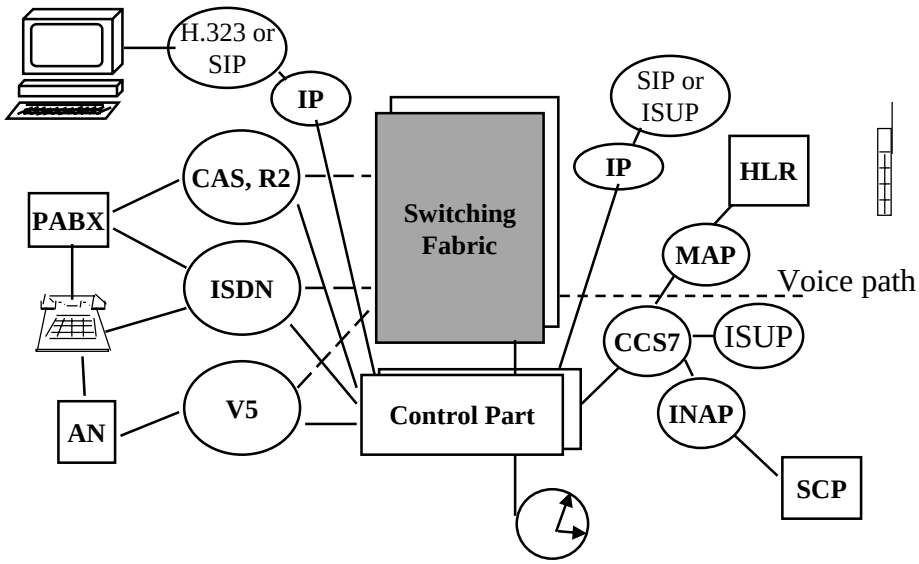
Fabrics for circuit switching

- ✔ **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

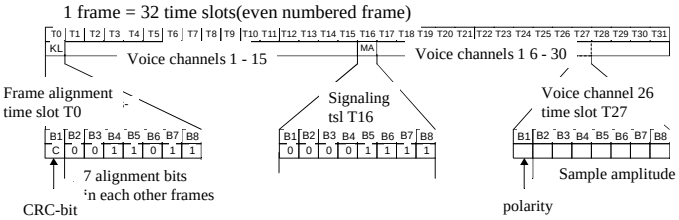


Goals of study of switch fabrics in this course

- ✔ **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**

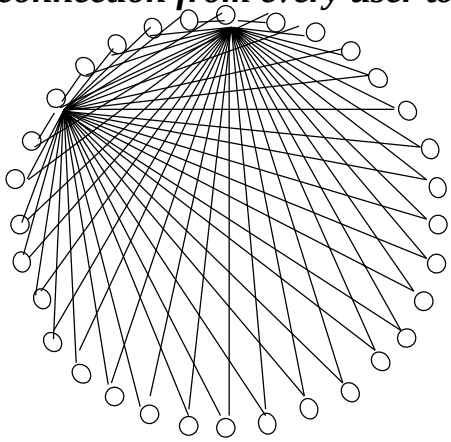
Narrow-band fabric switches PCM time slots

- ✔ **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

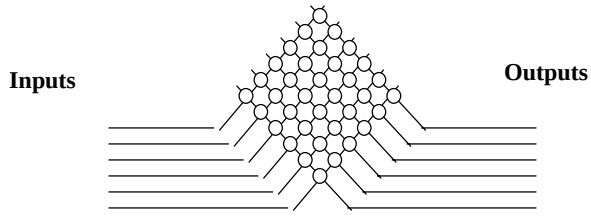
- **A connection between two terminals can be**
  - **permanent**
  - **switched (dial-up connection)**
- **A switched connection requires a mechanism that attaches the right information streams to each other**
- **Switching takes place in the *switching fabric*, the structure of which depends on the *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).**

