Fabrics for circuit switching

✔ **What and why**

✔ **Space switching**

✔ **Time switching**

✔ **Analogies**

§ **Space-to-space**

§ **Time-to-space**

✔ **Two stage switch fabrics**

§ **TT**

§ **TS**

§ **ST**

§ **SS**

# *Summary of course scope*
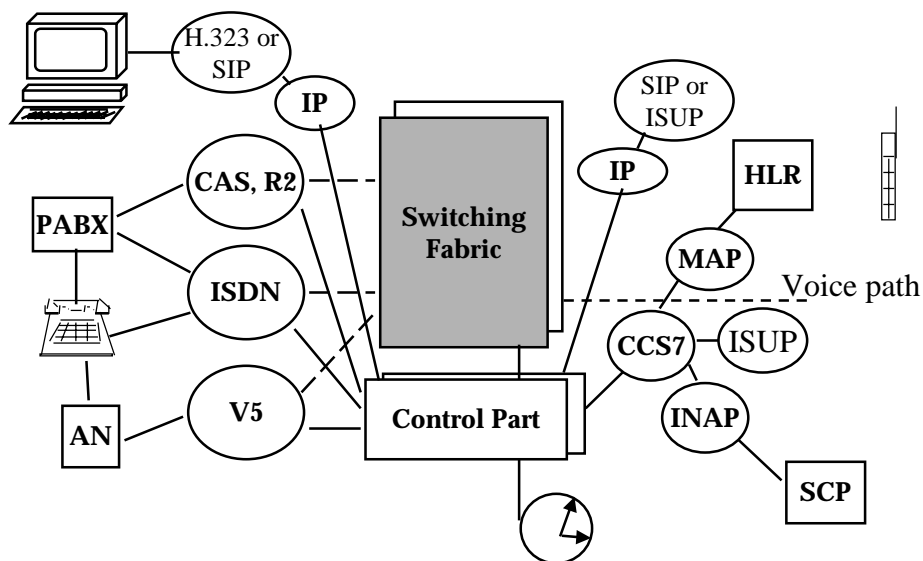
Goals of study of switch fabrics in this course

✔ **To understand how a switch fabric in an exchange works and what is its structure**

✔ **To understand how a larger fabric can be constructed using smaller fabrics as building blocks.**

✔ **To understand the technological limitations and the technology trend**

✔ **"Basics of the system design of switch fabrics"**

✔ **Learn to evaluate switch fabric technology**

✔ **To understand the fundaments of modern packet switches**


Narrow-band fabric switches PCM time slots

✔ **In PCM30 -frame tsl 0 differs in even and odd frames**

› **Even numbered frame has the frame alignment -> Time slots can be found in the received signal.**

› **Odd frame has management information**
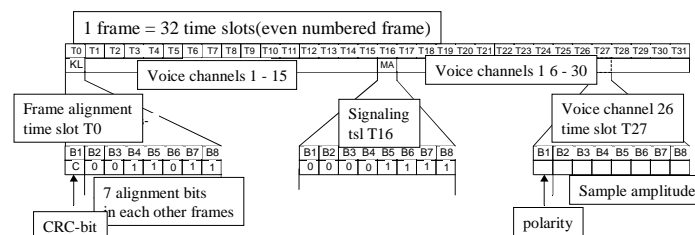
✓**Voice channel bit rate is 64kbit/s and PCM30 -frame total bit rate is 2,048 Mbit/s**

✓ **Prior to switching rate can be changed and serial signal can be converted into parallel (8 bits in parallel).**

Without switching connectivity requires a permanent connection from every user to every other user
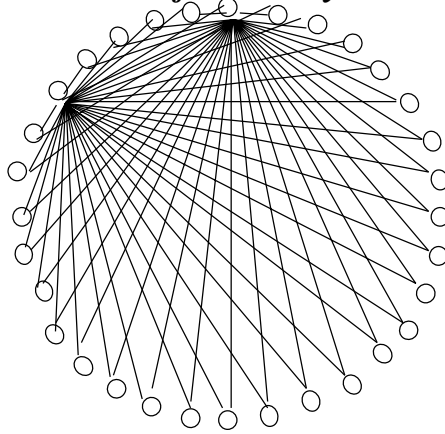
n*(n-1)/2 ¨connections - is a typical scalability problem, that often needs to be solved in different forms in networks. (IETF Chairman Baker: "Internet has only one problem: scalability".)

