Signaling Protocols - 5 ECTS

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Rka - Raimo Kantola

Contents and goal of the course

- ✓ **Introduction**
- ✓ **Signaling in PSTN and ISDN**
- ✓ **Signaling in GSM**
- ✓ **Signaling over IP in wireline networks**
- ✓ **Signaling in 3G networks (Rel 5…)**
- ✓ **Inter-working of signaling systems**

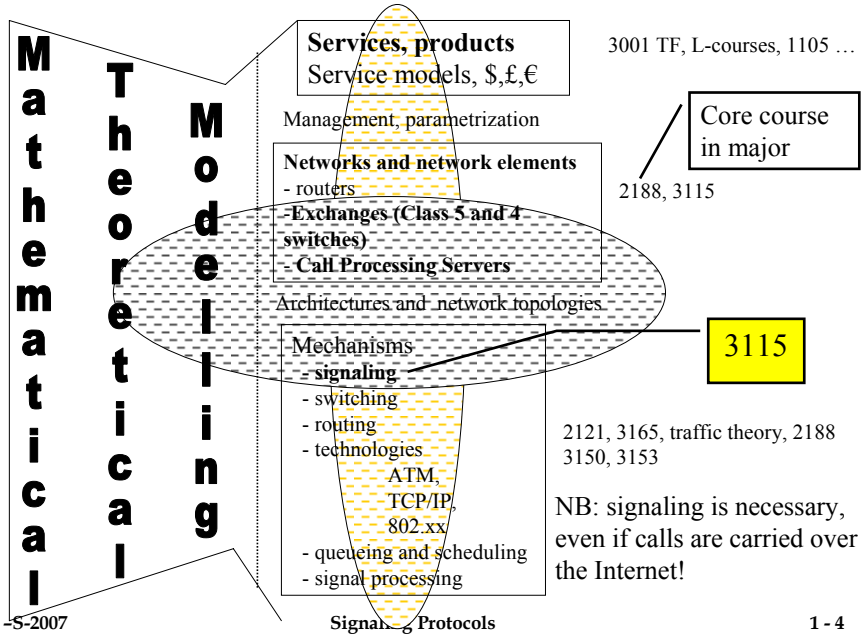
Signaling will be analyzed on a functional level. Focus is on understanding advantages and drawbacks of widespread solutions

Goal of the course: To understand signaling systems used in different networks.
→ to understand how networks interwork.
→ to understand the technology trend in signaling and call/session control
→ to understand how switching system functionality is inherited into a packet network environment

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**
  - ° **to agree technical parameters for communication**
- ✓ **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



Course (S38.3115) Requirements

- ✓ **These lecture notes**
- ✓ **Lectures are the best source for: Voip, TCAP, SCCP, MTP, MAP ...**
  - ◦ **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:**
  - ◦ **Richard Manterfield: Telecommunication Signalling;**
  - ◦ **Gonzalo Camarrillo, M.A. Garcia-Martin, the 3G IP Multimedia Subsystem;**
- ✓ **Recommended Reading**
  - ◦ **Two Diploma theses on IP based signaling.**
- ✓ **Exercises**
  - ◦ **Mandatory simple questions to be answered after each lecture on www – to make sure that you build some sort of a picture of the course content during the term.**
  - ◦ **SIP and ENUM exercise sessions**
- ✓ **Grading**
  - ◦ **SIP and Enum Exercises max + 2 points, QA sessions: 0 …3 points.**
  - ◦ **Mandatory: Answer Questions on the WWW + at least 1p on SIP or Enum ex.**
  - ◦ **Examination max 30 points**

Quizzes

- ✓ **We use a www based Questions and Answers tool. You have 7+ days to answer each Quiz.**
- ✓ **Each week about $Q_w = 4 \times 15$ questions are given requiring a simple answer of yes or no or an integer or an abbreviation.**
- ✓ **Each subset of questions matters, you must have an average of 85% right answers on the weekly set.**
- ✓ **You may earn 1 Quiz point by making no more than 2 mistakes on the set. Three mistakes or more gives zero Quiz points for the exam.**
- ✓ **You may fail no more than 1 Quiz to gain access to Exam. Those who failed at least 2 Quizzes, will have to give a seminar talk on the lecture material for the failed Quiz.**
- ✓ **Quiz points will be scaled so that max quiz points will give 3 points towards the exam mark (the exam itself gives max 30).**

NB: This tool has been created for the purpose of getting you to study during the term.
Experience shows that those who leave it until a few days before the exam, **will** fail the exam.

