# Network Design

Physical Layer (LAN, WAN) Aspects,
LAN Design

## Agenda

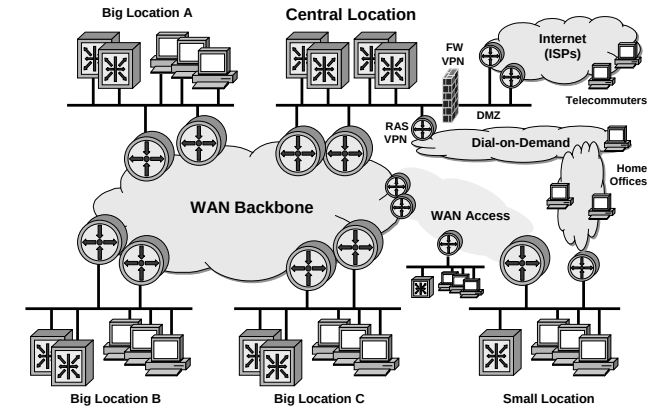
- **Scenarios**
- **Physical Layer**
  - Introduction
  - LAN
  - WAN
- **LAN (L2)**
  - Review Ethernet Technology
  - Design Considerations
  - Design Solution – Best Practices
  - Failover Handling
  - Advanced Techniques - Teaming
  - LAN – WAN Interconnection







## Scenarios Overview






## Basic Considerations

- **"Reliable Network Operation"**
  - L1 (Physical), L2 (LAN, WAN-Link), L3 (IP)
- **Automatic overcome of "Single-Point of Failures" (SPoF)**
  - Convergence time is one aspect
  - Configuration / administration is the other aspect
- **Network management implemented**
  - Signals SPoF and triggers corrective reaction to avoid splitting of network in isolated parts
- **Trusted environment**
  - Basically we can trust the inside network and their users
  - Otherwise a more complex implementation is necessary based on strong IP network security principles using cryptography and crypto-graphical strong security protocols
  - Need to be handled in a separate "IP/Internet Security Course"

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## Network Infrastructure

- **Technical equipment needs a defined environment for physical environment parameters**
  - Electricity
    - e.g. UPS
  - Humidity, Temperature
    - e.g. air-condition, positive air flow
- **Upper layer redundancy need to follow the physical paths**
  - e.g. two physical links to two different switches or routers should take separated paths (LAN and WAN)
  - redundant network components should be located at different physical places







## Network Infrastructure

- **Technical equipment needs conventional physical protection**
  - Access control for buildings, rooms
    - Guards, cards, passwords, …
  - Technical equipment in locked environment to avoid unauthorized access like direct attachment via management console
    - Hubs, switches, routers, server
    - WLAN access points (?)
    - Must be monitored (camera) and should produce an alarm in case of manipulation especially in public areas



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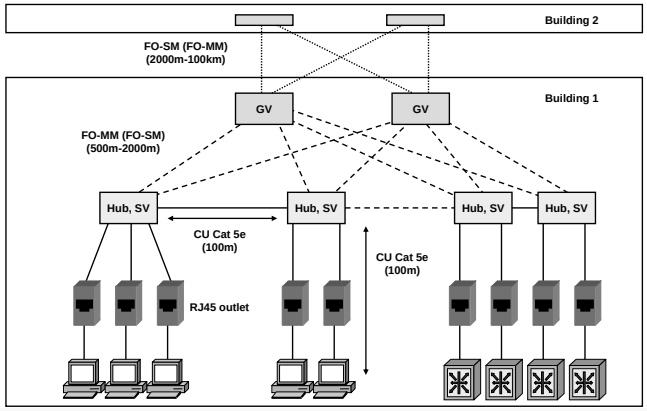
## Structured Cabling (LAN)

- **Physical Wiring**
  - Should follow the principle of structured cabling
  - Primary
    - End system to first “Hub” (Repeater or L2 Switch)
      - “Stockwerkverteiler”
    - CU-UTP, Category 5e or better
    - FO for extreme conditions only
  - Secondary
    - Hubs to central functions
      - “Gebäudeverteiler”
    - FO-MM (FO-SM)
  - Tertiary
    - Interconnections of buildings
    - FO-MM (FO-SM)



## Structured Cabling (LAN)







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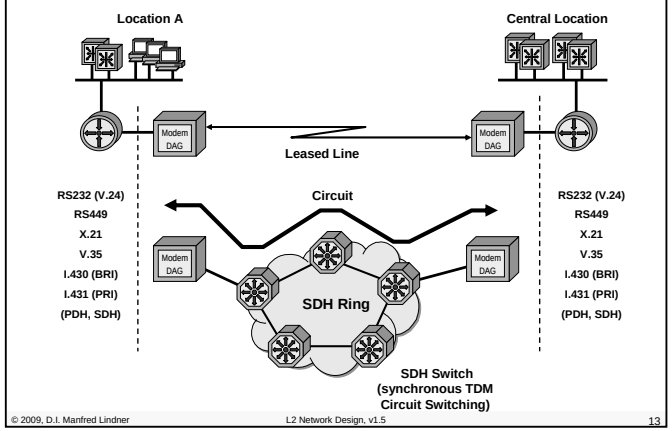
## WAN Alternatives

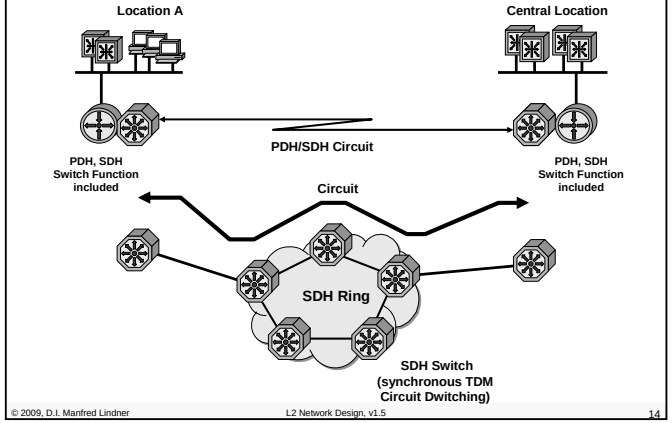
- **Leased line service**
  - Usually based on PDH, SDH or ISDN
  - “Standleitung”
  - “Circuit” with defined bandwidth and constant delay
- **Virtual circuit service**
  - X.25, Frame Relay, ATM
  - PVC or SVC
  - “Virtual circuit” with certain QoS (Quality of Service) guarantees (e.g. committed minimal throughput, bounded delay = worst case delay)
- **Backup service**
  - “Dial on Demand”, “Bandwidth on Demand”
  - ISDN (circuit), X.25-(Frame Relay)-ATM (virtual circuit in SVC operation mode

## WAN Alternatives 1



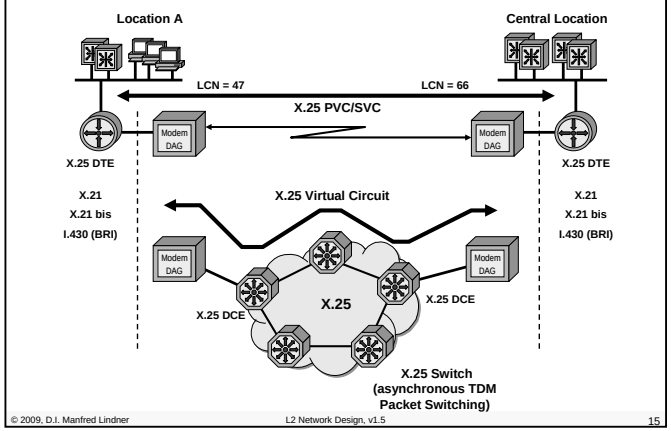



## WAN Alternatives 2



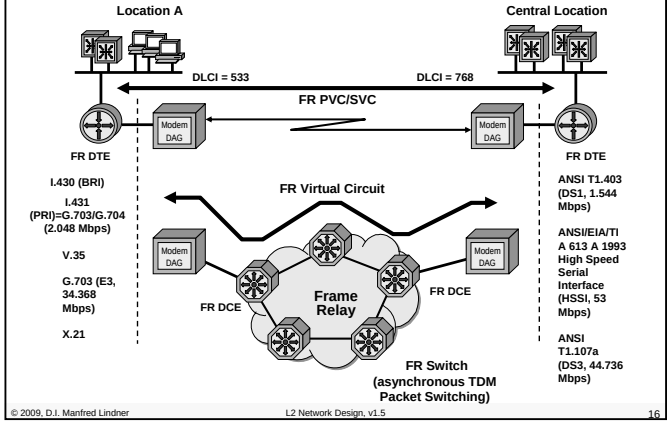



## WAN Alternatives 3






## WAN Alternatives (Frame Relay) 4





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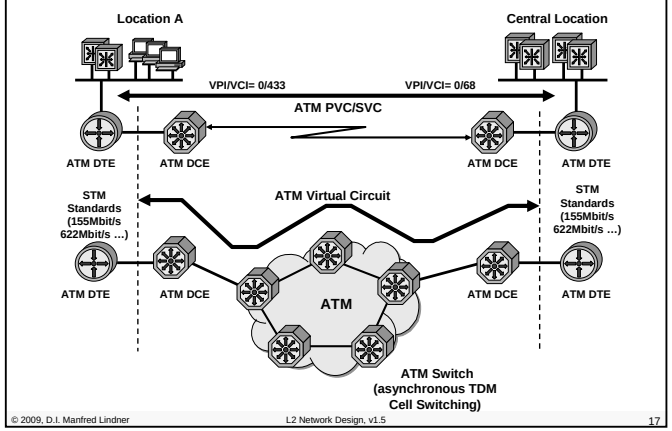
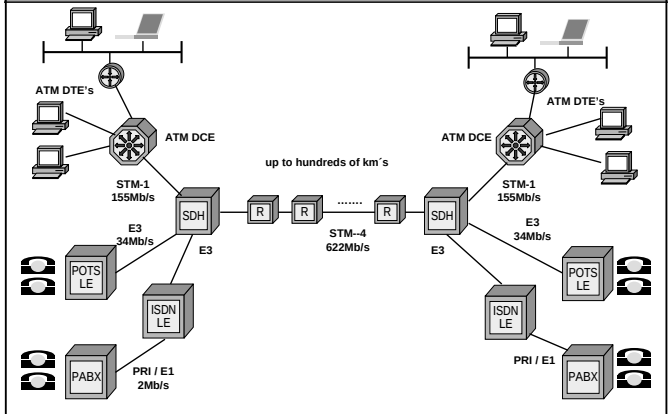
## WAN Alternatives (Asynchronous Transfer Mode) 5




 L2 Network Design, v1.5 17

## ATM as WAN Technology based on SDH

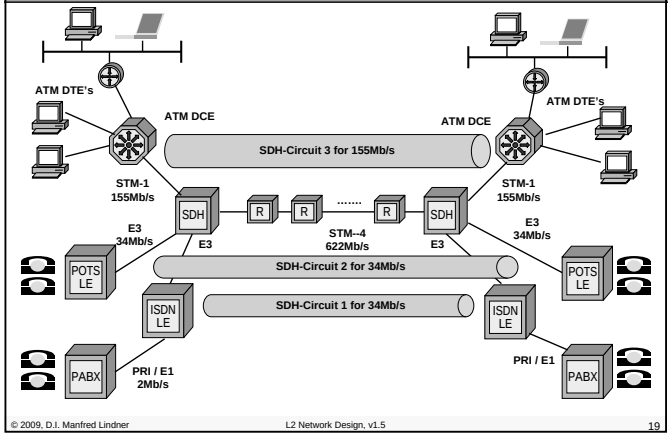



 L2 Network Design, v1.5 18



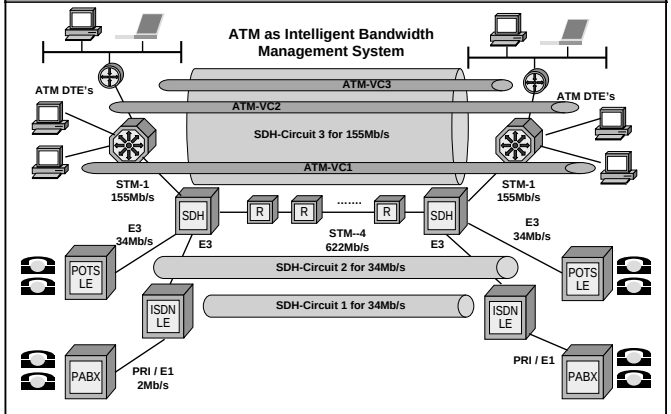


## SDH Circuits (Timeslots of S-TDM)



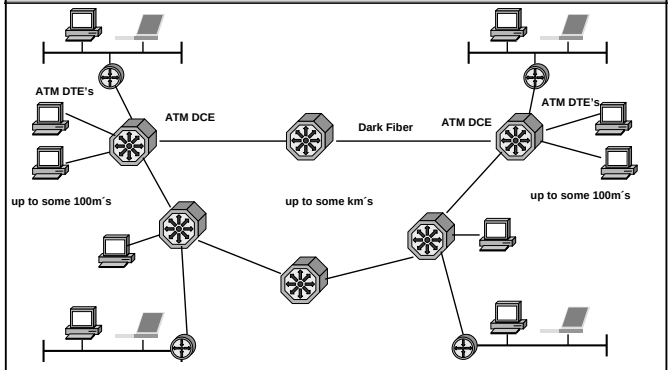

 L2 Network Design, v1.5 19

## ATM-VC´s inside SDH-Circuit




 L2 Network Design, v1.5 20

## ATM as LAN/ MAN Technology based on Dark Fiber is already gone






## WAN Service Considerations

- **Who is responsible for providing the service?**
  - Service Provider or
  - Department of own company
  - Note: functions of configuration, implementation, management, operation, monitoring, maintenance need to be established
  - Service Level Agreement (SLA)
- **What about redundancy?**
  - Can a redundant line take a true different physical way end-to-end?
  - Should different service providers be used?