Using a switching fabric, two lines can be connected on-demand for the duration of a call or less

Building a two-way voice path requires switching actions for two connections!

In Telecom networks, exchanges and digital cross-connects are able to switch connections

✔ **A connection between two terminals can be**
  › **permanent**
  › **switched (dial-up connection)**

✔ **A switched connection requires a mechanism that attaches the right information streams to each other**

✔ **Switching takes place in the *switching fabric*, the structure of which depends on the *mode of operation* of the network, *available technology* and the *required capacity*.**

✔ **We will look at two viewpoints: combinatorial and technological.**

Time and Space switching are basic functions of a switch fabric

✔ **Internally in exchanges often PCM 30 frames or their multiples are used.**

✔ **PCM 30 frame is based on time division multiplexing, so a voice channel is in a constant place in time in the frame.**

✔ **Two communicating terminals may use different PCM - lines. So, voice channels are tied to space (place - point of attachment in the exchange)**

✔ **This suggests that the signals need to switched both in time and in space.**

A Space Switch is a basic building block for a bigger fabric

✔ **A space switch is a cross-point matrix. By closing and opening the switches in the cross-points, information flow can be controlled (i.e. switched).**
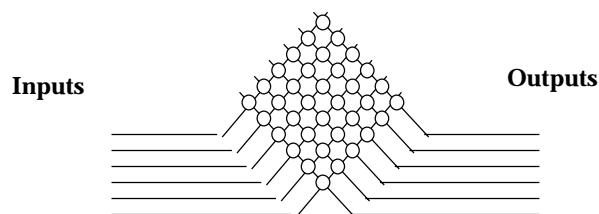
Inputs   Outputs

Each cross-point switch can be closed ○ or open ●
Only one cross-point can be attached ● to an output
at any given time.

# A space switch setting is either cyclic or constant

✔ **Setting mode depends on the nature of the switched signals.**

✔ **If inputs are PCM30 connections, we need a cyclic setting that changes between the last bit of a time slot and the first bit of the immediately following time slot.**

✔ **If inputs are 64 kbit/s voice channels, the setting can be constant. This is simpler but makes poor use of the modern hardware capability.**

Example implementation of a space stage
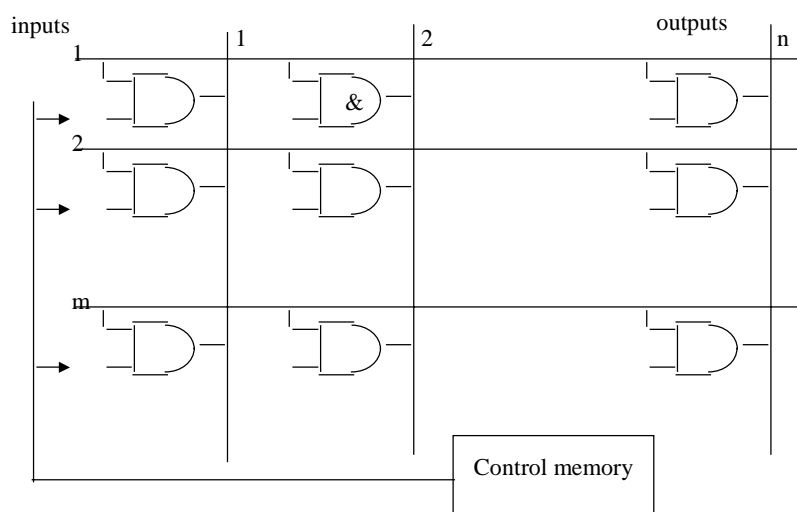
Another example of a space switch
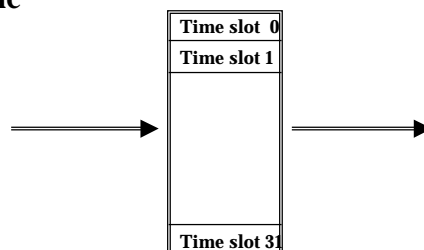
✔ **Nx1 -multiplexers implement a space switch**
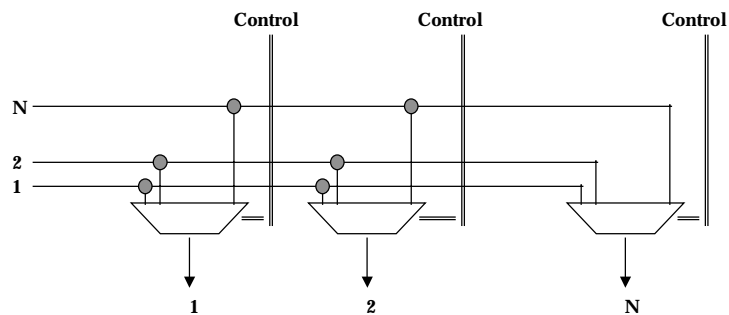
✓ **One output is attached to exactly one input at any given time. Each output always has some signal to carry in circuit switch, because the output is a circuit.**

