



# Bridge & Switch

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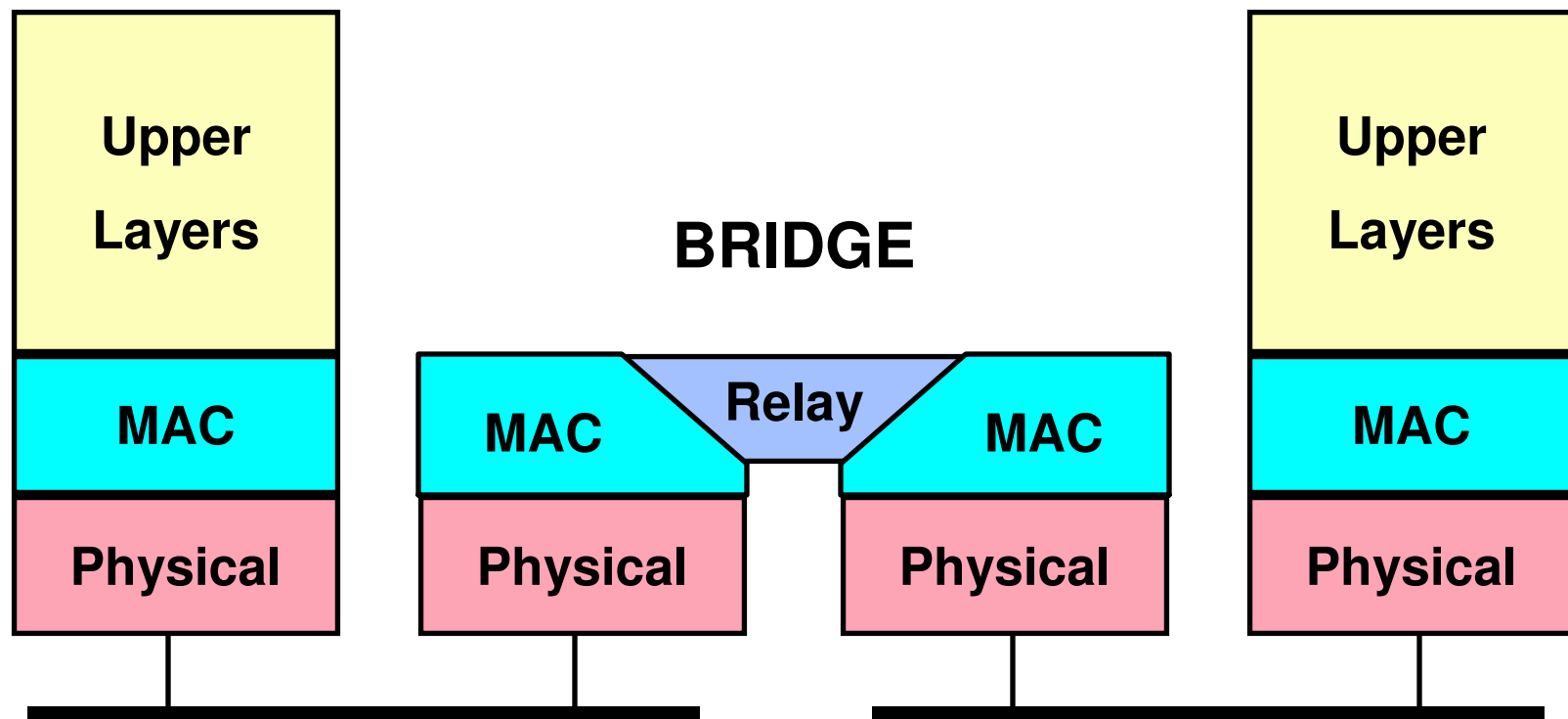


# Bridge

- Called also MAC Bridge
  - operate at layer 2
  - use simple forwarding algorithm
    - forwarding technique based on MAC destination address
  - are normally used for local connections

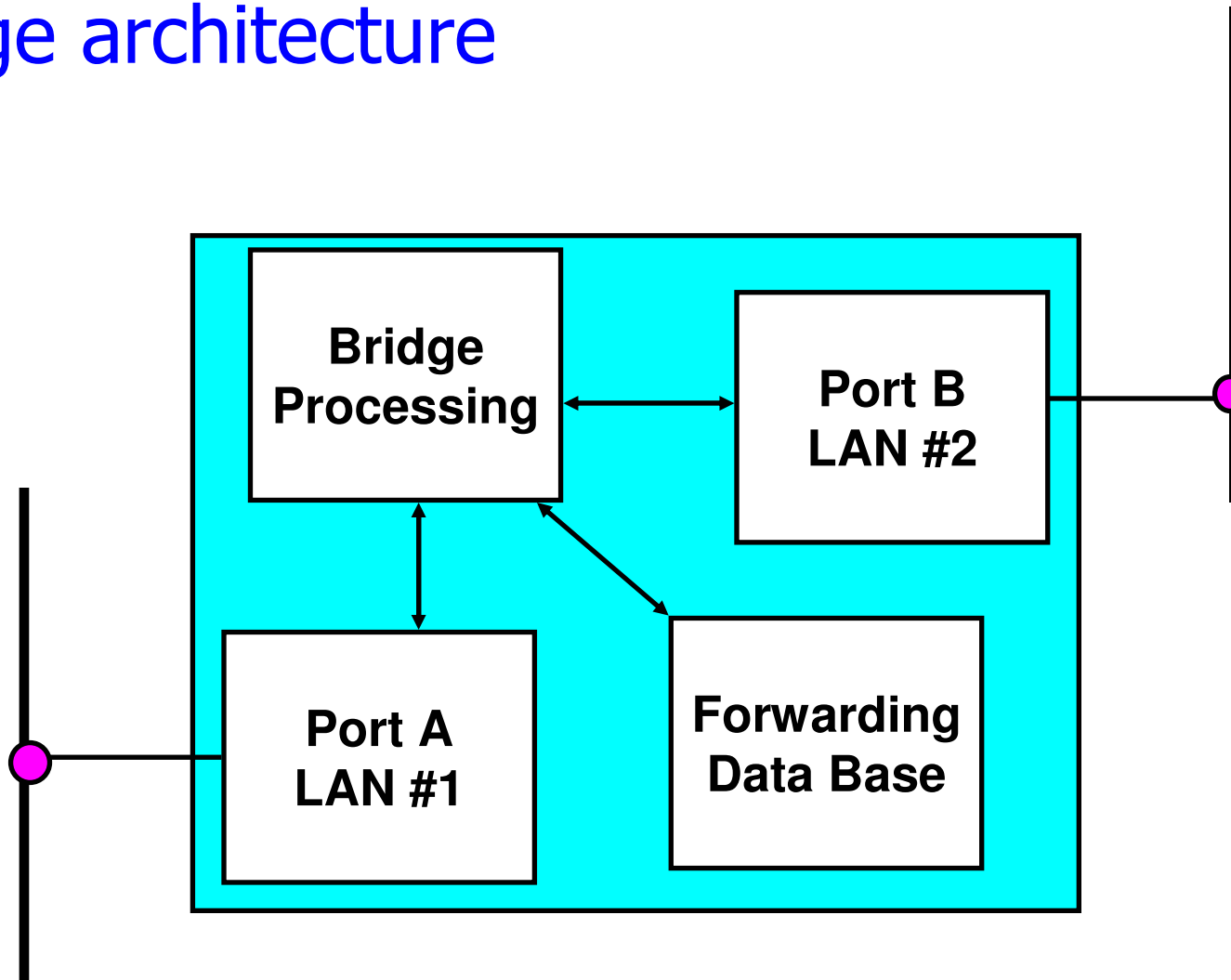


# Bridge model





# Bridge architecture





# Forwarding

- Forwarding table is calculated by:
  - backward learning
  - looking the Source MAC address
- Backward learning
  - work only over LAN with tree topology
  - other topologies are transformed to tree topology by spanning tree algorithm
- Spanning tree algorithm operate periodically (any second)
  - decide which port set to forwarding state and which port set to blocking state

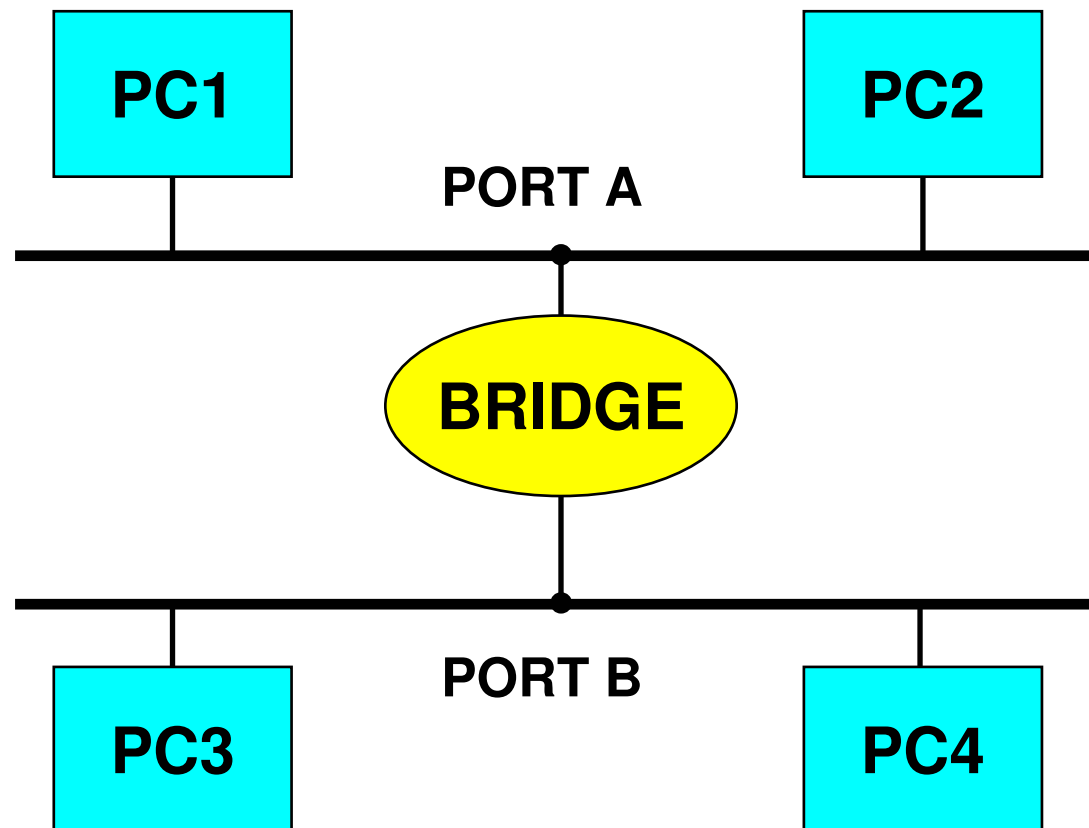


# Transparent Bridge

- IEEE standardized the bridge functions by 802.1D standard
- The bridge 802.1D work in transparent mode, for this reason are also called transparent bridge:
  - are derived from Ethernet
  - have a local forwarding table
- The main functions of the bridge are:
  - frame forwarding
    - **Singlecast** frames forwarding based on *Destination MAC Address*
    - **Broadcast** frames are forwarded in every ports except the port where as been received
  - stations auto-learning
  - loop detection by spanning tree algorithm