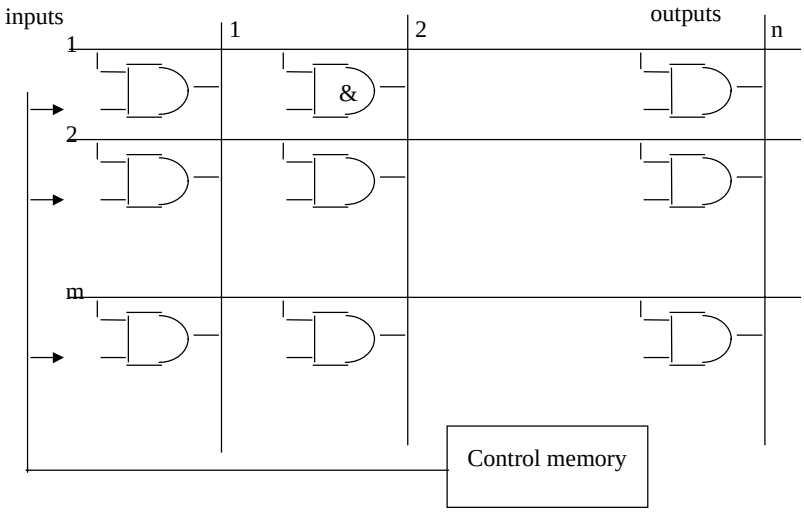


Each cross-point switch can be closed ○ or open ●
Only one cross-point can be attached ● to an output at any given time.

A space switch setting is either cyclic or constant

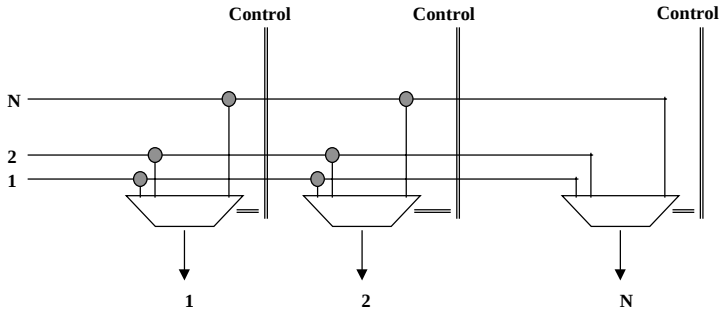
- ✔ **Setting mode depends on the nature of the switched signals.**
- ✔ **If inputs are PCM30 connections, we need a cyclic setting that changes between the last bit of a time slot and the first bit of the immediately following time slot.**
- ✔ **If inputs are 64 kbit/s voice channels, the setting can 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

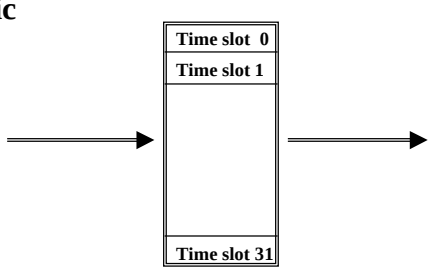
- ✔ **Nx1 -multiplexers implement a space switch**



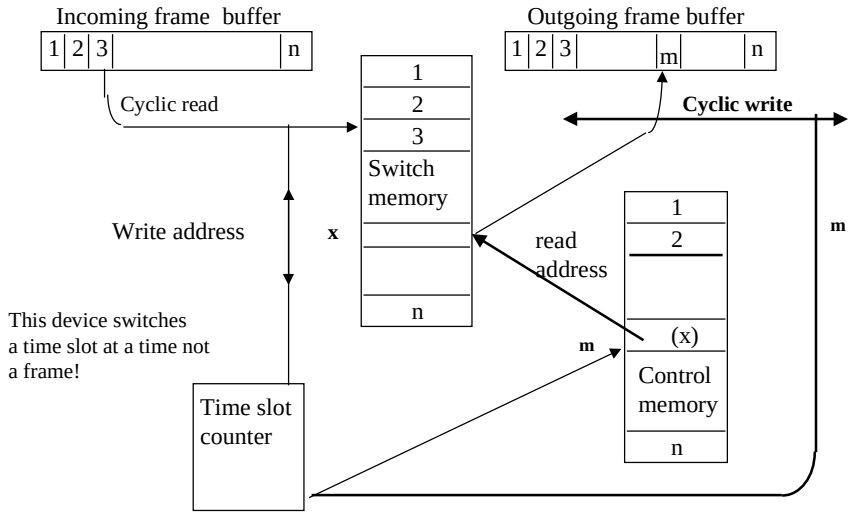
- ✓ **One output is attached to exactly one input at any given time. Each output always has some signal to carry in circuit switch, because the output is a circuit.**

