Packet Switching on L2 (LAN Level)

Transparent Bridging (TB), Spanning Tree Protocol (STP), Rapid STP, L2 Bridging versus L3 Routing

Agenda

- **Introduction**
- **Transparent Bridging Basics**
- **Spanning Tree Protocol**
- **Rapid Spanning Tree Protocol**
- **Comparison L3 Routing versus L2 Bridging**

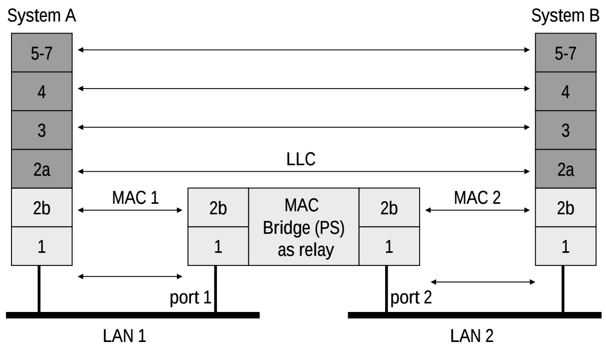
Why Packet Switching on LAN?

- **LAN was primarily designed for shared media**
  - but too many clients cause performance problems
    - higher probability for collisions in case of Ethernet
- **Partitioning of a network may be needed**
  - to achieve load balance
  - for error limitation
  - because of security reasons
  - to deal with technological limitations
    - geographical expansion, number of clients
  - for using resources of distant networks (remote networking)

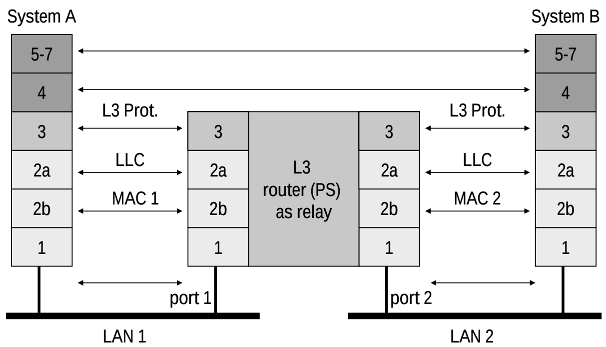
Bridge / Router

- **network partitioning**
  - can be done by packet switches (OSI relay stations on L3)
    - already well known store and forward principle of WAN world
- **bridge**
  - packet switch implemented on OSI layer 2
  - forwarding based on unstructured MAC addresses
  - signposts stored in MAC bridging table (= routing table of L2 packet switch)
  - above OSI Layer 2b bridges are transparent for all higher layer protocols (LLC and above)
- **router**
  - packet switch implemented on OSI layer 3
  - forwarding based on structured L3 addresses
  - end system must speak the corresponding L3 „language“

Bridge



Router



Bridging Methods

- **Transparent Bridging (Ethernet world)**
  - easy for end systems
  - more complex transferring-decisions (compared to source route bridging) have to be done by such a bridge
  - dedicated hardware
  - today's L2 switch technology (Ethernet switch) is actually a <u>fast</u> transparent bridge only
- **Source Routing Bridging (Token Ring world, IBM)**
  - more overhead for end systems (path finding)
  - source route bridges are less complex
  - could be done e.g. by a PC with two network cards
  - not further covered in this lecture

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Transparent Bridging 1

- **bridge is invisible for end systems**
  - LAN 1 and LAN 2 appear to the end systems like one single, logical, big LAN -> transparent
- **bridge uses layer 2 MAC-addresses**
  - to decide if a given frame must be a forwarded or not
    - destination-address of a frame is used for this
- **MAC-addresses of all stations are registered in a bridging table**
  - either statically done by administrator
  - or dynamically done by a self-learning mechanism
    - source-address of a frame is used for this

Transparent Bridging 2

- **in case of a dynamic bridging table**
  - an aging mechanism allows for changes of MAC addresses in the network
    - may caused either by change of network card or by location change of end system
    - if an already registered MAC address is not seen within e.g. 5 minutes as source address of a frame the bridging table entry is deleted
- **because of the transparency**
  - such a bridge must receive and process every frame on a LAN
- **flow control**
  - originally not done between end systems and bridges

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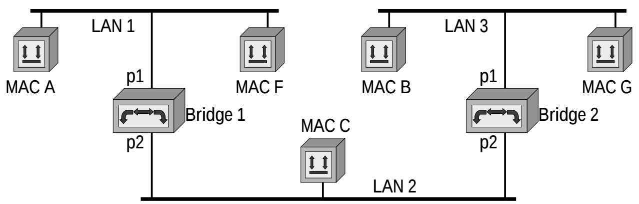
Transparent Bridging 3

- **destination address of a frame is used for table look up which enables a simple decision:**
  - filtering: frame will be rejected if destination's home is on the LAN segment of the receiving port
  - forwarding: a duplicate of the frame will be forwarded to the appropriate port if destination's home is registered in the table of another port
  - flooding: during learning time; frame will be forwarded to all other ports (multiport-bridge) if there is no entry in the table (unknown destination)
- **frames with broadcast/multicast-address**
  - are always forwarded to all other ports

Example for Studying Effects



bridging table of bridge 1

p1	p2

bridging table of bridge 2

p1	p2

Learning / Flooding

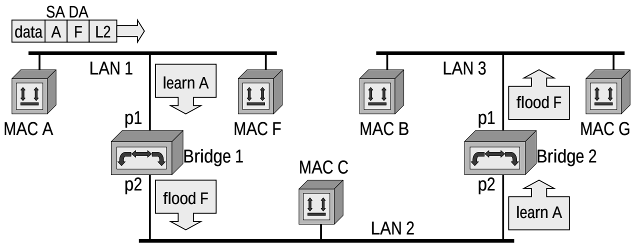


table of Bridge 1

p1	p2
A	

table of Bridge 2

p1	p2
	A

Learning / Filtering

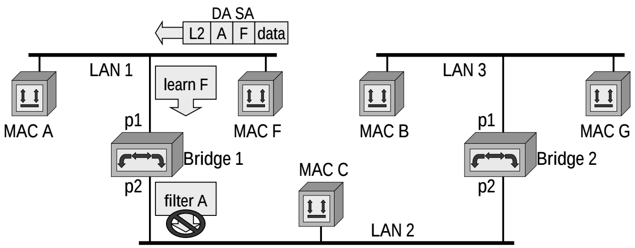


table of Bridge 1

p1	p2
A	
F	

table of Bridge 2

p1	p2
	A

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Learning / Flooding

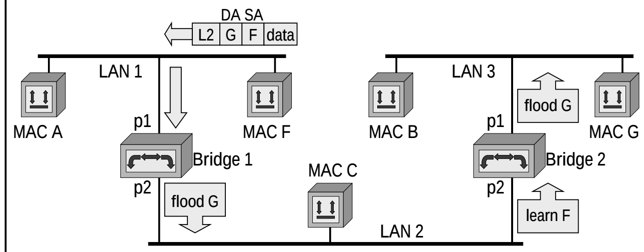


table of Bridge 1

p1	p2
A	
F	

table of Bridge 2

p1	p2
	A
	F

Learning / Forwarding

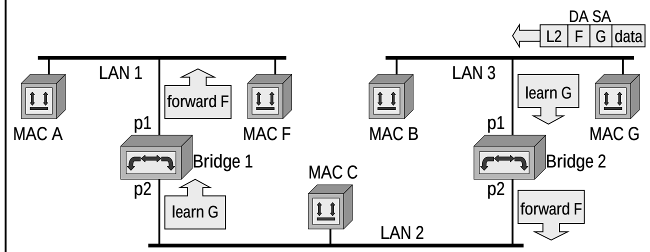


table of Bridge 1

p1	p2
A	G
F	

table of Bridge 2

p1	p2
G	A
	F

Final Picture

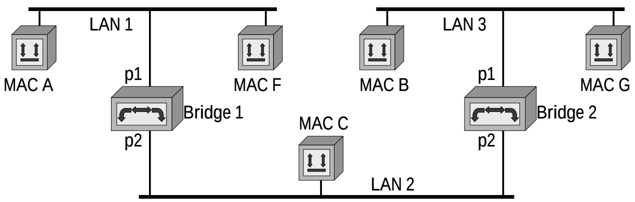


table of Bridge 1

p1	p2
A	G
F	C
	B

bridging table size is proportional to the number of all network devices of the whole net !!!