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 hand 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 Monday 22.01.2007 at 16.00-18.00 in lecture hall S2.**

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

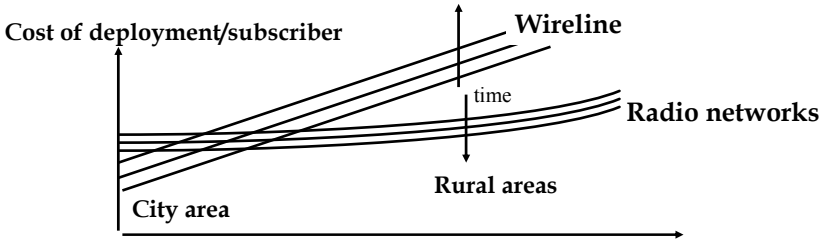
- ✓ **Switched Telephone Networks (PSTN, ISDN, GSM …)**
  - ◦ **CSN (Circuit Switched Networks)**
- ✓ **Computer (data) networks (x.25, Ethernet, GE, Internet, MPLS etc)**
- ✓ **Specialized or Professional Networks (PMR, Tetra …)**
  - ◦ **PMR - professional mobile radio**
- ✓ **This course concentrates 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 (wireline 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 nrof wireline telephone subscriptions is declining.**

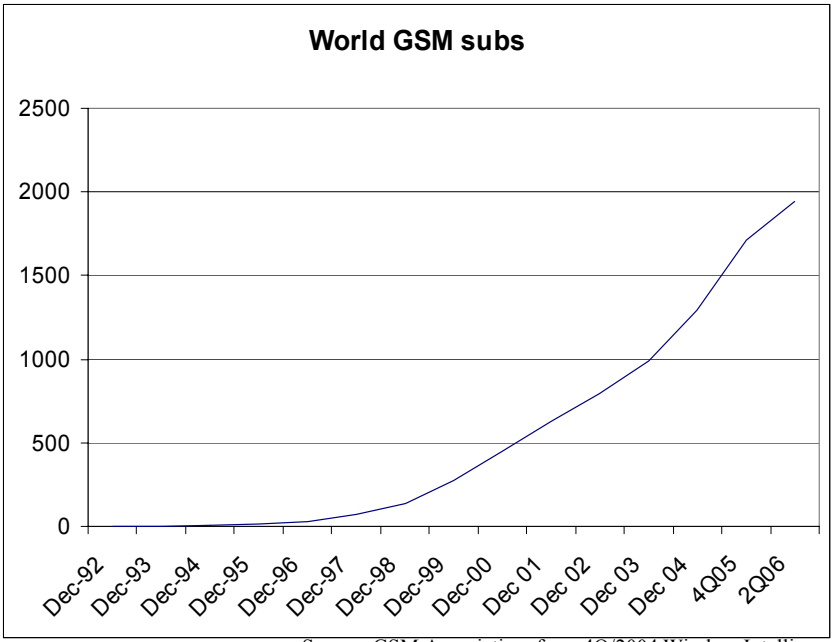


Also: people seem to prefer to use a personal device with an intuitive user i/f !

