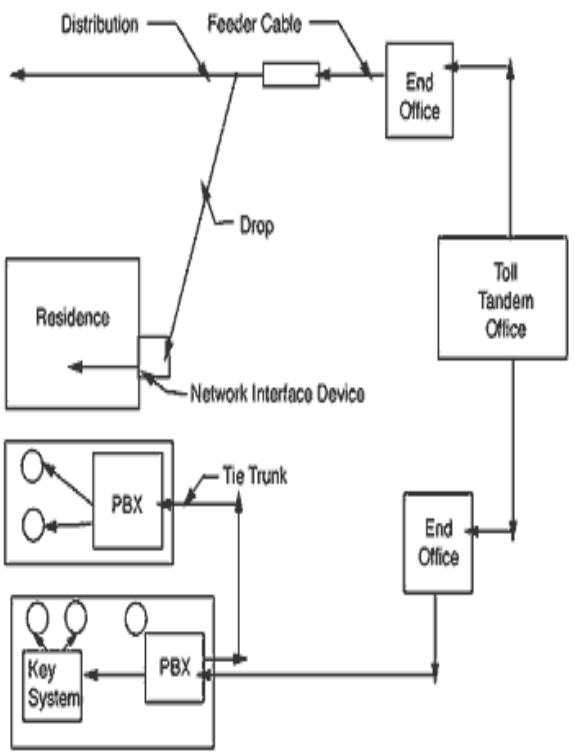
CISC452
Telecommunications Systems

Lesson 5
Switching, SS7 and the Intelligent Network

Public Switched Telephone Network (PSTN)

- **Traffic over a major "highway" system**
- **PSTN constructed by AT&T's research division, Bell Labs, by standardized transfer methods and central office switches**

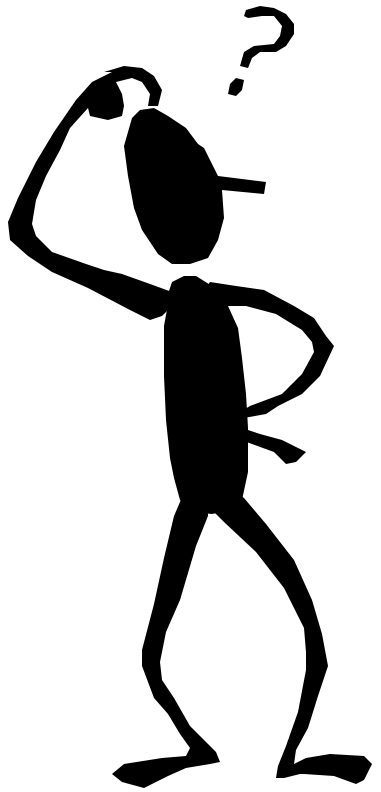


Switching

? (*definition*) **"The establishment on demand, of an individual connection from a desired inlet to a desired outlet within a set of inlets and outlets for as long as is required for the transfer of information."**

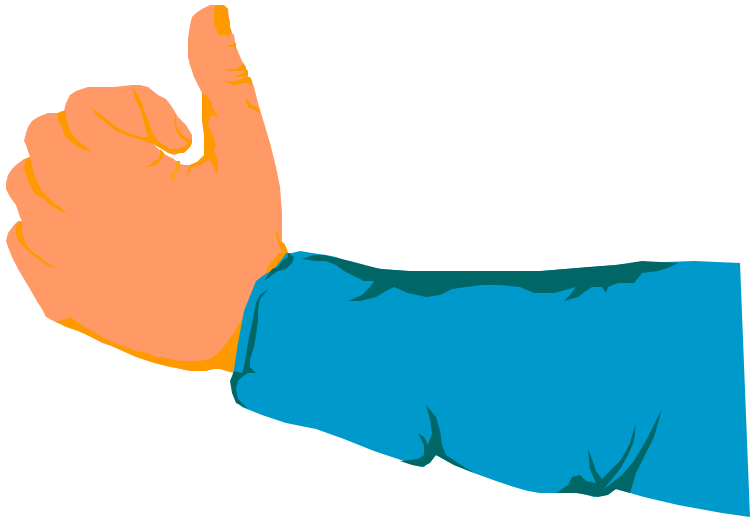
Switching...

? **“The establishment on demand, of an individual connection from a desired inlet to a desired outlet within a set of inlets and outlets for as long as is required for the transfer of information.”**



Switching

? **(*definition*) What goes in, comes out, for as long as desired from within the network until one party hangs up**



Intro to Switching

? **A switch routes a call based on a number system**

e.g 1 302 369 6923

access code

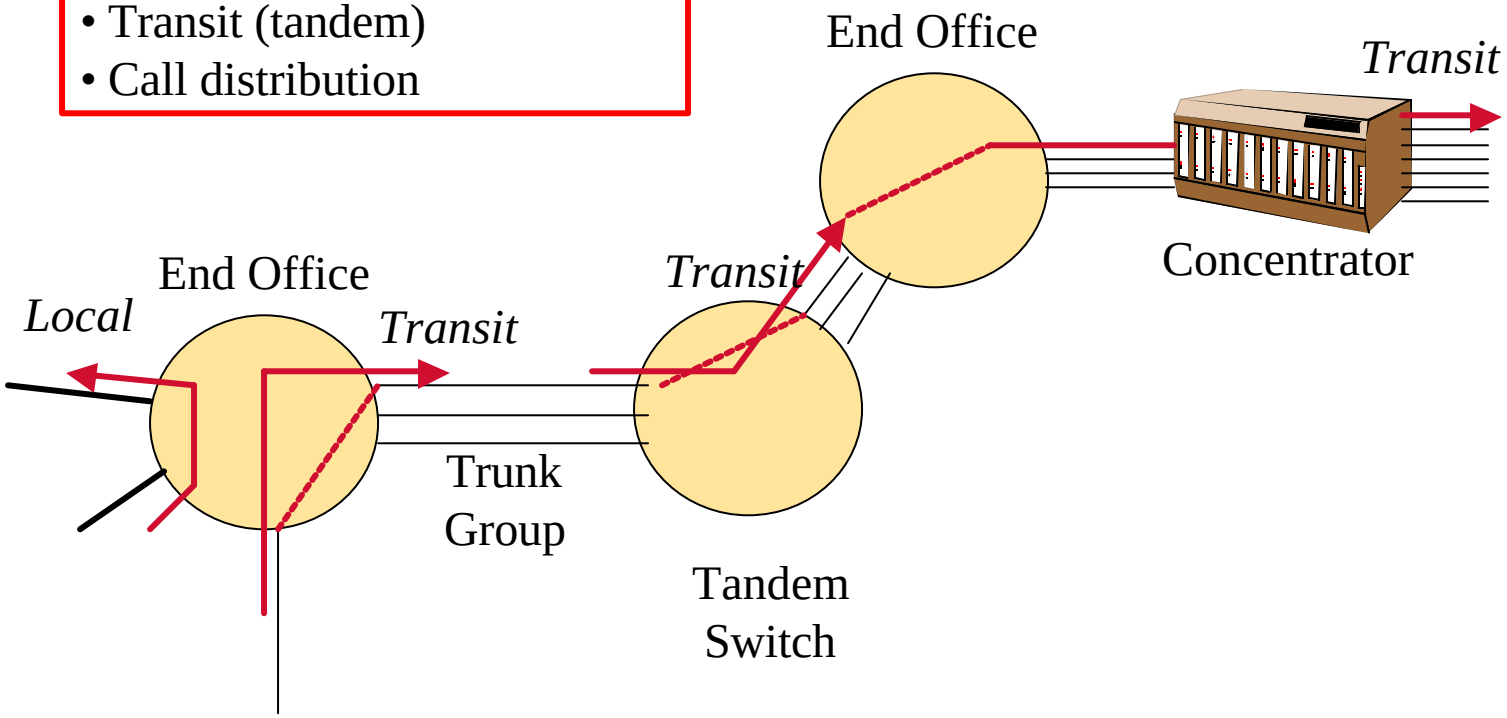
area code

exchange code

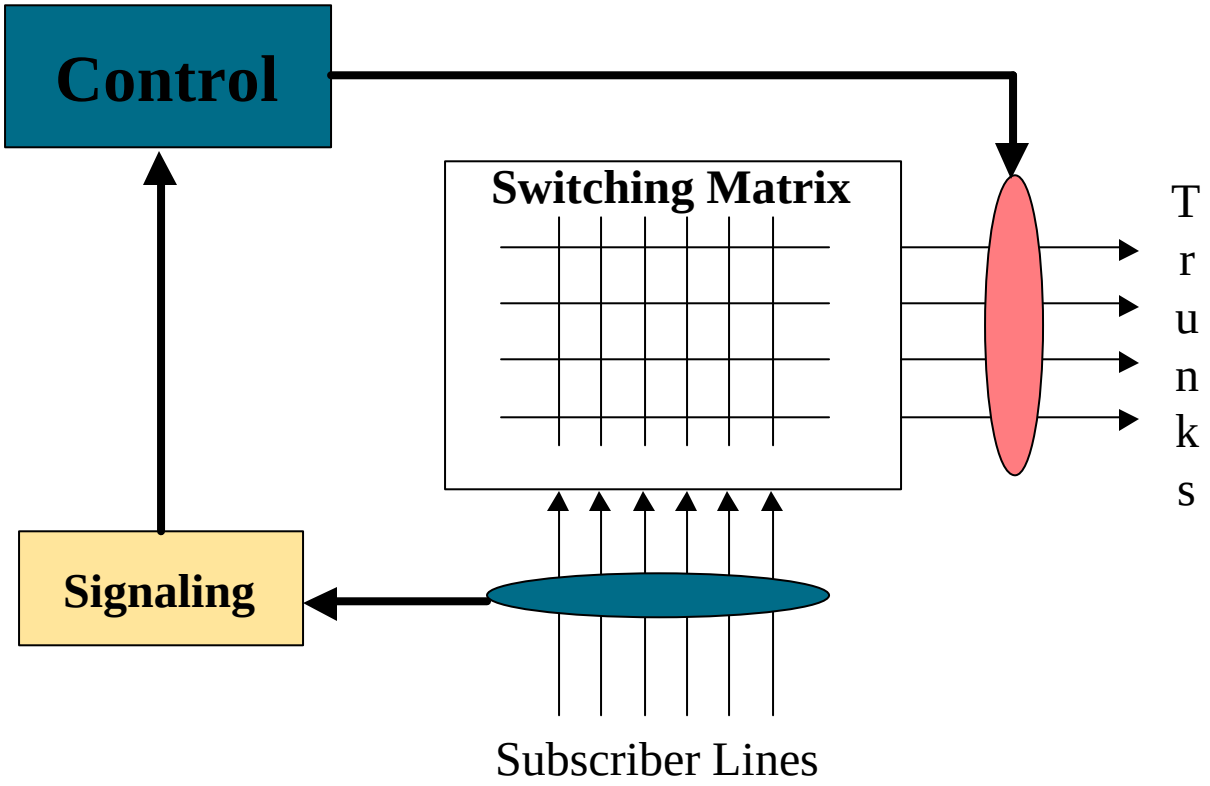
subscriber code

Intro to Switching

- Local (line-to-line) switching
- Transit (tandem)
- Call distribution



Switching System



Essential Switch Functions

- Interconnection
- Control
- Alerting
- Attending
- Information receiving
- Information sending
- Busy Testing
- Supervising

Functions of Switching Systems

- **Signaling**
  - monitor line activity
  - send incoming information to control function
  - send control signals to outgoing lines
- **Control**
  - process signaling and set-up/knock down connections
- **Switching**
  - make connections between input and output lines

Basic Switch Requirements

- A switch must be able to connect any incoming call to one of a multitude of outgoing calls
- A switch must have the ability to hold and terminate calls
- A switch has to prevent new calls from intruding into circuits already in use

General Switch Requirements

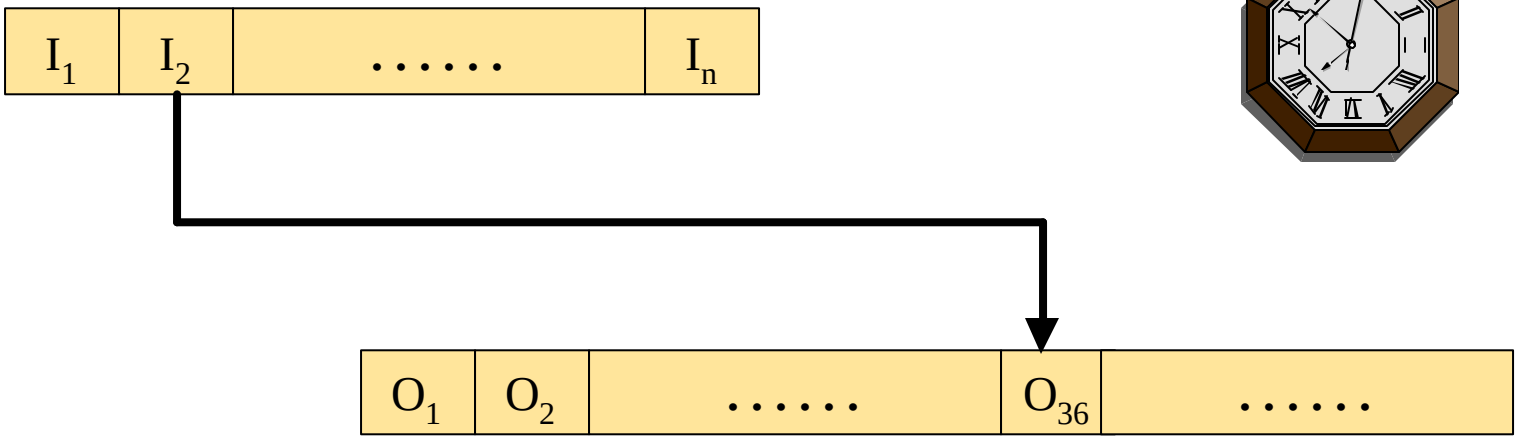
- **Speed of call setup should be kept short relative to the call holding time**
- **Grade of service should be high**
  - **.99 overall**
  - **.95 busy-hour**
- **HIGH availability!**

Switching Methods

- **Connectivity**
  - **Full: any input to any output**
- **Blocking**
  - **Blocking: Possibility exists that call setup may fail due to insufficient switching resources**
  - **Non-blocking: If any input I_j and output O_j are free, they can be connected**

