Telecom Networks and Switching:

Network Architecture

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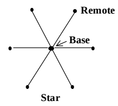
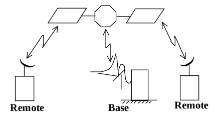
Classification of Communication Networks

- By topology
  - point-to-point link
    - one-way (simplex) or two-way (duplex)
  - point-to-multipoint or **star**
    - all traffic goes through Base node which performs switching

  e.g. cellular Base Station, VSAT network

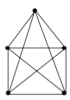


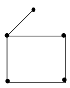


VSAT (Very Small Aperture Satellite) network

Classification of Communication Networks (contd.)

- **mesh**
  - fully connected vs. partially connected



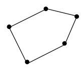


  - traffic *routed* by each node
    - nodes also perform repeater function for other nodes not directly linked

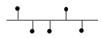
e.g. trunk exchanges in telecom network

Classification of Communication Networks (contd.)

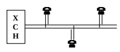
- **ring**
  - all nodes perform repeater function



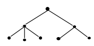
- **bus**
  - only one pair communicate at a time, but signal is broadcast to all nodes.



e.g. multiple telephone instruments on a single rural line connected to an exchange,
Ethernet LAN segment



- **tree**
  - like partially-connected mesh, but only one route between any node pair



Classification of Communication Networks (contd.)

- By scope of connectivity
  - local area — e.g. — PBX / Computer LAN
  - wide area — e.g. — Public Switched Telephone Network (PSTN) / Internet
- By mode of connectivity
  - non-switched : e.g., paging
  - switched : e.g., PSTN, Internet, PBX

Classification of Communication Networks (contd.)

- By type of switching
  - **circuit-switched :** a dedicated channel (with a fixed bandwidth or bitrate) is assigned on demand

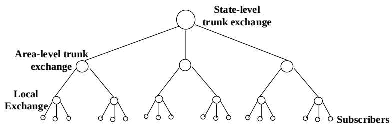
    ⇒ constant-delay, fixed-capacity channel established
  - **packet-switched :** no dedicated channel assigned

    ⇒ variable delay, variable bitrate, occasional loss of packets, packets can traverse different links out of sequence

Public Switched Telephone Network (PSTN)

A wide area, circuit-switched, mesh (partially-connected) network of star-connected subnetworks

— started out historically as a tree network



– vulnerable to failure

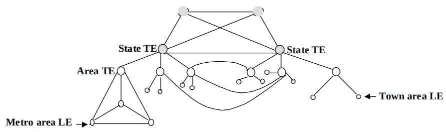
– high-traffic routes can be directly connected

⇒ requires sophisticated *routing* strategy

PSTN Today

- mesh connected Trunk exchanges at the state/regional level
- mesh connected local exchanges at bottom in metropolitan areas
- a large number of direct routes between Area-level trunk exchanges

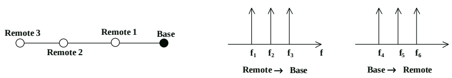
— hierarchical route selected only if direct route is not available



Physical Network vs. Logical Network

- Physical network topology need not resemble logical network topology

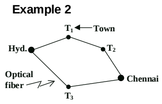
Example 1



— no direct communication between Remotes, only through Base (although Remotes may perform Repeater function)

⇒ star network (not bus)

Example 2



assignment of channels on fiber

Hyd.- T_1	1-10
Hyd. – T_2	11 - 15
T_1 - T_2	16 - 20
Hyd. – Chn.	21 - 60
	⋮

⇒ mesh network (not ring)

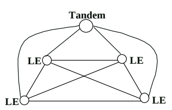
PSTN Building Blocks

- subscriber terminal : telephone instrument
  - — simple, robust, low-cost, powered by exchange
- local loop (LL) : a pair of wires from telephone to local exchange
  - — carries power to telephone, voice and signals both ways
- local exchange (LE) : a switching node that switches calls from one subscriber to another, as well as to/from trunks
  - — complex equipment
    - – call processing
    - – subscriber administration
    - – configuration/health monitoring
    - – battery
    - – LL terminations (**M**ain **D**istribution **F**rame)
    - – Trunk terminations (**D**igital **D**istribution **F**rame)

PSTN Building Blocks (contd.)