ARPU – Average Revenue Per Subscriber

- ✓ **Operators talk about ARPU = average monthly bill sent to their customer.**
- ✓ **In developed countries ARPU for cellular telephony service varies 30€….80€**
- ✓ **In developing countries ARPU may be 5…10€ in cellular networks**

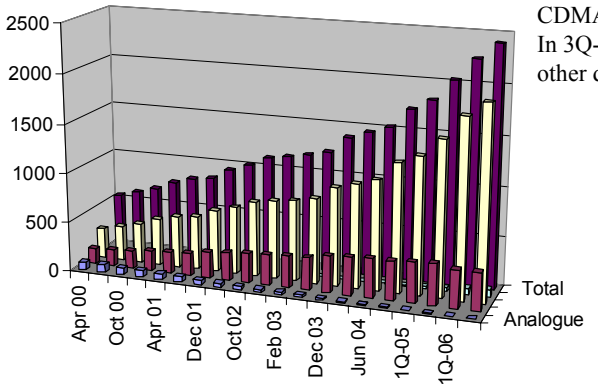
This course describes the production machinery that is used to earn this ARPU.



Source: GSM Association, from 4Q/2004 Wireless Intelligence.

World Wireless Subscribers

Total ≈ 2,5 Billion
GSM share about 82%
3GSM = WCDMA has 75M in 2Q/2006
CDMA share declining ->12%
In 3Q-05 to 1Q-06 first time other digital declined abs!

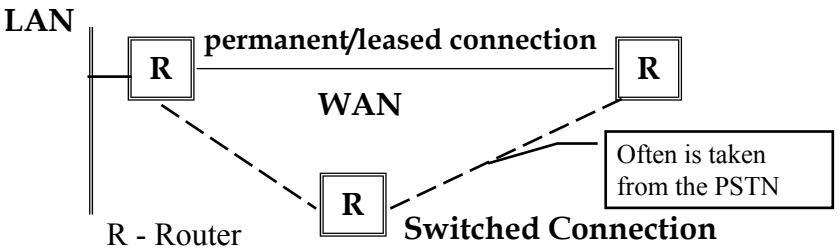


The remarkable thing in 2004-(late) …2006 is the growth of GSM from 1B to over 2B subs resulting in the increase of GSM share from 72% to 82%. GSM+3GSM share is 84% in 2Q-06

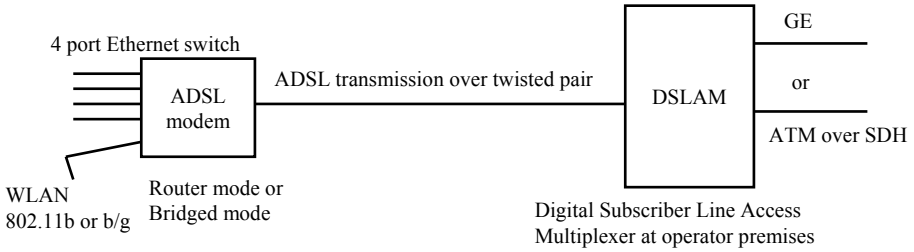
Source: GSM Association, from 4Q/2004 Wireless Intelligence.

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.**



A typical Broadband (ADSL) home access



- ✓ **ADSL →ADSL + →ADSL 2+ →VDSL etc**
- ✓ **In Japan Fiber to the Building (FTTB) has overtaken ADSL in new BB connections per month, provides > 50Mbit/s service to end-users**
- ✓ **Home wiring at least Cat5, twisted pair to homes are mostly much worse than Cat5.**

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 * 64kbit/s two ways = 25,6 Gbit/s.

In practise 70% of calls are local. It follows that largest needed link capacities are < 10 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+)

Future of Fixed Telephone Network

- ✓ **In Finland Nrof wireline subscribers is declining**
- ✓ **Nrof Broadband subscribers (ADSL + CaTV) is growing quickly**
- ✓ **Major operators have started offering VOIP 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 profitable.**

Recent phenomen is peer-to-peer VOIP!

