Switched LAN Design

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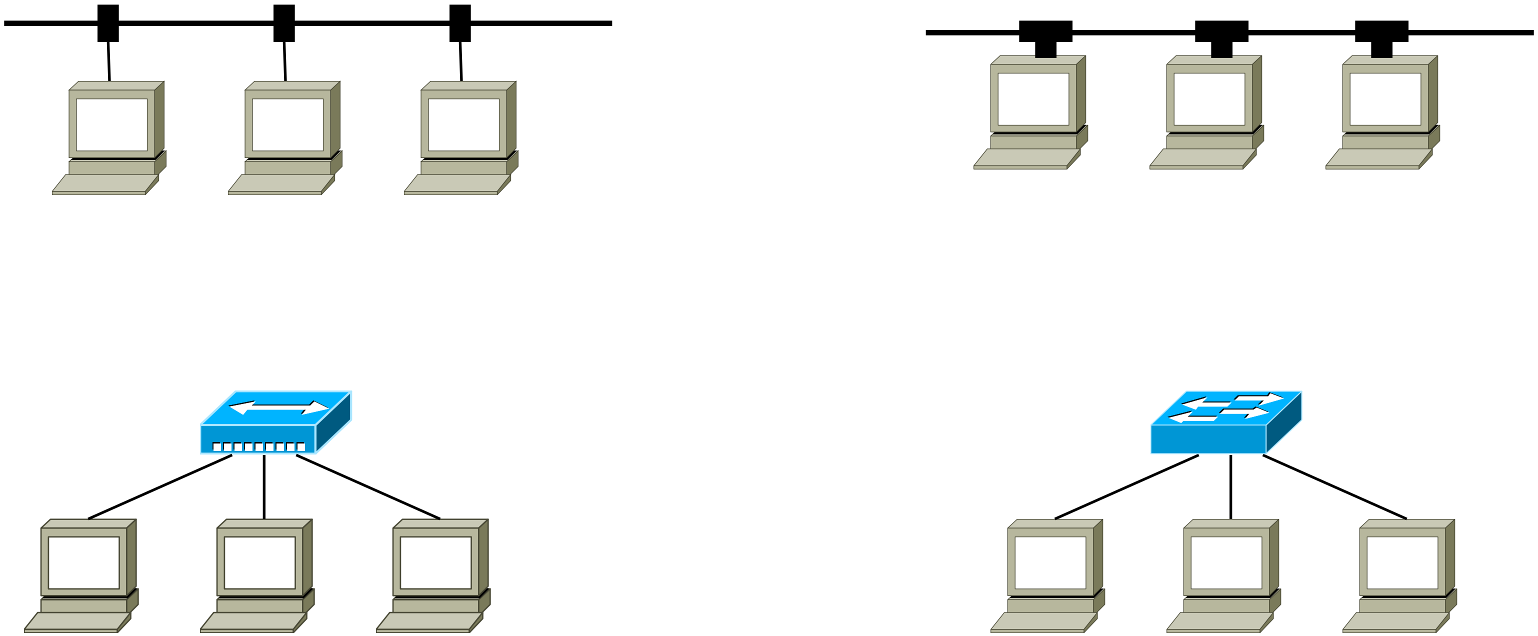
Outline

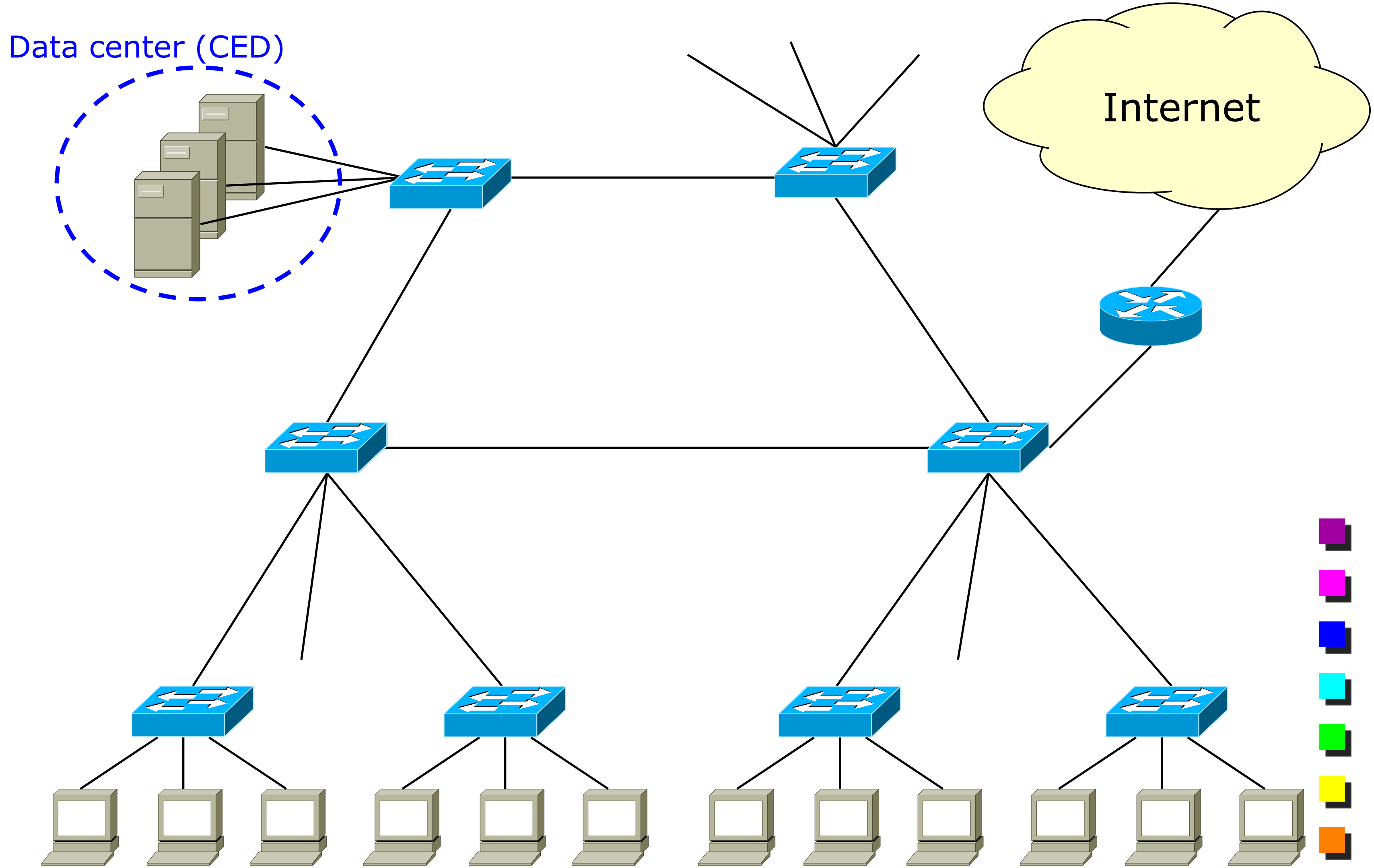
- This slide set is organized in two main parts
  - 1) Historical overview of switched LAN design
  - 2) Some more precise design criteria

