Why is signaling needed?

- To negotiate parameters of a session between two or more parties for a voice or voice+video call
  - to locate the other parties (one is the initiator)
  - to figure out whether the other party wishes to communicate

- In circuit networks to reserve, to keep track of all circuit resources for the call and to release the resources after the call

- In packet networks to reserve, keep track and release logical and physical resources for the session
  - Ports, holes in Firewalls, media processors, processes
  - To manage Quality of Service

Networking technology studies on 38.xxx courses

- Services, products, Service models, $,£,€
- Networks and network elements
  - routers
  - Exchanges (Class 5 and 4 switches)
  - Call Processing Servers
- Management, parametrization
- Architectures and network topologies
- Mechanisms
  - signaling
  - switching
  - routing
  - technologies
    - ATM, TCP/IP, 802.xx
    - queueing and scheduling
    - signal processing

Course (S38.3115) Requirements

- These slide handouts and Lecture Notes for about 40% of the course
  - Do not make the mistake of thinking that you can pass the exam just by scanning through these slides! These slides have been produced to accompany oral lectures. After the lecture – these slides give you a hint of what is covered in this course. You are expected to dig the real content on the subject from other sources, in particular RFCs, 3GPP specs ...
  - RFCs, a few Internet drafts and www.3gpp.org (for 3GPP specs)
  - Recommended course books:
    - Gonzalo Camarillo, M.A. Garcia-Martín, the 3G IP Multimedia Subsystem;
  - Recommended Reading
    - Two Diploma theses on IP based signaling.
    - Richard Nutterfield: Telecommunication Signalling;
  - Exercises
    - Mandatory: Mind mapping 2 first lectures + 50% of the rest.
    - SIP and ENUM exercise sessions
  - Grading
    - SIP and Exam Exercises max + 2 points.
    - Mandatory: Mind mapping + at least 1p on SIP or Exam ex.
    - Examination max: 30 points

Laboratory Course S38.3133 helps to learn theory as well

- It makes sense to do the signaling related Laboratory works in parallel with this course!
  - You get hands-on training on many aspects of signaling.
  - This helps to form a much more realistic mental framework for all the information presented in this course.
  - The compulsory starting lecture for S38.3133 Labworks will be held on xxday YY.01.2008 at 16.00-18.00 in lecture hall Sz.
Telecommunication networks - Introduction

- Types of telecom networks
- Equipment types in telecom networks
- Hierarchy in telecom networks
- Switching Systems
- 3G network
- Technology trend from CSN to IP networks

Communication networks can be divided into

- Switched Telephone Networks (PSTN, ISDN, GSM …)
  - CSN (Circuit Switched Networks)
- Computer (data) networks (x.25, Ethernet, GE, Internet, MPLS etc)
- Specialized or Professional Networks (PMR, Tetra …)
  - PMR - professional mobile radio

This course concentrates on telephony in circuit and packet networks.

Signaling is processed by Exchanges in circuit networks and by Signaling Servers in packet networks.

Exchanges or Switching Systems are used in Public Switched Telephone Networks, Integrated Services Digital Networks, Cellular Networks and Specialized Networks.

Telephone Networks growth takes place in Cellular

- Telephone networks can be divided into:
  - Fixed Networks (wired and wireless networks)
  - Mobile networks (cellular networks)
  - Public vs private (owned and operated by a corporation)
- Growth of subscriber base takes place in cellular networks. In Fixed networks we see very little new deployment while total new wired telephone subscriptions is declining.

Cost of deployment/subscriber

Wireless

Radio networks

Cost of deployment/subscriber

Growth of subscriber base takes place in cellular networks. In Fixed networks we see very little new deployment while total new wired telephone subscriptions is declining.

Subscriber Distance from exchange

Also: people seem to prefer to use a personal device with an intuitive user interface!

ARPU – Average Revenue Per Subscriber

- Operators talk about ARPU = Operator revenue per its number of subscribers.
  - Is earned mainly from subscribers and possibly other operators
- In developed countries ARPU for cellular telephony service varies 30€…80€
- In developing countries ARPU may be 5…10€ in cellular networks

This course describes the production machinery that is used to earn this ARPU.

