Plain Old Telephone System

From Comfort to Numbering

RIPE 46

VoIP and ENUM

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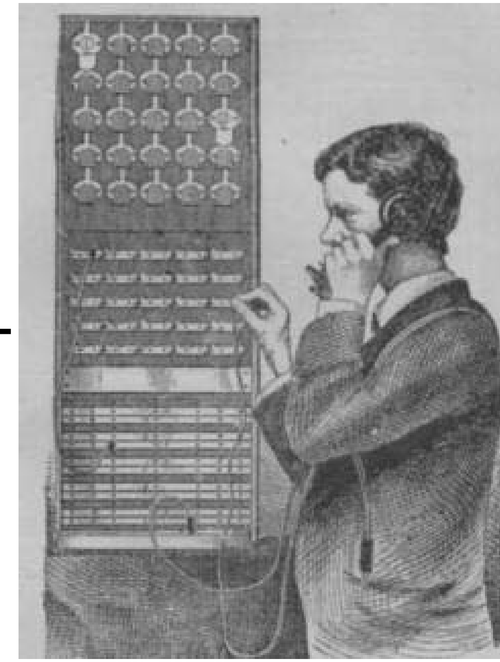
Today's Roadmap on Numbering

1. POTS – from Comfort to Numbering
   - Why are the numbers in the PSTN in the way they are?
   - A historical "Tour de Force"
2. ENUM and VoIP – Numbering and Dialing Plans
   - ENUM Mapping of E.164 Numbers to Internet Names and Addresses
   - E.164 Numbers for VoIP and Routing on the PSTN
   - Why Numbering and Dialing Plans for VoIP?
   - An Overview and a Proposal
3. VoIP and CLI – Trusted Identification
   - Calling Line Identification on VoIP
   - A Proposal

More then 100 Years of Telephony



- What has changed since 1900?
  - Not very much, same as railways ...
  - same speed, but reduced prices and reduced comfort

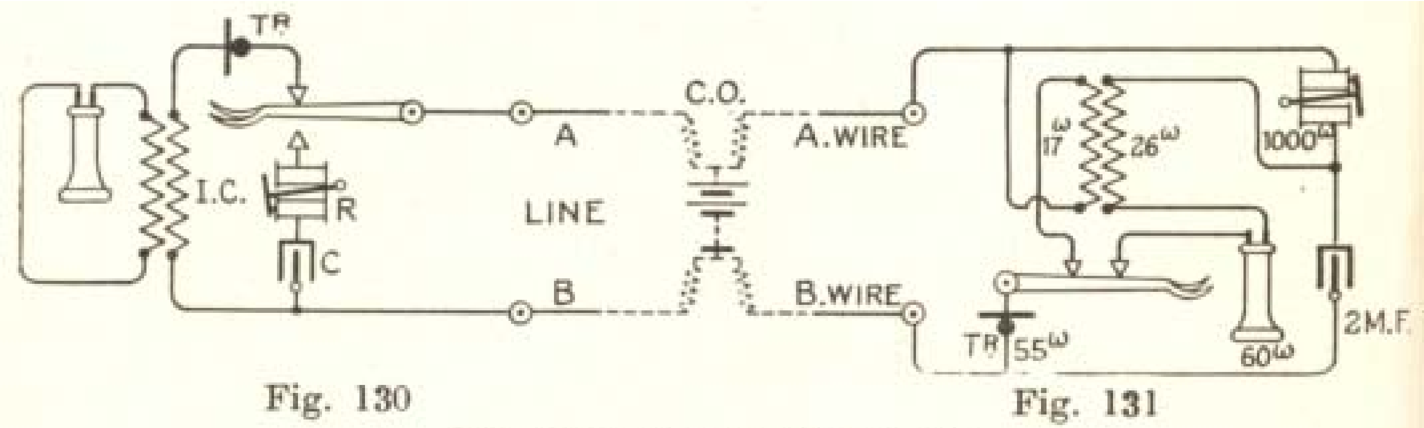
From POTS to VoIP

The technology was already established after 20 years (more then VoIP today)

Functions	then	now
Alerting, Ringing	✔	✔
Off hook – on hook	✔	✔
Call set up, dialing	Voice, Dial	Keys, MFC
Receiver and transmitter	✔	✔
Battery	central	local

C.B. Steam Phone Circuits

- A subscriber line with DC power from a Central Battery
- A hook-switch
- if on-hook
  - an AC circuit with a bell and a capacitor for Ringing (high resistance)
- if off-hook
  - a DC circuit with a microphone (low resistance for off-hook detection in C.O.)
  - an induction coil for separation of the transmitter (to block the DC current)



C.B. Systems, Local Circuits

The Switchboard in the Central Office

- You picked up the transmitter (off-hook)
- a flap signals this at the switchboard in the central office
- the operator answers
- you tell her: "Give me the Undertaker"
- and she establishes the connection - this was very comfortable

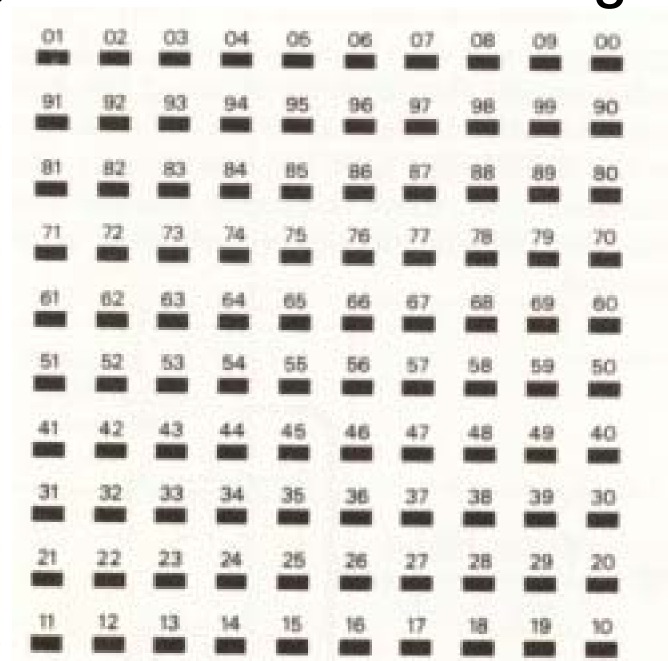
Almon Brown Strowger

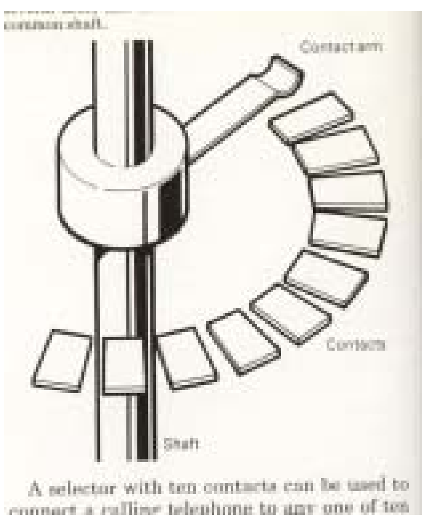
- This system was nearly perfect, but ...
- A.B. Strowger was an undertaker in Kansas City
  - and the operator was the wife of another undertaker
  - and connected the calls for undertakers to her husband
- Strowger did not like this at all
  - so he invented the automatic telephone exchange

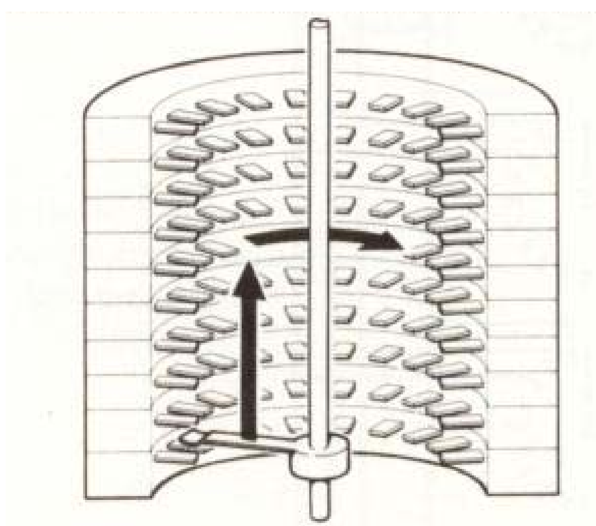
The Strowger Selector

- The strowger selector is controlled by the dial pulses directly
- A final selector is able to connect to 100 lines with two digits
- the first digit is stepping up vertically
- the second digit is turning horizontally
- and the digit '0' is ten steps!

bell-head counting

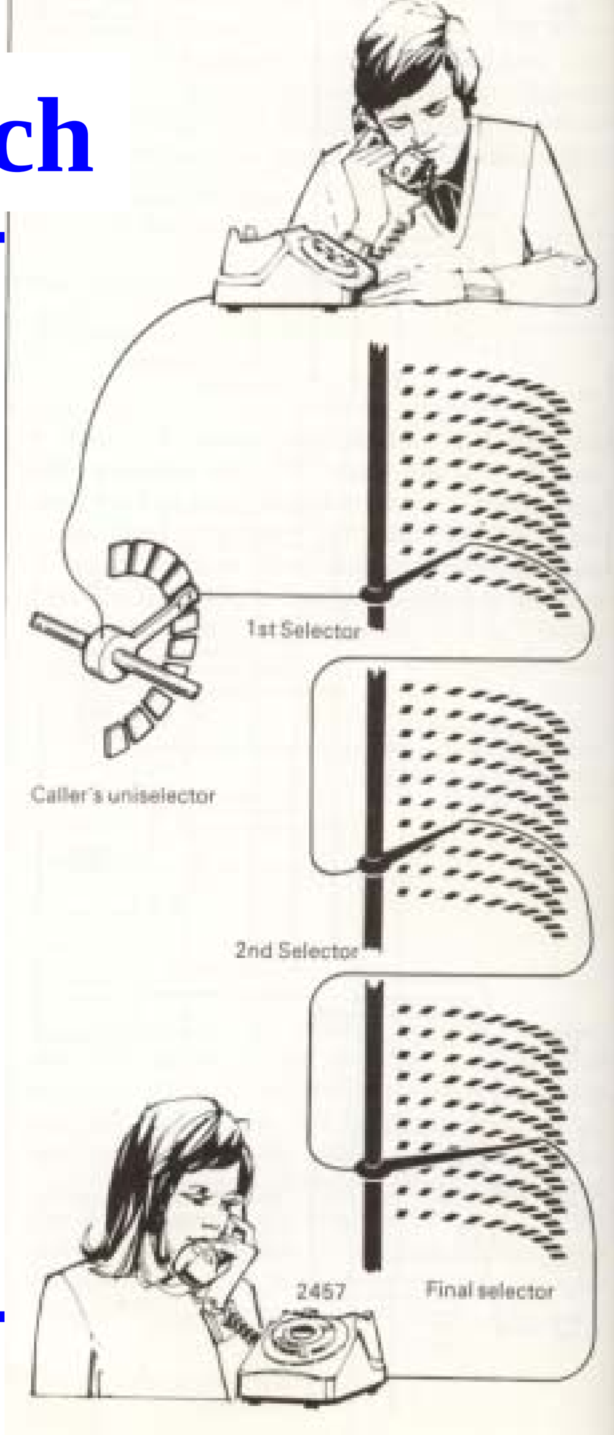






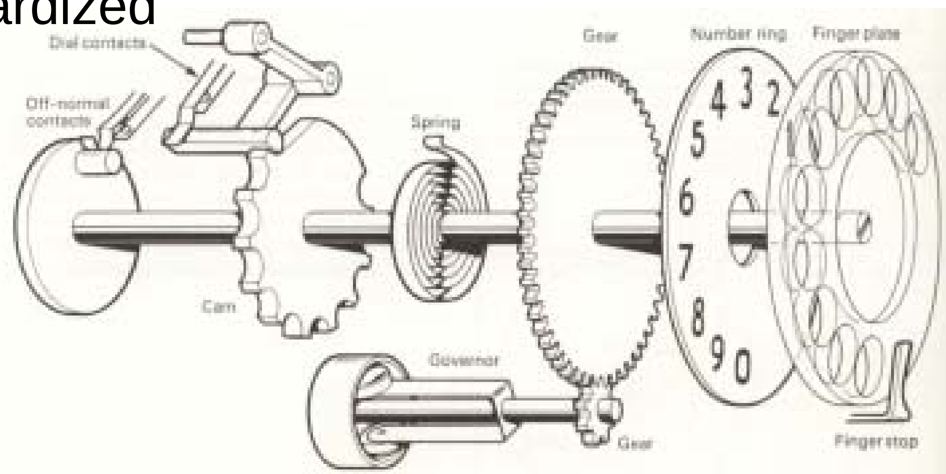
A complete automatic switch

- Three basic types of selectors:
  - Uniselector to find a free first selector and attach dial tone
  - eventually 1 or more group selectors (first, second, ...)
  - the group selector uses up 1 digit and searches for the next free selector
  - The final selector uses up 2 digits.
- So a local switch uses 2 or more digits
  - and a number was really an address