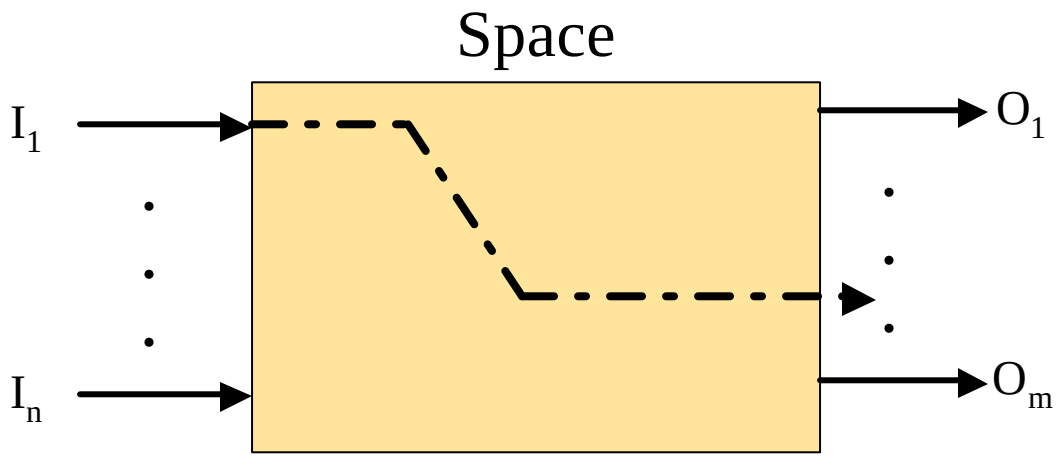
Time Division Switching

? **Time mapping of inputs and outputs**

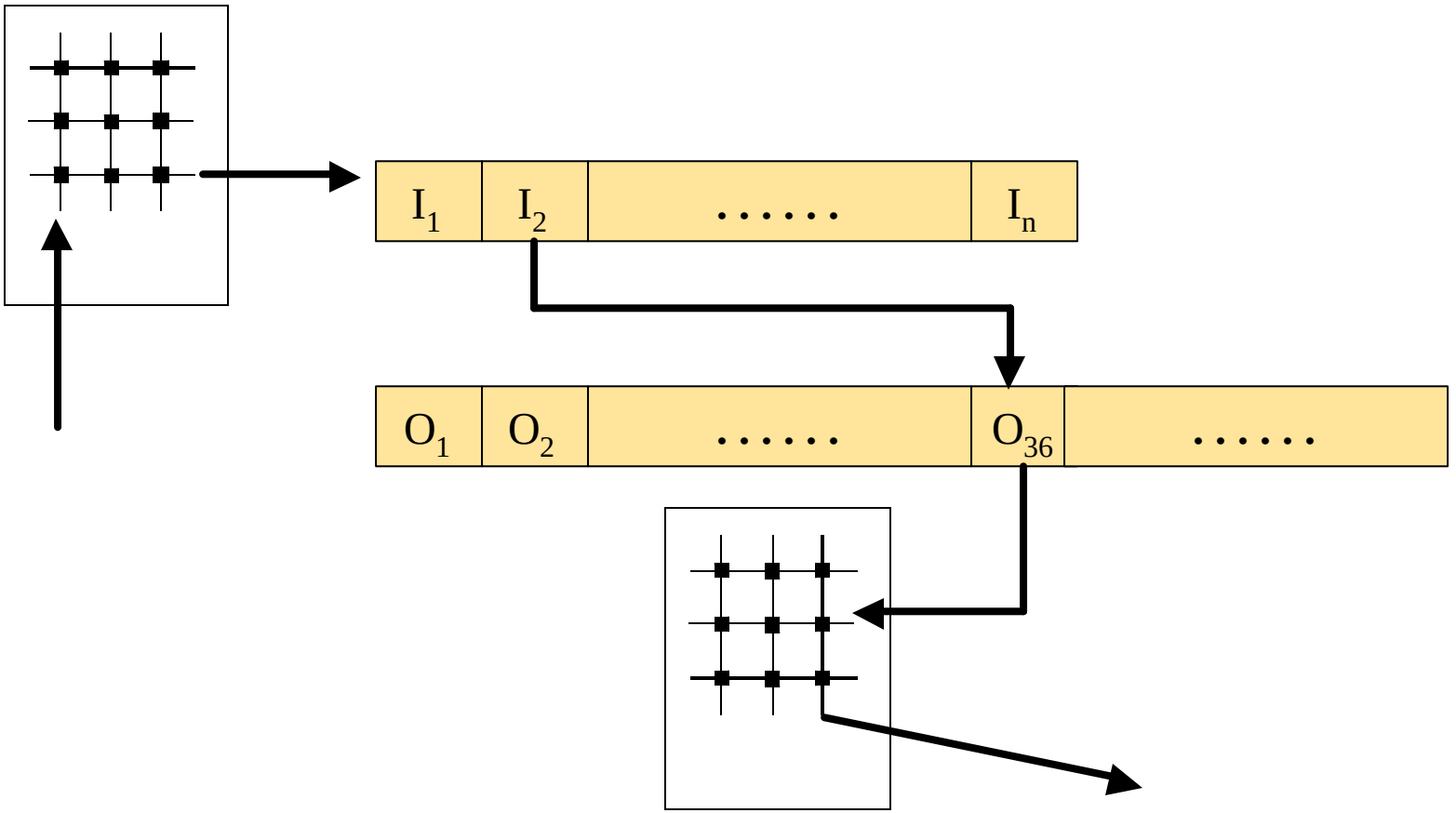


Space Division Switching

- **Spatial mapping of inputs and outputs**
  - **Used primarily in analog switching systems**

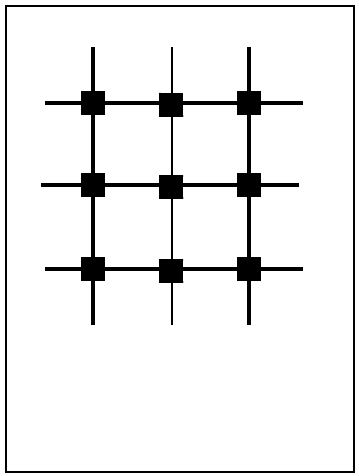


Space-Time-Space Switching



Single Stage Switches

- **Crosspoint switches**
  - **Complex - many crosspoints ($i \times j$)**
  - **Poor utilization of crosspoints**
  - **Not fault tolerant**

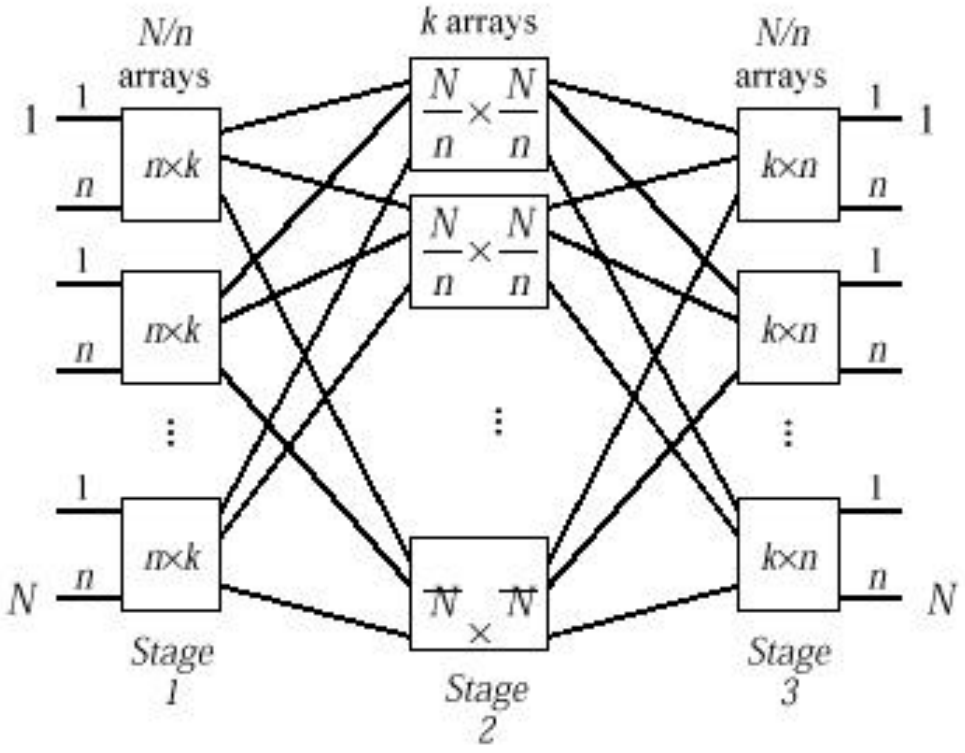


Multiple Stage Switches

- Input connected to output via two or more smaller switches
- Crosspoints shared by several possible connections (potential for blocking)
- Possible to provide multiple paths between any 2 ports

Three Stage Switch Matrix

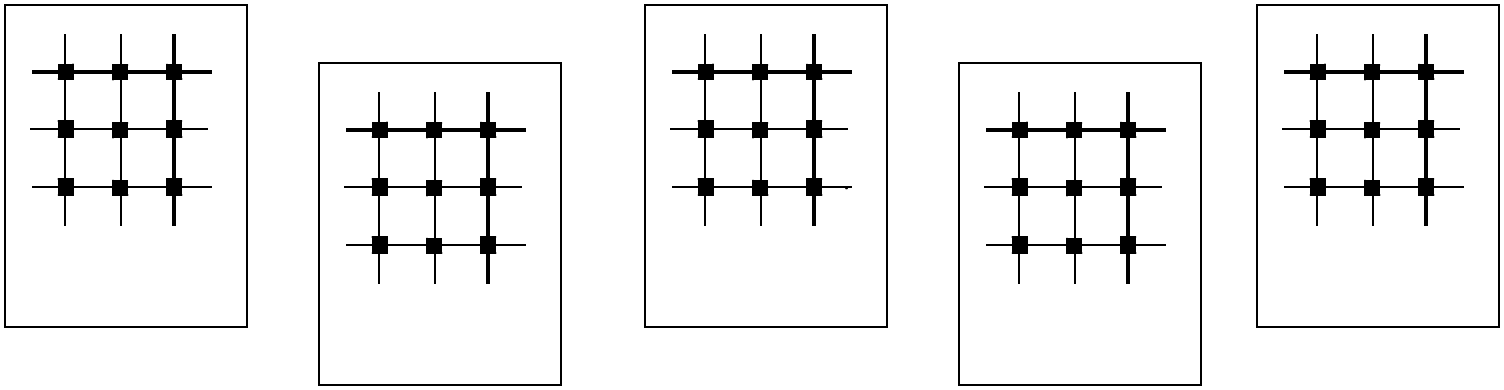
(Multiple Stage Switch example)



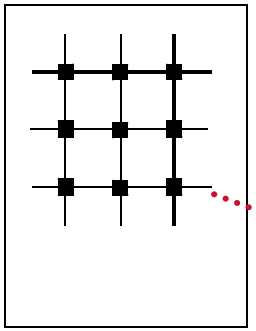
$N_x = 2(N/n)(nk) + k(N/n)^2 = 2Nk + k(N/n)^2$ crosspoints

Reducing Cross-point Complexity

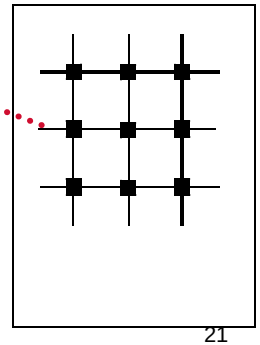
- Increase number of stages
- Allow some blocking
- Switch in more than one dimension



Number of Cross-points Non-blocking Switch



Nbr of Lines	3-Stage	1-Stage
128	7,680	16,256
512	63,488	261,635
2K	516,096	4.2M
8K	4.2M	67M
32K	33M	1B
128K	268M	17B



Digital Switching

- **Most of the switching in US is digital, why?**
  - **Transmission is digital**
  - **Maintenance of signal quality**
  - **Leverage improvements in density of Integrated Circuits**
  - **Advanced features and services through software**
  - **Integration of voice/data services**

Signaling

- (*definition*) **The exchange of information between call components required to provide and maintain service**
- (*examples*) **Dialing digits, providing dial tone, accessing voice mail, sending a call waiting tone, *69, etc.**

Functions of Signaling

- **Supervisory Signaling**
- **Address Signaling**
- **Call Progress Signaling**

Supervisory Signaling

- Provides information on line or circuit condition
- “It [signaling] informs a switch whether a circuit (internal to switch) or a trunk (external to switch) is busy or idle; a called party is off-hook or on-hook…”

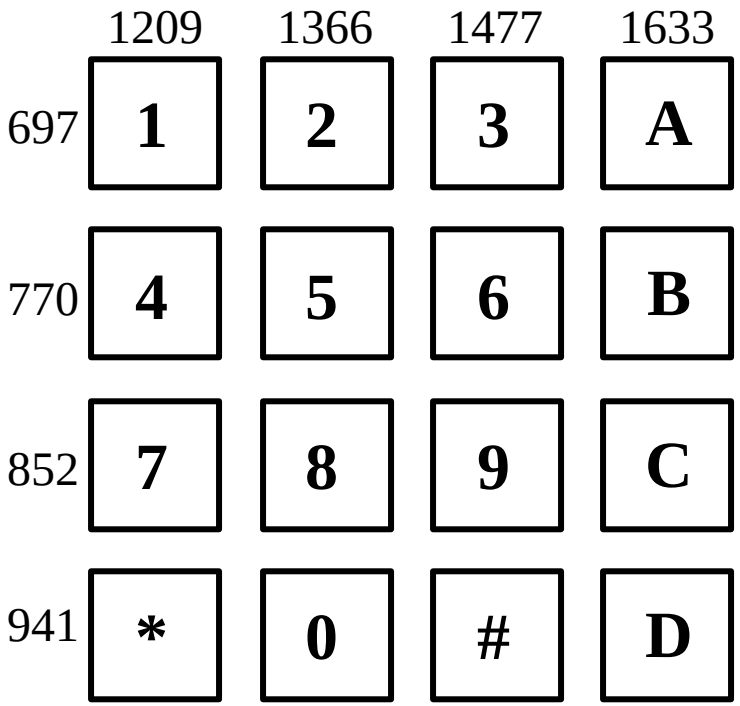
Supervisory Signals (cont'd)

- **Some supervisory signals:**
  - **Request for service -** off-hook
  - **Ready to receive address -** dial tone
  - **Call alerting -** ringing
  - **Call termination -** on-hook
  - **Request for operator -** hook-switch flash
  - **Called party station ringing -** ring back
  - **Network/called station busy -** busy tone

Address Signaling

- **Directs and routes a telephone call to the called subscriber**
- **If there is more than one switch involved in the call setup, signaling is required between switches (*interregister switching)***

Address Signaling: DTMF Signaling(dual tone multi frequency)



Call-Progress Signaling
(Audible - Visible)

- **Categorized by audio/visual signals sent in a forward and backward direction**
- **Forward Direction: A signal sent to your phone which tells it to ring**

Call-Progress Signaling(cont'd)

(Audible - Visible)

? **Backward Signaling:**

Ringback - the distant telephone you are calling is ringing

Busyback - the called line is busy

ATB - All trunks are busy (sometimes a voice announcement is used)

Loud Warble - Telephone is off hook

Signaling Techniques

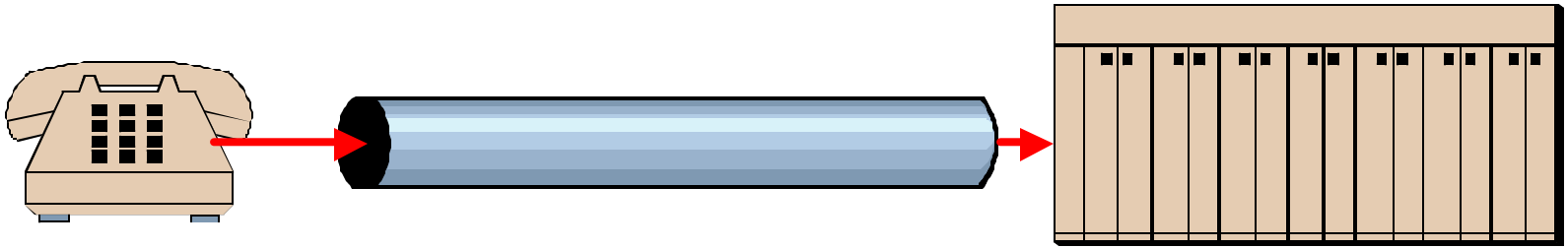
- In band signaling
- Out-of-band signaling
  - CCS signaling
- E&M signaling
- MF signaling

In - Band Signaling

- Signaling path = voice path
- Voice path clogged with signaling
- Busy calls, congestion, and “ring-no-answers” result in 20-35% of incomplete calls
- Slower call setup due to channel sharing