- Trunk : interconnects exchange to one another
  - — optical fiber
  - — microwave radio

  } multiple PCM trunks multiplexed on one link
- Trunk Exchange (TE) : Switching node which only switches calls between trunks
  - — TAX ("Trunk Automatic Exchange") : switches long-distance calls (dial 0 : call is routed to TAX)
  - — Tandem Exchange : switches calls between LEs in a metro; handles spillover traffic from direct routes



PSTN Network Topology : a summary

- Fully mesh-connected TAXs at highest level
  - — international gateways also connected to this subnetwork
- Second-level TAXs for states/regions/metros : connected to level-1 TAXs, but also partially amongst themselves
- Third-level TAXs (often, TAX-cum-local) also deployed at times
- LEs (sometimes, LE-cum-TE) at lowest level connect to subscribers
- Size of trunk group between any two TEs, depends on amount of *traffic*
  - — trunks often segregated as *outgoing* and *incoming*, but can also be *bothways*

Numbering plan

- *semi-open* plan : length of number differs by one or two digits (India, U.K,…)
- *closed* plan : uniform numbering (U.S, France,…)
- international plan : country code + national number
  1-3 digits 9-11 digits
  } Max = 12 as per ITU

— country code : world divided into 9 zones

N. America : 1xx, Africa : 2xx

S. America : 5xx, S. Asia : 9xx, and so on.

e.g. India : 91, Srilanka : 941

Numbering plan (contd.)

- National number : Access code + Exchange code + Line number

  U.S.A : 3+3+4 digits

  India : 7-9 digits in all : [2-6] + [3-1] + [4-2]

  example 1 : 44 + 491 + xxxx,
  Chennai Adyar

  example 2 : 452 + 88 + xxxx
  Madurai Tirunagar

  example 3 : 43-67 + 60 + xxx
  Thanjavur Tiruvaiyar

- India is divided into regions for STD codes
  - Maharashtra : 2
  - West Bengal : 3
  - Tamil Nadu : 4

Dialling Procedure

- dial full international number for all calls
  - ⇒ 11 digits every time
- use special prefixes for international and national calls, and dial only exchange code + telephone number for local calls
  - ⇒ 5-7 digits only for local calls
  - ⇒ 0 prefix for national calls, 00 for international calls
    first 0 makes LE route call to TAX, second 0 goes to TAX which routes calls to International Gateway Exchange
- Group Dialling: a separate dialling procedure for calls to neighbouring areas
  e.g. calling Kalpakkam from Chennai 04114 + 41+ xxx
  - ⇒ routed through Chennai TAX as STD call (STD charges)

    OR

    $\underbrace{9x}_{\text{access code for neighboring call areas}}$ + 41 + xxx
  - ⇒ routed by LE or tandem (with local call charges)
  - ⇒ exchange code cannot start with 9, thus reducing number space

PSTN Architecture : an Example

- Tamil Nadu circle (excluding Chennai) has 16 TAXs
  - Coimbatore TAX has trunks to the other TAXs as well as to TAXs in many other circles (e.g. Agra, Bangalore, Chennai, Delhi, Hyderabad, Patna…)
  - Madurai, Erode, Trichy, Salem, Tirunelveli have trunks to the other TAXs in the circle, and a few to major TAXs in other circles (Mumbai, Hyderabad, Delhi)
  - Other TAXs have trunks only to circle TAXs and to Chennai
  - every TAX has trunks to other TAXs and trunks to so-called *dependent stations* - exchanges (trunk-cum-local or local) that can route STD calls only through the TAX

⇒ decision to add direct trunks to other circles based on traffic measurements

PSTN Architecture : an Example (contd.)

- 18 Secondary Switching Areas (SSA)
  - Kumbakonam and Karaikudi do not have separate TAX
  - Some LEs can have trunks to 2 TAXs if both are nearby and traffic warrants it
- Each SSA has several Short Distances Charging Areas (SDCA)
  - Typically 8-10, sometimes as low as 2, or as high as 14
  - SDCA is a local calling area for metering purposes

PSTN Architecture : an Example (contd.)