A time switch interchanges or reorders the time slots

✔ **A time slot inter-changer is a memory that buffers an incoming PCM30 signal or its multiple.**

✔ **The Frame is read out from the memory onto the outgoing connection based on the order given by the control logic**
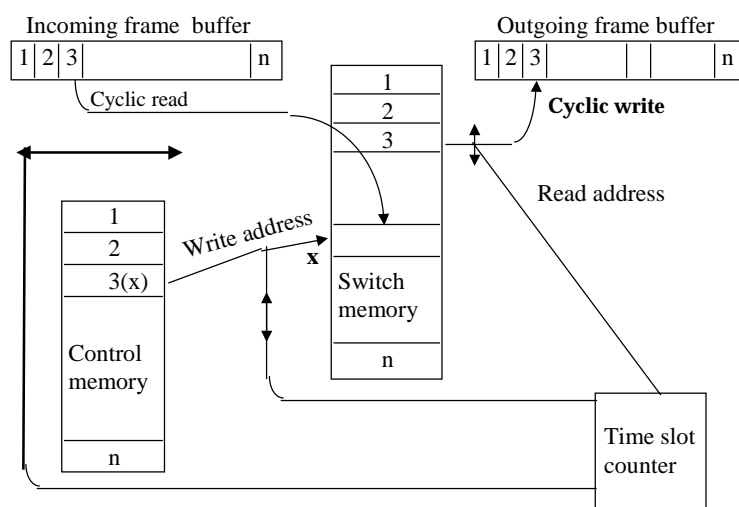
A time switch: serial write - address read

Incoming frame buffer

1	2	3		n

Cyclic read

Switch memory

1
2
3
Switch memory
n

Write address   **x**

This device switches
a time slot at a time not
a frame!

Time slot counter

Outgoing frame buffer

1	2	3		m		n

Cyclic write

read address

Control memory

1
2
(x)
Control memory
n

m

m
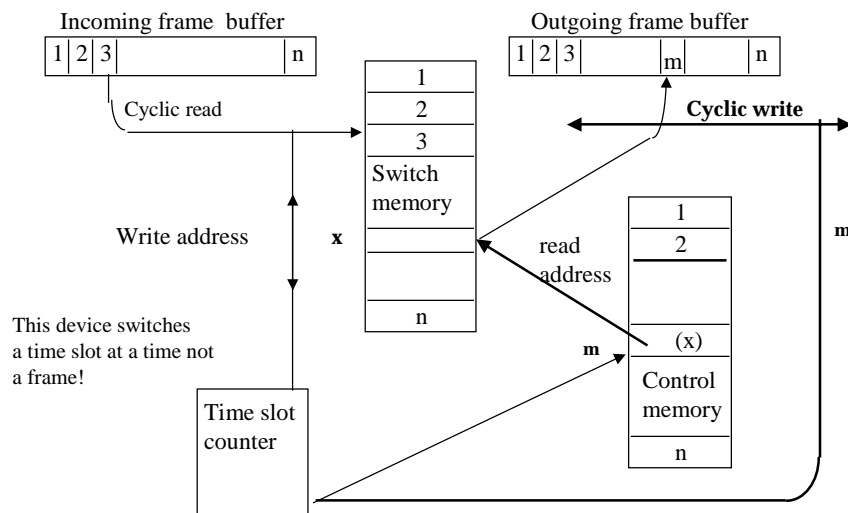
Time switch: address write - serial read