Penetration of mobile technologies

World Mobile Subscribers

GSM share grows from 57% in 2000 till 81% in 2006. From that point WCDMA starts this growth.

Source: GSM Association/Wireless Intelligence
Computer (data) networks

- Data network used to be any overlay networks on top of PSTN resources built for data traffic. Recently purpose built data networks have become widespread (ADSL + IP, or FTTx + IP).
- Data networks are built using both permanent and switched connections.
- Protocols in modern Data Networks include Ethernet (802.1), MPLS and the Internet protocol.
- Current development: Metro Ethernet, + scaling Ethernet to larger networks + IP being pushed to network edge, interconnects and hosts.

Data networks are built using both permanent and switched connections. Protocols in modern Data Networks include Ethernet (802.1), MPLS and the Internet protocol.

Capacity requirements for Telephony

- Case Finland:
  - Nrof users: 4 million.
  - Nrof simultaneous users(?) 400 000
  - Each call uses 64 kbit/s.

Assume all calls are carried on one link: Capacity requirement is:

\[ 400\,000 \times 64\text{ kbit/s} \times 2 = 25.6\, \text{Gbit/s}. \]

In practise 70% of calls are local. It follows that largest needed link capacities are \( \leq 10\text{ Gbit/s} \) (two ways).

IP network capacities:
- Current FUNET backbone links are 2.5 Gbit/s and 10 Gbit/s links!
- FUNET is supposed to serve only University people (300 000+)

Specialized networks

- Specialized (professional) networks include:
  - Military networks
  - Emergency services networks
  - Police networks
  - Company/Utilities communication networks (Railways, Gas and Electricity companies)

- Widely varied technologies are used, some networks are overlay networks making use of PSTN/ISDN/Core transport network resources, some are built using dedicated resources only.
- In Finland digital VIRVE, based on TETRA standard.
- Many types of (trunking) analogue radio networks exist (PMR - professional mobile radio).

A typical Broadband (ADSL) home access

- 4 port Ethernet switch
- ADLS modem
- DSLAM
- GE or ATM over SDH

Future of Fixed Telephone Network

- In Finland Nrof wireline subscribers is declining
- Nrof Broadband subscribers (ADSL + CATV) is saturating
- Major operators have started offering Vdig to BB customers
  - BT in UK has started phasing PSTN out with an all-IP next generation network
  - service is still poorly productized
- It is a matter of pricing of GSM services to make PSTN/ISDN telephone service unattractive to users
  - Corporations with a lot of buying power get GSM services on wholesale prices much lower than individual GSM customers. Even the lower priced GSM subscribers are likely to be profitable – why else sell at such prices?

Recent phenomena is peer-to-peer VOIP!

Equipment types in telecommunication networks

- Based on type of usage, the equipment can be categorized into:
  - Terminal equipment or CPE - customer premises equipment
  - Exchanges (Switching Systems, Central Office in US)
  - Call Processing Servers (e.g. 3G IP Multimedia Subsystem servers)
  - Network Service Nodes (Value added Services, IN Services)
  - Cross-connect Equipment
  - Transmission Systems

In terms of end-to-end service Cross-Connect and transmission equipment work on OSI layers 1 and 2. Nevertheless, they contain (management) software which can be on any OSI layer. In this course we just assume that these provide the necessary bit pipes.
Key issues on each layer in the telecom network include