Switched LANs evolution (1)

- Progressive replacement of shared segments with switches



Switched LANs evolution (2)



Switched LANs: state of the art (1)

- Currently, end systems directly connected to switches
  - More aggregated bandwidth
  - No need to replace NIC on clients when moving from hubs to switches
  - Switches may be 10/100/1000 and support different speed on the client side
    - Possibility to smooth upgrade of the network (NICs, hubs/switches), mixing different Ethernet technologies
    - Hub do not support multiple speed

Switched LANs: state of the art (2)

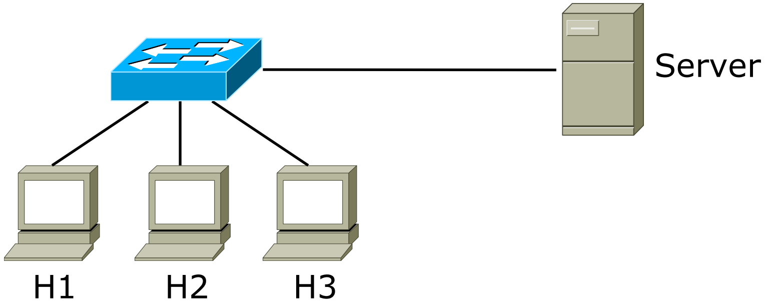
- Technologies no longer used in the real world of Ethernet
  - CSMA/CD
    - Only one station can be attached to a physical link (no need to arbitrate the channel)
  - Frame bursting
  - Carrier Extension
- What remains of the original Ethernet DIX
  - Framing
- Maximum diameter of an Ethernet (Fast/Giga/…) network
  - Max diameter (for collision domain) is no longer a problem
  - Max cable length (due to signal attenuation) is still a problem
    - E.g., 100m from end-system to a switch (twisted pair) is still a valid limit

Switched networks and throughput (1)

- Aggregate bandwidth increases

!Throughput may not !

- 1) Uplink speed is a critical factor
  - Uplinks must sustain the traffic of all the attached station
  - Links toward servers must be fast enough
  - Is it a good choice to have clients connected at 1Gbps?



Switched networks and throughput (2)

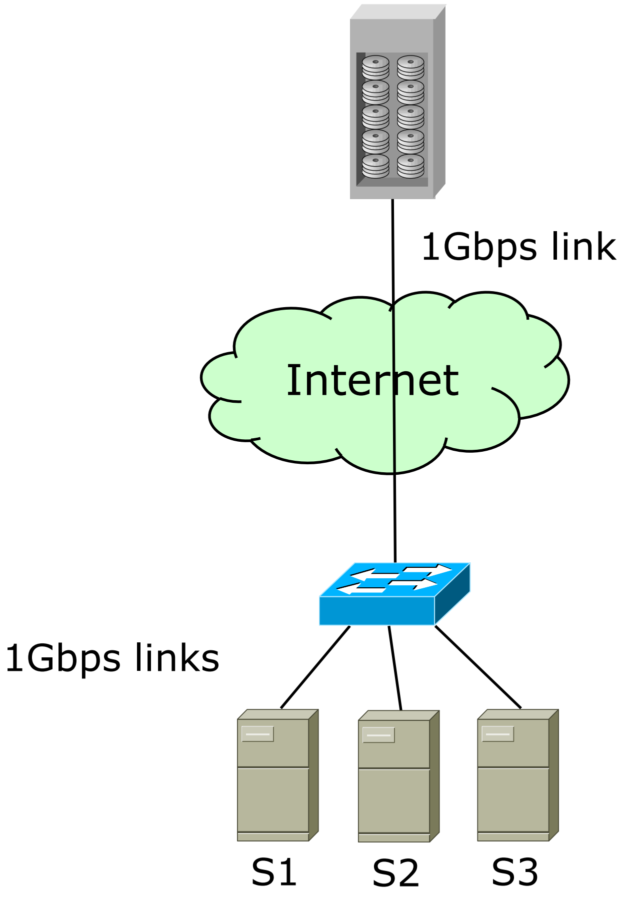
- 2) Poor segregation of different network segments
  - Multicast/broadcast propagated across the entire network
    - What about 50 lectures at 10Mbps each, transmitted on the University campus?
  - Backward learning process generates transient
    - Generates useless traffic across the network
  - Possibility to attack the network
    - Flooding attacks, ARP poisoning
    - Additional (useless) traffic across the network