A time switch interchanges or reorders the time slots

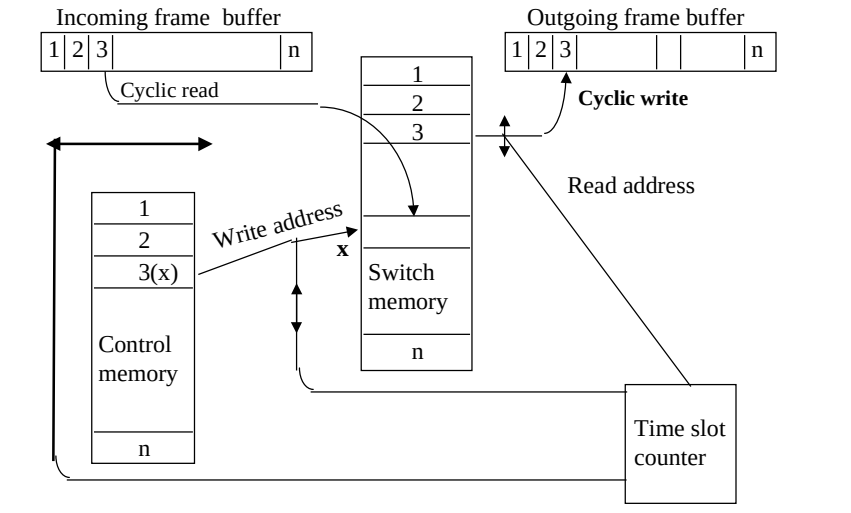
- ✔ **A time slot inter-changer is a memory that buffers an incoming PCM30 signal or its multiple.**
- ✔ **The Frame is read out from the memory onto the outgoing connection based on the order given by the control logic**



A time switch: serial write - address read



Time switch: address write - serial read

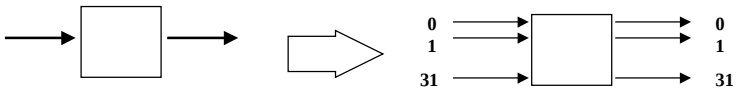


Properties of time switches

- ✔ **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

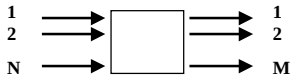
- ✔ **A time switching PCM30 -switch can be logically converted into a space switch by converting the time slots into a parallel format.**



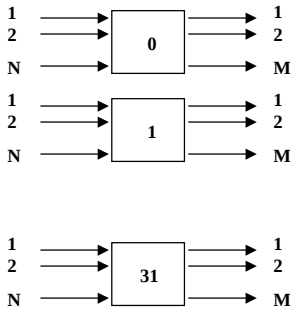
- ✓ **This space switch can be imagined to reside between the incoming frame buffer and the outgoing frame buffer**
- ✓ **Is this logical conversion fair?**