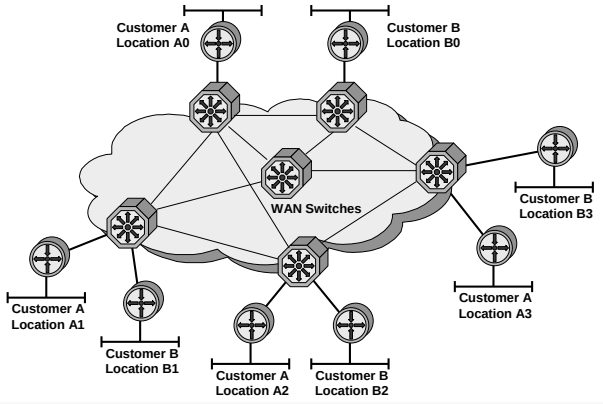
## Classical VPN´s

- X.25, Frame Relay or ATM in the core
- Dedicated physical switch ports for every customers CPE
  - router, bridge, computer
- Customer traffic separation in the core done by concept of virtual circuit
  - PVC service
    - management overhead
  - SVC service with closed user group feature
    - signaling overhead
- Separation of customers inherent to virtual circuit technique

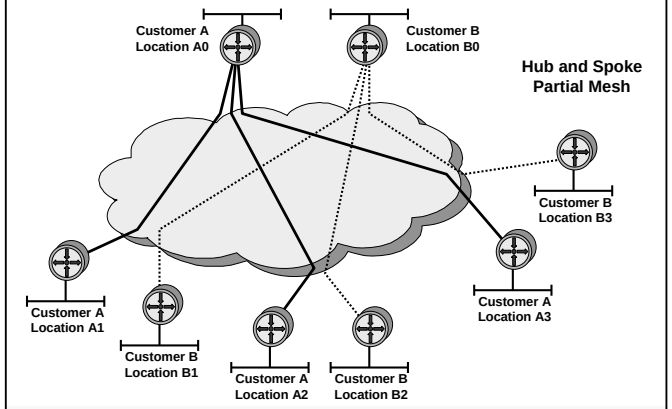
**VPN‘s based on Overlay Model**



## Physical Topology of Classical VPN

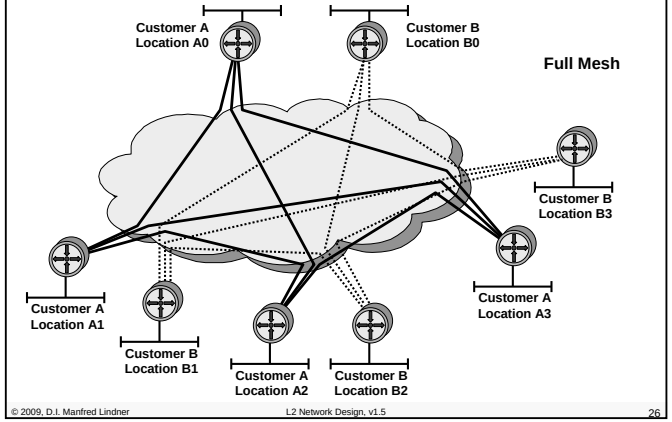


## Logical Topology Classic VPN (1)






## Logical Topology Classic VPN (2)









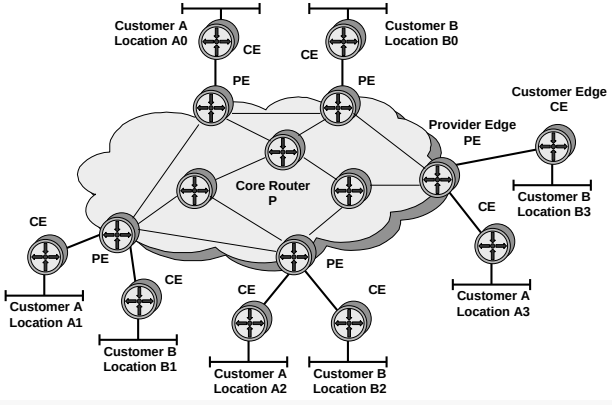

## Virtual Private Networks based on IP

- Single technology end-to-end
  - IP forwarding and IP routing
- No WAN switches in the core
  - Based on different technology (X.25, FR or ATM)
  - Administered by different management techniques
- Often private means control over separation but not privacy
  - Data are seen in clear-text in the core

**VPN´s based on Peer Model**



## Physical Topology IP VPN



## Possible Solutions for IP VPN´s

- **IP addresses of customers non overlapping**
  - filtering and policy routing techniques can be used in order to guarantee separation of IP traffic
    - exact technique depends on who manages routes at the customer site
- **IP addresses of customers overlapping**
  - tunneling techniques must be used in order to guarantee separation of IP traffic
    - GRE
    - L2F, PPTP, L2TP
    - MPLS-VPN
- **If privacy is a topic**
  - encryption techniques must be used
    - SSL/TLS, IPsec



## Tunneling Solutions for IP VPN´s

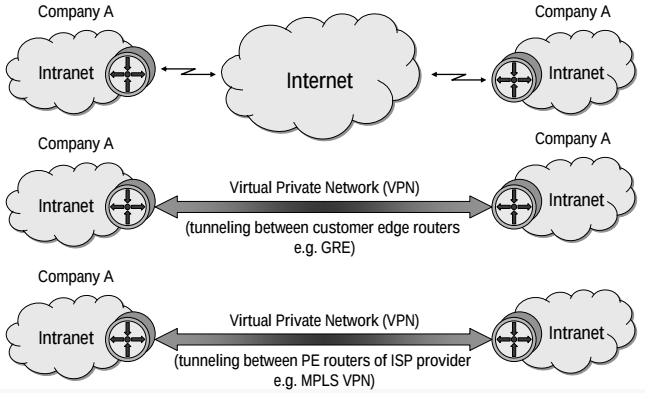
- **Tunneling techniques are used in order to guarantee separation of IP traffic**
  - IP in IP Tunneling or GRE (Generic Routing Encapsulations)
    - Bad performance on PE router
  - PPTP or L2TP for LAN to LAN interconnection
    - Originally designed for PPP Dial-up connections
    - LAN – LAN is just a special case
  - MPLS-VPN
    - Best performance on PE router
- **In all these cases**
  - Privacy still an aspect of the customer





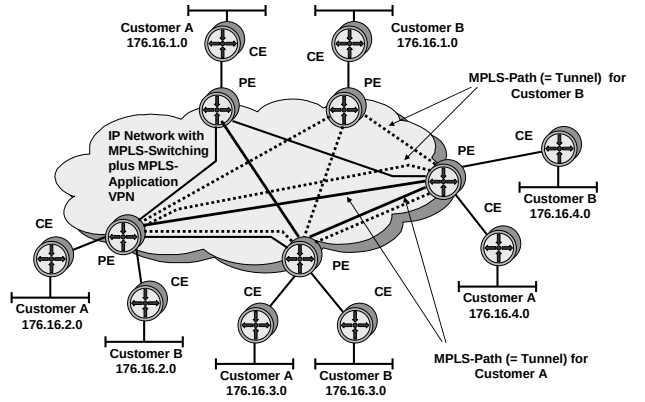


## Tunneling IP VPNs without Encryption






## MPLS-VPN



## MPLS VPN – Best of Both Worlds

- **Combines VPN Overlay model with VPN Peer model**
- **PE routers allow route isolation**
  - By using Virtual Routing and Forwarding Tables (VRF) for differentiating routes from the customers
  - Allows overlapping address spaces
- **PE routers participate in P-routing**
  - Hence optimum routing between sites
  - Label Switches Paths are used within the core network
  - Easy provisioning (sites only)
- **Overlapping VPNs possible**
  - By a simple (?) attribute syntax



## What does MPLS VPN mean for the Provider?

- **Requires MPLS Transport within the core**
  - Using the label stack feature of MPLS
- **Requires MP-BGP among PE routers**
  - Supports IPv4/v6, VPN-IPv4, multicast
  - Default behavior: BGP-4
- **Requires VPN-IPv4 96 bit addresses**
  - 64 bit Route Distinguisher (RD)
  - 32 bit IP address
- **Every PE router uses one VRF for each VPN**
  - Virtual Routing and Forwarding Table (VRF)





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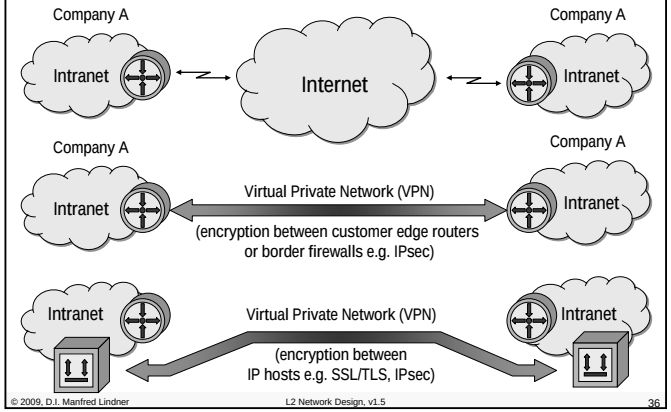
## Encryption Solutions for IP VPN´s

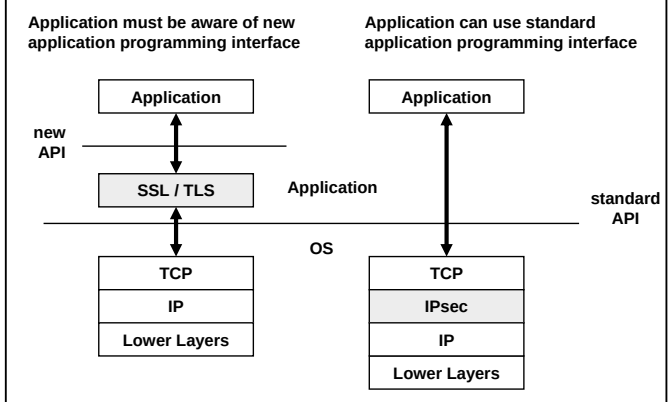
- **If privacy is a topic tunneling techniques with encryption are used in order to hide IP traffic**
  - SSL (secure socket layer)
    - Usually end-to-end
    - Between TCP and Application Layer
  - IPsec
    - Could be end-to-end
    - Could be between special network components (e.g. firewalls, VPN concentrators) only
    - Between IP and TCP/UDP Layer
  - PPTP and L2TP Tunnels
    - With encryption turned on via PPP option



## Tunneling IP VPNs without Encryption



## SSL/TLS versus IPsec



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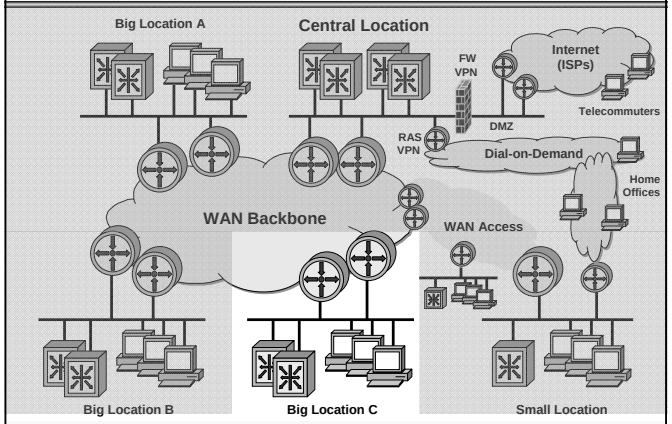
## L2 Scenario

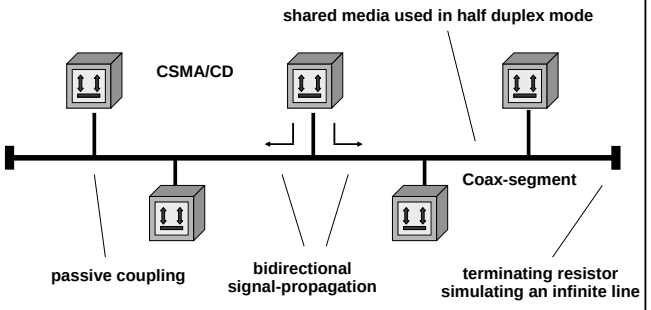





## Review L2 Network Components (Basic)

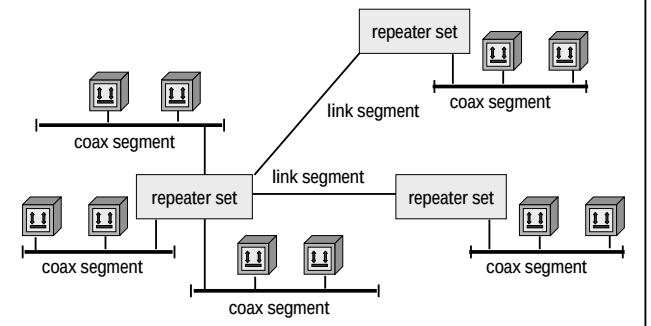
- **Ethernet**
  - LAN
  - Originally shared media (cable)
  - Coax segment
  - CSMA/CD as conflict solution if more than one network station access the cable
  - Limited distance
- **Repeater**
  - Amplifier
  - Expansion of LAN
  - Link segment to connect remote repeaters
  - Collision domain

## Basic Idea of Ethernet






## Multiport Repeater - One Collision Domain

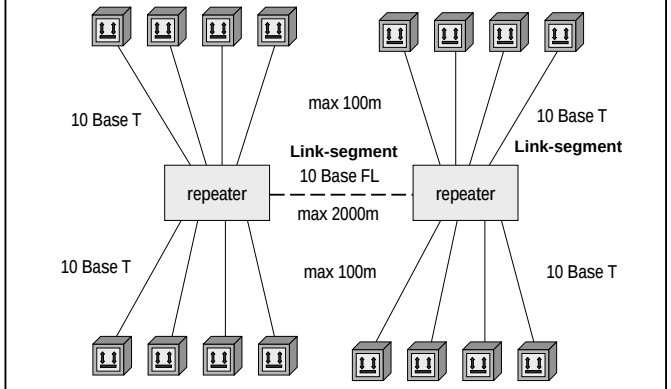






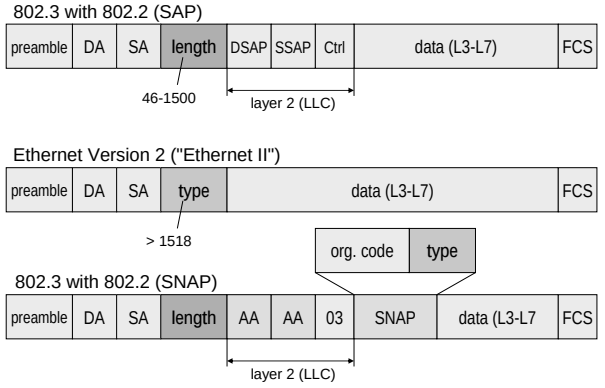



## Multiport Repeater as „Hub“






## SAP, SNAP, Ethernet V2 - Framing

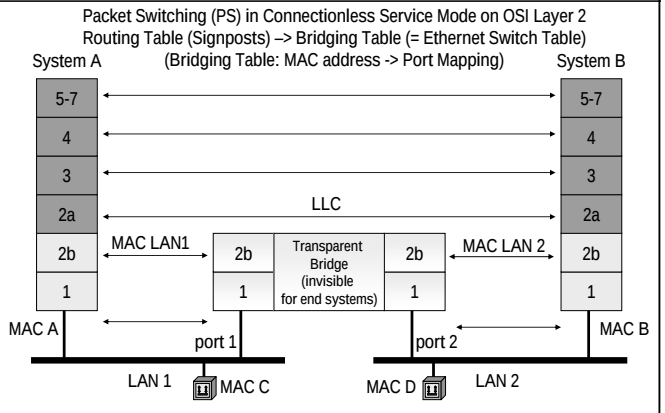


## Review L2 Network Components (Bridge)

- **Bridge**
  - Packet switch based on store and forward of frames
  - Bridging table based on MAC addresses
  - "Transparent Bridging"
    - Learning location of a system based on SA-MAC address with aging mechanism
    - Forwarding decision based on DA-MAC address with filtering and flooding
  - Broadcast domain
- **"Ethernet Switch" (L2 switch)**
  - Fast transparent bridge
  - More ports
  - VLAN capability