Scenarios for telephony:
• All voice goes wireless
• Wireless + operator provided wireline VOIP + Free Communication Service Voip a'la SKYPE
• Wireless + VOIP as a feature of BB applications

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 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).**

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			
7	Service Nodes	Intelligent Network Nodes, Voice Mail, ...	• Differentiation, fast service creation and deployment, new service architectures • Interoperability, billing
3	**Switching Systems**	***Exchanges, Concentrators, PBXs, Call Processing Servers***	• Network design and dimensioning, routing/routeing, • **interworking (signaling),** charging, **mobility** • circuit and packet switching • **breakdown to connectivity and session layers**
2	Transmission Systems	PDH, SDH, WDM, xDSL, BSS/GSM, Radio links, Cross-connects, GE …	• Coverage, large capacity (multiplexing), • Efficient use of radio band, radio network planning
1	Circuit connections	Copper cable, cox, fiber, radio path, ...	• Right of way, long life cycle, more efficient use of existing plant, move to FTTx • competition in the local loop/natural monopoly

In Circuit networks signaling functionality resides in Switching Systems. In Packet networks (all IP, 3G) signaling resides on Session Layer.

Terminal Equipment

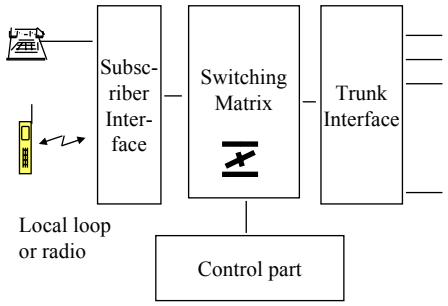
- ✓ **Terminal Equipment are owned and managed by the subscriber. They are used to communicate with another similar device across the network or with a Service Node in the network.**
- ✓ **Examples of terminal equipment types:**
  - **Phones, mobile phones, SIP phones, Office phones**
  - **Private (Automatic) Branch Exchange (PBX or PABX)**
  - **Modems**
  - **Router, bridge, 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)**
- ✓ **Governed 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 max 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.**
- ✓ **Governed 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**

Exchanges implement switched services



Software systems in the Control part:
- signaling and call control
- charging and statistics
- maintenance software (mgt of redundancy, Failovers etc.)

- ✓ **Carriers of network intelligence.**
- ✓ **Routeing of calls.**
- ✓ **Responsible for service level (grade of service)**
- ✓ **Giants of processor capacity and software ~ computers with many external connections and a lot of real-time parallel activity.**
- ✓ **Maintain signaling connections with subscribers, PABXs and with other public exchanges**
- ✓ **May have high initial cost. Avg. Cost per subscriber is not high.**
- ✓ **Vertically integrate all levels of functionality – are made by a single company.**
- ✓ **Examples: DX 200, EWSD, AXE, 5ESS …**
- ✓ **Capacities may be up-to several 100000 subscribers or e.g. 1M BHCA**
- ✓ **Capacity can be gracefully upgraded by adding more equipment**
- ✓ **BHCA = Busy Hour Call Attempts**
- ✓ **Many block in a an Exchange are replicated e.g following N+1 or 2N replication**

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 VOIP (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 system independent and have open software environment.
Service Nodes may also control the set-up of calls.

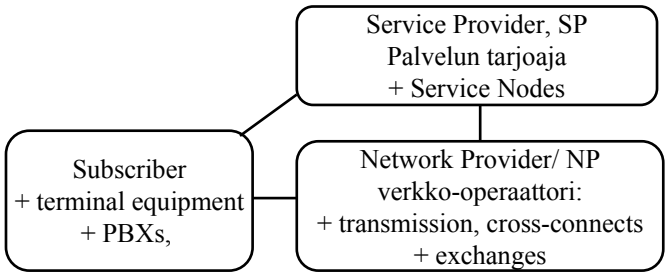
The purpose of Digital Cross-Connects is rearrangement of circuit connections

- ✓ **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 light-weight 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.**

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)*.**

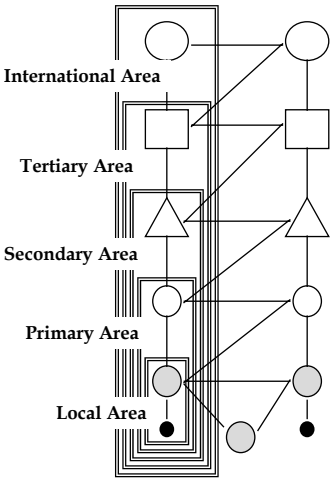
In business terms Communication Services can be broken down to Roles and Stakeholders



- 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!