Switched networks and throughput (3)

- 3) Buffers play an important role in switches
  - Classical Ethernet implements a “reliable” transmission
    - Why can CIFS and NFS use UDP for data transfers?
  - Switches may drop frames due to congestions (limited buffer size)
  - TCP algorithms (timeout, fast retransmit, …) come into play
    - Dramatic decline in throughput
    - TCP dimensioned for reacting in about hundred ms, not microseconds
  - By the way, buffers in switches may be very small (some tens of Kbytes even in professional switches)
    - We need fast memory, and fast memory is expensive
    - 1Gbps = 1 byte every 8ns, while DRAM has 60ns access time

Small buffers: Example 1

- A case from the real world: a remote backup on a geographical L2 network



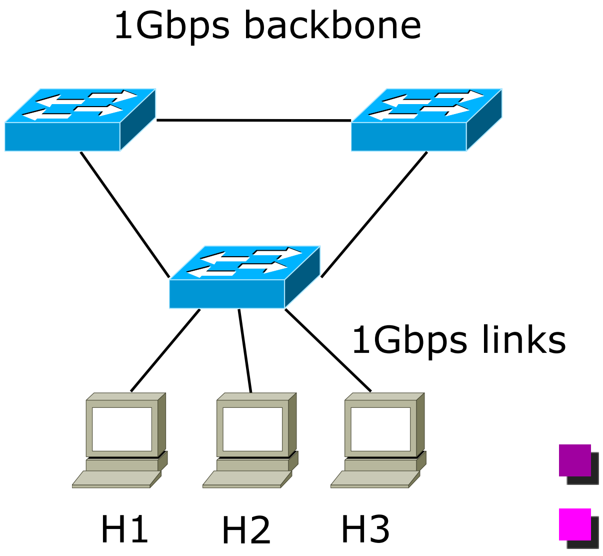
S1:
Throughput 1Gbps

S1+S2:
Throughput 1Gbps

S1+S2+S3:
Throughput <<1Gbps

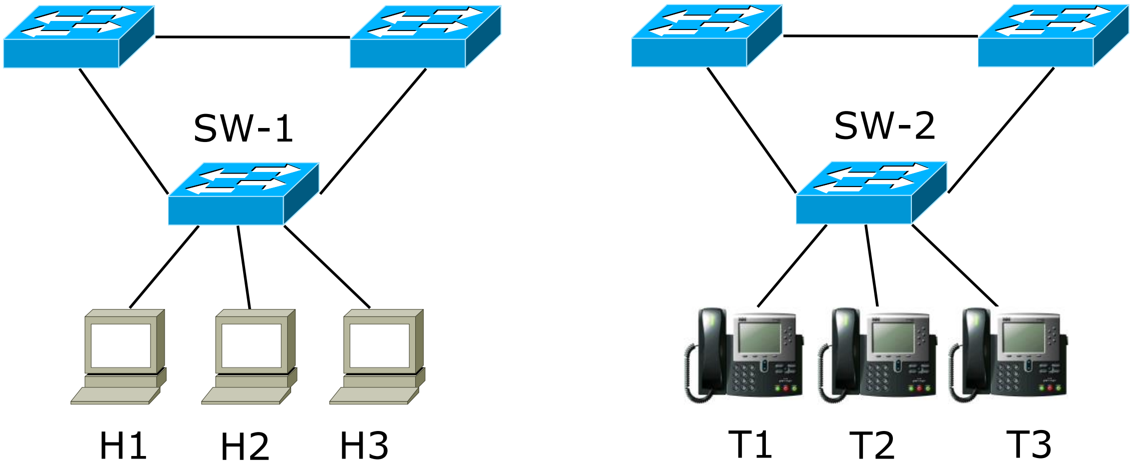
Small buffers: Example 2

- No enough difference in speed between access and backbone
  - Access at 1Gbps
    - Almost no cost difference with 100Mbps
    - Access at 100Mbps looks “antiquate”
  - Backbone at 1Gbps
    - 10Gbps costly
    - 1Gbps looks enough for the average traffic
  - Micro-congestions possible
    - Reasonable probability that several hosts send data at the same time and fills the buffer



Small buffers: Example 3

- VoIP and data often implemented in two separate networks
  - Common when VoIP outsourced to an external company, that has to provide some guarantees on the phone traffic
  - Don’t want to suffer from faults on the data network, which is not under the control of the Phone company
    - L2 network isolation
    - Switch buffers
    - etc



Switched networks and scalability

- Broadcast (and, in some sense, multicast) is still a problem
  - Single broadcast domain
- Network size limited by the number of stations
  - Usually, no more than 1000 stations
- Cannot use all the links of the network
  - Expensive especially on the wide area

