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4 Spanning Tree Protokoll 802.1D-2004

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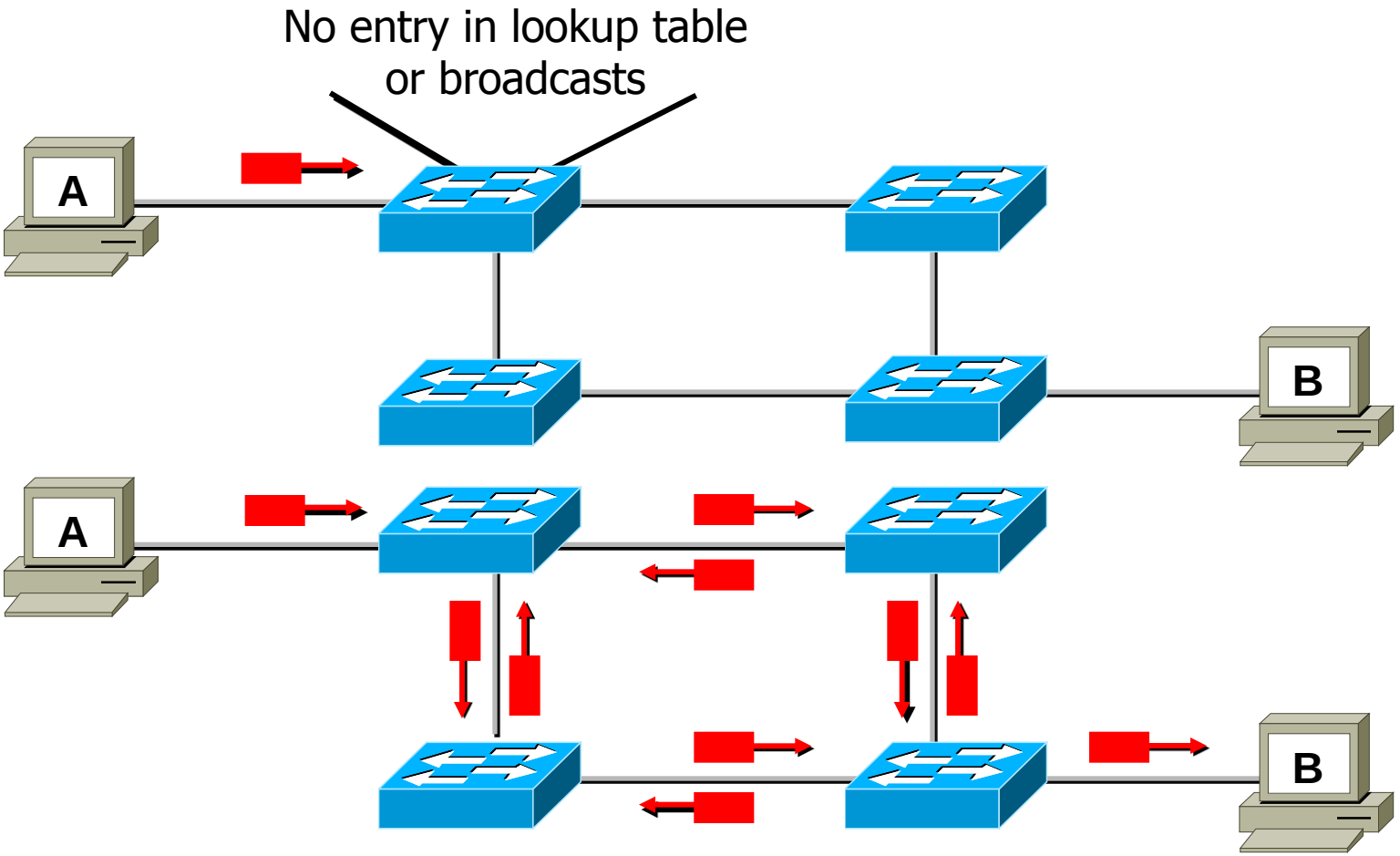
What happens without Spanning Tree