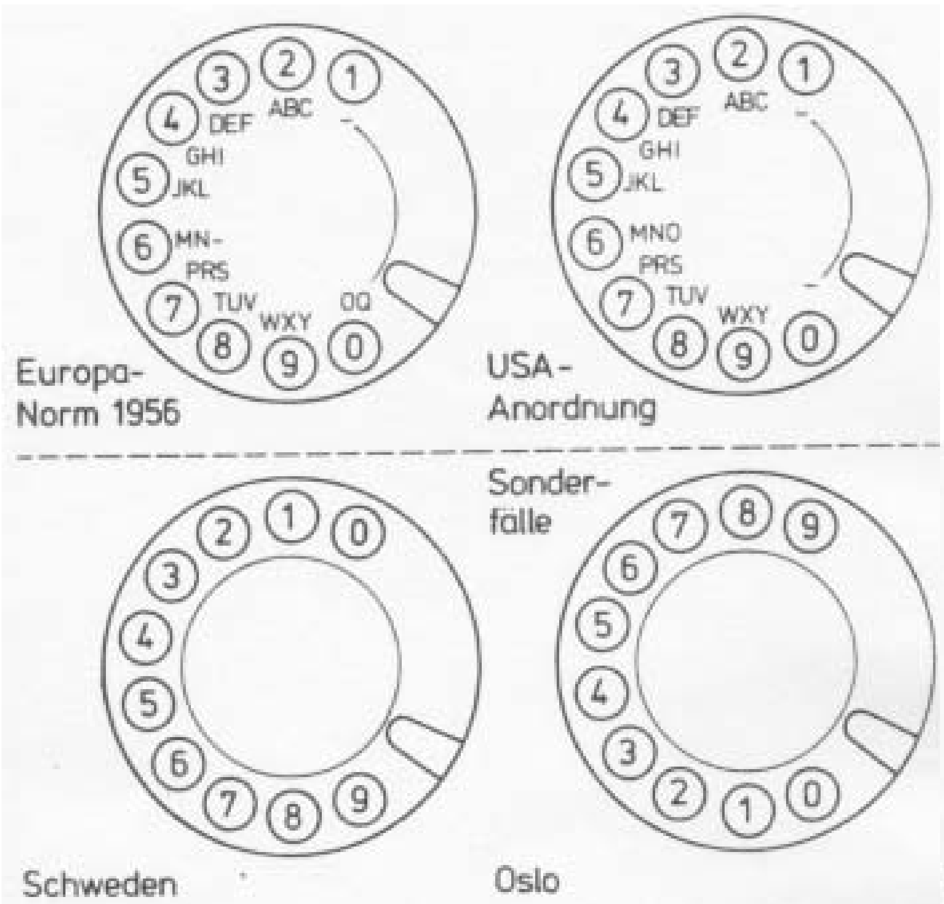
The Dial

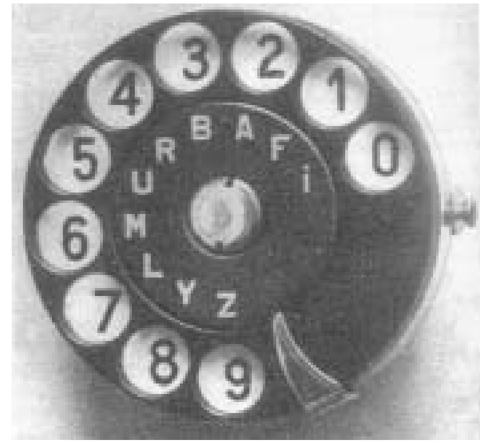
- To control the strowger selectors, a device was needed in the phone to generate the necessary pulses
  - The idea was, that the caller is controlling the phone system manually with a dial (so "automatic" is questionable)
  - The dial is able to generate digits transmitted as pulses by "breaking" the DC circuit (you may also dial with the hook switch)
  - The dial is providing a standardized length of "make" and "break"
- Dialing is signaling



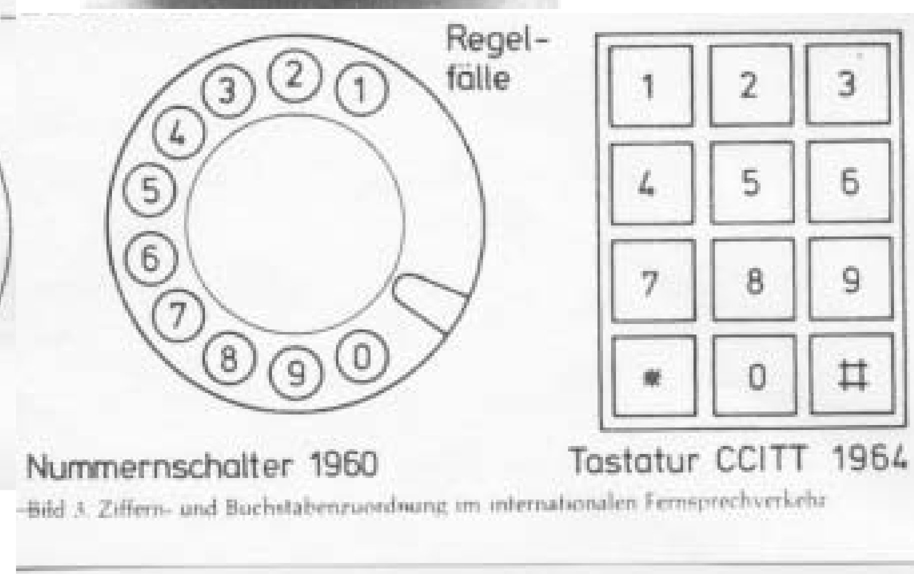
The modern dial is a carefully designed and accurately made precision instrument. In this drawing, the principal parts have been simplified and rearranged to show more clearly the way in which the dial works.

Dials – Number Rings and Finger Plates

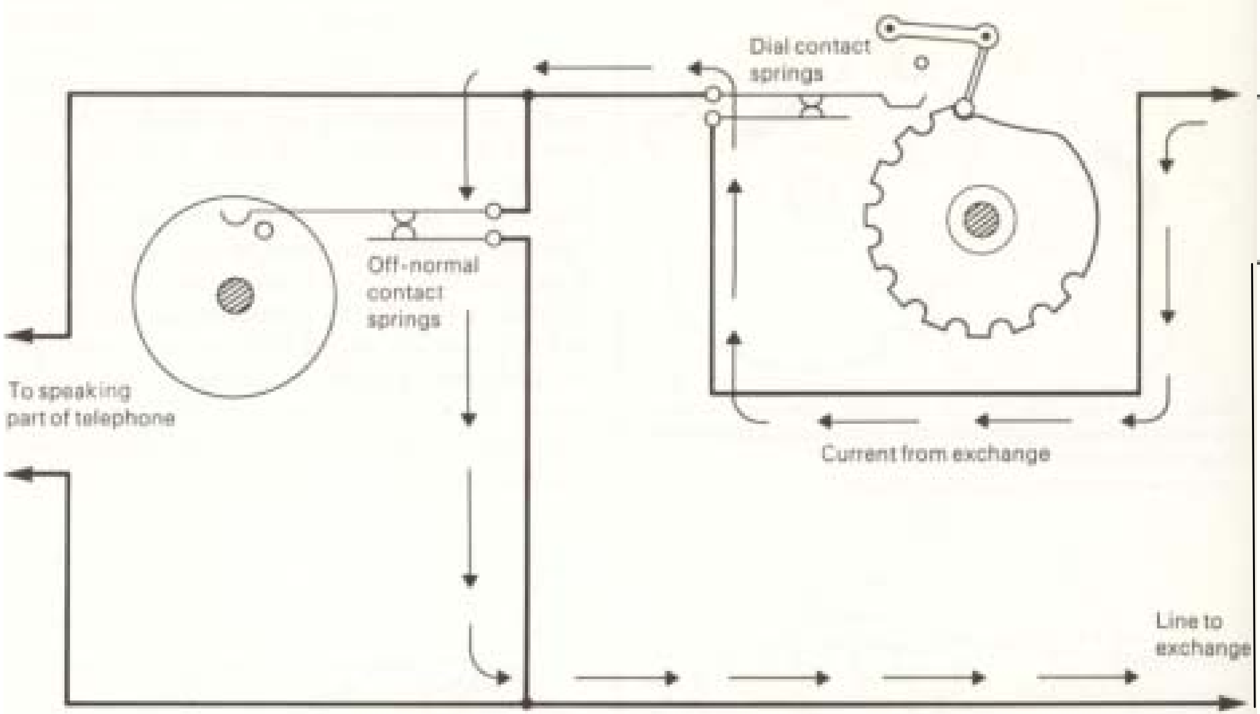




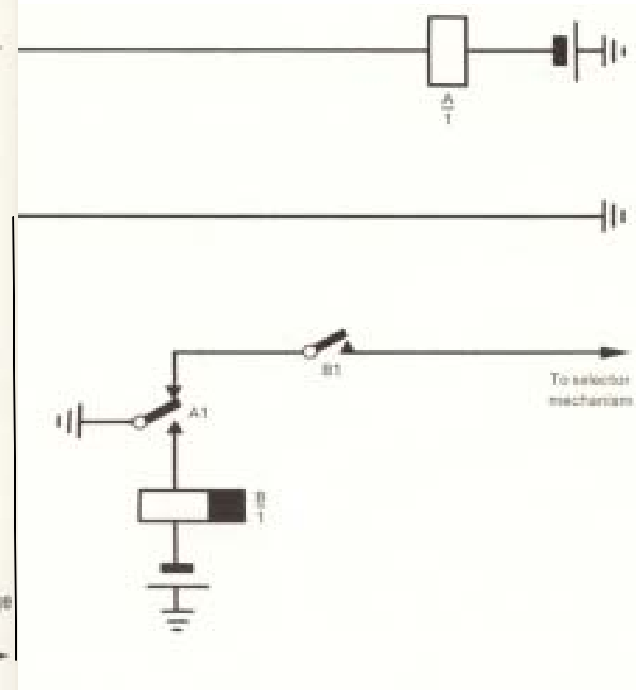
Vienna
1928



Dialing

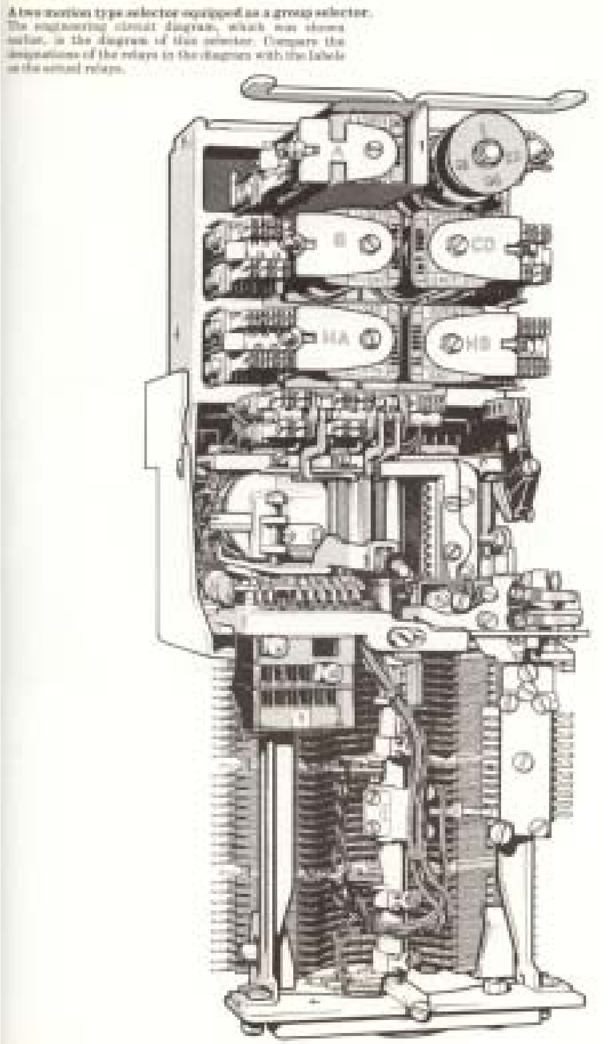


When the dial is used, the current from the exchange flows through the off-normal contacts, by-passing the speaking part of the telephone.



