**Transmission media**

- Electrical
  - Unshielded/shielded twisted pair
  - Coaxial cable
- Optical
  - Optical fiber
  - Laser
- Radio
  - Radio link (antennas) for point-to-point communication
  - Satellite
  - Cellular network
  - Wi-Fi

**Electrical media characteristics**

- Optimal media characterized by
  - Resistance, capacities and impedance
  - Traction resistance
  - Flexibility
- Electrical media characteristics depend on
  - Geometry
  - Number of cables and their distance
  - Material used for isolation
  - Shielding type

**Parameters for electrical media**

- Impedance (as a function of frequency)
- Signal propagation speed in the media (0.5c-0.7c for cables, 0.6c for fiber optics)
- For a given frequency, we report below
  - Attenuation (linearly increasing, in dB, with distance and with the square root of frequency)
  - Cross-Talk (noise introduced by adjacent cables – increases with the distance and then saturates)

**Twisted pair**

- Also simply named pair
- Used in the access segment of telephone networks
- Two copper conductors twisted to reduce electromagnetic interference using differential transmission techniques
- Low costs and ease of cabling
RJ45 connector (Ethernet)

Coaxial cable

• One central connector plus one or more covers to protect against electromagnetic interference
• Reduced interference thanks to its schielding properties (Faraday cage)
• Higher cost, complex cabling
• Transmission speed ~ hundreds of Mbit/s
• Two dominant types
  – Oscilloscope cable
  – TV cable (RG-59)

Fiber optic

• Very thin and flexible glass-based conductor composed by two parts (core and cladding) with different refraction index
• According to Snell law, the luminous ray (generated by a LED or by a laser) inserted in the fiber is restricted to propagate in the core if the incident angle is below a given threshold

Fiber optics

• Advantages
  – Immune to electromagnetic interference
  – High available bit rate (tens of Terabit/s)
  – Low attenuation (~0.1dB/km) see next slide
  – Relatively low cost and reduced size
• Disadvantages
  – Can be used only for point to point connections
  – Difficult to connect
  – Difficult to align transceivers
  – Not easy to lay
  – Suffers vibration

Fiber attenuation

UTP

• The Unshielded Twisted Pair is used in both telephone and data networks
• Seven categories of increasing transmission quality
• Category 7 with shielded twisted pair

Coaxial cable

• One central connector plus one or more covers to protect against electromagnetic interference
• Reduced interference thanks to its schielding properties (Faraday cage)
• Higher cost, complex cabling
• Transmission speed ~ hundreds of Mbit/s
• Two dominant types
  – Oscilloscope cable
  – TV cable (RG-59)
Submarine cables

- Amplifiers needed every 30/50 Km
- Each amplifier is backed up
- Need to transport also power supply over the cable
- Costly and time consuming maintenance

Radio (Ether)

- Environment may affect signal propagation
  - Interference for multiple paths created by reflected signal
  - Fading (quick signal amplitude variation due to the in phase combination of “copies” of the same signal)
  - Natural obstacles
    - Shadowing (slow signal amplitude variation)
  - Co-channel interference
  - May suffer for atmospheric phenomena (fog, rain, clouds)
  - Signal attenuation is a function of the squared distance

Transport and access networks

- Access network is the portion of the network including
  - Devices and transmission media that connect the user to the access node of the service provider network
- Transport network comprise
  - Devices and transmission media managed by one or more service providers connecting networks nodes
  - Metro and core segments

Plesiochronous Digital Hierarchy

- Plesiouchonous Digital Hierarchy (PDH) was the standard for digital transmission in telephone networks
- Time Division Multiplexing scheme
  - Defined to transfer 64kbit/s voice channels
  - Avoids Store-and-Forward
    - Strict synchronization between TX and RX is needed
    - Almost synchronous behaviour (plesio-synchronous)
  - Different standard in USA/Europe/Japan
  - Creates interface and interoperability complexity

T and E hierarchies

<table>
<thead>
<tr>
<th>Layer</th>
<th>America (T-)</th>
<th>Europe (E-)</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.064 Mb/s</td>
<td>0.064 Mb/s</td>
<td>0.064 Mb/s</td>
</tr>
<tr>
<td>1</td>
<td>1.544 Mb/s</td>
<td>2.048 Mb/s</td>
<td>1.544 Mb/s</td>
</tr>
<tr>
<td>2</td>
<td>6.312 Mb/s</td>
<td>8.488 Mb/s</td>
<td>6.312 Mb/s</td>
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<tr>
<td>3</td>
<td>44.736 Mb/s</td>
<td>34.368 Mb/s</td>
<td>32.064 Mb/s</td>
</tr>
<tr>
<td>4</td>
<td>274.176 Mb/s</td>
<td>139.264 Mb/s</td>
<td>97.928 Mb/s</td>
</tr>
</tbody>
</table>
**T-1 carrier system**

