Technical Elements of the Public Switched Telephone Network

- CPE, Access, Transport, Signaling

PSTN
Struttura delle rete telefonica pubblica - Public Switched Telephone Network (PSTN)

1. Customer Premises Equipment
Tipologie di apparecchiature dal lato utente

PBX: Private Branch eXchange
Elements of the Public Switched Telephone Network (PSTN)

The Access System consists of the access line to the customer (called the local loop) and termination equipment at the end office (nearest telephone office switch).
3. Transport Core

The Transport Core connects end office switches and core switches.

Trunk lines connect switches.
Elements of the PSTN

• Telephone Company Switch
Elements of the Public Switched Telephone Network (PSTN)

4. Signaling System

Transport is the actual transmission of voice.

**Signaling** is the control of calling (setup, teardown, billing, etc.).
SS7 in the United States
C7 in Europe
Points of Presence (POPs)

In the U.S., competing carriers connect at points of presence (POPs).

Local Access and Transport Area (LATA)

- Local Carrier 1 Switch
- Local Carrier 2 Switch
- Local Carrier 1 Customer
- Local Carrier 2 Customer

Other Local Area

- POP
- Long-Distance Carrier A

Other Country

- POP
- International Carrier X

In the U.S., competing carriers connect at points of presence (POPs).
PSTN: Inizialmente tutta analogica

Vecchia rete telefonica: tutta analogica
Switching di Circuito
Differenze tra il traffico vocale e quello dati

Full-Duplex (Two-Way) Circuit

Voice Traffic: Fairly Constant Use; Circuit Switching Is Fairly Efficient

Data Traffic: Short Bursts, Long Silences; Circuit Switching Is Inefficient

The reserved capacity of circuit switching is OK for voice, but not for bursty data transmission.
There are two types of circuits between customer premises: ordinary dial-up circuits and leased line circuits.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Dial-Up Circuits</th>
<th>Leased Line Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>Dial-Up. Separate circuit for each call.</td>
<td>Permanent circuit, always on.</td>
</tr>
<tr>
<td>Speed for Carrying Data</td>
<td>Up to 56 kbps Residence can only Send up to 33.6 kbps</td>
<td>56 kbps to gigabit speeds</td>
</tr>
<tr>
<td>Number of Voice Calls Multiplexed</td>
<td>One</td>
<td>Several due to multiplexing</td>
</tr>
</tbody>
</table>
## Local Loop Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Use</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Pair Voice-Grade UTP</td>
<td>Residences</td>
<td>Already installed</td>
</tr>
<tr>
<td>2-Pair Data-Grade UTP</td>
<td>Businesses for Lowest-speed access lines</td>
<td>Must be pulled to the customer premises (this is expensive)</td>
</tr>
<tr>
<td>Optical Fiber</td>
<td>Businesses for higher-speed access lines</td>
<td>Must be pulled to the customer premises (this is expensive)</td>
</tr>
</tbody>
</table>

Residential 1-pair voice-grade UTP is already installed. This makes it inexpensive to use.

Business 2-pair data-grade UTP and fiber for leased lines must be installed; this is expensive.
PSTN: per la maggior parte digitale con alcuni loop locali analogici

Attuale rete telefonica: Per la maggior parte digitale
Codec presso lo switch all’End Office

- La linea di accesso all’abbonato è analogica
- Lo Switch è digitale
- Il Codec converte i segnali trasmessi tra di loro

Diagramma:

- ADC
- Codec
- DAC
- Segnale Interno Digitale
- Switch Digitale
- Linea di accesso
- Loop locale
- Subscriber Signal
- Analog
Campionamento per effettuare conversioni da Analogico-a-Digitale (ADC)

- **IL Codec in primo luogo filtra la banda del segnale vocale**
  - Taglia tutte l’energia sotto i 300 Hz
  - Taglia tutta l’energia sopra i 3,400 Hz
  - Passa segnale filtrato da 300 Hz a 3.4 kHz

La voce umana

Distribuzione di energia per la voce umana

![Diagram](image-url)
Campionamento per effettuare conversioni da Analogico-a-Digitale (ADC)