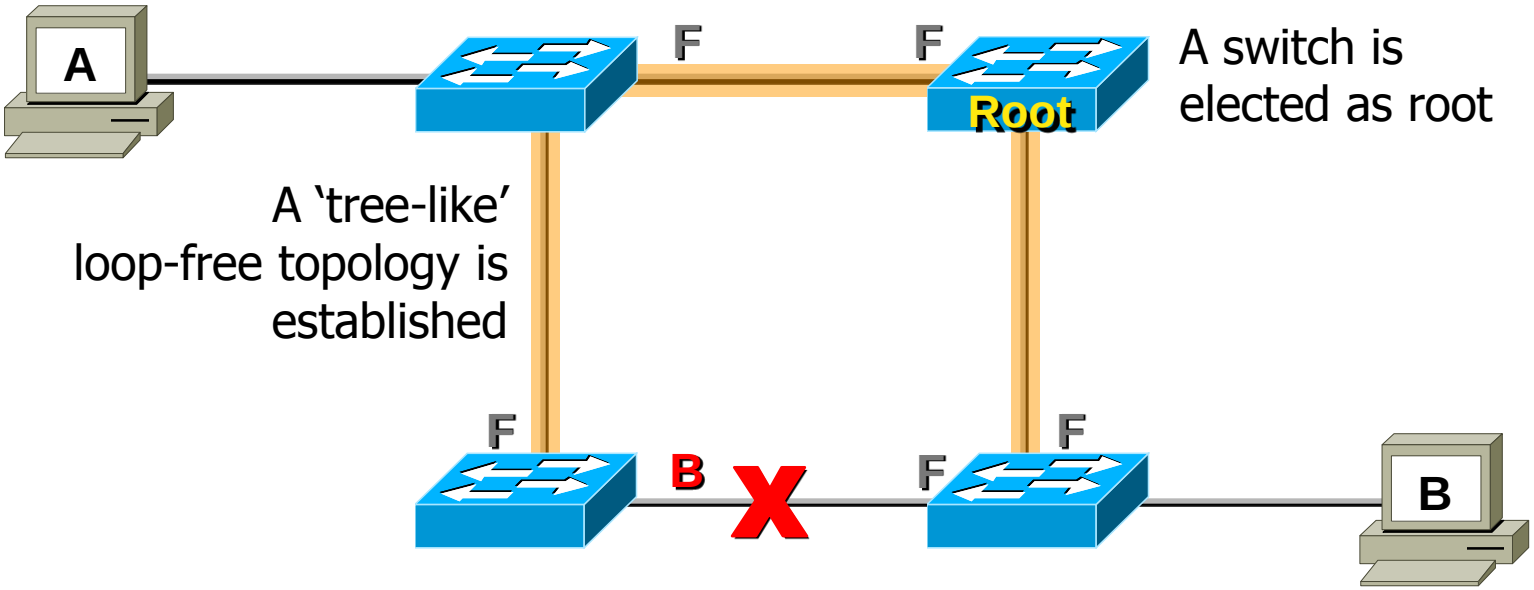


Broadcasts turn into packet storms

Parallel Paths

- Interconnected parallel paths between two LAN segments cause
  - endless circling of broadcast frames
  - endless circling of unicast frames during flooding phase
  - blocking of buffer resources
- Closed loops in more complex topologies cause
  - overflow of all buffer resources and stagnation of the LANs
  - Broadcast storms
- Solution to avoid these effects
  - Spanning Tree Protocol (STP)

Spanning Tree Basics



Loop-free connectivity

F orwarding

B locking

Spanning Tree

- Spanning Tree Protocol (STP):
  - guarantees that there is always exact one path between any 2 stations
  - is implemented by a special protocol that is used for communication among the bridges by exchanging BPDU (Bridge Protocol Data Unit) packets with the MAC multi-cast address 01-80-C2-00-00-00.
  - active path failure causes activation of a redundant path

- Main disadvantage of STP
  - redundant lines cannot be used for load balancing

Spanning-Tree Protocol Operation
Bridge Protocol Data Unit (BPDU)

Bytes	Field
2	Protocol ID
1	Version
1	Message Type
1	Flags
8	Root ID
4	Cost of Path
8	Bridge ID
2	Port ID
2	Message Age
2	Maximum Time
2	Hello Time
2	Forward Delay

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The BPDU is responsible for:

- electing a root bridge
- determining the location of loops
- blocking to prevent loops
- notifying the network of changes
- monitoring the state of the spanning tree

802.1D-2004 Bridge Address and Bridge Identifier

- 7.12.5 Unique identification of a bridge

  A unique 48-bit Universally Administered MAC Address, termed the Bridge Address, shall be assigned to each Bridge. The Bridge Address may be the individual MAC Address of a Bridge Port, in which case, use of the address of the lowest numbered Bridge Port (Port 1) is recommended.