- 24 voice channels coded in a TDM PCM frame
- One bit per frame signaling channel
- T-1 carries speed is \( (24 \times 8 + 1) \times 8000 = 1.544 \text{Mbit/s} \)
- One sample per channel every 125μsec
- Frame multiplexing to increase transmission speed

**PDH: synchronization**

- Every node has its own clock
- No global (network wide) synchronization
- Only link by link synchronization
- Local clock drift
  - Synchronization errors
  - Bit are stuffed to compensate for clock drifts

**SONET/SDH hierarchy**

<table>
<thead>
<tr>
<th>OC level</th>
<th>STS level</th>
<th>SDH level</th>
<th>Mbit/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC-1</td>
<td>STS-1</td>
<td>STM-1</td>
<td>51.84</td>
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<tr>
<td>OC-3</td>
<td>STS-3</td>
<td>STM-1</td>
<td>155.52</td>
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<td>OC-12</td>
<td>STS-12</td>
<td>STM-4</td>
<td>622.08</td>
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<td>OC-24</td>
<td>STS-24</td>
<td>STM-8</td>
<td>1244.16</td>
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<tr>
<td>OC-48</td>
<td>STS-48</td>
<td>STM-16</td>
<td>2488.32</td>
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<tr>
<td>OC-192</td>
<td>STS-192</td>
<td>STM-64</td>
<td>9953.28</td>
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<tr>
<td>OC-768</td>
<td>STS-768</td>
<td>STM-256</td>
<td>39813.12</td>
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<tr>
<td>OC-3072</td>
<td>STS-3072</td>
<td>STM-1024</td>
<td>159252.48</td>
</tr>
</tbody>
</table>

**SONET framing**

- Synchronous transmission
  - Bit continuously sent
  - Only possible on a point to point link
- Flow multiplexing obtained via a TDM scheme
  - Designed to ease VLSI implementation
- Every frame includes a physical layer PCI
  - Synchronisation info
  - Service voice channel
  - Error/fault management
SONET: STS-1 frame

• 51.84 Mbit/s

Access network

Gruppo Reti TLC
nome.cognome@polito.it
http://www.telematica.polito.it/

Access networks

• Used to reach the users (last mile)
• Also named local loop
• Main technologies:
  – Plain Old Telephone Service (POTS)
  – Integrated Services Digital Network (ISDN)
  – Asymmetric Digital Subscriber Loop (ADSL)
  – cable-modem over Cable-TV infrastructures (CATV)
  – wireless: Local Multipoint Distribution Service (LMDS), Wi-MAX
  – Cellular networks (GPRS, UMTS)
  – PONs (Passive Optical Networks)

Radio access networks

• Wireless network
  – Access to the network is obtained through a terminal connected via a wireless link
    • An access point can be identified
  – No support for mobility
• Cellular network
  – A large geographical area is covered via adjacent (sometimes superimposed) cells
  – Small areas under the control of an antenna.
  – The mobile terminal can move from one cell to another cell without any communication interruption
  – Support for mobility (handover)

POTS: modem

• MODEM: MOdulator / DEModulator
• Used for connection over public telephone networks
• Transmission: adapt the digital signal to the analog signal suited to be sent over the twisted pair
• Reception: analog to digital conversion
• Make the digital signal suitable for analog transmission on the voice band

POTS: the modem

• DTE = user terminal
• DCE = modem (netwrk device)
**Modem standard**

- Analog modulation (Bell and CCITT)
  - V.21 300 b/s
  - V.22 1200 b/s (Bell 212A)
  - V.22 bis 2400, 1200 b/s
  - V.23 75/1200 b/s usato per Videotel
  - V.32 9600, 4800 b/s
  - V.32 bis 14400, 12000, 9600, 7200, 4800 b/s
  - V.34 33600, 31200, 28800, 26400, 24000, 21600, 19200, 16800, 14400, .... b/s

- Last modem generation reached (standard V.90)
  56 kb/s in reception and 33.6 kb/s in transmission

---

**ISDN: digital access to telephone network**

- ISDN: Integrated Services Digital Network
- Integrated network (almost all)
  - Voice and data transport over the same telephone infrastructure
- Digital access
  - From the user terminal
  - Classical telephones need A/D converters
- Connection oriented
  - Time based pricing
- Exploits plesiochronous transmission (TDM frame based scheme)
- Packet and circuit services
  - Telephone, fax, data transmission

