Conventional Telephony

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Telephone
People Behind

- Innocenzo Manzetti
- Antonio Meucci
- Johann Philipp Reis
- Elisha Gray
- Alexander Graham Bell
- Thomas Edison
Telephone

- an apparatus of reproducing sound, especially that of the human voice, at a great distance, by means of electricity; consisting of transmitting and receiving instruments connected by a line or wire which conveys the electric current.
The Standard Telephone Set
The Standard Telephone Set

- Basically a simple analog transceiver designed with the primary purpose of converting speech or acoustical signals to electric signals.
Bell System 500-type – rotary dial telephone
Bell System 302-type

- telephone with hand crank magneto, fixed microphone, hand-held.
Bell System 2500-type

- touch-tone telephone
IP Telephone
Factors Affecting the Quality of Transmission

- Received volume
- Relative frequency response of the telephone circuit
- Degree of interference
Functions of the Telephone Set

- Notify the subscriber when there is an incoming call.
- Provide a signal to the telephone network verifying when the incoming call has been acknowledged and answered.
- Convert speech energy to electrical energy.
Functions of the Telephone Set

- Incorporate some method of inputting and sending destination telephone numbers from the telephone set to C.O. switch via the local loop.
- Regulate the amplitude of the speech signal the calling person outputs onto the telephone line.
- Incorporate some means of notifying the C.O. when a subscriber wishes to place an outgoing call.
Functions of the Telephone Set

- Ensure that a small amount of the transmit signal is fed back to the speaker, enabling talkers to hear themselves speaking.
- Provide an open circuit condition to the local loop when not in use and closed circuit when in use.
- Provide a means of transmitting and receiving call progress signals between the central office switch and the subscriber, such as on and off hook, busy, ringing, dial pulses, touch-tone signals, and dial tone.
Telephone Set

- Handle
- Sleeve
- Ring
- Tip
Telephone Set

Tip (green) – used to transmit the signal

Ring (red) – used to receive the signal far-end

Slave (yellow) – used as a spare or for special-purpose applications
Parts of the Telephone

Transmitter/Microphone

It converts acoustical energy into electrical energy by means of a carbon granule transmitter.
Carbon Transmitter

a sound-to-electrical signal transducer consisting of two metal plates separated by granules of carbon.

Has the advantage of simplicity and the ability to generate a relatively large signal without amplification.

Poor audio quality
Carbon Transmitter

- Diaphragm (flexible electrode)
- Carbon granules
- Fixed electrode
- Voltage source (battery)
- Sound waves
- Signal
Telephone Transmitter

Electret Condenser

Has a vibrating diaphragm that effectively changes the plate spacing in a permanently charged capacitor consisting of electrodes on both sides of a layer of plastics that has a permanently stored electrical charge.
Parts of the Telephone

Receiver/Speaker

It converts electrical signals to acoustical signal understandable by human.
Parts of the Telephone

Switch Hook (Plunger)

A DPST switch placed across tip and ring.

*On-Hook*: handset in idle condition
*Off-Hook*: headset is lifted up
Parts of the Telephone

**Dialer**

enables the subscriber to input telephone number of the party being called.
Parts of the Telephone

Ringer

device that converts electrical signals from C.O. to an audible signal to notify the subscriber by an incoming call.

Equalizers

Combinations of passive components that are used to regulate the amplitude and frequency response of the voice signals.

Hybrid Coil

Convert a two-wire circuit into four-wire and vice versa.
Parts of the Telephone

- Ring (-48 Vdc)
- Local RJ-11 loop Connector
- Tip (ground)
- Ringer (bell or oscillator)
- On/off hook
- Equalizer
- Resistors, Capacitors, and Inductors
- Hybrid
  - 2 wire
  - 4 wire
- Speaker
- Microphone
- Dialing circuit – mechanical dialer or touch-tone keypad
Dialling Methods

1. Dial Pulsing or Pulse Dialling

Defined as a momentary on-hook condition that causes loop making and breaking from the telephone set dialer toward the central office.