Switched networks and security

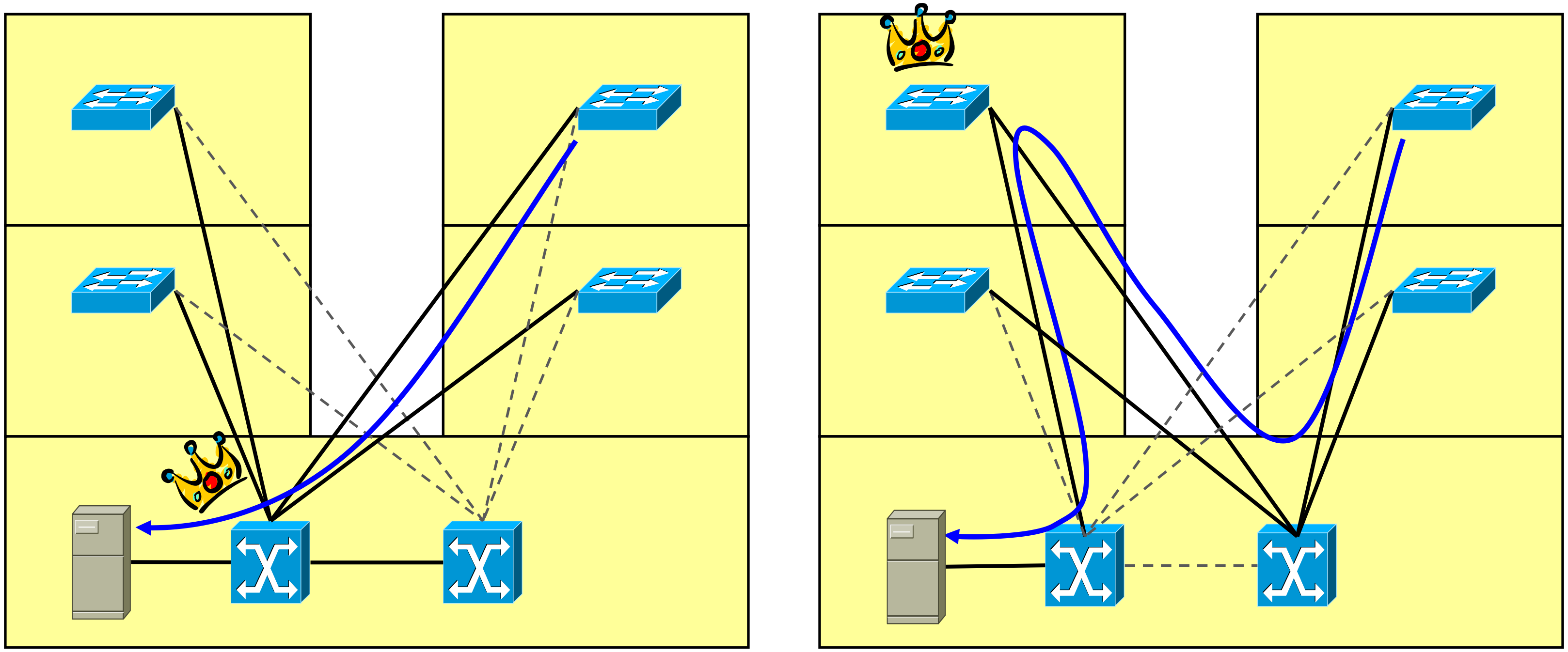
- Poor segregation of different network segments
  - Backward learning process generates transient
  - Possibility to attack the network (flooding attacks, …)
  - No “hard” way to segregate traffic in multiple segments
    - Unless VLANs are used

Switched networks and VLANs

- VLANs are ubiquitous
- An enterprise-class switched LAN will have VLANs
- VLANs are a must-have technology

- Usually, L3 is integrated in modern switched LANs
  - More details in the L3 design slides

Designing an STP network: BridgeID (1)



Note: dashed lines are present for better comprehension. However, in practice we disable ports, not links.

Designing an STP network: BridgeID (1)

- STP is plug-and-play, but the resulting network may not be appropriate
- Suggestions:
  - Customize the Bridge Priority field in order to force a specific bridge to become Root Bridge
  - Get prepared for any trouble the Root Bridge may have, and define which should be the next root bridge in case the first one fails
    - Backup Root Bridge
  - Customize the Bridge Priority field of the “backup root bridge” in order to force that bridge to become Root Bridge in case the first one fails
  - You may have also to change some cost links in order to force STP to select the paths you want

A more detailed view of switched LANs design

Criteria and tips for engineering a network

Introduction

- Network is the backbone of all information system
  - If it works, nobody notices it
  - If it doesn't, everyone complains (also the CEO) and you may be in trouble
- Please note that…
  - If something else doesn't work properly, the problem will always be the network
  - People never blame servers, applications, …
- Therefore…
  - Your network must be as good as possible in order to work properly
  - You must clever enough to have data that demonstrate that it is not your fault!

Design criteria

- Focusing on L2 networks

- Criteria
  - (A) Reliability
  - (B) Fault tolerance
  - (C) Security
  - (D) Performance
  - (E) Modularity and extensibility
  - (F) Debugging
  - (G) Additional features

(A) Reliability (1)

- Good cabling system is a fundamental prerequisite
  - Several faults (usually intermittent and very difficult to diagnose) may arise in case of a poor quality cabling
    - E.g. Are you sure that your cables will follow the shortest path when connecting point A to point B?
- Selection of network devices
  - Different families of network devices, apparently with same characteristics
  - What about redundant modules?
  - What about MTBF?

Reliability (2)

- Observance of standard specifications
  - Do not exceed the known limitations of the standards
    - Cabling
    - Particular attention is needed for fiber-optics backbones
    - Attenuation
    - Number of cascading switches
    - …

(B) Fault tolerance

- The network must be able to operate also when facing one or more failures
  - Links
  - Devices
  - Device parts
    - Interfaces
    - Power suppliers

How do we achieve fault tolerance?

- Adding redundancy on critical elements
  - Interface level
    - Parallel interfaces
    - Redundant ports
  - Device level
    - Processor
    - Power supplier
    - NICs
  - Network level
    - Additional links (i.e., alternate paths)
    - Duplicating a device (e.g., a second (backup) switch)
- Combining all of these
- Robust devices, or many devices with backup capabilities?

How much redundancy?

