Common Channel Signaling Nr 7 (CCS7)

CCS7 is a message based, multi-layer network to network signaling system designed for fully digital exchanges.

- Limitation of analogue signaling systems
- Basic definitions for CCS7
- CCS7 Requirements
- Functional Structure
- MTP and SCCP
- User Parts
- Strengths and weaknesses
Summary of course scope

Control Part of an Exchange Or Call Processing Server

- CAS, R2
- ISDN
- ...
Limitations of Analogue signaling

› Limited set of signals --> limited set of services
› Always bound to a voice path --> architectural limitation.
› Difficult to change anything in an established call because registers have been released and voice channel is reserved for voice.
› Slow --> uneconomical use of network resources.
› MF requires special equipment - Only later general purpose DSPs became powerful and cost efficient enough.

‡ Vs. HDLC on silicon --> processing hdlc frames and messages is simple and efficient on any computer.
Does CCS7 remove all limitations?

- Digital messages --> unlimited signal set: e.g. $2^{100}$ different signals can easily be devised.
- Common signaling channel for many voice channels (out-of-band) --> signaling is not, in principle, bound to calls nor voice/information channels. Signaling can continue during the call.
- Message round-trip delay on a 64kbit/s channel is $\approx 50$ ms. --> post dialling delay (delay from the dialing of the last digit until the ringing tone) approaches zero.
- Makes use of HDLC -protocol framing and principles.
Basis of CCS7 is the signaling network - a special kind of data network.

Example: In Finnish CCS7 no specialized STP -nodes were originally deployed. STP functions were integrated in exchanges. E.g in USA, specialized STP-nodes are commonplace. A use case of STPs is for concentrating IN signaling traffic towards IN nodes that provide Nationwide services.
**Key definitions for CCS7**

*Signaling Point* is a logical entity, e.g. in an exchange, there can be one or more SPs. In one CCS7 signaling network an exchange will, however, have only one *Signaling Point Code*.

An exchange or any other CCS7 node that resides on a border of two CSS7 networks will have two or more signaling point codes.
Key concepts in Message Transfer Part (MTP) are

- Signalling link – one 64 kbit/s point-to-point channel
- Signalling link set (SLS) – set of sig. links with the same endpoints
- Signalling Route – a sequence of sign link sets between two SPs.
- Signalling Route set – all sign. Routes connecting two SPs.
Signaling connection can be either direct or indirect (through STP nodes)

In non-associated mode, voice is routed on a different path than signaling →
There must be direct voice circuits between SP A and SP B in the Fig. Otherwise, how could telephony routing work? It follows that non-associated mode is more relevant for non-call associated signaling such as location updates or IN services.
Between exchanges, normally calls are routed hop by hop

✓ On an end to end path, through several intermediate exchanges, call setup progresses hop-by-hop, i.e. each exchange processes call setup signaling and performs call routing (associated mode of signaling in CCS7).

✓ For call related signaling, CCS7 uses ISUP. ISUP messages are mapped (1-to-1) to voice circuits by Circuit Identification Code (CIC) in each message. I.e. each control plane signaling and call control FSM is tied to the corresponding voice circuit 1-to-1.

✓ Some of the information fields in signaling messages may just need to be copied blindly (= forwarded) from incoming signaling to outgoing signaling. Still this operation is done by the call control FSM running on a call processing computer in each intermediate exchange.
**CCS7 reliability is built by software**

- Speed: post dial delay (until ringing tone) \( \leq 2.2\)s.
- MTP:
  - unavailability of signaling route set \( \leq 10 \) min/annum
  - share of undetected faulty signaling messages: \( \leq 10^{-10} \)
  - loss probability of signaling messages \( \leq 10^{-7} \)
  - probability of reordering or replication of signaling messages \( \leq 10^{-10} \)

- Expected quality of of the underlying transmission network:
  - Long term bit error rate \( \leq 10^{-6} \)
  - Medium term bit error rate \( \leq 10^{-4} \)

- Using software means reliability is increased by several 10-folds!!
  ( from \( 10^{-4} \) in bits to \( 10^{-7} \) in messages improvement is 100 000 times)
Why is it a good idea to require high availability performance from signaling?

R_1  R_2  R_3  R_4

Signaling  Voice path  Call unrelated operator infra  Terminal

✓ All parts of the above sequential reliability model need to work for an operator to earn money on a voice call. The weakest link determines the availability perceived by the end user.