Signaling Techniques

? In-channel signaling



In-band

- SF Signaling (2600 Hz)
- MF Signaling
- DTMF Signaling

Out-of-band

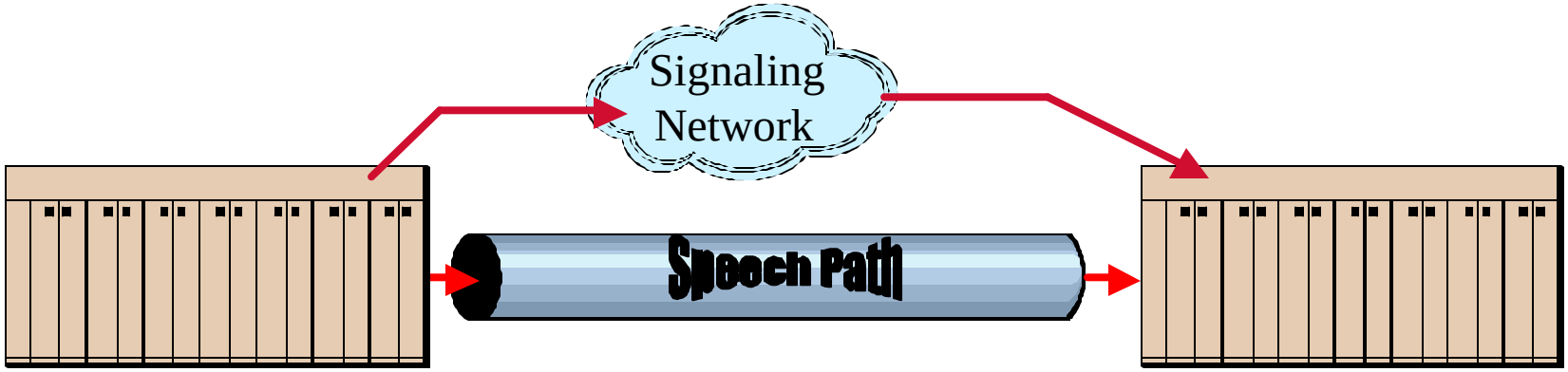
- DC Current (on-/off-hook
- Dial pulses (10 pps)
- 20 Hz Ringing voltage

Out - of - Band Signaling

- Signaling path done on a separate channel
- Voice path dedicated only to voice
- Much faster call setup and knockdown
- Led to SS7 and AIN

Signaling Techniques

? Common Channel Signaling (CCS)



Dedicated data link between systems

- Trunk group associated
- Trunk group disassociated

Advantages of CCS

- One signaling path needed per trunk group
- Faster and simpler to transfer information between control processors
- No possibility of interference with speech path
- Signaling can’t be accessed by customer

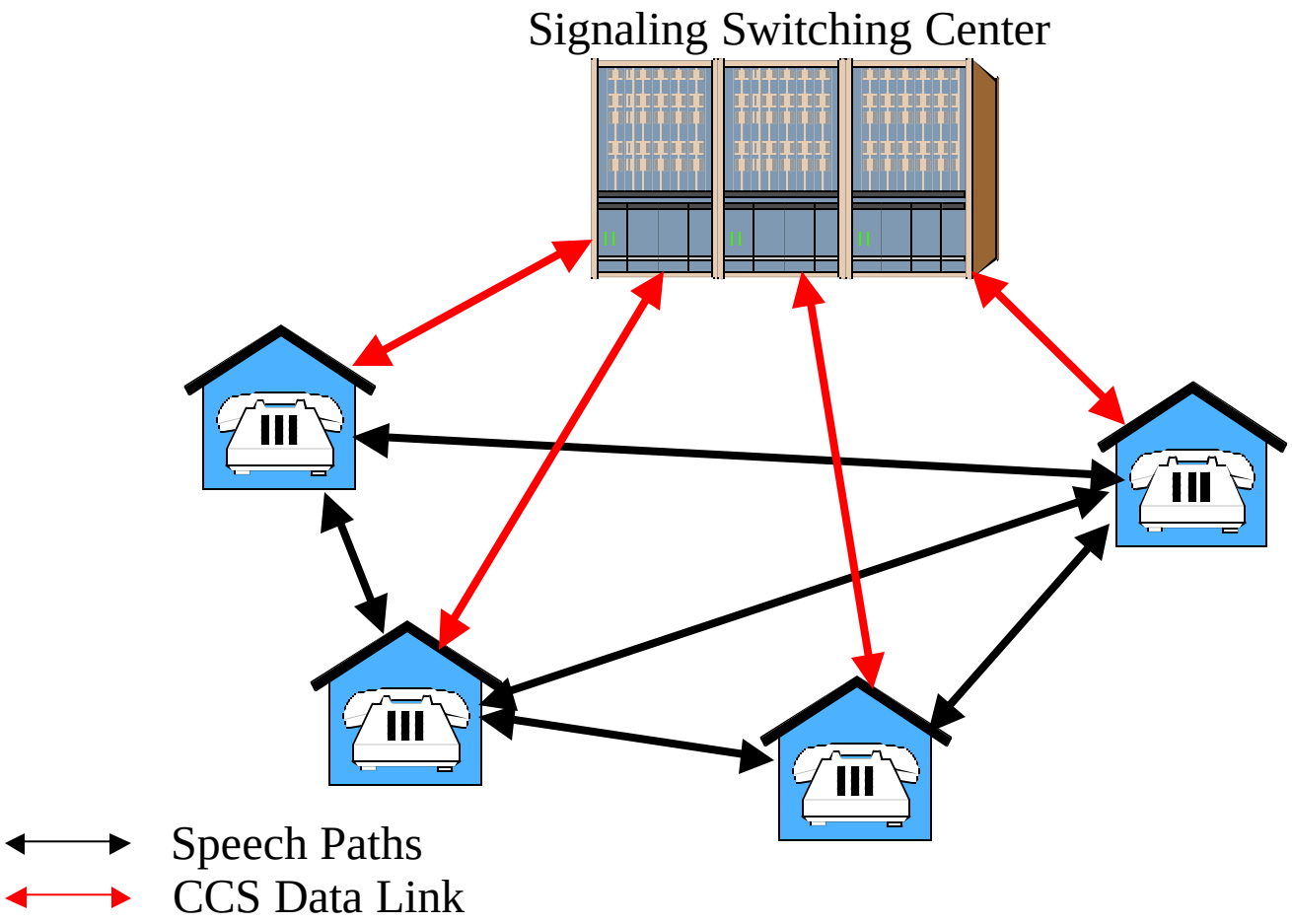
Advantages of CCS

- **Value-added services of a signaling control point**
  - **Shared processing for small offices**
  - **Allows centralized decision making (flow mgmt)**
  - **Permits Advanced Intelligent Network (AIN) services**

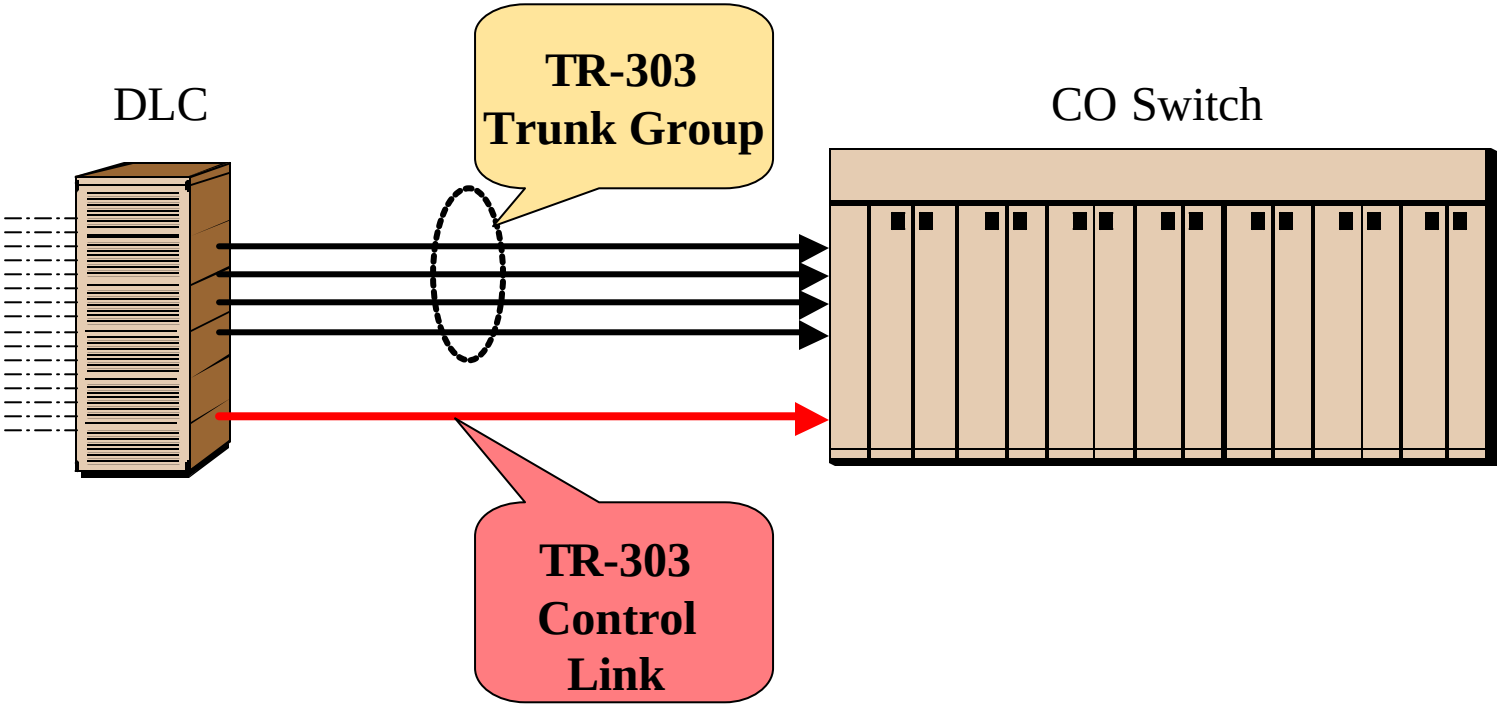
Disadvantages of CCS

- CCS links can be a single point of failure
- No inherent testing of speech path by call setup signaling
- CCS response time is critical

Trunk Group *Disassociated* CCS



Trunk Group *Associated* CCS



E&M Signaling

- **Used mostly for trunk supervision on an analog network**
- **E-lead: carries signals <u>to</u> the switching equipment**
- **M-lead: carries signals <u>away</u> from the switching equipment**

E&M Example

Direction		Condition at A		Condition at B	
Signal A to B	Signal B to A	M - Lead	E - Lead	M - Lead	E - Lead
On - Hook	On - Hook	Ground	Open	Ground	Open
Off - Hook	On - Hook	Battery	Open	Ground	Ground
On - Hook	Off - Hook	Ground	Ground	Battery	Open
Off - Hook	Off - Hook	Battery	Ground	Battery	Ground

MF Signaling

- **Used primarily for interregister signaling**
  - **R 1 System**
  - **CCITT No. 5 Signaling Code**
  - **R 2 System Code**

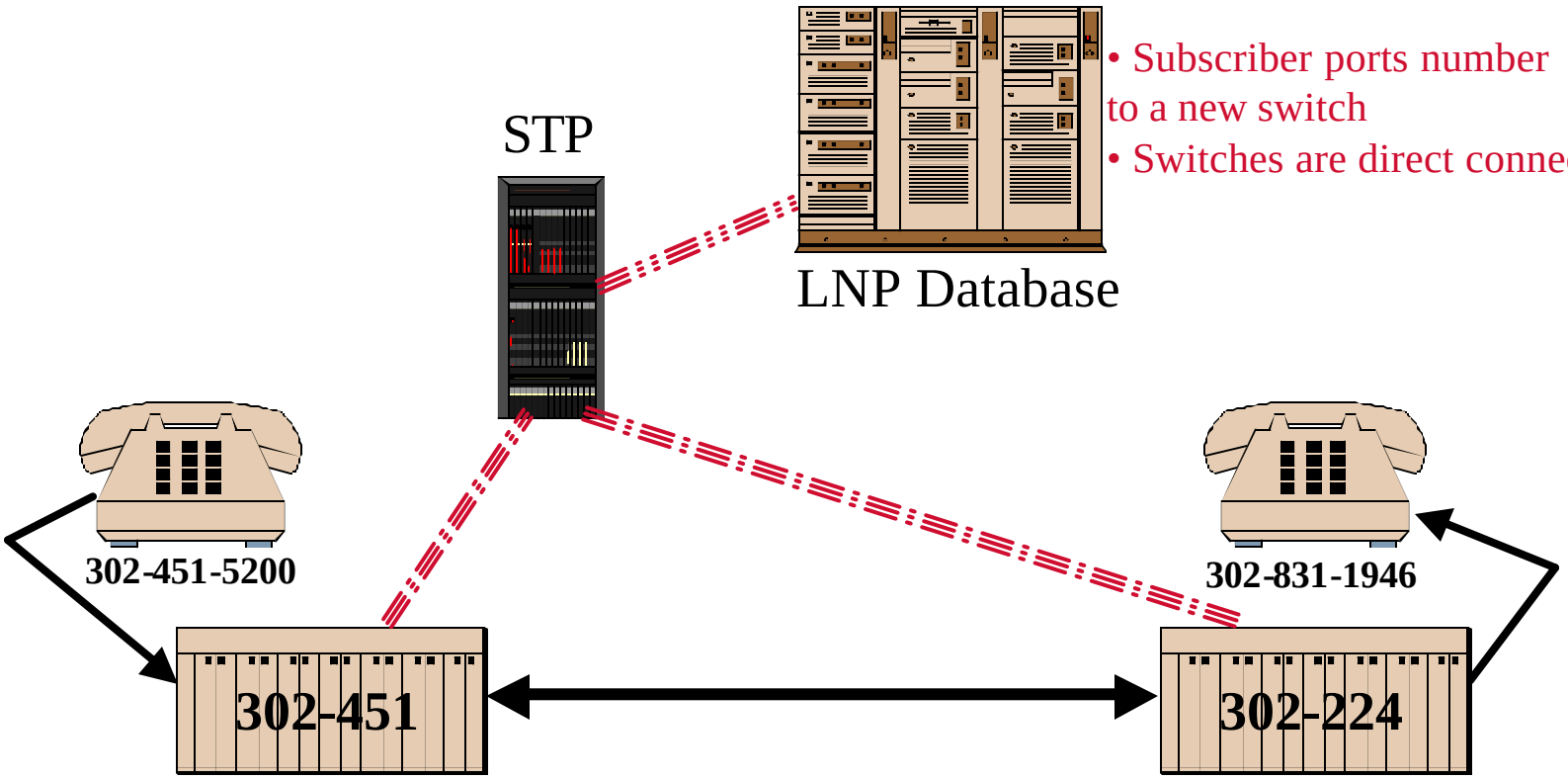
Signaling/Switching Dependence

? **Signaling and Switching are closely tied. Signaling allows switching to automate the network.**