- **Codec Campiona il segnale della voce**
  - Divide ciascun secondo in 8,000 *periodi di campionamento*
  - Ciascun periodo di campionamento è’ 1/8,000 di secondo

![Sample](image)

1/8,000 sec Periodo di campionamento
Analog-to-Digital Conversion (ADC): Bandpass Filtering and Pulse Code Modulation (PCM)

A signal must be sampled at twice its highest frequency (4 kHz) for adequate quality. In PCM, there are 8,000 samples per second.
Campionamento per effettuare conversioni da Analogico-a-Digitale (ADC)

- **Codec Misura l’intensità dei segnali**
  - Converte il valore decimale 210 nel valore binario di 8-bit, 11010010

![Diagram](image.png)

<table>
<thead>
<tr>
<th>Valore di Intensità’ 210/255 (1010010)</th>
<th>Campione</th>
</tr>
</thead>
</table>

1/8,000 sec Periodo di campionamento
Campionamento per effettuare conversioni da Analogico-a-Digitale (ADC)

- **Codec**
  - 8,000 campioni/sec * 8 bit/campione = 64 kbps
  - Questo è il motivo per cui le linee telefoniche hanno la velocità di 64 kbps
    - Sviluppate per la voce digitalizzata
    - Spesso i fornitori (Carrier) “rubano” 8 kbps per segnali di supervisione, sui 56 kbps
Conversione Digitale-da-Analogica (DAC)

Segnale digitale in arrivo
Da uno Switch telefonico
(8,000 campioni/Sec)

00000100 00000011 00000111

1/8000 Secondo
(8 bits)

Segnale analogico
generato
Per la linea dell’abbonato

E’ di buona qualita’ se ci sono abbastanza campioni per secondo
Telefonia Cellulare

- Cellsites
Telefonia cellulare

1. Divide un Area
   In celle

2. Un cellulare
   Comunica
   Via Cellsites,
   Con il MTSO
   (Mobile Thelephon
    Switching Office)

3. To
   PSTN

Mobile Telephone
Switching Office

Cellsites

PSTN
**TELEFONIA CELLULARE**

1. **TECNOLOGIA TRADIZIONALE**
   - Si riutilizzano canali in celle non adiacenti.

2. **Usa il canale 47 nella cella A**

3. **Riutilizza il canale 47 in D e F**

**PSTN**

**Cellsite**
1. Usa il canale 47 in A, D, e F
2. In quali altre Celle Riutilizza il canale 47?
Telefonia cellulare

1. Handoff automatico tra Cellsites da O a P nel Momento in cui Il cellulare viaggia Tra le due celle
Handoffs vs Roaming

- Handoff
  - Per muoversi tra le celle di un singolo sistema telefonico cellulare
  - Telefonia cellulare
  - 802.11 wireless LANs

- Roaming
  - Muoversi tra sistemi
  - Telefonia cellulare: per utilizzare un telefono cellulare in un altra città
Tipologie di tecnologie cellulari

- GSM is the worldwide standard for cellular voice
  - Uses time division multiplexing (TDM)
  - Uses 200 kHz channels
  - Divides each second into many frame periods
  - Divides each frame into 8 slots
  - Gives same slot in each frame to a conversation

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Time Frame 1

Slot 1
Conversation A

Slot 2
Conversation B

……

Slot 8
Conversation H

Slot 1
Conversation A

Frame 2
Tipologie di tecnologie cellulari

- Cannot use the same channel in adjacent cells
  - So can only reuse a channel about every 7 cells
  - For example, suppose there are 50 cells
    - Channel can be reused $50 / 7$ times
    - This is 7 (not precise, so round things off)
    - So each channel can support 7 simultaneous customers in these 7 cells
Tipologie di tecnologie cellulari

- Code Division Multiple Access (CDMA)
  - Also used in the United States
  - A form of spread spectrum transmission
  - 1.25 MHz channels
  - Unlike traditional spread spectrum technology, multiple users can transmit simultaneously
  - Can support many users per channel

- Can use the same channel in adjacent cells
  - So can only reuse a channel in every cell
Voice over IP (VoIP)

VoIP carries telephone calls over LANs (for data link service) and the Internet.