at central office

Selector



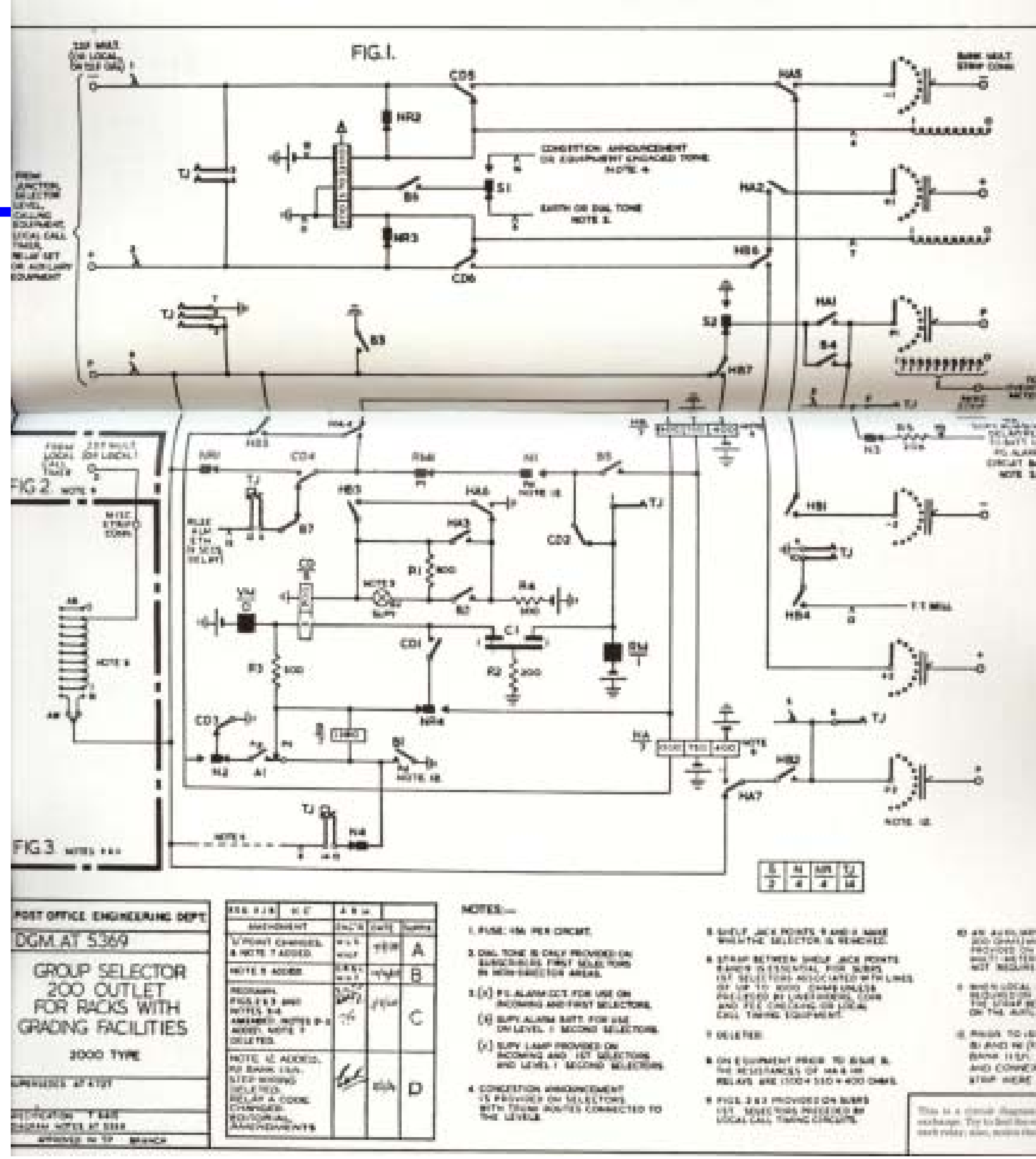
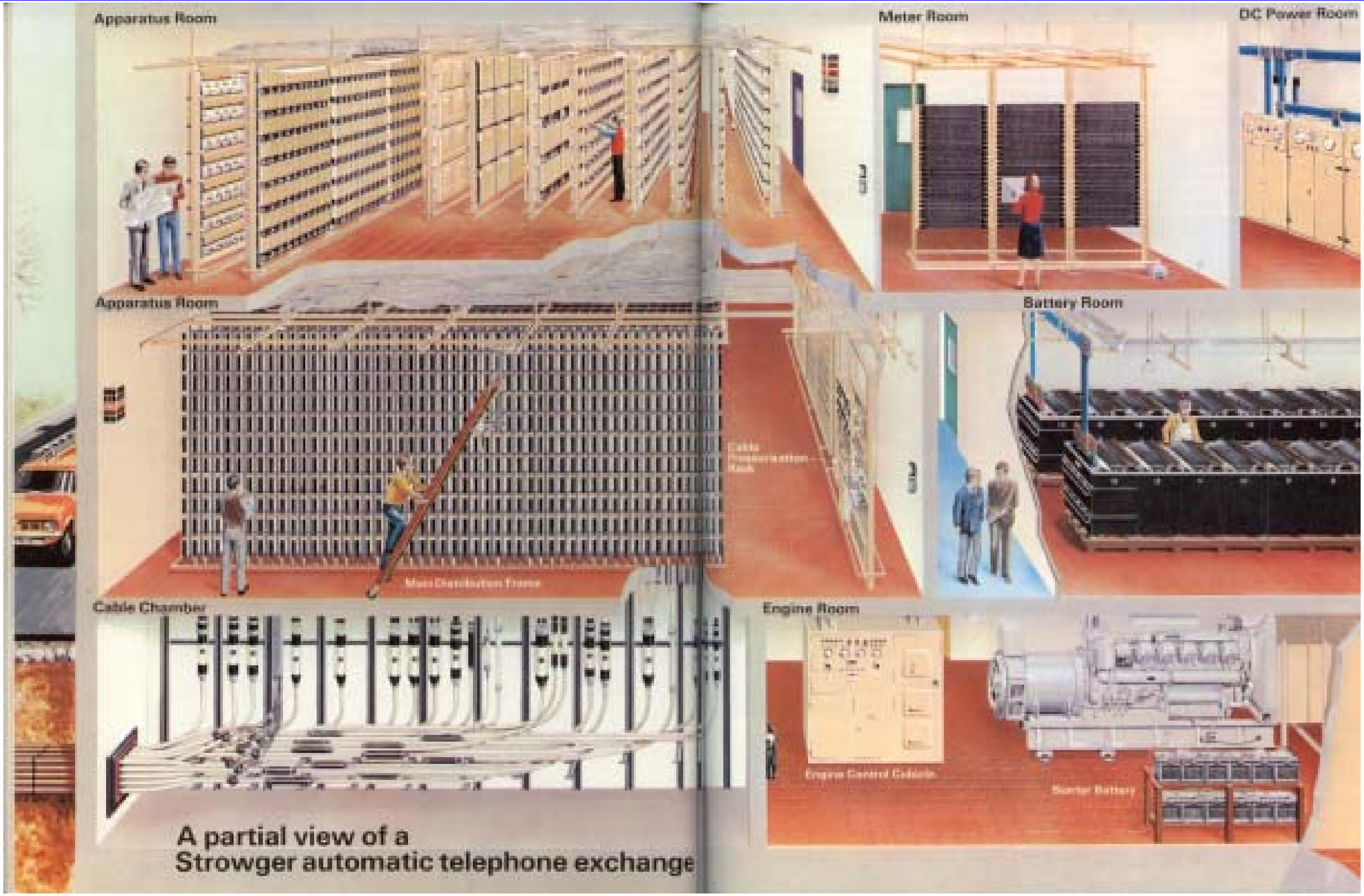


FIG.1.
FIG 2
FIG 3
POST OFFICE ENGINEERING DEPT
DGM.AT 5369
GROUP SELECTOR
200 OUTLET
FOR RACKS WITH
GRADING FACILITIES
2000 TYPE
NOTES:-

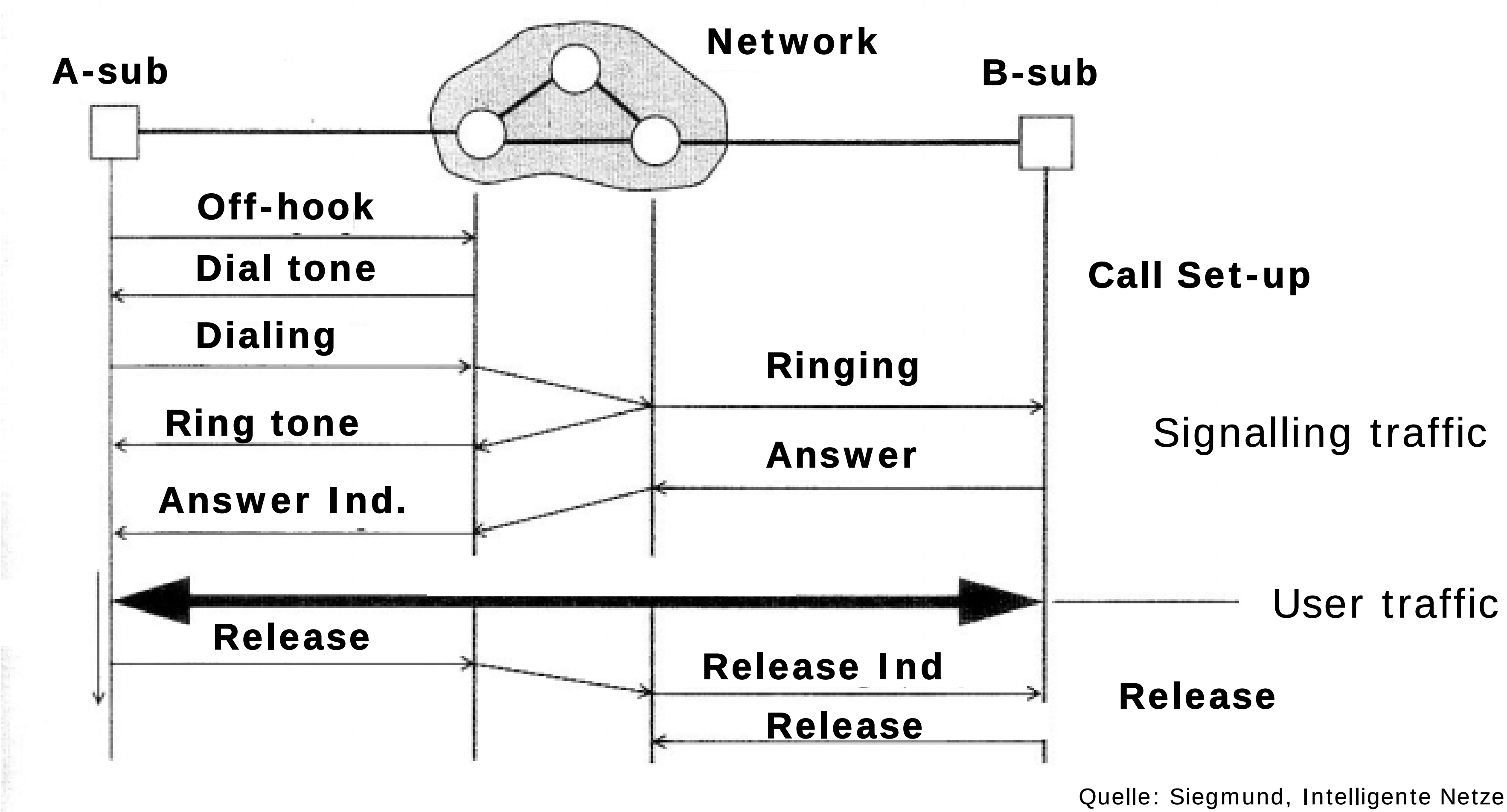
A Strowger automatic exchange



Basic Signals Then

- Before we continue, we should recapitulate the basic signals in step–by-step systems, transmitted in-band with
  DC signals, AC signals or audible tones:
  - Off-hook (DC)
  - dialtone (tone)
  - dialing (DC)
  - call proceeding (clacker, tucker, hackety-hack, … ;-)
  - trunk busy (tone)
  - subscriber busy (tone)
  - number unavailable (tone)
  - ringtone (tone)
  - ringing (AC)
  - Answer
  - on-hook or release from far end (DC and tone)
- These are still the main signals we have now.