- 9.2.5 Encoding of Bridge Identifiers

  A Bridge Identifier shall be encoded as eight octets, taken to represent an unsigned binary number. The four most significant bits of the most significant octet of a Bridge Identifier comprise a settable priority component that permits the relative priority of Bridges to be managed. The nextmost significant twelve bits of a Bridge Identifier comprise a locally assigned system ID extension. The six least significant octets ensure the uniqueness of the Bridge Identifier; they shall be derived from the globally unique Bridge Address.

Parameters for STP

- Bridge Identifier (Bridge ID)
  - combination of MAC-address and a priority number
  - priority number can be configured by the administrator
    - default 32768
  - lowest Bridge ID has highest priority
    - lowest configurated priority number and lowest MAC-address
- Port Cost (C)
  - costs in order to access local interface
  - inverse proportional to the transmission rate
  - original definition: cost = 1000 / transmission rate in Mbit/s
  - revised in 2001 and 2004 to accommodate higher speeds

Recommended Spanning-Tree Path Costs

Link Speed	Cost (32 bits) 802.1D-2004	Cost (16 bits) 802.1D-2004	Cost 802.1t-2001	Cost 802.1D-1998
≤100 kb/s	200'000'000	65'535	10'000	10'000
1 Mb/s	20'000'000	65'535	1000	1000
10 Mb/s	2'000'000	65'535	100	100
100 Mb/s	200'000	65'535	19	10
1 Gb/s	20'000	20'000	4	1
10 Gb/s	2'000	2'000	2	-
100 Gb/s	200	200	-	-
1 Tb/s	20	20	-	-
10 Tb/s	2	2	-	-