## Transparent Bridge = Ethernet Switch

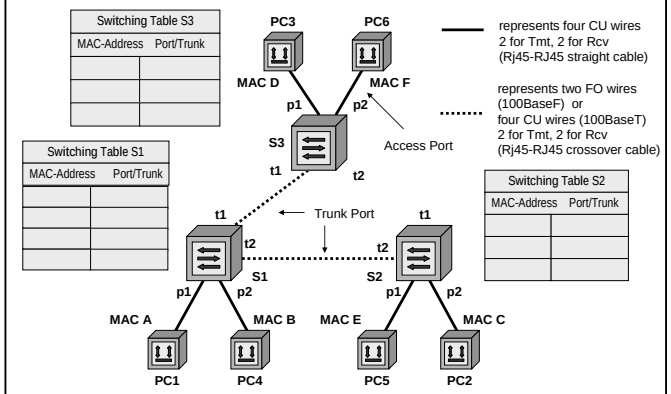






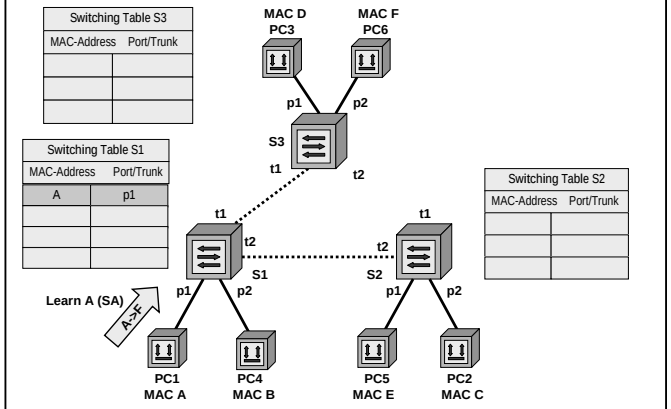



## Ethernet Switch Table - Power On
**(MAC Address Table - Empty)**

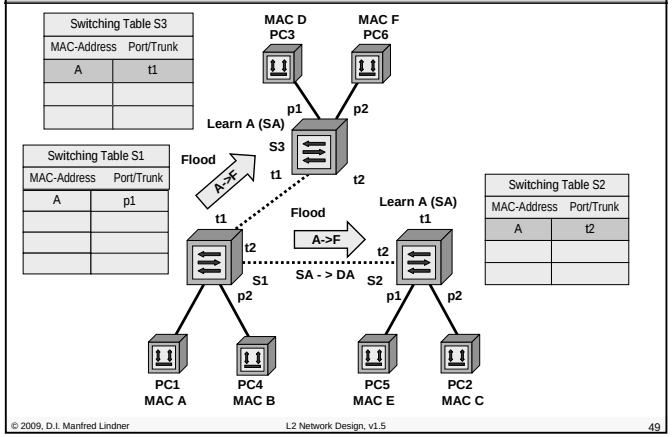





## Table Building for Ethernet Frame MAC-A to MAC-F 1

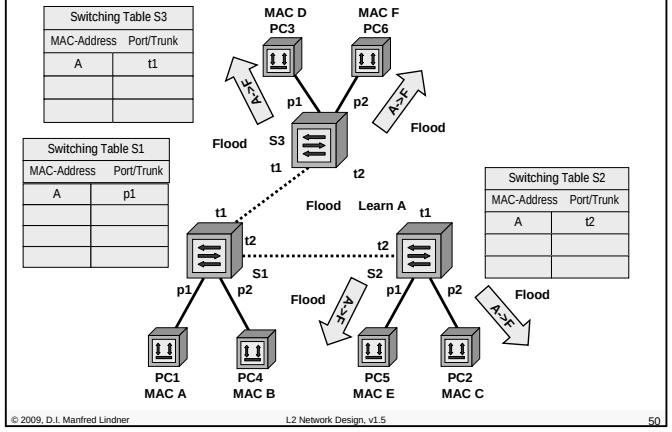


## Table Building for Ethernet Frame MAC-A to MAC-F 2



## Table Building for Ethernet Frame MAC-A to MAC-F 3

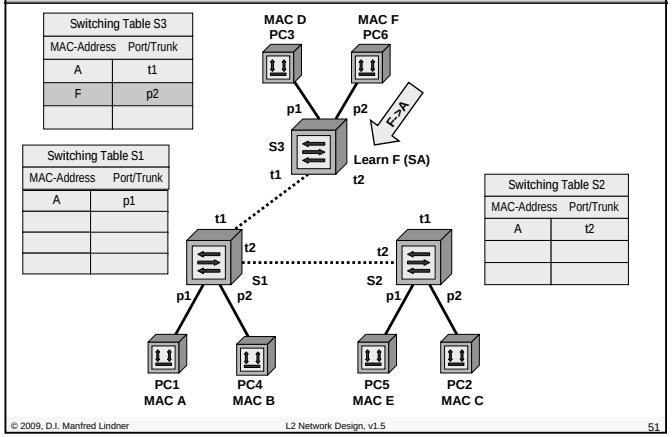




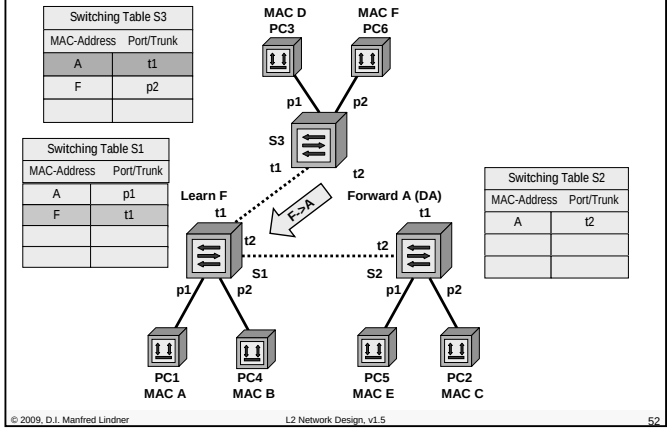


## Table Building / Table Usage for Ethernet Frame MAC-F to MAC-A 1



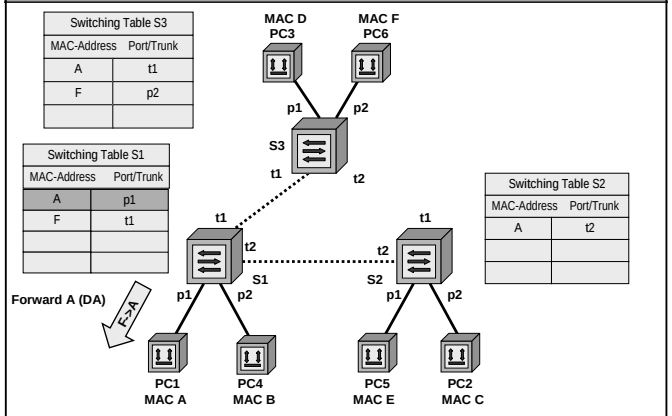

 

## Table Building / Table Usage (Forwarding Decision) for Ethernet Frame MAC-F to MAC-A 2



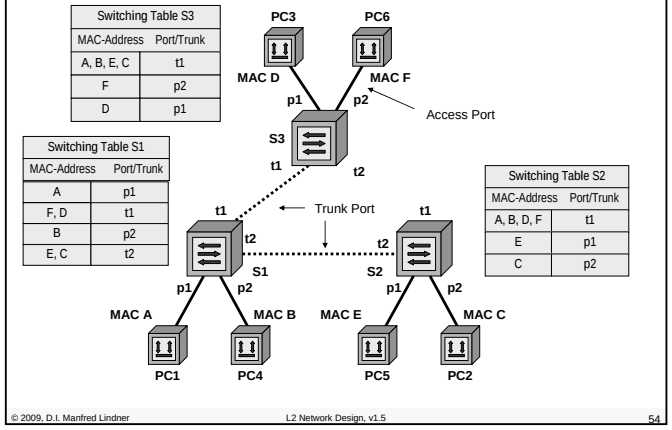

 

## Table Building / Table Usage (Forwarding Decision) for Ethernet Frame MAC-F to MAC-A 3






## Ethernet Switch Table – Final State
**(All MAC addresses learned)**

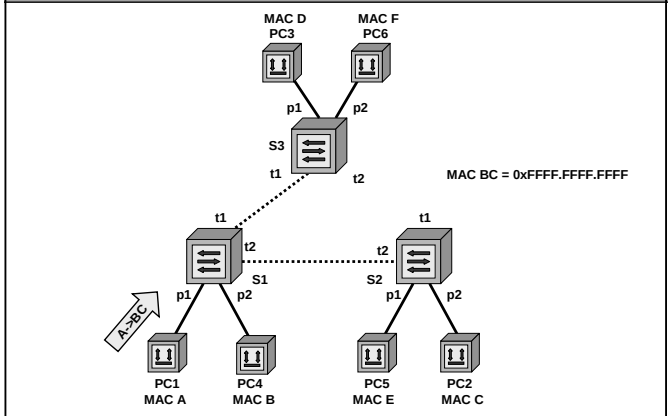






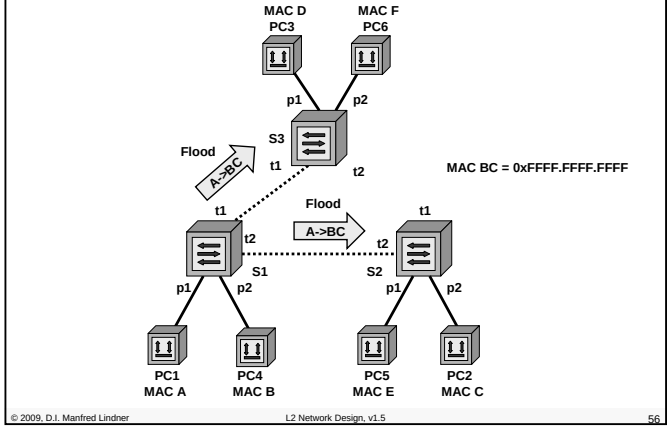



## Ethernet Broadcast (BC) 1

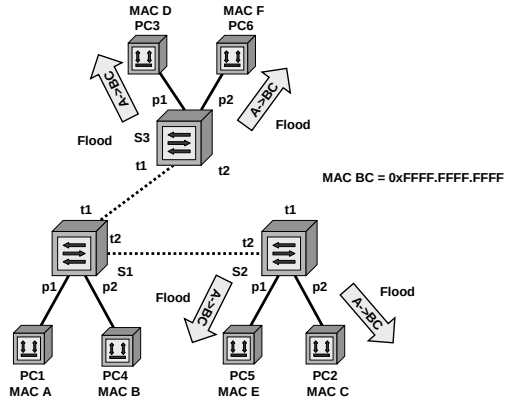





## Ethernet Broadcast (BC) 2



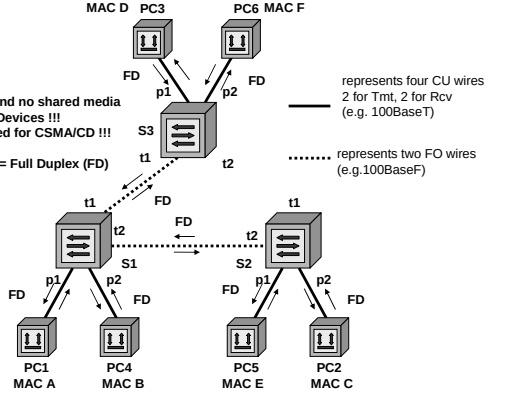
## Ethernet Broadcast (BC) 3






## Ethernet Switching – Full Duplex (FD)

**(Point-to-Point Links and FD Everywhere)**



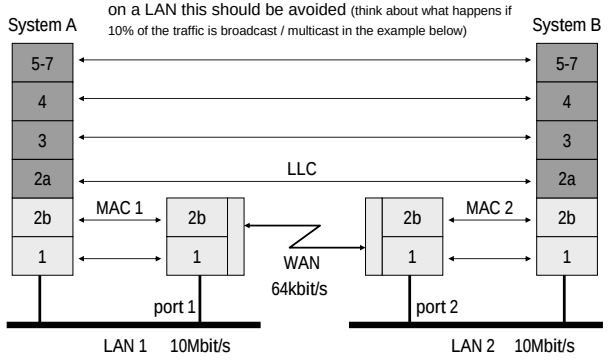







## Remote Bridging ? (<- TB means Broadcast Domain!)

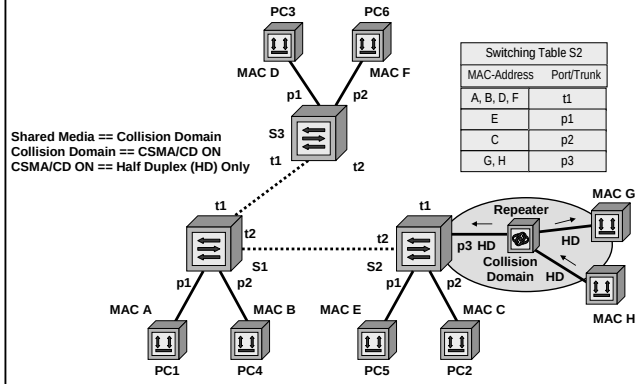
Because of inherent L2 broadcast / multicast percentage on a LAN this should be avoided (think about what happens if 10% of the traffic is broadcast / multicast in the example below)



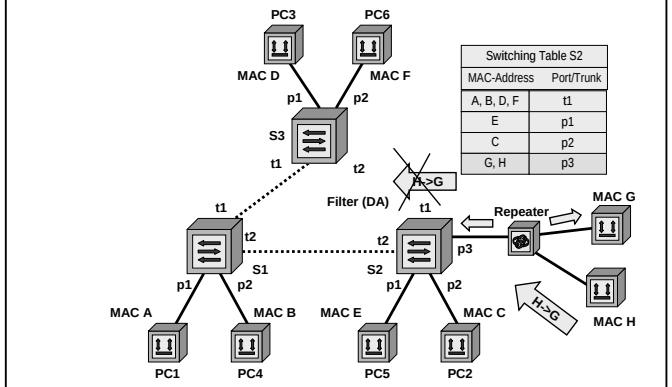



## Ethernet Switching – Repeater (Hub)

**(Point-to-Point Links Everywhere but on Shared Media – Half Duplex)**



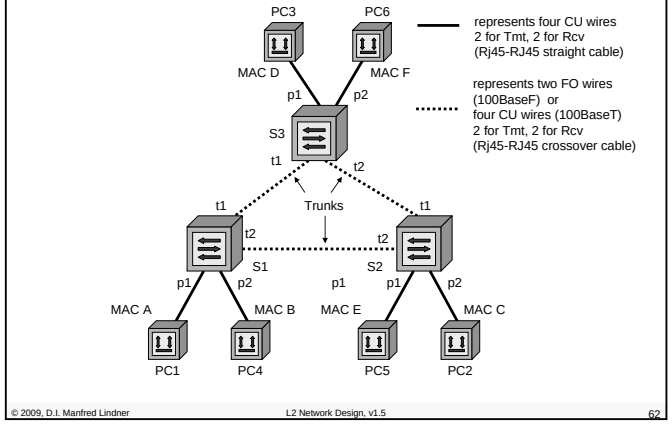
## Table Usage (Filtering Decision) for Ethernet Frame MAC-H to MAC-G




| Switching Table S2 | |
|---|---|
| MAC-Address | Port/Trunk |
| A, B, D, F | t1 |
| E | p1 |
| C | p2 |
| G, H | p3 |