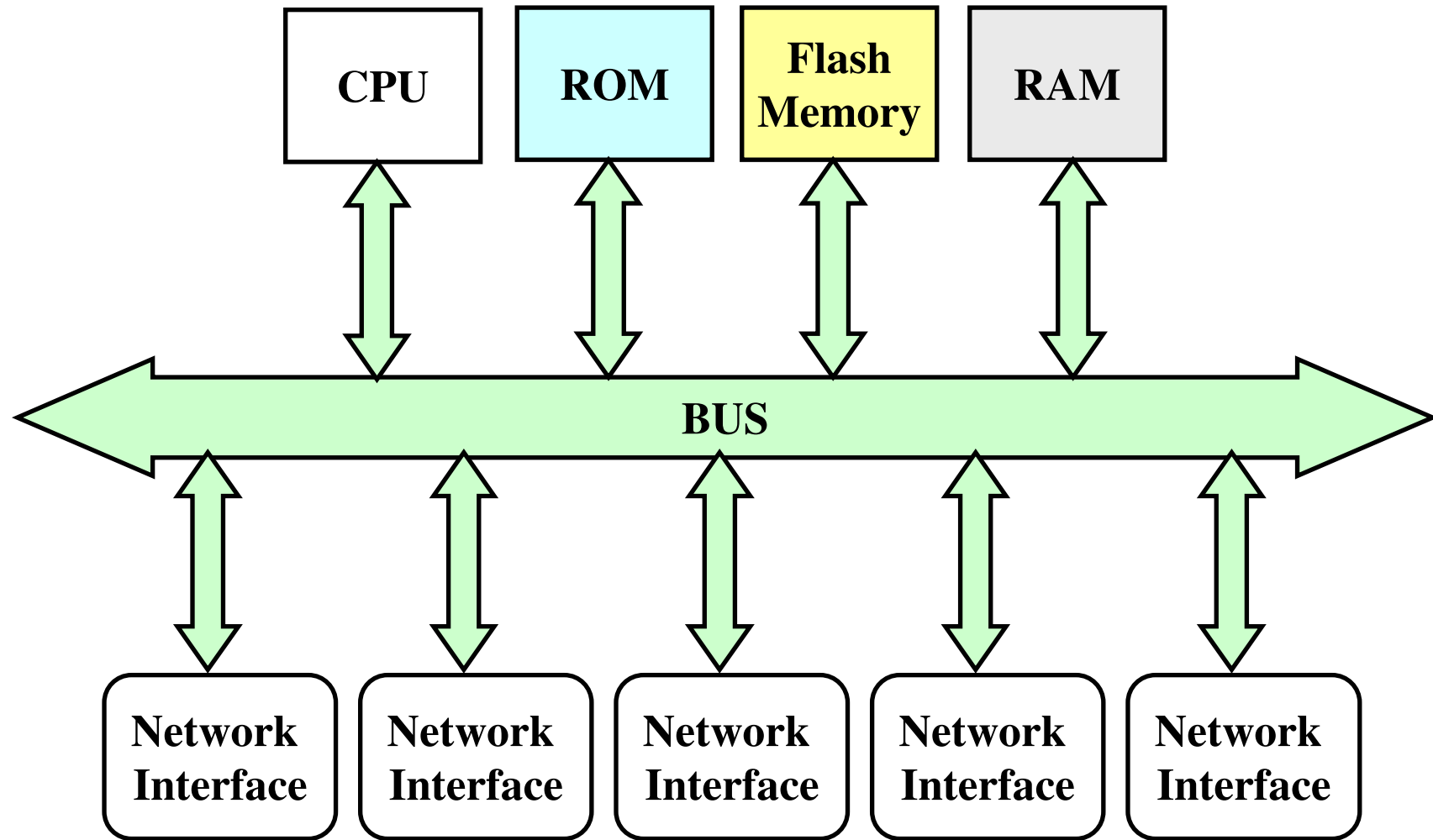


# Transparent Bridge



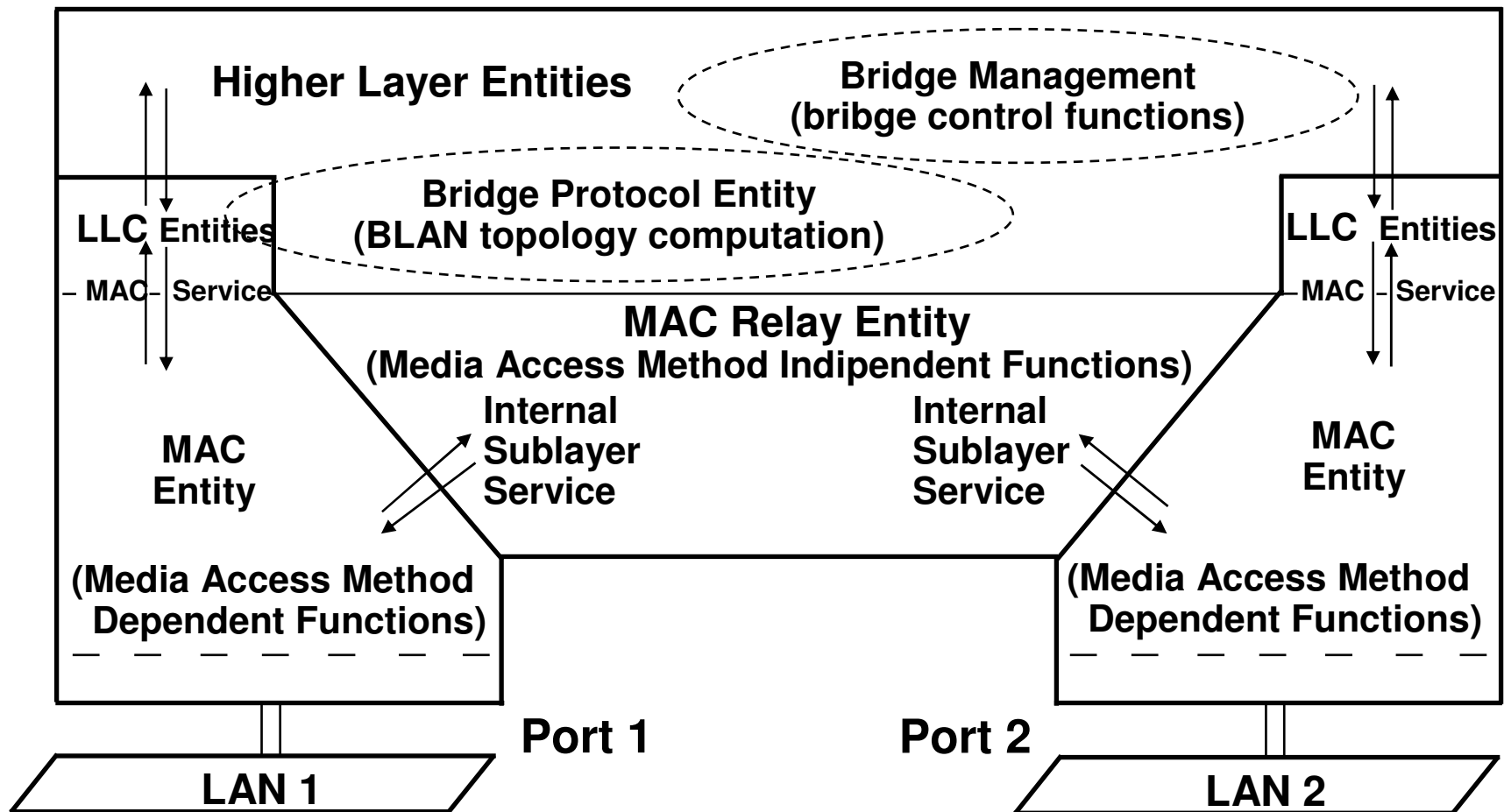


# Bridge physical architecture



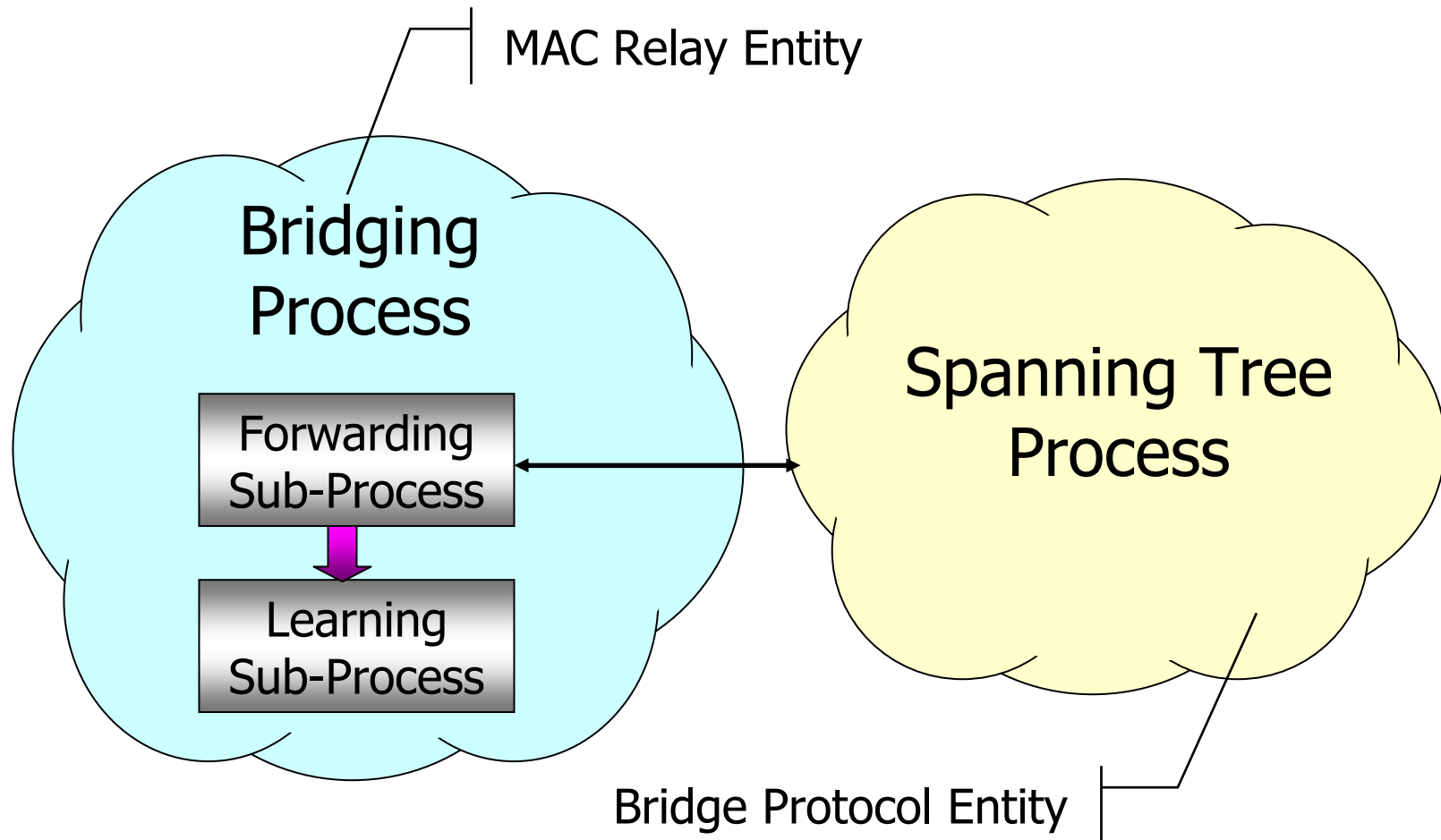


# Bridge logical architecture





# Bridge functions





# Filtering data base

- ***Entry*** fields
  - MAC address
  - Destination port
  - Ageing time (default expire after 300 s)
  - Port status (depending by spanning tree protocol)
  - Entry type
    - dynamic
      - Updated by learning process
      - Max entries: 1024 ÷ 65 K
    - static
      - Not updated by learning process
      - 256 entries typically
- Lookup by CAM (Content Addressable Memory)



# Filtering database example

filtering database show command

Switch-1> show cam dynamic

\* = Static Entry. + = Permanent Entry.

# = System Entry X = Port Security Entry

Dest MAC Address	Ports	Age
00-00-86-1a-a6-44	1/1	1
00-00-c9-10-b3-0f	1/1	0
00-00-f8-31-1c-3b	1/2	4
00-00-f8-31-f7-a0	1/1	2
00-01-e7-00-e3-80	2/2	0
00-02-a5-84-a7-a6	2/1	1
00-02-b3-1e-b4-aa	2/1	5
00-02-b3-1e-da-da	2/5	1
00-02-b3-1e-dc-fd	2/4	2