Make – circuit closed/off-hook
Break – circuit opened/on-hook
Pulse Dialling

Nominally:
- break period = 61 ms
- make period = 39 ms

Pulse Period = 0.1 s/pulse
Interdigital Delay = 0.5 s

Interdigital Delay – idle period separation
Pulse Dialling

Example:

What is the minimum time required to dial the 7-digit telephone number 395-4258 using a rotary type telephone set?
2. Multifrequency Dialling or DTMF Dialling

- Dual-Tone Multifrequency originally called as Touch-Tone

- A simple two-to-eight encoding scheme where each digit is represented by the linear addition of two frequencies.
# DTMF Dialling

<table>
<thead>
<tr>
<th>Low-Group Frequencies</th>
<th>High-Group Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>697 Hz</strong></td>
<td></td>
</tr>
<tr>
<td>1209 Hz</td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>1336 Hz</td>
<td><strong>2</strong> ABC</td>
</tr>
<tr>
<td>1477 Hz</td>
<td><strong>3</strong> DEF</td>
</tr>
<tr>
<td>1633 Hz</td>
<td><strong>A</strong></td>
</tr>
<tr>
<td><strong>770 Hz</strong></td>
<td></td>
</tr>
<tr>
<td>1209 Hz</td>
<td><strong>4</strong> GHI</td>
</tr>
<tr>
<td>1336 Hz</td>
<td><strong>5</strong> JKL</td>
</tr>
<tr>
<td>1477 Hz</td>
<td><strong>6</strong> MNO</td>
</tr>
<tr>
<td>1633 Hz</td>
<td><strong>B</strong></td>
</tr>
<tr>
<td><strong>852 Hz</strong></td>
<td></td>
</tr>
<tr>
<td>1209 Hz</td>
<td><strong>7</strong> PQRS</td>
</tr>
<tr>
<td>1336 Hz</td>
<td><strong>8</strong> TUV</td>
</tr>
<tr>
<td>1477 Hz</td>
<td><strong>9</strong> WXYZ</td>
</tr>
<tr>
<td>1633 Hz</td>
<td><strong>C</strong></td>
</tr>
<tr>
<td><strong>941 Hz</strong></td>
<td></td>
</tr>
<tr>
<td>1209 Hz</td>
<td><strong>0</strong></td>
</tr>
<tr>
<td>1336 Hz</td>
<td><strong>#</strong></td>
</tr>
<tr>
<td>1477 Hz</td>
<td><strong>D</strong></td>
</tr>
</tbody>
</table>
The Telephone Circuit

- Central office
- Tandem Office
- Long-distance (inter-exchange) carriers

Diagram:
- Central (end) office
- Central (end) office
- Central (end) office
Plain Old Telephone System (POTS)

- The simplest and most straightforward form of telephone service.
- Bi-directional, or full duplex, voiceband path with limited frequency range of 300 to 3400 Hz: in other words, a signal to carry the sound of the human voice both ways at once;
- Call-progress tones, such as dial tone and ringing signal;
- Subscriber dialing;
- Operator services, such as directory assistance, long distance calling, and conference calling assistance;
Local Subscriber Loop (Local Loop)

- Provides a means of connecting a telephone set at a subscriber’s location to the closest telephone office.
Local Subscriber Loop (Local Loop)

- Carries voice signal both ways.
- It carries signalling information both ways: dialling pulses or tones to the central office from the network to the subscriber.
- Copper wire is preferred over optical fiber.
Main Component Parts That Make Up a Traditional Local Loop

1. Feeder Cable (F1)
   - Largest cable used in a local loop.

2. Serving Area Interface (SAI)
   - A cross-connect point used to distribute the larger feeder cable into smaller distribution cable.

3. Distribution Cable
   - A smaller version of a feeder cable containing less wire pairs.
On the Local Loop

4. Subscriber or Standard Network Interface (SNI)
   - Device that serves as the demarcation point between local telephone company responsibility and subscriber responsibility for telephone service.

5. Drop Wire
   - The final length of cable pair that terminates at the SNI.

6. Aerial
   - A portion of the local loop that is strung between poles.
7. Distribution Cable and Drop-Wire Cross-Connect Point
   - Location where individual cable pairs within a distribution cable are
     separated and extended to the subscriber’s location on a drop wire.
Attenuation On the Local Loop

![Graph showing attenuation on the local loop with nonloaded and H88 loading curves. The graph plots frequency (Hz) on the x-axis and attenuation (dB) on the y-axis. The nonloaded curve is a smooth line, while the H88 loading curve shows a more pronounced increase in attenuation at higher frequencies.]
Attenuation On the Local Loop
Attenuation on the Local Loop

Loading Coils

- Use to decrease the attenuation, increase the line impedance, and improve transmission levels for circuits longer than 18,000 ft.