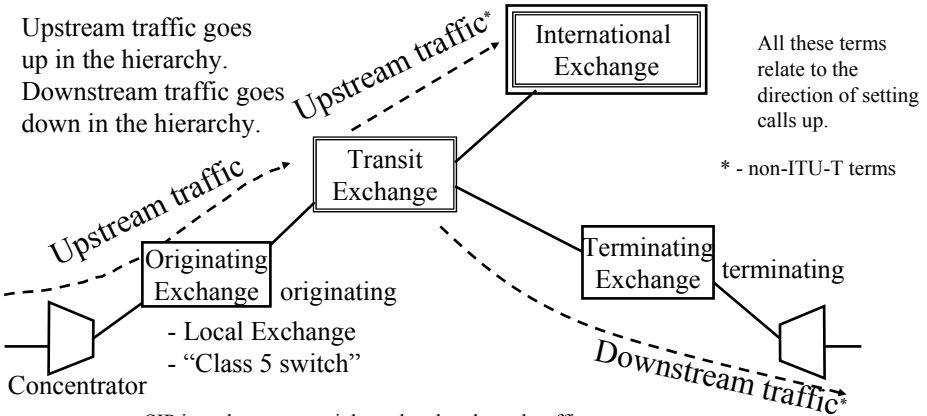
Telecommunication network hierarchy

- ✓ **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**



Categories of traffic and exchanges

Upstream traffic goes up in the hierarchy. Downstream traffic goes down in the hierarchy.



All these terms relate to the direction of setting calls up.

* - non-ITU-T terms

SIP introduces terms: inbound and outbound traffic.

In Addition: *outgoing* traffic , incoming traffic (from the point of view of an exchange)
Internal traffic: from one subscriber connection to another in a local exchange,
terminating traffic: traffic that is terminated to subscribers at a terminating exchange,
transit traffic = from one network connection to another.

Definitions

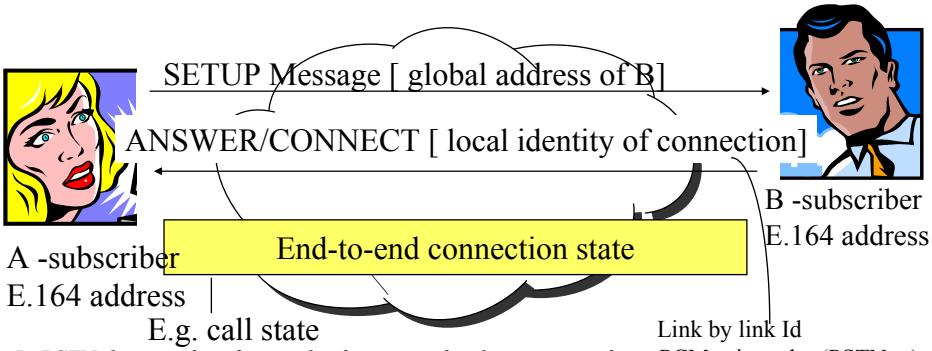
- ✓ ***Originating traffic*** **(syntyvä liikenne) is the traffic originating from subscribers of the Local exchange under scrutiny**
- ✓ ***Terminating traffic*** **(päättyvä liikenne) is the traffic terminating in the local exchange under scrutiny**
- ✓ **Internal traffic (sisäliikenne) is the traffic from subscribers of a local exchange to other subscribers of the same exchange**
- ✓ **Transit traffic (kauttakulkeva liikenne) 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 up 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