Incoming frame buffer

1	2	3		n

Cyclic read

Write address   **x**

Control memory

1
2
3(x)
Control memory
n

Switch memory

1
2
3
Switch memory
n

Outgoing frame buffer

| 1	2	3				n

Cyclic write

Read address

Time slot counter

Properties of time switches

✔ **Incoming buffer is fed by the incoming circuit on the "wire" bit rate, outgoing buffer needs to feed the outgoing connection on "wire" bit rate - so, the former needs to be read out on the same speed and in a cycle, the latter needs to be written to on the same speed and in a cycle.**

✔ **The number of time slots in a frame = nrof read operations = nrof write operations per frame in the switch memory -> speed of the switch memory is a critical parameter: available speed needs to be made full use of but the same speed determines switch capacity without parallelism.**

✔ **It is a good idea of doing Serial-to-parallel and P/S -conversions in the frame buffers - otherwise switch memory speed requirement is multiplied by 8.**

✔ **Control memory speed requirement is somewhat above half of the switch memory requirement to allow changing contents**
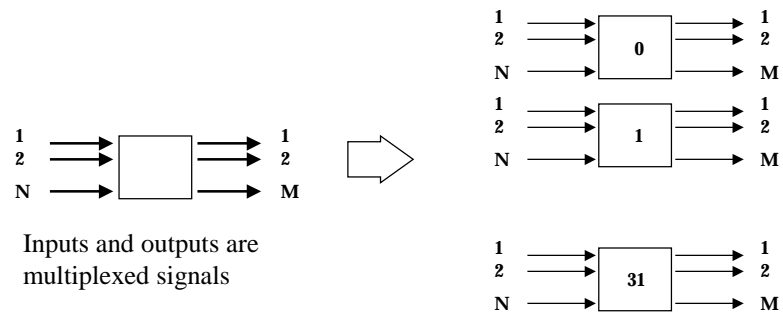

Time-Space analogy

✔ **A time switching PCM30 -switch can be logically converted into a space switch by converting the time slots into a parallel format.**
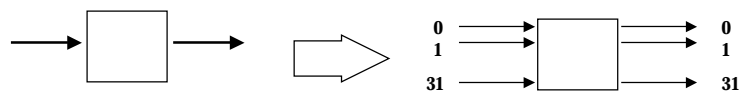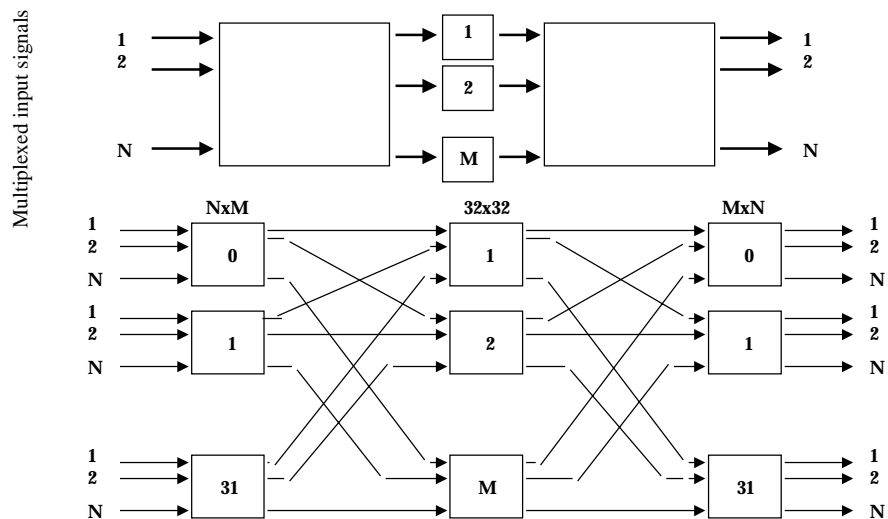

✓ **This space switch can be imagined to reside between the incoming frame buffer and the outgoing frame buffer**

✓ **Is this logical conversion fair?**

Space-space - analogy

✔ **A space switching PCM30 - switch fabric can be logically converted into a pure space switch (without cyclic control) by distributing each time slot into its own space switch.**

Inputs and outputs are
multiplexed signals

To switch a time slot, it is
enough to control one of the boxes

An example conversion

Properties of space and time switches

Space switches

✔ The nrof cross-points (AND-gate) grows as:

nrof inputs x nrof outputs

i.e. n^2.