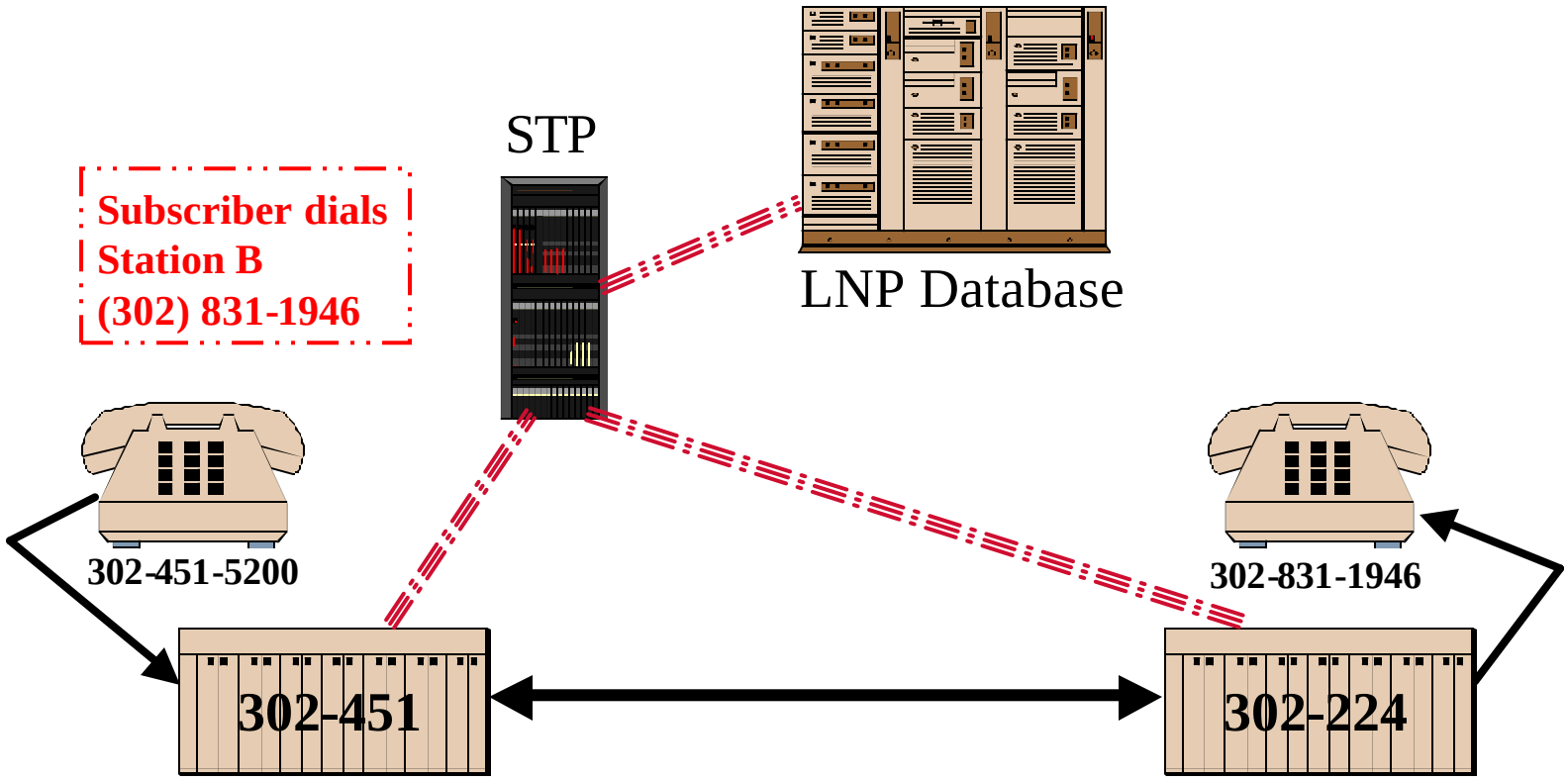
Call Processing - Local Call

- Detect off-hook condition
- Send dial-tone to calling station
- Collect dialed digits
- Translate digits to a called number
- Route call
- Prepare connection between stations
- Send ring voltage to called station / ring-back tone to calling station
- Detect off-hook by called station and cut-through the call
- Detect disconnect and terminate call

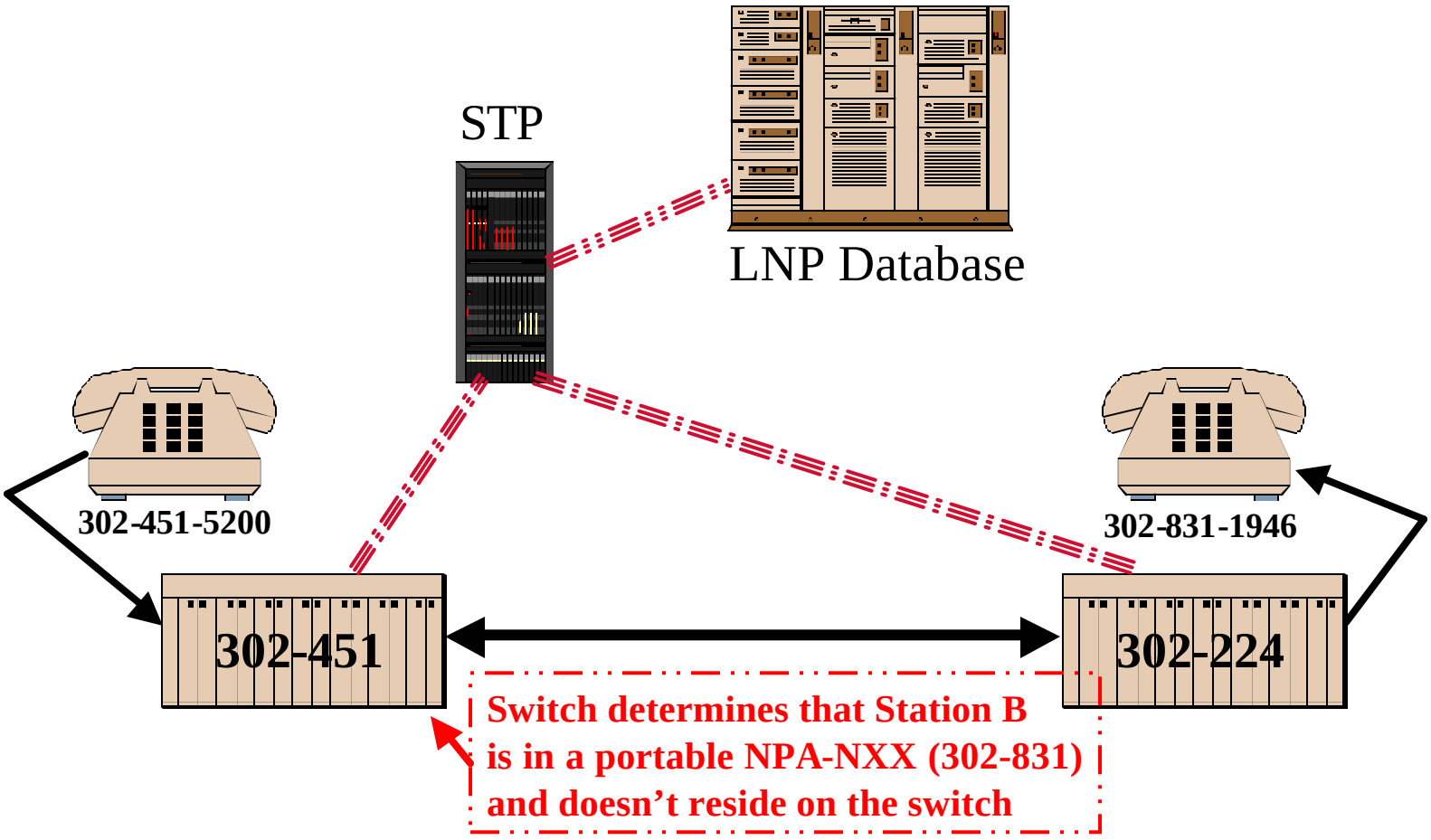
Call Flow - Common Case



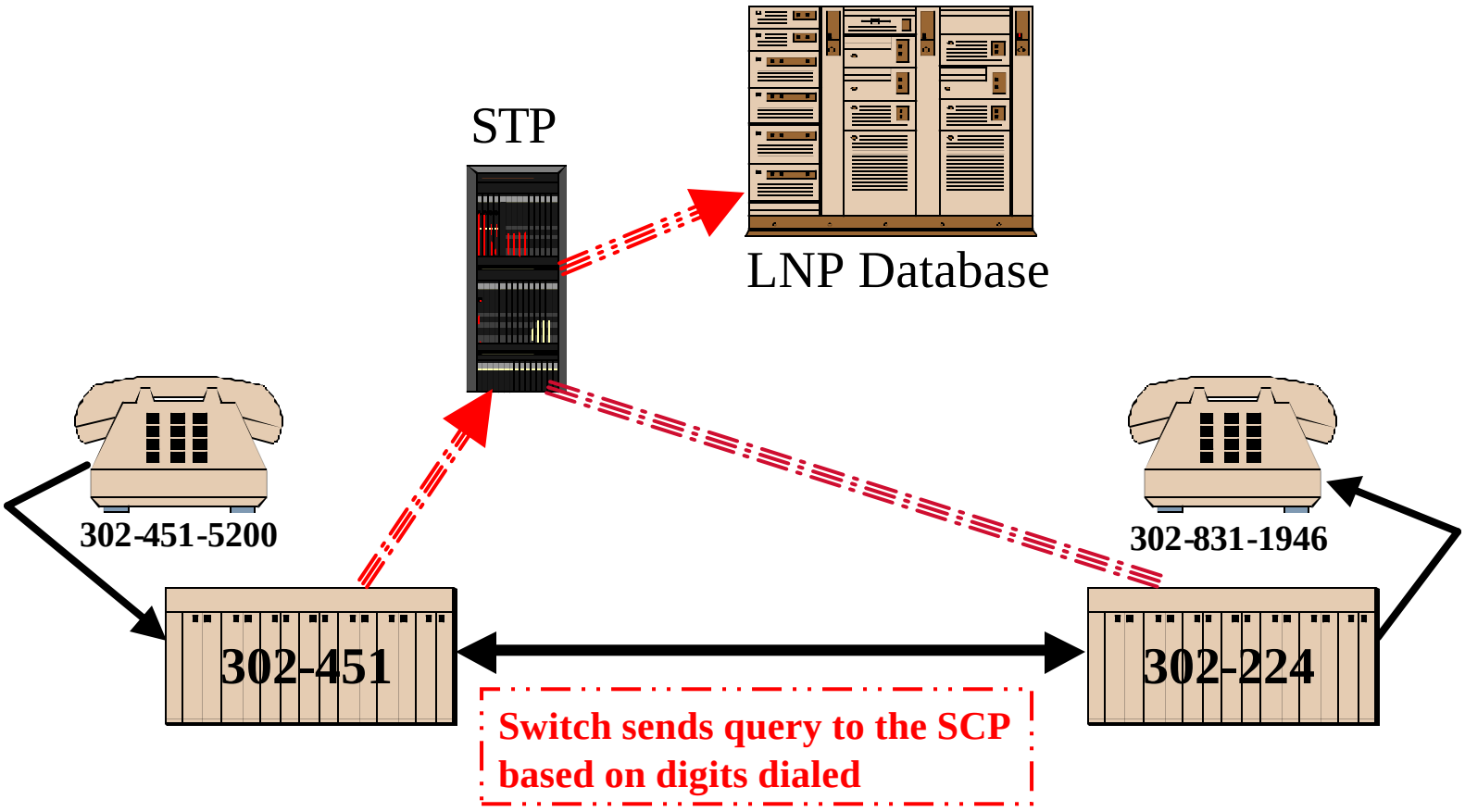
Call Processing (1)



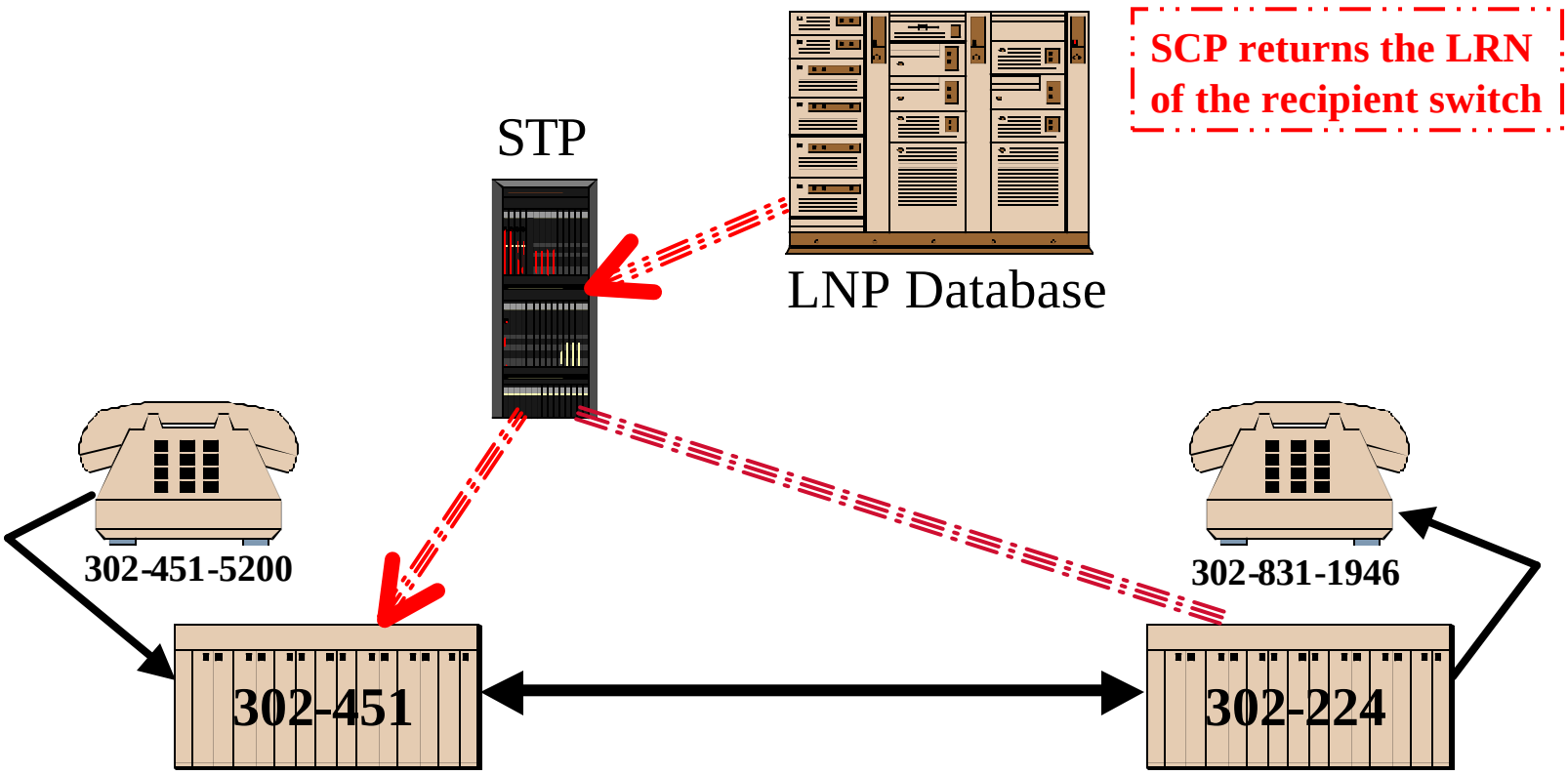
Call Processing (2)