---

**ISDN: motivations and standardization**

- ISDN main goals were
  - Extend TLC services beyond telephone
  - Uniform and standardized access
  - Unified digital interface for all services
- ISDN standardization process
  - From 1980 to 1988 within CCITT (ITU-T)
  - Standardized starting in the last ’70 s up to early ’90s
  - Commercially available in the ’80s (starting in the USA)

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**ISDN: transmission interface**

- Two types of channels:
  - B channel - Bearer - 64 kb/s
    - Voice, data, fax, low resolution video
  - D channel - Data - 16 kb/s (or 64 kb/s)
    - Signaling, Data, telecontrol
- An ISDN access can be obtained by freely combining the two channels
  - nB + mD (with arbitrary n and m)
- In practice, only few combinations of m and n are available

---

**ISDN architecture**

- Few standard interfaces where defined
  - BRI - Basic Rate Interface –
    - 2B + D (128kb/s)
  - PRI - Primary Rate Interface –
    - 30B + D (EU)
    - 23B + D (USA)
- Channels are separated in time (TDM)
ISDN: Basic Rate Interface
- Used for domestic access or in small offices
- Adaptors are used to keep compatibility with existing devices
- The digital signal is distributed among devices in user premises through the S-bus.

ISDN: Primary Rate Interface
- Used for business access
- Groups several B channels in a single H channel:
  - H0 - 6B - 384 kb/s
  - H11 - 24B - 1536 kb/s - equivalent to DS1
  - H12 - 30B - 1920 kb/s - equivalent to E1

ISDN: reference points and functional architecture
- TE1: Terminal equipment
- TE2: Terminal equipment
- TA: Terminal Adapter
- NT2: Network termination
- NT1: Network termination
- S-bus: Signals distribution

DSL access
- DSL (Digital Subscriber Line) is a family of technologies (also named xDSL)
  - Data transfer in the access segment at high speed
- Most widely deployed ADSL (Asymmetric DSL)
  - Higher bit rate in downstream, lower in upstream
    - Designed for client-server applications, web browsing
- Maximum ADSL bit rate
  - Highly dependent on the distance between the user and the first access node
  - From few Mbit/s to tens of Mbit/s
- Dedicated bit rate from the user to the first access node

ADSL: scenario
- Splitter filter
  - Separates voice signal from data
- Modem
  - Modulates/demodulates the signals to the proper frequency band

ADSL at user premises
- Voice line
- Data line
- Voice Only Twisted Pair
- Voice & Data Twisted Pair
- Data Only Twisted Pair
- Digital Subscriber Line Access Multiplexer (DSLAM)
- Public Switch
- Telephone
- Home
- Business
**ADSL in the network**

- Filter/modem POTS
  - separates voice and data flows
- DSLAM (DSL Access Multiplexer)
  - Receives several data flows from users and multiplex them on a single channel

**HFC access network**

- CATV (cable TC) are also named Hybrid Fiber Coax (HFC)
- Designed originally for unidirectional transmission

**HFC**

- Exploit the cable TV transmission medium (fiber in the network and coax in the last mile)
- Tree topology
- Bandwidth multiplied among all users
  - Shared bandwidth
- Data and TV signals exploits separate bandwidth (filter used at the receiving end in user premises)
  - 50-450 Mhz for TV, 6Mhz per channel
  - 450-750 Mhz for downstream data
  - 5-50 Mhz for upstream data (often not usable due to mono directional amplifiers, may rely on the telephone network)
- **Cable modem** used by users to decode data

**ADSL vs HFC**

- HFC bandwidth is shared among all users in a given area, ADSL bandwidth is dedicated (in the access link)
- HFC have security issues (shared medium)
- DSL exploits telephone twisted pairs, HFC requires Cable TV or laying ad hoc cables
- ADSL bit rate decreases with the distance, HFC bit rate is almost distance independent

**Accesso Radio Mobile**

- Well established technologies
  - Data access through cellular access: GPRS, UMTS
  - Hot Spot coverage: IEEE 802.11 (Wi-Fi)
- More recent technologies
  - IEEE802.16 (Wi-Max)

**Mobile radio access**

- Satellite networks
  - GEO (35000 km, 270ms, 3 satellites for global coverage), used for broadcast transmission and data services
  - MEO (15000 km, 50ms, >10 satellites), used for GPS not for telecom applications
  - LEO (<1000 km, 5ms, >50 satellites), satellite telephony with worldwide coverage. Low delays
    - Iridium, Globalstar
  - Stratospherich platform (under study)
Iridium

- 66 active satellites and 11 backup satellites
- Constellation of six polar planes
- Each plane has 11 satellites acting as switching nodes
- One satellite available on each earth region
- Original value $5 billion, sold at $25 millions

Globalstar

- 48 active satellites and 4 backup satellites
- Constellation with crossing multiplanes
- CDMA transmission