✔ The output bitrate determines the speed requirement for the components .

✔ Has bus structures both on input and output lines. Makes fault location difficult.

Time switches

✔ Size of switch and control memory grows:

sm+cm=2 x 2 x nrof time slots

i.e. linearly until the available memory speed is enough.

✔ A simple and cost efficient structure until memory speed is enough.

✔ Memory speed determines the maximum capacity.

# A switching fabric can be constructed as a combination of space and time switches

✔ The Fabric is a network of switches (that may contain cross-points.

✔ Two-way information transfer through the switch requires two through connections in the switch fabric.

✔ The fabric should introduce small probability of blocking or better be non-blocking.

✔ Non-blocking = switching to a free output from any input is *always* possible.

✔ Efficient multicast is nowadays a typical functional requirement. Multicast = one input is copied to many outputs at the same time.

Two stage switching fabric

✔ **Possible combinations of time and space switches are:**
- › **Time-Time (TT)**
- › **Time-Space (TS)**
- › **Space-time (ST)**
- › **Space-Space (SS)**

✔ **TT-fabric does not give any benefit compared to a single stage T -switch.**

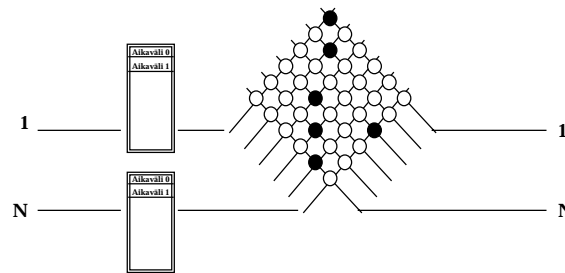✔ **SS-switch is not a good idea, because blocking probability is high and no benefit is achieved.**

Space-time switching fabric

✔ **ST -switch gives high probability of blocking, because Space switching can create blocking on an arbitrary bus.**