- Each new element has a fault probability and a cost
  - Fault probability of each element must be analyzed carefully
- Too many elements may
  - Increase fault tolerance capabilities marginally
  - Increase costs substantially
- So, better to duplicate only the weakest elements
- Fault tolerance is always a compromise among
  - Real fault tolerance needs
    - How much does it cost to my organization a stop of N minutes in the network?
    - Please note that a stop of N min of the network may cause a stop of M min of some services
  - Cost

The golden rule

The fault tolerant solution must be as simple as possible and use the lowest number of redundant elements required to guarantee a “path” that can replace the faulty one

(C) Security

- Network isolation
  - VLANs
  - Access Control Links (at various level)
- 802.1x

(D) Performance

- Two aspects
  - Dimensioning of network devices and link bandwidth
  - Network topology
- In both cases, an accurate traffic study is required

Performance: traffic survey

- Traffic typology
  - Client-server, peer-to-peer
  - Departmental servers, or corporate servers
    - Servers (with higher bandwidth) near users or in datacenter
  - Mostly internal to the LAN, or mostly toward the Internet
- Special events (e.g. corporate-wise conventions)
- Traffic monitoring (over different time scales) may be required
  - In case of new installations, we can try with a traffic survey of some similar companies

Performance: selection of devices / links

- Given the traffic survey, we can choose devices / links

- Selection of network devices
  - Possibility to accommodate fastest network interfaces
  - Internal switching capabilities (frames per second)
    - Attention required for multicast and/or other special traffic
    - Necessity of QoS capabilities (e.g. hw queues on interfaces)
- Links
  - Bandwidth
  - Link aggregation

Performance: dimensioning

- The most common approach is to over-dimension the network…
  - Inexpensive
  - Simplest to achieve
  - Simple to manage
  - No traffic engineering
  - No resource reservation
- … and setup a continuous monitoring infrastructure in order to detect bottlenecks as soon as possible
- Often the bottleneck is the connection to the Internet, which is usually slower than the internal network
  - Cannot over-dimension the Internet connection due to cost problems

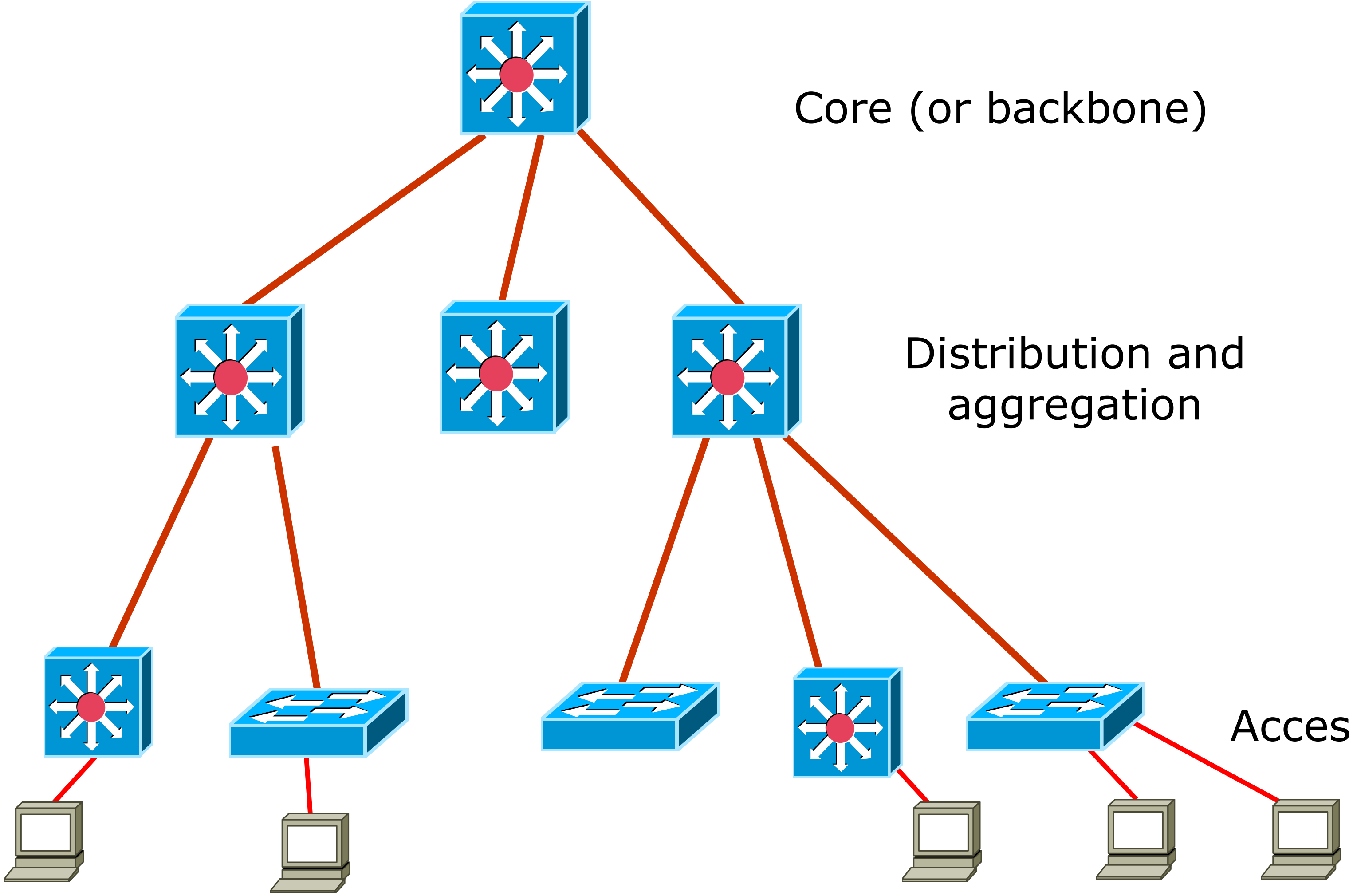
Network topology (1)

- Key decision for achieving performance, reliability, security, fault tolerance
- Unfortunately, often network topology is in some sense forced by some external constraint
  - E.g. location of the wiring cabinets
    - Interior designers seems to have more importance than network engineers
  - Network specialists must do their best anyway