With IP, there is no wasted capacity as there is with circuit switching. This reduces cost.
Voice over IP (VoIP)

Stations can be special IP telephones with IP functionality

Or a PC with multimedia hardware and VoIP software

IP phones need a codec to convert voice analog signals from the microphone into digital IP signals

PC with Multimedia Hardware and VoIP Software

IP Telephone with Codec and TCP/IP Functionality

Gateway

PSTN
Voice over IP (VoIP)

A media gateway connects a VoIP network to the PSTN.
Handles transport and signaling differences.

PC with Multimedia Hardware and VoIP Software

Internet

IP Telephone with Codec and TCP/IP Functionality

Media Gateway

PSTN
Protocolli VoIP

Signaling: SIP or H.323
(Call setup, breakdown, accounting, and other supervisory tasks)

Transport is the transmission of voice (carries codec data).

Signaling is call supervision.
VoIP transport packets use UDP at the transport layer. (There is no time for retransmissions to repair errors.) The receiver puts in fill sounds for lost packets.
The UDP header is followed by a Real Time Protocol (RTP) header, which contains a sequence number and timing information. Receiver uses timing information to smooth out sound playback.
Protocolli VoIP

Signaling: SIP or H.323
(Call setup, breakdown, accounting, and other supervisory tasks)

PC with Multimedia and VoIP Software

IP Telephone

Signaling is call supervision.
The H.323 signaling standard came first.
SIP is simpler and is beginning to dominate

SIP: Session Initiation Protocol
Video over IP

• The Other VoIP
  – It’s not just voice over IP
  – Video Telephones
  – Video Conferencing
    • Multiparty
    • Sometimes room-to-room
  – Video Downloads on Demand
Tipologie di collegamenti ad internet domestici

- Telephone Modems
- Asymmetric Digital Subscriber Line (ADSL)
- Cable Modem Service
- 3G Cellular Data Service
- WiMAX (802.16d and 802.16e)
- Broadband over Power Lines
- Fiber to the Home (FTTH)
Telephone modems convert digital computer signals to analog telephone signals.
ISP does not have a modem.

It has a digital leased line so can send at 56 kbps.
(There is no bandpass filtering on digital leased lines.)
Connessione telefonica via modem ad un ISP

Dial-up circuits connect the client with the ISP. 56 kbps downstream, 33.6 kbps upstream
Limiti dei modem telefonici

• Very low transmission speeds
  – Long delays in downloading webpages

• Subscriber cannot simultaneously use the telephone line for voice calls

• Still used by 30% to 40% of Internet users.
Modems modulate signals—convert binary (digital) computer data into an analog signal to travel over the PSTN.
In amplitude modulation, there are two amplitude (loudness levels)—one for 1 and one for 0.

1011 is loud-soft-loud-loud.
Asymmetric Digital Subscriber Line (ADSL)

ADSL uses the existing residential local loop technology. Inexpensive because there is no need to pull new wires, but 1-pair voice-grade UTP is not great for data.
Asymmetric Digital Subscriber Line (ADSL)

Subscriber needs an ADSL modem. Also needs a splitter for each telephone wall outlet.

Telephone carrier needs a digital subscriber line access multiplexer (DSLAM) to separate the two signals.
Asymmetric Digital Subscriber Line (ADSL)

Unlike telephone modems, ADSL service provides simultaneous voice and data transmission.

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**Diagram Details:**
- **PC and ADSL Modem:** Inside the Subscriber Premises.
- **Telephone:** Inside the Subscriber Premises.
- **Splitter:** Connects the PC and Telephone to ADSL Modem.
- **Downstream Data:** Up to 3 Mbps from DSLAM to Subscriber Premises.
- **Upstream Data:** Up to 512 kbps from Subscriber Premises to DSLAM.
- **Single Pair of Voice-Grade UTP Wires:** Connects Subscriber Premises to DSLAM.
- **DSLAM:** Telephone Company End Office Switch.
- **Data WAN:** Connected to DSLAM.
- **PSTN:** Connected to DSLAM.
Asymmetric Digital Subscriber Line (ADSL)