table of Bridge 2

p1	p2
G	A
B	F
	C

L2 Broadcast / L2 Multicast

mc … multicast address
bc … broadcast address

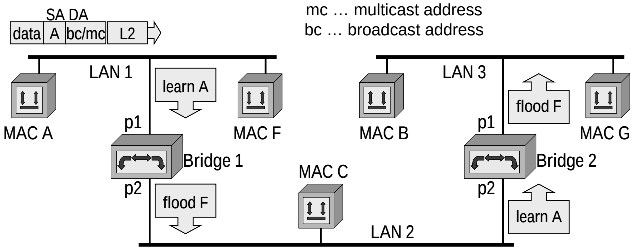


table of Bridge 1

p1	p2
A	G
F	C
	B

L2 broadcasts or multicasts are always flooded over the whole network !!!

table of Bridge 2

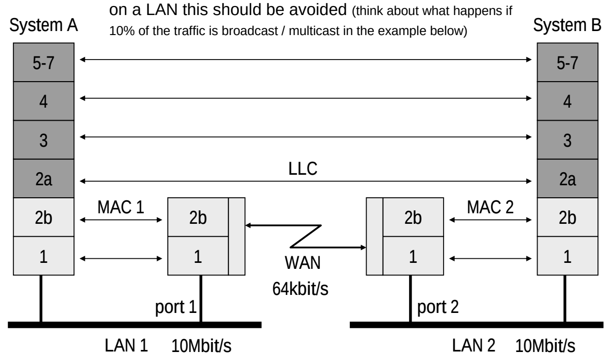
p1	p2
G	A
B	F
	C

Collision Domain versus Broadcast Domain

- **bridge separates LAN into**
  - multiple collision domains
  - a collision on one LAN segment will not be seen on other LAN segments
  - reason: store and forward behavior of bridge
  - note: a repeater can't do that
- **but a bridged network is still**
  - one broadcast domain
  - broadcast frames are always flooded
  - reason: bridged LAN is still seen as one logical LAN by end systems, bridges are transparent for them

Remote Bridging ? (<- TB means Broadcast Domain!)

Because of inherent L2 broadcast / multicast percentage on a LAN this should be avoided (think about what happens if 10% of the traffic is broadcast / multicast in the example below)



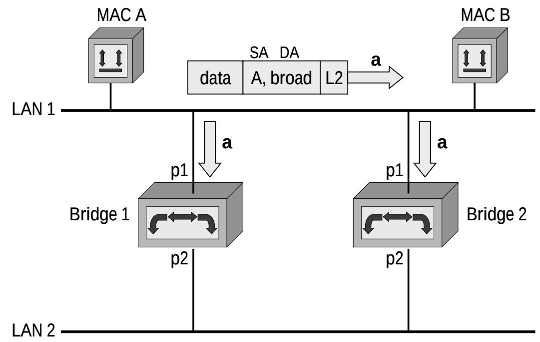
Remote Bridging

- **relay function of local bridge**
  - is split in two half-bridges
- **coupling of the half-bridges**
  - via WAN-connection
- **high amount of broadcast on a LAN**
  - mismatch of data rates
  - slow WAN-connection can cause a buffer overflow in the bridge
  - therefore transparent bridging over WAN or any other Ethernet tunnelling technique should be avoided

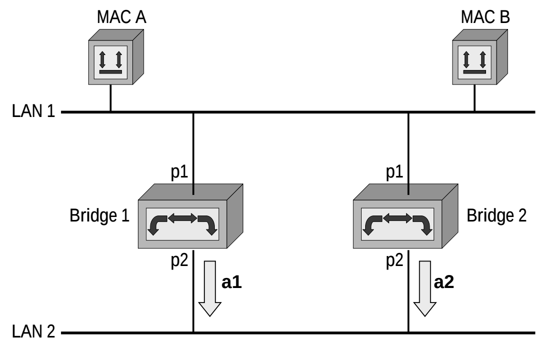
Parallel Paths

- **parallel paths between two LAN segments cause**
  - endless circling of frames with unknown destination
  - endless circling of broadcast-frames
  - endless circling of direct addressed frames during flooding phase
  - blocking of buffer-resources
- **parallel paths in a more complex topology cause**
  - overflow of all buffer-resources and stagnation of the LANs
  - **Broadcast Storm**
- **to avoid these effects**
  - Spanning Tree Protocol (STP)

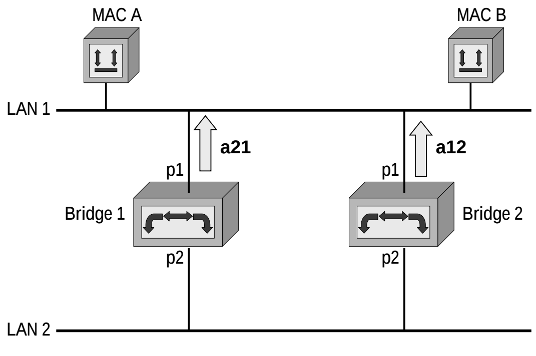
Endless Circling 1



Endless Circling 2



Endless Circling 3



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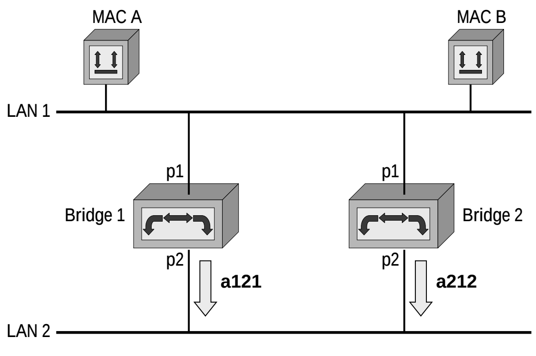
Endless Circling 4



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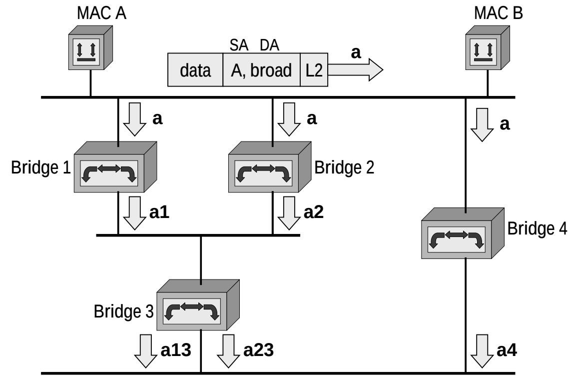
L06 - Packet Switching on LAN (TB, STP)