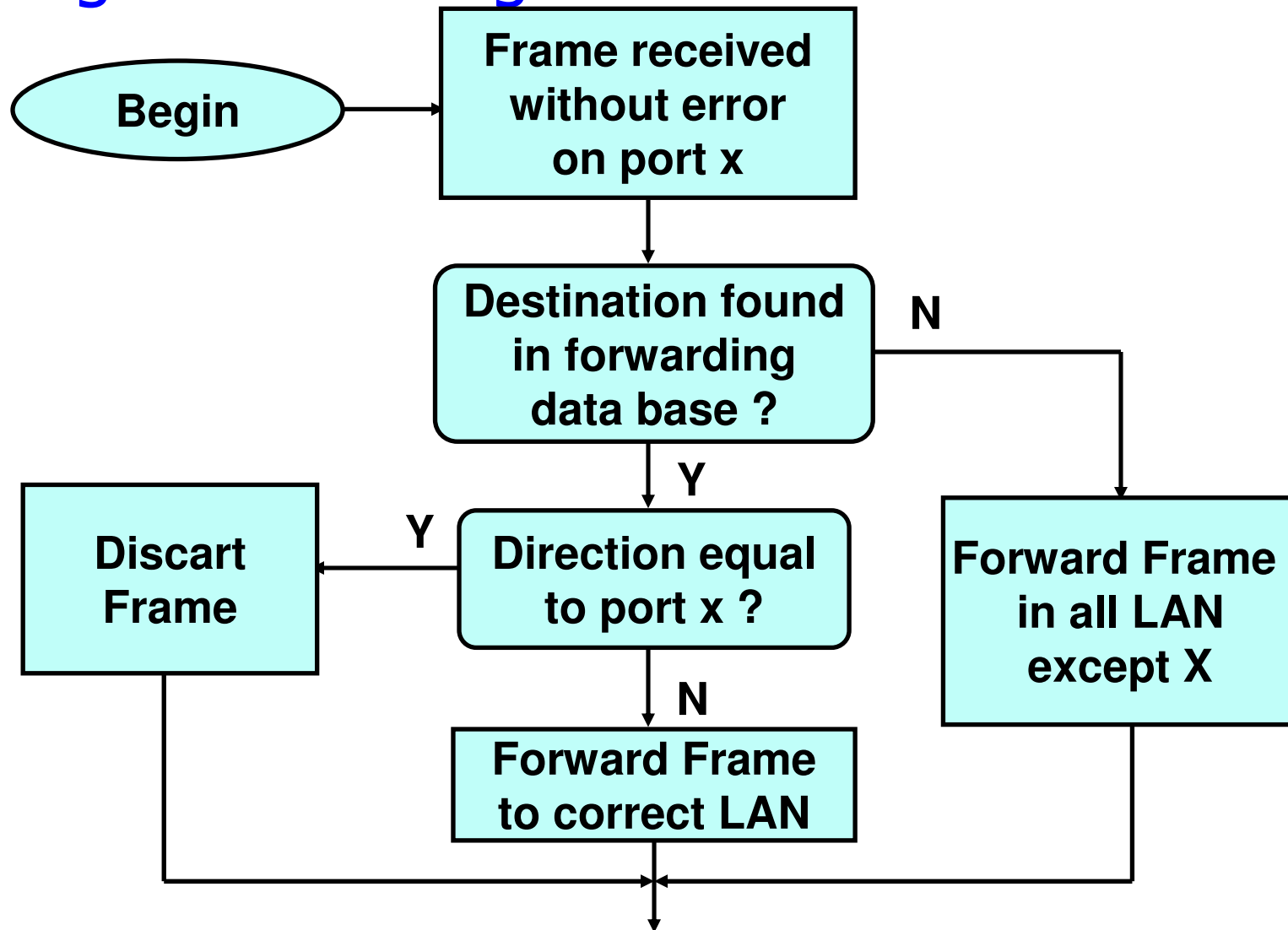
Modular switch: slot/port

Ageing time

Stations MAC address

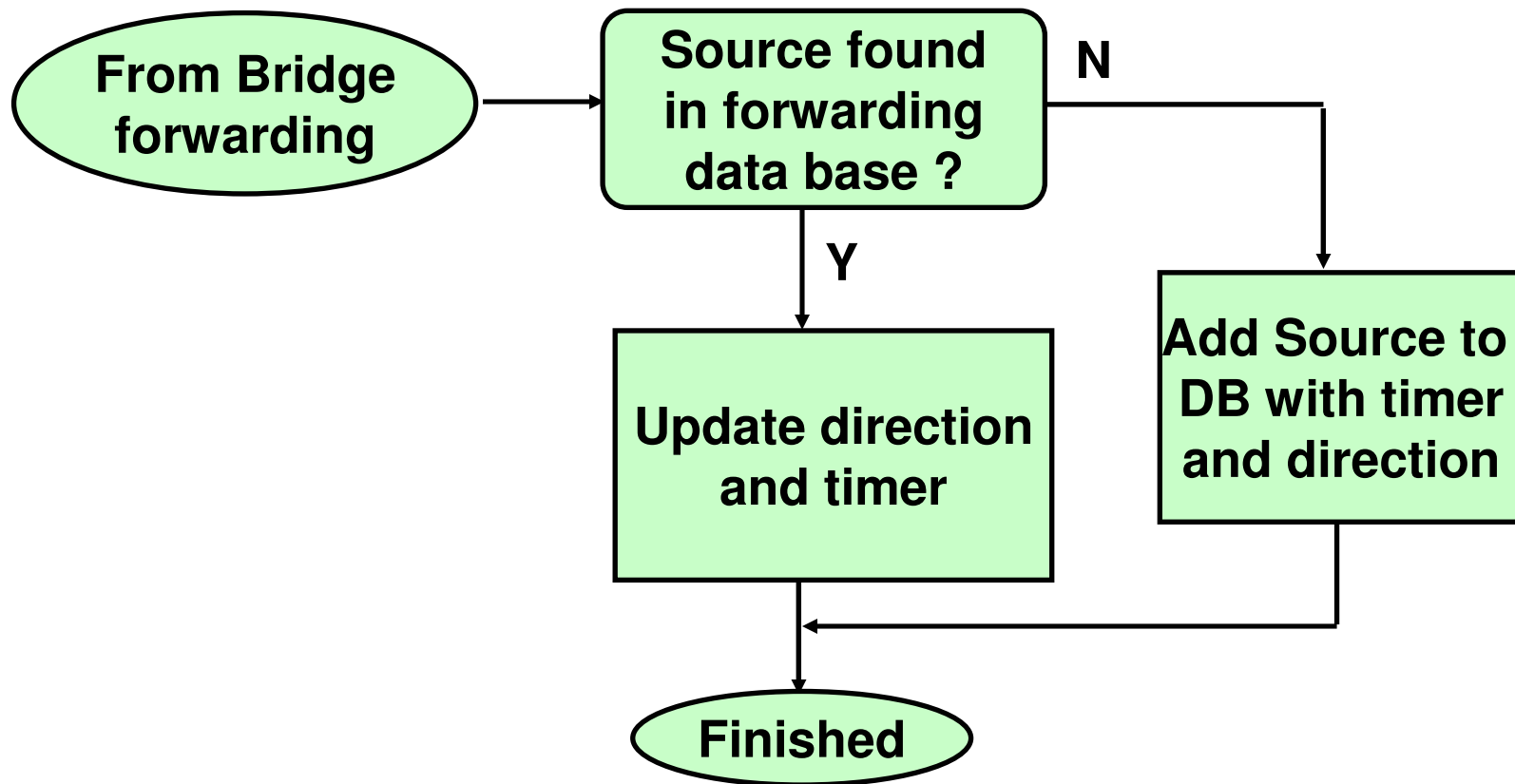


# Bridge Forwarding



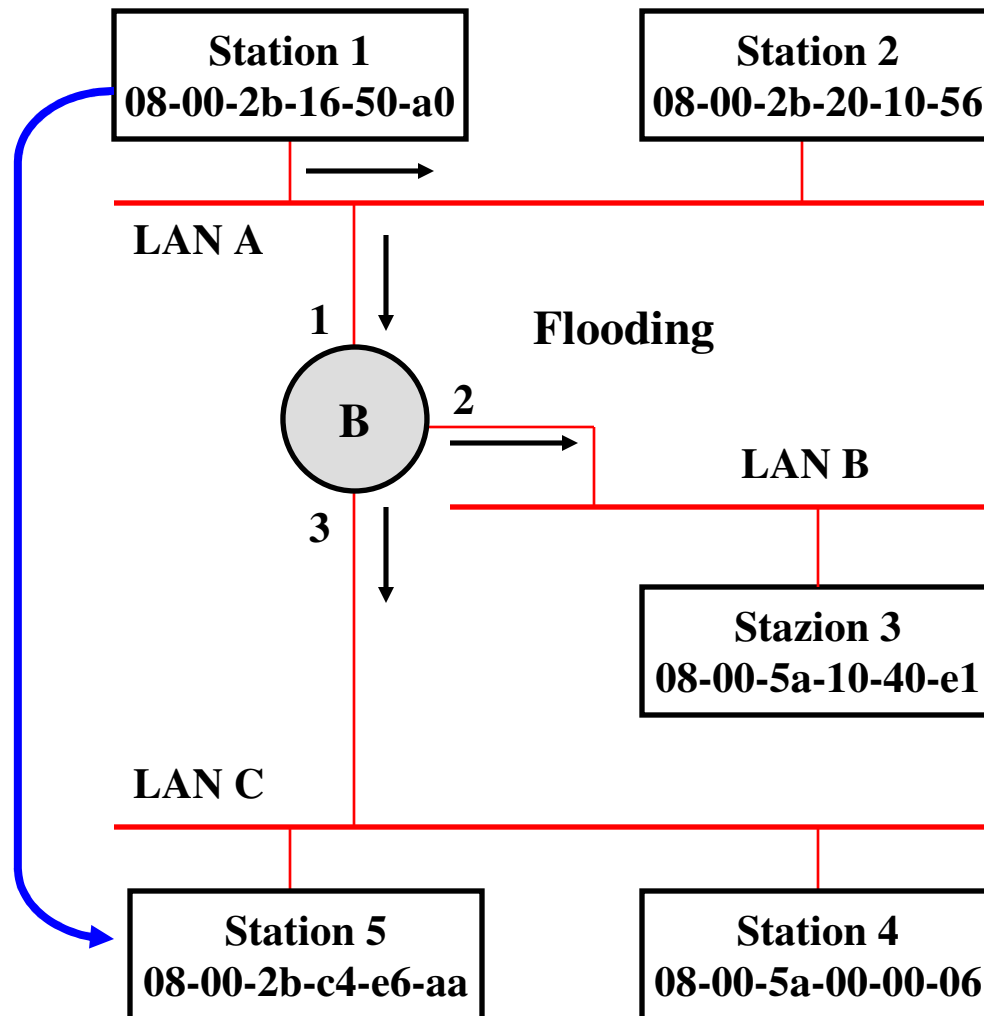


# Bridge Learning





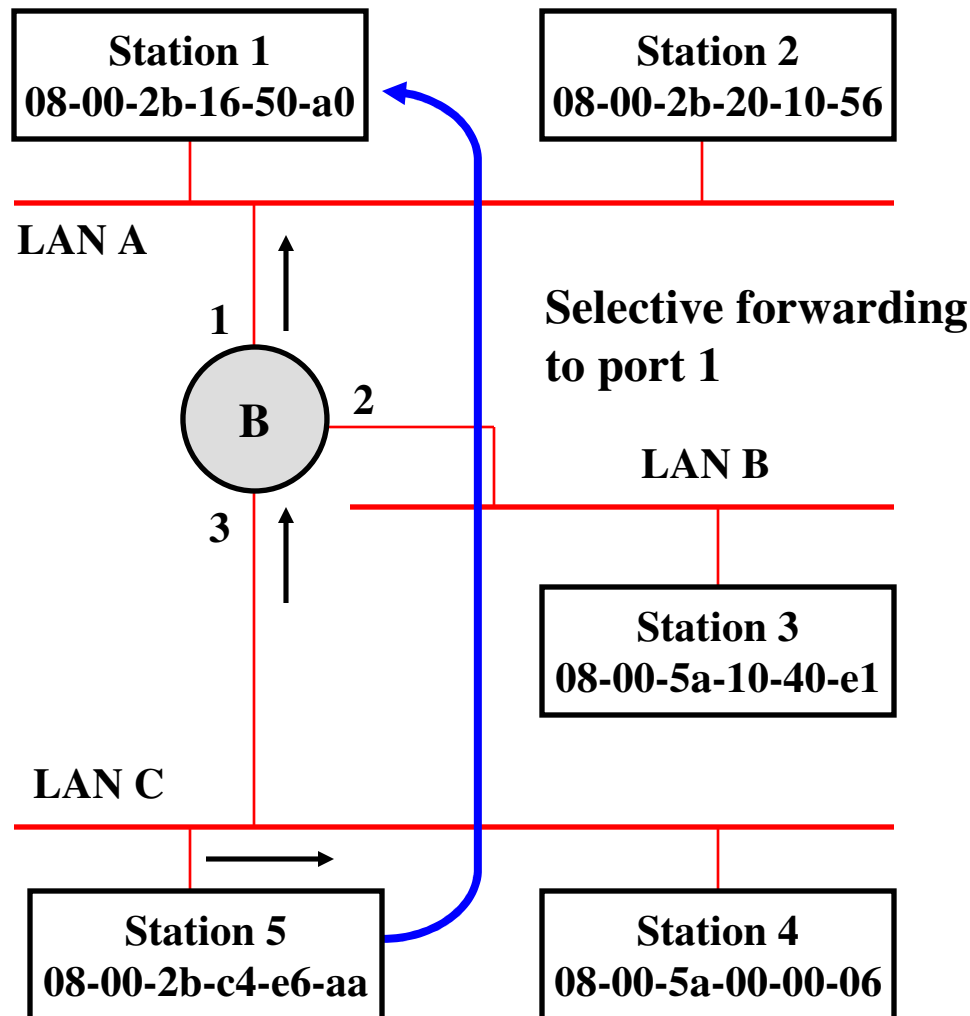
# Forwarding frame to unknown destination



Port	MAC adress	Ageing time
1	08-00-2b-16-50-a0	0



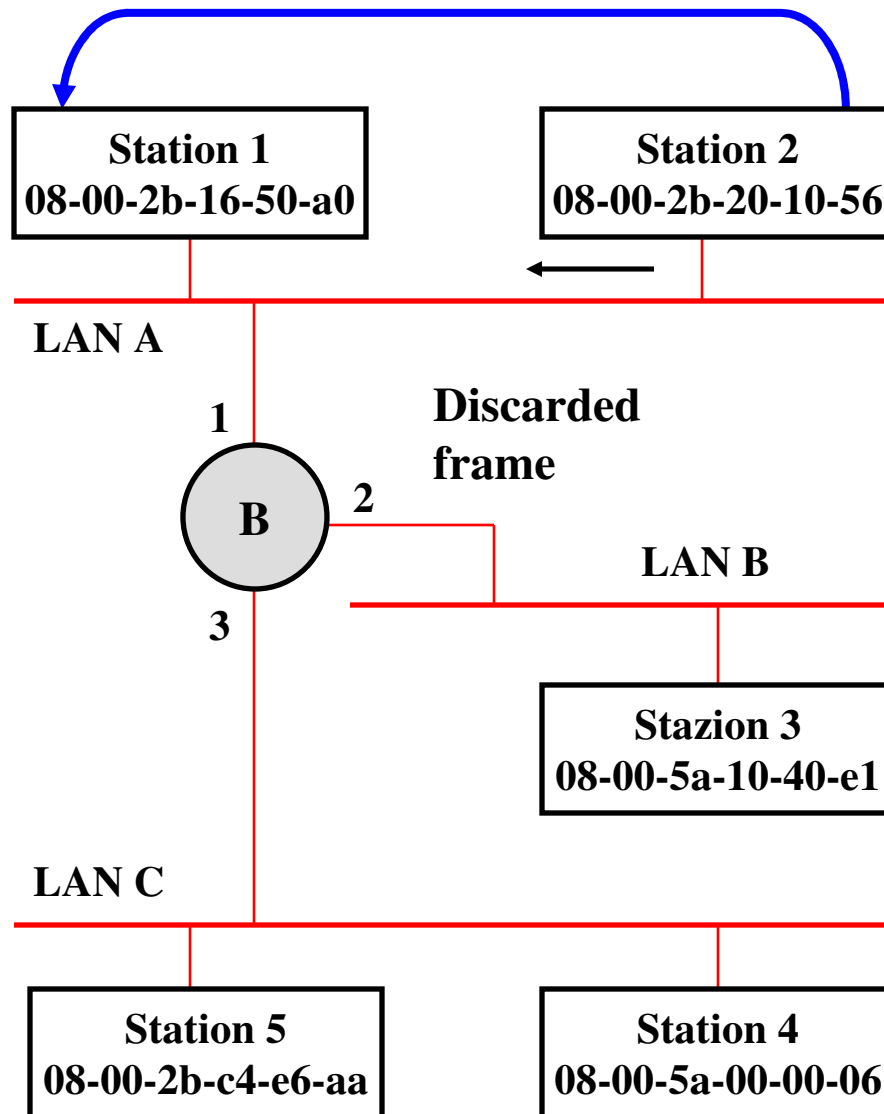
# Forwarding frame to known address destination



Port	MAC adress	Ageing time
1	08-00-2b-16-50-a0	5
3	08-00-2b-c4-e6-aa	0



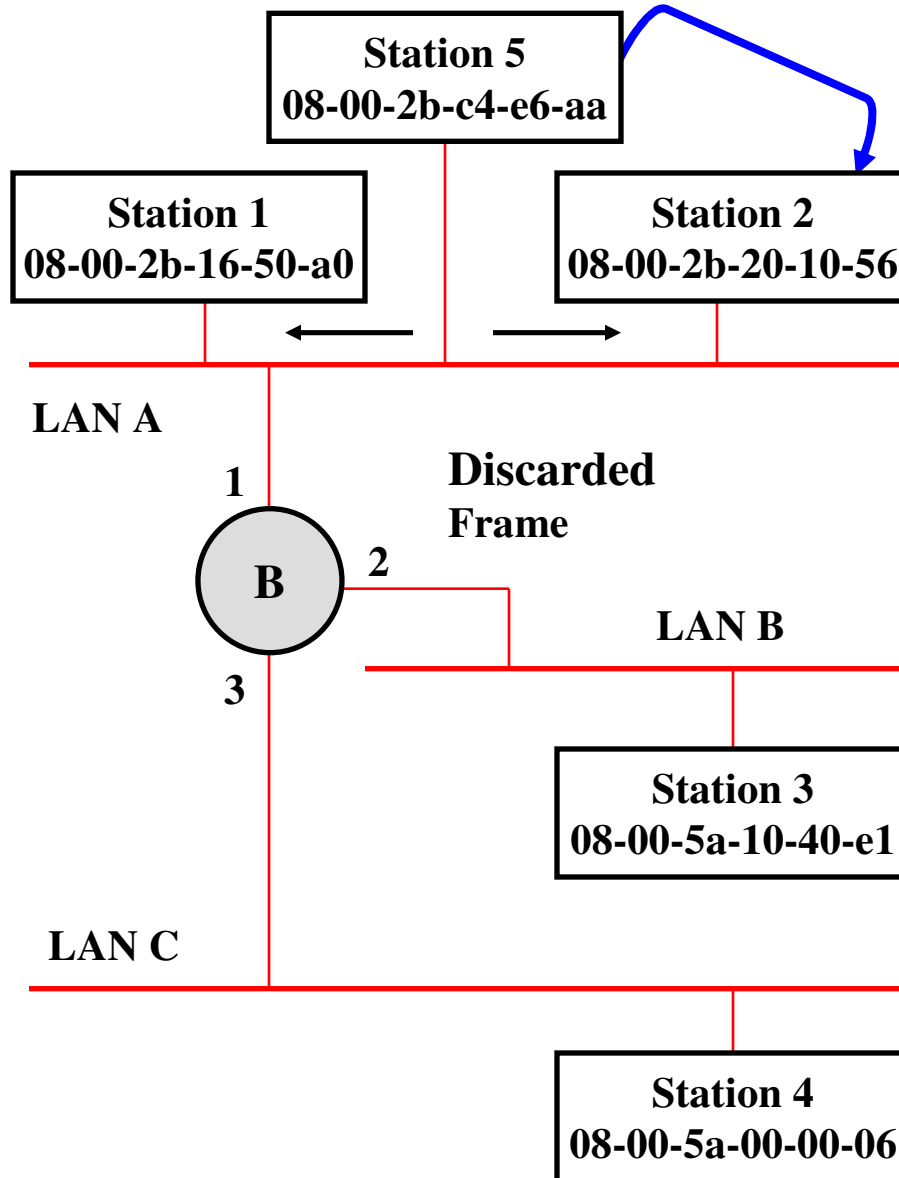
# Traffic limitation



Port	MAC adress	Ageing time
1	08-00-2b-16-50-a0	12
3	08-00-2b-c4-e6-aa	13
1	08-00-2b-20-10-56	0



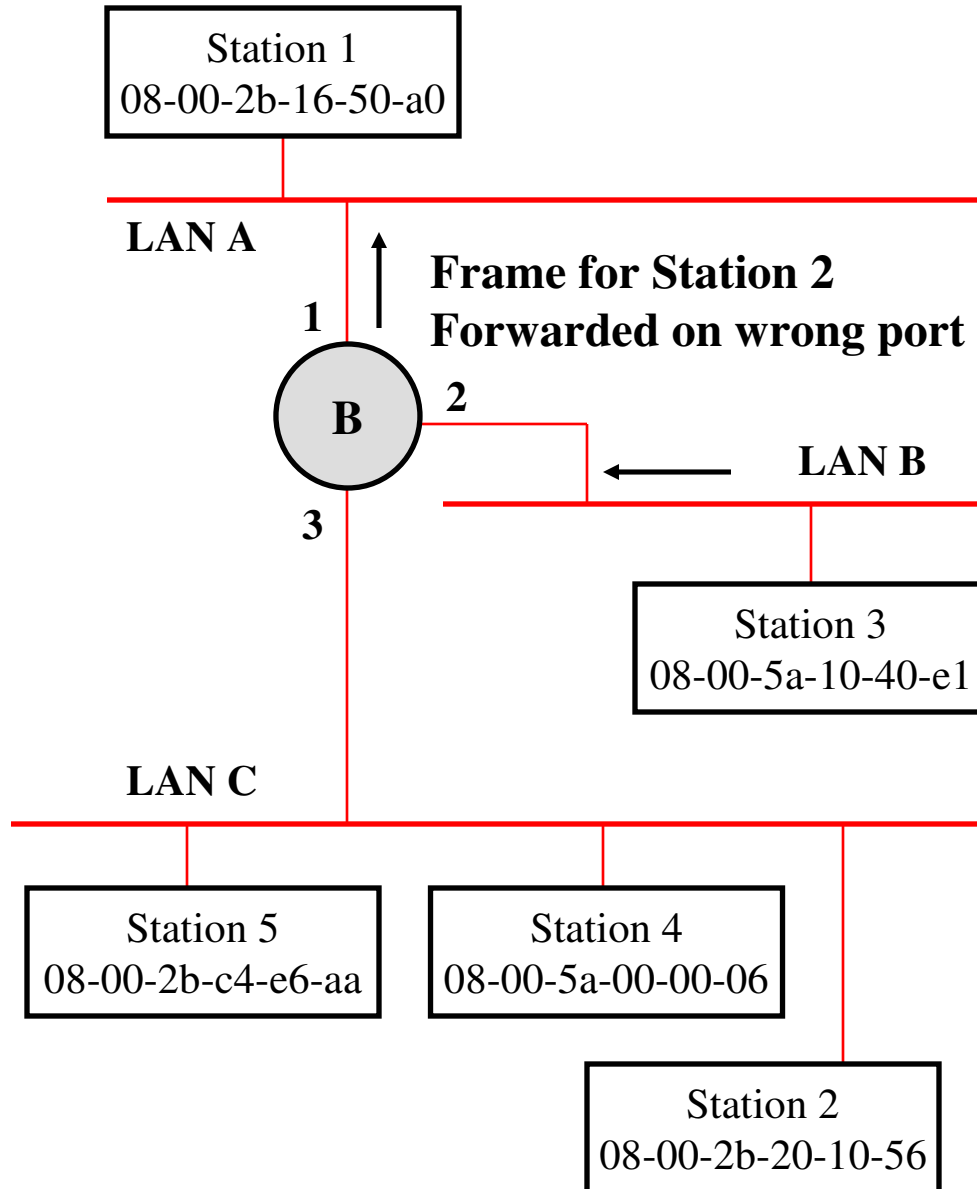
# Station 5 move and Filtering Data Base update