Network topology (2)

- Network performance highly depends on the quality and topology of the underlying cabling system
  - Best choice: design everything at the same time
    - Wiring closets and cabinets
    - Cabling conduits
    - Link/device topology
    - Link/device dimensioning
    - Servers positioning

Logical topology (1)



Core (or backbone)

Distribution and aggregation

Access

Logical topology (2)

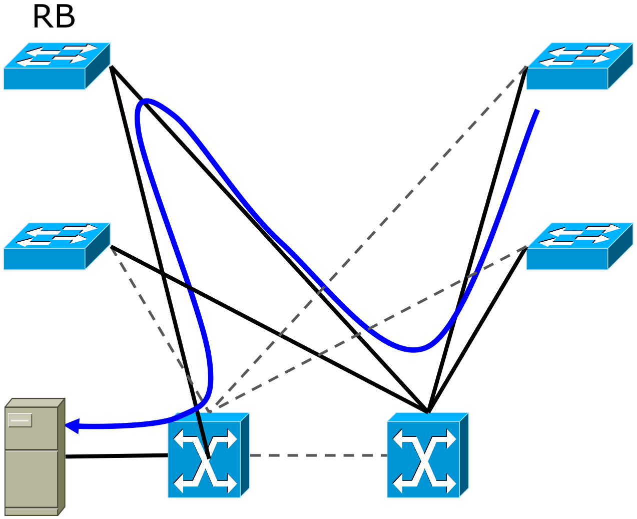
- Core/backbone
  - Usually between different buildings in the same campus
  - Usually concentrated in a few switches, connected to the corporate data center
- Distribution/aggregation
  - Usually within the same building (vertical wiring)
- Access
  - Usually connects hosts on the same floor (horizontal wiring)
  - User control (e.g. 802.1x, …)
  - Reliability may not be so important
- In all cases, point-to-point links

Logical topology: backbones

- Star-based system
  - N devices, N-1 links (with no fault tolerance at all)
  - Highly scalable (we can add new links from the star center or upgrade the star center in order to have more bandwidth)
- Tree
  - Evolution of the hub-and-spoke, for larger topologies
- Ring
  - Very efficient in terms of resiliency
  - “Shared” bandwidth
  - N devices, N links (with resiliency)
- Mesh
  - Usually discouraged
  - Large number of links/devices, no clear outcome of the network in case of fault
  - Difficult to debug

Logical topology and Spanning Tree

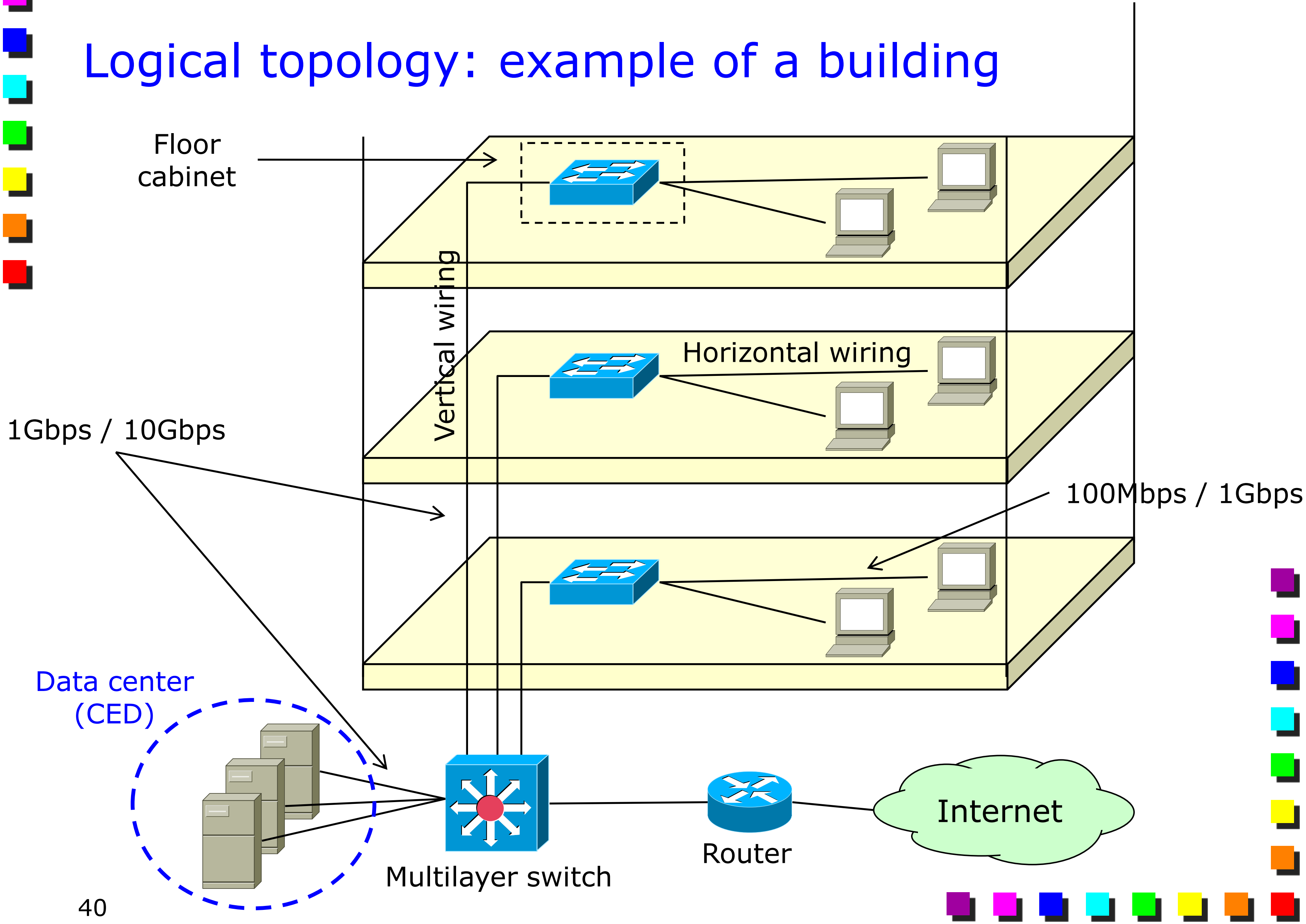
- Have you considered that the actual topology depends on the configuration decided by the STP?
  - Customize Bridge ID for better Root bridge selection and Designated Port Selection
  - Do not forget to design the network in order to perform well also in case of the most critical failures (e.g., root bridge)
- PVST may be another option