Broadcast-Storm 1



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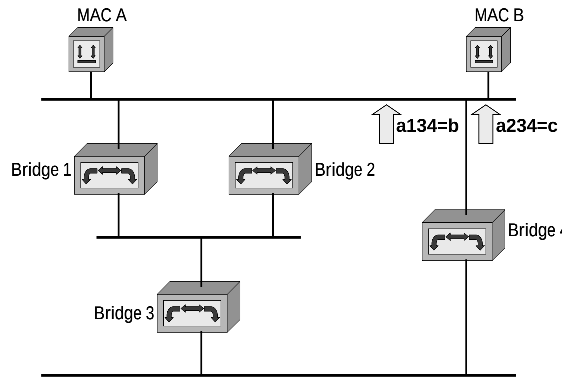
Broadcast-Storm 2



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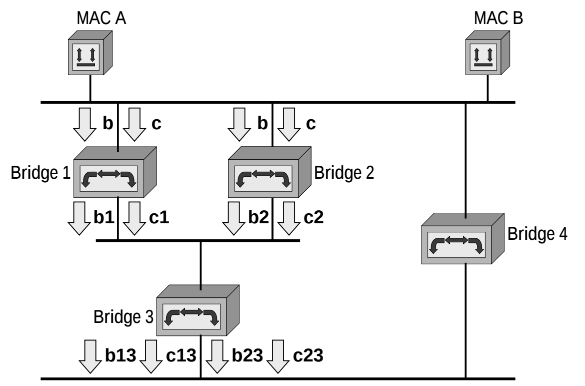
Broadcast-Storm 3



Broadcast-Storm 4

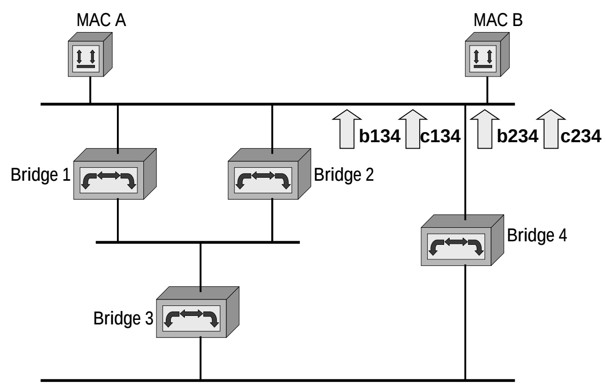


Table Rewriting (Unknown Destination) 1

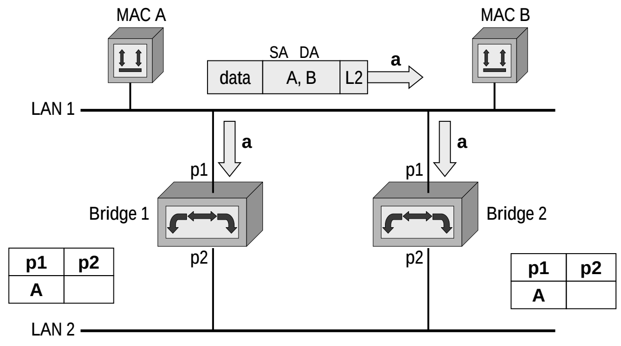


Table Rewriting (Unknown Destination) 2

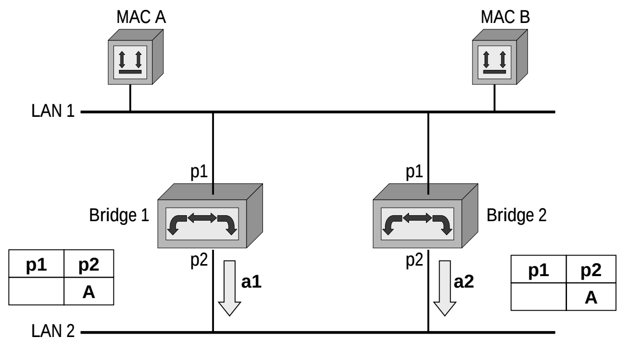
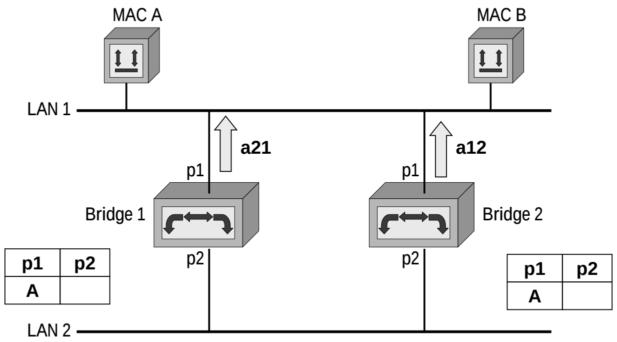


Table Rewriting (Unknown Destination) 3



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L06 - Packet Switching on LAN (TB, STP)

Spanning Tree (IEEE 802.1D)

- **Spanning Tree Protocol (STP):**
  - takes care that there is always exact only one active path between any 2 stations
  - implemented by a special communication protocol between the bridges
    - using BPDU (Bridge Protocol Data Unit) packets with MAC-multicast address
  - failure of active path causes activation of a redundant path
- **main disadvantage of STP**
  - redundant lines or redundant network components cannot be used for load balancing

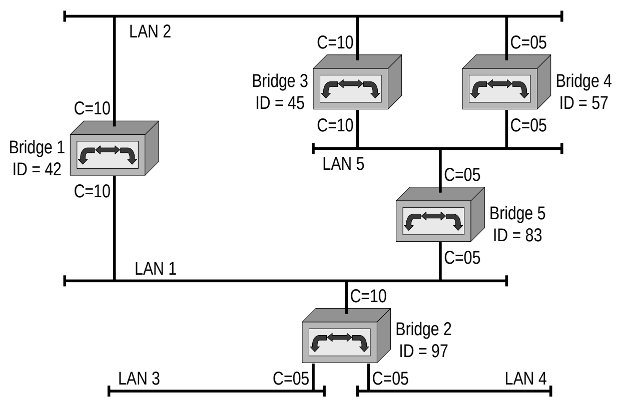
Parameters for STP 1

- **Bridge Identifier (Bridge ID)**
  - combination of MAC-address and a priority number
    - typically, the lowest MAC-address of all ports is used for that
    - note: although bridge will not be seen by end systems, for bridge communication and management purposes a bridge will listen to one or more dedicated MAC addresses
    - <u>Bridge-ID = priority# (2 Byte) + mac# (6 Byte)</u>
  - priority number can be configured by the administrator
    - default value is 32768
  - lowest Bridge ID has highest priority
    - lowest configured priority number
  - if you keep default values
    - the bridge with the lowest MAC address will have the highest priority

Parameters for STP 2

- **Port Cost (C)**
  - costs in order to access local interface
  - inverse proportional to the transmission rate
  - default cost = 1000 / transmission rate in Mbit/s
    - so 10 Mbit/s Ethernet has a default Path Cost of 100
    - with occurrence of 1Gbit/s Ethernet rule was adapted
      - 100 Mbit/s = 19, 1Gbit/s = 4, 10Gbit/s = 2
  - can be configured to a different value by the administrator
- **Port Identifier (Port ID)**
  - combination of port number and a priority number
    - Port-ID = port priority#.port#
  - configured by the administrator
    - default port priority = 128