- Each SDCA has unique STD access code
- Typically, SDCA has a trunk-cum-local exchange at the main town
- Several LEs in other towns are parented to SDCA's main exchange
  - direct trunk to SSA TAX if justified by traffic
- If SDCA is a city, e.g. Coimbatore, LEs are also mesh connected
- Neighbouring SDCA main exchanges increasingly directly linked to each other, apart from via the SSA TAX

SSA and SDCAs : an Example

SSA : Chengalpattu (Kanchipuram 3000 line TAX) : next to Chennai, beyond Tambaram

SDCAs : Sriperumbudur (6), Chenaglpattu (14), Tiruttani (11), Ponneri (14), Thiruvallur (14), Madurantakam (12), Kanchipuram (10)
[number in parenthesis is the number of dependant LEs]

— main exchange at each town of same name

— STD codes: 4111/12/14/15/16/18/19

⇒ Total of 86 exchanges, ~ 60,000 lines

Number Space

- 0 is used as prefix for STD, 00 for ISD
  - ⇒ no telephone number can start with 0
  - ⇒ no STD code can start with 0
- first digit 1 is reserved for special service numbers like ambulance, police, fireservice, railway information, etc.
  - — when anyone dials 100, call is routed by LE (as programmed) to a central control room *located anywhere*
  - ⇒ no telephone number can start with 1
- first digit 9 is reserved for value-added services etc.
  - — cellular numbers start with 98
  - ⇒ no local number can start with 9
  - ⇒ with n-digit local number, available local telephone numbers = $7 \times 10^{n-1}$

Cellular Overlay

- Mobile Switching Centres (MSC) are like large local-cum-trunk exchanges
  - — MSCs handle all cellular subscribers
  - — MSCs are connected to TAXs on trunks
- All cellular numbers start with 98
  - ⇒ an operator is given an access code *pqr* and a cellular number is 98pqr xxxxx
    - ⇒ 10^5 subcribers per access code
- PSTN subscriber dials 98… if in same circle, and 098…. if in another circle

e.g. Chennai PSTN subscriber dialling Chennai cellular ⇒ 98….

Chennai PSTN subscriber dialling TN circle cellular ⇒ 098….

TN circle PSTN subscriber in Vellore dialling TN circle cellular subscriber ⇒ 98...

⇒ TAX treats cellular number 98pqr as any other access code for routing

Cellular Overlay (contd.)

- Cellular subscriber dialling any PSTN subscriber ⇒ dial *full national* number i.e., access code + telephone number
- "Local Call" : within circle
- "STD Call" : call to a party in another circle
- If cellular subscriber *roams* to another cellular circle,
  - — incoming call goes to home circle first and then is *forwarded*
    - ⇒ cellular subscriber pays for STD charges between home circle and current location
  - — outgoing call made just like cellular subscriber of the circle
    - ⇒ accounting between cellular operations for billing

⇒ Cellular Network is a circle-level overlay with one or more interconnects to corresponding TAXs in each circle

Telecom Networks and Switching:

The Local Loop

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The Local Loop

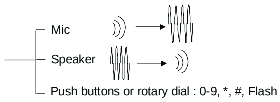
- A pair of copper wires connecting subscriber terminal to the exchange *line interface port*
  - — the pair is twisted (~ 3-4 twists every foot or so) to reduce induced coupling to other pairs in same bundle
    - ⇒ called *twisted pair*, or *tp*
  - — characteristic impedance is 600 ohms
- if subscriber terminal draws less than 20 mA into a 600 Ω termination (~250 mW) , exchange can power the terminal
  - ⇒ the *tp* comes in various *gauges* (diameter)

26 gauge – 0.4 mm
↓
19 gauge – 0.9 mm

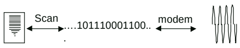
⇒ typically 0.5 mm dia used to get of exchange (primary cable), dropping to 0.4 mm dia for the last segment to the subscriber

Subscriber Terminal

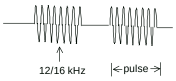
- Telephone



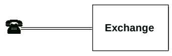
- Fax Machine / Modem



- PCO
  - like a telephone in 0-4 kHz band
  +
  metering pulses at 12/16 kHz

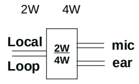


Twisted Pair



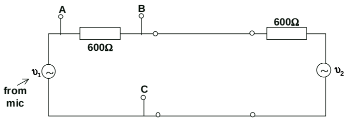
- Same pair carries *superposition* of voice signals both to and from telephone