The path costs can be set to arbitrary values by the network administrator

Spanning Tree Process Steps

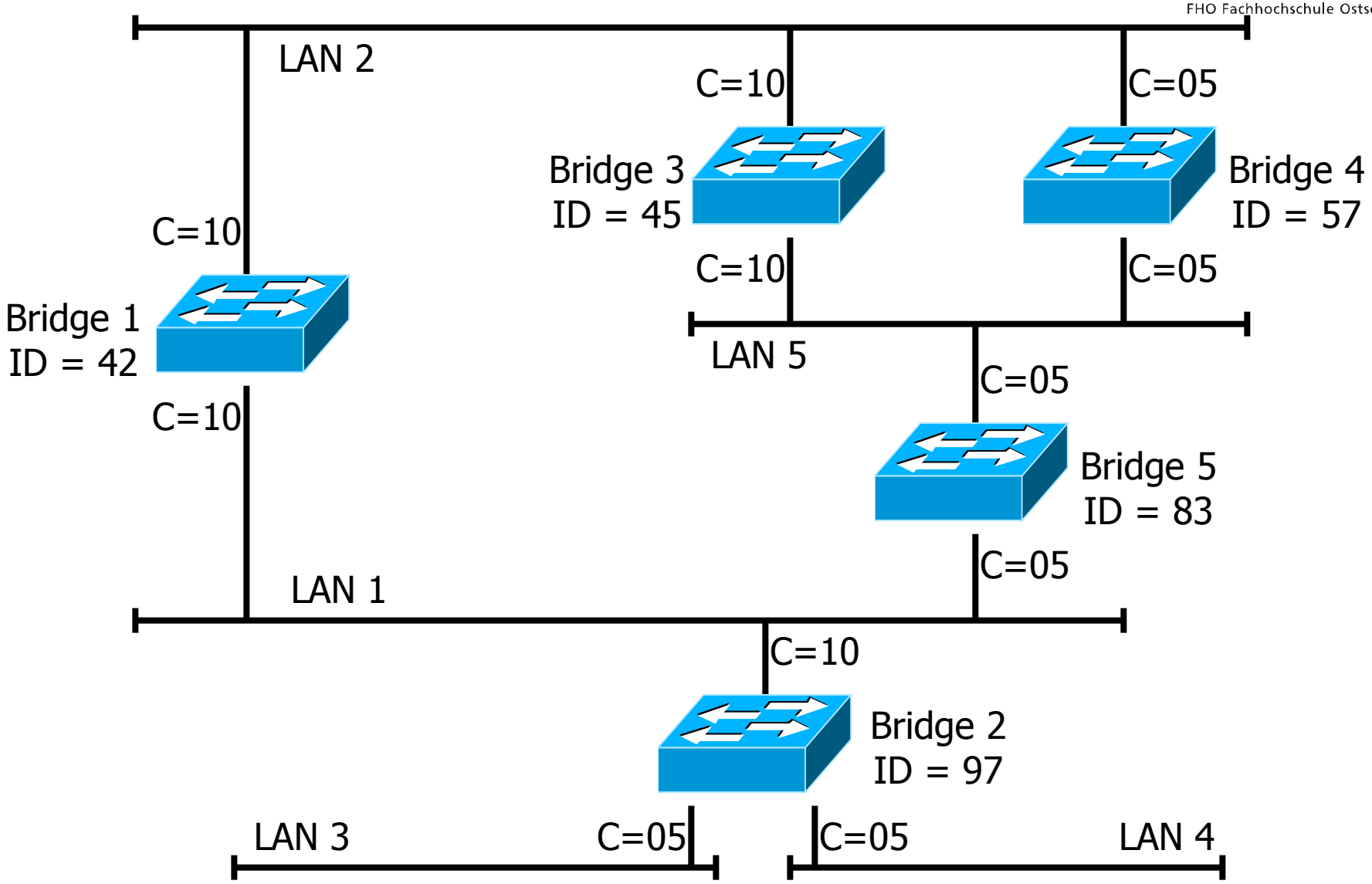
Step 1: Electing a Root Bridge