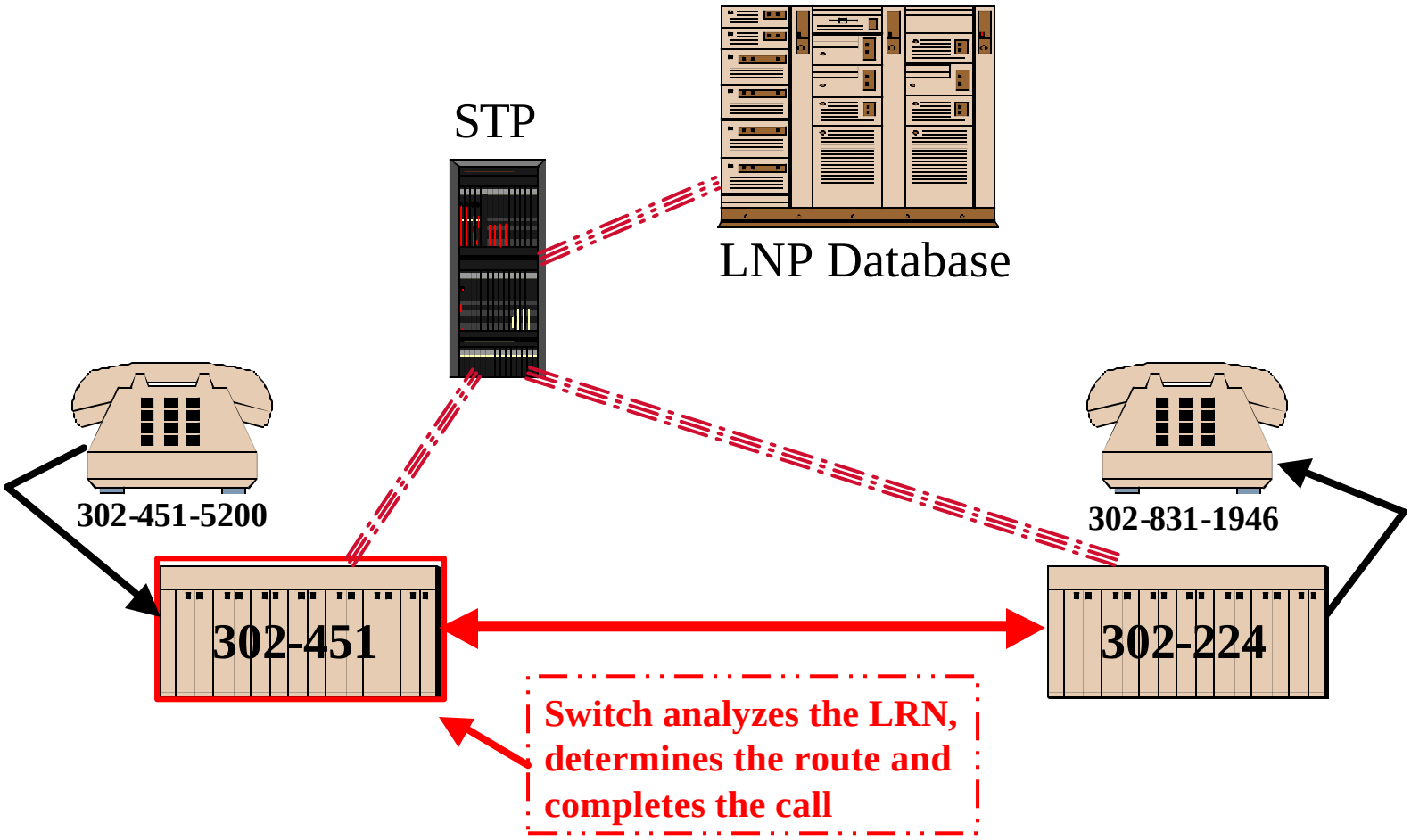
Call Processing (3)



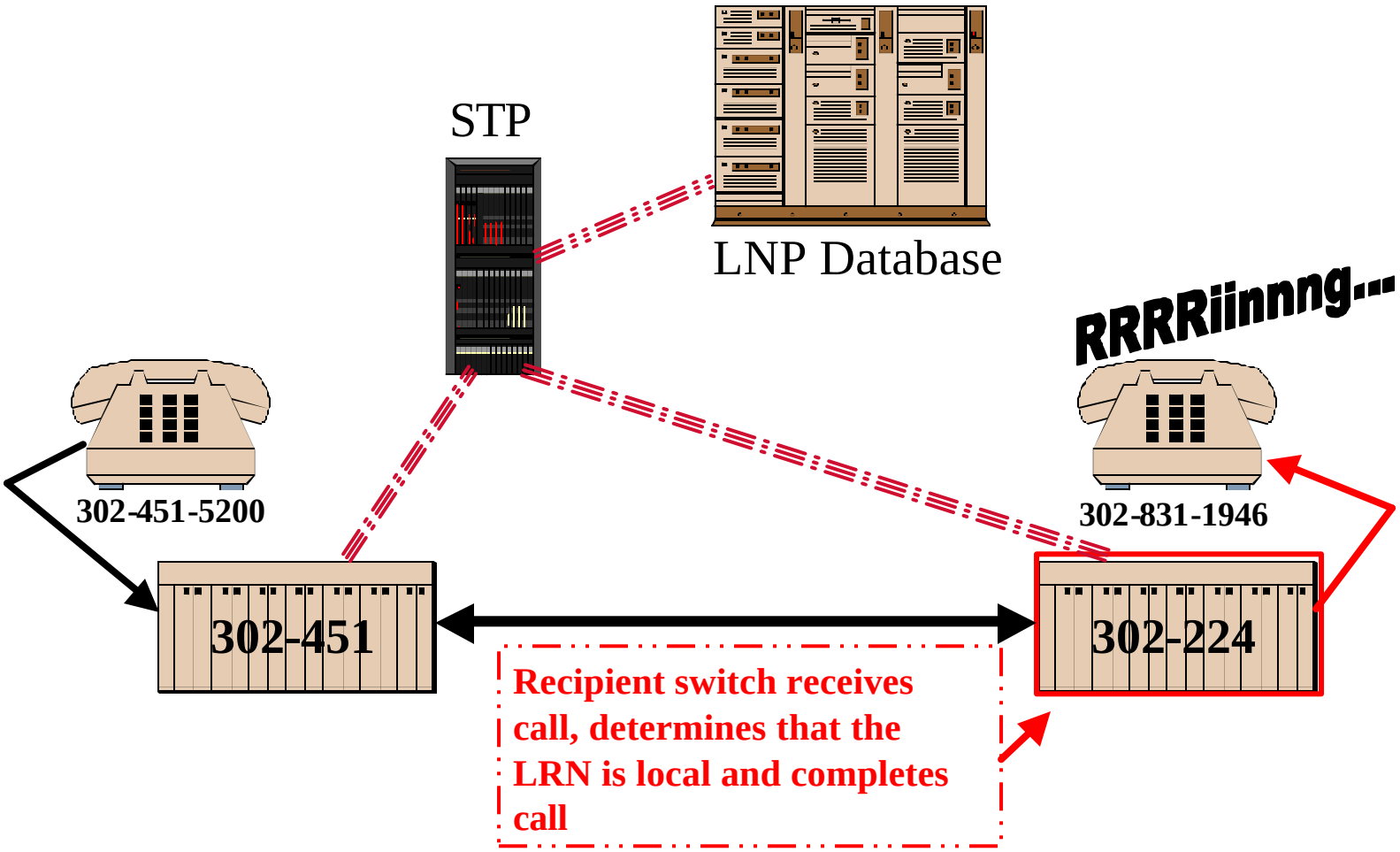
Call Processing (4)



Call Processing (5)



Call Processing (6)



Progression of Technology

- **Electromechanical Switches**
  - **crossbar, step-by-step**
- **SPC with relays**
  - **AT&T/Lucent 1A ESS**

- **SPC with electronic switches**
  - **AT&T/Lucent 4 ESS**
- **Digital**

NORTEL

  - **AT&T/Lucent 5 ESS, Nortel DMSx00**

A typical CO…way back

Early Switch Technology

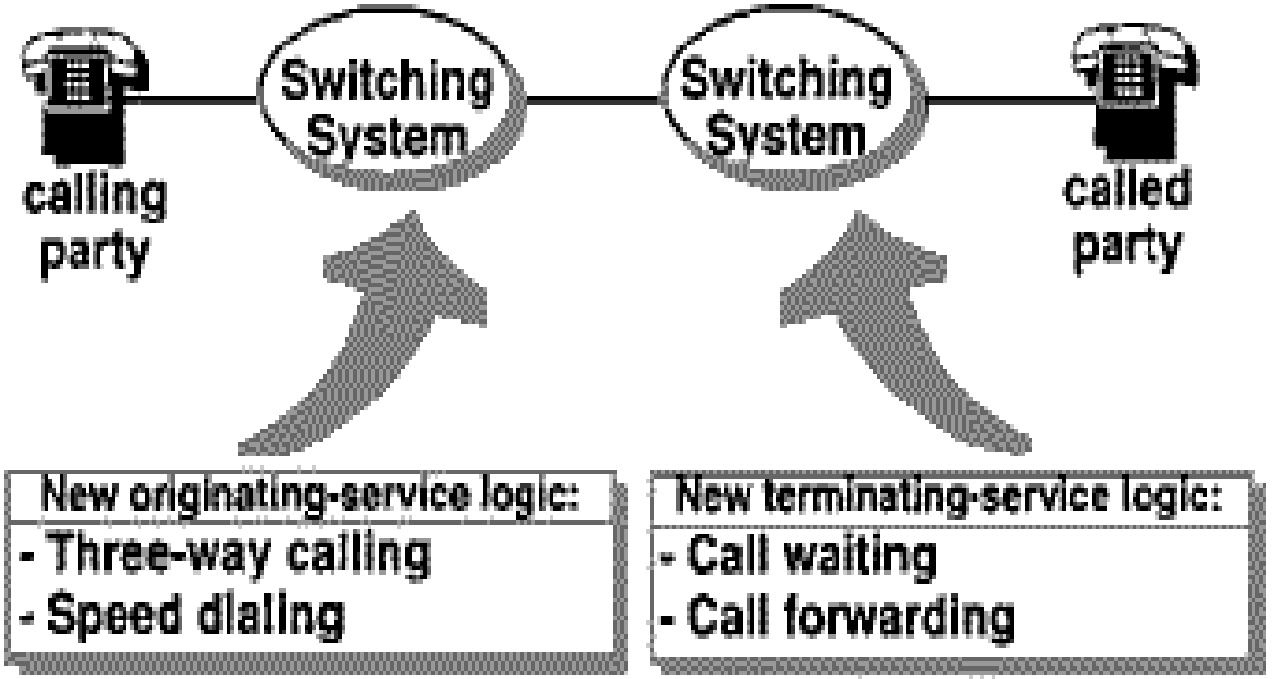
"(snort) Here at the Phone Company we handle eighty four billion calls a year. Serving everyone from presidents and kings to scum of the earth. (snort) We realize that every so often you can't get an operator, for no apparent reason your phone goes out of order [plucks plug out of switchboard], or perhaps you get charged for a call you didn't make. We don't care.

Watch this -- [bangs on a switch panel like a cheap piano] just lost Peoria. (snort) You see, this phone system consists of a multibillion-dollar matrix of space-age technology that is so sophisticated, even we can't handle it. But that's your problem, isn't it ? Next time you complain about your phone service, why don't you try using two Dixie cups with a string. We don't care. We don't have to. (snort) We're the Phone Company."

Lily (Ernestine) Tomlin on Saturday Night Live

The OLD Way…

Plain Old Telephone Service (POTS)



How Did POTS work?

- All switching logic had to be “hard-wired”
- Analog transmission
- Pre-1960’s technology
- In - band signaling

Technology Limitations

- **Switching systems were not easily scalable because changes had to be implemented in Hardware**
- **As systems were upgraded, services were not the same in all areas**
- **The existing technology was not able to handle the changing needs of callers**

Technology Limitations(cont'd)

? **As modems became popular the nature of calls changing from voice to data put a strain on the analog switches due to the variation in the length of calls. Data calls tend to be much longer than voice calls.**

Something About Digital...

? **“The North American PSTN will be entirely digital by the year 2000”**

- Roger Freeman

SS7

- **Signaling System No. 7 takes a whole new (digital) approach to signaling. With the new approach comes great functionality and better service.**

SS7 Requirements

- Optimized for operation with digital (ISDN) networks
- can meet present and future requirements for information transfer for inter processor transactions
- to provide a reliable means of information transfer in correct sequence and without loss or duplication

SS7 Signaling Links

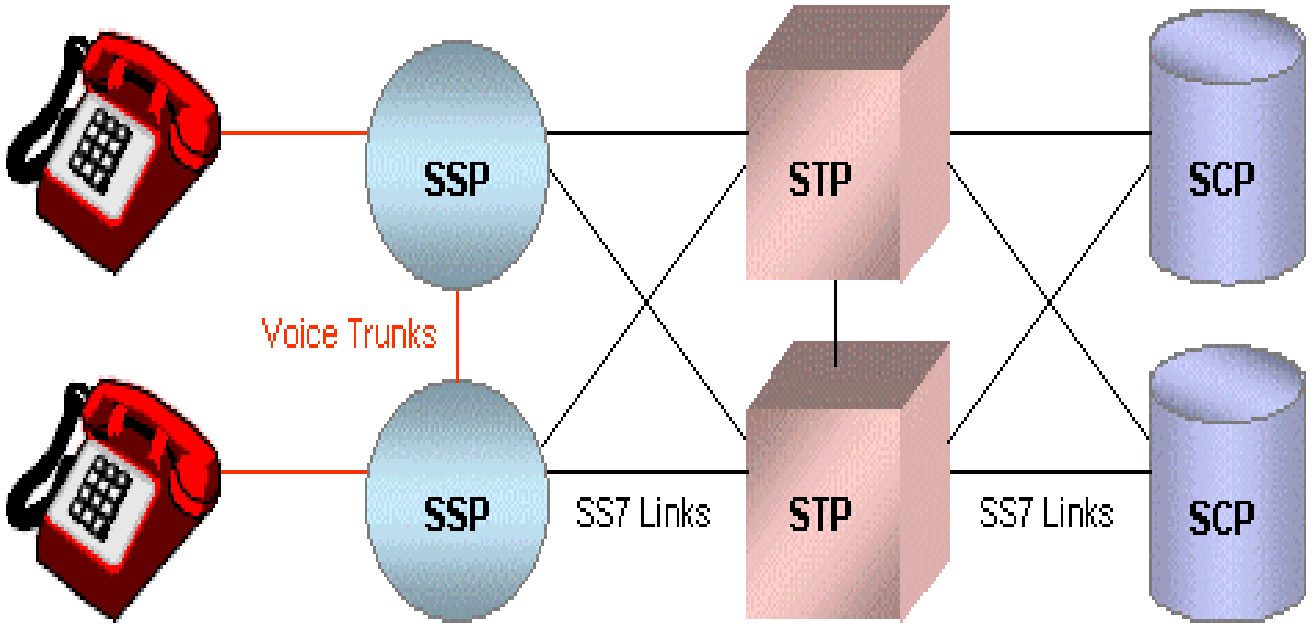
- Out of band signaling
- Messages exchanged over 56 or 64K bi-directional signaling links
- Supports services requiring database systems (IN)
- Allows for improved control over fraudulent network usage

SS7 Signaling Points

? **3 types of signaling points:**

1) **SSP(Service Switching Point)**
2) **STP(Signal Transfer Point)**
3) **Service Control Point**