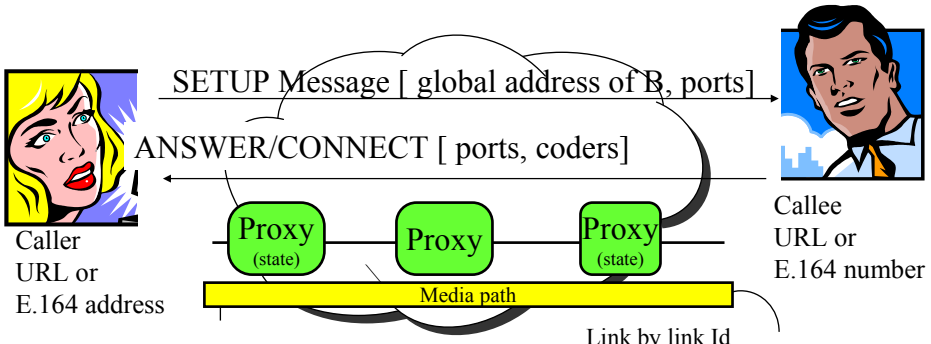


In PSTN the transfer of control information for the purpose of setting up, tearing down and maintaining of calls is called signalling (UK) or signaling (US).

Link by link Id
- PCM+ time-slot (PSTN…)
- logical channel (x.25)
- ...

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 takes care of connectivity



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

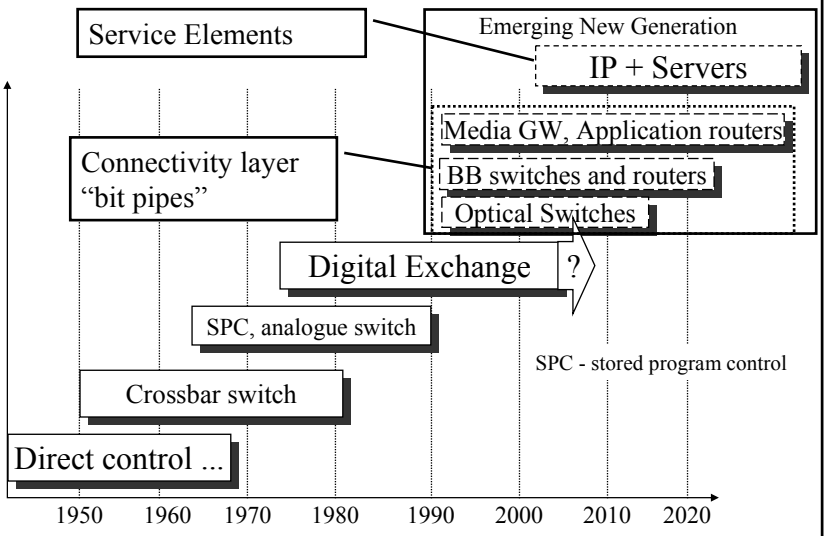
Link by link Id
- connectivity layer issues,
- signaling does not need to worry about these

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.