- Cancels capacitance that inherently builds up between wires with distance.

- Specified by the addition of letter codes A, B, C, D, E, F, H, X, or Y, which designate the distance between loading coils and by numbers, which indicate the inductance value of the wire gauge.
<table>
<thead>
<tr>
<th>Letter Designation</th>
<th>Distance(ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>700</td>
</tr>
<tr>
<td>B</td>
<td>3000</td>
</tr>
<tr>
<td>C</td>
<td>929</td>
</tr>
<tr>
<td>D</td>
<td>4500</td>
</tr>
<tr>
<td>E</td>
<td>5575</td>
</tr>
<tr>
<td>F</td>
<td>2787</td>
</tr>
<tr>
<td>H</td>
<td>6000</td>
</tr>
<tr>
<td>X</td>
<td>680</td>
</tr>
<tr>
<td>Y</td>
<td>2130</td>
</tr>
</tbody>
</table>
The Telephone Circuit

Tandem Office

Central (end) office

Central (end) office

Central (end) office

Long-distance (inter-exchange) carriers
The Telephone Circuit

Central Office

- A central location where subscribers are interconnected, either temporarily or on a permanent basis.
Central Office

Primary Functions:

1. To provide battery (DC voltage) to a telephone. This DC voltage is used to operate the telephone and to determine when a subscriber has gone off or on-hook.
2. To provide ringing voltage.
3. To provide dial tone.
4. To accept the digits dialled.
5. To provide connection to subscribers.
6. Supervise the calling process
The Telephone Circuit

**Tandem Office**

- A Class 4, or Tandem, central office telephone exchange used to interconnect local exchange carrier offices for long distance communications in the Public Switched Telephone Network.

**Trunk Circuit (interoffice trunk)**

- Connection between C.O.

**Tandem Trunk(intermediate trunk)**

- Truck connecting tandem office and any other C.O.
The Telephone Circuit

Local Exchange Carrier (LEC)

- A regulatory term in telecommunications for so-called local telephone company.

International Gateway Facilities

- Consists of international transmission, switching and network management facilities which serves as point of entry and exit in the Philippines of international traffic between the national network and points outside the Philippines.
1. Bandwidth parameters
   a. Attenuation distortion
   b. Envelope delay distortion

2. Interface parameters
   a. Terminal impedance
   b. In-band and out-of-band signal power
   c. Test signal power
   d. Ground isolation

3. Facility parameters
   a. Noise measurements
   b. Frequency and phase distortion
   c. Amplitude distortion
   d. Nonlinear distortion
Bandwidth Parameters

Attenuation distortion

The difference in circuit gain experienced at a particular frequency with respect to the circuit gain at reference frequency.

Also called as frequency response, differential gain and 1004-Hz deviation

Envelope Delay Distortion

The difference in phase shifts with respect to frequency that signals experience as they propagate through a medium.
Interface Parameters

1. Electrical protection of the telephone network and its personnel.
2. Standardization of design arrangements.
Interface Parameters

600Ω – station equipment impedance over the usable voice band

20 MΩ dc and 50 kΩ ac – minimum station equipment isolation from ground

0 dBm – maximum transmitted signal power for private-line circuit

Circuit gain at 3000 Hz is 3 dB below the specified in-band signal power

Signal must be received at the Telco office at -12dBm
Facility Parameters

Includes potential impairments to data signal due to the telephone company equipments
1. Impulse Noise

Characterized by high-amplitude peaks (impulse) of short duration having an approximately flat spectrum.

2. Gain Hits and Drop-Outs

Gain Hits – a sudden, random change in the gain of a circuit resulting in a temporary change in the signal level. Caused by noise transients (impulses) on transmission facilities during the normal course of a day.

Drop-Out – decrease in circuit gain of more than 12dB lasting for more than 4 ms. Caused by deep fades or by switching delays.
Facility Parameters

3. Phase Hits
   Sudden, random changes in the phase of a signal.

4. Phase Jitter
   A form of incidental phase modulation that occurs at a 300-Hz rate or lower.

5. Single-Frequency Interference
   Presence of one or more continuous, unwanted tones within a message channel – called spurious tones.
   Often caused by crosstalk or cross-modulation between adjacent channels due to system nonlinearities.
Phase hit
rapid changes $> 20 \, p$

Phase jitter
continuous changes $< 10 \, p-p$
Crosstalk

Any disturbance created in a communications channel by signals in other communications channels.
Crosstalk

Nature of Crosstalk

1. Intelligible Crosstalk
   Particularly annoying and objectionable because the listener senses a real or fancied loss of privacy.