Port	MAC adress	Ageing time
1	08-00-2b-16-50-a0	40
<b>1</b>	08-00-2b-c4-e6-aa	0
1	08-00-2b-20-10-56	20



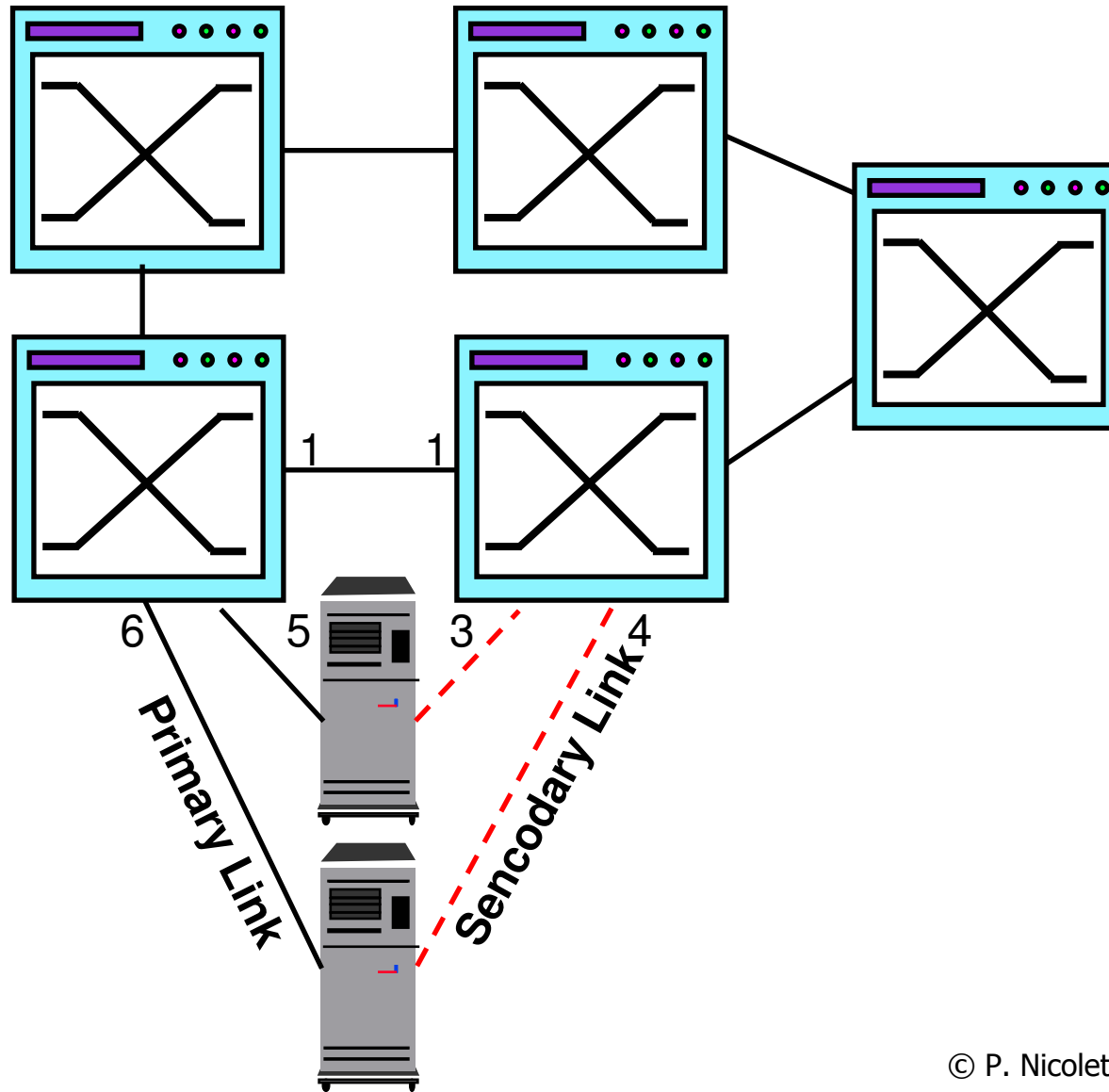
# Station 2 move and forwarding error



Port	MAC adress	Ageing time
1	08-00-2b-16-50-a0	50
3	08-00-2b-c4-e6-aa	51
1	08-00-2b-20-10-56	40
2	08-00-5a-10-40-e1	0



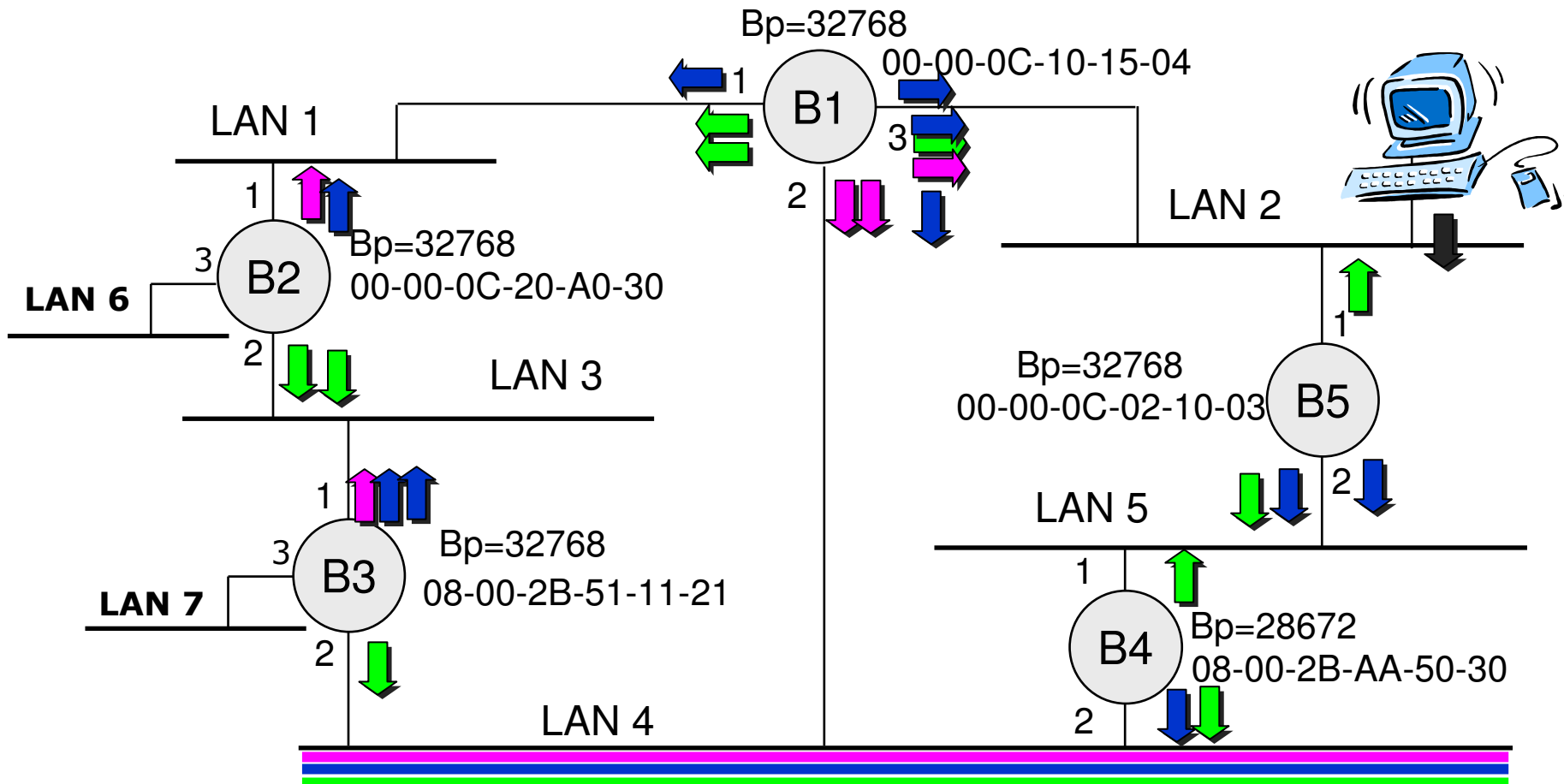
# Fault Tolerant network and Filtering Data Base Update





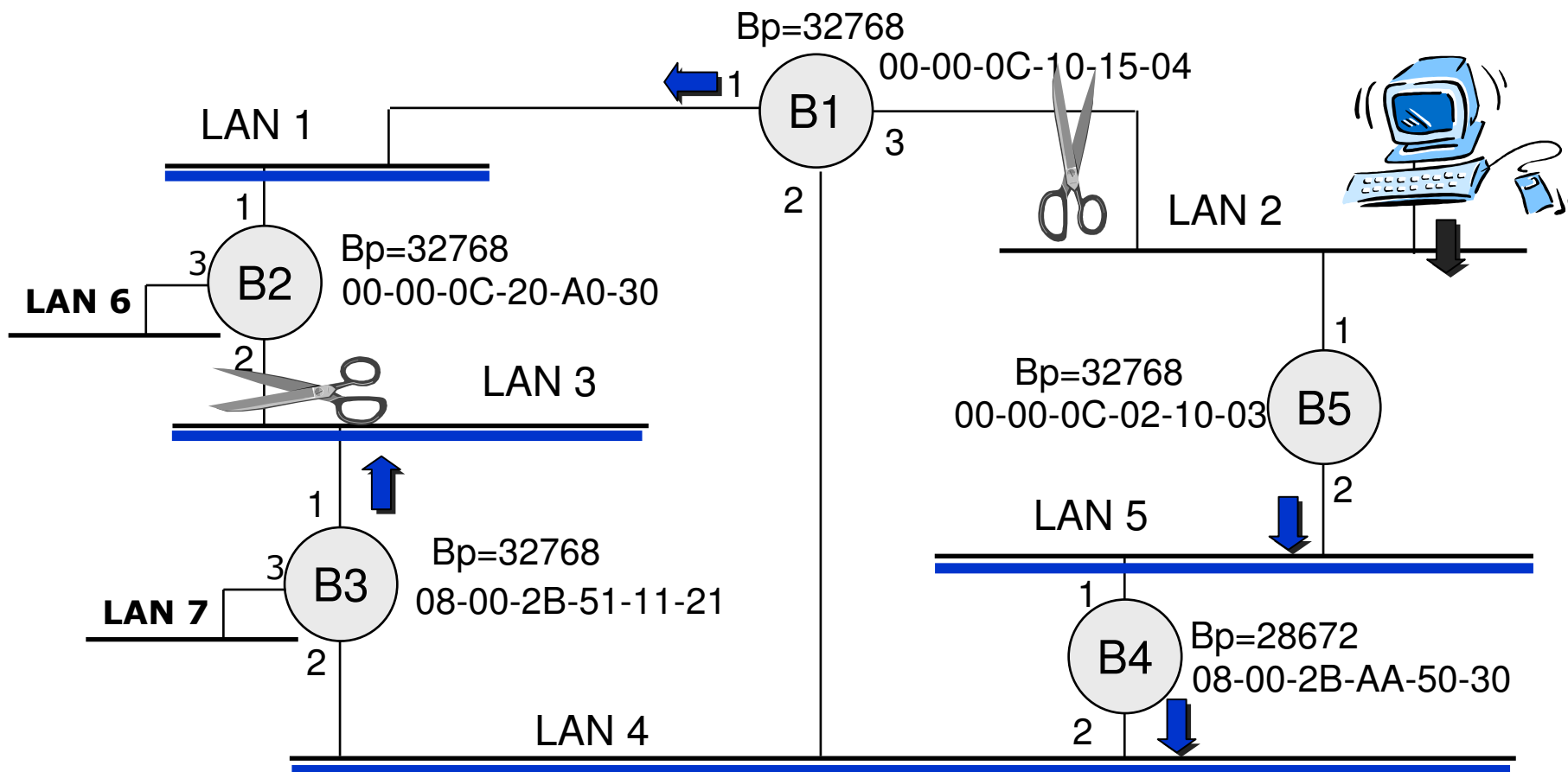
# Loop on the network

- Broadcast are not filtered: **broadcast storm**





# Solution: cut the loops



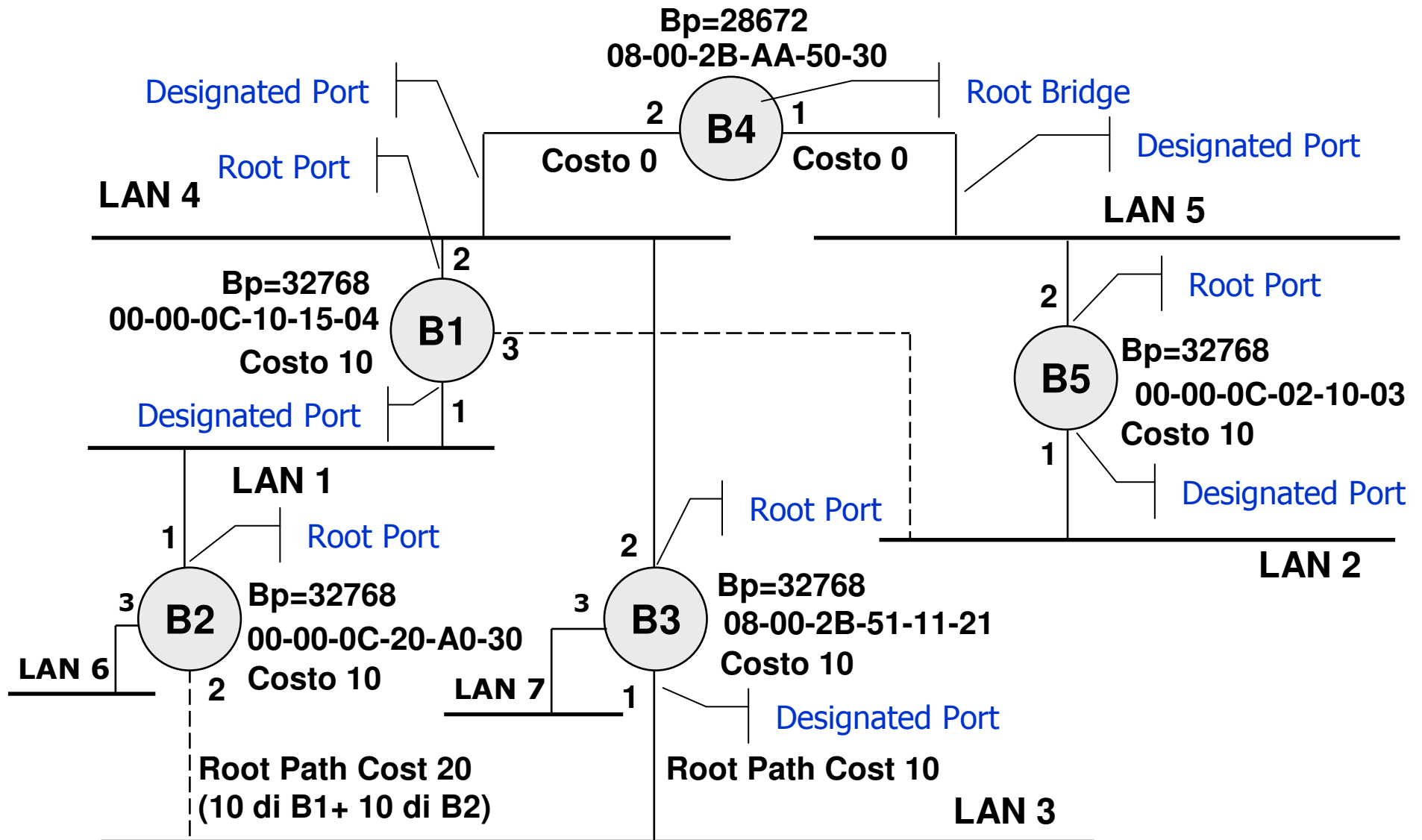


# Spanning Tree

- All bridge in the network must be IEEE 802.1D spanning tree compliant
- The spanning tree algorithm operate with the following steps:
  - Root Bridge election
  - Root Port selection
  - Designated/Blocking Port selection
- The spanning tree protocol use the BPDU (Bridge Protocol Data Unit)