✔ **Some time slots from buses 1 and N are attempting to flow onto output bus nr 1 at the same time.**
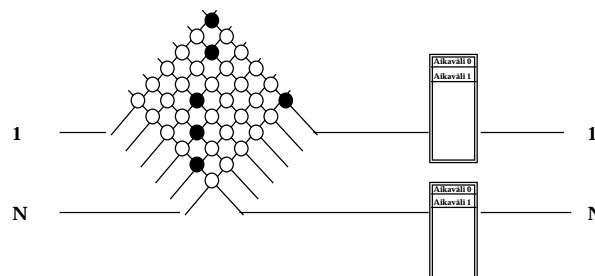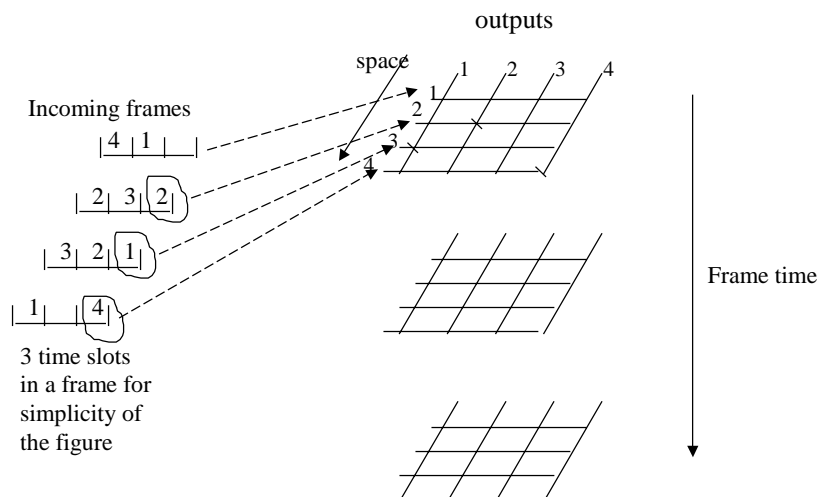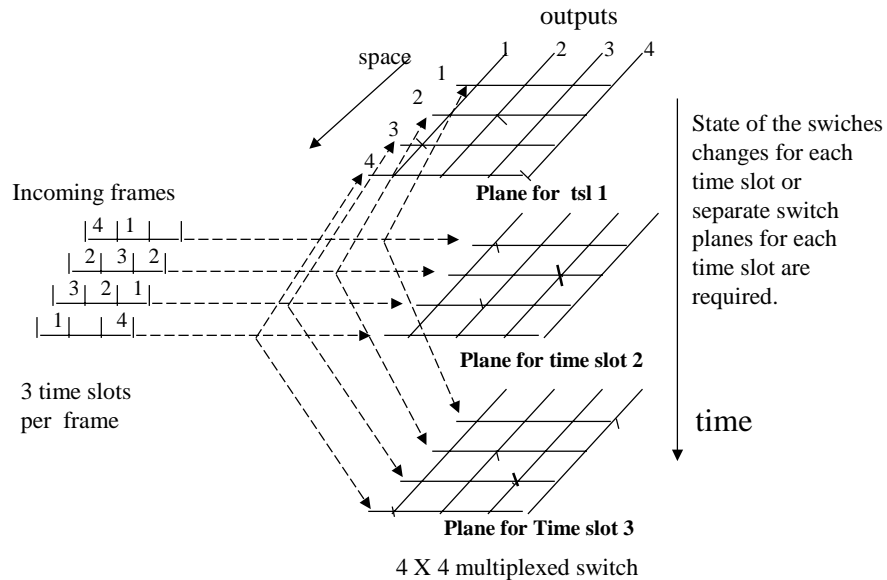
Time- Space switching fabric

✔ **TS-fabric has low probability of blocking, because the time switch allows rearranging of time slots so that Space switching can be done without blocking.**
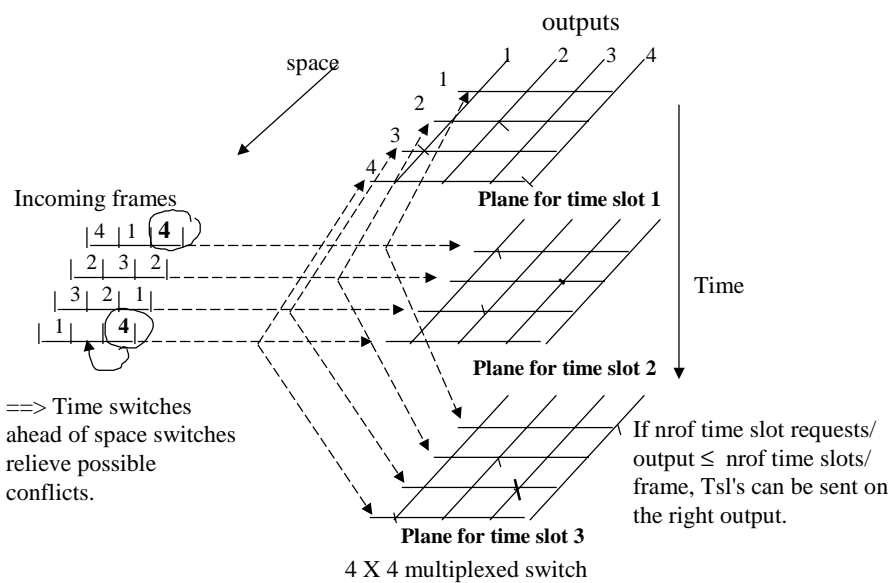

Multiplexing of a switch

outputs

space

Incoming frames

|4 |1 | |

|2 |3 |2|

|3 |2 |1|

|1 | |4|

3 time slots
in a frame for
simplicity of
the figure

Frame time

Multiplexing of a switch

outputs

space

1 2 3 4

1

2

3

4

Plane for tsl 1

Incoming frames

4	1	
2	3	2
3	2	1
1		4

3 time slots
per frame

Plane for time slot 2

State of the swiches
changes for each
time slot or
separate switch
planes for each
time slot are
required.

time

Plane for Time slot 3

4 X 4 multiplexed switch

Rearranging the incoming time slots

outputs

space

1 2 3 4

1

2

3

4

Plane for time slot 1

Incoming frames

4	1	**4**
2	3	2
3	2	1
1	**4**	

Time

Plane for time slot 2

==> Time switches
ahead of space switches
relieve possible
conflicts.