  ⇒ Telephone has 2-wire / 4-wire converter



- 48V (dc) battery is connected to local loop at exchange end
  — current typically limited to 30 mA

2W/4W Conversion



$\upsilon_{AB} = (\upsilon_1 - \upsilon_2) / 2$

- Sense υ_{AB} using an amplifier with high input impedance and gain 2 : $\upsilon_0 = \upsilon_1 - \upsilon_2$
- Subtract υ_0 from υ_1 using a subtractor ⇒ υ_2 (to earpiece)

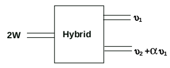
  ⇒ 2W/4W convertor (υ_1 on 2W and υ_2 on 2W) is called a **hybrid**

Echo

- 600 Ω terminations are not exact,or characteristic impedance of line varies or due to other component (subtractor, etc.) tolerances,

  ⇒ extraction of υ_2 not perfect

  ⇒ $\upsilon_2 + \alpha\upsilon_1$



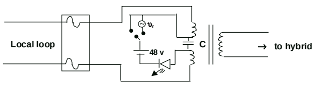
- an echo of one's own speech is heard

  ⇒ talker echo
- this is desirable in a telephone instrument 2W/4W hybrid, as one wants to hear oneself speak

  ⇒ avoid "plugged ears" effect

  — α made small but significant in telephone (called *sidetone*)

Line Interface in exchange



- isolation transformer to isolate line from rest of exchange
- 48V battery (with current limiting to 30 mA) power feed
- C is "short" for voice band from 150 Hz upwards, but "open" for 25 Hz
- υ_r is a 75V ±5V r.m.s, 25 Hz, sinewave ringer (superposed on 48Vd.c)
- fuse and gas-discharge tube (GDT) surge arrestor at MDF protects exchange from 230V and lightning
- opto-isolated sensor for sensing current flow

  ⇒ detecting telephone activity

  — when OFF-Hook, loop is closed, and d.c current flows

Twisted Pair Frequency Response

- Frequency response is bandpass

  — isolation transformer/capacitor blocks around d.c

  — *tp* causes increasing attenuation with frequency
- on very long loops, (>5 km) *loading calls* placed periodically to improve flatness of frequency response till ~3 kHz, but sacrifice beyond 4 kHz

  ⇒ more prevalent in analog 2W trunks in the old days

  ⇒ "voice band" in telephony ≡ 0.3 - 3.4 kHz
- in-band loss increases with distance, and more for thinner *tp*

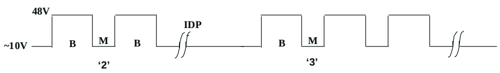
Signalling in the local loop

- Out-of-band signalling : << 100 Hz or >> 4 kHz
  - ⇒ pulsing caused by flowing/stopping of current due to closing/opening loop
  - ⇒ 12 or 16 kHz pulses used for metering to PCOs
  - ⇒ battery polarity reversal to indicate that metering has begun
- in-band signalling: 0.3 - 3.4 kHz
  - ⇒ touch-tone dialling
  - ⇒ dial tone, busy tone, ring back tone, announcements, etc. fed by exchange towards subscriber
  - ⇒ Calling Line Identification (CLI) tones

Out-of-band Signalling

- On-Hook-/OFF-Hook
  - — When telephone handset is lifted from cradle, the local loop, *which is normally open* is closed
    - ⇒ current flows, value depends on a loop resistance, but limited to 20-30 mA
    - ⇒ voltage drops from 48V (on open circuit) to ~ 12V (600 Ω x 20 mA) across telephone
- ringing is caused by 75 r.m.s, 25 Hz a.c signal
  - — *cadence* (ON period / OFF period) varies with country
  - — 75 v r.m.s not needed these days for piezo electric buzzers, but this is a legacy of the days when the telephone had a bell
  - — current drawn by ringing phone is small

Out-of-band Signalling (contd.)