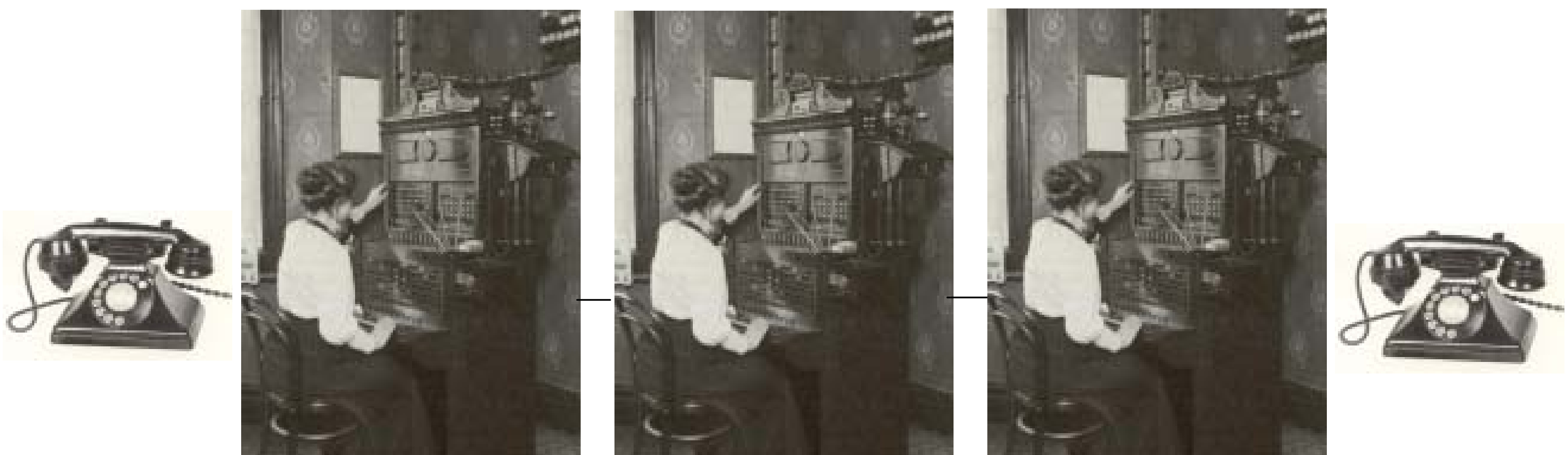
Basic Signals Now



Quelle: Siegmund, Intelligente Netze

A phone network

- All phone or subscriber lines where connected to the local office
- but people sometimes people also wanted to call long distance
- so even in switchboard times a central office was connected via "trunk" lines to other central offices



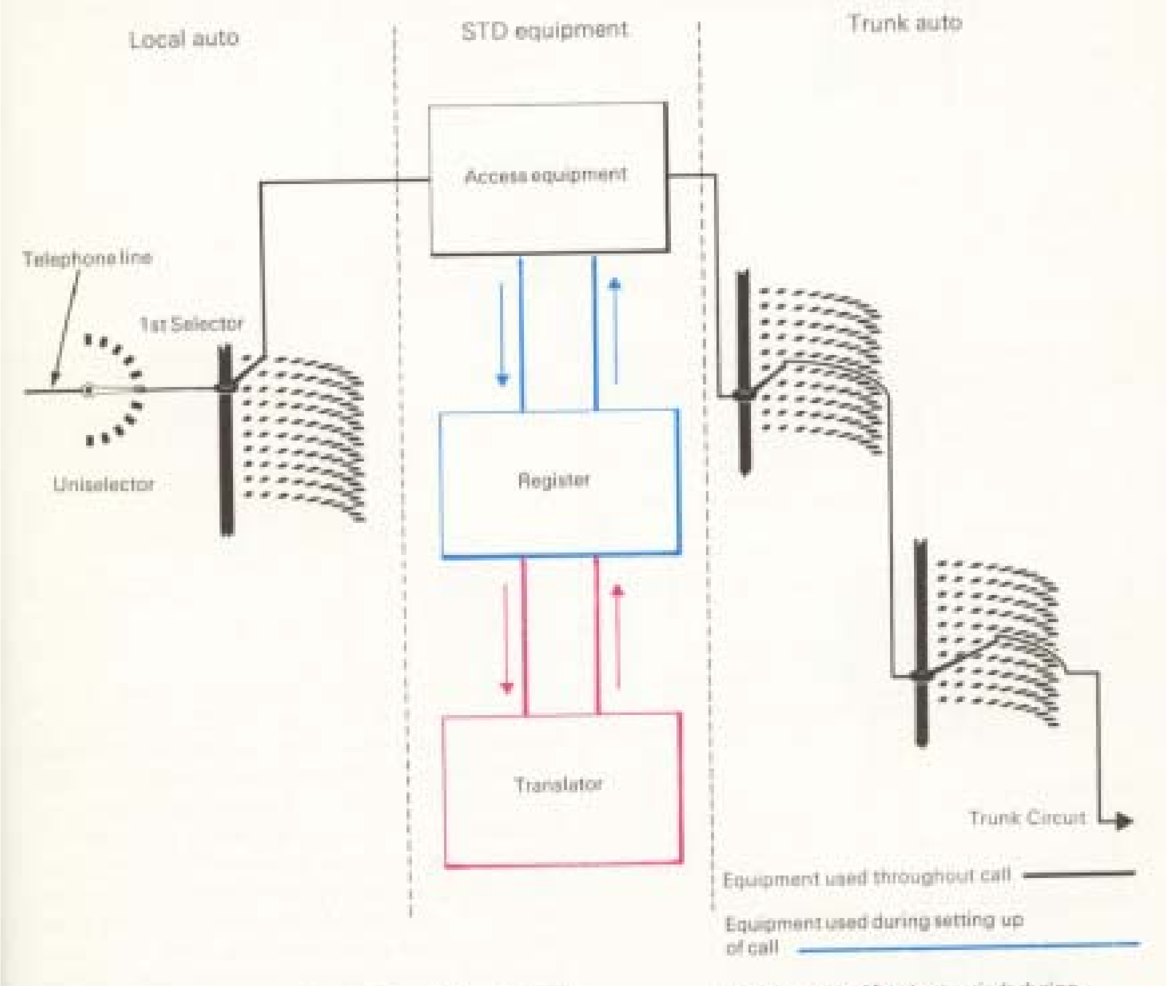
Trunking

- Even if local calls could be made automatically in the first half of the last century, long distance calls still required operators.
- The connections between the local offices (the trunks) where still only accessible from switchboard operators.
- In many cases the digit '0' of the first selector was used to route the call to a switchboard and the operator established the "trunk" call ('0' was selected because it was used rarely)
- Subscriber Trunk Dialing (STD) on large scale was introduced in the 50s
- International Subscriber Dialing (ISD) was introduced
  - in the 60s continental and
  - in the 70s inter-continental.

Trunk Auto

- In the beginning, the caller dialed directly into the trunk network like into the local network
- but the problem was that the numbers (trunk codes) to dial for a given destination were different for each origination
- To unify all trunk codes in a country, additional equipment was necessary between local network and the trunk network
  - the access equipment (e.g. 2-to-4 wire conversion, tariff pulses)
  - the register (storing and out pulsing of digits, tariff selection)
  - and the translator (digit translation) – a preliminary IN-service ;-)
- access equipment was needed throughout the call, registers only during call set-up and translators only during translation

Access to Trunk Auto



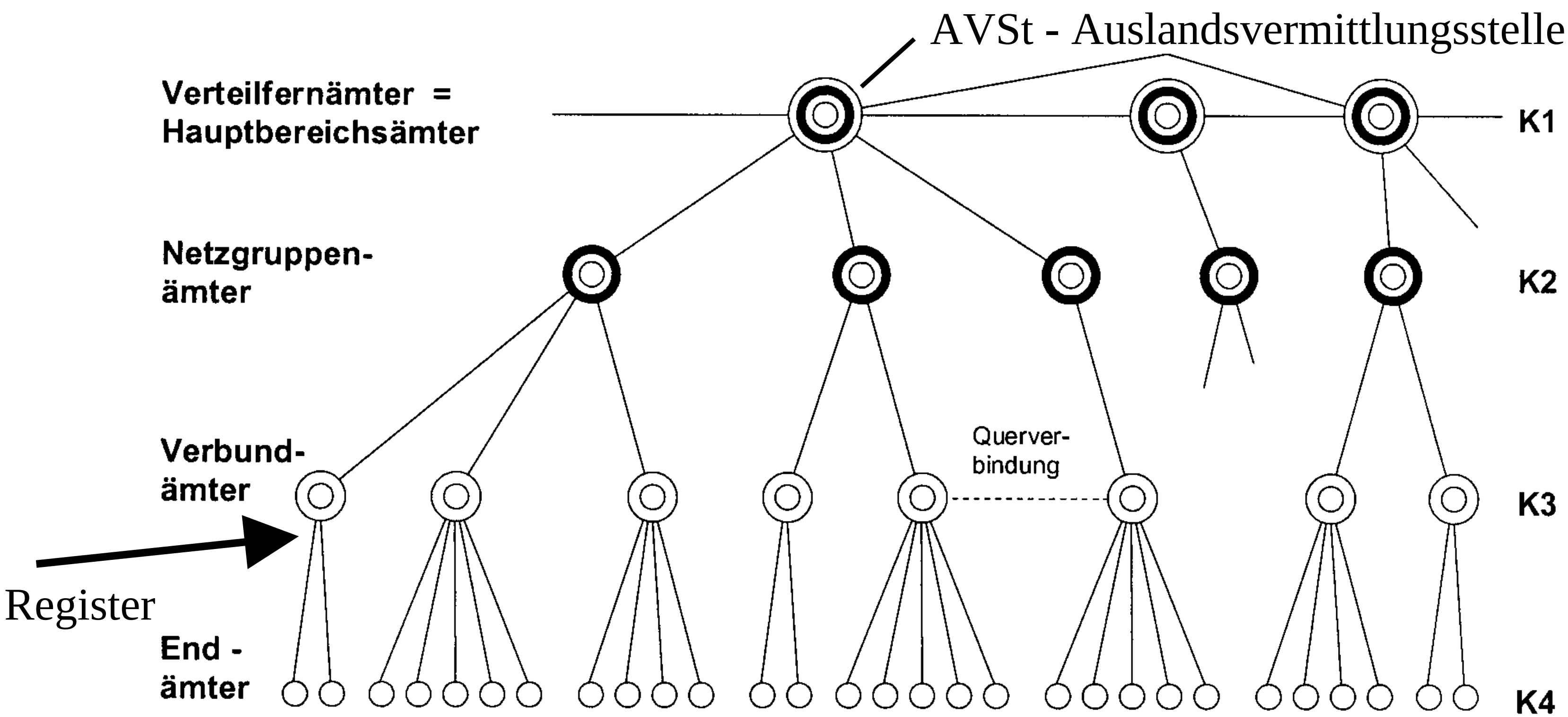
The equipment used to make an STD call in a typical exchange.