# Spanning tree protocol result





# Bridge Protocol Data Unit (BPDU)

- **Configuration** BPDU
- **Topology Change Notification** BPDU

Dest. Addr.	Source Addr.	Length	DSAP	SSAP	Control	BPDU	
Multicast 01-80-C2 00-00-00	Singlecast MAC Bridge Address	XY	042H	042H	XID	Configuration BPDU or Topology Change Notification BPDU	FCS

**BPDU: Bridge Protocol Data Unit**  
**DSAP: Destination Service Access Point**  
**SSAP: Source Service Access Point**



# Configuration BPDU

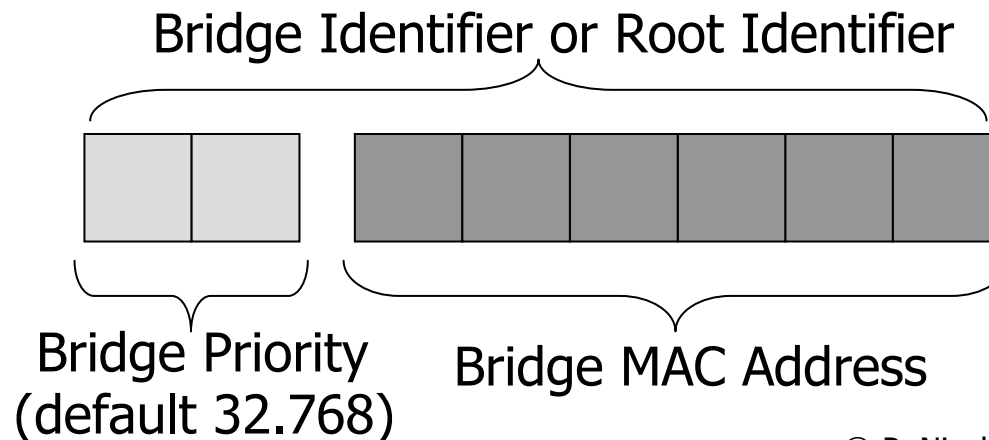
- **Root Identifier**
  - bridge identifier of root bridge
- **Root Path Cost**
  - Cost to reach the root bridge
  - Zero on BPDU transmitted by root bridge
- **Bridge Identifier**
- **Port Identifier**

Byte 1÷2	<b>Protocol Identifier:</b>	<b>00-00</b>
3	<b>Protocol Version Identifier:</b>	<b>00</b>
4	<b>BPDU Type:</b>	<b>00</b>
5	TC	Flags
		TCA
6÷13	<b>Root Identifier</b> First 2 byte = Bridge Priority Last 6 byte = Root Bridge MAC Address	
14÷17	<b>Root Path Cost</b>	
18÷25	<b>Bridge Identifier</b> First 2 byte = Bridge Priority Last 6 byte = Bridge MAC Address witch transmit BPDU	
26÷27	<b>Port Identifier</b> First byte = Port Priority second byte = port number	
28÷29	<b>Message Age</b>	
30÷31	<b>Max Age</b>	
32÷33	<b>Hello Time</b>	
34÷35	<b>Forward Delay</b>	



## Bridge Identifier

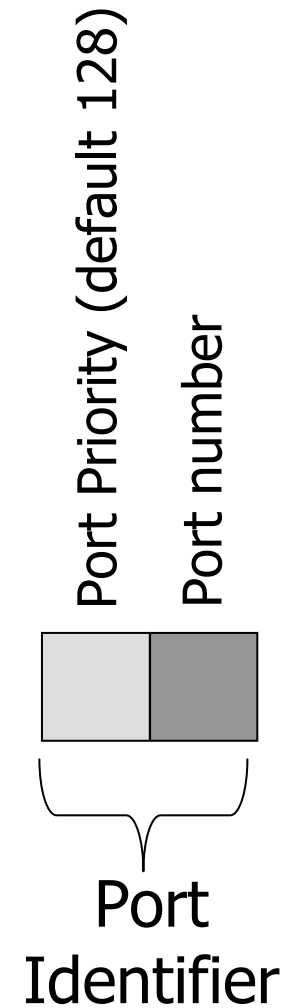
- MAC Address assigned to the Bridge
- Priority assigned to the Bridge: ***bridge priority***
  - Configuration
  - Default value to guarantee "plug&play" operation
- Became root bridge the bridge with less bridge identifier
  - Less bridge priority determine the root bridge election
  - If Bridge priority is the same in every bridge the lowest MAC address determine the root bridge election





# Port Identifier

- Identify the port witch transmit the BPDU on connected LAN





# The algorithm principle

- Root Bridge election
  - Is selected as root bridge the bridge with lowest Bridge Identifier
- Root port
  - The port (only one) connection to the root bridge
- Designated Port
  - The port that forwards frames from that LAN towards the Root
  - A bridge may one or more designated ports



# The algorithm principle: Root & Designated Port selection

- Rule for Root and Designated Port selection
  - **Lowest Root Path Cost**
  - In case of equal Root Path Cost the algorithm look for **Lowest Bridge Identifier**
  - In case of equal Root Path Cost and equal Bridge Identifier the algorithm look for **Lowest Port Identifier**
  - If there is only one port to connect a LAN that port is immediately elected as Designated Port
  - All the active port of the root Bridge are selected as Designated Port
- The ports that are not been selected as root or designated go to *Blocking State*



# Port State

## ■ Listening

- Receive frames
- Do not forward frames
- Do not update the forwarding data base
- Compute received BPDU
- Transmit BPDU

## ■ Forwarding

- Receive frames
- Forward frames
- Update the forwarding data base
- Compute received BPDU
- Transmit BPDU

## ■ Learning

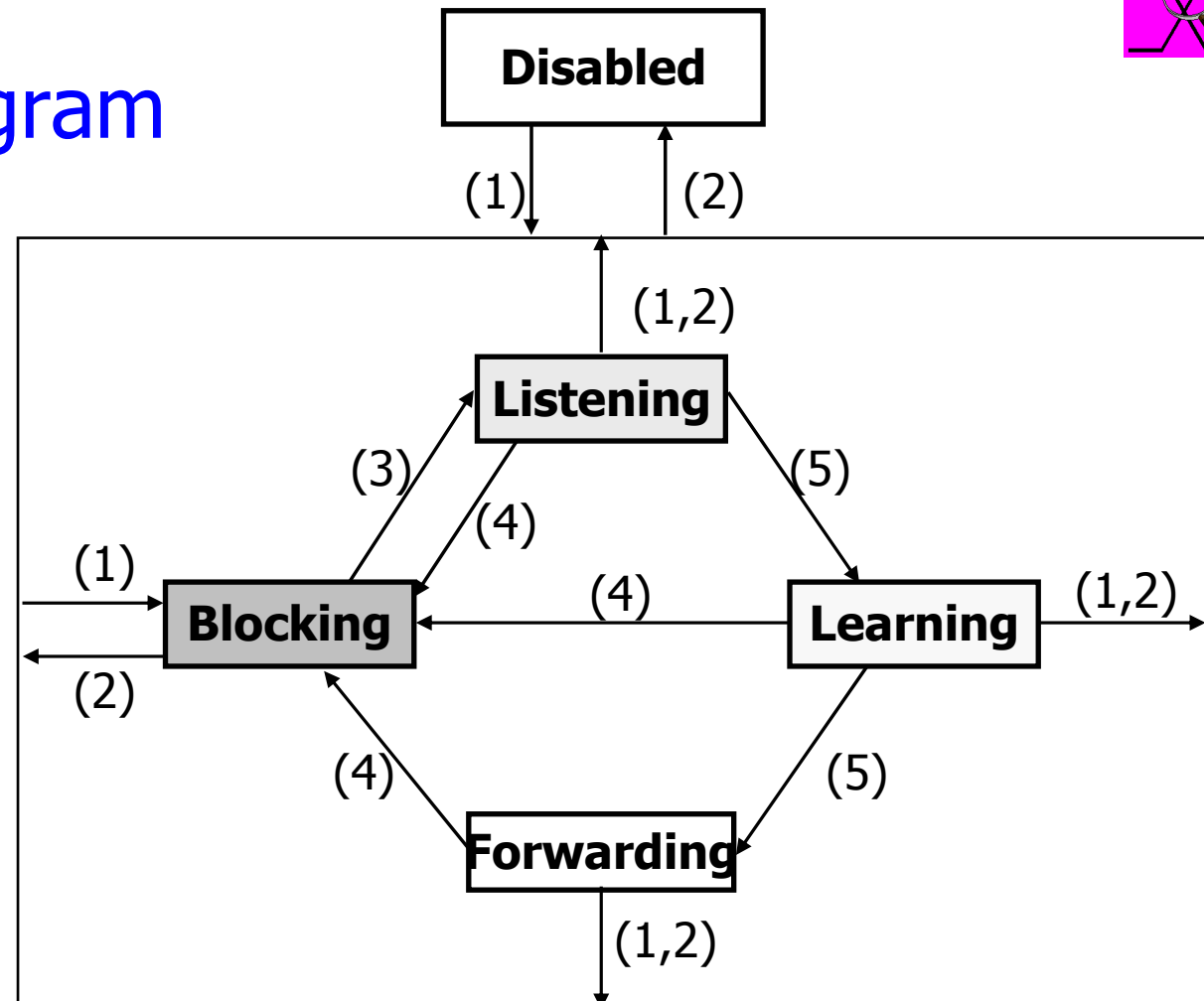
- Receive frames
- Do not forward frames
- Update the forwarding data base
- Compute received BPDU
- Transmit BPDU

## ■ Blocking

- Receive frames
- Do not forward frames
- Do not update the forwarding data base
- Compute received BPDU
- DO not transmit BPDU



# Port state diagram



- 1) Port enabled, by management or initialization
- 2) Port disabled, by management or failure
- 3) Algorithm selects as Designated or Root Port
- 4) Algorithm selects as Alternate Port
- 5) Protocol timer expiry (Forwarding Timer)



## Topology Change

- If a bridge detect a topology change send a Topology Change Notification BPDU trough root port
  - A bridge that receive a TCN BPDU forward that frame trough root port
- Root bridge answer with a Configuration BPDU with **topology change** bit set
  - The bridge receiving that BPDU from root port forward a BPDU with **topology change acknowledgment** bit set
- A bridge detecting or informed about a topology change set a short time to remove the entries equal to forward delay timer

Byte

1÷2	Protocol Identifier: 00-00
3	Protocol Version Identifier: 00
4	BPDU Type: 80

**TCN**



# Timers values

- Hello time
  - Configuration BPDU generation interval
  - Range: 1 - 10 seconds - Recommended: 2 seconds
- Forward delay timer
  - Delay port state change: from listening to learning, from learning to forwarding state
  - short time to remove the entries from filtering database
  - Range: 4 - 30 seconds - Recommended: 15 seconds
- Max age
  - The maximum age of received protocol information before it is discarded (unblocking timer port).
  - Range: 6 - 40 seconds - Recommended: 20 seconds
- The timers are announced by the root bridge on the configuration BPDU



## Timers limit

- The recommended timers assure a STP convergence of 50 seconds
- The recommended timers assure a correct STP operation with a maximum bridge diameter up 7 bridge
  - The **maximum bridge diameter** of the Bridge LAN is the maximum number of Bridges between any two points of attachment of end stations.
- Changing the timers may:
  - Increase or decrease the STP convergence
  - Increase or decrease the maximum bridge diameter



# STP Configuration parameters

- The bridges are plug&play
  - They may work with default configuration parameters
- Bridge priority
  - Range: 0 - 61440
  - Default/recommended: 32768
  - Suggested increment (IEEE 802.1t): 4096
- Port priority
  - Range: 0 - 240
  - Default/recommended: 128
  - Suggested increment (IEEE 802.1t): 16
- Port Path cost
  - Range: 0 - 65535
  - Recommended (IEEE 802.1D):  $1000/(\text{Speed in Mb/s})$



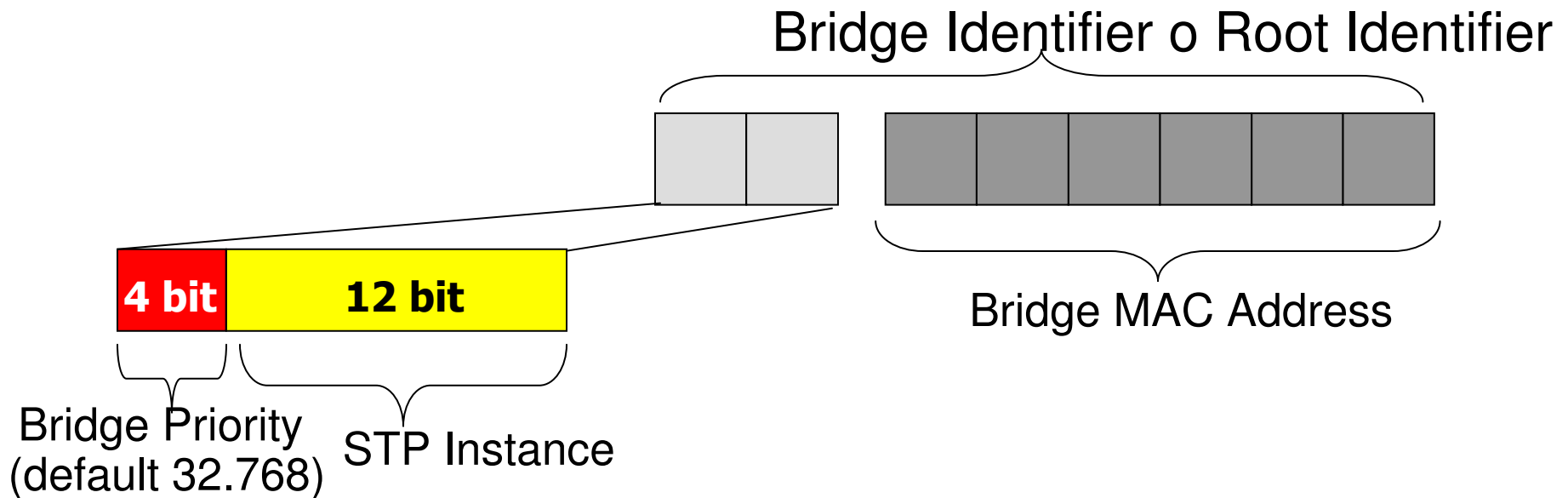
# Recommended Port Path Cost by IEEE 802.D rev1998