- **Subscriber Premises**
  - PC
  - ADSL Modem
  - Splitter
  - Telephone

- **Telephone Company End Office Switch**
  - DSLAM

- **WAN**

- **PSTN**

**Speed is asymmetric**
- Faster downstream than upstream
- Ideal for Web access
- Acceptable for e-mail

**Downstream Data**
- Up to 3 Mbps

**Upstream Data**
- Up to 512 kbps

**Single Pair of Voice-Grade UTP Wires**
Cable modem service brings high-speed optical fiber lines to the neighborhood.
In the neighborhood, thick coaxial cable brings service to households.

This bandwidth is shared by everyone in the neighborhood.

A thin coax line goes to each home’s cable modem.

Maximum download throughput is about 5 Mbps.
Cable Modem Service

Thick Coaxial Cable in Neighborhood (Shared Throughput)

Maximum download throughput is about 5 Mbps

Downstream speeds up to 5 Mbps. Upstream speeds up to about 1 Mbps.
ADSL versus Cable Modem Service

• Do Not Over-Stress the Importance of Sharing
  – Cable modem service usually is still faster than ADSL service
  – DSLAM sharing can slow ADSL service too

• The Bottom Line Today:
  – Cable modem service usually is faster
  – ADSL service usually is cheaper
    • ADSL offers more speed-price options

• Both are improving rapidly in terms of speed and (sometimes) price
Third-Generation (3G) Cellular Data Services

- Cellphone connects to computer via a cellphone modem or USB
3G technologies

- W-CDMA
  - UMTS
  - FOMA
- cdma2000 1x EVDO (Evolution-Data Optimized), 3x
- TD-SCDMA
- UMA
- EDGE - Enhanced Data rates for GSM Evolution
3G Technologies

- 1G and 2G Technologies:
  - GSM (Global System for Mobile communications);
  - CDMA (Code Division Multiple Access).
- 2.5G Technologies:
  - GPRS (General Packet Radio Service);
  - EDGE (Enhanced Data rates for GSM Evolution).
- 3G Technologies:
  - W-CDMA (UMTS).
  - HSDPA & MBMS.
  - cdma2000 1x EVDO (Evolution-Data Optimized)
  - 3x
Technologie 2.5G

- Advantages
  - Provides data rate comparable to 3G.
  - Work on the same spectrum allocated to 2G.
  - Provide an opportunity to players to compete who do not want to invest heavily in 3G.
  - GPRS & EDGE are the main drivers.
UMTS

- Universal Mobile Telecommunications System.
- UMTS system uses the same core network as the GPRS and uses entirely new radio interface UTRAN.
- UMTS Multiplexing
  - Wideband CDMA for air interface.
- Up/Downlink Frequency
  - Downlink: 2110 - 2170MHz.
- The UE is connected to Node-B over high speed Uu (up to 2 Mbps) Interface.
## Evoluzione delle Tecnologie Cellulari

<table>
<thead>
<tr>
<th>1G</th>
<th>2G</th>
<th>2G+</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDC</td>
<td>ARIB (WCDMA)</td>
<td>WCDMA</td>
<td>FDD/TDD</td>
</tr>
<tr>
<td>GSM</td>
<td>UTRA (WCDMA)</td>
<td>EDGE</td>
<td>TD-SCDMA</td>
</tr>
<tr>
<td>AMPS</td>
<td>IS-54</td>
<td>GPRS</td>
<td>IS-856 IxEV-DO</td>
</tr>
<tr>
<td></td>
<td>IS-136</td>
<td></td>
<td>CDMA2000 1xRTT</td>
</tr>
<tr>
<td></td>
<td>IS-95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 1. Evolution of cellular technologies.*

Evoluzione dei servizi dati nelle due principali famiglie

<table>
<thead>
<tr>
<th>10 kbps (far too slow)</th>
<th>GSM Family</th>
<th>CDMA Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional GSM (1 slot/frame)</td>
<td>Traditional CDMA</td>
<td></td>
</tr>
</tbody>
</table>