✓ By eliminating loss of revenue due to signaling and call control failures, operators make good of the investment on the expensive transmission path for voice and recover the huge fixed cost that they must carry.
In previous setting the total reliability is

\[ R = R_1 \times R_2 \times R_3 \times R_4 \]

Example

\[ R_1 = 0.999, \ R_2 = 0.998, \ R_3 = 0.997, \ R_4 = 0.92 \]

\[ R = 0.999 \times 0.998 \times 0.997 \times 0.92 = 0.914 \]

The weakest link determines the total reliability

A term that is close to 1 has no impact.
Key requirements for CCS7 were reliability and performance

- **Why Reliability**
  - The analogue transmission plant in place at the time of design
  - Reliability → lower OPEX, less manual operation
  - In line with the main advantage of digital exchanges as compared to analogue: less manual operation

- **Why performance**
  - Fast operation → efficient use of transmission resources
  - Better perception of quality of service by the end user

- **Why not Flexibility**
  - Monopoly operators ruled the specification, the art of software design was not that well understood at the time
  - Limited processing power at the time
Use of PCM time slots in the Finnish CCS7 network

Voice channels

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Signaling link

PCM-alarms, frame alignment

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Principal components in CCS7

- **INAP** - IN Application part
- **CAP** - CAMEL Application part
- **CAMEL** - Customized Applications for Mobile Enhanced Logic = “INAP” extension in GSM
- **TUP** - Telephony User Part
- **ISUP** - ISDN User Part
- **SCCP** - Signaling Connection Control Part
- **TCAP** - Transaction Capabilities Application Part
- **MAP** - Mobile Application Part
- **MTP** - Message Transfer Part

**Diagram:**
- **Call setup and release**
- **Transport of signaling messages**
Structure of CCS7

- INAP
- CAP
- MAP
- BSSAP
- ISUP
- TUP
- MUP
- HUP

Levels:
- Level 1 - Signaling data link (MTP1)
- Level 2 - Signaling link (MTP2)
- Level 3 - Signaling network (MTP3)

7 Application services

6 Presentation
5 Session
4 Transport
3 Network
2 Link
1 Physical

INAP → GSM → ISDN → PSTN → NMT

TC

SCCP
Message transfer part, MTP, is the basis of CCS7

Level 4... Level 3 Level 2 Level 1

MTP - message transfer part

Signaling network functions
- Signaling message handling
  - Message distribution
  - Message discrimination
  - Message routing

Management of signaling network
- Signaling traffic management
- Routing management
- Link management

Signaling data link
- Signaling link functions
  - Switching functions
  - Transmission channel

Testing and maintenance functions

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MTP has three message types

OP

MSU - Message Signal Unit

LSSU - Link State Signal Unit

FISU - Fill-in Signal Unit

DP

MSU - carries all payload of upper layers
LSSU - MTP level messaging between neighboring SPs
FISU - when there is nothing else to send! Originally made implementation difficult - short FISUs -> when there is no useful information to send the signaling terminal had the peak load! → fast fault detection.
Message Signaling Unit structure is

F - Flag (delimiter -01111110)
BSN - Backward sequence number
BIB - Backward indicator bit
FSN - Forward sequence number
FIB - Forward indicator bit

BSN and FSN have link local significance
Service Information Octet (SIO) defines the target application

<table>
<thead>
<tr>
<th>DCBA</th>
<th>DCBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-service field, SSF</td>
<td>Service indicator, SI</td>
</tr>
</tbody>
</table>

Direction of transmission

Addressing to an MTP function or a User Part or an Application Part

Network indicator: National NA0, 1 or International IN0, 1-network.

A CCS7 network is not global. The global signaling network is formed by interconnecting CCS7 networks owned by different operators.
**MTP Route Label has three fields**

SLS - Signalling link selection (for link load sharing)
DPC - destination point code
OPC - originating point code

The shown lengths are acc to International(and Finnish) specification, in ANSI specs OPC/DPC lengths are 24 bits!
MTP service to upper layers is connectionless

✓ The term “signaling connection” means a path on which MTP sends messages, there is no dynamic connection state that needs to be dynamically “set up” or released for a telephone call; rather the “connection” is permanent (from restart to restart)

✓ Routing is static – i.e. MTP forms a network that is similar to an IP network except that
  › There are no dynamic routing protocols like in IP networks
  › Routing is based on 14 bit signaling point codes, not IP addresses
  › MTP has enhanced reliability features such as:
    Ŷ Buffering, resending over other channel (channel failover), fast detection of failures, removal of duplicates etc.
MTP adds reliability

✓ MTP supports a continuous flow (L2 frames are sent back-to-back) of messages, each message has a checksum

✓ If a PCM connection with a signaling link fails,
  › MTP will quickly detect the failure due to detecting a break in the continuous flow of messages
  › It will automatically, switch the traffic to another signaling link on another PCM line
  › It will go back to copies of the unacknowledged MTP messages it has sent,
  › It will resend the messages

✓ The receiver will detect duplicate and lost messages due to message numbering and

✓ The UP or AP will see no difference
  › All these recovery actions have high real time performance requirements
Fourth level (here ISUP) is needed, when MTP-signal message routing is not enough

- Messages/calls through an international signaling point
- Calls across an operator boundary
- Intelligent Network calls
- In general, when the OP does not know the location of the called party

4th level = SCCP or a User Part.