Parameters for STP Example



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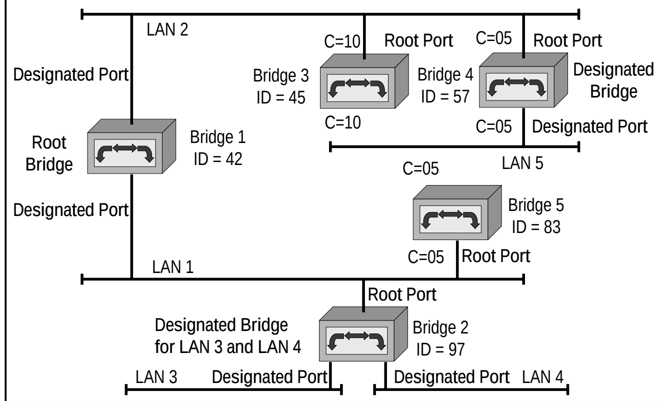
L06 - Packet Switching on LAN (TB, STP)

Spanning Tree Algorithm Summary

- select the root bridge
  - bridge with the lowest Bridge Identifier
- select the root ports
  - by computation of the shortest path from any other bridge to the root bridge
  - root port points to the shortest path towards the root
- select one designated bridge for every LAN segment which can be reached by more than one bridge
  - bridge with lowest root path costs on the root port side
  - corresponding port on other side is called designated port
- set the designated and root ports in forwarding state
- set all other ports in blocking state
- creates single paths from the root to all leaves (LAN segments) of the network

Spanning Tree Applied



Format of STP Messages - BPDU Format

Prot. ID	Prot. Vers.	BPDU Type	Flags	Root ID	Root Path Costs	Bridge ID	Port ID	Mess. Age	Max Age	Hello Time	Fwd. Delay
2 Byte	1 Byte	1 Byte	1 Byte	8 Byte	4 Byte	8 Byte	2 Byte	2 Byte	2 Byte	2 Byte	2 Byte

BPDU .... Bridge Protocol Data Unit (OSI term for this kind of message)

Root ID .... Who seems to be or who is the root bridge (R-ID)?

Root Path Cost .... How far is the root bridge away from me (RPC)?

Bridge ID .... ID of bridge transmitting this BPDU (O-ID)

Port ID .... port over which this BPDU was transmitted (P-ID)

BPDU Fields 1

- Protocol Identifier:
  - **0000 (hex) for STP 802.1D**
- Protocol Version:
  - **00 (hex) for version 802.1D (1998)**
  - **02 (hex) for version 802.1D (2004)**
- BPDU Type:
  - **00 (hex) for Configuration BPDU**
  - **80 (hex) for Topology Change Notification (TCN) BPDU**
- Root Identifier:
  - **2 bytes for priority (default 32768)**
  - **6 bytes for MAC-address**
- Root Path Costs in binary representation:
  - **range 1-65535**
- Bridge Identifier:
  - **structure like Root Identifier**

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L06 - Packet Switching on LAN (TB, STP)

BPDU Fields 2

- Port Identifier:
  - **1 byte priority (default 128)**
  - **1 byte port number**
- Message Age (range 1-10s):
  - **age of Configuration BPDU**
  - **transmitted by root-bridge initially using zero value, each passing-on (by designated bridge) increases this number**
- Max Age (range 6-40s):
  - **aging limit for information obtained from Configuration BPDU**
  - **basic parameter for detecting idle failures (e.g. root bridge = dead)**
  - **default 20 seconds**
- Hello Time (range 1-10s):
  - **time interval for generation of periodic Configuration BPDUs by root bridge**
  - **default 2 seconds**

BPDU Fields 3

- Forward Delay (range 4-30s):
  - **time delay for putting a port in the forwarding state**
  - **default 15 seconds**
  - **but that means 15 seconds listening plus 15 seconds learning**
- Hello Time, Max Age, Forward Delay are specified by Root-Bridge
- Flags (a "1" indicates the function):
  - **bit 8 ... Topology Change Acknowledgement (TCA)**
  - **bit 1 ... Topology Change (TC)**
  - **used in TCN BPDU's for signalling topology changes**
    - **TCN … Topology Change Notification**
    - **in case of a topology change the MAC addresses should change quickly to another port of the corresponding bridging table (convergence) in order to avoid forwarding of frames to the wrong port/direction and not waiting for the natural timeout of the dynamic entry**
    - **the bridge recognizing the topology change sends a TCN BPDU on the root port as long as a CONF BPDU with TCA is received on its root port**
    - **bridge one hop closer to the root passes TCN BPDU on towards the root bridge and acknowledges locally to the initiating bridge by usage of CONF BPDU with TCA**
    - **when the root bridge is reached a flushing of all bridging table is triggered by the root bridge by usage of CONF BPDUs with TC and TCA set**
    - **the new location (port) is dynamically relearned by the actual user traffic**

MAC Addresses / LLC / Network Diameter

- **bridges use for STP-communication:**
  - multicast address:
    - **0180 C200 0000 hex**
    - **0180 C200 0001 to 0180 C200 000F are reserved**
    - **0180 C200 0010 hex** All LAN Bridges Management Group Address
  - the DSAP/SSAP of LLC header
    - **42 hex Bridge Spanning Tree Protocol**
- **Maximum Bridge Diameter**
  - maximum number of bridges between any two end systems is 7 using default values for hello time, forward delay and max age
- **For details of STP operation look to corresponding chapter in "Collection of all lectures of Manfred Lindner"**

STP Error Detection

- **normally the root bridge generates (triggers)**
  - every 1-10 seconds (hello time interval) a Configuration BPDU to be received on the root port of every other bridge and carried on through the designated ports
  - bridges which are not designated are still listening to such messages on blocked ports
- **if triggering ages out two scenarios are possible**
  - root bridge failure
    - a new root bridge will be selected based on the lowest Bridge-ID and the whole spanning tree may be modified
  - designated bridge failure
    - if there is an other bridge which can support a LAN segment this bridge will become the new designated bridge

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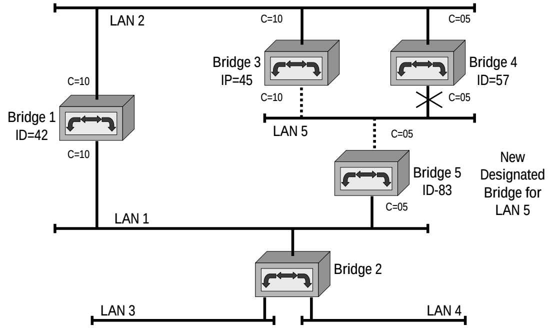
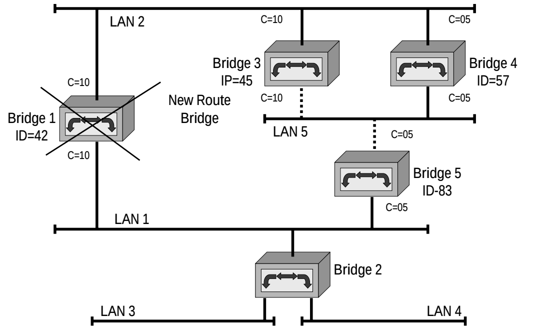
STP Convergence Time – Failure of Designated Bridge