## Redundant Topology L2 Switching

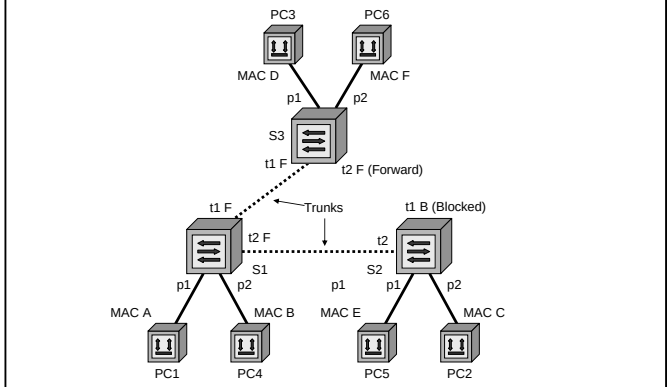






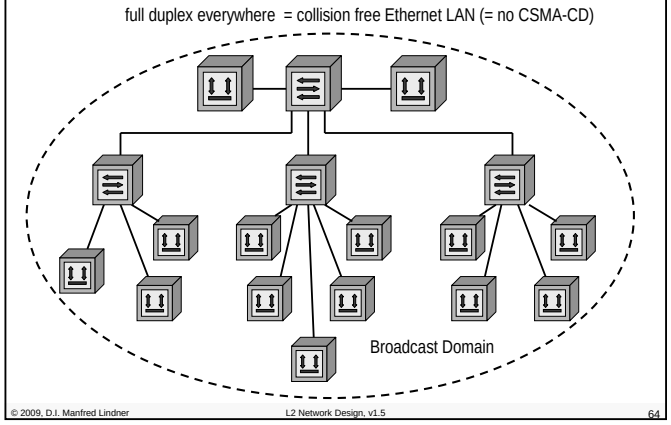



## Spanning Tree Applied

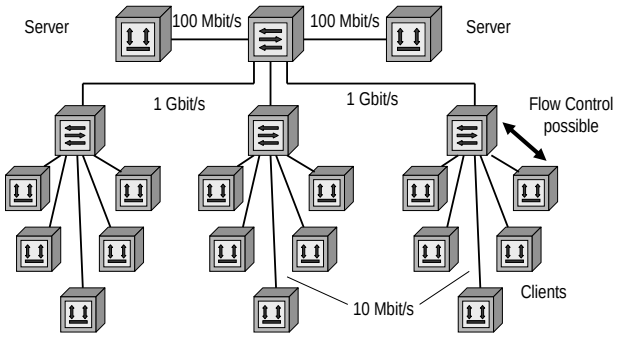





## Switching: Full Duplex Ethernet



## Switching: Variable Speed, QoS and Flow Control






## Review L2 Network Components (STP)

- **"Spanning Tree Protocol" (STP)**
  - Parallel paths between two LAN segments would cause broadcast storm
  - STP takes care that there is always exact one active path between any 2 stations
  - implemented by a special bridge protocol which is used between the bridges for communication
    - using BPDU (Bridge Protocol Data Unit) packets with MAC-multicast address
  - failure of active path causes activation of a redundant path
    - Convergence time worst case 50 seconds with default parameters for hello time, max age and forward delay
      - time = max age + 2 * (forward delay)







## Parameters for STP 1

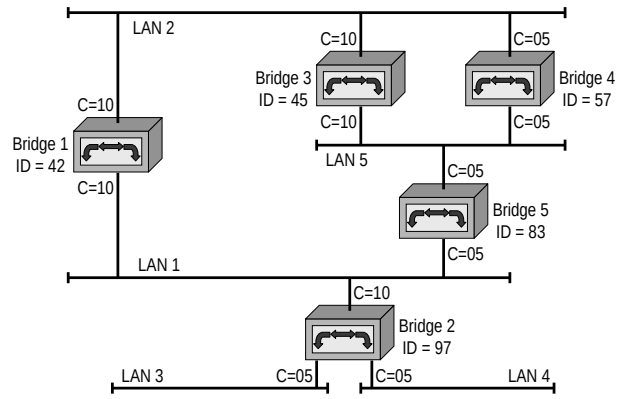
- **Bridge Identifier (Bridge ID)**
  - combination of MAC-address and a priority number
    - typically, the lowest MAC-address of all ports is used for that
    - note: although bridge will not be seen by end systems, for bridge communication and management purposes a bridge will listen to one or more dedicated MAC addresses
    - Bridge-ID = priority#.mac#
  - 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






## 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 actual version**
- 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**



## 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 together with TCN BPDUs for signalling topology changes**
    - **note: in case of topology change MAC addresses may be found on an other port in the bridging table; therefore relearning of the dynamic bridging table is necessary; relearning is triggered by the root bridge**



## MAC Addresses / LSAP / 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
  - Note :
    - all addresses in Ethernet format
    - on the Token Ring the functional address: **0300 0000 8000 hex**
  - the L-SAP 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





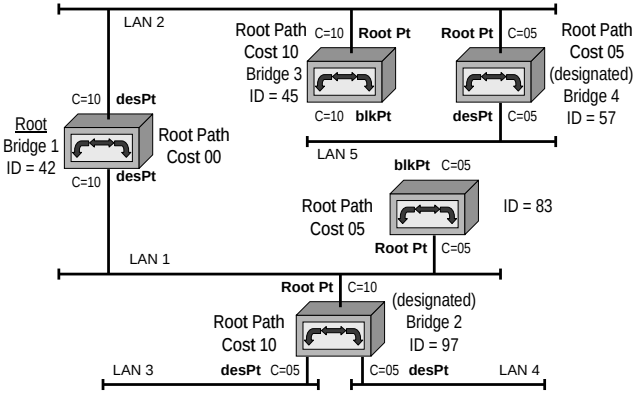


## Spanning Tree applied

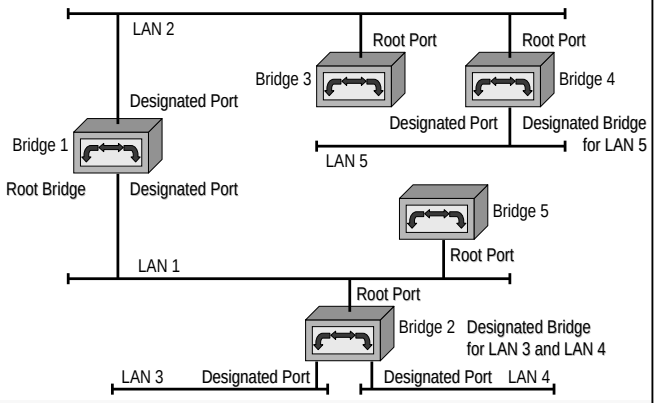
- **STP Algorithm summarized:**
  - select the root bridge
  - select the root ports
    - by computation of the shortest path from any other bridge to the root bridge
    - root port points to the shortest path towards the root
  - select one designated bridge for every LAN segment
    - corresponding port 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



## Final STP Picture for Example



## Spanning Tree Terms






## STP Error Detection

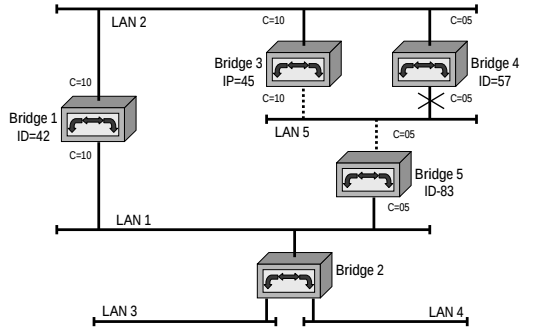
- **normally the root bridge generates (triggers)**
  - every 1-10 seconds (hello time interval) a Configuration BPDU to be received on the root port of every other bridge and carried on through the designated ports
  - bridges which are not designated are still listening to such messages on blocked 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







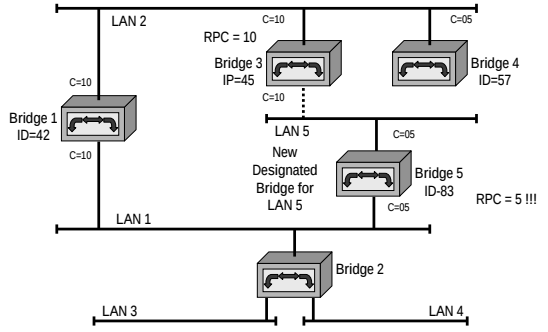
## STP Convergence Time – Failure at Designated Bridge




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

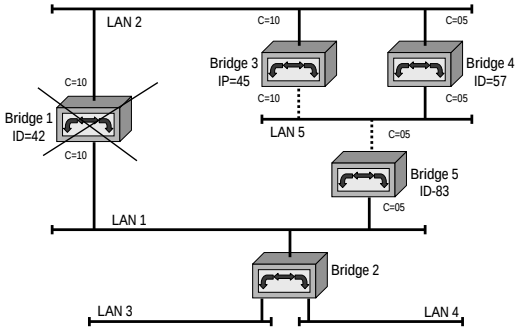


## STP Convergence Time – Failure at Designated Bridge – New Topology




- **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**

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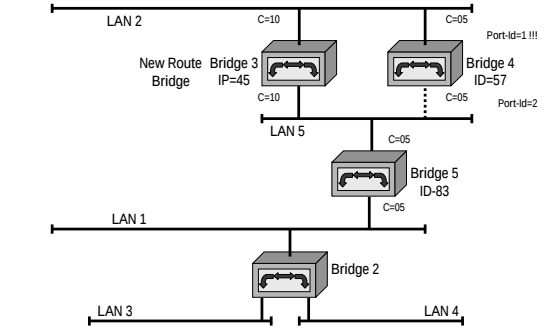
## STP Convergence Time – Failure of Root Bridge – New Topology




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

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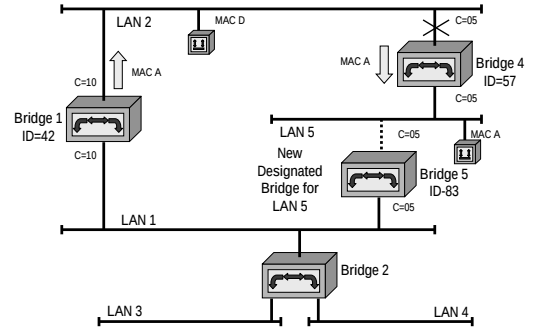
## STP Convergence Time – Failure of Root Port




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

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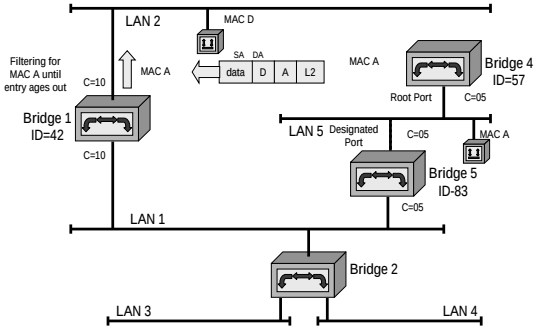
## STP Convergence Time – Failure of Root Port - Interruption of Connectivity D->A




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

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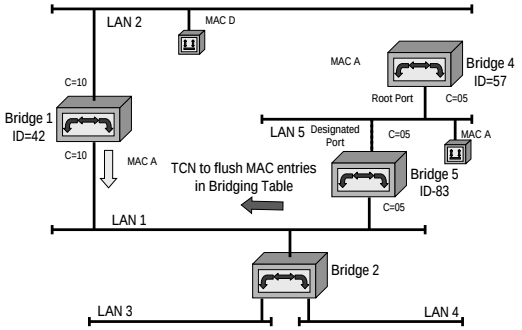
## STP Convergence Time – Failure of Root Port – Topology Change Notification (TCN)




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



## What has changed with Rapid Spanning Tree?

- **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
    - Better to avoid it
  - 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 slide for details)







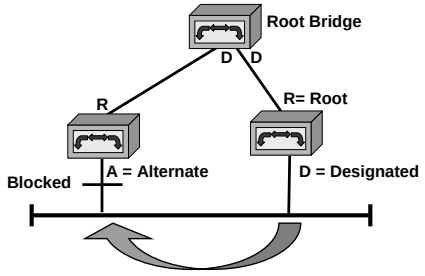
## Port States Comparison

| 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 |



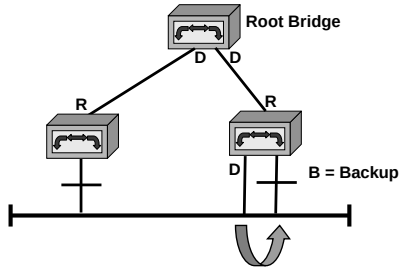
## New Port Roles

- **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

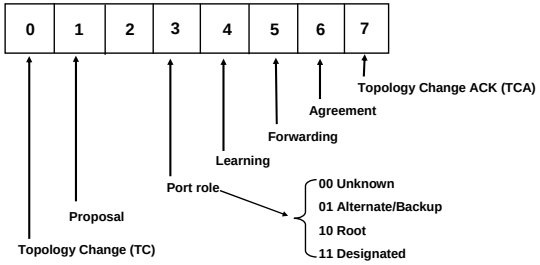
- **Backup Port**
  - A port blocked by receiving BPDU's from the same bridge
  - Provides a redundant connectivity to the same segment






## 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

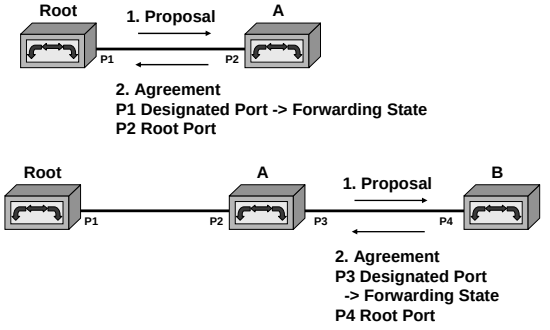


## Proposal / Agreement

- **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 a new switch B is inserted**






## 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







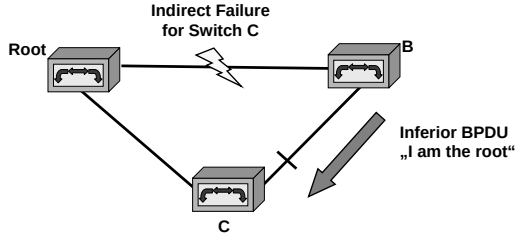
## Rapid Transition to Forwarding State

- **RSTP can only achieve rapid transition to forwarding**
  - On edge ports
  - On point-to-point links (trunks between L2 switches)
- **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



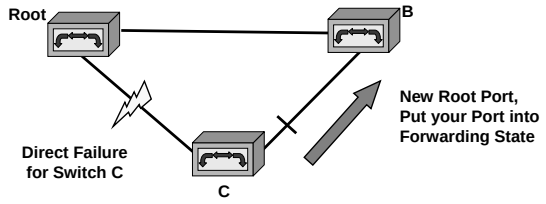
## Accepting Inferior BPDU's

- 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 ort
- C set its port to forwarding
- Like Cisco's Uplink Fast

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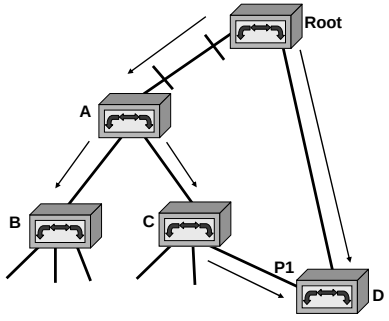
## Slow Convergence with Legacy STP 1

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




*New ports coming up on the root and the switch A are immediately set in listening state, blocking traffic.*