Logical topology and link speed

- Important to have an adequate difference between access and distribution/core
  - Limits dropped frames in L2 network
  - QoS issues
- Usually, 100Mbps is enough
  - Most people (vendors?) prefer 1Gbps, though

Logical topology: example of a building



(E) Modularity and Extensibility

- Links
  - Link type (e.g. copper, fiber, …)
    - GBIC, for a better choice of the proper physical technology
  - Other characteristics (e.g. simple fiber, armored fiber, …)
- Devices
  - Fixed format
  - Chassis-based
  - Stackable devices
  - Hardware-based vs software based
    - Impacts performance as well
- Configurability
  - Fixed features, no field-upgradable operating system
  - Field-upgradable operating system (with new features)

(F) Debugging (1)

- First, adopt standard technologies
  - The standard specifies how the device should operate
  - Required for interoperability as well
- Second, be prepared in case users complain about the network
  - The network has to be reasonably robust
  - We must have debug facilities
    - For debugging the network (and, more important)
    - For debugging servers and clients
  - Mirror (also known as “span”) ports are a must

Debugging (2)

- Remember that, in the common belief, the problem is always the network
  - Either in terms of reachability (“I cannot reach my web server”) or in terms of performance (“the server is slow”)
- Be prepared to demonstrate that it’s not your fault
  - Network traffic live recording
    - In case regulations allow you to do so
  - Monitoring tools

Debugging (3)

- Prevention is better than cure
  - Systems for the management and control of the network for revealing anomalies and faults
  - Otherwise, the fault may happen and it remains unfixed because the network manager does not notice it
    - E.g., automatic network reconvergence (STP)

(G) Additional features

- Power over Ethernet (PoE)
- Quality of Service (QoS)
- VLANs

Good practices: power

- Redundant devices must have an independent power supply
  - Two power units, connected to different electrical backbones
  - Two independent electrical backbones
- Uninterruptible Power Supply systems for important devices
  - Usually 15-20 minutes with batteries
  - Then, a power generation must be activated
- Power distribution must be done with care
  - Different distribution lines for network and other users (e.g. lights)
    - Are you sure that you have no stoves connected to your distribution line?
  - Multiple lines for network devices for redundancy
    - What about everything under the same differential switch, which may go off?

Good practice: cabinets

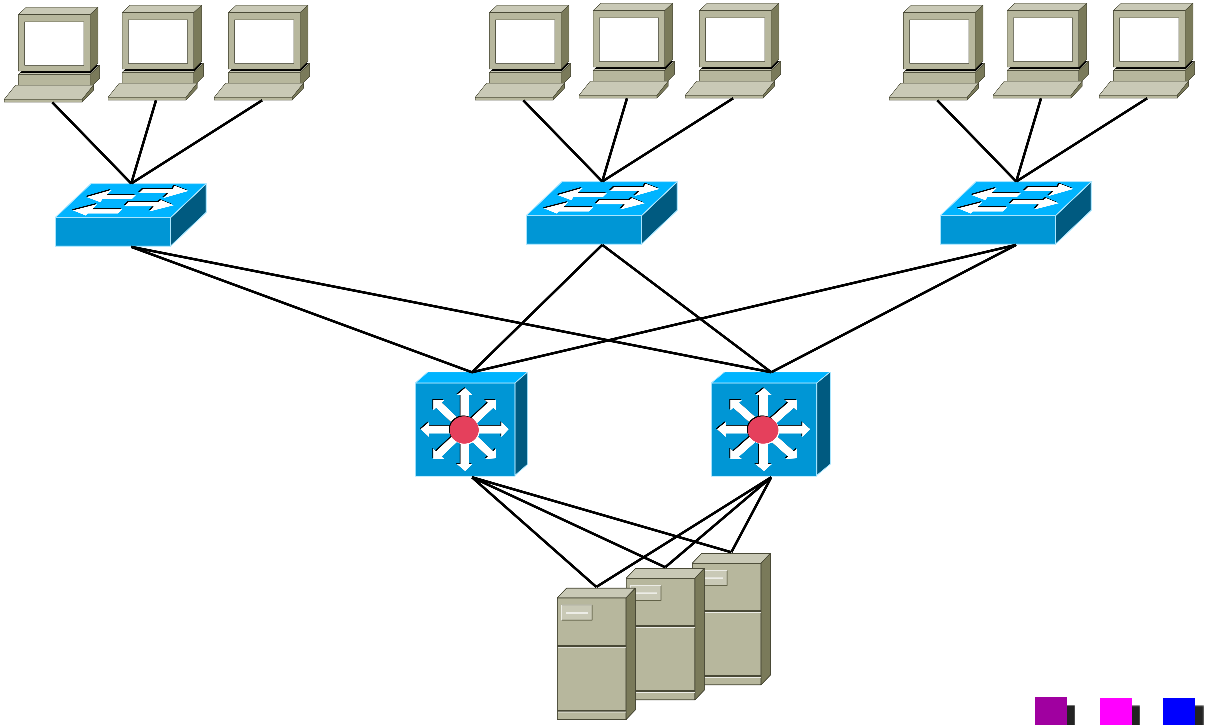
- Cabinets and data centers are often in the basement
- Check that everything is safe in case of flooding
    - Do you have water pumps in order to keep your datacenter safe?