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.**

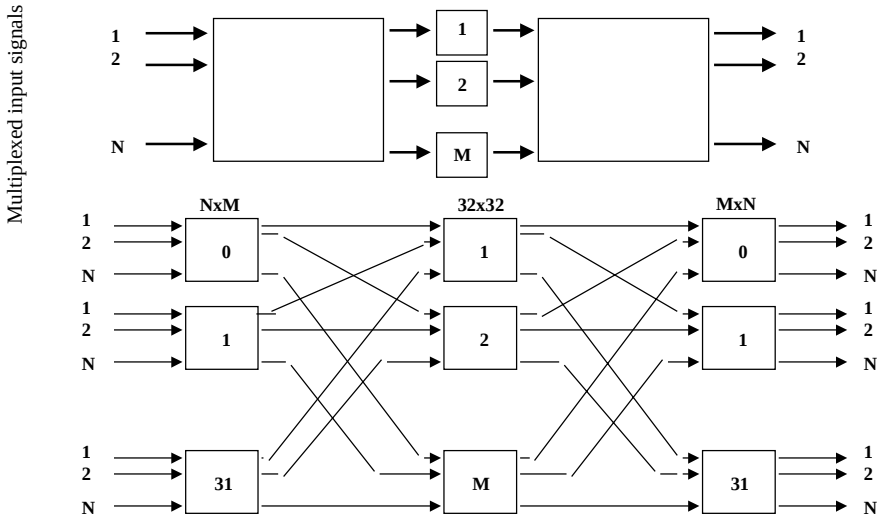


Inputs and outputs are multiplexed signals



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

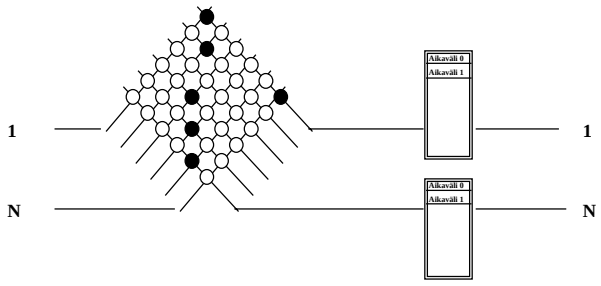
- ✔ **The Fabric is a network of switches (that may contain cross-points.**
- ✔ **Two-way information transfer through the switch requires two through connections in the switch fabric.**
- ✔ **The fabric should introduce small probability of blocking or better be non-blocking.**
- ✔ **Non-blocking = 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.**

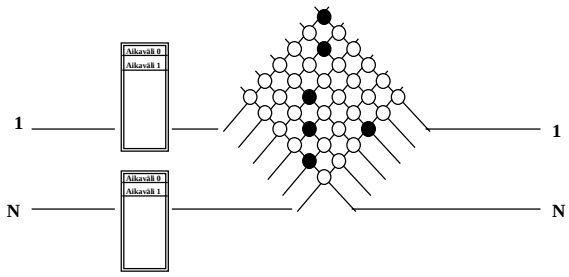
Space-time switching fabric

- ✔ **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.**

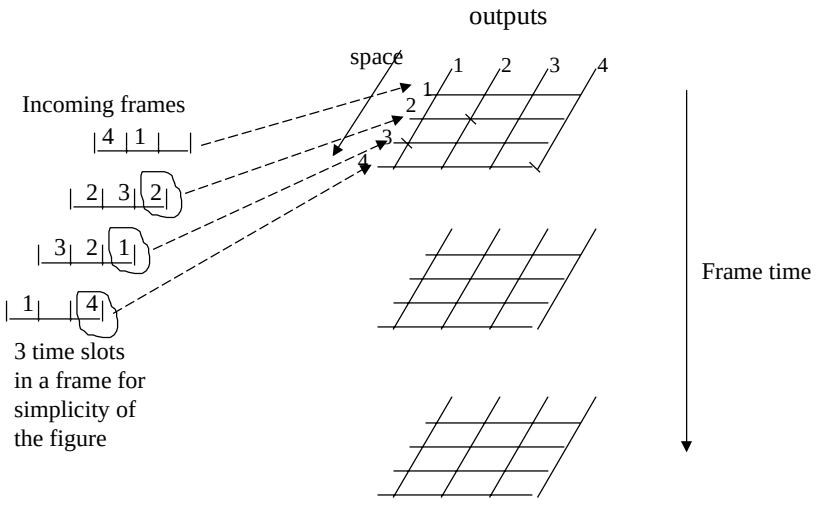


Time- Space switching fabric

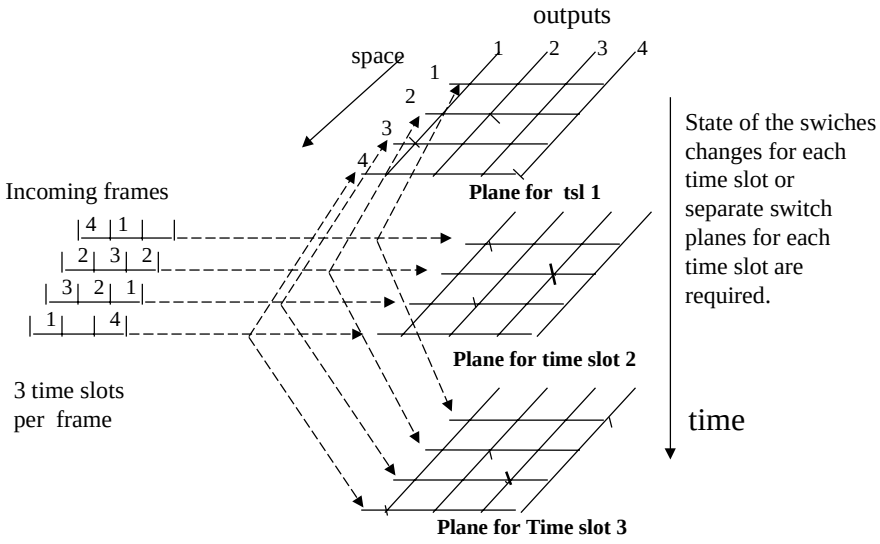
✔ **TS-fabric has low probability of blocking, because the time switch allows rearranging of time slots so that Space switching can be done without blocking.**