If signaling is call related – UP, if not SCCP. If UP usually no SCCP is needed.
Terms

✓ BSSAP – Base Station Subsystem Application Part
  › used for BSS to MSC signaling in GSM
  › MSC – Mobile Switching Center
  › Handover support and location updates are important features of BSSAP
  › BSSAP includes DTAP data transfer application part

✓ ISUP – ISDN user part

✓ SCCP – Signaling Connection Control Part
  › used for call unrelated signaling

✓ TCAP – Transaction Capabilities Application Part
  › provides generic application services for transactions such as IN service logic requests and responses

✓ INAP – Intelligent Network Application Part
  › the protocol that exchanges (containing SSF service switching functions) use to access IN service logic in SCFs, Service Control Functions and SCFs use to access data in Service Data Functions (SDF)
An example allocation of MTP-functions in a Switching system (DX 200)

Distributed part
- preprocessors
- Main processors
- Handling of messages
- User parts
- Level 2
  - Signaling terminal

Centralized and replicated
- Management functions

Internal messaging

PCM x/ tsl 1
Signaling links

Switch Fabric
Summary of MTP main functions

• Switching functions: - reconfiguration of the signaling network

• LEVEL 2: Signaling channel functions: - LAPB / cmp. HDLC
  • frame alignment flags (delimiters) acc to HDLC principles
  • checksum, retransmission of message units, supervision of message ordering, acknowledgements, link fault detection and recovery

LEVEL 3:
• Load sharing among signaling links
• STP and distribution to User Parts
• Routing is based on 14-bit (ETSI) signaling point codes.

• Management of signaling traffic:
  • link switchover - messages are not lost!
  • (Original) link restoration
  • forced re-routing
  • controlled re-routing
Load sharing has an impact on signal routing

To preserve the order of signals, higher levels set the SLS value so that the route remains the same e.g. for all signal messages of a single call.
Flow of signaling messages in case of International GSM location update

NA0 - used National CCS7 network
IN0 - used International CCS7 network

Signaling Point Codes are unique only in one signaling network!!
In this example, SCCP would be used to carry MAP/TCAP messages
Explanations to location update example

✓ Location update may be the most obvious use case of non-call related signaling.

✓ Location update signaling uses MAP (we will discuss MAP later in detail) – adding location update to ISUP would be very cumbersome due ISUP FSM identification principle that is based on CIC (circuit id code)

✓ Because MTP uses point codes unique for a network, in the example, we need to send MAP messages across several addressing spaces (in terms of point codes), therefore, between MAP and MTP, an additional network service is needed. This is called SCCP – signaling connection control part.
  › SCCP in a boundary node receives a message from one SS7 network (e.g SSF = NA0) and sends it to another SS7 network (e.g. SSF=IN0)
  › In order to do that SCCP uses a globally significant address called Global Title (in practice a kind of telephone number allocated to some network node)
SCCP - Signalling Connection Control
Part expands MTP networking services

- MTP uses 14-bit signaling point codes as addresses - this is not enough in the global network.
- No relationship to voice channels: SCCP can be used to signal events that are unrelated to calls (such as location updates in mobile networks).
- SCCP brings Global Title - an extension to the addressing mechanisms provided by the MTP.
Global Title in SCCP supports global messaging over the CCS7 network

Calling and called party in SCCP

<table>
<thead>
<tr>
<th>National use</th>
<th>RI - Routing indicator</th>
<th>GT Indicator</th>
<th>SSN ind</th>
<th>PCode ind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signing Point Code</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub System Number (SSN)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global title translation type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numbering plan Coding method</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Address type</td>
<td></td>
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</tr>
<tr>
<td>Address information</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

SSN (cmp. Port Numbers in TCP/IP)
1 - SCCP management
2 - TUP
3 - ISUP
4 - OMAP - Operation and Maintenance AP
5 - MAP - Mobile AP
6 - MAP/HLR
7 - MAP/VLR
8 - MAP/MSC
9 - MAP/EIR - Equipment Id reg
10 - MAP/AuC
11 - ISUP/SS ISUP supplementary services
12...247, 249...252 reserved
248 - MUP (NMT Mobile UP)
253 - OMC - Operation and Maintenance Center
254 - BSSAP - BSS Applic. part
**Address Information in GT of SCCP can be a telephone number or a subscriber identity**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Format</th>
<th>Example 1</th>
<th>Example 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.212: IMSI:</td>
<td>MCC  MNC  MSIN</td>
<td>E.g. 244 05 87654321</td>
<td></td>
</tr>
<tr>
<td>E.164: MISDN:</td>
<td>CC  NDC  SN</td>
<td>E.g. 358 40 540 3127</td>
<td></td>
</tr>
<tr>
<td>E.214: Hybrid:</td>
<td>CC  NDC  MSIN</td>
<td>E.g. 358 40 87654321</td>
<td></td>
</tr>
</tbody>
</table>