Register and Translator

- Since at this time registers and translators where electromechanical, they had to be simple
- Most translation was done by simply deleting and/or adding digits
- How could this be achieved?
- By creating a tree structured hierarchy of central offices (switching centers)

Austrian Trunk Network

- The Austrian Hierarchy - EA, VBA, NGA, HBA, (AVSt)
- The Austrian Trunk Code is normally 4 digits: K1 K2 K3 K4
- The Registers are located at the incoming VBA trunks and are adding '0's to go up the hierarchy and/or deleting digits
- Step-by-Step System using an Open Numbering Plan (variable digit length)



The translation by the register (RV) – introduced 1951

- The user always dials '0 K1 K2 K3 K4'
- The RV dials: To other local office in own "Verbundgruppe" – 'K3 K4'
- To other local office in own "Netzgruppe" – '0 K3 K4'
- All other: '0 0 K1 K2 K3 K4'

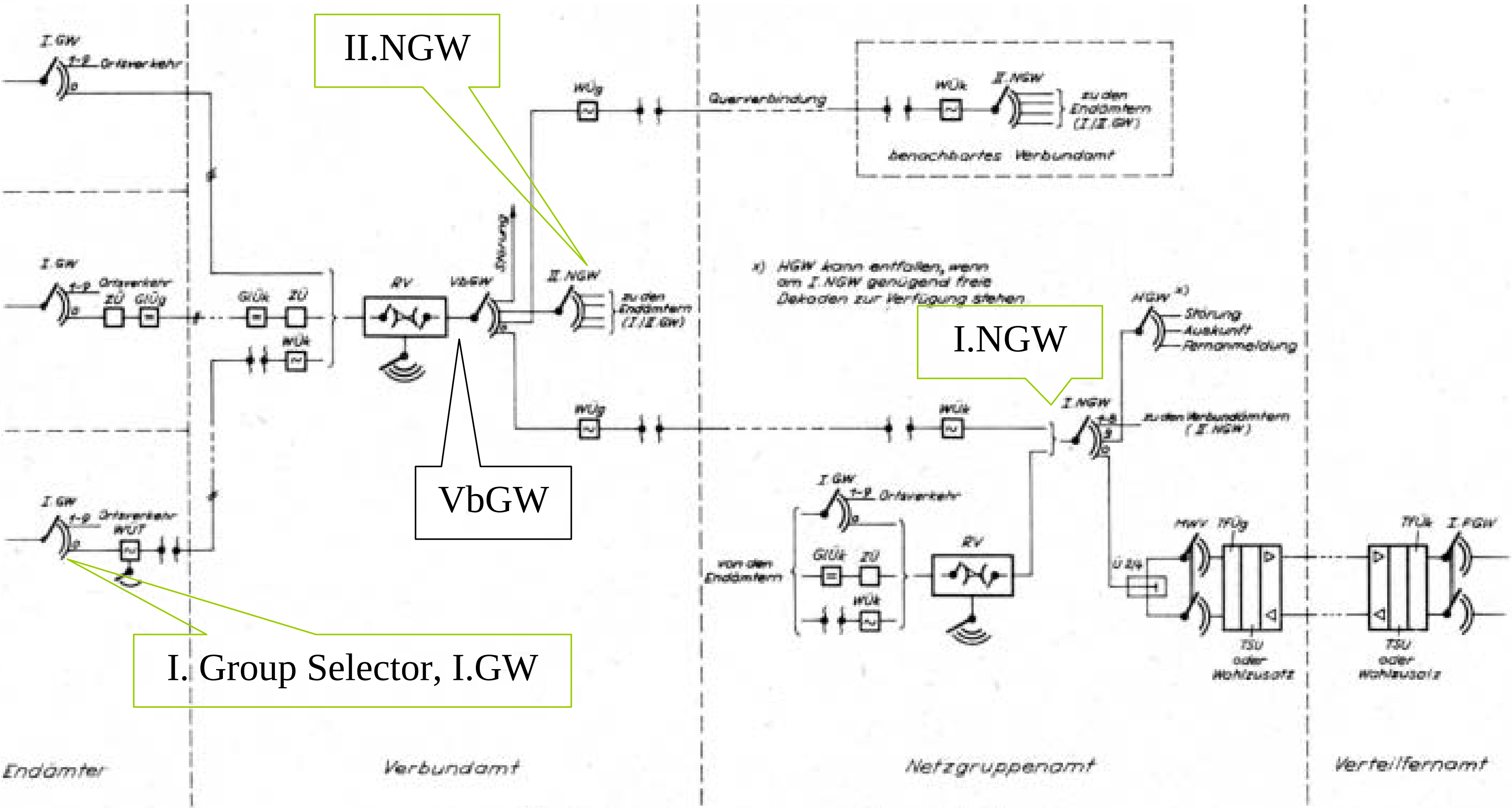


Abb. 4. Gruppierung im unverstärkten Verkehr

North American Trunk Network

- The NANP Hierarchy
  - Class 1 Regional Center
  - Class 2 Sectional Center
  - Class 3 Primary Center
  - Class 4 Toll Centre
  - Class 5 End Office
- Crossbar system using a Closed Numbering System originally in the format X0/1N XXN NNNN; since 1974 in the format XXN XXN NNNN; where X= 2-9 and N=1 to 0;
- In addition to the Numbering and Routing Plan also a Transmission Plan and a Tariff Plan was necessary

Dialling Plans

- Dialing Plans have a clear hierarchy
- for local calls, the local number (subscriber) is dialed directly
- for national (trunk) calls
  - the national trunk network is accessed with a prefix (e.g. '0'),
  - then the trunk code is dialed to reach the distant local office
  - and then the local number in the distant local office is dialed
- for international (trunk) calls
  - the national trunk network is accessed with a prefix (e.g. '0')
  - then the international trunk network is accessed with another prefix (e.g. '0')
  - then the country code to reach the national network of the foreign country
  - then the trunk code to reach the distant local office
  - and then the local number in the distant local office is dialed
- e.g. '0 0 CountryCode TrunkCode SubscriberNumber'
- This will be discussed in more detail in Part II

International Subscriber Dialing

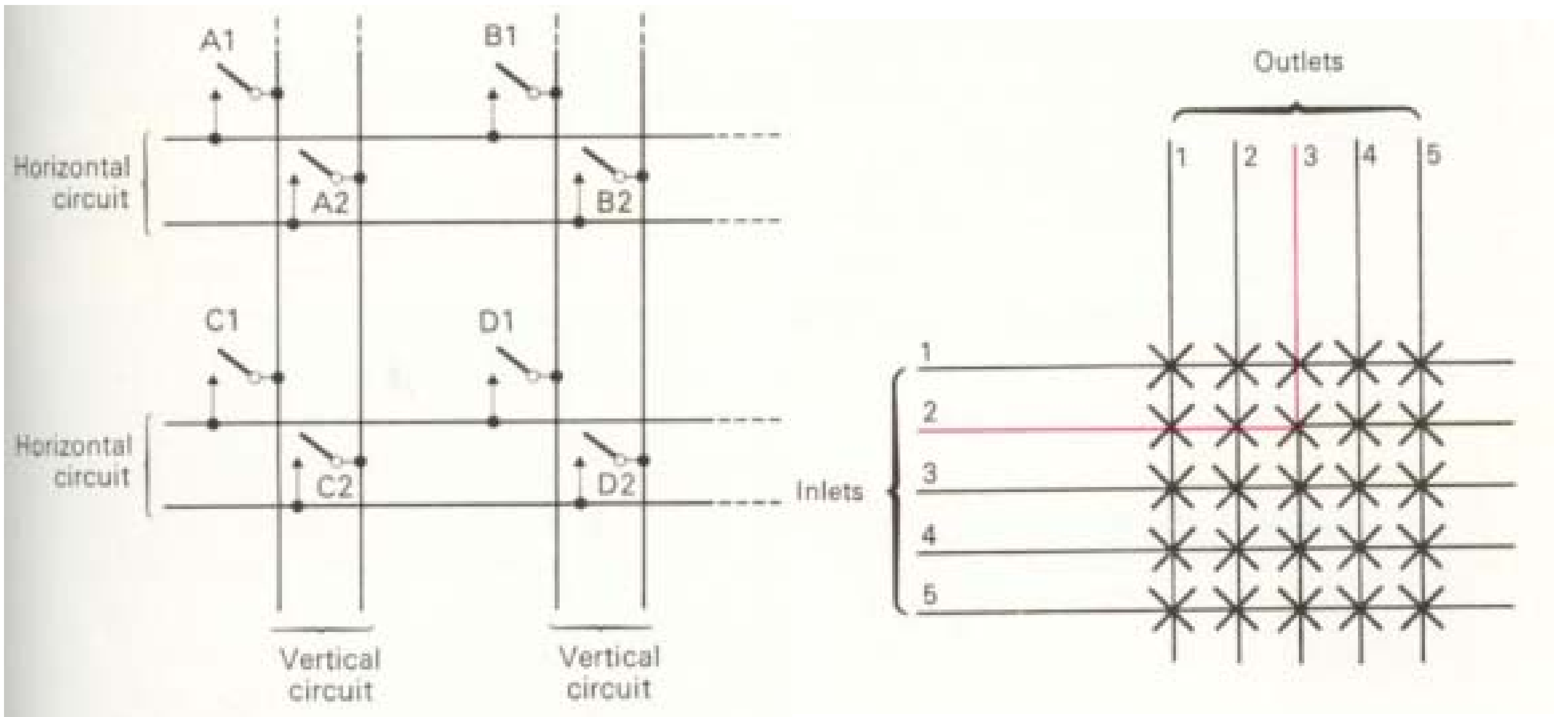
- ISD was introduced in 1960
- Many concerns where raised:
  - Who needs it?
    - International traffic in Germany 1960 was 0.6%
  - My Grandma (= normal subscribers) cannot use it!
    - She will not be able to dial 11 to 14 digits in one rush without making a mistake.
  - All dials need to be unified (remember slide 11)
    - Who will pay for this? (CCITT Redbook 1960 Unified Dials, no letters – Keypad 1964)
  - Automatic Tariffing (time and distance proportional) required
- In many countries it was considered problematic that a citizen is able to call any other foreign citizen in the world without asking anybody for permission.

History of ITU and E.164

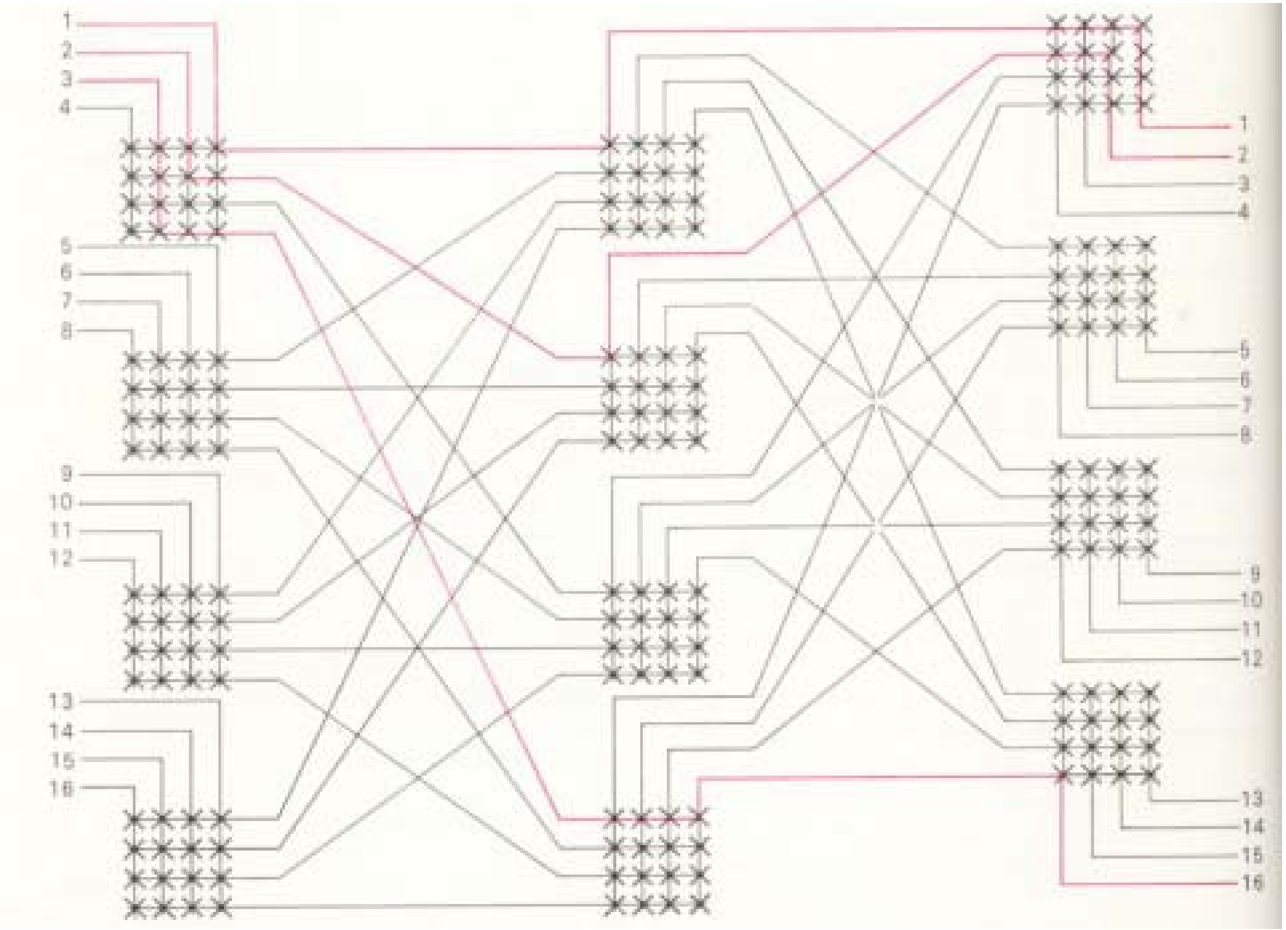
- ITU was founded in 1865 (International Telegraph Union)
  - CCIR(1927), CCIF(1924) and CCIT(1925) merged 1956 to form CCITT
  - 1932 ITU changed name to International Telecommunication Union
  - 1956 CCIF(1924) and CCIT(1925) merged to form CCITT
  - 1989 Sectors ITU-T, ITU-R and ITU-D
- History of county codes
  - 1960 CCITT Red Book featured a list of 2 digit country codes for Europe (some of them are still in force)
  - 1964 CCITT Blue Book E.29: basis for existing international numbering plan
  - 1968 CCITT White Book E.161/Q.11
  - 1972 CCITT Green Book E.161/Q.11
  - 1976 CCITT Orange Book E.163
  - 1980 CCITT Yellow Book E.163
  - 1984 CCITT Red Book E.163, E.164 for ISDN
  - 1988 CCITT Blue Book E.163, E.164 for IDSN
  - 1992 onwards ITU-T White Book E.164, E.164.1, E.164.3, E.164.3

Fast Forward: Switching Matrix

- The next step where electromechanical register systems (e.g. Crossbar and reed relay systems) ...