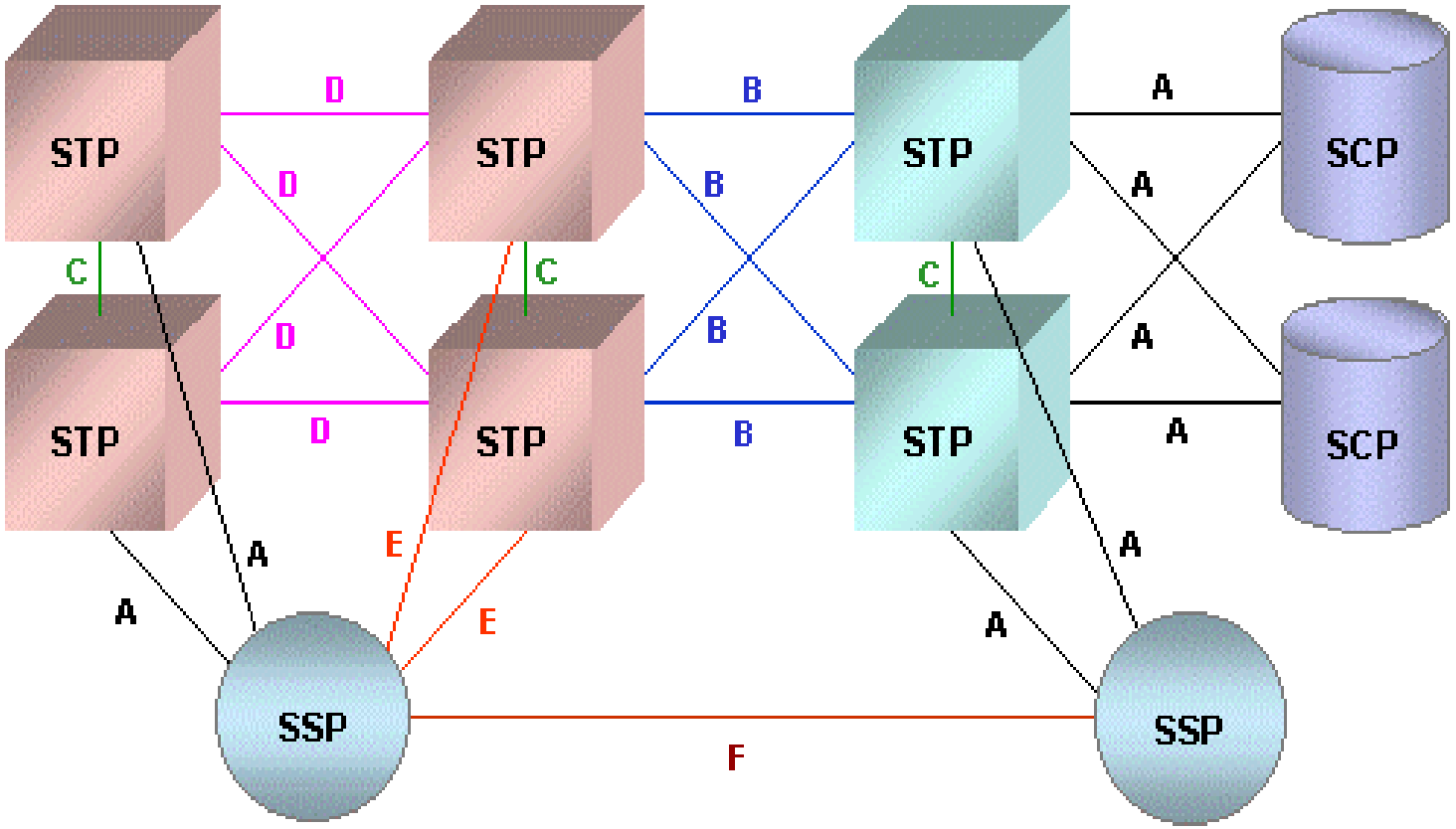
SS7 Signaling Points Diagram



Signaling Architecture Components

Component	Function
Signal Switching Points (SSP's)	SSP's are telephone switches (end offices or tandems) equipped with SS7-capable software and terminating signaling links. They generally originate, terminate, or switch calls.
Signal Transfer Points (STP's)	STP's are the packet switches of the SS7 network. The receive and route incoming signaling messages towards the proper destination. They also perform specialized routing functions.
Signal Control Points (SCP's)	SCP's are databases that provide information necessary for advanced call-processing capabilities

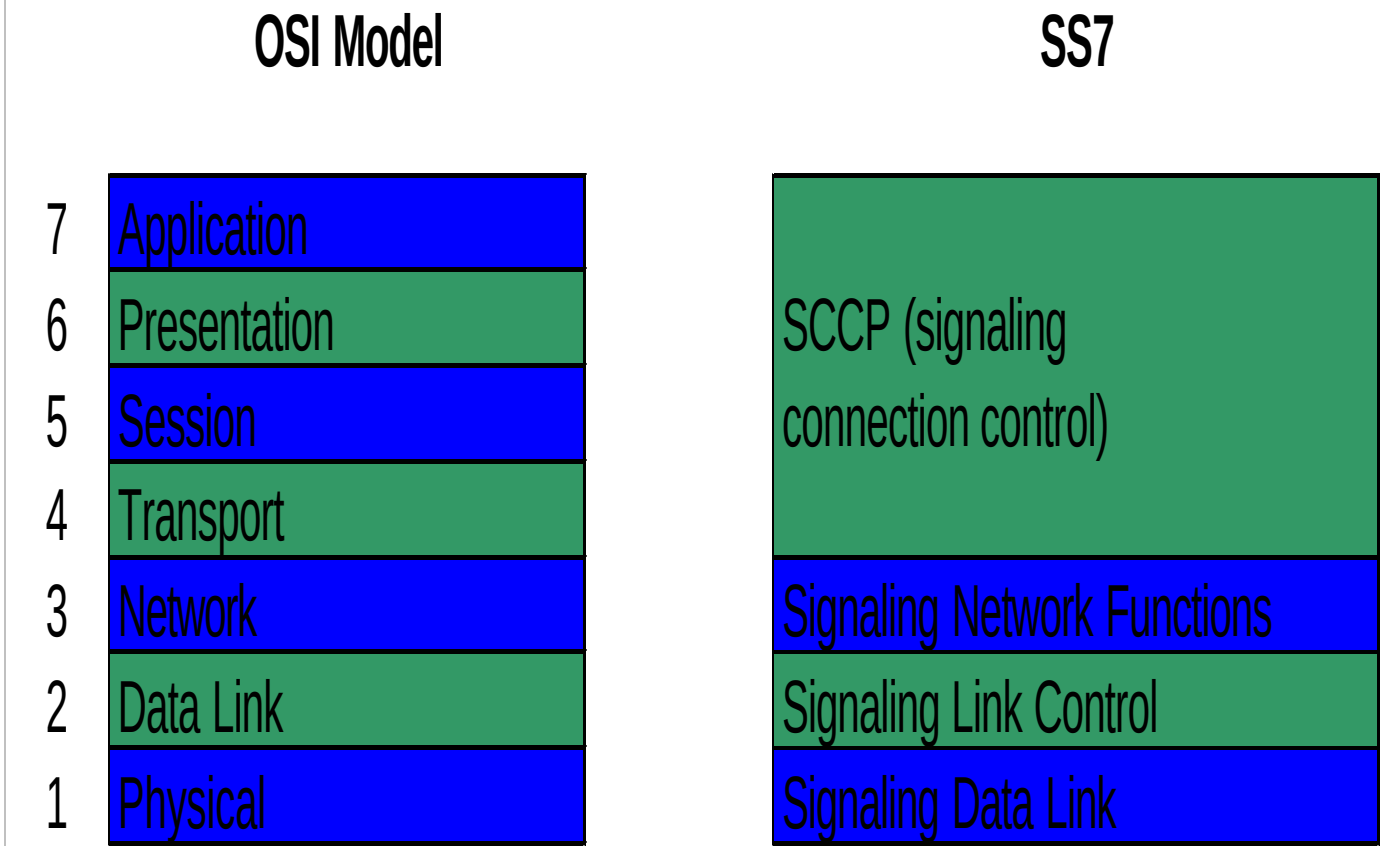
SS7 Signaling Links



SS7 Link Types

- **“A” Link: An *access* link connects a SSP or SCP to an STP.**
- **“B” Link: A *bridge* link connects an STP to another STP.**
- **“C” Link: A *cross* link connects two “mated pair” STP. This is done to improve reliability**
- **“D” Link: A *diagonal* links similarly to a B link**
- **“E” Link: An *extended* link connects an SSP to an extra STP in the event that the A link cannot reach one.**
- **“F” Link: A *fully associated* link connects SSP’s**

SS7 Relationship to OSI



SS7 Data-Link Layer (Layer 1)

- Physical layer in OSI
- Two bi-directional transmission paths for signaling
- Two data channels running in opposite directions at same date rate (usually 56-64K)

SS7 Signal Link Layer (Layer 2)

- Signal unit alignment and delimitation
- Error detection
- Error correction (preventive cyclic retransmission method)
- Flow Control

SS7 Signal Units

- **Signaling units come in three types**
  1) **MSU (message signal unit) - carries signaling information**
  2) **LSSU (link station signal unit) - carries the link status information**
  3) **FISU (Fill-in signal unit) - fills in idle time**

SS7 Network Functions (Layer 3)

? **Message-handling functions**

*** message routing: used at each signaling point to determine the outgoing link**

*** message discrimination: determines if a received message is destined for it, or another point**

*** message distribution: delivers received message to correct user part**

SS7 Network Functions (Layer 3)

? **Traffic Management Functions**

*** To control message routing. This includes modification of message routing to destination points, or to continue normal routing.**

*** Control signaling traffic by avoiding irregularities in message flow**

*** Flow control**

SS7 Network Functions (Layer 3)

? **Link Management**

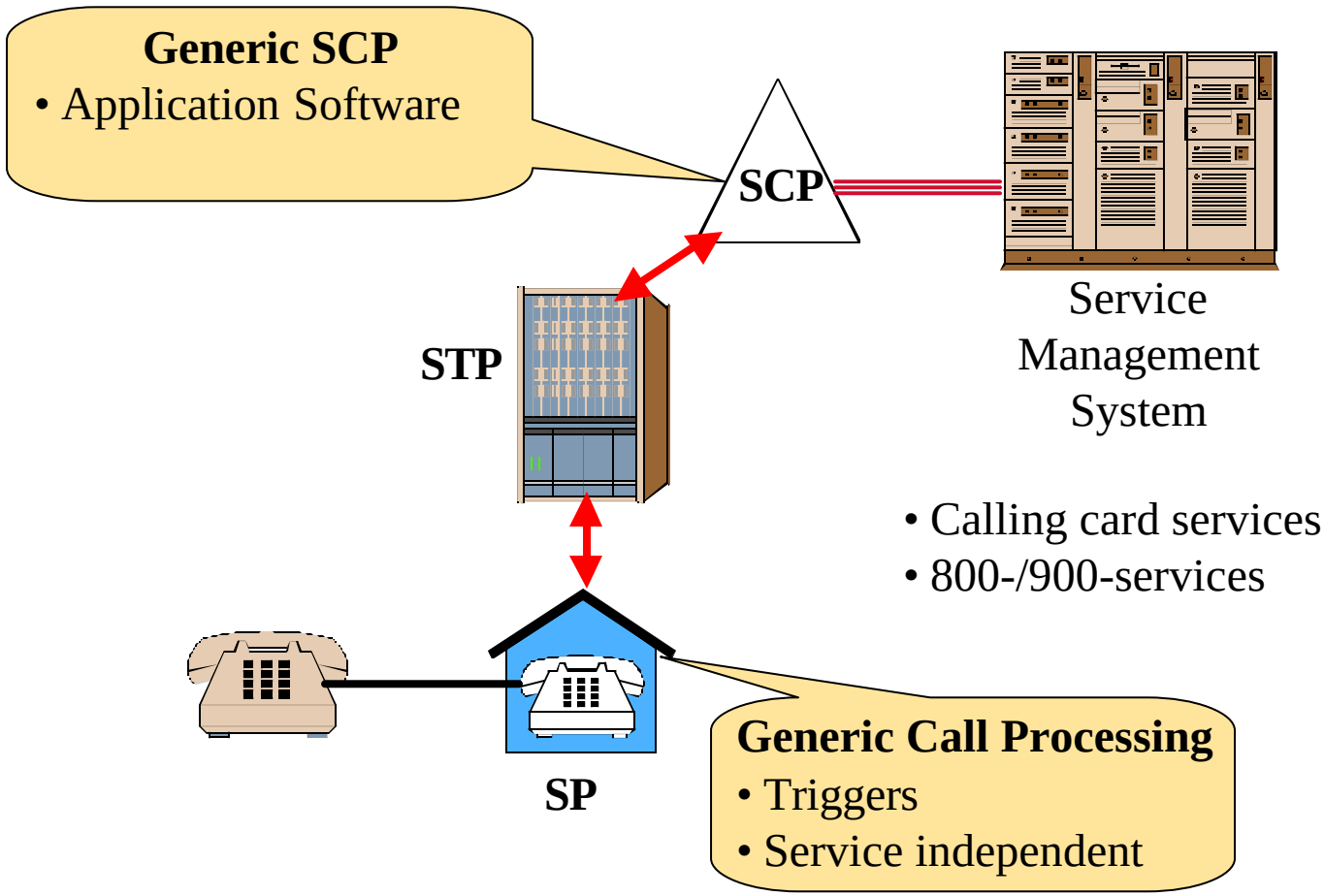
* **Can restore the availability of a link set**
* **Monitors status of signaling link**
* **Corrects out-of-service links**
* **Can provision new signaling links**
* **Automatically configures/reconfigures signaling links**

SS7 Connection Control Part

? **Services:**

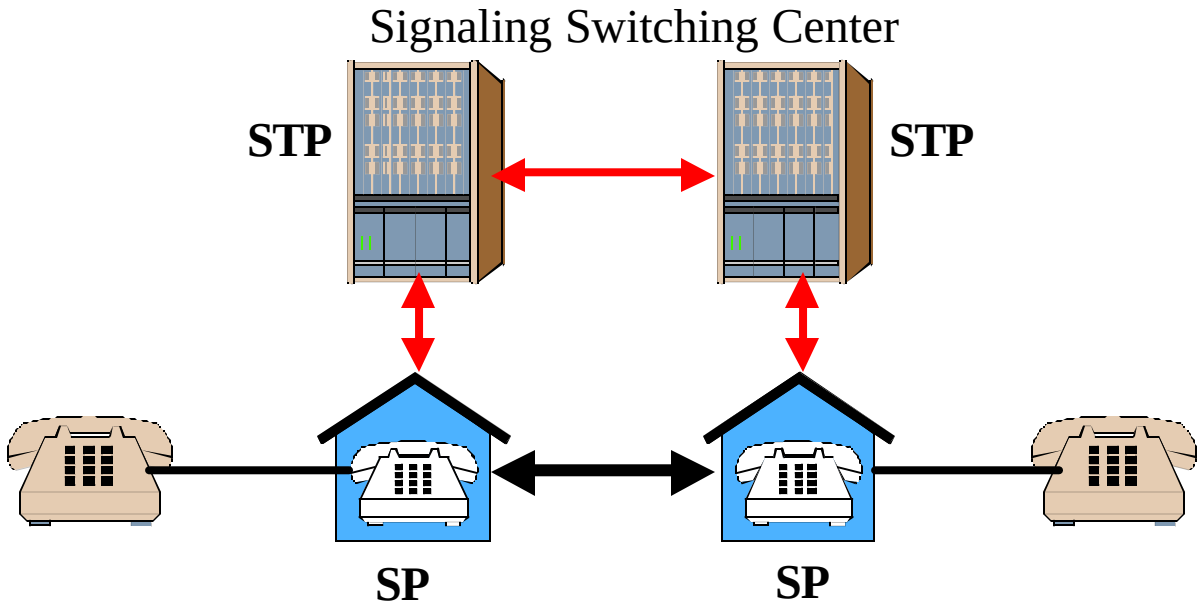
- **connection oriented**
- **connection-less**
- **peer-to-peer communication**
    * **Connection established**
    * **Data transfer starts**
    * **Connection releases**

Introduction of IN



Advanced Intelligent Network (AIN)