- pulse, or *decadic*, dialling
  - — Break : Make : : 2 : 1
  - — Make + Break duration is 100 ms
    - ⇒ 10 **p**ulses **p**er **s**ec
  - — **I**nter-**D**igital **P**ause > 1 sec

  } nominal

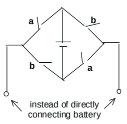
Out-of-band Signalling (contd.)

- Tolerance at Exchange
  - — 8 -12 pps
  - — Break/Make Ratio : 1:1 to 4:1
  - — IDP > 400 msec,

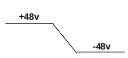
    but once it exceeds $\underset{(1:1)}{\tfrac{1}{2}} \times \underset{(8pps)}{125}$ = 62.5 ms, we can declare digit
  - — maximum IDP = 5 sec, to declare dialling complete
- Tolerances for telephone instrument are obviously tighter
  - — in rotary-dial phones, min. IDP ensured by time taken to rotate dial
  - — in push button phones, pulsing controlled by electronic timer
- Off-Hook → On-Hook (clear signal) min. : 250 msec
- Hook-Flash : Off-Hook →On-Hook →Off-Hook, with maximum On-Hook duration = 200 msec (many telephones have >250 msec flash duration!)
  - — used for "interrupting" exchange for some special service

Out-of-band Signalling (contd.)

- Battery reversal
  - — used to indicate maturing of call (i.e., beginning of metering)
  - — implemented with a bridge at line interface

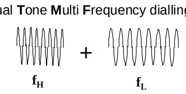


close aa to get one polarity, bb to get the other
  - ⇒ switching must be done rapidly
  - — more sophisticated : *soft* reversal
    - ⇒ avoiding "click" sound



Dual-Tone Multi-Frequency (DTMF) Signalling

- Pulse Dialling too slow
  - ⇒ 10 digit number takes average of $\underset{\text{digit '5'}}{0.5 \times 10} + \underset{\text{IDP}}{1 \times 9} \cong 14$ sec.
  - ⇒ Inter-exchange signalling changed from pulse to tone-based
- low-cost electronic tone generation possible in telephone instrument
  - ⇒ change subscriber dialling to tone-based (DTMF)
- **D**ual **T**one **M**ulti **F**requency dialling



f_H (Hz) \ f_L (Hz)	697	770	842	941
1209	1	4	7	*
1336	2	5	8	0
1477	3	6	9	#
1633	A	B	C	D

DTMF Specifications

- Main problem is **talk-off**: false detection of digit due to speech, or failure to detect digit in background speech/noise
  - ⇒ to reduce probability of talk-off
    - — most telephones cut mic path when keys are pressed
    - — DTMF receivers in exchange are connected to a line *only on demand*
      - ⇒ when one goes off-hook, or one presses FLASH
- Choice of frequencies and amplitudes to minimise talk-off
  - ⇒ probability of talk-off cannot be made zero
    - — problem of any in-band signalling scheme

DTMF Specifications (contd.)

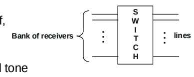
- Single tone easily imitated by speech
  - ⇒ 2 tones at least
- one frequency each from 2 bands : *low-band* and *high-band*
  - ⇒ difficult for speech to have one strong components each in 2 specific bands
- 2dB higher transmit power in high-band to compensate for frequency response of line: ± 1 dB tolerance in each band
  - ⇒ ratio of tone levels in 2 bands (called *twist*) > 6 dB not accepted

DTMF Specifications (contd.)

- error in frequencies : < ± 1.5 %
  - ⇒ low-cost oscillator in telephone
- large LCM among frequencies both within band and between bands
  - ⇒ reduce talk-off due to harmonics
- minimum tone duration as large as possible, consistent with average human dialling speed
  - ⇒ 40 msec
- minimum IDP = 40 msec
- nominal dialling speed = 10 digits/sec (e.g., when *redial* button is pressed)
  - — typical user presses each button for 160 msec and IDP = 350 msec