2. Unintelligible Crosstalk
   Does not violate privacy but still annoying
Crosstalk

Primary Types

1. Nonlinear Crosstalk
   Direct result of nonlinear amplification in analog system.
   Produces harmonics and cross products.

2. Transmittance Crosstalk
   Caused by inadequate control of the transfer characteristics or transmittance of networks – (frequency response of a transmission system, poor filter design, or poor filter performance)
Crosstalk

3. Coupling Crosstalk

Electromagnetic coupling between two or more physically isolated transmission media.

Types of Coupling Crosstalk

a. Near-end crosstalk (NEXT)

Occurs at the transmit end of a circuit and travels in the opposite direction as the signal in the disturbing channel.

b. Far-end crosstalk (FEXT)

Occurs at the very far end receiver and is energy that travels in the same direction as the signal in the disturbing channel.
Signalling

Provides the means for operating and supervising a telephone communications system.

Main Functions of Signalling

1. To help the switching equipment provides connection
2. To announce incoming calls.
3. To supply dial tone
4. To send the busy signal
Signalling Messages are divided into:

1. **Alerting**
   Indicate a request for service, such as going off hook or ringing the destination telephone.

2. **Supervising**
   Provides call status information, such as busy or ring-back signals.

3. **Controlling**
   Provide information in the form of announcement.

4. **Addressing**
   Provide the routing information.
Call Progress Tones and Signals

Acknowledgement and status signals that ensure the processes necessary to set up and terminate a telephone call are completed in a timely manner.
Signals on the Local Loop

1. Dial Tone
   - A tone advising that the exchange is ready to receive call information and inviting the user to start sending call information

   **Breaking Dial Tone**
   - Dial tone is removed as the subscriber begins dialling

   **No Dial Tone**
   - When a subscriber goes off-hook and doesn’t receive dial tone.

2. Station Busy
   - Sent from switching machine back to the calling party whenever the called telephone number is off-hook (in use).
Signals on the Local Loop

3. Equipment Busy
   - Congestion tone or no-circuit-available tone.
   - Sent from the switching machine back to the calling station whenever the system cannot complete the call because of equipment unavailability.

Blocking
   - Condition whereby equipments are temporarily unavailable

4. Ringing Signal
   - Sent from C.O. To a subscriber whenever there is an incoming call.
5. Ring-back signal
   - Sent back to the calling party at the same time the ringing signal is sent to the called party.

4. Ringing Signal
   - Sent from C.O. To a subscriber whenever there is an incoming call.
## Signals on the Local Loop

### Call Progress Tone Direction of Propagation

<table>
<thead>
<tr>
<th>Tone Signal</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dial Tone</td>
<td>C.O. to calling station</td>
</tr>
<tr>
<td>DTMF</td>
<td>Calling station to C.O.</td>
</tr>
<tr>
<td>Dial Pulses</td>
<td>Calling subscriber to C.O.</td>
</tr>
<tr>
<td>Station Busy</td>
<td>C.O. to calling subscriber</td>
</tr>
<tr>
<td>Ringing</td>
<td>C.O. to called subscriber</td>
</tr>
<tr>
<td>Ring-back</td>
<td>C.O. to calling subscriber</td>
</tr>
<tr>
<td>Receiver on-hook</td>
<td>Calling subscriber to C.O.</td>
</tr>
<tr>
<td>Receiver off-hook</td>
<td>Calling subscriber to C.O.</td>
</tr>
<tr>
<td>Receiver-Left-Off-Hook-Alert</td>
<td>C.O. to calling subscriber</td>
</tr>
<tr>
<td>Equipment Busy</td>
<td>C.O. to calling subscriber</td>
</tr>
</tbody>
</table>
Signaling Techniques

Loop Start Signalling

Provides a way to indicate on-hook and off-hook conditions in a voice network.

Used primarily when connecting from the telephone set to a switch
C.O.