Telephone modem service speeds

<table>
<thead>
<tr>
<th>GSM Family</th>
<th>CDMA Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPRS (3 slots / frame)</td>
<td>1x</td>
</tr>
</tbody>
</table>

DSL / cable modem service speeds

<table>
<thead>
<tr>
<th>GSM Family</th>
<th>CDMA Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDGE (4 to 8 slots/frame)</td>
<td>1x EV-DO Rev. A will triple EV-DO speed</td>
</tr>
</tbody>
</table>

Future

<table>
<thead>
<tr>
<th>GSM Family</th>
<th>CDMA Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wideband CDMA</td>
<td>3X (uses three channels)</td>
</tr>
</tbody>
</table>
## Bit rate nelle diverse generazioni di servizi cellulari

<table>
<thead>
<tr>
<th>Generation</th>
<th>First</th>
<th>2nd</th>
<th>2.5G</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tecnologia</td>
<td>Analogica</td>
<td>Digitale</td>
<td>Digitale</td>
<td>Digitale</td>
</tr>
<tr>
<td>Data Transfer Rate</td>
<td>Data Transfer Is Difficult</td>
<td>10 kbps*</td>
<td>20 kbps to 144 kbps</td>
<td>144 kbps to 2 Mbps</td>
</tr>
<tr>
<td>Canali</td>
<td>~800</td>
<td>~800 + 2,500</td>
<td>~800 + 2,500</td>
<td>?</td>
</tr>
<tr>
<td>Celle/ canali Riutilizzo</td>
<td>Largo/ Medio</td>
<td>Piccolo/ Alto</td>
<td>basato Su 2G</td>
<td>Buono</td>
</tr>
</tbody>
</table>

*Sufficienti per Short Message Service (SMS) e wireless Web access Utilizzando il Wireless Access Protocol (WAP) o i-mode*
Attenzione! - Velocità 3G!

- ITU Speed Requirements for 3G
  - 2 Mbps per dispositivi fissi
  - 384 kbps per persone che camminano
  - 144 kbps per utenti in auto

- Tutto il resto è’ 2.5 G
  - Attenzione alcuni tra i produttori 2.5G dicono di essere 3G ma non forniscono le prestazioni adequate
4G Technologies

- ITU-R will release the requirements of 4G in 2008.
- Could go beyond the cell phone and provide mobile data services to consumer electronics & other devices.
- Example are sending of photos from camera to printer.
- All 4G technologies will be IP-based & packet-switched.
- Spectrally efficient modulation schemes have been developed but they wont work with existing 3G as it requires receivers to work with more complex technology Example 64 QAM.
- The 4G Technology would enable IP-based voice, data and streaming multimedia theoretically at the speed of 288 Mbps.
4G?

- LTE
- UMB
- WIMAX.
Residential Internet Access Services

• WiMax (802.16)
  – Wireless Internet access for metropolitan areas
  – Basic 802.16d standard: ADSL speeds to fixed locations
    • Will use dish antennas
    • Just reaching the market
  – 802.16e will extend the service to mobile users
    • Will use omni-directional antennas
WiMax (IEEE 802.16)

Worldwide operability for microwave access

- Up to 75 Mbps, up to 50 km reach

WiMax is a standards-based technology that provides high-speed wireless communication for metropolitan area networks (MANs). It can be used for "last mile" broadband connections to home or office, for creating wireless hotspots, and for providing high-speed enterprise connectivity for businesses.
Residential Internet Access Services

• Satellite Internet Access
  – Very expensive
  – Often needed to serve rural areas
Residential Internet Access Services

- Broadband over Power Lines
  - Broadband data from your electrical company
  - It already has transmission wires and access to residences and businesses
  - It modulates data signals over electrical power lines
  - It works, but has very limited availability
  - Especially promising for rural areas
Residential Internet Access Services

• Fiber to the Home (FTTH)
  – Carrier runs fiber to the home
  – Provides speeds of tens of megabits per second for high-speed video, etc.
    • Less if fiber only goes to the curb (FTTC)
    • Or to the neighborhood (FTTN)
  – Much faster than other residential internet access services
  – Could dominate residential (and business) Internet access in the future