DTMF Receivers

- Sophisticated spectral estimation devices that look for
  - — one and only one frequency in each band
  - — twist within tolerance limit
  - — power in 2 tones >> rest of power
  - — frequencies within tolerance limit
    - ⇒ high-resolution frequency estimation from 30 msec signal
  - — minimum tone duration, IDP,…
- typically, no need for one per subscriber line
  - — connected "on demand" via the switch itself, this also reduces talk-off



Off-hook → assign receiver → feed dial tone

Hook-flash → assign receiver → feed acceptance tone

Comparison of Decadic and DTMF Dialling

Decadic	DTMF
Slow (< 1 digit / sec)	fast (upto 10 digits / sec)
Out-of-band (<100 Hz)	in-band
Signalling from end to end not possible	end-to-end signalling possible → man-machine communication, Interactive Voice Response (IVR) possible
false digits due to speech not possible	false digits possible
one on-line detector per line	assigned on demand by exchange

DTMF phones always push-button type

On decadic phone, * button makes it *temporarily* DTMF (till call is disconnected) to enable end-to-end signalling

Metering Pulses

- "home" metering introduced
  - ⇒ enables PCOs and PBX to provide individual billing
- out-of-band 16 ± 1% kHz (12 kHz in some countries) pulses used
  - — one pulse indicates one meter unit
  - — not audible, can be additionally filtered by subscriber equipment
- pulse durations = 125 msec ± 25 msec
- pulses detected by subscriber-end equipment for billing purposes

Calling Line Identification

— tones sent by exchange before feeding ring voltage

— tones fed to "open" line

⇒ high impedance termination (>20 kohms) on subscriber-end

… no off-hook current detected

— always 10 digits are sent

— subscriber terminal detects tones (no talk-off problem) and displays digits

Subscriber Line Interface

- Performs the following functions

Battery Feed

Overvoltage protection : GDT + fuse on MDF for primary protection, isolation transformer + varistor on interface card for secondary protection

Ring Feed

Supervision : detection of line status On/Off - hook

Codec : analog-to-digital conversion and vice versa, in digital switches

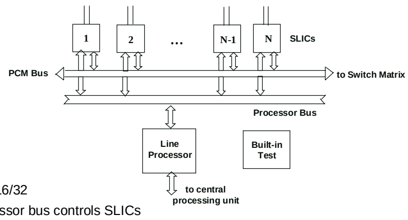
Hybrid : for 2W/4W conversion in digital switches

Test : built-in capability for measuring line capacitance, insulation resistance, interference voltage, "click" test (reverse polarity in On-hook state)

Subscriber Line Interface Circuit

- a SLIC is a highly integrated, low-cost device that provides all the required line interface functions (except primary protection)
- controlled typically by a microcontroller / DSP
- often also has programmable gains and codec
- some universal SLICs have programmable terminating impedance
  — 600Ω, 900Ω, complex impedance,…
- some generate 75 ringfeed, some need external input, some need a low-voltage a.c. drive (from switch via codec!)
  ⇒ critical cost device in an exchange
  ⇒ need one per line
- metering pulses require additional circuitry (cannot support via codec!)
  ⇒ not all lines need this

Typical Architecture of Line Interface card

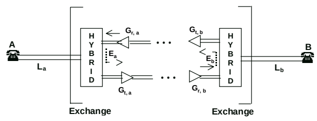


- N=8/16/32
- processor bus controls SLICs
- PCM bus is connected to switch matrix
- processor also communicates with central call processing unit
- built-in-test permits each local loop in turn to be physically connected to measurement devices

Main Tasks of Line Processor

- detection and validation of On-hook/Off-hook status and decadic digit detection
  ⇒ de-bounce and validate make and break to reject when outside tolerance limits
- setting of gains, etc.
- assist in conducting line tests; increase speed of testing
  ⇒ test 100 k lines in 24 hours!
- take actions (feed ring, reverse polarity) & report events (on-hook / off-hook flash)
  ⇒ in general, offload low level tasks from central processor and parallelise the operations