Step 2: Electing a Root Port on each non-root bridge

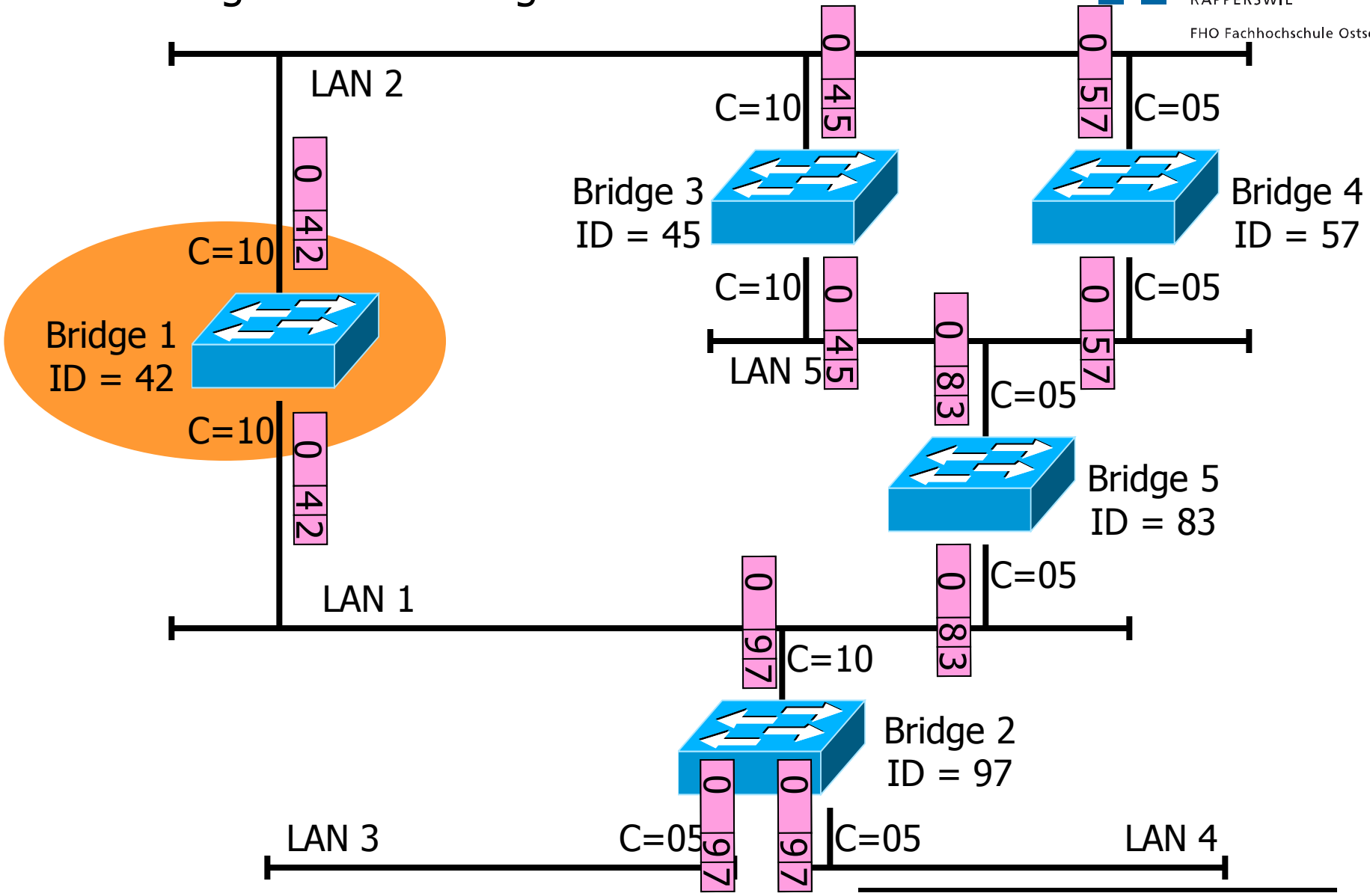
Step 3: Electing a Designated Port on each LAN segment