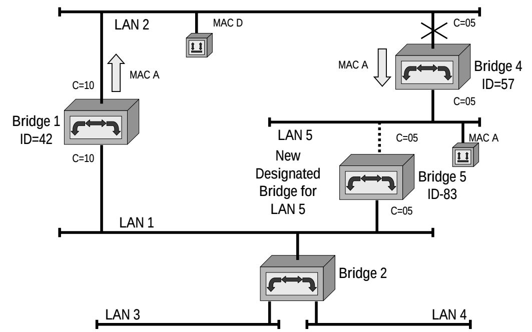
- **Time = max age (20 sec) + 2*forward delay (15 sec Listening + 15 sec Learning) = 50 sec**

STP Convergence Time – Failure of Root Bridge



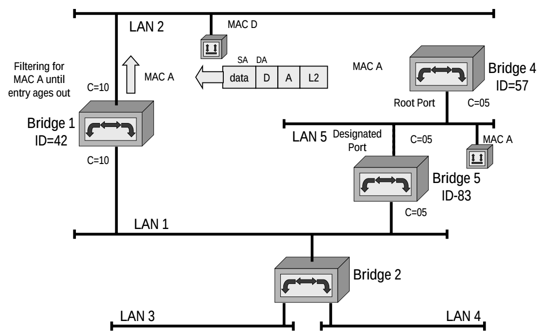
- **Time = max age (20 sec) + 2*forward delay (15 sec Listening + 15 sec Learning) = 50 sec**

STP Convergence Time – Failure of Root Port



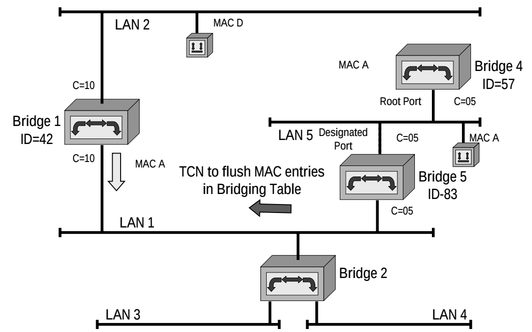
- **Time = 2*forward delay (15 sec Listening + 15 sec Learning) = 30 sec**

STP Convergence Time – Failure of Root Port - Interruption of Connectivity



- **Time = 2*forward delay (15 sec Listening + 15 sec Learning) = 30 sec**

STP Convergence Time – Failure of Root Port – Topology Change Notification (TCN)



- **Time = 2*forward delay (15 sec Listening + 15 sec Learning) = 30 sec**

Some STP Facts

- **disadvantages of STP**
  - active paths are always calculated from the root, but the actual information flow of the network may use other paths
    - note: network-manager can control this via Bridge Priority, Path Costs und Port Priority to achieve a certain policy under normal operation
    - hence STP should be designed to overcome plug and play behaviour of default values
  - redundant paths cannot be used for load balancing
    - redundant bridges may be never used if there is no failure of the currently active components
    - for remote bridging via WAN the same is true for redundant WAN links
  - convergence time between 30 and 50 seconds
    - note: in order to improve convergence time Rapid Spanning Tree Protocol has been developed (802.1D version 2004)

Agenda

- Introduction
- Transparent Bridging Basics
- Spanning Tree Protocol
- <u>Rapid Spanning Tree Protocol</u>
- Comparison L3 Routing versus L2 Bridging

Introduction

- **Rapid Spanning Tree (RSTP)**
  - IEEE 802.1D version 2004 (former IEEE 802.1w)
  - Can be seen as an evolution of the Spanning Tree Protocol (STP; IEEE 802.1D)
  - Capable of reverting back to 802.1D version 1998
  - Convergence time reduced to few seconds !!!
- **Terminology slightly changed**
  - Blocking port role is split into the Backup and Alternate port roles
    - Alternate port
    - Backup port
  - Root port and Designated port roles still remain the same
  - New port state
    - Discarding (see next slides for details)

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L06 - Packet Switching on LAN (TB, STP)

Port States Comparison

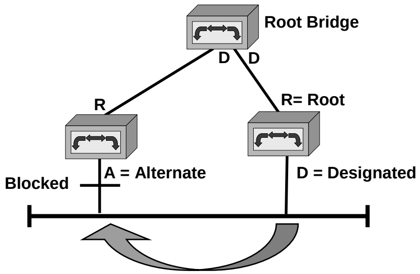
STP (802.1d) Port State	RSTP (802.1w) Port State	Is Port included in active Topology?	Is Port learning MAC addresses?
disabled	discarding	No	No
blocking	discarding	No	No
listening	discarding	Yes	No
learning	learning	Yes	Yes
forwarding	forwarding	Yes	Yes

Port Roles

- **Root Port Role**
  - Receives the best BPDU (so it is closest to the root bridge)
- **Designated Port Role**
  - A port is designated if it can send the best BDPU on the segment to which it is connected
  - On a given segment, there can be only one path toward the root-bridge

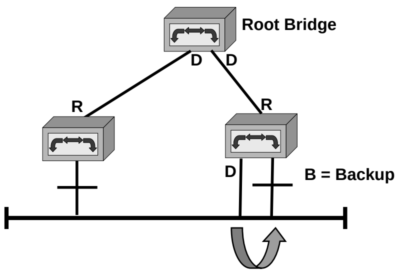
New Port Roles

- **Alternate Port Roles**
  - A port blocked by receiving BPDU's from a different bridge
  - Provides an alternate path to the root bridge



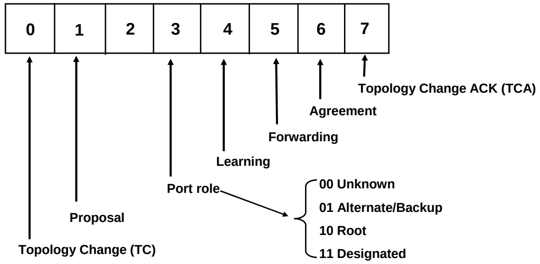
New Port Roles

- **Backup Port**
  - A port blocked by receiving BPDU's from the same bridge
  - Provides a redundant connectivity to the same segment



BPDU Flag Field – New Values

- **Few changes have been introduced by RSTP**
  - TC and TCA used by old STP
  - RSTP also uses the 6 remaining bits



NEW BPDU Handling

- **Faster Failure Detection**
  - BPDU's acting now as keepalives messages
    - Different to the 802.1D STP a bridge now sends a BPDU with its current information every <hello-time> seconds (2 by default), even if it does not receive any from the root bridge
  - If hellos are not received for 3 consecutive times, port information is invalidated
    - because BPDU's are now used as keep-alive mechanism between bridges
  - If a bridge fails to receive BPDU's from a neighbor, the connection has been lost
  - No more max age and message age fields
    - Hop count is used instead

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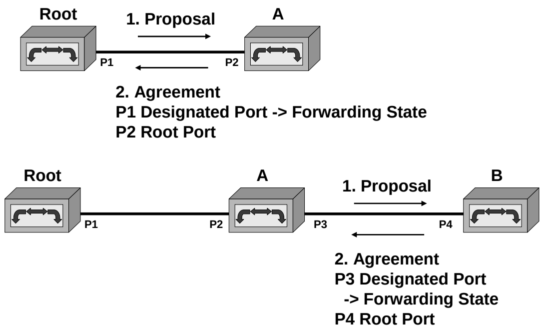
Proposal / Agreement

