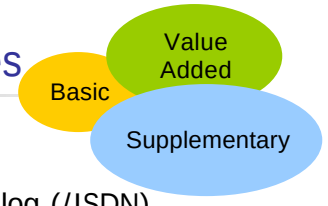
**nowadays in ISDN & PLMN: common channel signaling (CCS): SS7*

Present-day PSTN 'terminals[1]'

- Fixed-line phones (analog, ISDN)
- Cordless phones (PBX-RF interface: DECT[2])
- Fax
- Pay phones
- Private Branch Exchange (PBX)
- Gateways to Public Land Mobile Networks (PLMN):
  - GSM
  - wireless local area networks (WLAN)
- Local loop data extensions
  - modems
  - ADSL technology
  - (leased lines)

[1]Means here interfaces to other nets & equipment
[2]DECT: Digital Enhanced Cordless Telecommunications

Present-day PSTN services



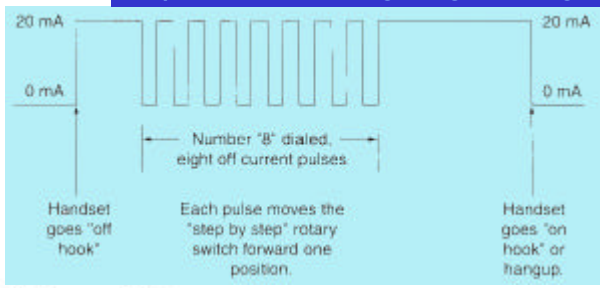
- Basic service
  - Bearer service (*local loop access*): analog (/ISDN)
- Value-added services (*telephonist-originated*) services as
  - directory inquiry (118)
  - weather, stock exchange, ticket reservation ...
- Supplementary services (*Intelligent Terminal (IN) implementation*)
  - distributed supplementary as 'call forwarding unconditional', 'call waiting', 'queuing' ...
  - centralized supplementary services (IN) use specialized routing & charging as VPN, credit card calls, free phone (receiver pays), universal access number (connected automatically to the nearest office), ...

PSTN today summarized

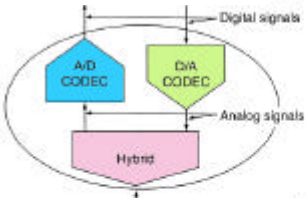
- Gets still more subscribers!
- ISDN very popular in switches (in Finland all-digital exchanges)
- ISDN getting popular also for local loop access
- Versatile access part
- Conventional local loop technology develops fast
- Remote controlled O&M
- IN services fully-developed - Intelligence moves to terminals
- Fiber-optical DWDM links connect exchanges
- Common channel signaling (SS7)
- SDH-based (Synchronous Digital Hierarchy) trunk-networking

Analog local loop interface

Loop current used for signaling & message



Digital-lines to ISDN central office

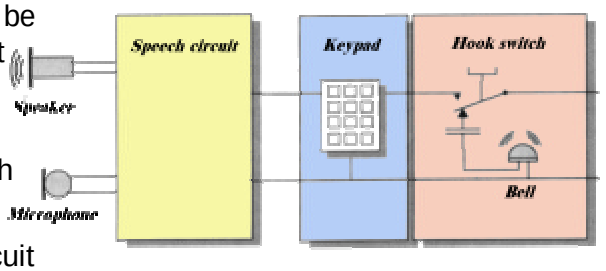


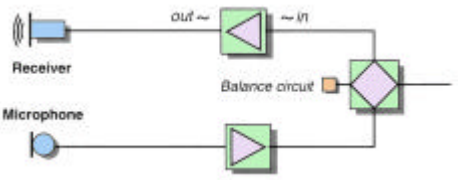
Analog-line

per trunk signaling in local loop:
- long setup time
- hacking easy
- voice grade circuits
- interference & cross-talk sensitive
- expensive

Basic telephone terminal

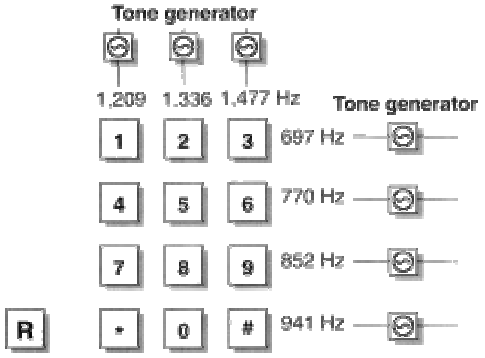
- A basic phone can be made by using just four units
  - The bell
  - The hook switch
  - The keypad
  - The speech circuit
- Modern keypads use dual-tone dialing
- The speech circuit adapts voice levels and isolates mic and speaker