Port speed	Recommended values	Recommended range values	Accepted range values
4Mb/s	250	100 - 1000	1 - 65535
10 Mb/s	100	50 - 600	1 - 65535
16 Mb/s	62	40-400	1 - 65535
100 Mb/s	19	10 - 60	1 - 65535
1 Gb/s	4	3 - 10	1 - 65535
10 Gb/s	2	1 - 5	1 - 65535



# IEEE 802.1t: new STP parameters adopted by 802.1w e 802.1s standards

- Extended Port Path Cost in a range from 1 to 200.000.000
- Extended System Identifier



# Path Cost IEEE 802.1t & 802.1w

June 2006



<b>Port speed</b>	<b>Recommended value</b>	<b>Recommended range</b>	<b>Accepted range values</b>
<= 100 Kb/s	200.000.000	20.000.000 - 200.000.000	1 - 200.000.000
1 Mb/s	20.000.000	2.000.000 - 200.000.000	1 - 200.000.000
10 Mb/s	2.000.000	200.000 - 20.000.000	1 - 200.000.000
100 Mb/s	200.000	20.000 - 2.000.000	1 - 200.000.000
1 Gb/s	20.000	2.000 - 200.000	1 - 200.000.000
10 Gb/s	2000	200 - 20.000	1 - 200.000.000
100 Gb/s	200	20 - 2000	1 - 200.000.000
1 Tb/s	20	2 - 200	1 - 200.000.000
10 Tb/s	2	1 -20	1 - 200.000.000



# Rapid Spanning Tree Protocol (RSTP) 802.1w

- Fast convergence Spanning tree:
  - Less than 1 second
- Interoperable with STP IEEE 802.1D
  - Without fast convergence
- Modern solution for mission critical BLAN
- Operate only on point-to-point links
  - Direct connections (no hub)



## Port rules

- Blocking state substitute by Alternate & Backup port rules
- Alternate
  - Port that offers an alternate path in the direction of the Root Bridge to that provided by the Bridge's own Root Port.
- Backup
  - Acts as a backup for the path provided by a Designated Port in the direction of the leaves of the Spanning Tree.
  - Backup Ports exist only where there are two or more connections from a given Bridge to a given LAN.
- Root
- Designated
- Disabled



## Edge Port

- Edge port is a terminating that connect a end-station
- Edge port do not work as other port:
  - As soon detect a Link Integrity Test go immediately to Forwarding state without Listening e Learning state
  - A port changing state do not cause a TCN BPDU transmission trough root port



# Diagrammatic conventions

Legenda	
Graphic Symbol	
<p style="text-align: center;"><b>Bridge Identifier</b></p> <p style="text-align: center;"><b>Port Identifier &amp; Port Cost</b></p> <div style="text-align: center;"> </div> <p style="text-align: center;"><b>Root Identifier</b></p> <p style="text-align: center;"><b>Root Path Cost</b></p>	<b>BRIDGE</b>
	<b>LAN</b>



# Diagrammatic conventions

Port rule	Port state	Legenda
<b>Designated</b>	Discarding	●+———
	Learning	●++———
	Forwarding	●———
Edge Port	Forwarding	●◊———
<b>Root Port</b>	Discarding	○+———
	Learning	○++———
	Forwarding	○———
<b>Alternate</b>	Discarding	——++———
<b>Backup</b>	Discarding	——+++———
<b>Disabled</b>	-----	—/———
<b>BPDU trasmesse</b>		
<b>Designated</b>		————→
<b>Designated Proposal</b>		————→
<b>Root</b>		————▷
<b>Root Agreement</b>		————▷

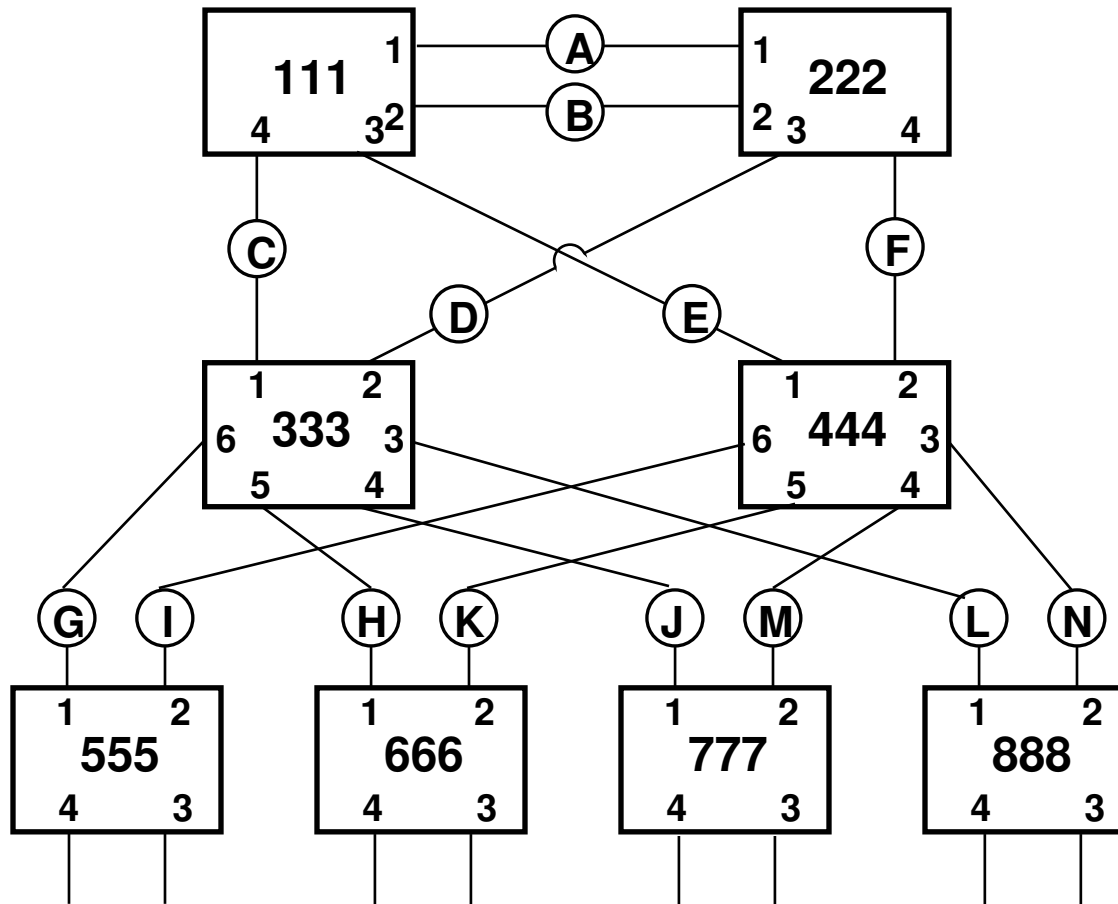


## The algorithm principle

- Same as STP
- Root Bridge election
- Root port
- Designated Port
- The port not selected as root or designated are selected as:
  - Alternate if connected to a port on different bridge
  - Backup if connected to a different port of the same bridge