- **Explicit handshake between bridges**
  - Upon link up event the bridge sends a proposal to become designated for that segment
  - Remote bridge responses with an agreement if the port on which it received the proposal is the root port of the remote bridge
  - As soon as receiving an agreement, bridge moves the port to the forwarding state

Proposal/Agreement Sequence

- **Suppose a new link is created between the root and switch A and then a new switch B is inserted**



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L06 - Packet Switching on LAN (TB, STP)

Rapid Transition to Forwarding State

- **Most important feature in 802.1w**
- **The legacy STP was passively waiting for the network to converge before turning a port into the forwarding state**
- **New RSTP is able to actively confirm that a port can safely transition to forwarding**
- **Real feedback mechanism, that takes place between RSTP-compliant bridges**
- **To achieve fast convergence on a port, the protocol relies upon 2 new variables**
  - Edge ports
  - Link type

Rapid Transition to Forwarding State

- **Edge Ports**
  - Ports, which are directly connected to end stations cannot create bridging loops in the network and can thus directly perform on link setup transition to forwarding, skipping the listening and learning states
- **Link type**
  - Is automatically derived from the duplex mode of a port
    - A port operating in full-duplex will be assumed to be point-to-point
    - A port operating in half-duplex will be assumed to be a shared port
- **RSTP can only achieve rapid transition to forwarding**
  - On edge ports
  - On point-to-point links (trunks between L2 switches)
  - But not on shared Ports

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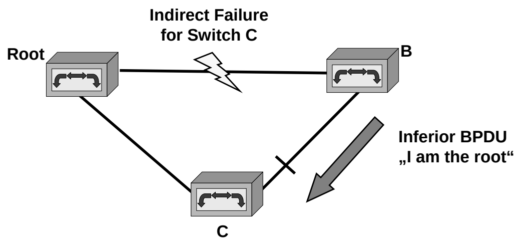
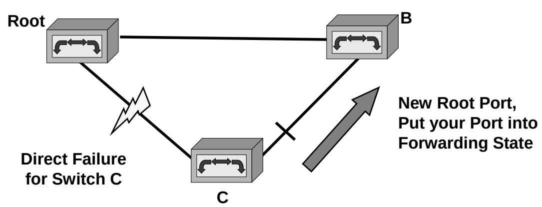
Accepting Inferior BPDU's

- B looses root port and sends BPDU claiming to be the root
- C immediately becomes designated for the blocked link between C and B and sends a proposal to B
- B sends an agreement and C set its port to forwarding
- Like Cisco's Backbone Fast



Accepting New Root Port BPDU's

- C looses root port and sends BPDU on the blocked link agreeing that this port is now root port
- C set its port to forwarding
- Like Cisco's Uplink Fast



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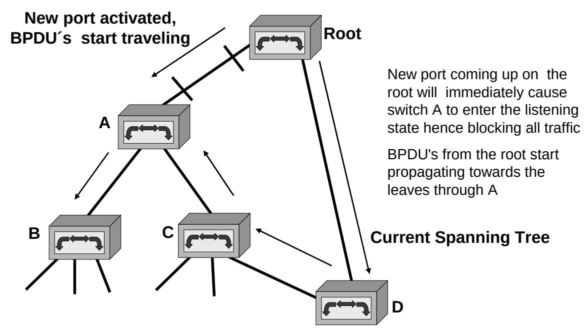
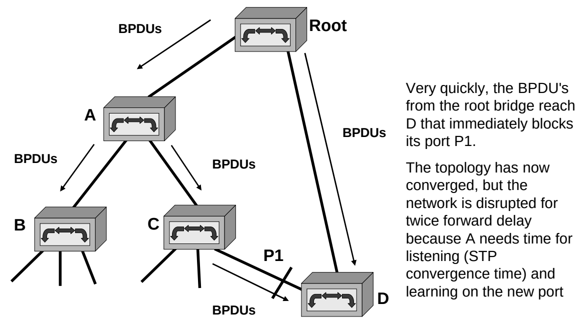
L06 - Packet Switching on LAN (TB, STP)

Slow Convergence with Legacy STP 1

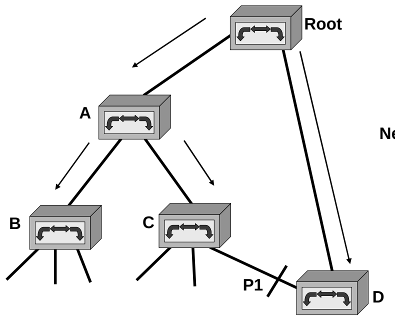
A new link between A and Root is being added to the bridged network



Slow Convergence with Legacy STP 2



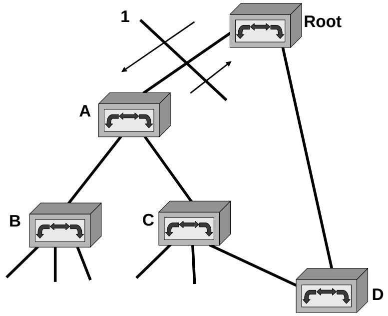
Slow Convergence with Legacy STP 3



New Spanning Tree

Fast Convergence with RSTP 1

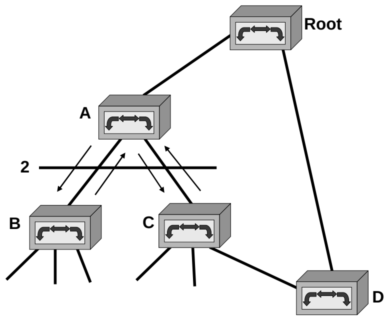
A new link between A and Root is being added to the bridged network



Both ports on link between A and the root are put in so called designated blocking as soon as they come up.

As soon as A receives the roots BPDU, it blocks its non-edge designated ports until synchronization is achieved. Through the agreement A explicitly authorizes the root bridge to put its port in forwarding

Fast Convergence with RSTP 2

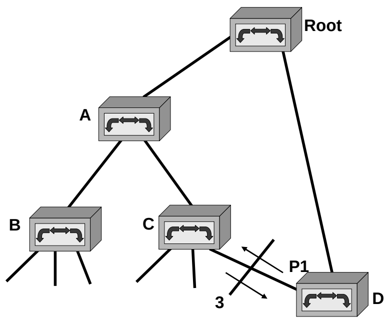


Now the link between switch A and the root is put in forwarding state.

The network below switch A is still blocking until port roles are negotiated at the next stage between switch A and switch B or A and C.

Switch B and C will enter the new spanning tree and A will put its ports in the forwarding state and the negotiations will proceed between C and D

Fast Convergence with RSTP 3



Switch C blocks its port to D because it root path costs of D are better than the root path costs of C

We have reached the final topology, which means that port P1 on D ends up blocking. It's the same final topology as for the STP example.

But we got this topology just time necessary for the new BPDU's to travel down the tree. No timer has been involved in this quick convergence.