Telephone Set

48 V
C.O.

Telephone Set

48 V
A local loop has a resistance of 1 kΩ, and the telephone connected to it has an off-hook resistance of 200 Ω. Calculate the loop current and the voltage across the telephone when the phone is:

a. On-hook
b. Off-hook
Signaling Techniques

Ground Start Signaling

Used in a switch-to-switch connection

Similar operation with loop start signaling method
Common Channel Signaling System

High-Level Data Link Control (HDLC)-based message oriented signalling systems
Signaling System 7

- A packet-switched data network linking C.O. to each other, to long-distance switching centers, and to centralized databases used for many applications.
- Allows much more data to be sent more quickly, and less interface.
- Uses dedicated 64 kbps data channels.
A more realistic example...

Packet arrives

Egress router removes label

Packet forwarded based on label

Ingress router adds label to packet

Unlabeled Packet arrives

Autonomous system boundary
A more realistic example…

Label switched path
Switching

- Method of connecting one telephone set to another by bringing one pair of wires from each telephone to a central location where a connection can be made for a certain period of time between any two subscribers.
Switching

\[ N = \frac{n(n - 1)}{2} \]

N = no. in interconnecting wire
n= no. of parties
Types of Switching Systems

1. Manual Switching (1870’s until 1975)

- Uses switchboards
- Calls are manually switched using patchcords and jacks
Switching
Switching
2. Strowger System (step-by-step switching)

- Developed by Almon B. Strowger in 1989
- Aka SXS switch
- Stepping process continued until all the digits of the telephone numbers were entered.
- Uses a relay which is called the stepping relays
Types of Switching Systems

- Hunter
- Dial '5'
- Busy Trunk
- First Selectors
- Connector
- Dial '3'
- Dial '0'
- 5-3-9
- 5-3-0
3. Common Control Switching

- Aka crossbar system (XBAR)
- Method by a common control unit
- Select a closed path through electromechanical switching
- Utilizes a switching matrix externally managed by common control to route telephone calls.
Types of Switching Systems

Input

Tie Lines

Output
Crossbar Switching

Major Functional Area

1. Line Equipment
   Recognizes a request for service from the customer end and starts the request for dial tone

2. Switching Network
   Provides path for dial tone and a path for call completion.

3. Common Control Equipment
   Performs the vital coordinating functions of the whole system

4. Trunk Equipment
   Interface between the facility and the switching office maintaining the connection.
Types of Switching Systems

4. Electronic Switching System (ESS)

- A digital computer based system capable of controlling matrices that connect analog signals as well as digital signals
**FDMA**
(Frequency Division Multiple Access)

**TDMA**
(Time Division Multiple Access)

**CDMA**
(Code Division Multiple Access)
Electronic Switching System

ESS Parts

1. Central Control Section
   Coordinates the system operation

2. Permanent Memory
   Stores programs such as restrictions, features, etc.

3. Temporary Memory
   Serves as type of electronic scratch pad.

4. Line Sensor
   Senses each line a few times per second to determine whether the line is busy or idle

5. Switching Network
   It contains mostly of relays and drivers.
Subscriber Line Interface Card

- Circuit board that connects a local loop to the central office
SLIC Functions

- **Battery**: the 48 Vdc supply
- **Overvoltage Protection**: protection against lightning and other high-voltage transients
- **Ringing**: the 100V, 20Hz ac ringing voltage connected to the line by a relay on the line card.
- **Supervision**: monitoring the line for on- or off-hook conditions
- **Coding**: for digital switches, analog-to-digital conversion take place here, at the interface between the analog loop and the digital switch.
- **Hybrid**: the local loop is a two-wire circuit with signals travelling in both directions on the same pair, and the rest of the network is usually four-wire. Conversion is done.
- **Testing**: Checking of the line for opens, shorts, and so forth.
1. Insertion Loss
2. Net Loss
3. Transducer Loss
4. Return Loss
Insertion Loss

- Caused by the transmission of a gain element to a transmission medium
- It is the ratio of the power delivered from a source to a load, to the power delivered from the same source to the same load through a transducer.
Net Loss

- The ratio of the signal power at the input and the output of the channel
Transducer Loss

- The ratio of the maximum power available from a source to the power delivered by that source to a load through a transducer.
Return Loss

- Measure of the match between the two impedances on either side of a junction point.

\[ RL \ (dB) = 20 \log \left( \frac{Z_1 + Z_2}{Z_1 - Z_2} \right) \]
Return Loss

Echo Return Loss (ERL)

- The weighted power-average loss at the reflection point.