*BPDU's from the root start propagating towards the leaves through A*

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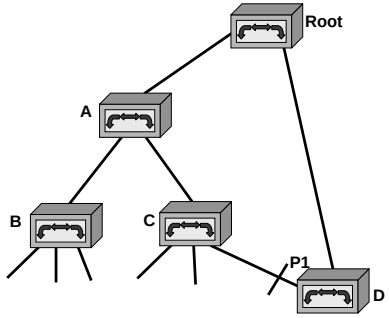
## Slow Convergence with Legacy STP 2




*Very quickly, the BPDU's from the root via A reach D that immediately blocks its port P1.*

*The topology has now converged, though, the network is disrupted for twice forward delay because A needs time for Listening and Learning on the new Port*

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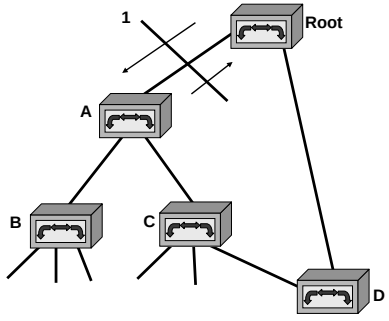
## Fast Convergence with RSTP 1

**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 designated blocking as soon as they come up.*

*As soon as A receives the root´s BPDU, it blocks its non-edge designated ports (="sync"). A explicitly authorizes the root bridge to put its port in forwarding*

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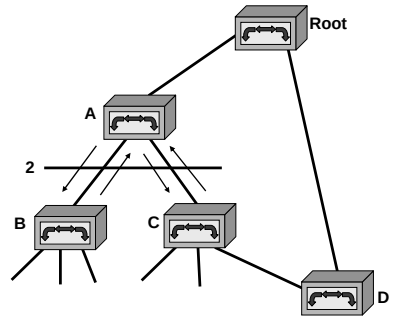
## Fast Convergence with RSTP 2

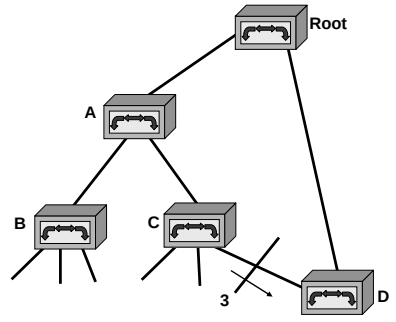



*The link between Switch A and the root is put in forwarding state.*

*The network is now blocking below Switch A. This cut will travel down the tree along with the BPDU's originated by the root through Switch A. At that stage, the newly blocked ports on Switch A will also negotiate a quick transition to forwarding with their neighboring ports in Switch B and Switch C, that both in turn will initiate a sync operation (especially C to D in our case)*



## Fast Convergence with RSTP 3




*Switch C blocks its designated port to D.*

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

*But we got this topology just in 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*





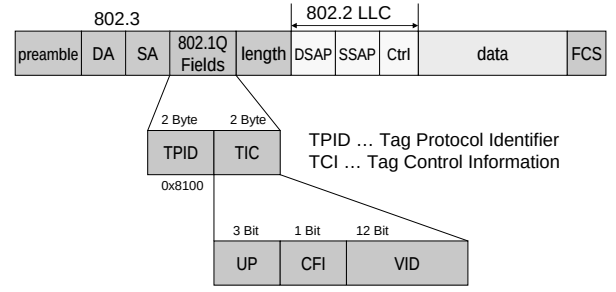


## Review L2 Network Components (VLAN)

- **VLAN Switch**
  - Several virtual Ethernet switches in one physical box
  - Each of them implementing a separate Virtual LAN to corresponding connected LAN user ports (access ports)
    - A separate bridging/switching table per VLAN
  - Trunk ports used for interconnection of VLAN switches
    - VLAN Tagging (IEEE 802.1Q or Cisco ISL)
    - VLAN management protocols (like Cisco's VTP, DTP)
  - Sometimes access ports
    - Use VLAN tagging to connect a network station (PC, router, firewall, etc…) to several VLAN's
  - "Spanning Tree Protocol"
    - One Single STP for all VLAN's (802.1D)
    - Per VLAN STP (Cisco)
    - MIST (802.1w)



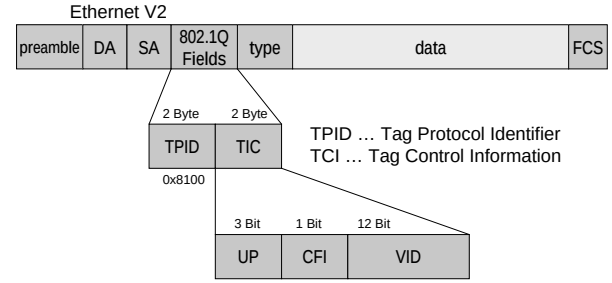
## 802.1Q VLAN Tagging 1




note: With tagging Ethernets maximal frame length = 1522, minimal frame length = 68

UP … User Priority
CFI … Canonical Format Identifier
VID … VLAN Identifier

## 802.1Q VLAN Tagging 2




note: With tagging Ethernets maximal frame length = 1522, minimal frame length = 68

## VLAN Assignment

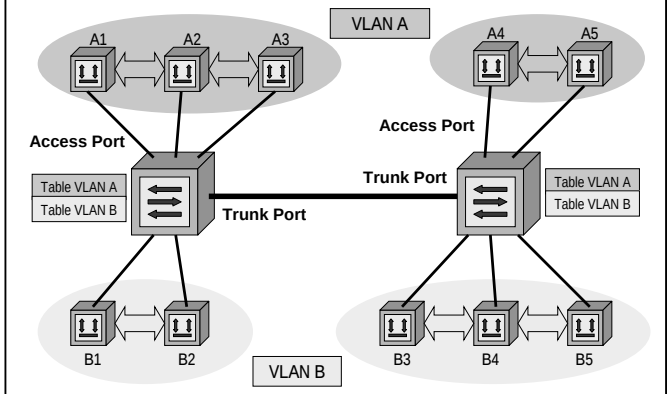
- **a station may be assigned to a VLAN**
  - port-based
    - fixed assignment port 4 -> VLAN x
    - most common approach
    - a station is member of one specific VLAN only
  - MAC-based
    - MAC A -> VLAN x
    - allows integration of older shared-media components and automatic location change support
    - a station is member of one specific VLAN only
  - protocol-based
    - IP-traffic, port 1 -> VLAN x
    - NetBEUI-traffic, port 1 -> VLAN y
    - a station could be member of different VLANs



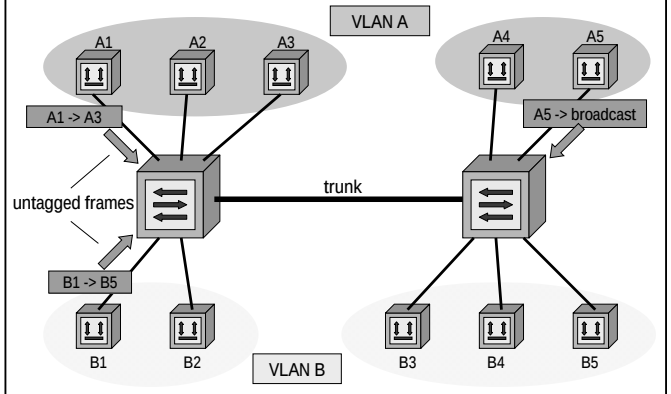


## VLAN Example



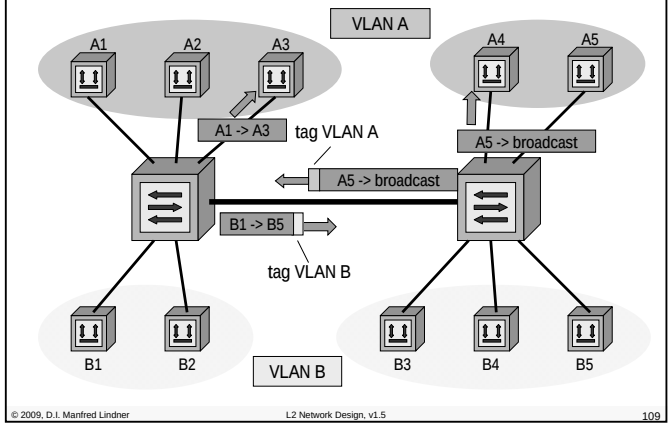

 

## VLAN Operation (1)

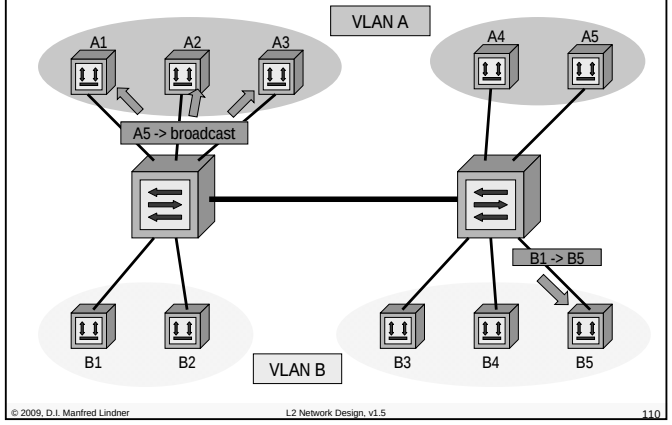


## VLAN Operation (2)



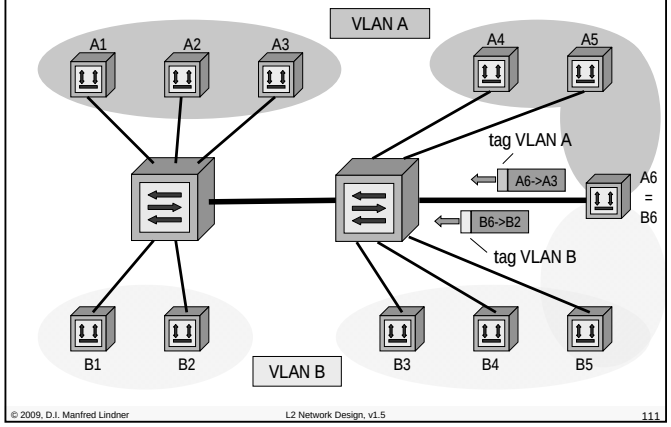

## VLAN Operation (3)



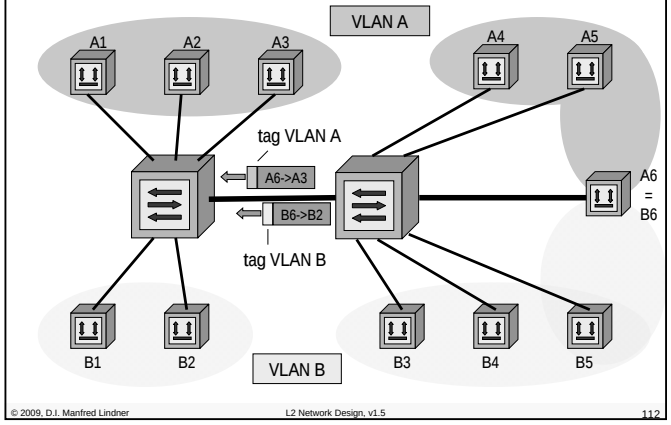




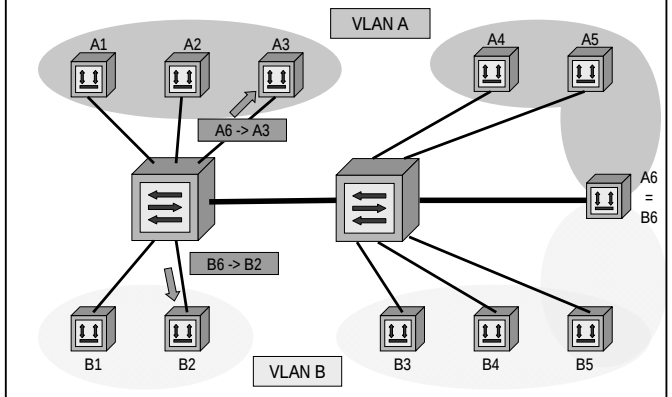

## Multihomed VLAN 1




## Multihomed VLAN 2



## Multihomed VLAN 3






## Trunking between L2 Switches

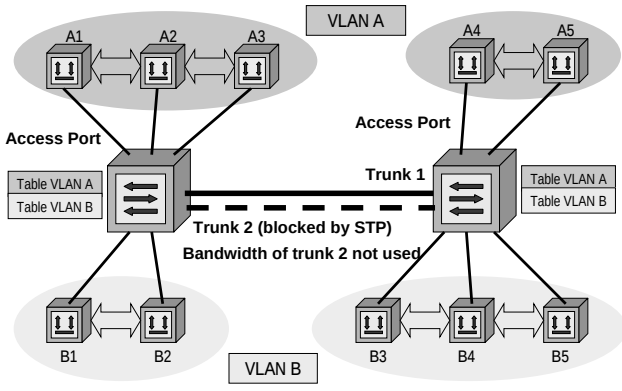
- **on trunks between multiport switches full duplex operation is possible**
  - hence "200 Mbit/s" with Fast Ethernet
  - hence "2 Gbit/s" with Gigabit Ethernet
- **on trunks bundling (aggregation) of physical links to one logical link is possible**
  - Fast Ethernet Channeling (Cisco)
    - 400 / 800 Mbit/s
  - Gigabit Ethernet Channeling (Cisco)
    - 4 / 8 Gbit/s
  - IEEE 802.3 (2002) LACP (Link Aggregation Control Protocol





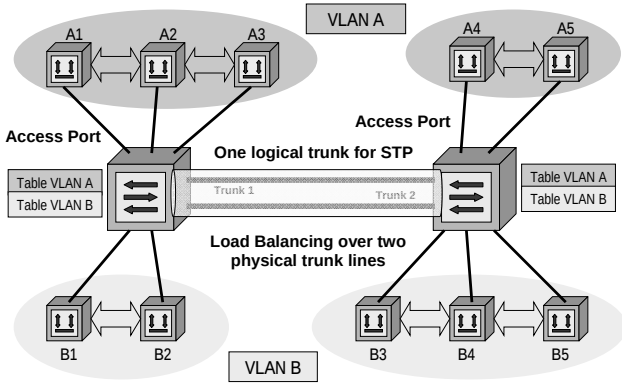


## Trunking without LCAP (FEC, GEC)






## Trunking with LCAP (FEC, GEC)



## Agenda

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## Design Principles

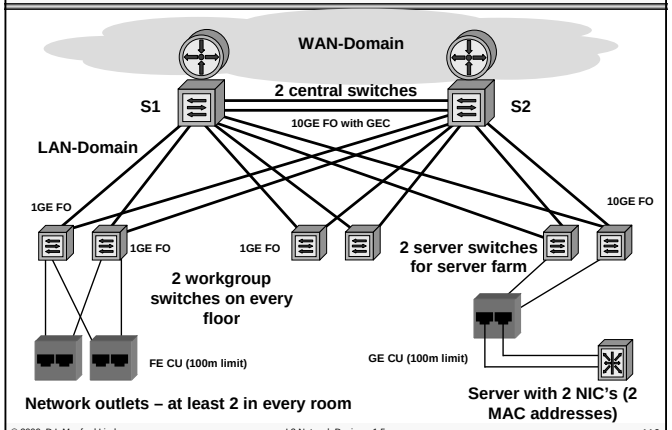
- **Avoiding of "Single Point of Failure"**
  - Physical link failure
    - Access link
    - Trunk link (LAN or WAN)
  - Network component failure
    - L2 Switch
    - Router, DHCP Server, DNS Server, Production Server
- **Load balancing in normal situations**
- **Server with two or more NIC's**
  - OS must support parallel operation and/or switch over between cards
- **Clients with two network outlets**
  - Two NIC's and special OS aspects may not economically be justified