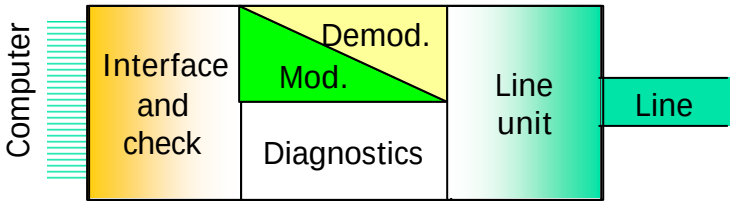
Dual-tone dialing

- Dual-tone dialing is used in subscriber loop to transmit the selected B-subscriber number
- Earlier pulse selection was applied (very rare nowadays)



Basic modules of a modem

- Diagnostic unit
  - Checks faults and controls the modem
- Interface and line units
  - Adapt the modem and terminal
- Modem performs A/D and D/A conversion and select rate such that transmission quality criteria (error rate) can be meet



What is specified in a modem recommendation?

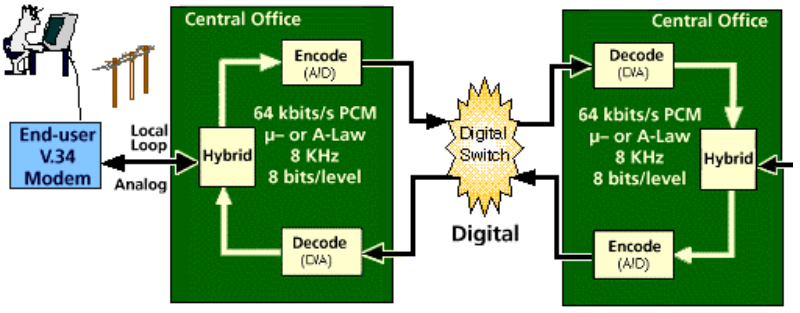
- Data signaling rates, symbol rates, carrier frequencies pre-emphasis, scrambler, framing, encoder
- Interface circuits
- Start-up signals and sequences
- Operating procedures
- Testing facilities
- There are two kind of modems specified by ITU-T:
- Digital modems: Generates G.711 signals and receives V.34 signals passed through a G.711 encoder. Connected to a digital switched network through a digital interface
- Analog modems: Generates V.34 signals and receives G.711 signals that have been passed through a G.711 decoder in an analog PSTN local loop

G.711 (11/88) - Pulse code modulation (PCM) of voice frequencies
V.34 (02/98) - A modem operating (up to 33 600 bit/s) for use in 2-wire analog PSTN

Some modem specifications

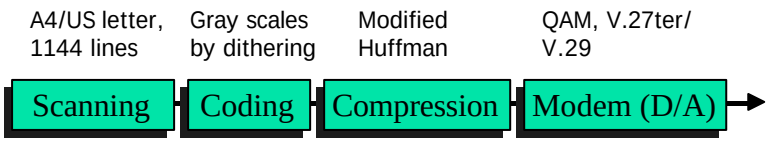
- ITU-T specifies several modem standards as
  - V.26 (11/88) - 2400 bits per second modem for use on 4-wire leased lines
  - V.27 (11/88) - 4800 bits per second modem for use on leased lines
  - V.27ter (11/88) - 4800/2400 bits per second modem for use in the general switched telephone
  - V.29 (11/88) - 9600 bits per second modem for use on point-to-point 4-wire leased lines
  - V.90 (09/98) - 56 000 bit/s downstream and up to 33 600 bit/s upstream modem for use in the general switched telephone

Connecting V.34 (33.6 kb/s) modem



Fax communications over PSTN

- Faxes follow standard PSTN modem communications recommendations or IEEE recommendations, as V.17 *(02/91) (- Wire modem for facsimile applications with rates up to 14 400 bit/s)*
- Faxes are divided into groups:
  - Group 1 (´68): Analog scanning, 2400 bits/s
  - Group 2 (´76): Analog scanning, 4800 bits/s
  - Group 3 (´80): Digital scanning, 14400 bits/s
  - Group 4 (´84): Digital scanning, 64 kbit/s (ISDN)
- Example of modules in group 3 transmitting fax:



PSTN in ITU-T standards *(www.itu.org)*

- Series D Recommendations - General tariff principles
- Series E Recommendations - Overall network operation, telephone service, service operation and human factors
- Series G Recommendations - Transmission systems and media, digital systems and networks
- Series I Recommendations - Integrated services digital network (ISDN)
- Series M Recommendations - Network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile, and leased circuits