Multiplexing of a switch

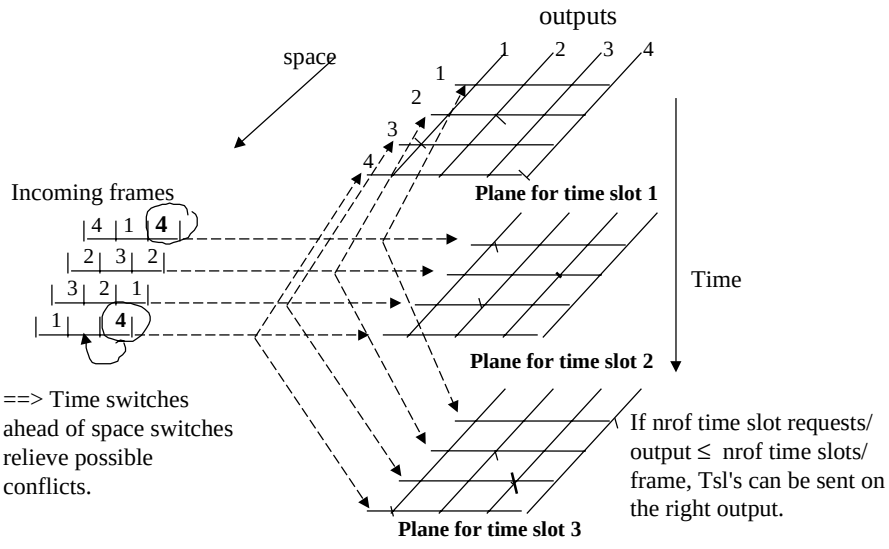


Multiplexing of a switch



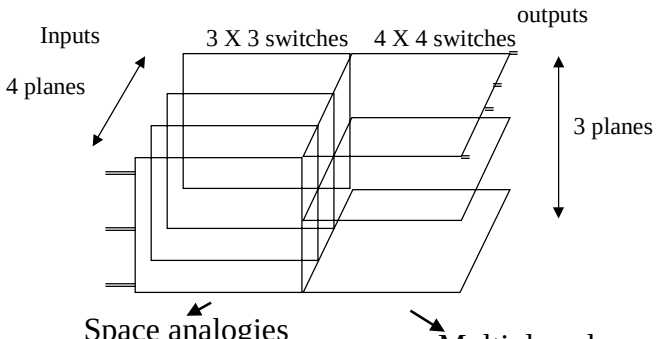
4 X 4 multiplexed switch

Rearranging the incoming time slots



4 X 4 multiplexed switch

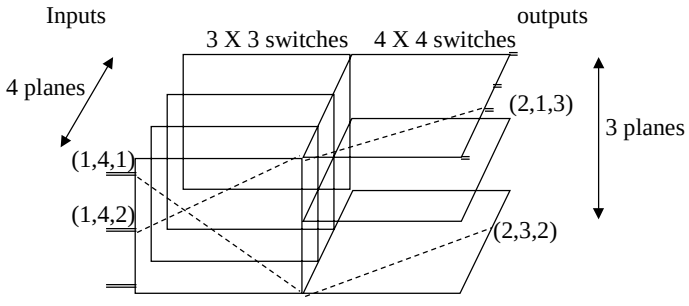
An analogous SS -switch corresponding to a Time-Space switch



Space analogies
of the time switches
on the prev. slide

Multiplexed space switches
from the previous slide

A connection through a SS-switch



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.**