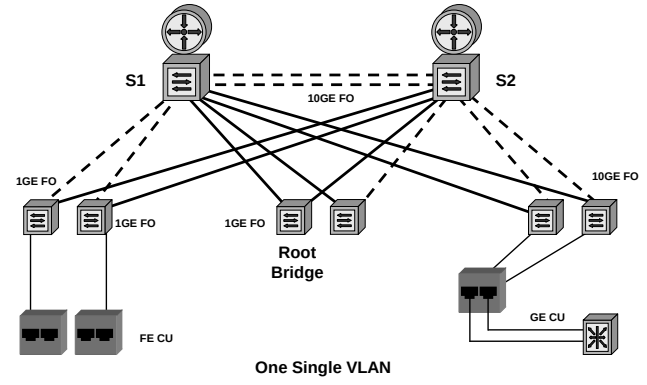


## Physical Layer

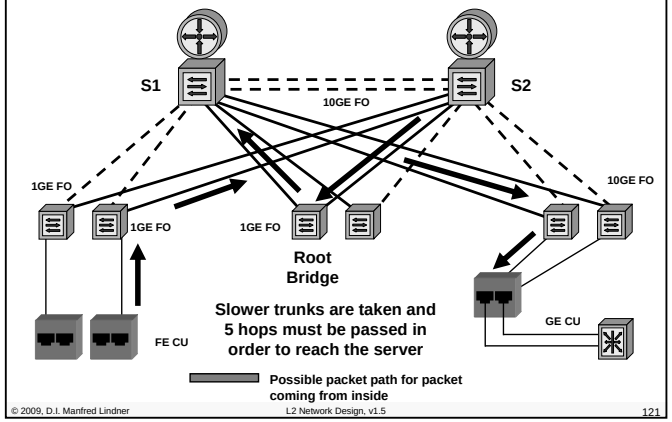





## Spanning Tree Problem Plug & Play 1

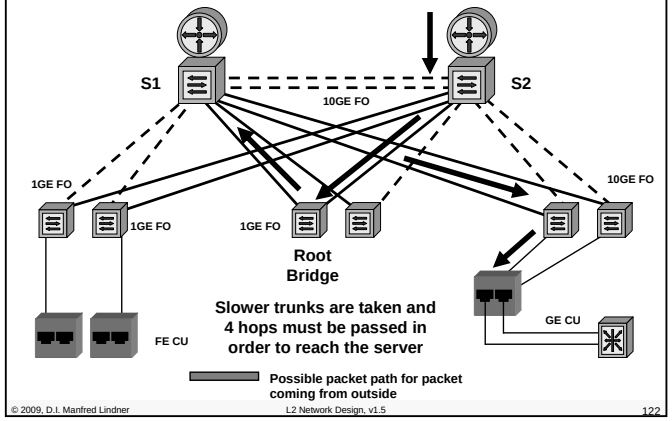


## Spanning Tree Problem Plug & Play 2




 L2 Network Design, v1.5 121

## Spanning Tree Problem Plug & Play 3

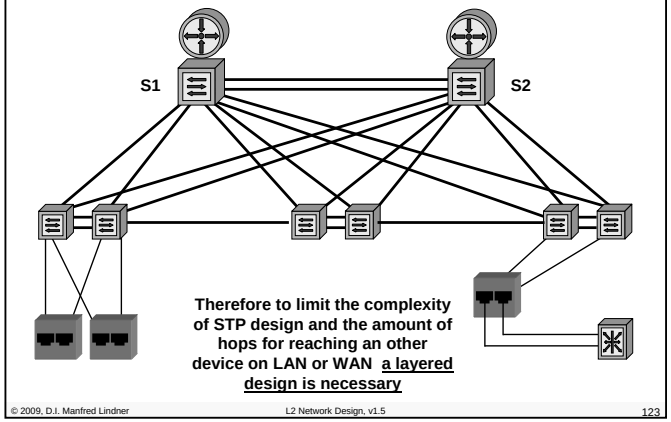



 L2 Network Design, v1.5 122



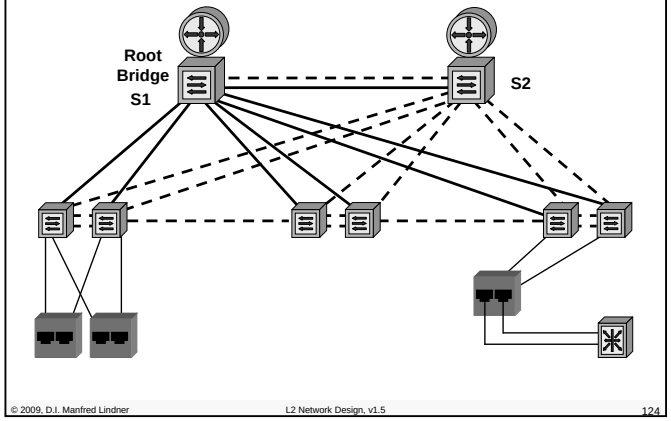


## Figure Out STP in Complex Scenarios



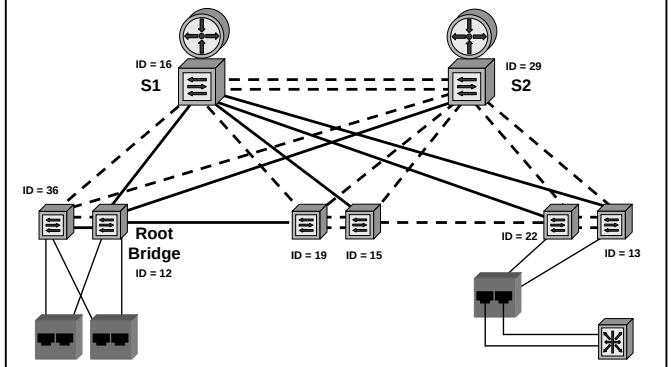

 L2 Network Design, v1.5 123

## Figure Out STP in Complex Scenarios Spanning Tree – Good Luck



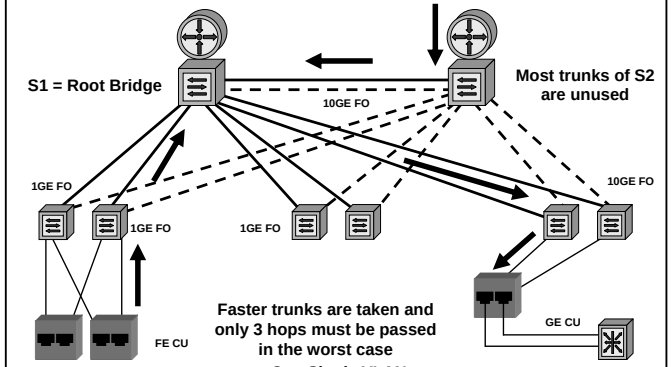

 L2 Network Design, v1.5 124

## Figure Out STP in Complex Scenarios Spanning Tree – Bad Luck with Bridge IDs






## Spanning Tree Problem Unequal Load Balancing with Single VLAN

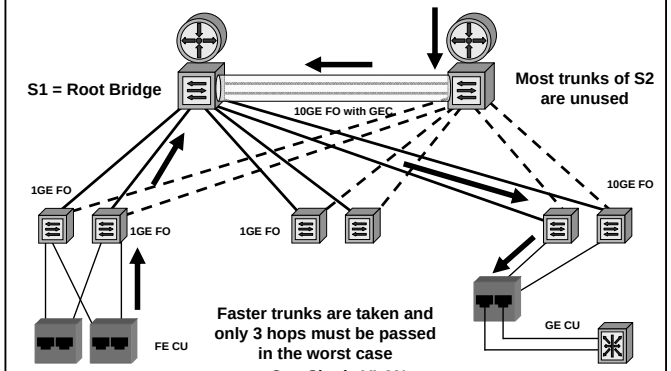









## Improvement on Trunk S1 – S2 by Using GEC / LCAP



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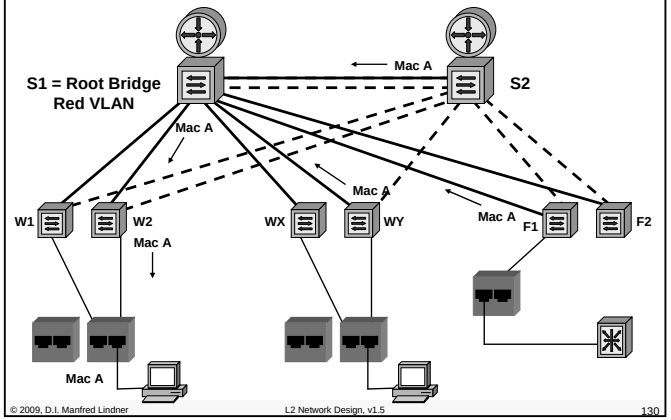
## Best Practices

- **Build at least two separated VLAN's**
  - In case of IP that means two IP subnets
- **How to achieve?**
  - Per VLAN STP (Cisco)
  - MIST (Multiple Instances Spanning Tree)
    - IEEE 802.1d
- **Tune STP parameters**
  - In order to use all trunks and all switches in a similar way

## Build STP for VLAN 1



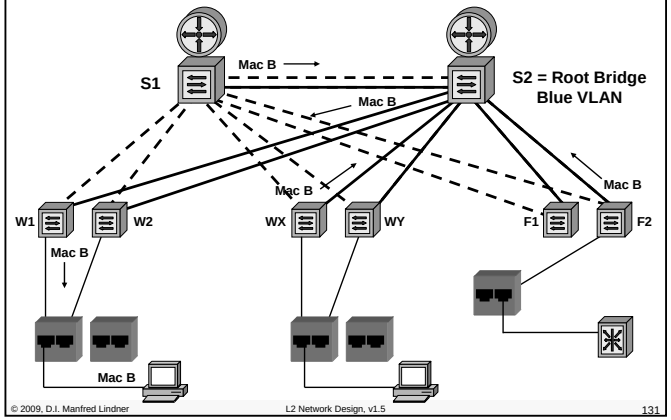

 





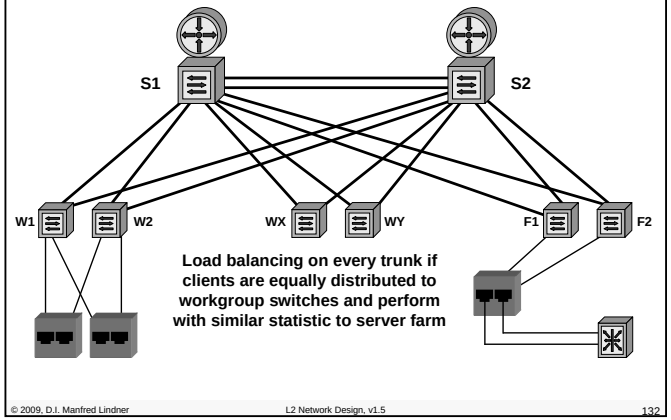


## Build STP for VLAN 2



## Solution – Load Balancing using 2 VLAN's



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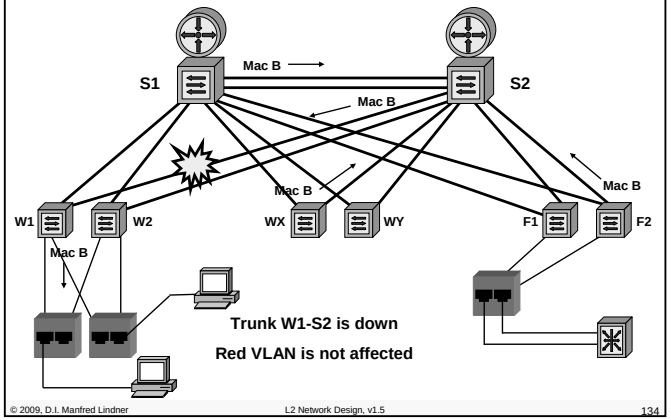
## Link Failure (Trunk) 1

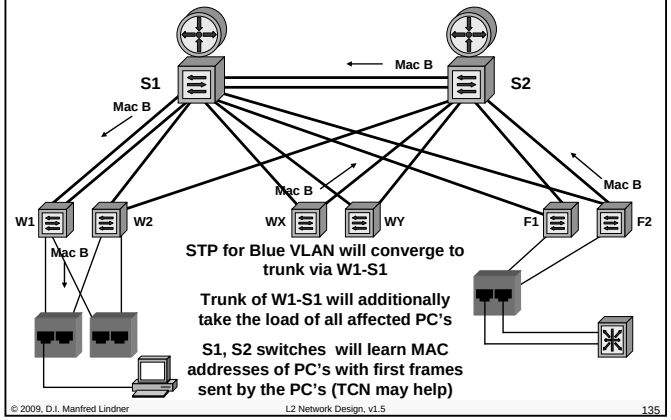




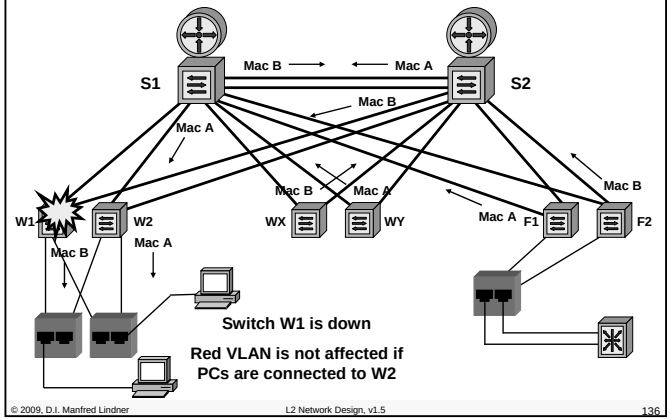


## Link Failure (Trunk) - Solution 2



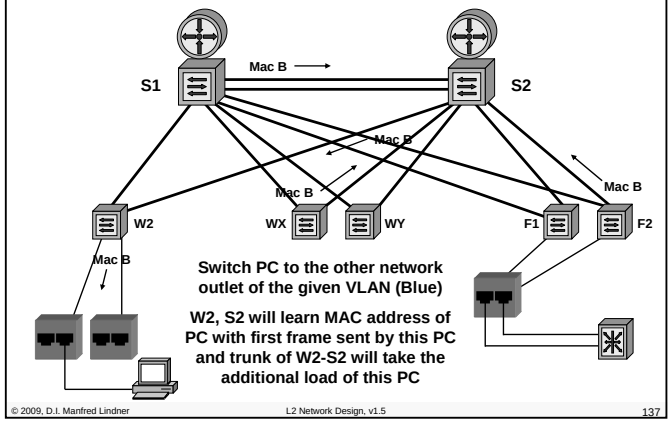

 