OSI

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSI</td>
<td>Service</td>
<td>Switching</td>
<td>Transmission</td>
</tr>
<tr>
<td>Nodes</td>
<td>Networks</td>
<td>Systems</td>
<td>Systems</td>
</tr>
<tr>
<td>Intelligent</td>
<td>Exchanges</td>
<td>PABXs</td>
<td>PDH, SDH, WDM, MDH, B-ISDN, radio infra, cross connects, GI</td>
</tr>
<tr>
<td>Node, Voice Mail, ...</td>
<td>Concentrators</td>
<td>Call Processing Servers</td>
<td>Cross-connects, GI, ...</td>
</tr>
<tr>
<td>Differentiation, fast service creation and deployment, new service architectures</td>
<td>Network design and dimensioning, routing/routing, interworking (signaling), charging, mobility</td>
<td>circuit and packet switching, break down in connectivity and session layers</td>
<td></td>
</tr>
<tr>
<td>Interoperability, billing</td>
<td>Services</td>
<td>Coverage, large capacity (multiplexing),</td>
<td>Efficient use of radio band, radio network planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Right of way, long life cycle, more efficient use of existing plant, move to FTTH</td>
<td>competition in the local loop/natural monopoly</td>
</tr>
</tbody>
</table>


Terminal Equipment

- Terminal Equipment are owned and managed by the subscriber. They are used to communicate with another similar device across the network or with a Service Node in the network.
- Examples of terminal equipment types:
  - Phones, mobile phones, SIP phones, other phones
  - Private (Automatic Branch Exchange (PBX) or PABX)
  - Modems
  - Routers, bridges, LAN switch, hub
  - Telemetric equipment
- Are connected to public networks using so-called subscriber criteria.
- PABXs can form corporate networks. Use their own signaling methods such as QSIG, DPNSS (UK), also many proprietary signaling systems...

A key assumption from the network point of view is whether TEs are Intelligent or not! This has a big impact on the choice of solutions on the switching or session layer in the network.

A megatrend in networks is that functionality/intelligence is moving from the network to the user terminals – a recent manifestation of this trend is peer-to-peer, e.g., Skype.

Private vs Public telephone networks

- Very wide set of services.
- Do not need to worry so much about charging but exists for company internal needs.
- Limited capacity nodes (PABXs) even centralized single computer controlled implementations are present.
- Not everything is duplicated.
- Wireline subscriber line requirements are eased (indoor use and line lengths).
- Covered by single vendor networks often proprietary features in signaling systems.
- Owned by a single corporation.
- Is connected to a public network with subscriber criteria.
- Quickly moving to IP PBX/VOIP
- Rather wide set of services (but less so than in private networks).
- Most important feature is charging: must be accurate.
- Large capacity of nodes. Distributed implementations are usual.
- Carrier grade quality: 2 min downtime/node/year.
- Must identify the subscriber accurately for charging and emergency calls.
- Gove by multi-vendor interworking requirements based on standards.
- Inter-Operator Interface – inter admin accounting of calls (Network to Network Interface). Moving to NGN = VOIP+COIP

When calls move to IP networks

- Connectivity and Session layers are separated
  - On connectivity layer we have transmission and packet routing
  - On Session layer we have signaling and session control including routing of sessions
- Call control and signaling server can reside anywhere in the IP network in relation to the caller and callee!
- Call Processing Servers inherit most of the Exchange functionality of Circuit networks
  - Session control (former call control)
  - Signaling
  - Charging (caller authentication etc)
- Switching functionality of Exchanges is replaced by the packet routing infrastructure

With static IP addresses peer-to-peer (e.g., Skype) is a possibility – no network based servers are needed, every user has the same application but signaling is proprietary!

Service Nodes are computers connected to the edge of the telecom network

- Intelligent Network SCP - Service Control Point
- Voice mail systems
- Intelligent announcement device (intelligent peripheral or SRP - special resource point)
- Voice response system

By using Service Nodes operators aim to differentiate their service and thus compete not only on price.

Operators are looking for implementations that are switching systems independent and have open software environment. Service Nodes may also control the set-up of calls.
The purpose of Digital Cross-Connects is rearrangement of circuit connections

- Work on OSI Layer 1 in the end-to-end view.
- Use cases: management of leased circuits, grooming of PCM connections (from partially filled PCMs to fully filled PCMs).
- A Digital Cross-Connect has a switching matrix and a lightweight control part that implements commands issued by a management system.
- The network management system is responsible for managing end-to-end circuit connections. The network management system issues commands to the cross connects to set up and tear down connections. The Cross connect may try to recover existing connections also in case of partial failures.