Singing Return Loss

- Same as ERL but over a considerably narrow band near an edge of the voice band.
Transmission Loss Plans

Via-Net Loss

- Loss to be introduces to avoid “singing” phenomenon.

\[ VNL = \left( \frac{0.2L}{V_p} + 0.4 \right) dB \]

\[ VNL = (0.2t + 0.4) dB \]

L = circuit length in km

\( V_p \) = velocity of propagation in the facility (km/s)

\( t \) = time delay (ms) for propagation one way along the line
Example

- Calculate the via net loss (VNL) of a telephone signal that takes place 3 ms to reach its destination for an acceptable amount of echo.
Overall Connection Loss (OCL)

\[ OCL = 0.102D + 0.4N + 5 \]

- \( D \) = path delay (ms)
- \( N \) = number of trunks in tandem
Traffic Theory

- In a voice or data communication, sources generate calls to a facility, or servers. When a call arrives at a group of servers, and one is available, the call is handled. When all servers are busy (depending on system design), the caller can:
Traffic Theory

- Receive a busy signal requiring the caller to hang up and try later.
- Automatically route to another facility
- Queue (wait) in a holding facility until the server is available
- Queue for some tolerable interval, then disconnect of not served.
Traffic Engineering

Measurement of Telephone Traffic

Traffic Intensity

- The ratio of the traffic volume and the length of time during which it is measured.
- Average traffic density during 1-h period
- aka *Traffic Load*
Traffic Intensity (A)

\[ A = C t_h = \frac{\sum t_n}{60} \]

A = traffic intensity (Erlang)
C = number of calls within the duration of observation period (calls/min?)
\( t_h \) = average holding time per call (min/call)
\( t_n \) = occupancy of each path (min)
Units of Traffic Intensity

Erlang

- International dimensionless unit of traffic intensity
- One Erlang is the traffic intensity represented by an average of one circuit busy out of a group of circuits over some period of time
Agner Krarup Erlang

- Danish mathematician, statistician and engineer, who invented the fields of traffic engineering and queuing theory.
Units of Traffic Intensity

Call-Second, Call-Minute, Call-Hour

- Units of traffic quantity representing the occupation of a circuit for a second, minute or hour.
Units of Traffic Intensity

Century Call-Second (CCS)

- Units of traffic intensity equal to 1/36 of an Erlang.
- It is otherwise known as *Hundred Call-Second (HCS)*.
Units of Traffic Intensity

Equated Busy Hour Call (EBHC)

- European unit of traffic intensity equal to 1/36 of an Erlang.
Units of Traffic Intensity

1 Erlang = 60 Cmin = 36 CCS = 36 HCS = 3600 CS = 36 EBHC
$T = NP$

$T =$ traffic in Erlangs  
$N =$ number of customers  
$P =$ probability that a given customer is using the phone
A telephone system has uses a 120 channels system and 20,000 subscribers. Each subscriber uses the phone on average 30 minutes per day, but on average 10 of those minutes are used during the peak hour.

Calculate

a. the average and peak traffic in Erlangs for the whole system

b. the average and peak traffic in Erlangs for one call, assuming callers are evenly distributed over the system
Grade of Service

- A measure of the probability that during a specified period of peak traffic, a call is offered to a group of trunks or circuits will fail to find an idle circuit at the first attempt.
- Usually applied to the busy hour traffic.
Call Congestion

\[ P = \frac{C_{\text{lost}}}{C_{\text{offered}}} \]

\[ C_{\text{lost}} = \text{no. of lost calls} \]
\[ C_{\text{offered}} = \text{no. of offered calls} \]
Blocking Probability Models

Erlang B

- Blocked Calls Cleared (BCC) or Lost Calls Cleared (LCC)
- Based on the assumption that calls not immediately satisfied at the first attempt are cleared from the system and do not reappear during the period under consideration
- Generally a good estimator of single-hour service
Erlang B

\[ B(c, \alpha) = \frac{\left( \frac{\alpha^c}{C!} \right)}{\sum_{x=0}^{x=c} \left( \frac{a^x}{x!} \right)} \]
Erlang C