Echoes in the Telephone Network

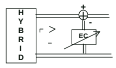


- *talker* echo from distant exchange
  — audibility depends on level of echo at hybrid **and** on losses in local loop **and** on gains in SLIC
  Echo at A = $L_a G_{t,a} G_{r,b} E_b G_{t,b} G_{r,a} L_a$ x (Transmit Level)
- *listener* echo: echo heard by B when A speaks, due to double reflection
  — level = $L_a G_{t,a}^2 G_{r,b}^2 E_b G_{t,b} G_{r,a} E_a L_b$
- Echo Return Loss (ERL) = $\frac{\text{signal level}}{\text{echo level}}$ ⇒ ∞ for perfect hybrid

Problems Caused by Echoes

- If round-trip delay <20 msec, echo not heard distinctly
  - ⇒ not a problem in terrestrial links except transoceanic links
- to reduce echo, G_t, G_r programmed such that typical end-to-end loss ~ 7-10 dB
  - ⇒ G_t, G_r usually are losses; higher when $L_{a/b}$ is less
- if round-trip delay is large, possibility of oscillation exists at a low frequency for which ERL is not good
  - ⇒ called *singing*
- echo suppressors/cancellors used if round-trip delay is large, e.g; via satellite links
  - — echo suppressor cuts in/out 9-12 dB attenuation in A's receive-path based on whether A is talking/listening respectively
  - — echo cancellor is an adaptive digital filter that learns the echo impulse response and subtracts the echo

⇒ hybrid + EC ≡ better hybrid



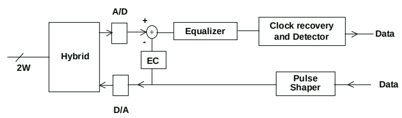
ISDN: Local Loop goes Digital

- Unloaded tp has a bandpass frequency response
  - — for high frequencies, attenuation **in dB** $\propto \sqrt{f}$
  - — delay distortion : delay $\propto \frac{1}{f}$
  - ⇒ a wideband pulse will get distorted
    - — both amplitude and phase distortion : H(f)
- Employ digital transmission with adaptive *equalisation*
  - ⇒ equaliser adapts to channel and tries to become ≈ $\frac{1}{H(f)}$
- Beyond this, main impairment is *cross-talk* from other pairs in same cable also carrying wideband digital transmission

Digital Transmission in ISDN

- Pulse transmission at 80,000 pulses/sec
- 4 amplitude levels (2 +, 2 -) employed
  - ⇒ 4 "symbols" : quaternary alphabet : 160 kbits/sec
    - ⇒ 2 B1Q (2 Bits, 1 Quarternary Symbol)
- Pulse shape chosen to minimise inter-symbol Interference on ideal channel
- Equaliser in the receiver compensates for channel-induced distortion
- duplex transmission on 2 wires, as in analog telephony
  - ⇒ 2W/4W hybrid necessary
- Fixed analog hybrid not good enough : echo is undesirable interference
  - ⇒ employ adaptive *echo cancellor* also

ISDN Receiver



- Receiver is primarily DSP based
- adaptive equaliser and echo cancellor get *trained* at link set-up using special training signals that sound the channel, and echo path, respectively
  - — subsequently, the two blocks track slow changes based on the detected data

ISDN Payload

- 160 kbits/sec = $\underbrace{2 \times 64}_{2B}$ + $\underbrace{16}_{D}$ + $\underbrace{16 \text{ kbps}}_{\text{Overhead}}$
- B channels : two 64 kbps user payload channels
  - — circuit-switched
- D channel : one 16 kbps channel used for signalling
  - a) between ISDN terminal and network
  - b) user equipment and network
  - c) user equipment and user equipment
  - — packet switched

ISDN Terminals

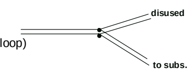
- Standard interfaces are defined : network termination (NT), user terminal, terminal adapter
- User terminals provide
  - — 1/2 telephone links for voice/fax/modem
  - — 64/128 kbps data circuit to another ISDN terminal
    - e.g. ISDN dial-up to Internet Remote Access Server
  - — packet-switched data paths between
    - (i) user and network
    - (ii) user and user
    - e.g. – send digits, get metering information, temporary suspension of circuits (type (i))
      - – send message to user terminal at other end (type ii))

ISDN Addressing

- international ISDN number + Subaddress
  15 digits (max) 40 digits (max)
  — ISDN number allowed more digits than PSTN number
- international ISDN number : country code + national ISDN number
  — national ISDN number can be longer than PSTN number
  ⇒ allows a prefix for indicating multiple networks (PSTN, X.25 messaging network,…)
- subaddress is used for user-to-user messaging
  — e.g., to identify a specific device at user termination
  — transparent to network