In business terms Communication Services can be broken down to Roles and Stakeholders

- Service Provider, SP + Service Nodes
- Subscriber + terminal equipment + PBXs
- Network Provider/ NP + transmission, cross-connects + exchanges

- This course analyses signaling which is the language used on the interfaces in the above figure.
- We will show that the real world signaling systems do not ideally match this business model.
- This has a significant impact on business boundaries: although NP business is considered dull and boring, NP is still the king! - I hope you will be able to argue on these matters after this course!

Categories of traffic and exchanges

- Upstream traffic goes up in the hierarchy. Downstream traffic goes down in the hierarchy.
- Transit traffic goes in the hierarchy.
- Origination of Exchange originating + Local Exchange + “Class 5 switch”
- Termination of Exchange terminating + Subscribers

Transmission systems are used to optimize the use of physical circuits and to build coverage

- Carry large bit streams across any distances.
- Are on OSI layer 1 in end-to-end view.
- Use optical or electronic components.
- E.g. PDH-systems ja SDH-systems
- An SDH-system needs more than one million source lines of software code is a software product!
- Cost of transmitting a bit/km is declining fast.
- Trend is from synchronous to asynchronous and optical (SDH -> 10G Ethernet + Optical)
- Exchanges and transmission systems need to be compatible: they need a common specification on what does a bit and a frame look like on a circuit connection. They need a common understanding on time (bit time, frame time).

Telecommunication network hierarchy

- ITU-T has specified a world wide hierarchy for the telecom network.
  - An end-to-end connection can have max 12 circuit connections out of which 4 can be international.
  - Addressing is hierarchical
- Exchange types
  - local exchange (Class 5 Switch in US)
  - originating/terminating exchange
  - transit exchange
  - long distance exchange
  - international exchange
- Traffic categories in exchanges
  - upstream, downstream
  - incoming, outgoing, internal, terminating, originating, transit

Definitions

- Originating traffic (syntyvä liikenne) is the traffic originating from subscribers of the Local exchange under scrutiny
- Terminating traffic (päättävä liikenne) is the traffic terminating in the local exchange under scrutiny
- Internal traffic (sisäliikenne) is the traffic from subscribers of a local exchange to other subscribers of the same exchange
- Transit traffic (katurakennelaites) comes in from one circuit connection and is sent out on another circuit connection to another exchange.
- Outgoing traffic (lähtevä liikenne) is the traffic an exchange sends out.
- Incoming traffic (tuleva liikenne) is the traffic and exchange must handle.
- Upstream traffic (nouseva liikenne) goes in the exchange hierarchy
- Downstream traffic (laskeva liikenne) goes down in the exchange hierarchy
**Service Paradigm in a Circuit Switched Network**

- A permanent capacity circuit is set up on demand and sold or “rented” to the customer. The network guarantees the quality of the circuit.
- After set-up customers can not disturb each other.
- The customer can use the transfer capacity as best he/she can or as poorly as he/she can.
- The customer pays based on used network resources (usage based charging, usually = time based charging).

Still: have look at your regular phone bill if you have a regular phone:
- there are lot of flat rate monthly charges!

**In the Connection Oriented Model connections are set up, and in the process the network translates global addresses to local**

```plaintext
SETUP Message [ global address of B ]
B - subscriber
ANSWER/CONNECT [ local identity of connection ]
A - subscriber
E.164 address
E.g. call state
Link by link Id
- PCM+ time-slot (PSTN…)
- logical channel (x.25)

In PSTN the transfer of control information for the purpose of setting up, tearing down and maintaining of calls is called signalling (UK) or signaling (US).

Without switching, a physical connection is needed from every user to every other user.
```

**IP network is connectionless: Caller and Callee must agree on parameters. Routing infra care of connectivity**

```plaintext
SETUP Message [ global address of B, ports ]
Callee
URL or E.164 address
ANSWER/CONNECT [ ports, coders ]
Callee URL or E.164 number
Proxy
Proxy
Proxy
Link by link Id
- connectivity layer issues,
- signaling does not need to worry about these

Big issues are end-to-end delay and Reliability (99,5%) instead of 99,999% of circuit networks!
```

**Connections can be set up also using network management commands**

- The PSTN was widely used for providing leased connections
- An alternative technology for leased connections e.g. for LAN-interconnection is Frame Relay transferring variable length frames or packets. A frame carries a local address. Now different types of Virtual networks (VPNs) are used for LAN interconnection (e.g. MPLS VPNs).
- Also ATM - Asynchronous Transfer Mode can be used for setting up semi-permanent virtual connections

  In this model, network nodes do not need to support (but may support) any form of signaling.