- Blocked Calls Delayed (BCD) or Lost Calls Delayed (LCD)
- Based on the assumption that calls not immediately satisfied at the first attempt are held in the system until satisfied.
Erlang C

\[ C(c, a) = \frac{\left(\frac{a^c}{c!}\right) \left[\frac{c}{(c-a)}\right]}{\left\{ \sum_{x=0}^{c-1} \frac{a^x}{x!} + \left(\frac{a^c}{c!}\right) \left[\frac{c}{c-a}\right] \right\}} \]

a = offered load (Erlang)
c = number of circuits/servers
Poisson Probability

- Blocked Calls Held (BCH) or Lost Calls Held (LCH)
- Based on the assumption that calls not immediately satisfied at the first attempt are held in the system until saved or abandoned.
- A good estimation of the service given on the average over a busy season during which the offered load varies over a wider range that would be expected from the assumptions of random offered traffic.
% Overflow or % Blocking

- The measure of the rate at which subscriber’s call attempt failed or blocked

\[
\% \text{ Overflow} = \frac{\text{no. of calls rejected}}{\text{no. of calls accepted} + \text{no. of calls rejected}} \times 100\%
\]
Occupancy of Utilization

- Traffic intensity per traffic path

\[
\% \text{ Occupancy} = \frac{\text{total traffic}}{\text{total no. of lines}} \times 100\%
\]
Offered Traffic ($a_o$)
- The equivalent traffic offered to a group of switch.

Carried Traffic ($a_c$)
- The equivalent traffic carried by a group of trunk lines.

\[ a_o = \frac{a_c}{(1 - \% \text{ overflow})} \]
FDM Telephony

- Employs SSB or SSBSC modulation technique
- 4 kHz spectrum is allocated to each conversation
- Allows small guard bands between channels
AT&T’s FDM Hierarchy

Group
- Consists of 12 LSB signals
- 60 kHz to 108 kHz range

Supergroup
- Consists of 5 groups
- Has 60 voice channels
- Occupies 312 kHz to 552 kHz
AT&T’s FDM Hierarchy

Mastergroup U600

- Consists of 10 supergroups
- Has 600 voice channels
- Occupies 564 kHz to 3084 kHz
- Has a bandwidth of 2520 kHz
Mastergroup L600

- Consists of 10 supergroups
- Has 600 voice channels
- Occupies 60 kHz to 2788 kHz
- Has a bandwidth of 2728 kHz
AT&T’s FDM Hierarchy

Jumbogroup
- Consists of 6 mastergroups
- 3600 voiceband channels

Superjumbogroup
- Consists of 3 jumbogroups
- 10,800 voiceband channels
FDM Telephony

(a) Group: twelve signals, all LSB, each in 4kHz band
FDM Telephony

(b) Supergroup: five groups

(c) Mastergroup: ten supergroups, separated by guard bands
Channel 1
0-3.3 kHz

Channel 2
0-3.3 kHz

Baseband Inputs
0-4 kHz

Channel 11
0-3.3 kHz

Channel 12
0-3.3 kHz

Balanced Modulator

BPF

104 kHz

100-104 kHz

64-68 kHz

60-64 kHz

104 kHz

108 kHz

104-108 kHz

Group Output
60-108 kHz

Linear Summer
<table>
<thead>
<tr>
<th>LEVEL</th>
<th>VB</th>
<th>B (kHz)</th>
<th>Range (kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>msg. channel</td>
<td>1</td>
<td>4</td>
<td>0 – 4</td>
</tr>
<tr>
<td>Group</td>
<td>12</td>
<td>48</td>
<td>60 – 108</td>
</tr>
<tr>
<td>Supergroup</td>
<td>60</td>
<td>240</td>
<td>312 – 552</td>
</tr>
<tr>
<td>MG U600</td>
<td>600</td>
<td>2520</td>
<td>564 – 3084</td>
</tr>
<tr>
<td>MG L600</td>
<td>600</td>
<td>2728</td>
<td>60 – 2788</td>
</tr>
<tr>
<td>Jumbogroup</td>
<td>3600</td>
<td>16 984</td>
<td></td>
</tr>
<tr>
<td>Superjumbo</td>
<td>10 800</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Digital telephony is the use of digital electronics in the provision of digital telephone services and systems. Since the 1960s a digital core network has almost entirely replaced the old analog system, and much of the access network has also been digitized. Digital telephony was introduced to provide voice services at lower cost, but was then found to be of great value to new network services such as ISDN that could use digital facilities to transfer data speedily over telephone lines.
Digital Telephony

\[ f_b(\text{voice}) = 8 \text{ bits/sample} \times 8000 \text{ samples/second} = 64 \text{ kbps} \]
Time-Division Multiplexing