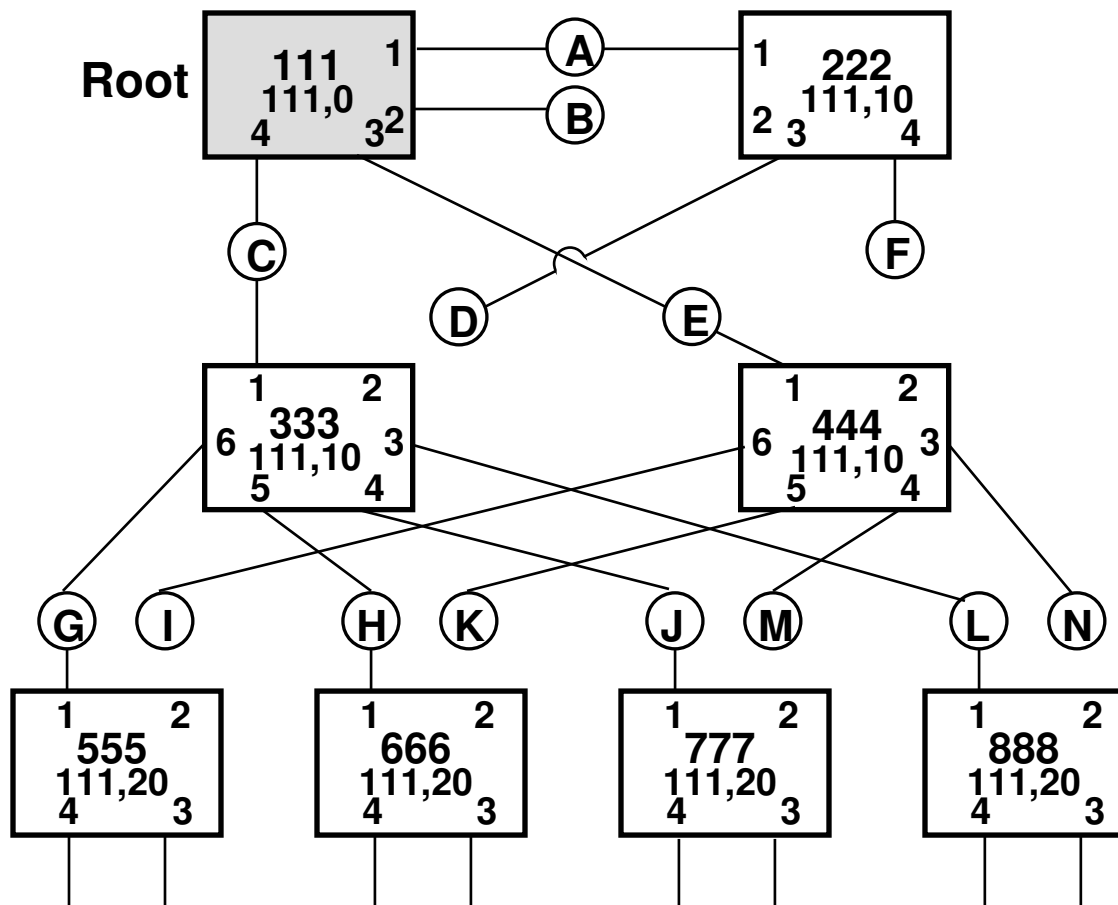


# Physical redundant star topology



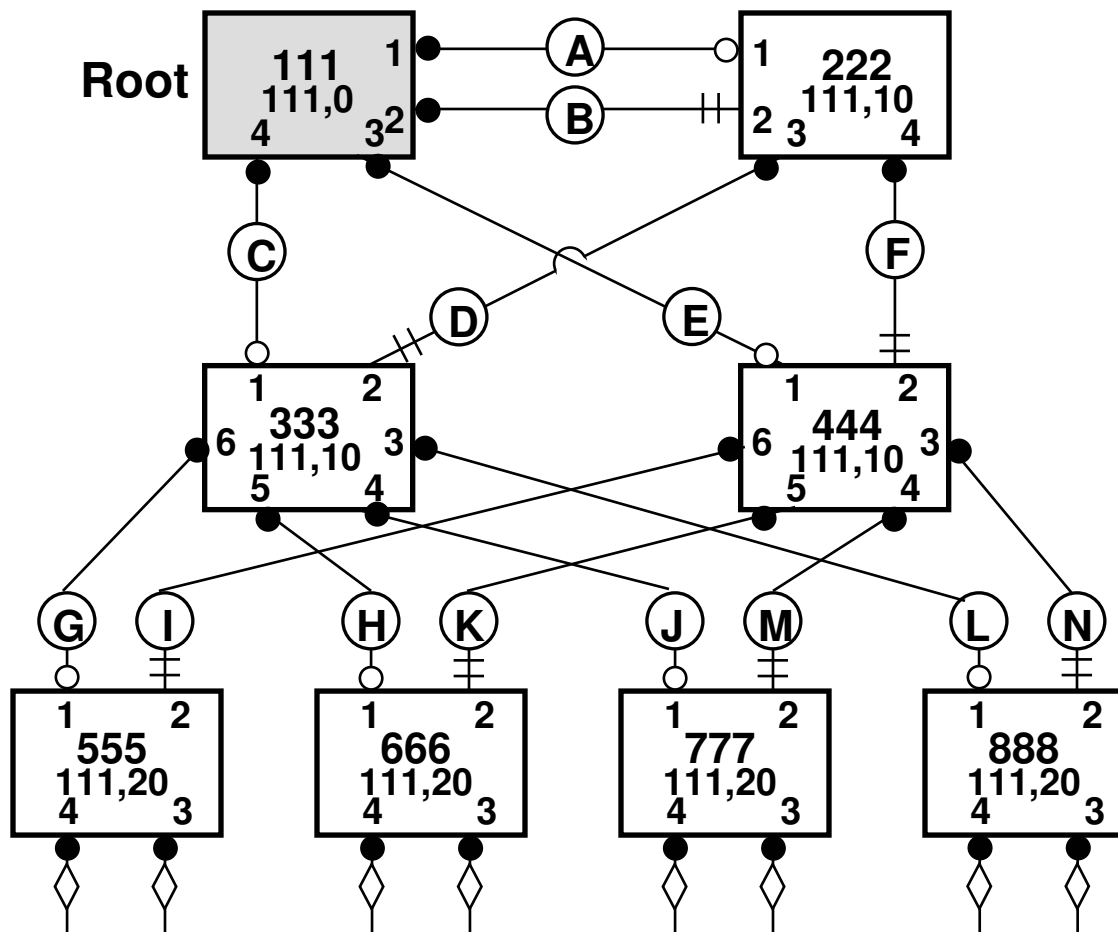


# RSTP active topology



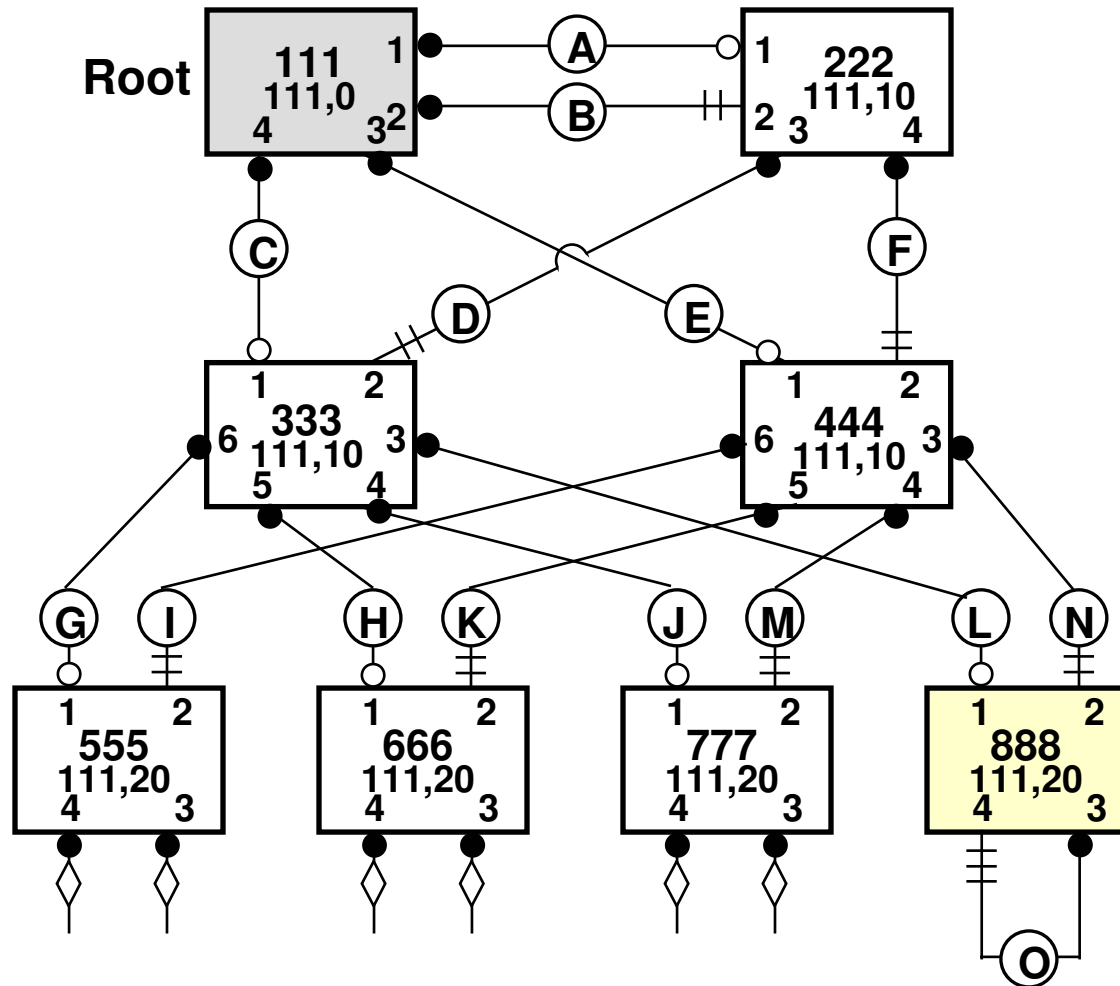


# RSTP tree & port state



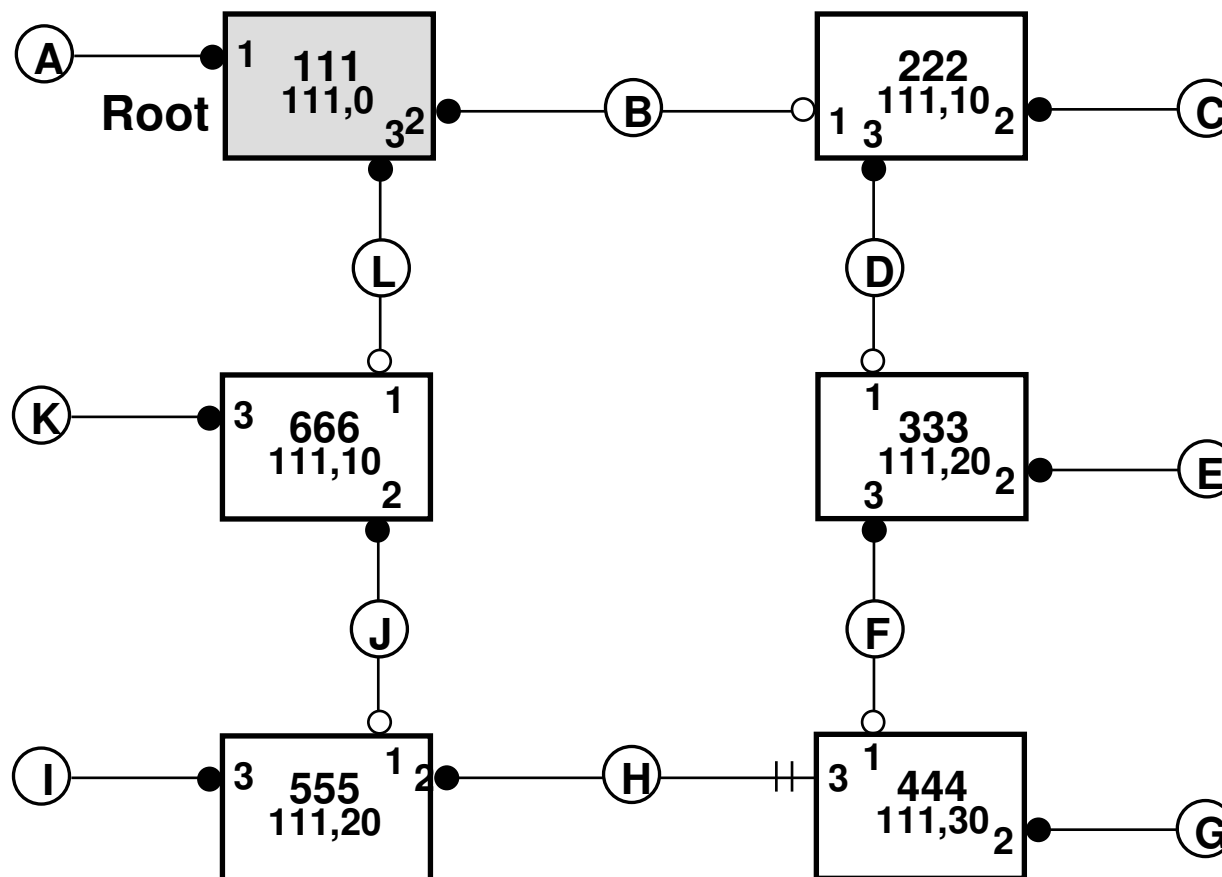


# Backup port example





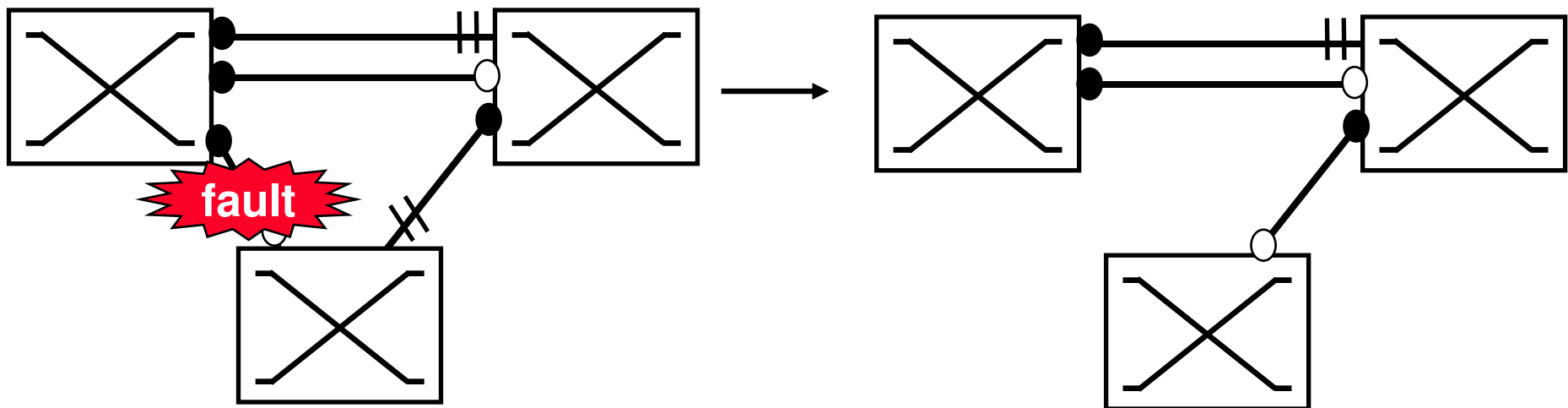
# Ring topology





# Fault recovery based on physical level fault detection

- If the switch loose a root port activate immediately the alternate port that became a new root port
  - Fault detection and recovery based on physical layer



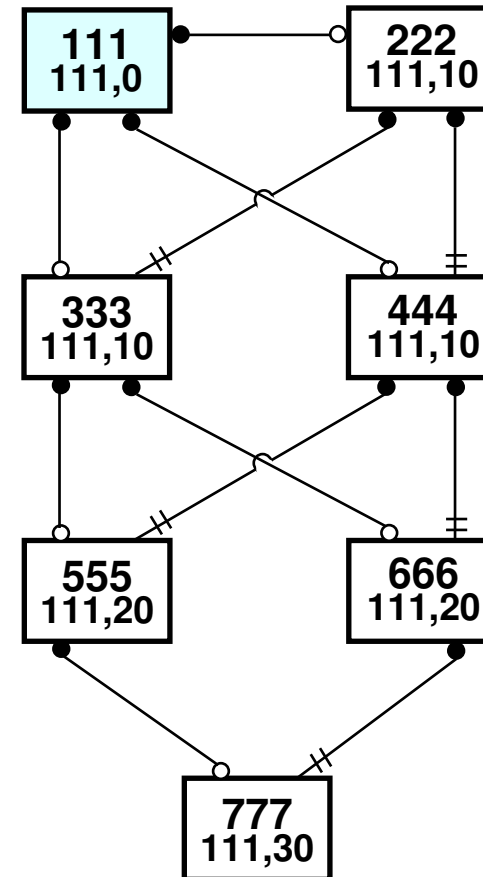
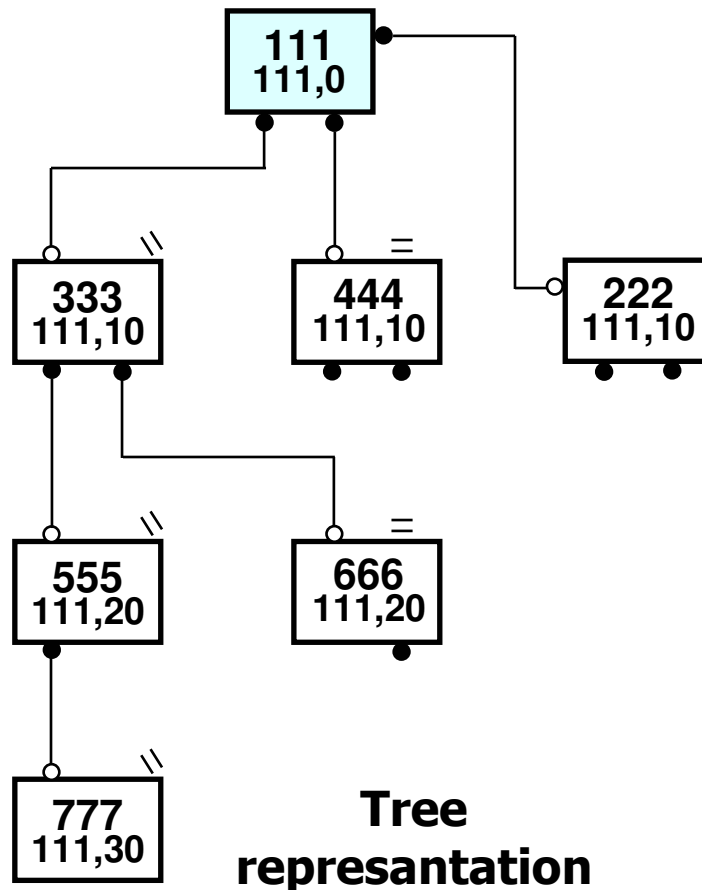


## Fault detection and flush entry

- Local flush entries
  - The bridge flush immediately the entries that have a faulty port as destination port
    - Local flush entries on bridge ports at end of faulty link
- A bridge that change an Alternate Port to a Root Port send a ***Topology Change Notification*** (TCN) BPDU trough root port
- A bridge that receive a TCN BPDU:
  - Flush the entries on every ports except the port were the TCN as been received
  - Forward TCN on every ports in forwarding state except the port were the TCN as been received



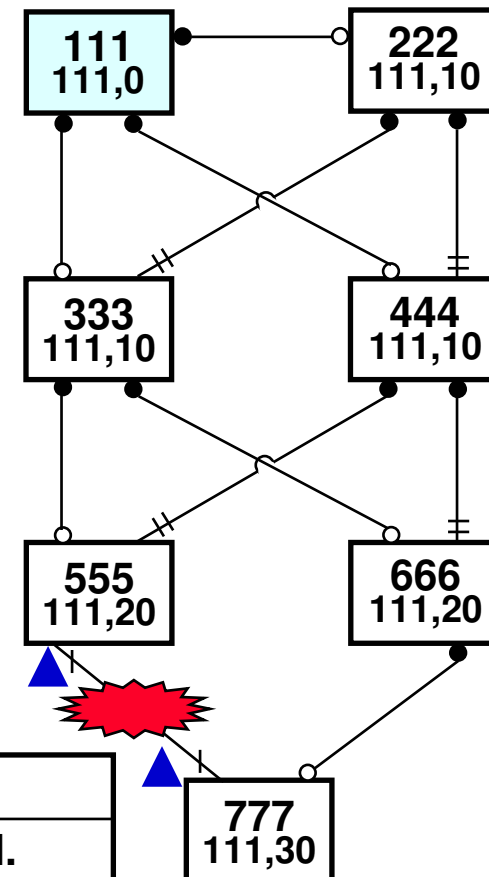
# Flush entry example: initial configuration








## Flush entry: step 1

- The link 555-777 fails, and both 555 and 777 notice. It can be seen that all the Ports indicated will need to be flushed.



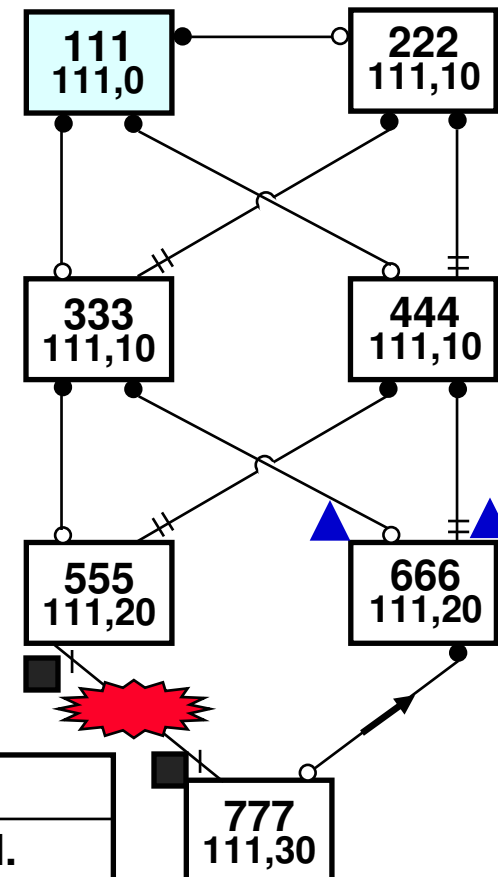
### Legenda

-  Addresses learnt on these Ports need to be flushed.
-  Addresses learnt on these Ports have been flushed.
-  TCN transmitted in the direction of the arrow



## Flush entry: step 2

- 555 and 777 flush addresses for their failed Ports.
- 777 change the port state from alternate to root
- 777 sends a TCN message (an RSTP BPDUs with TC set).