**Life cycles of Product Generations**

<table>
<thead>
<tr>
<th>Service Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity layer</td>
</tr>
<tr>
<td>“bit pipes”</td>
</tr>
<tr>
<td>Digital Exchange</td>
</tr>
<tr>
<td>Crossbar switch</td>
</tr>
<tr>
<td>Direct control</td>
</tr>
</tbody>
</table>

**New element in Next Generation Networks**

- Optical switches switch lightpaths, each lightpath can carry e.g. 2.5 or 10 Gbit's binary stream
- Routing of lightpaths is a network design or dimensioning matter
- Broadband switches and routers switch or route packets on gigabit speeds. The backplane may switch terabits.
- The key protocol is IP – Internet Protocol
- Application routers (session border controllers) are placed on technology and administrative boundaries
- Address and port translations on administrative boundaries (NAT’s have turned IP networks into A-subscriber networks)
- Firewall filtering on administrative boundaries
- Media translations between transmission and coding formats
- One can view these elements as successors of switching matrices that we have on Circuit Switching Systems.
- Servers are signaling servers and application servers. SS process signaling logic, ASs provide complicated services and may use many application level protocols (E.g. SIP, HTTP, etc…).
**Road map of Networking technology in Finland**

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>Automation of long distance telephony</td>
</tr>
<tr>
<td>1960</td>
<td>Digital transmission</td>
</tr>
<tr>
<td>1965</td>
<td>Digitalization of Exchanges</td>
</tr>
<tr>
<td>1970</td>
<td>ISDN</td>
</tr>
<tr>
<td>1975</td>
<td>Data networks</td>
</tr>
<tr>
<td>1980</td>
<td>WWW</td>
</tr>
<tr>
<td>1985</td>
<td>Arpanet --&gt; Internet technology</td>
</tr>
<tr>
<td>1990</td>
<td>Circuit switching</td>
</tr>
<tr>
<td>1995</td>
<td>Packet switching</td>
</tr>
<tr>
<td>2000</td>
<td>Media Gateway or Switching Fabric</td>
</tr>
</tbody>
</table>

**Summary of course scope (1)**

- **Control Part of an Exchange or Call Processing Server**
- **IP**
- **SIP**
- **IP or ISUP**
- **HLR**
- **R9**
- **HSS**
- **MTC**
- **ISUP**
- **MAP**
- **IP**
- **CCS7**
- **INAP**
- **SIP**
- **SIP or ISUP**
- **Diameter**
- **Megaco/MGCP/…**
- **SCCP**
- **circuit packets**

**Summary of Course scope (2): 3G**

- **Home Subscriber Server**
- **P-CSCF**
- **I-CSCF**
- **S-CSCF**
- **MMTE**
- **MMTE**
- **PCEF**
- **GGSN**

**Impact of IP Voice and IP Telephony**

- New signaling systems are needed but most of ISDN signaling properties will be reused or inherited.
- Exchanges turn into “Call Processing Servers”.
  - These will not have a switching fabric for voice signals.
  - The Switching Fabric is replaced by the router network.
  - In Peta- Giga- and Terabit routers a packet switching fabric is needed.
- Control plane (session layer) and the transport plane (connectivity layer) will be clearly separated:
  - Calls are first set up as logical sessions and only when it is known that the parties involved can and wish to communicate the transfer of voice packets starts.
  - Voice packets and signaling typically take quite different paths.
- Hybrid networks CS+PS with gateways.
  - Gateway can be in the phone, intranet, Internet.

NB: 3G also has a Circuit Switched subsystem that provides switched call services!