- All switches send out Configuration Bridge Protocol Data Units (Configuration BPDU's)
- BPDU's are sent out of all interfaces every two seconds (by default - tunable)
- All ports are in Blocking Mode during the initial Spanning Tree process (prior to 802.1D-2004 only).

Parameter Example



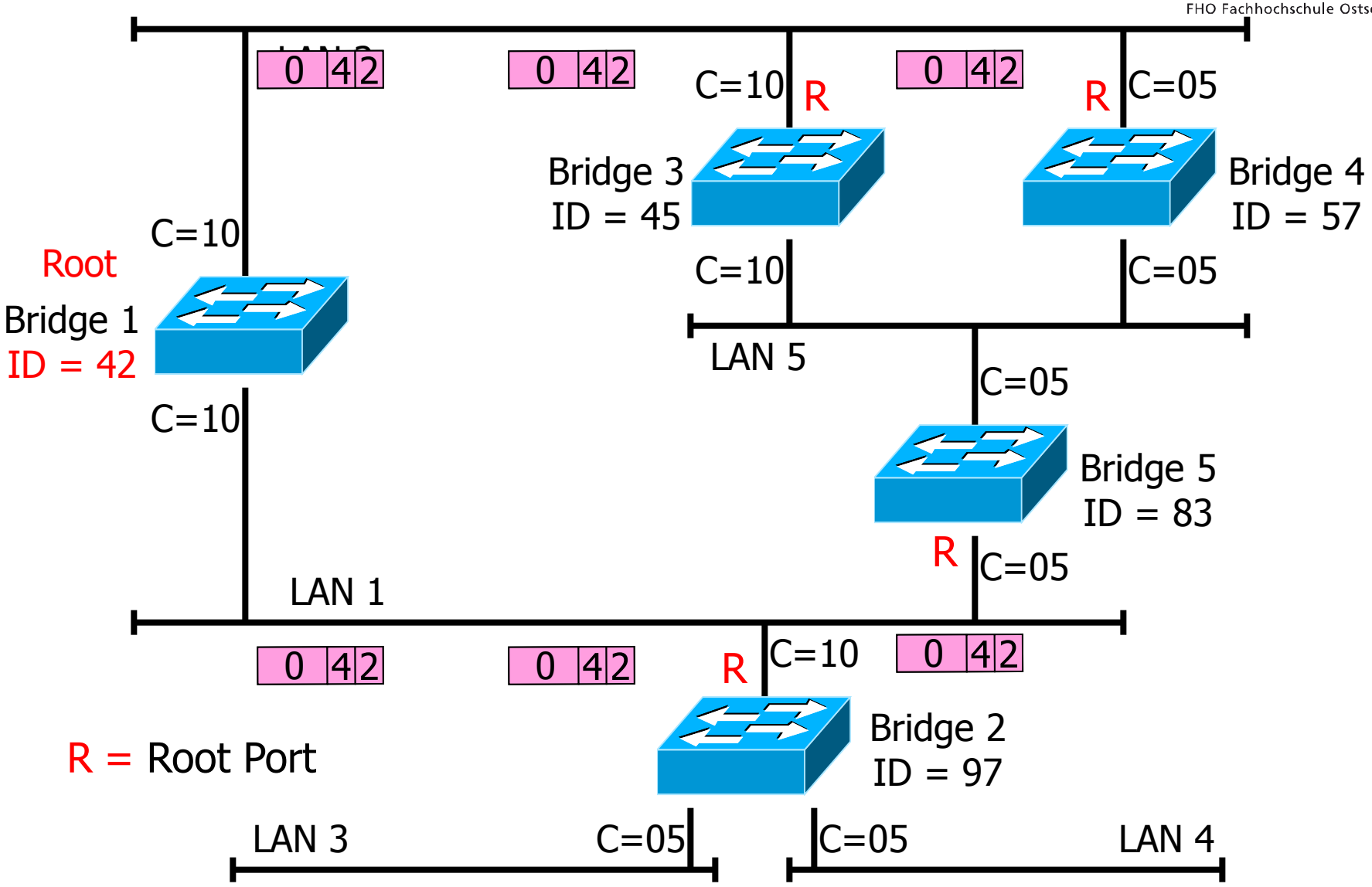
Electing the Root Bridge



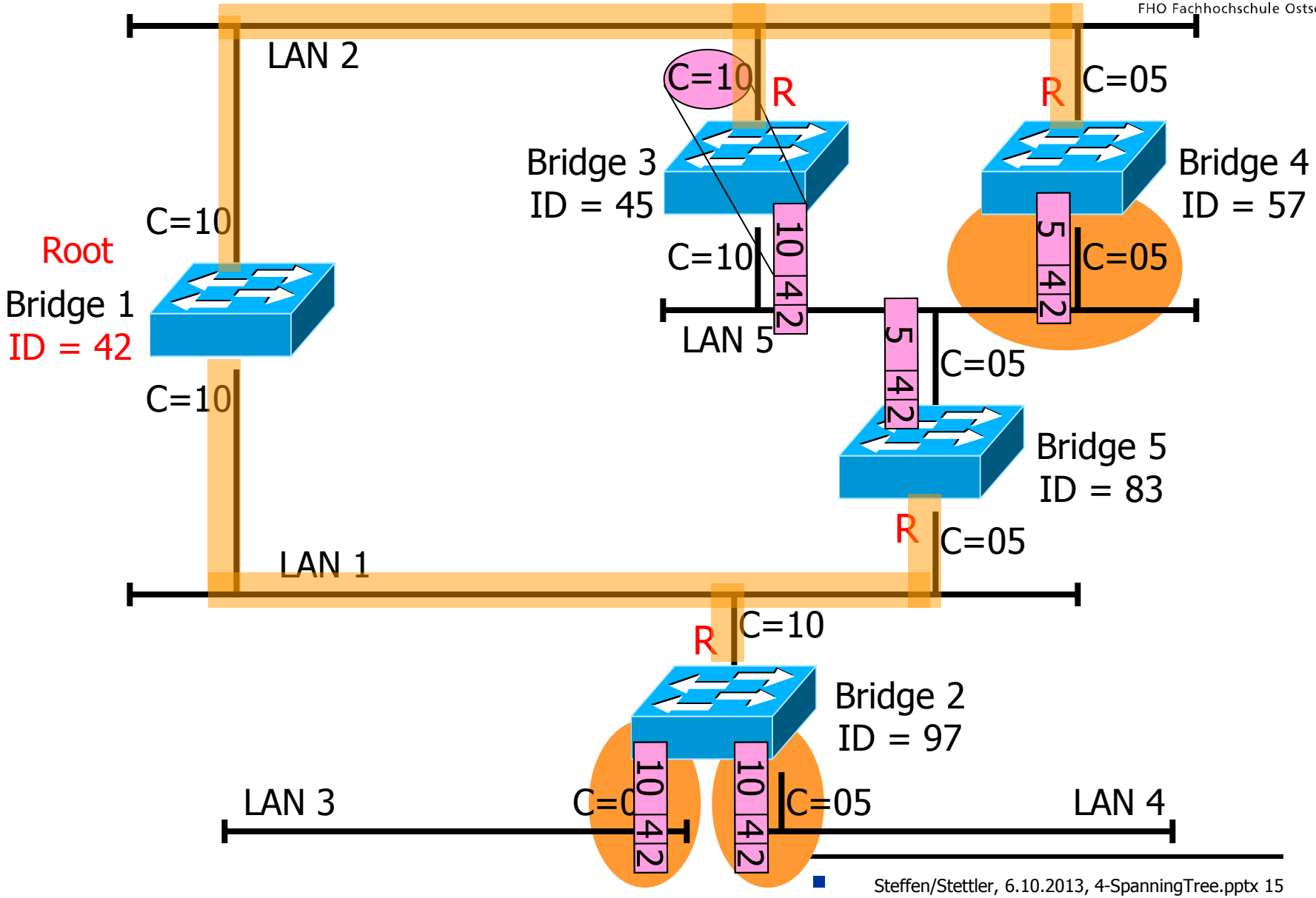
Election of the Root Bridge

- Strategy to determine Root Bridge :
  - if bridge receives Configuration BPDU with lower Root Bridge ID as own Bridge ID, it aborts emitting own Configuration BPDUs on the concerned port, the received Configuration BPDU is passed on to all other ports
  - if bridge receives Configuration BPDU with higher Root Bridge ID as own Bridge ID, it continues emitting own Bridge ID as proposed Root Bridge ID via Configuration BPDUs on all ports → the other bridges must give up