Good practice: links

- Redundant links
  - Fiber is better, especially in backbone
    - Copper is an electric conductor
      - Lightning
      - Some electrical cable that goes in touch with networking cables
  - Armored links (if needed)
  - Fiber over long distances
    - We may have intermittent problems (link flapping)
    - A de-flapper mechanism may be extremely useful
      - Especially if RSTP is used

Good practice: devices

- Redundant devices (e.g. the star center)
- What about servers?



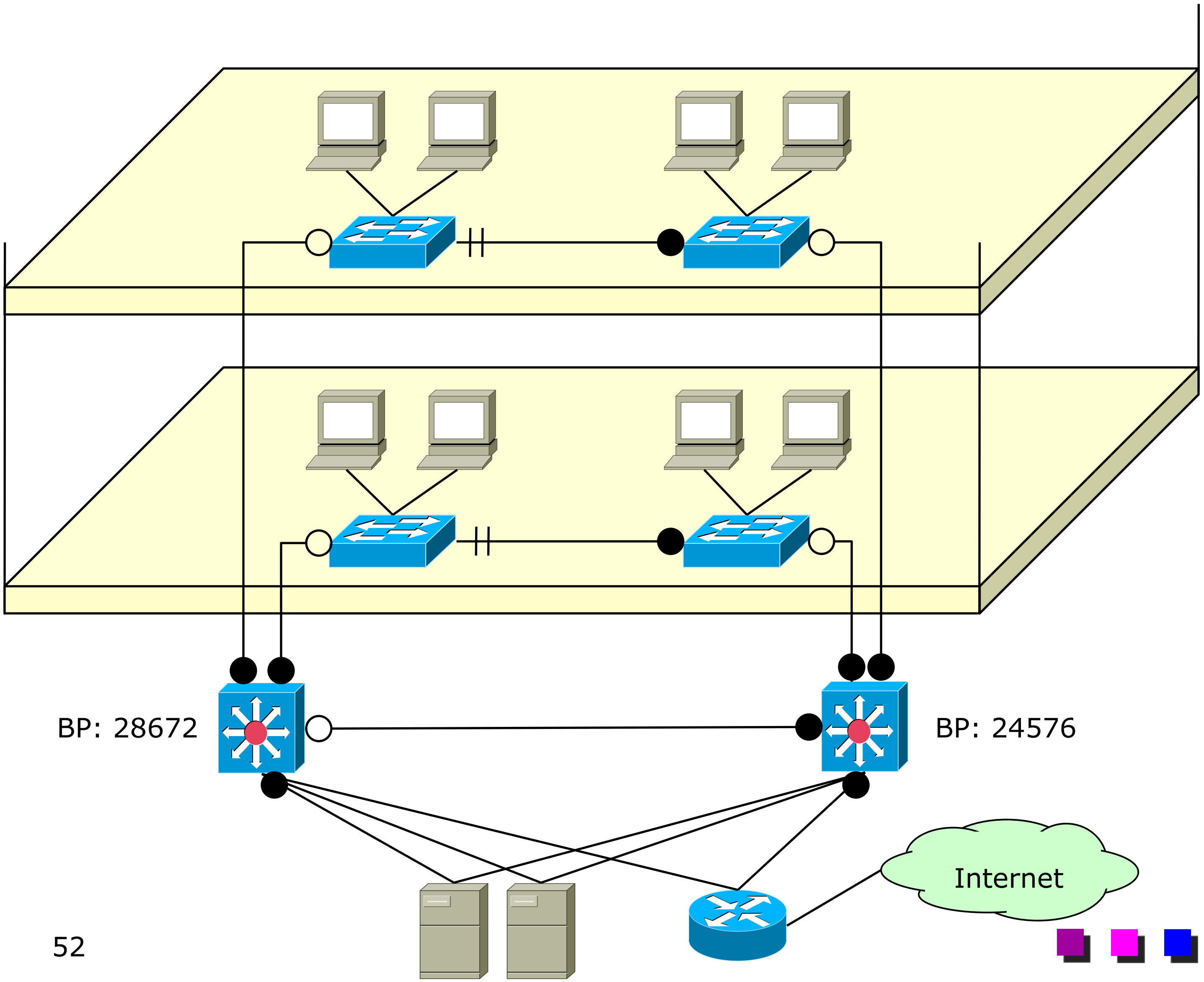
Good practice: redundant paths

- Link Aggregation (when possible)
- Spanning Tree
  - Network analysis of the topology in case of fault of the most critical links/devices
    - Appropriateness of the resulting topology
  - Customization of BridgeID for Root bridge and backup root bridge

Spanning Tree and Fault Reaction

- Fault Reaction in 50 seconds
  - Is this time appropriate for my network?
  - Re-convergence of other services may be higher than 50s
- In case faster reaction is needed
  - New values for timers
  - Rapid STP
- STP limits
  - Max 7 bridges (also on the topology that comes out after a fault)
  - Single spanning tree (i.e. unused resources)
    - VLANs and MST?
    - L3 routing?

Redundant backbone: example



Conclusions

- The network is the backbone of any information system
- Not easy to design a good network
  - Many different aspects
    - From electrical system, to location of cabinets, to cabling, networking equipment, network topology, network protocols, air conditioning, data centers
  - Perhaps the most difficult problem is to foresee all the possible faults
- Experience matters