- Service-independent telecommunications
- Intelligence moved out of switches



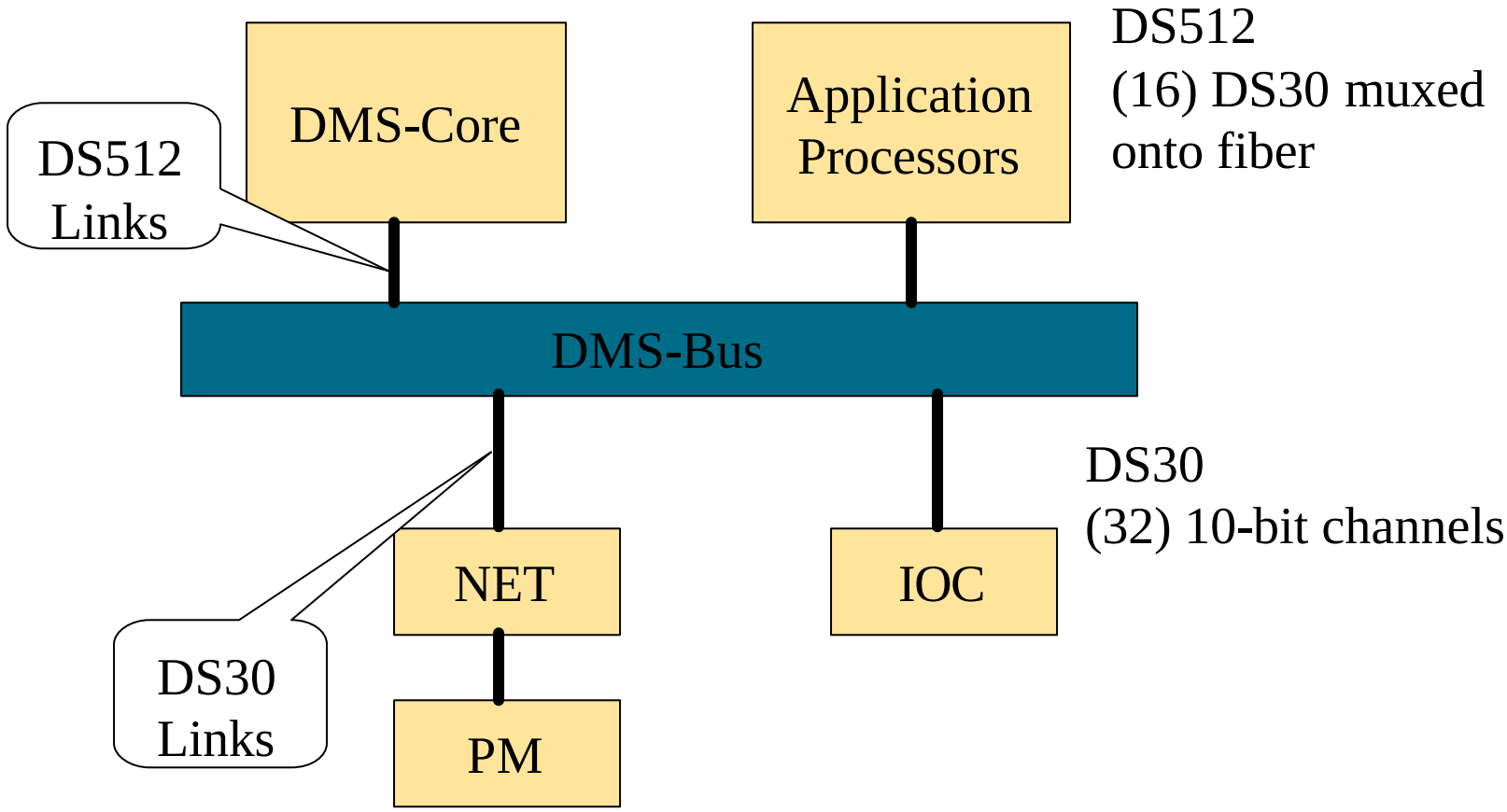
The DMS Family

- DMS-10 community end-office
- DMS-100 local services switch
- DMS-200 operator tandem
- DMS-250 tandem switch (LD)
- DMS-300 international gateway
- DMS-MTX cellular switch
- DMS-500 local/LD switch

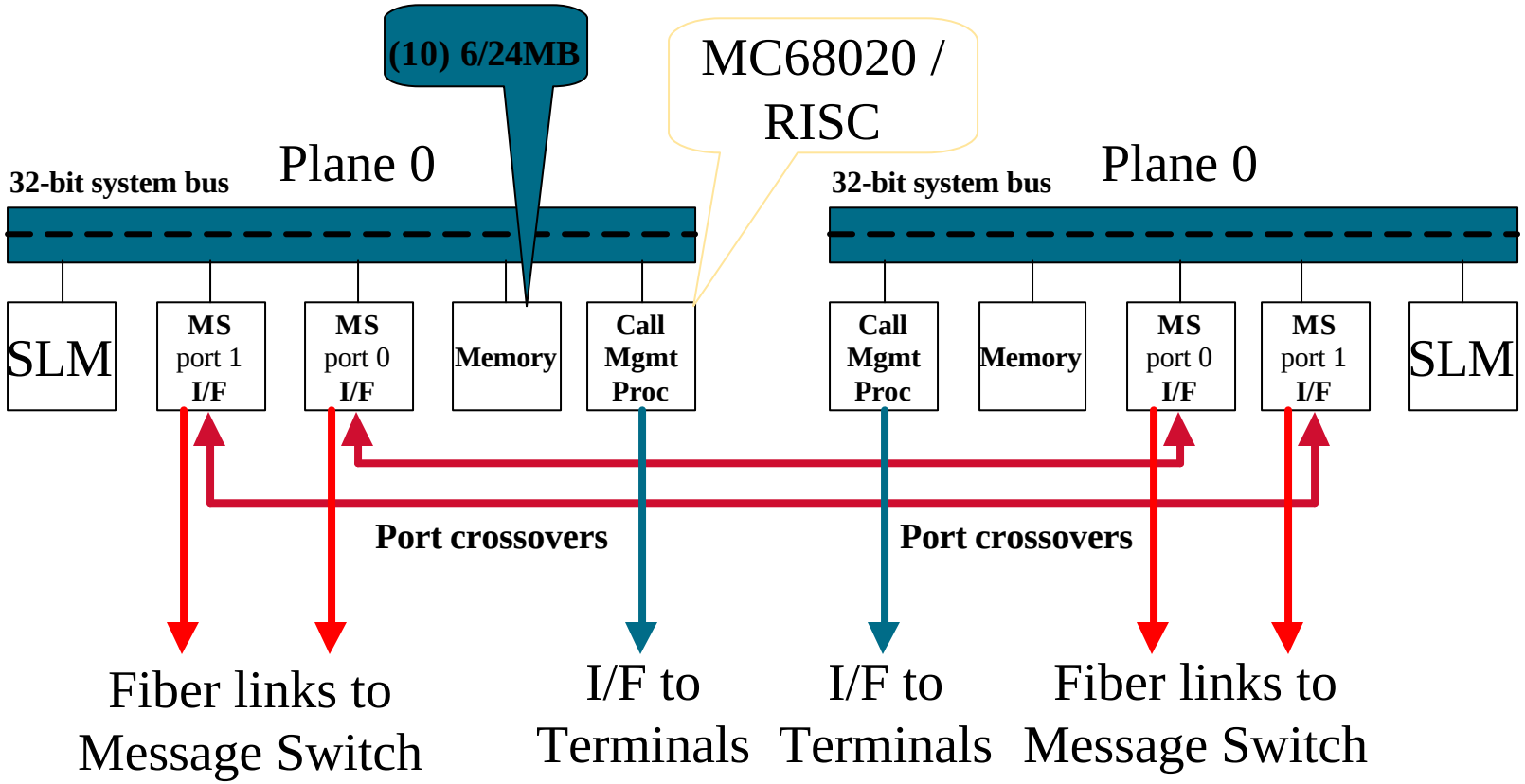
DMS-500 Switch

- **DMS-100 family hardware**
  - **scalable central processor core**
  - **junctored (NT40) or non-blocking (ENET) switch fabrics**
  - **software load from DMS-100/-250 in one machine**
  - **scalable to 100K lines**

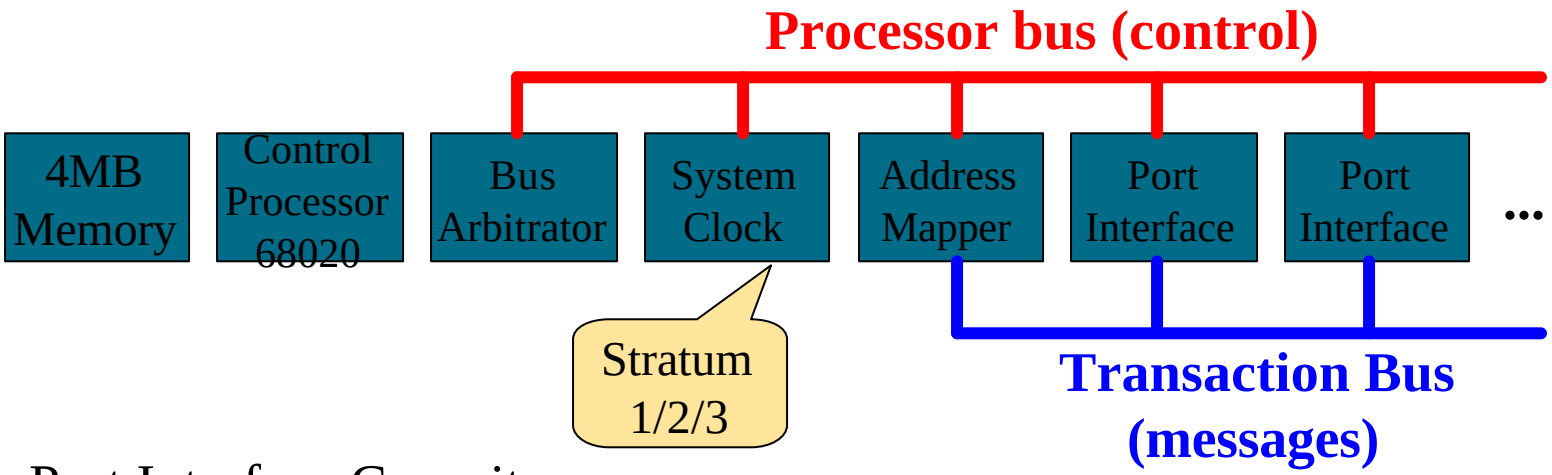
DMS SuperNode Architecture



DMS-Core Duplex Architecture



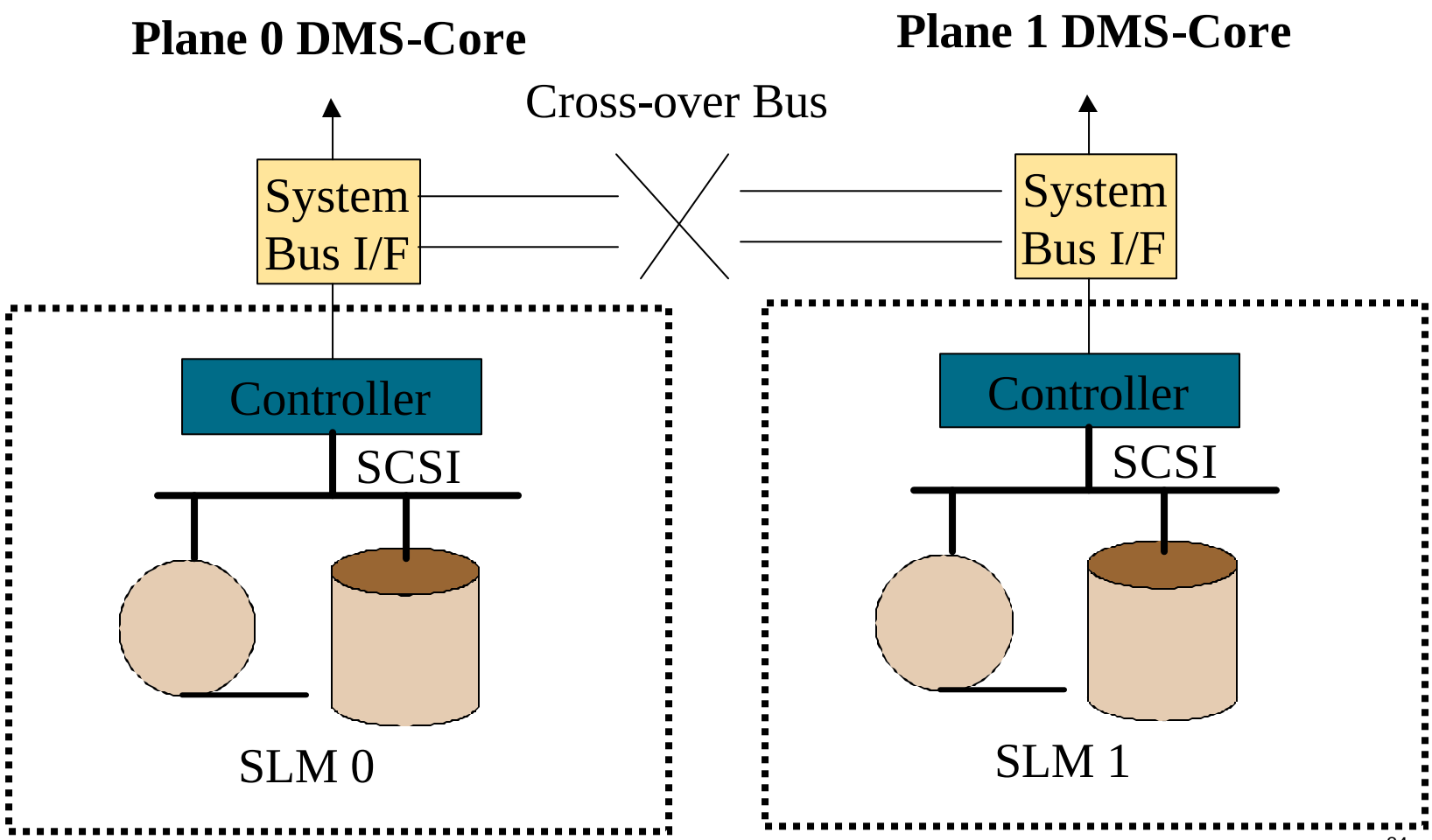
DMS-Bus Structure



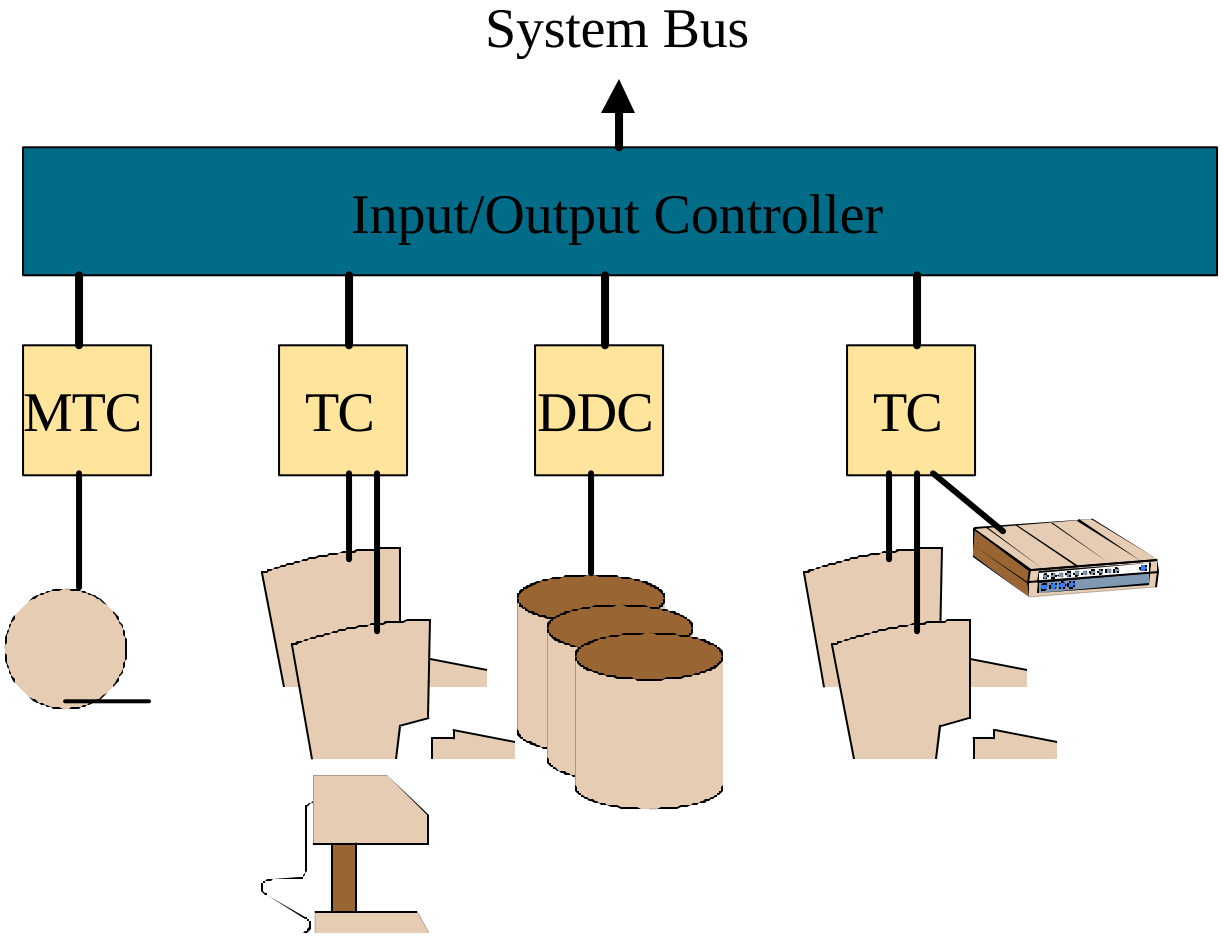
Port Interface Capacity

- 4 ports/card, 20 cards/shelf
- 2 cards dedicated to DMS-Core interface
- 2 cards dedicated to up to (4) I/O Controllers
- 16 cards for up to 32 network modules (64,000 channels)