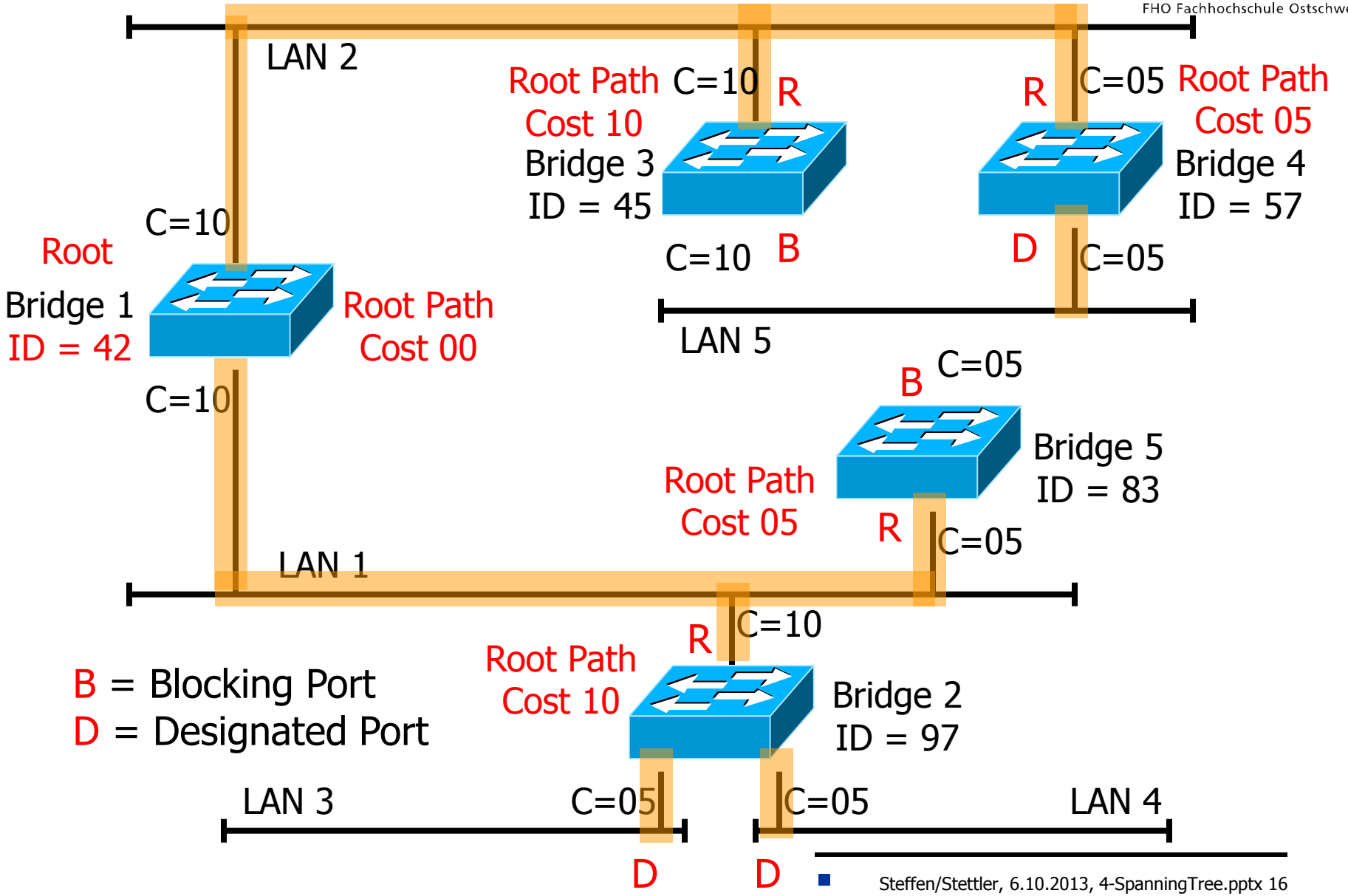
Electing Root Ports



Electing Designated Bridges



Spanning Tree applied III



Root Port and Designated Bridge Election Rules

- Every bridge computes
  - which of its ports has the lowest Root Path Cost
    - calculation based on sum of Root Path Costs received in BPDU plus port costs of interface which has received BPDU message
    - sum of all port costs from bridge over path to RB
- this port becomes the Root Port
    - at equal costs the port ID decides (lower means better)
- similar to Root Bridge selection
  - a Designated Bridge (DB) is selected for each LAN-segment
    - bridge with lowest Root Path Cost on its Root Port
    - at equal costs the bridge with lowest Bridge ID wins

Root Path Cost Determination Rules

- Strategy for Root Port and Designated Bridge determination:
  - if a bridge receives a Configuration BPDU on a port which is closer to the Root Bridge
    - the own port costs are appended to this BPDU and then the BPDU is passed on to all other ports
    - closer means that the sum of Root Path costs received in the BPDU plus port costs of the receiving interface is lower than the actual Root Path Cost stored in the bridge
  - if a bridge receives a Configuration BPDU on a port which is more distant to the Root Bridge
    - the bridge emits the Configuration BPDU on the same port (which received the BPDU originally) but replaces the Root Path Cost with its own local stored cost
    - more distant means that the sum of Root Path costs received in the BPDU plus port costs of the receiving interface is higher than the actual Root Path Cost stored in the bridge

Bridge Port States

- **Blocking**
  - Won't forward frames; listens to BPDUs. All ports are in blocking state by default when the switch is powered up.
- **Listening**
  - Listens to BPDUs to make sure no loops occur on the network before passing data frames. Calculation of Topology
- **Learning**
  - Learns MAC addresses and builds a filter table but does not forward frames.
- **Forwarding**
  - Sends and receives all data on the bridged port.

Spanning Tree Summary

- Purpose: To maintain loop-free topologies in a redundant layer 2 infrastructure
- Provides path recovery services in case of component or link failure
- Original 802.1D-1998 Spanning Tree Protocol (STP)
  - High availability was mediocre at best
  - Convergence time was quite slow (>50 seconds)
- New 802.1w Rapid Spanning Tree Protocol (RSTP)
  - Achieves significant improvements in reconfiguration speed and reliability by defining Backup and Alternate bridge ports in addition to Designated and Disabled bridge ports.
  - RSTP obsoleted STP in the IEEE 802.1D-2004 revision (chapter 17 RSTP completely replaced chapter 8 STP).