Convergence Time < 1 second

Topology Change Detection

- **When a RSTP bridge detects a topology change, the following happens:**
  - It starts the TC While timer with a value twice the hello time for all its non-edge designated ports and its root port if necessary
  - It flushes the MAC addresses associated with all these ports from the MAC bridging table

Topology Change Propagation

- **When a bridge receives a BPDU with the TC bit set from a neighbor, the following happens:**
  - It clears the MAC addresses learnt on all its ports except the one that received the topology change
  - It starts the TC While timer and sends BPDU's with TC set on all its designated ports and root port (RSTP no longer uses the specific TCN BPDU, unless a legacy bridge need to be notified)

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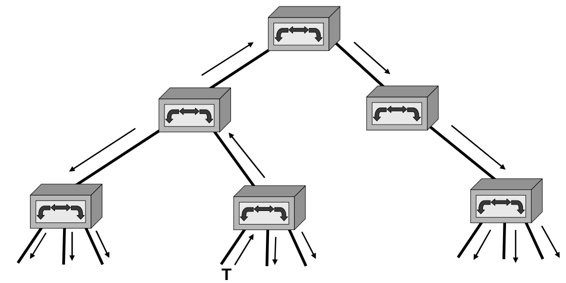
L06 - Packet Switching on LAN (TB, STP)

Topology Change Propagation



The originator of the TC directly floods this information through the network

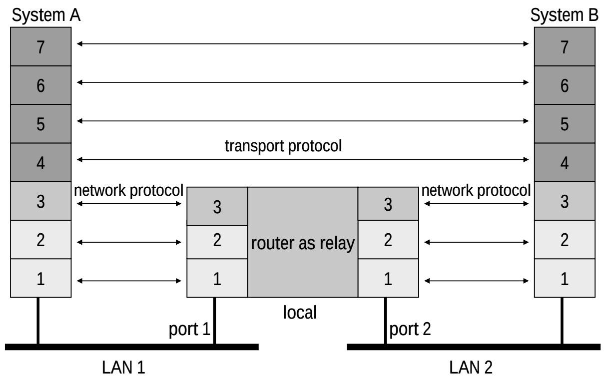
Agenda

- **Introduction**
- **Transparent Bridging Basics**
- **Spanning Tree Protocol**
- **Rapid Spanning Tree Protocol**
- **<u>Comparison L3 Routing versus L2 Bridging</u>**

Router

- **router forwards packets**
  - based on layer 3 addresses and protocols
- **layer 3 address**
  - structured versus unstructured layer 2 address
    - at least two level hierarchy: subnet and end system (host)
  - hardware independent
  - identifies a certain end system located in one subnet in a non-ambiguous way
  - a structured address is laid upon the unstructured MAC-address
- **router connects**
  - subnets knowing the best path to other subnets

Router and OSI Model



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L06 - Packet Switching on LAN (TB, STP)

Requirements for Routers

- **consistent layer-3 functionality**
  - for entire transport system
  - from one end-system over all routers in between to the other end-system
  - hence routing is not protocol-transparent
    - all elements must speak the same „language“
- **end-system**
  - must know about default router
  - on location change, end-system must adjust its layer 3 address
- **to keep the routing tables consistent**
  - routers must exchange information about the network topology by using routing-protocols

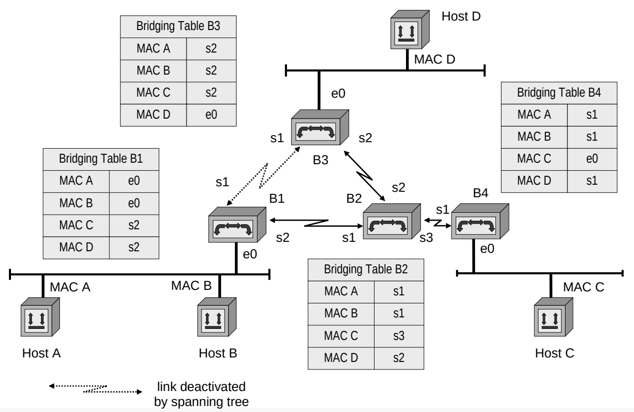
Routing Facts 1

- **in contrast to bridges**
  - router maintains only the subnet-part of the layer 3 addresses in its routing table
  - the routing table size is direct proportional to the number of subnets and not to the number of end-systems
- **transport on a given subnet**
  - still relies on layer 2 addresses
- **end systems forward data packets for remote destinations**
  - to a selected router using the router's MAC-address as destination
  - only these packets must be processed by the router

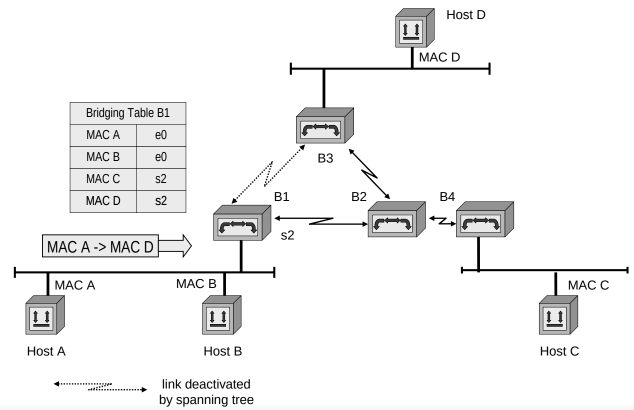
Routing Facts 2

- **flow control between router and end system is principally possible**
  - end systems knows about the local router
- **broadcast/multicast-packets in the particular subnet**
  - are blocked by the router so broad/multicast traffic on the subnets doesn't stress WAN connections
- **independent of layer 1, 2**
  - so coupling of heterogeneous networks is possible
- **routers can use redundant paths**
  - meshed topologies are usual
- **routers can use parallel paths for load balancing**

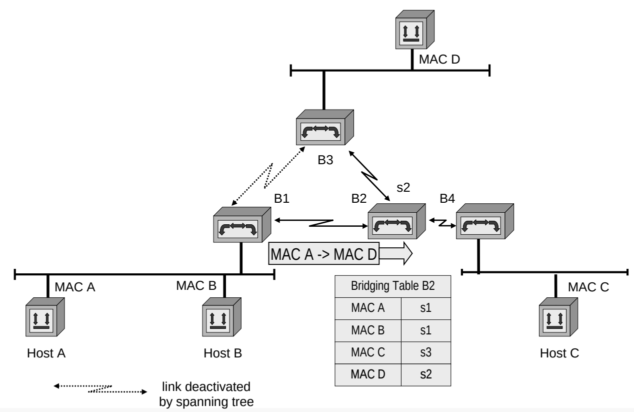
Example Topology: Bridging



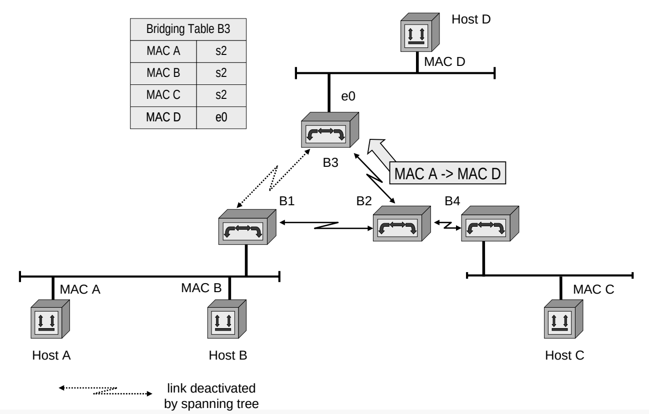
Frame MAC A to MAC D (1)