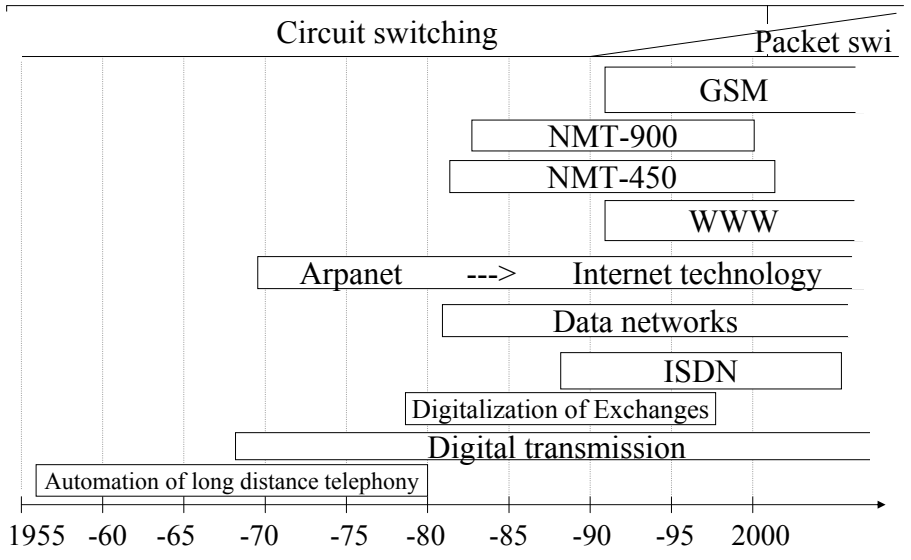
Life cycles of Product Generations



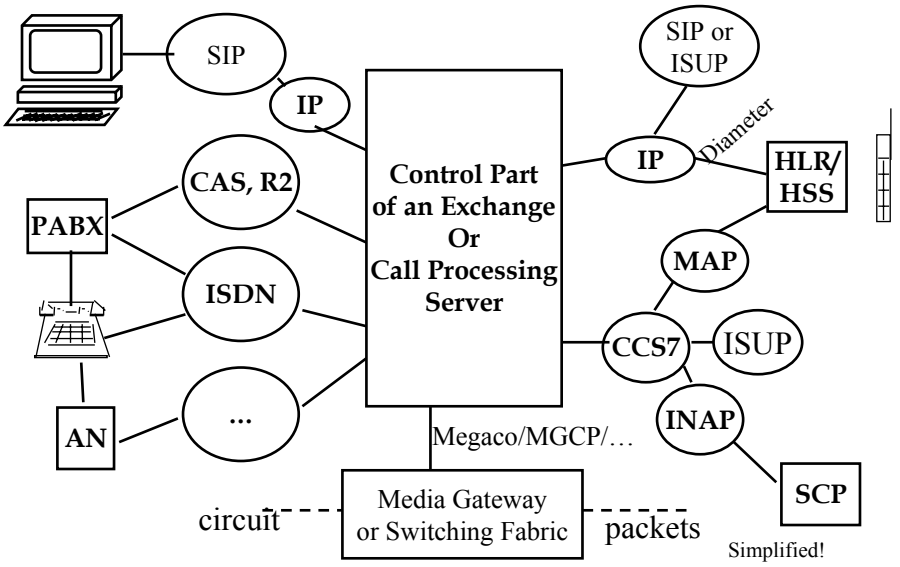
New element in Next Generation Networks

- ✓ **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 dimentioning 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 admin boundaries (NAT's have turned IP networks into A-subscriber networks)**
  - ° **Firewall filtering on admin 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…)**

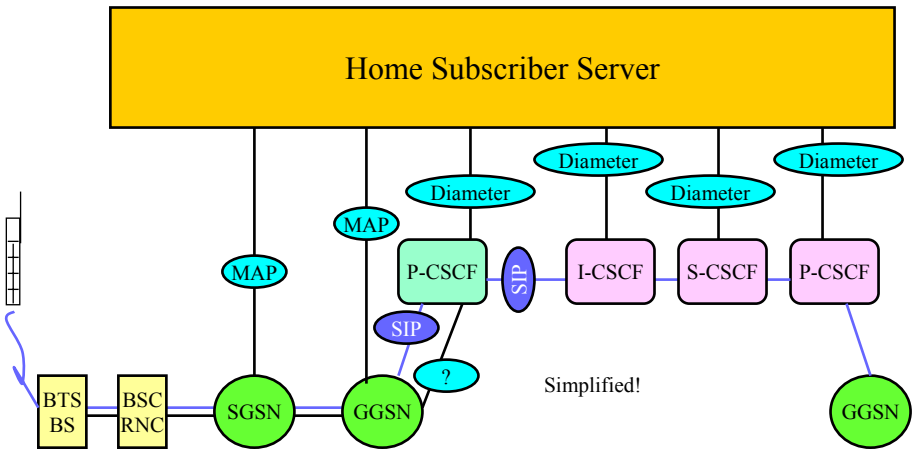
Road map of Networking technology in Finland



Summary of course scope (1)



Summary of Course scope (2): 3G



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

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**