System Load Module



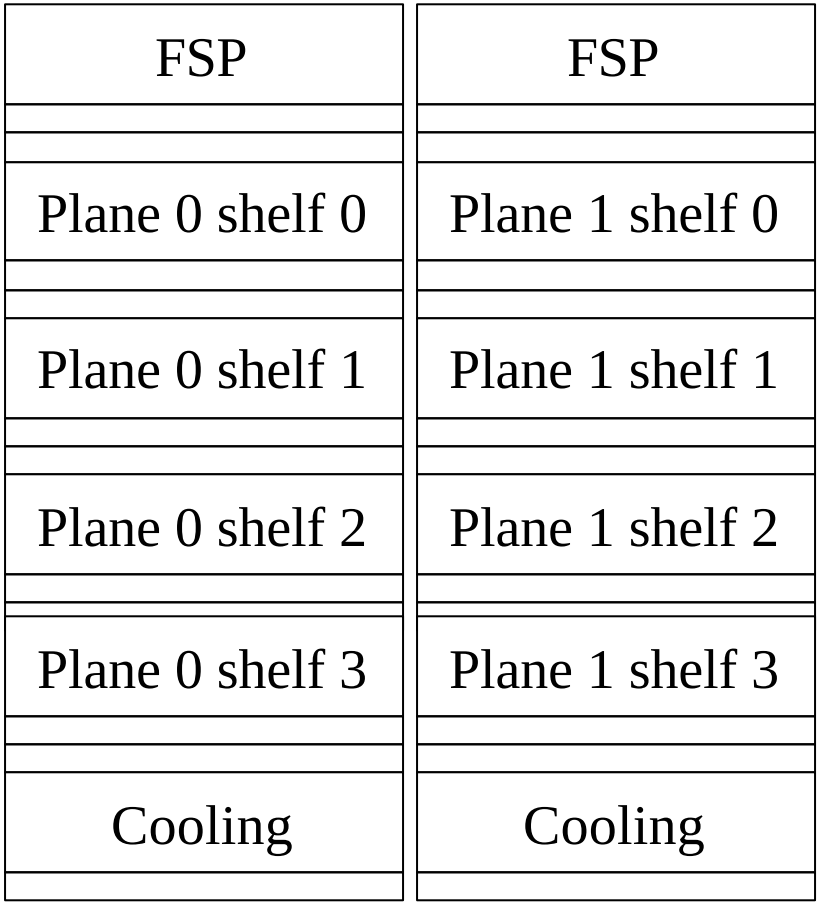
I/O Controller



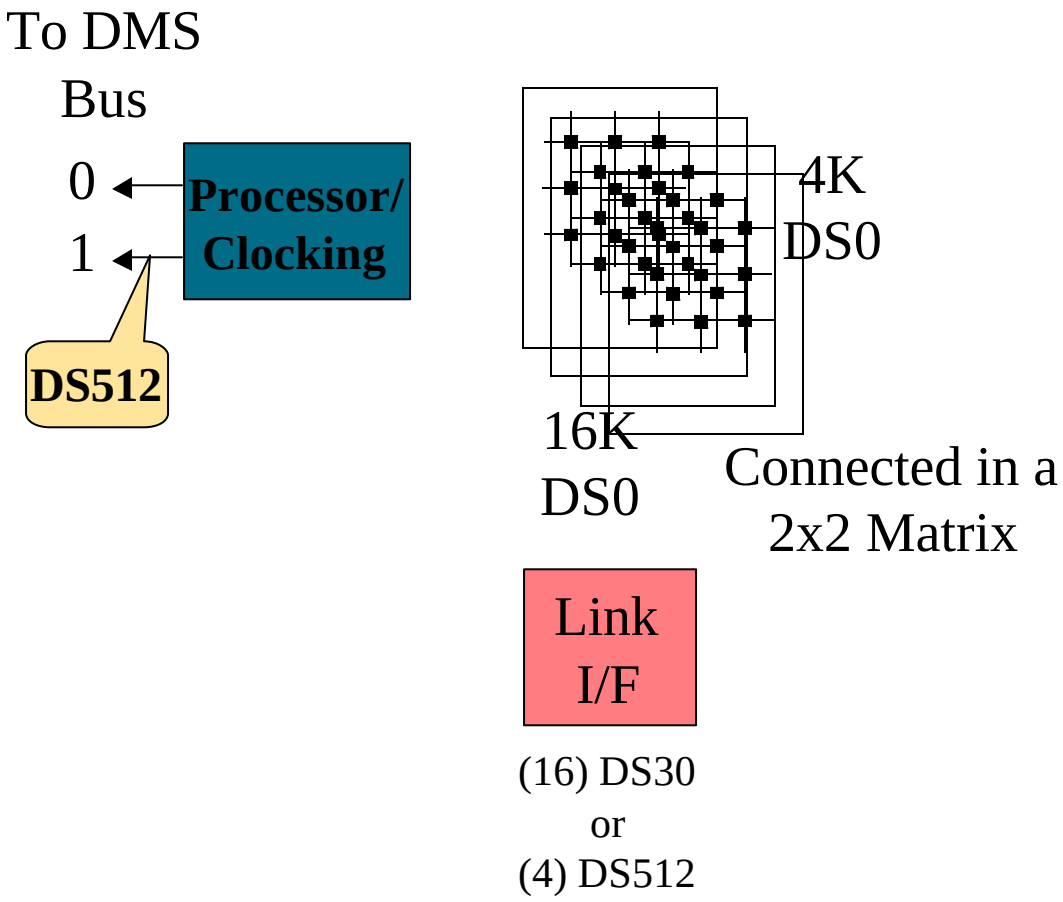
Enhanced NETwork

- Port capacity of 128,000 channels
- 64-kilobit/second clear channel paths
- Fully duplexed for reliability
- Contains its own CPU, clocking cards, DS30 and DS512 interfaces

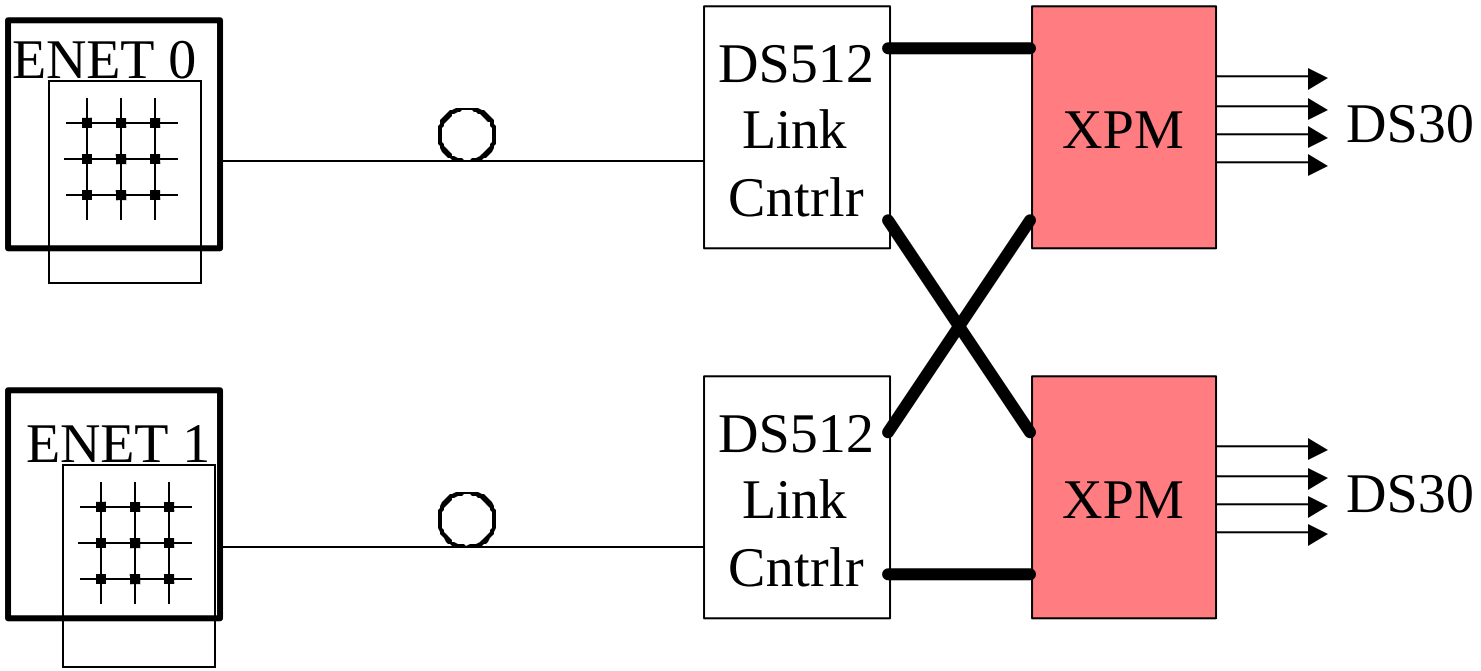
ENET Layout


FSP
FSP
Plane 0 shelf 0
Plane 1 shelf 0
Plane 0 shelf 1
Plane 1 shelf 1
Plane 0 shelf 2
Plane 1 shelf 2
Plane 0 shelf 3
Plane 1 shelf 3
Cooling
Cooling

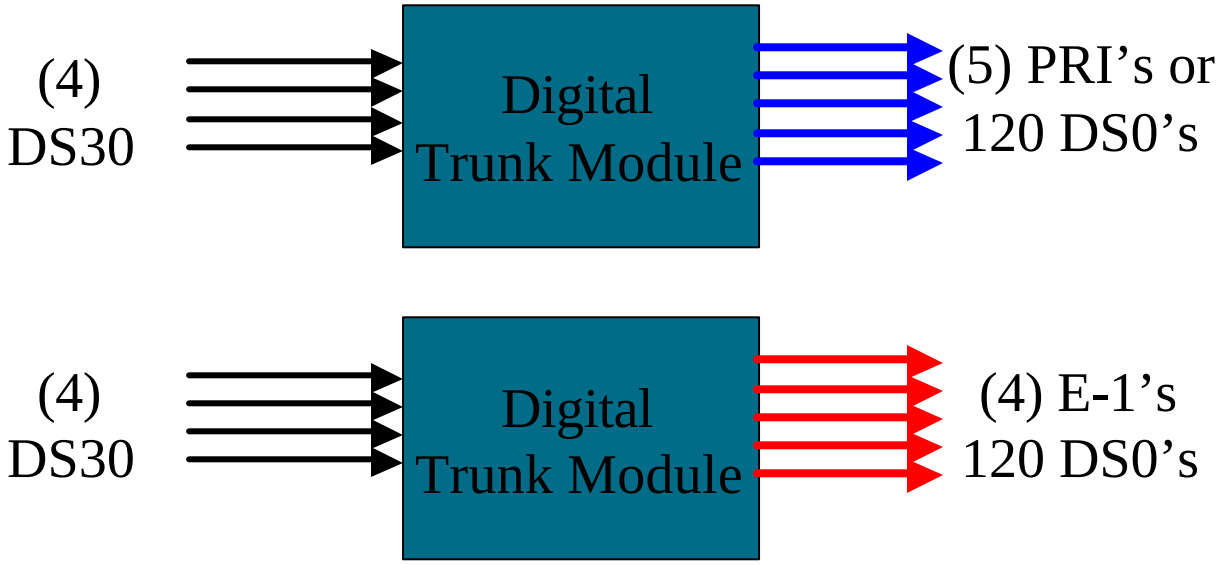
ENET Design


To DMS
Bus
0
1
Processor/
Clocking
DS512
4K
DS0
16K
DS0
Connected in a
2x2 Matrix
Link
I/F
(16) DS30
or
(4) DS512

ENET Connections



Typical Trunk Module



Link Peripheral Processor

- Dual local message switches (LMS) attached to the DMS-Bus
- Up to three Link Interface Shelves with up to 12 links(LIU7)/shelf
- Any LMS to any LIU7

Support Systems

- **Clocking**
  - **internal clocks - stratum 1/2/3**
  - **external clock source (BITS)**
- **Power**
  - **redundant DC power feeds from PDCs**
  - **AC power via redundant inverters**
- **MAP**
  - **pairs of terminals, printers**
- **Software Data Manager (SDM)**

Alarms

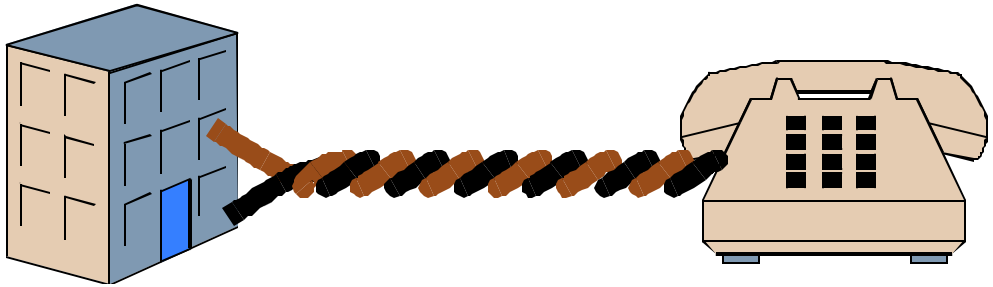
- Minor/major/critical (stall detection) alarms
  - contact closures
  - light panels and bells
- System events logged to disk, printers

Local Number Portability

"You *CAN* take it with you!

Telecom Act of 1996

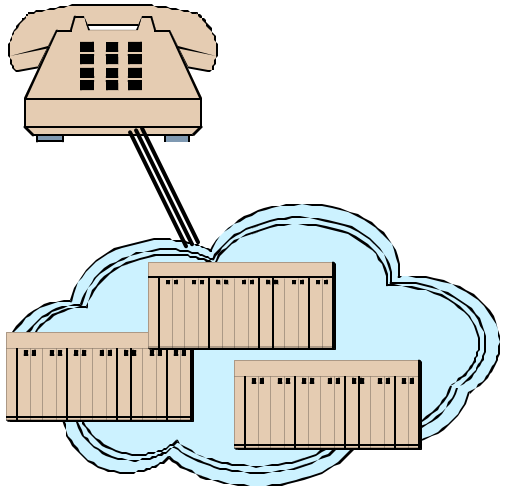
- **Opening of local service competition**
  - **Collocation**
  - **Virtual Collocation**
  - **Unbundling of Services**
  - **Access to local loop**



Objectives of LNP

? **Ability to move an end-user's telephone service from switch to switch while keeping the original Directory Number (DN)**

- **scope of portability**
  - **service**
  - **location**
  - **provider**
- **features**
- **E911 information**



LNP Implementation

- Based upon Bellcore AIN 0.1 protocol
- NPA-NXX are declared portable as readied
- Databases maintained by Martin Marietta Data Systems