## Switch Failure (Access) 1



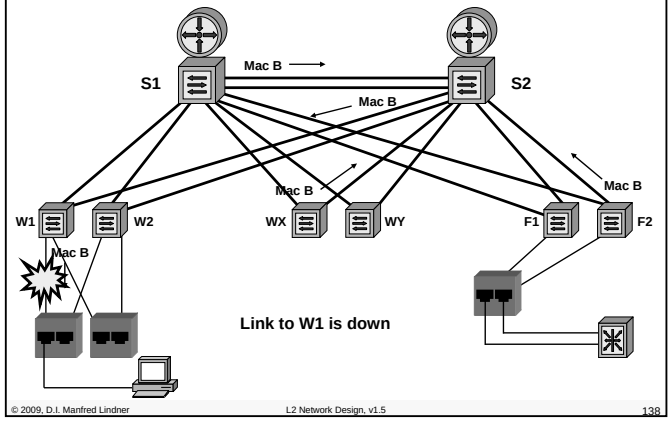

 

## Switch Failure (Access) - Solution 2




 L2 Network Design, v1.5 137

## Link Failure (Access) 1

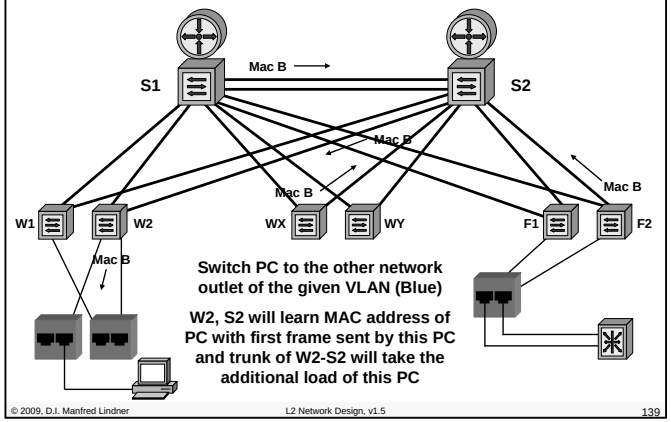



 L2 Network Design, v1.5 138



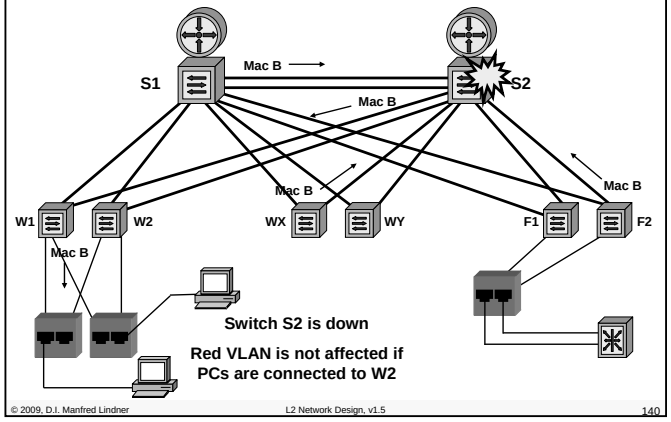


## Link Failure (Access) - Solution 2



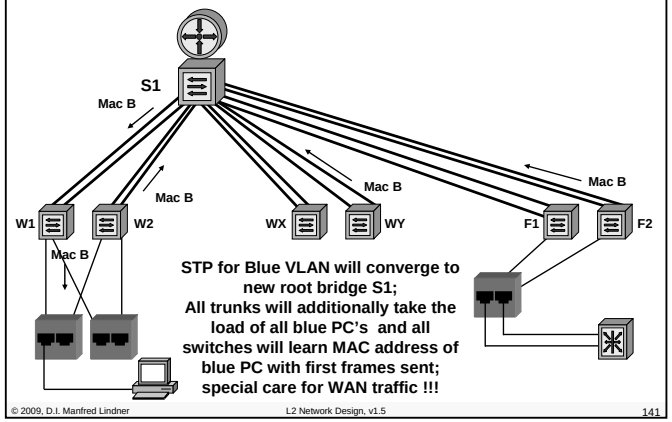

 L2 Network Design, v1.5 139

## Switch Failure (Central) 1



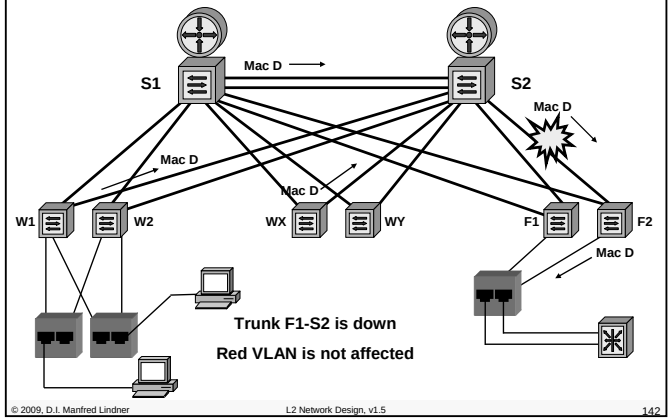

 L2 Network Design, v1.5 140

## Switch Failure (Central) - Solution 2




 L2 Network Design, v1.5 141

## Trunk Failure (F-Switches) 1

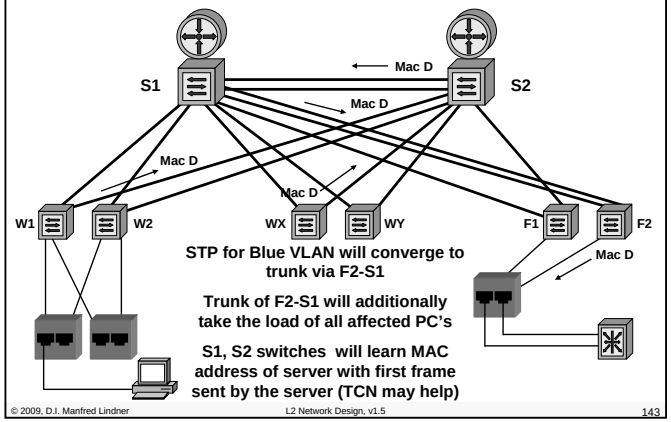



 L2 Network Design, v1.5 142



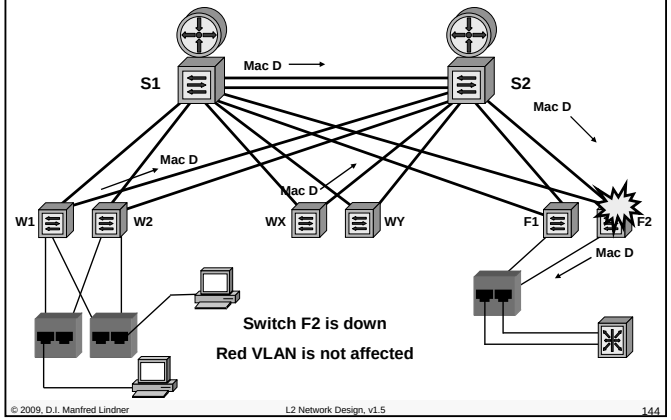


## Trunk Failure (F-Switches) - Solution 2



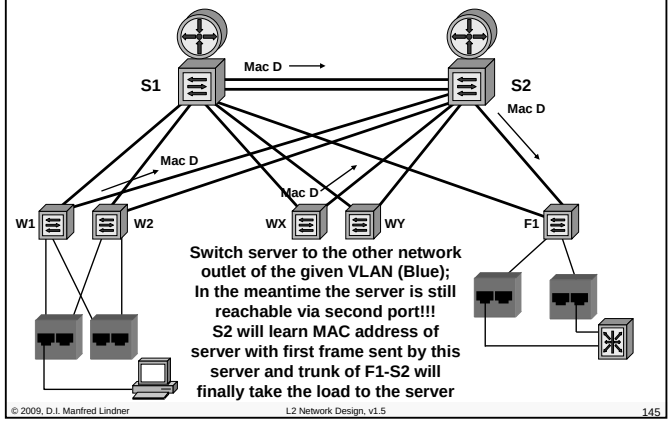

 L2 Network Design, v1.5 143

## Switch Failure (F-Switches) 1

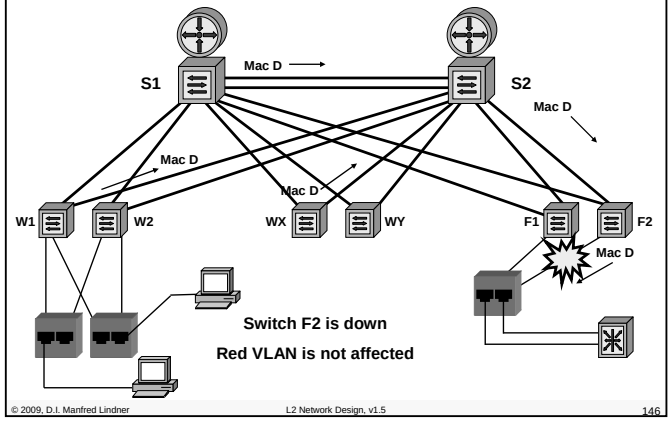



 L2 Network Design, v1.5 144

## Switch Failure (F-Switches) - Solution 2



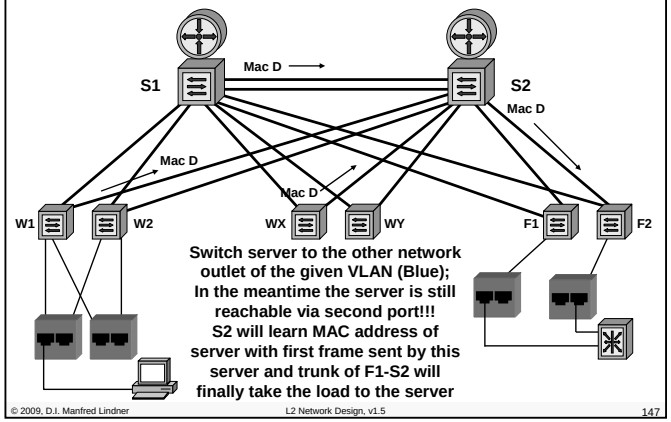

## Link Failure (F-Switches) 1



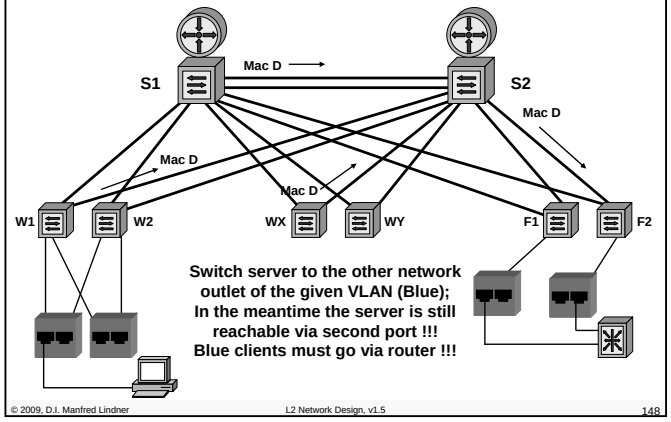





## Link Failure (F-Switches) - Solution 2A




## Link Failure (F-Switches) - Solution 2B



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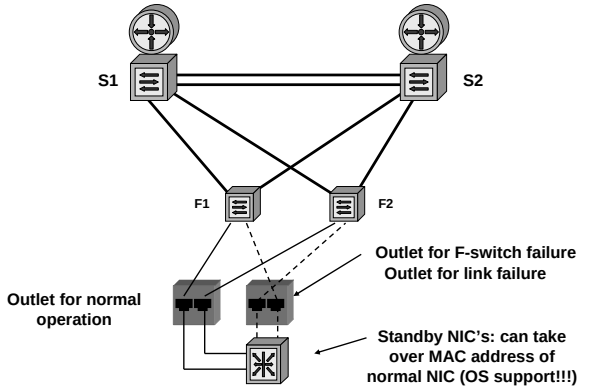
## Server Connections to F-Switches – Advanced Techniques

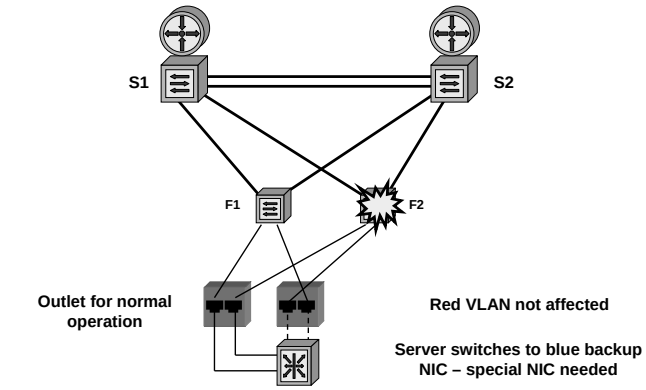






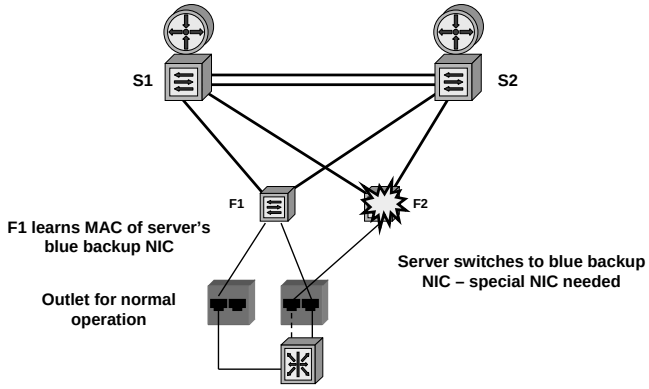



## Switch Failure (F-Switches)

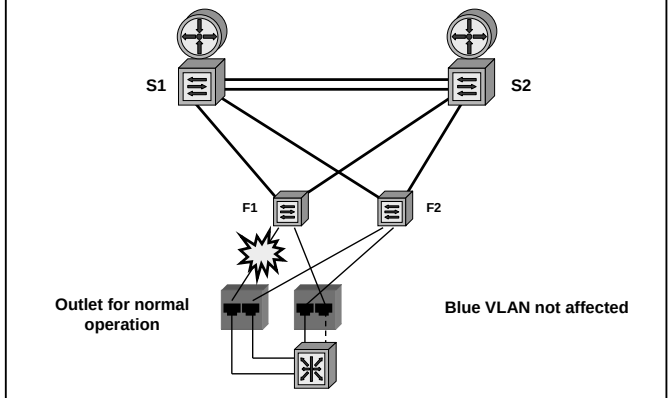





## New Server Connection for Blue VLAN to F-Switches

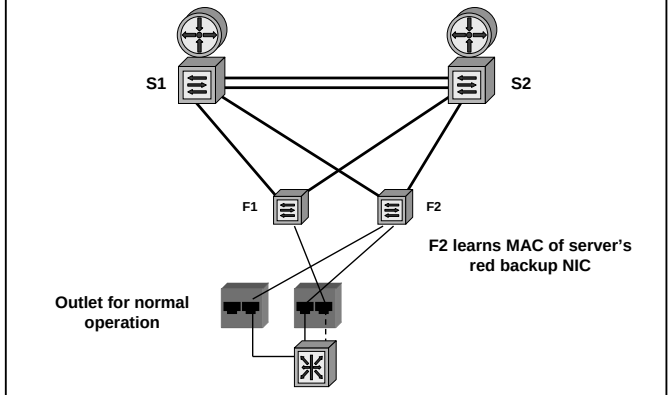


## Link Failure (F-Switches)






## New Server Connection for Blue VLAN to F-Switches










## Configuration Options for Redundant NIC

VLAN Blue / IP NET Blue

Type-A

only one NIC active, the other NIC in standby (will take over in case of failure)