If nrof time slot requests/
output ≤ nrof time slots/
frame, Tsl's can be sent on
the right output.

Plane for time slot 3

4 X 4 multiplexed switch

An analogous SS -switch correspon-
ding to a Time-Space switch

Inputs

outputs

3 X 3 switches   4 X 4 switches

4 planes

3 planes

Space analogies
of the time switches
on the prev. slide

Multiplexed space switches
from the previous slide
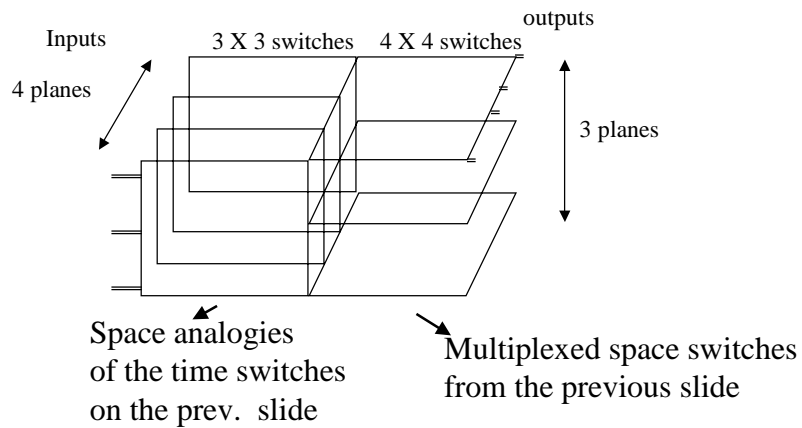
A connection through a SS-switch

Inputs

outputs

3 X 3 switches   4 X 4 switches

4 planes

3 planes

(2,1,3)

(1,4,1)

(1,4,2)

(2,3,2)

Coordinate   (x,y,z)

port (input of output)

plane
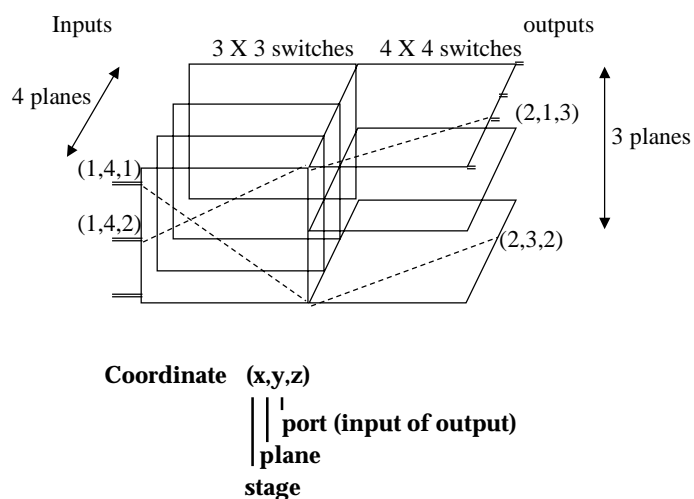
stage

Three stage switching fabrics

✔ **Three stage switching fabrics are made of three time and/or space switching stages connected back-to-back**

✔ **Possible combinations are:**

› **Time-time-time (TTT) (not significant, no connection from PCM to PCM)**

› **Time-time-Space (TTS) (=TS)**

› **Time-Space-Time (TST)**

› **Time-Space-Space (TSS)**

› **Space-Time-Time (STT) (=ST)**

› **Space-Time-Space (STS)**

› **Space-Space-Time (SST) (=ST)**

› **Space-Space-Space (SSS) (not significant, high probability of blocking)**

✔ **Three interesting new combinations TST, TSS and STS.**