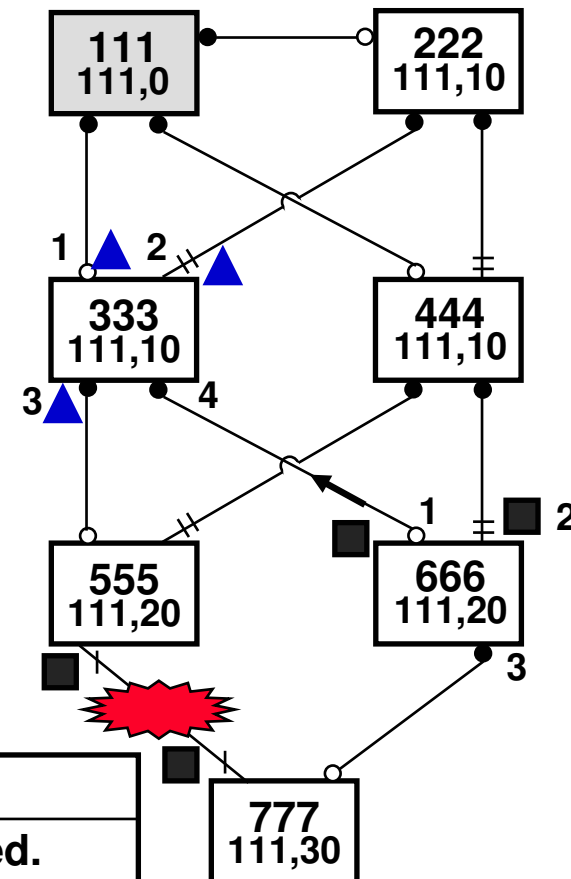
### Legenda

- ▲ Addresses learnt on these Ports need to be flushed.
- Addresses learnt on these Ports have been flushed.
- TCN transmitted in the direction of the arrow



## Flush entry: step 3

- 666 receives the TCN message, flushes addresses on all other Ports, and forwards a TCN.

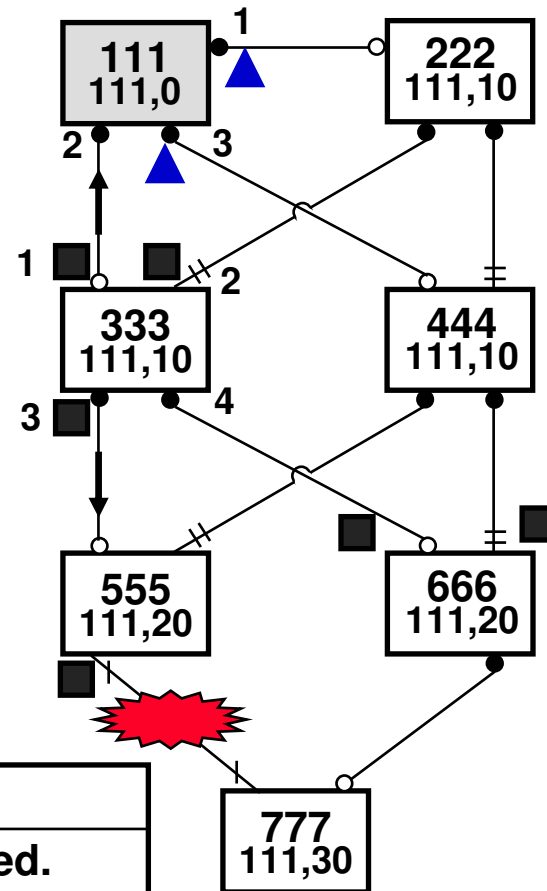


Legenda	
▲	Addresses learnt on these Ports need to be flushed.
■	Addresses learnt on these Ports have been flushed.
→	TCN transmitted in the direction of the arrow



# Flush entry: step 4

- 333 receives the TCN message, flushes, and forwards the TCN to 111 and 555.

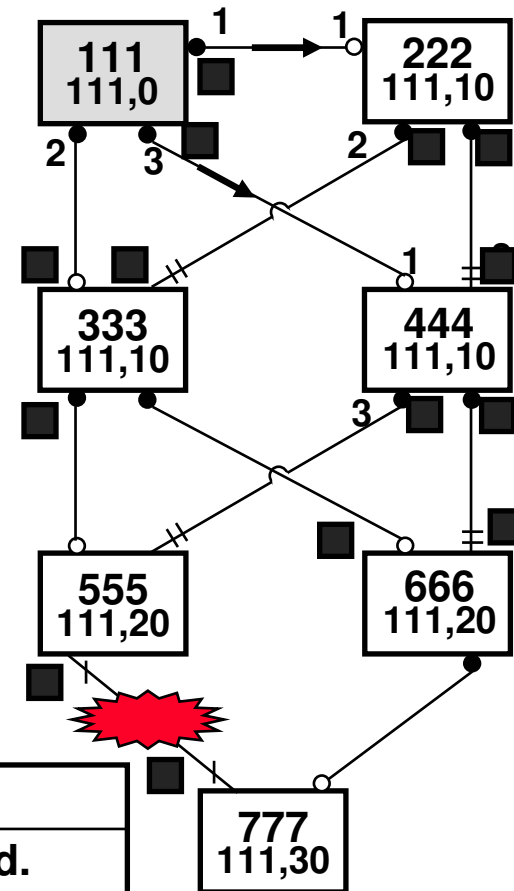


Legenda	
▲	Addresses learnt on these Ports need to be flushed.
■	Addresses learnt on these Ports have been flushed.
→	TCN transmitted in the direction of the arrow

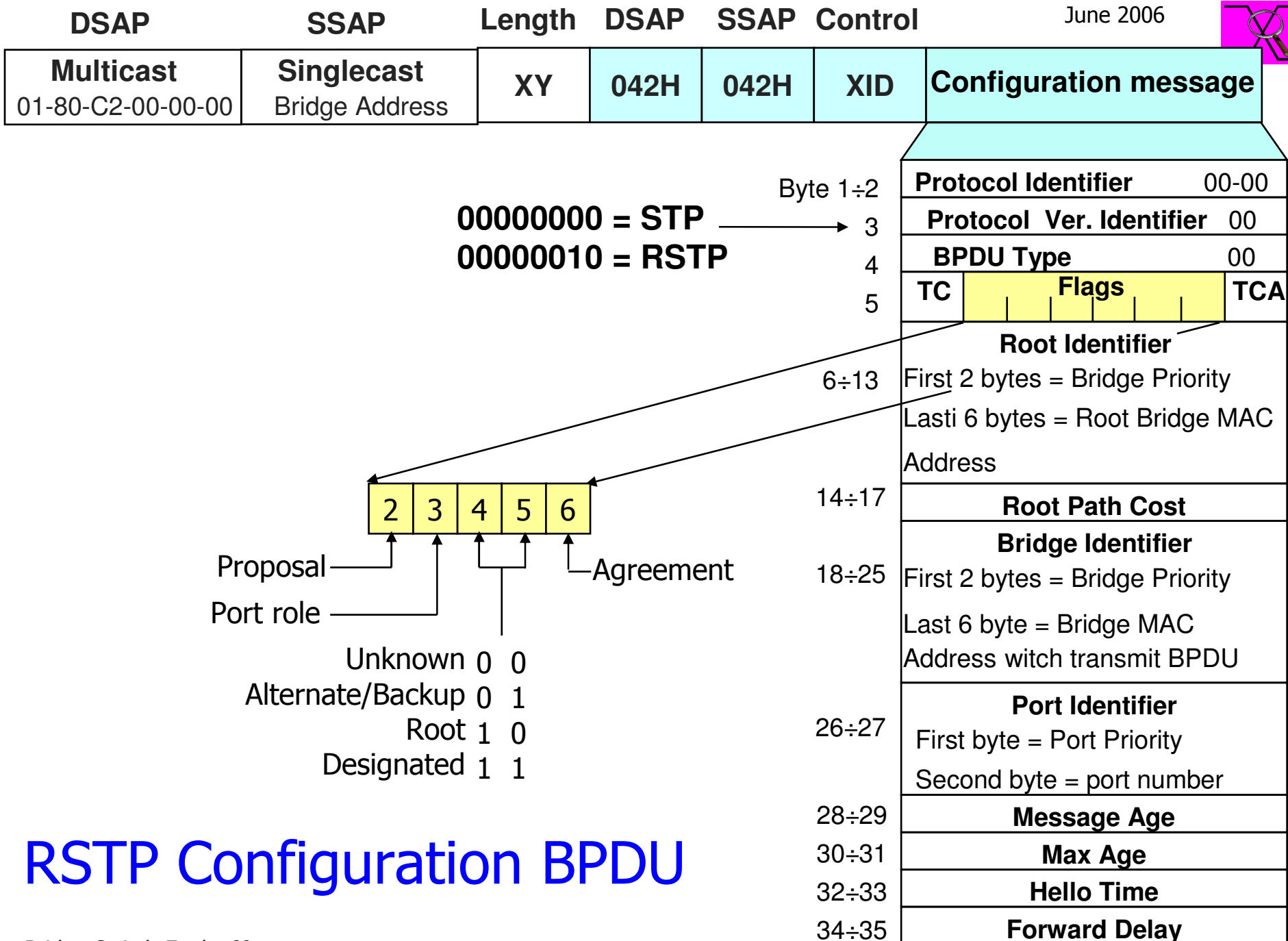


# Flush entry: step 5

- 111 receives the TCN, flushes and sends TCN messages on all other Ports.
- Receipt of the TCN will cause 222 and 444 to flush their Ports.



Legenda	
▲	Addresses learnt on these Ports need to be flushed.
■	Addresses learnt on these Ports have been flushed.
→	TCN transmitted in the direction of the arrow



# RSTP Configuration BPDUs

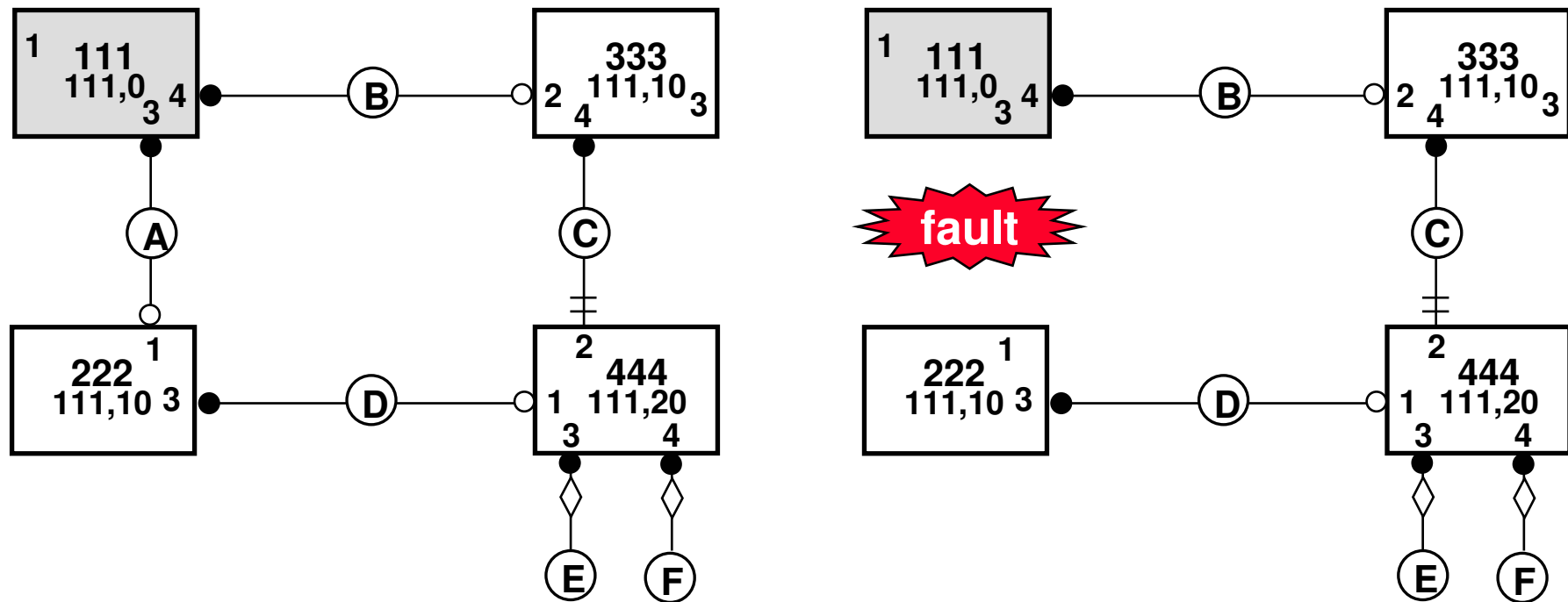


# Ring topology and fast recovery

- Fault on the ring
  - If the bridge have an alternate port change immediately the state from alternate to root state
    - Recovery based physical layer
  - If the bridge don't have an alternate port propose it self as Root Bridge
    - Recovery based on new protocol handshaking
      - Fast BPDU Proposal and Agreement type handshaking
- Sync & Agree operations
  - Port receiving BPDU with *Designated Proposal flag* execute a *Sync operation*
    - Discard all packet received on non-edge ports
  - Port discarding packet (Sync) go immediately on Forwarding State when receive a BPDU with *Designated Agreement flag*

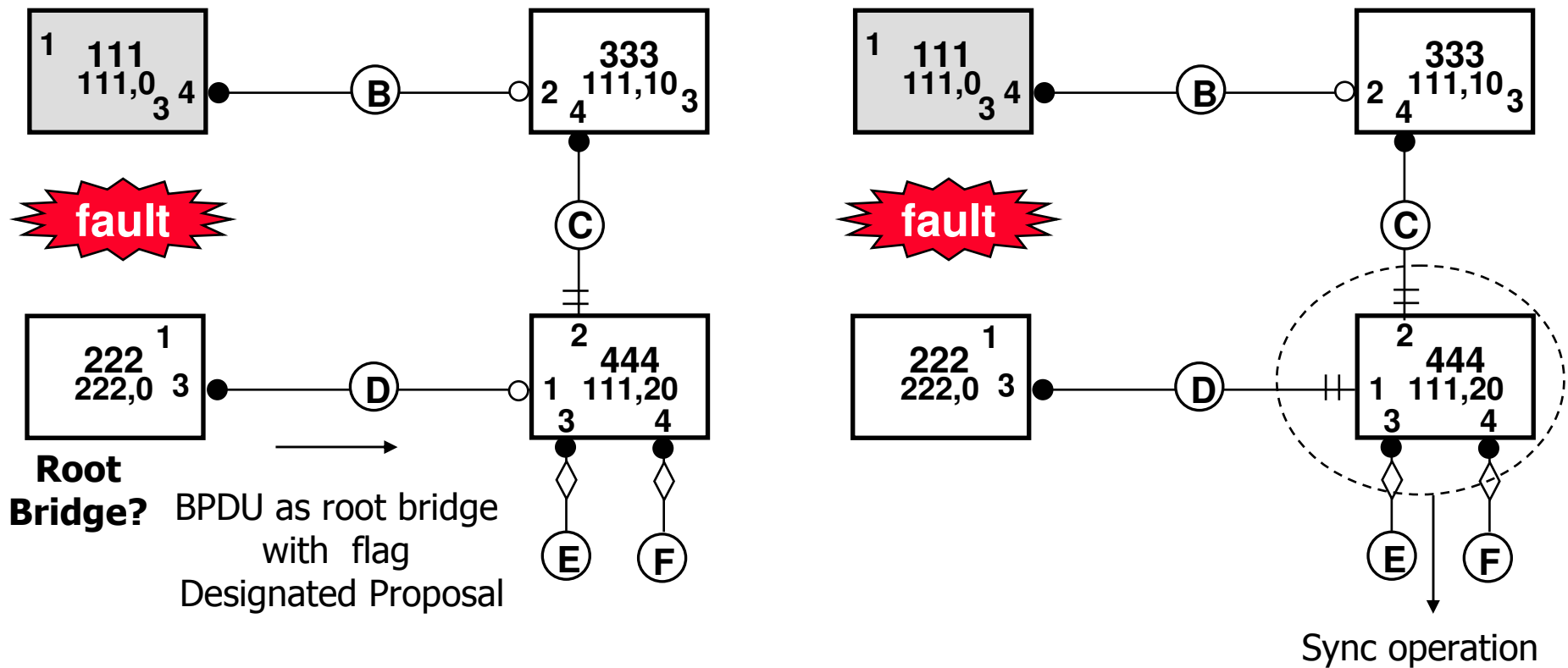


# Ring topology fault: step 1





# Ring topology fault and new Root proposal





# Ring topology fault: Sync Operation