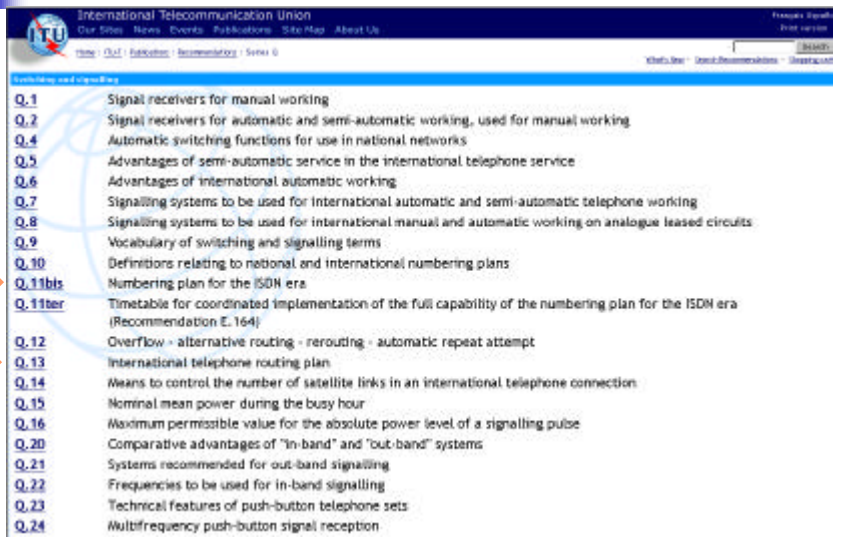
ITU: International Telecommunications Union

More PSTN standards...

- Series Q Recommendations - Specifications of measuring equipment
- Series P Recommendations - Telephone transmission quality, telephone installations, local line networks
- Series Q Recommendations - Switching and signaling (Signaling Systems no:4,5,6, and 7, Register Signaling no: R1, R2, IN - Service)
- Series V Recommendations - Data communication over the telephone lines

Example: Q-recommendations: Switching and signalling*

(Illustrative examples denoted by arrows)



*http://www.itu.int/rec/recommendation.asp?type=products&lang=e&parent=T-REC-Q

Switching and signalling (cont.)

Q.52	Signalling between international switching centers and stand-alone echo control devices
Q.55	Signalling between signal processing network equipment (SPNE) and international switching centres (ISC)
Q.56	Signalling between signal processing network equipment (SPNE) and international switching centres (ISC) over an IP network
Q.65	The unified functional methodology for the characterization of services and network capabilities
Q.68	Overview of methodology for developing management services
Q.71	ISDN circuit mode switched bearer services
Q.72	Stage 2 description for packet mode services
Q.76	Service procedures for Universal Personal Telecommunication - Functional modelling and information flows
Q.80	Introduction to stage 2 service descriptions for supplementary services
Q.81.1	Direct dialling-in
Q.81.2	Multiple subscriber number
Q.81.3	Calling line identification presentation (CLIP) and calling line identification restriction (CLIR)
Q.81.5	Connected line identification, presentation and restriction (COLP) and (COLR)
Q.81.7	Malicious call identification (MCID)
Q.81.8	Sub-addressing (SUB)
Q.82.1	Call transfer
Q.82.2	Call forwarding
Q.82.3	Call deflection
Q.82.4	Line hunting
Q.82.7	Explicit call transfer
Q.83.1	Call waiting (CW)
Q.83.2	Call hold
Q.83.3	Stage 2 description for call completion supplementary services : Completion of call to busy subscriber
Q.83.4	Terminal portability
Q.84.1	Conference calling (CONF)

If you don't find it from Recommendations something is lost: How to use pay phones?

- Recommendation E.134 (03/93) - Human factors aspects of public terminals: Generic operating procedures

Terminal type	User action					
	Initialization	Means of payment	Identification	Communication	Next	End
Payphone	Lift handset	Insert means of payment	Input number (Address)	Transfer information	Press desig-nated button	Replace handset
Public fax (Sendmode)	Place document	Insert means of payment	Input number	Transfer information	Press desig-nated button	Automatic
Public fax (Receive mode)	Place document	Insert means of payment	Input number (of Network Node)	Transfer information	Press desig-nated button	Automatic
Public Videotex		Insert means (if required)	Select option	Transfer information	Select another option	

Switching: Transfer modes & connections

Transfer modes

PSTN

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
- variable delays

Ethernet

Connection types

ATM

Connection oriented

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

Frame-relay

X.25

Connectionless

- broadcasting
- modest error rates often accepted
- fast data in good channels

UDP*

*User Datagram Protocol