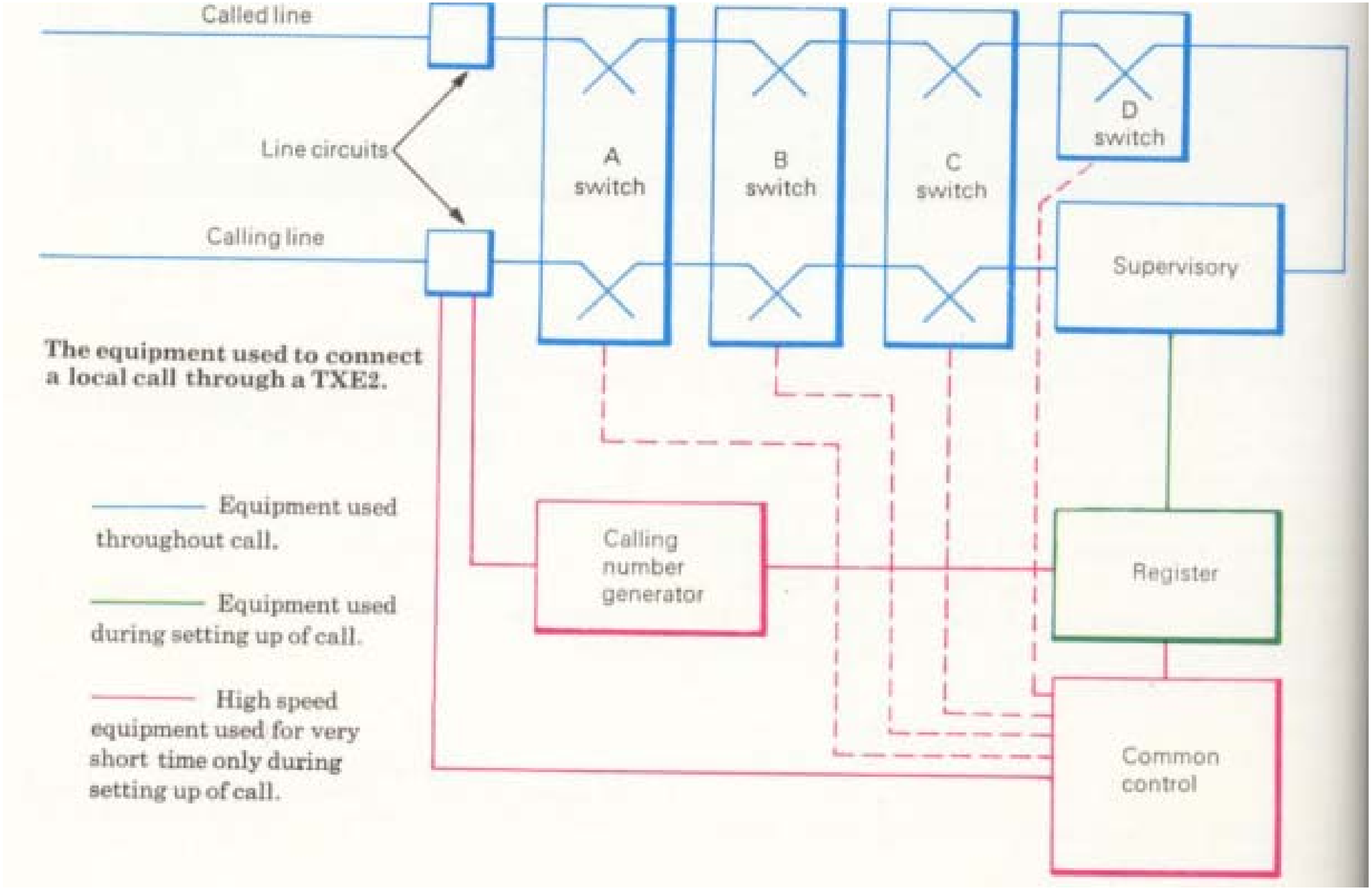


Switching Matrices requiring…



Twelve 4 × 4 matrices, switching sixteen circuits, in three stages. Typical connections are shown in red. Inlet 1 is shown connected to outlet 1; inlet 2 to outlet 2; and inlet 3 to outlet 16.

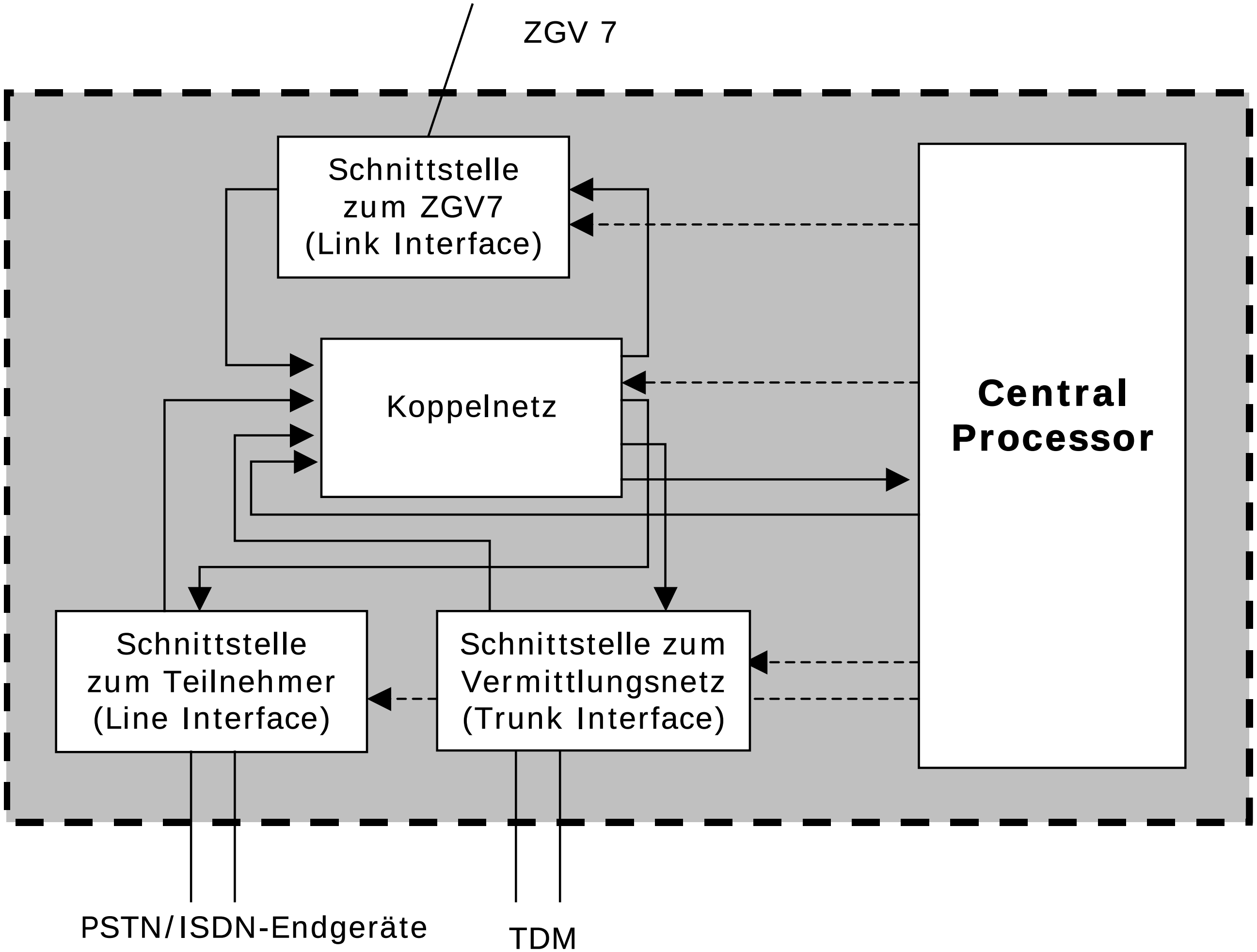
Common Control, leading to ...



Stored Progam Controlled Systems

- SPC systems
  - analog and digital transmission and switching networks
  - all combinations existed
- These systems had in principle 3 parts
  - the line and trunk circuits and its controllers (analog and digital)
  - the switching network (analog and digital)
  - and the central control (digital)
- Line or trunk signaling was detected by circuits
  - submitted to the central control
  - the central control analyses the information (e.g. digits dialed)
  - and connects the incoming and outgoing circuits via the switching network
- Routing was now more flexible

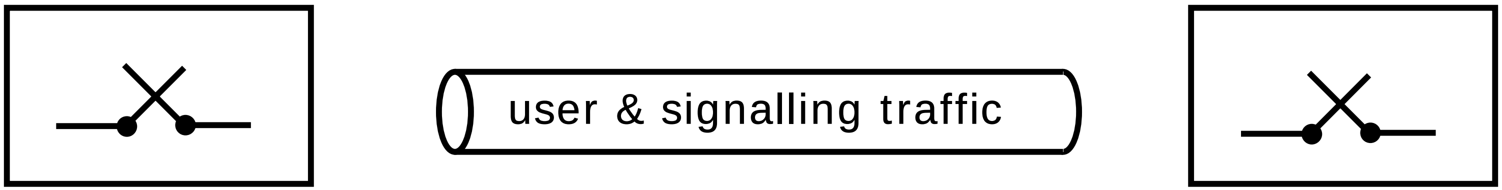
Digital Switching System



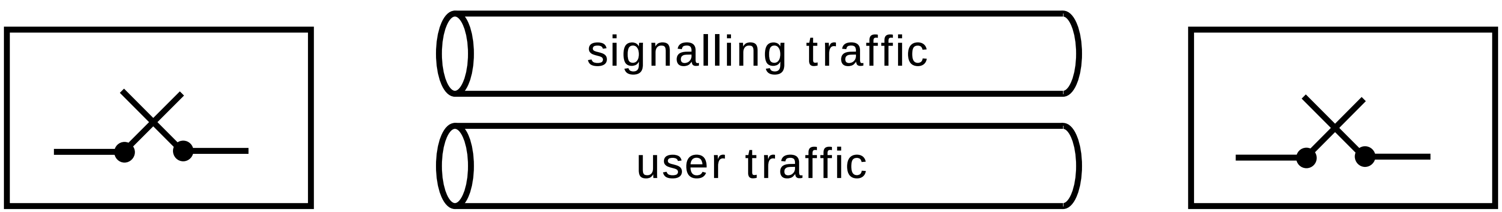
Signalling

- Signalling evolved from …
- The Strowger type systems are called step-by-step systems
  - Fully distributed, very reliable
  - In-band Signaling (dial pulse, MFC R2 and others)
- With SPC systems first the same in-band signaling systems where used
- With the SPC systems and also with the introduction of digital transmission (e.g. PCM30) also out-band signaling was introduced.
- First associated (e.g. 4-bit signaling PCM30),
- then Common Channel Signaling Systems 6 and 7