1 server IP address and 1 server MAC address, 1 Default Gateway

VLAN Blue / IP NET Blue

Type-B

both NIC's active, load balancing possible

2 server IP addresses and 2 server MAC addresses, 1 Default Gateway, strategy which NIC to use is necessary

VLAN Red / IP NET Red

VLAN Blue / IP NET Blue

Type-C

both NIC's active, load balancing possible

2 server IP addresses and 2 server MAC addresses, 2 Default Gateways, strategy which NIC to use is necessary

VLAN Red / IP NET Red

VLAN Blue / IP NET Blue

Type-D

both NIC's active and connected to internal router, load balancing via routing protocol is possible

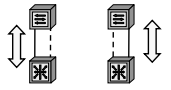
1 server IP addresses on the loopback interface, which connects the server to the internal router



## Redundant NIC Type-A, Intel Teaming 1

Normal operation

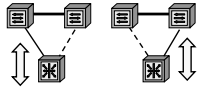
In case of primary failure




**Intel Teaming Basic AFT** (Adapter Fault Tolerance) Feature;
one primary adapter, up to 7 secondary adapters
primary for transmitting and receiving all traffic from and to the unique server MAC address;
multicast/broadcast probes to ensure a secondary adapter is available, therefore all links are physically active and all secondary adapters have their own MAC address;
secondary will take over in case primary fails that means it starts sending traffic with the server MAC address and receiving traffic for the server MAC address;
STP must be switched off

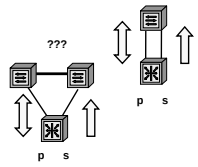
Normal operation

In case of primary failure

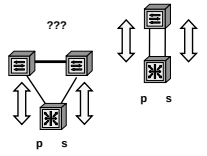



**Intel Teaming SFT** /Switch Fault Tolerance) Feature;
one primary adapter, one secondary adapter
primary for transmitting and receiving all traffic from and for the unique server MAC address;
multicast/broadcast probes to ensure a secondary adapter is available, therefore all links are active and all secondary adapters have their own MAC address;
secondary will take over in case primary fails that means it starts sending traffic with the server MAC address and receiving traffic for the server MAC address;
STP must be switched on

## Redundant NIC Type-A, Intel Teaming




**Intel Teaming ALB (Adaptive Load balancing) Feature;**
**one primary adapter, up to 7 secondary adapters**
**primary for receiving all traffic to the unique server MAC address and unique server IP address;**
**secondary are used for balancing the load for transmit traffic; all links are active and all secondary adapters have their own MAC address;**
**secondary send with their own MAC address and will not answer ARP Requests to the server IP address;**
**thus the server MAC address will not be seen on switch ports leading to secondary adapters**
**(? Doing so will not solve the ARP cache problem of the client-PCs because every received Ethernet frame at the client-PC will refresh/change the ARP cache ?)**

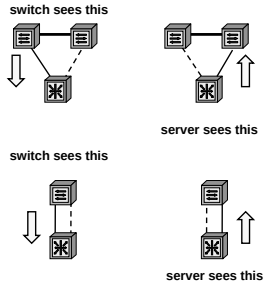



**Intel Teaming RLB (Receiver Tolerance) Feature;**
**same as ALB, but now secondary answer ARP requests based on a internal scheduling decision hence populating the ARP cache of different client-PCs with different MAC addresses for the same unique server IP address;**
**Tricky procedure in case the server itself sends an ARP request for a client with its unique server MAC address -> client-PC ARP caches would be refreshed and traffic would be directed to the primary -> hence appropriate ARP replies must be sent out to correct ARP cache again**



## Redundant NIC Critical Aspect

**In case of active / standby it is important that both sides (PC and the switch(es)) have the same sight who is active and who is standby (symmetric view)**









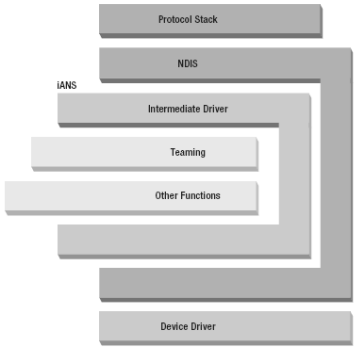

## Intel Advanced Network Services Software (ANS)

- What is Intel ANS
- Teaming Features
- Teaming Modes
- Dependencies
- Details – How it works
  - Probe Packets
  - Server Load Balancing
  - Receive Load Balancing
  - Static Link Aggregation
  - 802.3ad Dynamic Mode



## What is Intel ANS

- **Implemented as an intermediate driver in the servers driver stack**
- **Windows and Linux supported**
- **Should Work also with „non-Intel Adapters“**
  - Min. 1 Intel Pro Server Adapter need but we have bad experiences with such scenarios in FRQ -> **Avoid it**



## Teaming Features

- **Fault Tolerance**
  - 1 or more secondary adapter take over if primary fails
- **Link Aggregation**
  - Combine multiple adapters into a single channel
  - Bandwidth increase only available to multiple destination addresses
  - Must be supported by connected switch!
- **Load balancing**
  - Distribution of transmission and reception load among aggregates network adapters
  - Agent in ANS analyzes traffic and distributes the packets based on destination addresses



## Teaming Modes

- **Adapter Fault Tolerance (AFT)**
  - 2-8 adapter supported
  - If primary fails -> secondary takes over
  - All adapters must be connected to same network
- **Switch Fault Tolerance (SFT)**
  - Failover relationship between 2 Adapters connected to different switches
  - STP must be enabled on the switches
  - STP must be disabled on connected Ports







## Teaming Modes

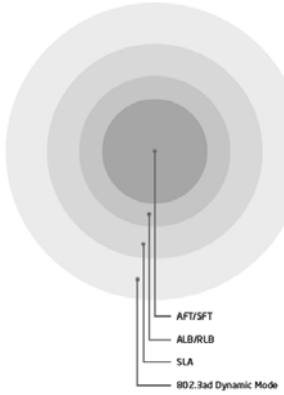
- **Adaptive Load Balancing (ALB)**
  - Load balancing of transmit traffic
  - Receive Load Balancing (RLB) is advanced feature – enabled by default
- **Static Link Aggregation (SLA)**
  - IEEE 802.3ad static and dynamic mode
    - Needs compatible switch!
  - Intel Link Aggregation (LA), Cisco Fast EtherChannel (FEC), Gigabit EtherChannel (GEC) replaced by static link aggregation mode
  - 2-8 Adapters – all ports same speed
  - Incorporates AFT and ALB modes



## Teaming Features and Modes

| Features | Modes | | | | |
|---|---|---|---|---|---|
| | AFT | ALB | RLB | SLA | Dynamic 802.3ad LACP |
| Fault Tolerance | X | X | X | X | X |
| Link Aggregation | | X | X | X | X |
| Load Balancing | | Tx | Tx/Rx | Tx/Rx | Tx/Rx |
| Layer 3 Address Aggregation | | X | IP only | X | X |
| Layer 2 Address Aggregation | | | | X | X |
| Mixed Speed Adapters | X | X | | | |

## Dependencies






## Details – How does it work

- **How To Detect State And Health Of Adapters**
  - Probe Packets
    - Adapters send and receive them to determine presence and state of other adapters
    - Either broadcast or multicast – configurable in software
  - Activity Based Tolerance
    - If probe packets are not used or do not reach their destination -> sensing activity on the line
  - Link Based Tolerance
    - Used if neither probe packets nor activity based tolerance are available or successful







## Probe Packets Details

- **2 different types of user configurable probes**
- **Each member uses 2 flags – Send and Receive – to track status**
- **When adapter sends probe sets both flags to Pending state**
- **When packet is received by a member of same team – it sets its receive flag to ReceiveComplete and sets sending Flag to SendComplete**
- **If Primary Adapter is set to disabled -> Secondary Adapter takes this role – new Secondary will be elected**



## Server Load Balancing Methods

- **Adaptive Load Balancing (ALB)**
  - Receive Load Balancing (RLB) is a subset of ALB
  - Transmit Traffic balanced by Hash Table of last Octet of receivers IP address
  - New Dataflows are assigned to least loaded team member
  - After timeout of load bal. timer Dataflows are rebalanced
  - ALB without RLB uses Primary Team Members MAC in ARP Reply Packets
  - Send Packets include Team Members MAC as source
  - Failover: Secondary Adapter gets MAC of Primary
  - Do not Hotplug Primary and reuse somewhere else until Server Reboot

## Receive Load Balancing (RLB)

- When receiving ARP Request -> Intel ANS answers with MAC Address of the port which is chosen to service this client
- Clients are allocated in a “Round-Robin” manor
- RLB client table is refreshed after ReceiveBalancing Interval
- OS ARP requests are send through primary port
  - Receive load collapses to primary
  - ANS sends gratuitous ARP to all clients in hash to restart RLB



## Static Link Aggregation (SLA)

- All Ports share same MAC Address
- For the switch this is a single link
- No designated primary port in the team
- Links must be same speed
- Switch handles receive load balancing







## 802.3ad Dynamic Mode

- All members share same MAC
- Switch ports must use LACP protocol
- Switch communicates with Intel ANS to add or remove members of team
- No designated primary – but first teamed port is initiator to switch
- Removal of Initiator could lead to packet loss
- To avoid this -> preconfigure the switch ports for added or removed members



## Overview

| Function | Intel (AFT, SFT, ALB) | Intel (SLA) | Intel (802.3ad) |
|---|---|---|---|
| Number of NICs per team | 8 (2 for SFT) | 8 | 8 |
| NIC Fault Tolerance | Yes | Yes | Yes |
| Switch Fault Tolerance | 2 | Yes | Yes |
| Tx Load Balance | Yes | Yes | Yes |
| Rx Load Balance | Yes | Yes | Yes |
| Requires compatible switch | Yes | Yes | Yes |
| Heartbeats to check connectivity | Yes | No | No |
| NICs with different media | Yes | No | Yes |
| NICs with different speeds | Yes | No | Yes |
| Load balances TCP/IP | Yes | Yes | Yes |
| Load balances other protocols | Yes | Yes | Yes |
| Same MAC address for all team members | No | Yes | Yes |
| Same IP address for all team members | Yes | Yes | Yes |
| Load balancing by IP address | Yes | No | No |
| Load balancing by MAC address | Yes | Yes | Yes |
| 802.1q tagged VLANs | Yes | Yes | Yes |
| Untagged VLANs | Yes | Yes | Yes |

## Information - Sources

- **Intel Advanced Network Service Software Whitepaper**
  - www.intel.com/network/connectivity/resources/doc_librarywhite_papers/254031.pdf
- **Ethertype 886 from the Intel Website**
  - http://thetechfirm.com/packets/886/886.ppt



## Agenda

- **Scenarios**
- **Physical Layer**
  - Introduction
  - LAN
  - WAN
- **LAN (L2)**
  - Review Ethernet Technology
  - Design Considerations
  - Design Solution – Best Practices
  - Failover Handling
  - Advanced Techniques - Teaming
  - LAN – WAN Interconnection





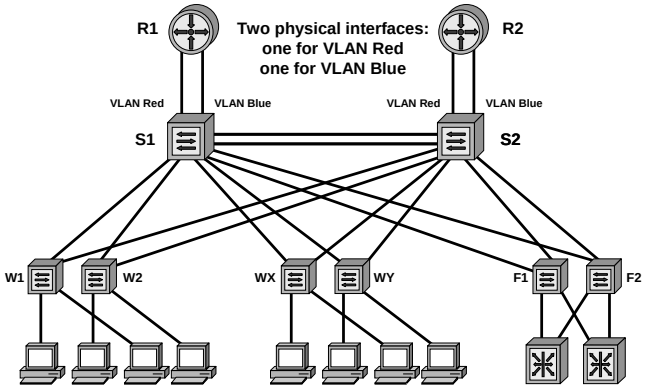


## LAN – WAN Interconnection VLAN Interconnection

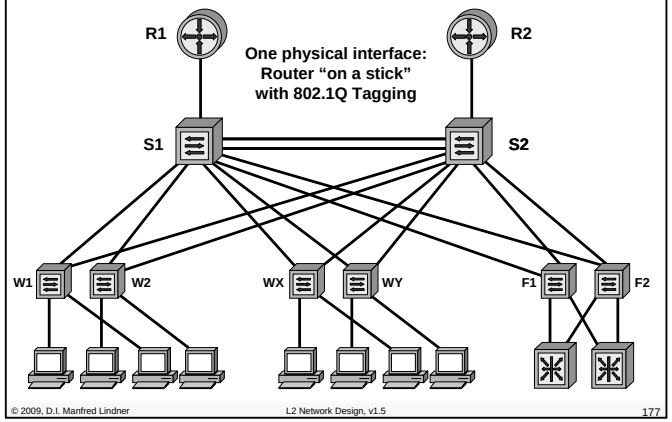
- **Now let us look to Layer 3 (IP)**
- **We need routers**
  - For connecting the two VLAN's
  - For connecting the LAN infrastructure of a site to the WAN infrastructure
- **Be very careful to differentiate between**
  - L1 look of your network
  - L2 look of your network (VLAN, STP)
  - L3 look of your network (IP, ARP)



## Router Connections 1

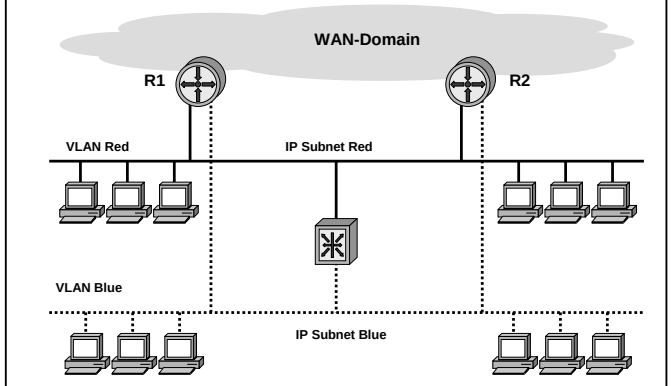


## Router Connections 2






## Layer 3 View 1

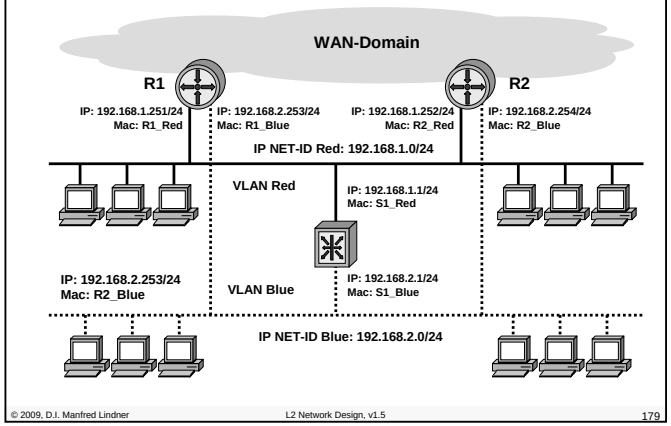









## Layer 3 View (NET-ID, IP Addressing) 2






## Layer 3 View (Routing Table, ARP) 3