IMSI - International Mobile Subscriber Identity  
MCC - Mobile Country Code  
MNC - Mobile Network Code  
MSIN - Mobile Subscriber Identity Number  
CC - Country Code  
NDC - National Destination Code  
SN - Subscriber Number
A use case of addressing

Signaling Point A
Signaling point code = 7654
GT = 358405152

Signaling Point B
Signaling point code = 2456
GT = 3584065523

VLR

MSC

SCCP

MTP

HLR

MAP
TCAP
SSN = 7

MAP
TCAP
SSN = 8

MAP
TCAP
SSN = 6

MAP
TCAP
SSN = 12

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SCCP provides four service classes

SCCP service classes

Connection-less services

1. Connection-less Basic Service

2. Order preserving connection-less service
cmp. IP

Connection Oriented Services

3. Connection Oriented basic service

4. Flow controlled connection oriented service

√ Connection Oriented message transfer

Only classes 1 ...3 are in use.

› on demand connections as a service to UPs
› permanent connections with management commands
CCS7 and PABXs

- Signaling Point codes are NOT allocated to private network devices such as PABXs and CCS7 does not support connecting a PABX to the public network – for this purpose e.g. DSS1 PRI can be used.

- If a PABX network supports a large set of business services, rich information in the private signaling system can not be mapped to any of the User parts in CCS7 and information is lost.

- If an ISDN exchange needs to be a node in a private network with private signaling extensions and providing the same set of services as the private network, then the ISDN exchange needs to support the private network signaling as well (e.g. QSIG).
Global Title addressing vs. MSISDN

✓ GT addresses are allocated for Network elements such as MSC or HLR.
  › Number portability will not cause difficulties for GT addressing since GT numbers are not ported from network to network like user allocated MSISDN numbers can be.
  › When e.g. a user’s MSISDN appears in a call related ISUP message it is carried in a Called_party or some such information element not Global Title.
  › A user’s MSISDN number can point to HLR serving that user and maintaining information about the location of the user
**SCCP use cases**

✓ Use cases for SCCP are not directly call related:

› MAP: location update, HLR to VLR subscriber profile updates, routing information requests from GMSC to HLR etc

› INAP: call service logic requests from an exchange (Service Switching Function - SSF) to an IN node (SCF – Service Control Function). During such signaling, voice channel control stays in the SSF. The SCF may be remote, even in a different network cmp to SSF (will come back to IN on lecture 7).

› CAP: similar to INAP. SCF resides in most cases in the home network.

✓ If a call requires global addressing, then globally unique E.164 telephone numbers are used in ISUP, no SCCP is in practise needed.
User Parts (Ups) and APs

For call setup, release and supplementary services!

✓ TUP - Telephony User Part - oldest and simples
  › National variants!
  › Messages bound to voice channels with Circuit Identification Code (CIC) in every message

✓ ISUP - ISDN User Part
  › supports wire-line ISDN calls and e.g. GSM calls
  › -speech, 64kbit/s, multi-channel: 128, 384, 1536, 1920 kbit/s services

✓ MAP - Mobile Application part -
  › used in GSM e.g. for HLR - MSC communication
  › provides mobility management and other non-call related services
### CCS7

#### Strengths

- Large nrof of signals
- Message based -> native for digital exchanges and computers
- Out-of-band --> signaling can continue for the duration of the call and even independent of any calls
- Reliable
- MAP - provides mobility management

#### Weaknesses

- Complicated to implement
- Heritage of a closed market
- Service dependent - new services require new fields into signaling messages and thus software upgrades in exchanges
- Requires new features to be secure in a competitive multi-operator environment

* At its best overlying a rather unreliable base network, reliability has been enhanced by software functions.
* Carries the legacy of narrowband PCM 64kbit/s channels
The current CCS7 environment may have potentially hostile third parties

New CCS7 speakers

A need to worry about the security
Summary of CSS7 Requirements

+ Support of Operator to Operator Business in processing calls
+ An operator can hide its network from the rest of the world due to MTP Point code addressing

- Business requirements
  - Reliability: Very high
  - Performance: One roundtrip ~ 50ms
    - Call flow transfer delay < 20ms
    - Post dialing delay → close to zero

- System
  - Scalability: Scales to oligopolistic markets
    - i.e. markets of a few players only
  - Flexibility: Limited, but
    - fixed and mobile are OK.