in-band/out-of-band Signalling

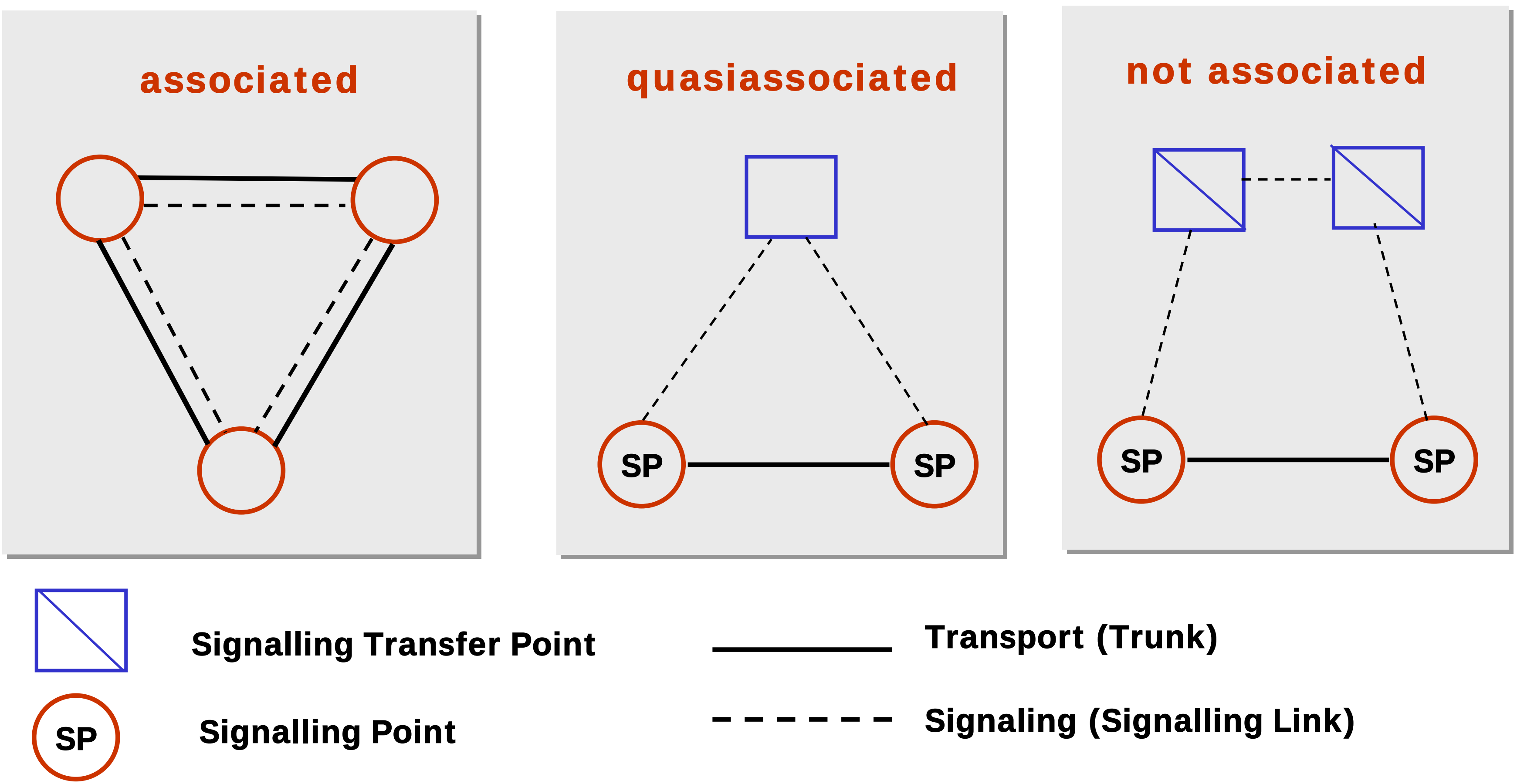


Channel Associated Signalling

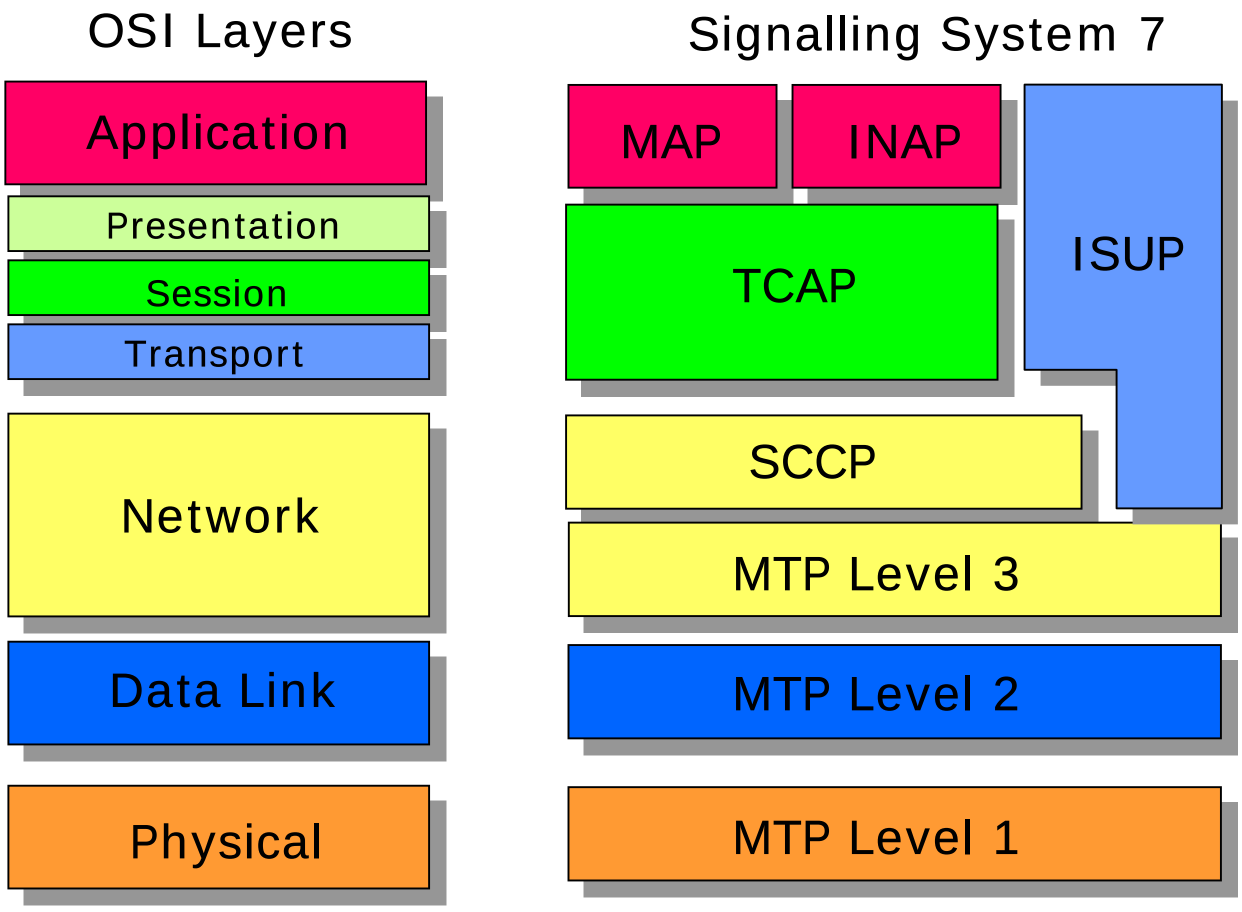


Common Channel Signalling

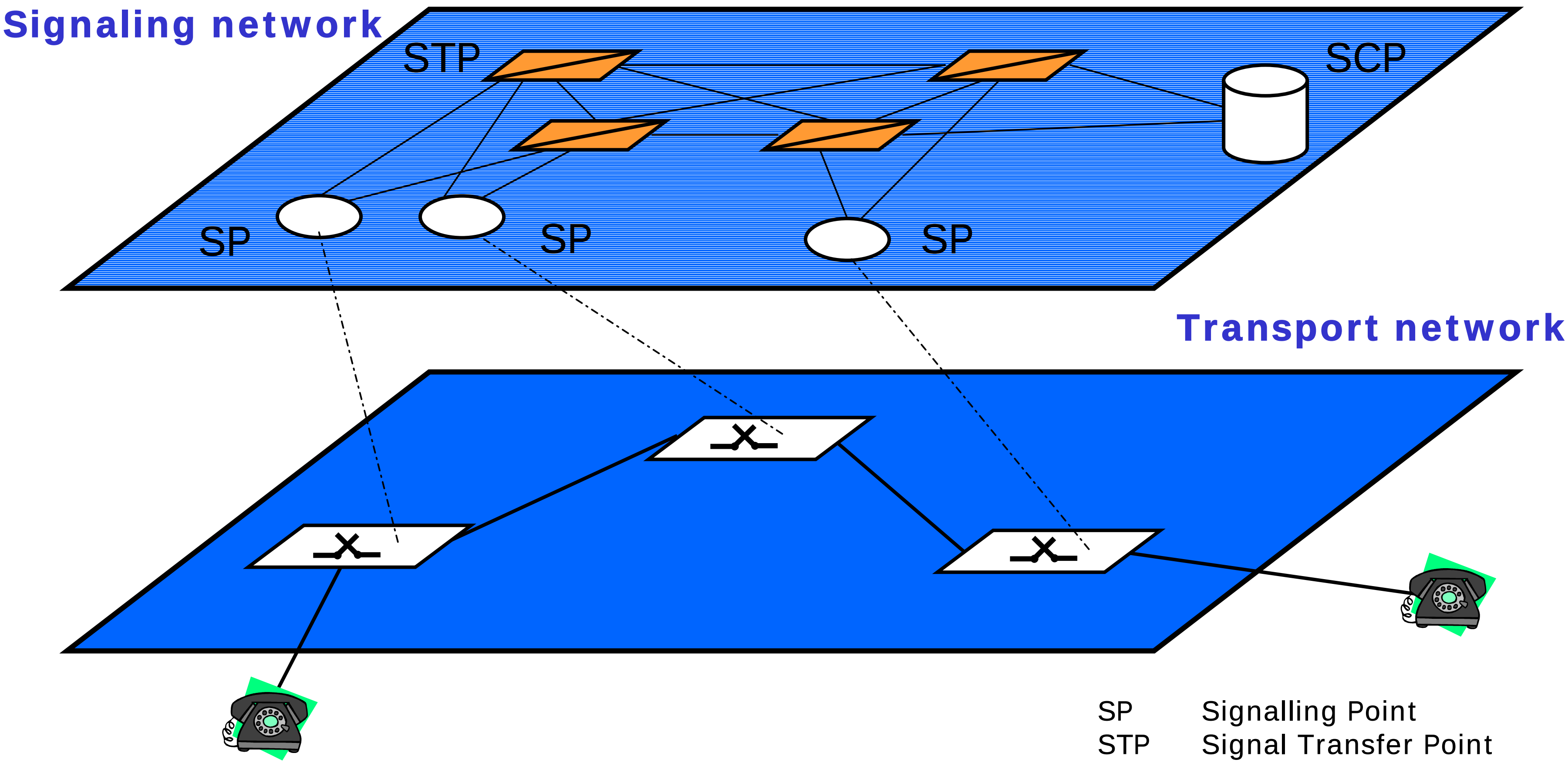
Common Channel Signaling



OSI vs. Signalling System 7



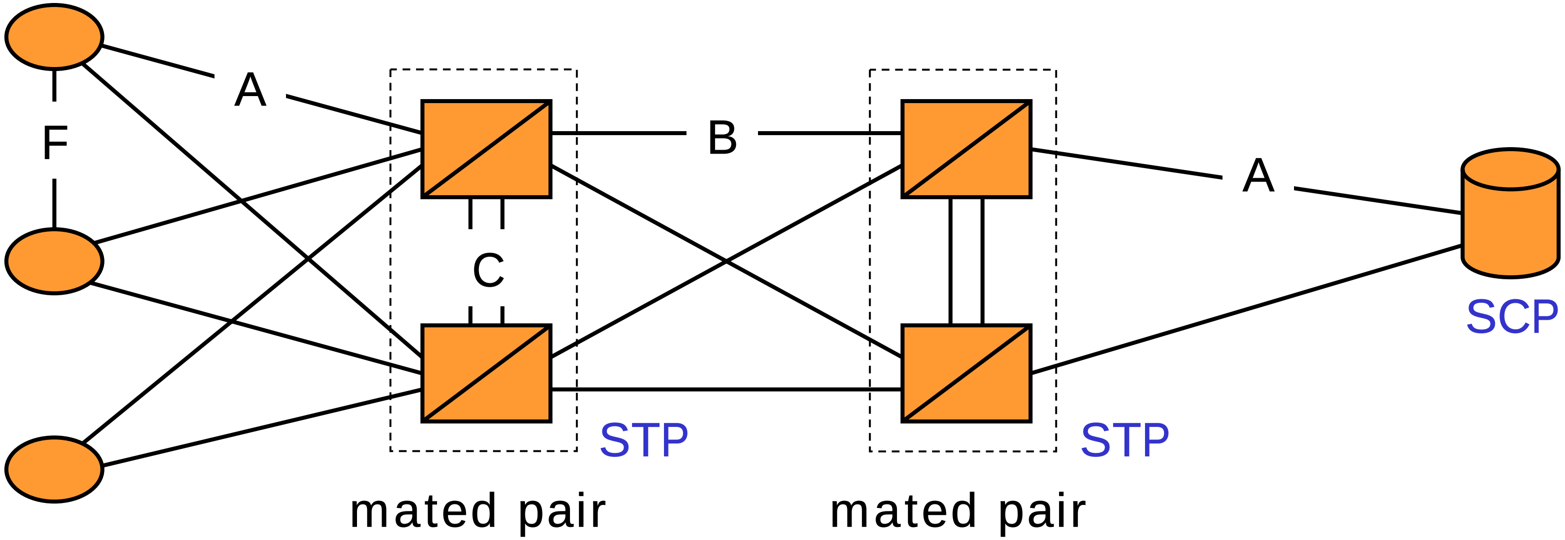
SS7 Planes



SP	Signalling Point
STP	Signal Transfer Point
SCP	Signal Control Point

SS7 Quad

Nodes:
SP Signalling Point
STP Signal Transfer Point (Router)
SCP Signal Control Point (Database)