DS-1

- Has one sample (8 bits) from each 24 telephone channels plus one framing bit.

\[(DS - 1) = 24 \text{ channels} \times 8 \frac{\text{bits}}{\text{channel}} + 1 \text{ framing bit} = 193 \text{ bits}\]

\[f_b(DS - 1) = 193 \text{ bits} \times 8 \text{ kHz} = 1.544 \text{ Mbps}\]
Time-Division Multiplexing

Framing Bits

- Used to enable the receiver to determine which bit is being received at a given time.
<table>
<thead>
<tr>
<th>Carrier</th>
<th>Signal</th>
<th>Voice Channel</th>
<th>Bit Rate (Mbps)</th>
<th>Typical Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>DS-1</td>
<td>24</td>
<td>1.544</td>
<td>Twisted pair</td>
</tr>
<tr>
<td>T1C</td>
<td>DS-1C</td>
<td>48</td>
<td>3.152</td>
<td>Twisted pair</td>
</tr>
<tr>
<td>T2</td>
<td>DS-2</td>
<td>96</td>
<td>6.312</td>
<td>Low capacitance twisted pair, microwave</td>
</tr>
<tr>
<td>T3</td>
<td>DS-3</td>
<td>672</td>
<td>44.736</td>
<td>Coax, microwave</td>
</tr>
<tr>
<td>T4</td>
<td>DS-4</td>
<td>4032</td>
<td>274.176</td>
<td>Coax, FOC</td>
</tr>
<tr>
<td>T5</td>
<td>DS-5</td>
<td>8064</td>
<td>560.16</td>
<td>FOC</td>
</tr>
</tbody>
</table>
Integrated Service Digital Network (ISDN)

- Designed to allow voice and data to be sent in the same way doing the same lines.
- Allows the telephone system to be completely digital from end to end.
Integrated Service Digital Network (ISDN)

Types of Connection in ISDN

1. Primary Access Point

- Used by large users with a data rate of 1.544 Mbps
- Includes 24 channels with a data rate of 64 kbps each
- Has one D channel and 23 B channels
Primary Access Point

D-Channel

- Used for common-channel signalling, that is, for setting up and monitoring calls.

B-Channel

- Can be used for voice or data, or combined, to handle high-speed data or digitized video signals.
2. Basic Interface

- Used for connecting individual terminal through a basic access rate of 192 kbps
- Users have two 65 kbps B-channels for voice or data, one 16 kbps D channel, and 48 kbps for network overhead.
ISDN Access

- **TE1**
- **TE2**
- **TA**
- **NT2**
- **NT1**

**R**

- S
- T

T – Primary Interface
S – Basic Interface
TE – Terminal Equipment
TA – Terminal Adapter
NT – Network Terminal Equipment

To Network
ISDN Access

Terminal Equipment Type 1 (TE1)

- Terminal equipment as digital telephone and data terminals, designed specifically for use with ISDN.
- Connects directly to the network at point S

Network Termination Equipment

- Could be a PBx, a small computer network (LAN) or a central office.
Terminal Equipment Type 2 (TE2)

- Terminal equipment not specifically designed for ISDN.
- Needs to connect through (TA) Terminal Adapter to allow it to work with the ISDN.

Terminal Adapter

- Serves as an interface between different systems.
- Could be a modem
Asymmetrical Digital Subscriber Line (ADSL)

- A data communications technology that enables faster data transmission over copper telephone lines than a conventional voiceband modem can provide.
Asymmetrical Digital Subscriber Line (ADSL)

Downstream (to the subscriber): 1 to 8 Mbps

Upstream (from the subscriber): 160 to 640 kbps
ADSL Spectrum

- **Voice**: 4 kHz
- **Upstream**: 25 kHz
- **Downstream**: 250 kHz

Frequency (kHz)
Broadband ISDN

- Uses much larger bandwidths and higher data rates.
- Has a data rate of 100 to 600 Mbps
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Thank You!