Implementation of ISDN

- Existing local loop can be used
  — *bridge taps* (open tps that are "hanging off" the loop) must be disconnected



- new interface card in exchange
  — two 64 kbps B channel circuits from each line to/from circuit switching matrix
  — messages to/from D channel sent from/to packet switch
- messages/packets travel between exchanges on SS7 network
  ⇒ SS7 is a pre-requisite for ISDN services

An Example of a Sophisticated ISDN service

- Always - On, Dynamic ISDN
  — Internet access using ISDN port
- 9.6 kbps packet-switched link to ISP on D channel is *always on*
- 64/128 kbps circuit-switched B channel set up when required by user terminal
  ⇒ set up to handle bursts of IP packets
  — suspended when traffic is less
- results in better utilisation of PSTN circuits for Internet access

Telecoms Network and Switching:

New Developments

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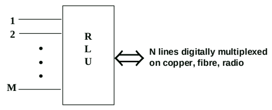
From Local Loop to Access Network (AN)

- Copper pair getting costlier by the day
- Concentration can effectively reduce the number of lines needed form a cluster of subscribers
- New multiplexing and transmission technologies can be leveraged to efficiently carry the N concentrated lines to the exchange
  ⇒ Concept of Remote Line Unit (RLU)



— RLU also performs all functions of exchange line interface

RLU - Exchange Interface

- Physical interface usually standard
  ⇒ permits standard transmission equipment to be used
- Signalling protocol proprietary
  ⇒ Brand X exchange works only with Brand X RLU

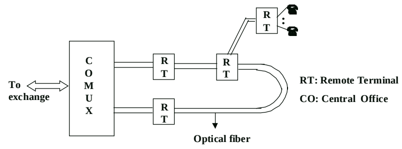
In 1996,

- V5.2 Signalling protocol standardised for interfacing Access Network (AN) to Local Exchange (LE)
  ⇒ Brand X exchange with V5.2 supports Brand Y AN (RLU is one type of AN)
- V5.1 protocol is for AN without concentration

V5.1/V5.2 Protocol

- Message-based protocol for subscriber signalling
  - events generated by subscriber (ON Hook / OFF Hook, Digits…) and exchange (ring, tests,…) are mapped to messages
  - ISDN D-channel messages also transported between LE and AN
- in V5.2, AN's port number has to be mapped to PCM channel number for each call due to concentration
- a bundle of upto 16 E1s constitutes one V5.1 / V5.2 interface
  - some PCM channels can be configured for V5.1 / V5.2 signalling protocol
  - in case of failure of an E1 being used for signalling, PCM channels on another E1 take over, based on prior configuration

Fibre Access Network

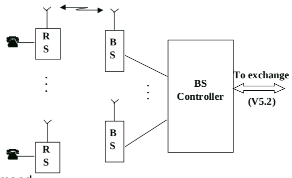


- RT is like RLU is functionality
- Several RTs connected to a Multiplexer (MUX) with Central Office (or Exchange) using optical fiber
- Dual fiber-ring ensures survivability against single node/link failure
- Interface to exchange uses V5.2 signalling protocol

Wireless Access Network (also called Wireless Local Loop, WLL)

- Telephone connected to a Remote Station (RS)
- RS communicates on radio to Base Station (BS)
- BS controller (BSC) controls several BS
- Radio channels assigned on demand

  ⇒ **concentration occurs on air** itself
- Quick deployment, no wires / cables (except may be for a few BS - BSC links)
  - but telephone now powered locally



In Summary,

- The AN
  - reduces (or eliminates) copper pair length
  - concentrates teletraffic
  - typically converts to digital form closer subscriber
  - interface to LE using V5.2 protocol
- For LE without V5.2 support,
  - either proprietary signalling to proprietary AN (e.g. WLL/RLU mated to a specific switch)
  - or, expand again (at CO-MUX or BSC) to a standard subscriber interface, usually analog 2W!

    e.g. Digital Loop Carrier