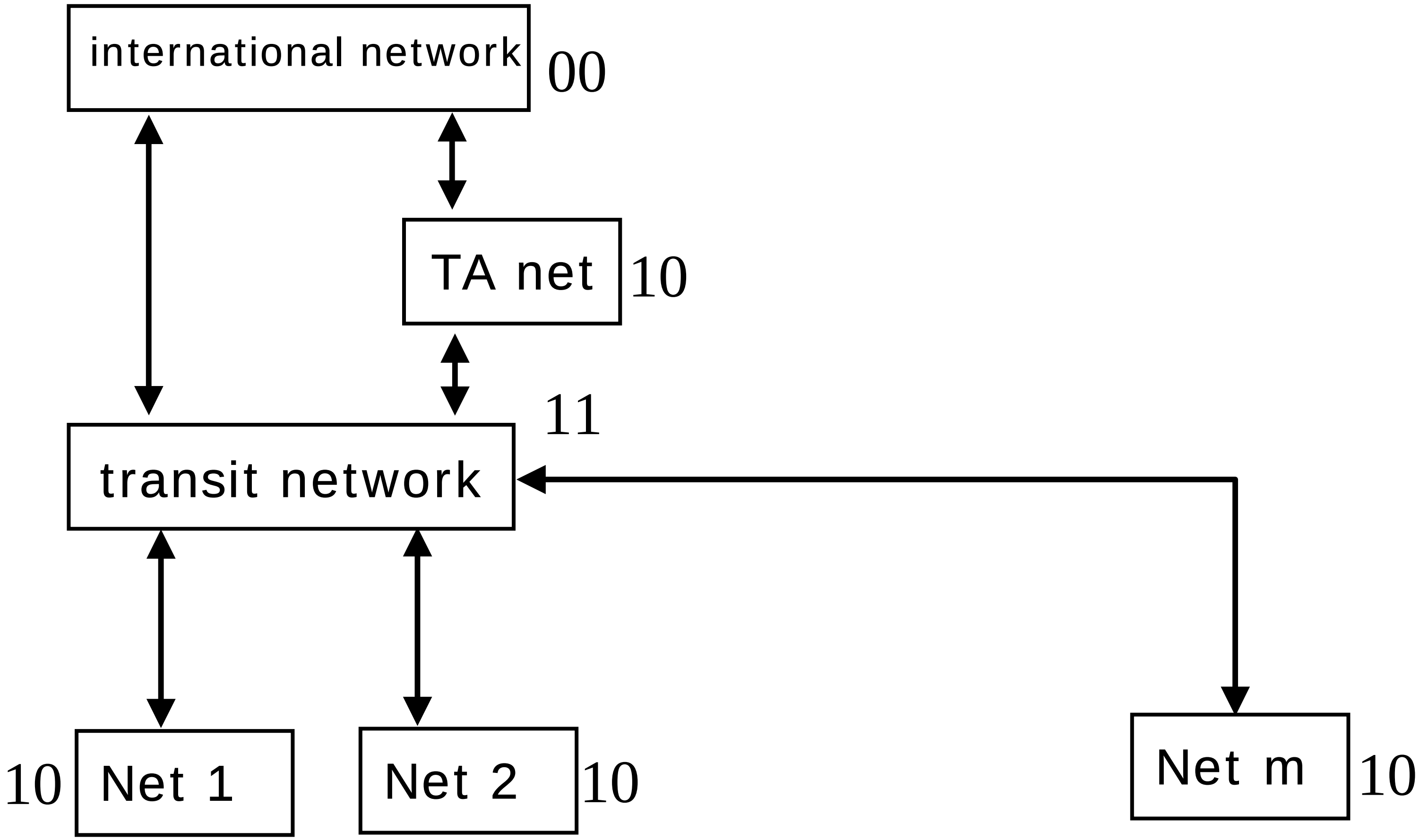
Interconnection of Signaling Networks

- MTP is in principle like IP (with an address of 16 bit)

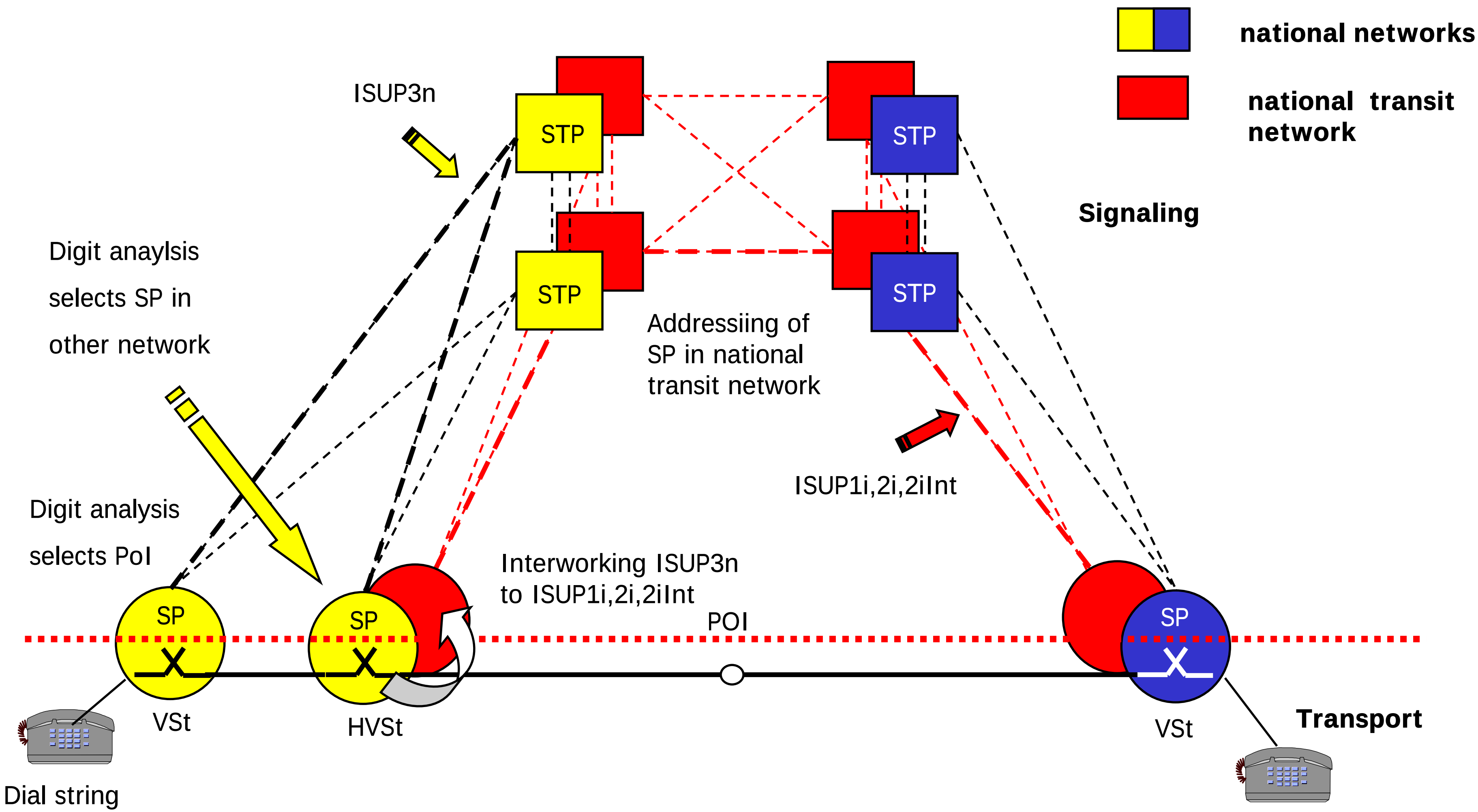
- Network Indicator
  - 00 international network
  - 01 spare international network
  - 10 national use
  - 11 spare national use

- Pointcode:
  Within his network, every Signalling Point has a unique Pointcode.
  (14 Bit, maximum of 16.384 Pointcodes/network).

Transit Network



Connection of Signaling Networks



ISUP Messages

Call Processing:

IAM Initial Address Message

Setup of connection on a defined trunk (CIC)

SAM Subsequent Address Message

additional digits (overlap sending/en bloc sending)

ACM Address Complete

Destination reached (ringing)

ANM Answer

Called subscriber went off-hook

REL Release

Subscriber went on-hook

RLC Release Complete

ack of release message

DSS1 and ISUP Numbers and Parms

- DSS1
  - called party number
  - calling party number
  - connected number
  - redirecting number
  - redirection number
- ISUP V3
  - called party number
  - calling party number
  - connected number
  - generic number
  - original called party number
  - redirecting number
  - redirection number
- presentation indicator (PI)
  - presentation allowed
  - presentation restricted
  - number not avail (due interworking)
- type of number (TON)
  - unknown
  - subscriber number
  - national number
  - international number
- screening indicator (SI)
  - user provided, not screened
  - user provided, verified and passed
  - network provided
- nature of address indicator (NAI)
  - subscriber number
  - national significant number
  - international number
- screening indicator (SI)
  - user provided, verified and passed
  - network provided

Number portability

- started with number portability within a SPC switch
- Local number portability
  - portability within a region
  - keeping the same provider
- Service Provider Portability
  - changing the service provider
  - geographic number portability within region
  - mobile number portability
  - service number portability
    - (one IN dip for SP, the second IN-dip for the service)
- Raises the question of the number holder
- Global number portability?

Numbering from Addressing to Naming

- Within local step-by-step systems the number dialed was equivalent 1:1 to the physical addresses of the phone line
- This was also the case with the first trunk codes, but very soon the dialed trunk codes where translated by registers.
  - Different numbers where used for routing (addressing)
  - But there was still a strict hierarchy CC, NDC(TC), office code (OFC) and subscriber number (SN)
- With the introduction of SPC systems and IN-services this hierarchy was dissolved from bottom to top
  - Within a central office, physical addresses of lines and trunk where independent of numbers, so people could move around keeping their numbers within an central office.
  - As a next step, with the introduction of IN-services and local number portability they could move around within a region.
  - National service numbers could move around anywhere in the country
  - International service numberss could terminate anywhere in the world.
- Now with global Internet technology any E.164 number could in principle terminate anywhere in the world.
  - How this can be achieved with ENUM and
  - if this makes sense for all types of numbers will be discussed in part II

Telephone Development

- Operator System
  - service logic by humans
- Plain Old Telephone Service (POTS)
  - service logic hardwired into the system
- Stored Program Controlled (SPC)
  - service logic by software
  - not modular; service interaction a problem
- Common Channel Signaling (CCS 7)
  - separation of signaling and transport
  - independent packet network
- Intelligent Network (IN)
  - external service logic
  - freephone, calling card service, VPNs, number portability
- The raise of the stupid network (IP)
  - migration of transport, signaling and service logic to the Internet
  - transport in the core, signaling and service logic to the edge

The End

Thank you for your attention