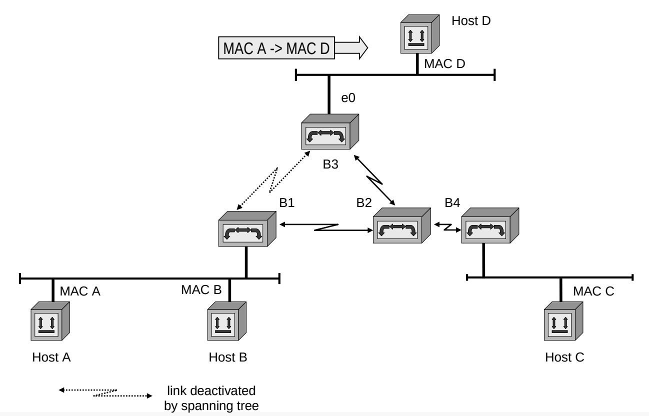
Frame MAC A to MAC D (2)



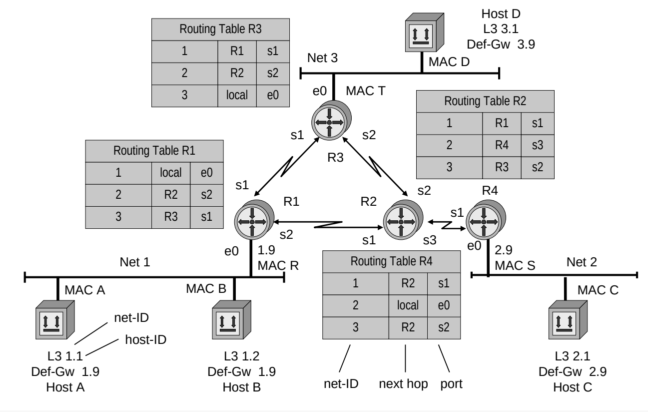
Frame MAC A to MAC D (3)



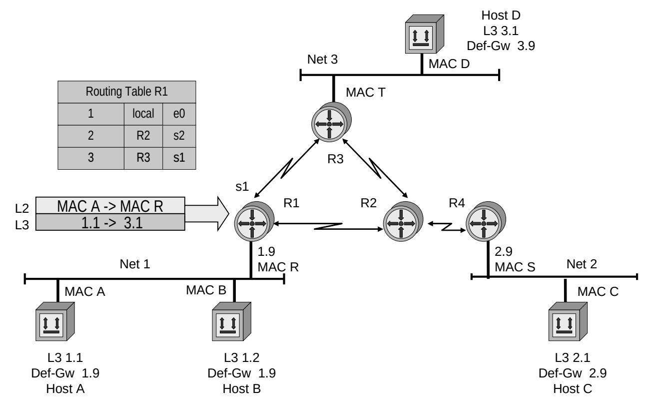
Frame MAC A to MAC D (4)



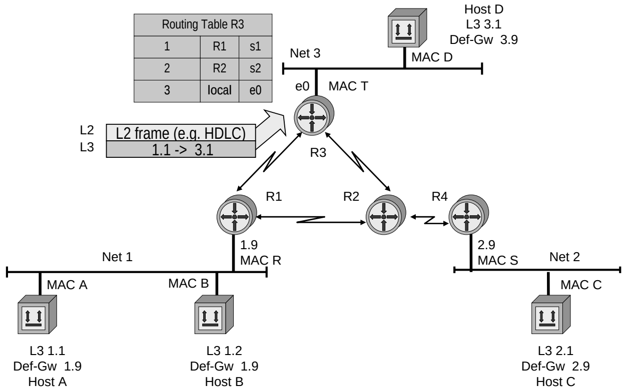
Example Topology: Generic Routing



Frame 1.1 to 3.1 (1)

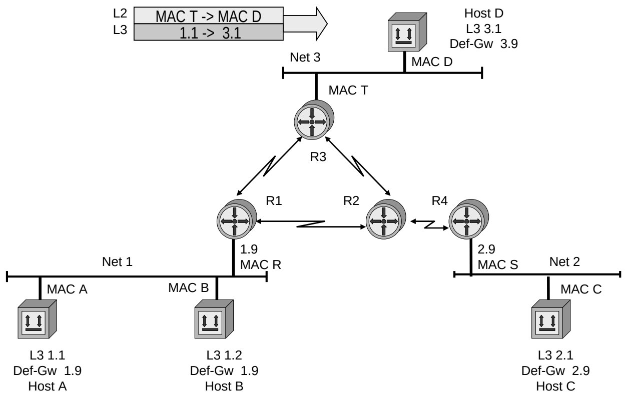


Frame 1.1 to 3.1 (2)



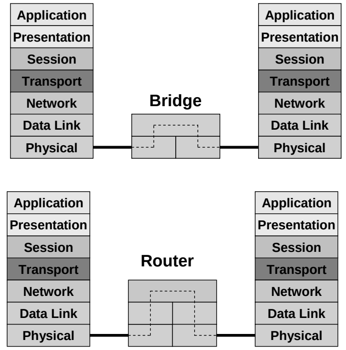
 Packet Switching on L2, v4.11 89

Frame 1.1 to 3.1 (3)



 Packet Switching on L2, v4.11 90

OSI Comparison



- **MAC addresses not routable**
  - NetBIOS over NetBEUI not routable (no L3)
- **Bridge supports different physical media on each port**
  - E.g. 10Mbit/s to 100Mbit/s
- **Router supports different layer-2 technologies**
  - E.g. Ethernet to Frame Relay

 Packet Switching on L2, v4.11 91

Transparent Bridging versus Routing

	Bridging		Routing
+	depends on MAC addresses only	−	requires structured addresses (must be configured)
+	invisible for end-systems; transparent for higher layers	−	end system must know its default-router
−	must process every frame	+	processes only frames addressed to it
−	number of table-entries = number of all devices in the whole network	+	number of table-entries = number of subnets only
−	Spanning Tree eliminates redundant lines; no load balance	+	redundant lines and load balance possible
−	no flow control (may be changed by usage of MAC Pause command)	+	flow control is possible (router is seen by end systems)

 Packet Switching on L2, v4.11 92

Transparent Bridging versus Routing

Bridging	Routing
(−) no LAN/WAN coupling because of high traffic (broadcast domain!)	(+) does not stress WAN with subnet's broad- or multicasts; commonly used as "gateway"
(−) paths selected by STP may not match communication behaviour / needs of end systems	(+) router knows best way for each frame
(+) faster, because implemented in HW; no address resolution	(−) slower, because usually implemented in SW; address resolution (ARP) necessary
(+) location change of an end-system does not require updating any addresses	(−) location change of an end-system requires adjustment of layer 3 address (may be solved by DHCP)

Transparent Bridging versus Routing

Bridging	Routing
(−) spanning tree necessary against endless circling of frames and broadcast storms	(−) routing-protocols necessary to determine network topology

- **but today's L2 switches can improve network performance by enabling full duplex, collision-free subnets**
- **MAC address resolution of routers is considered as unnecessary overhead -> trend goes to layer 3 switching (fast routing)**

Most Important !

- **bridge separates LAN into**
  - multiple collision domains
- **but a bridged network is still**
  - one broadcast domain
  - broadcast frames are always flooded
- **router separates the whole Inter-network**
  - into multiple broadcast domains
  - broadcast frames arriving on a LAN are always stopped at the router
  - they can´t leave their origin LAN

Ethernet Switching

- **Ethernet switch is basically a bridge, differences are only:**
  - faster because implemented in HW
  - multiple ports
  - improved functionality (e.g. VLAN)
  - note: packet switching / connectionless mode with frame forwarding based on unstructured MAC addresses
- **don't confuse it with WAN Switching!**
  - e.g. X.25 switch, Frame Relay switch, ATM switch
  - completely different!
  - that is packet switching / connection-oriented mode with forwarding based on local connection identifiers