Networking Technologies and Applications

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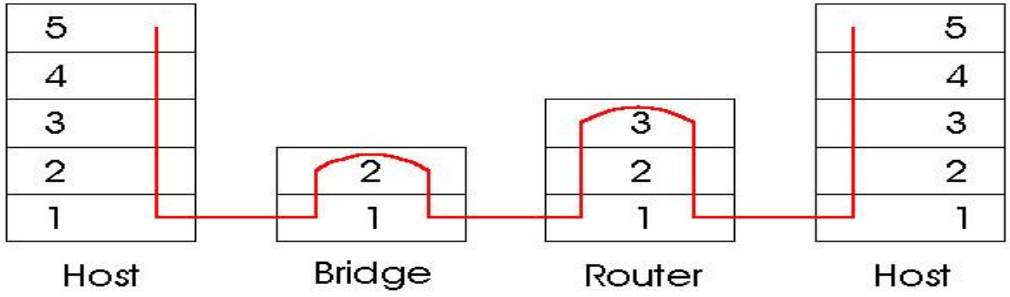
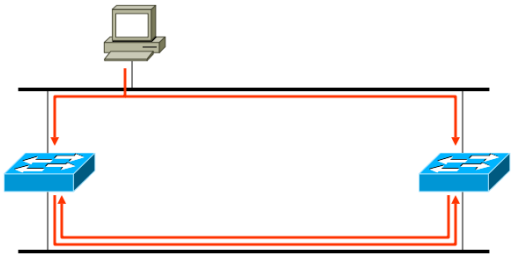
Switch (bridge) vs. router

- Intelligent store-and-forward devices
- Router
  - In the network layer (L3), based on IP addresses
  - Stores routing tables, uses routing protocols
- Switch
  - In the data link layer (L2), based on MAC addresses
  - Stores switching tables, uses address learning algorithms

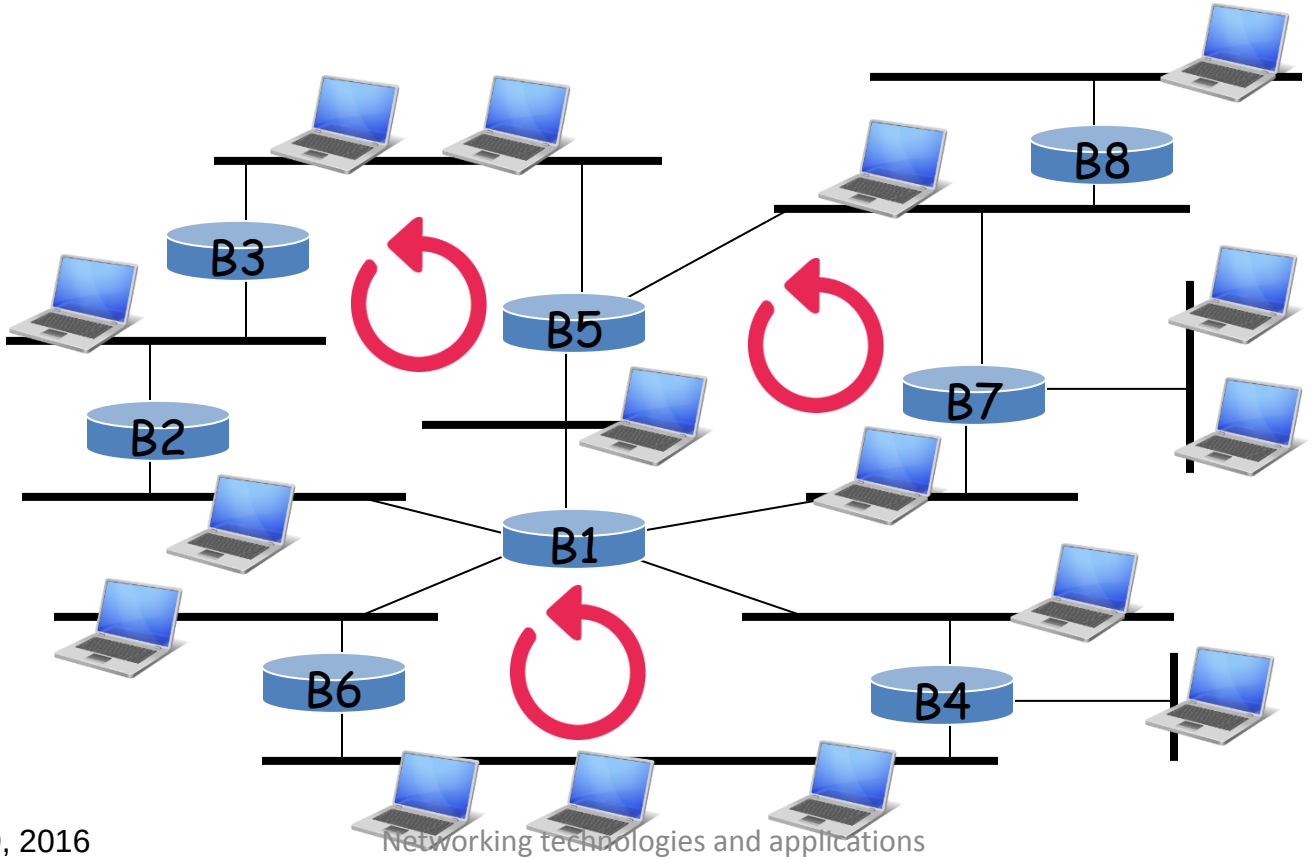


STP

- Spanning Tree Protocol
  - Part of the IEEE 802.1D standard
    - Radia Perlman (MIT, DEC)
  - Loop-free trees on a bridged LAN
    - No TTL in Ethernet (Time To Live)
      - In case of a loop, packets travel indefinitely in the network
    - Need for redundancy
      - In case of an error, there should be an alternative path



Example topology

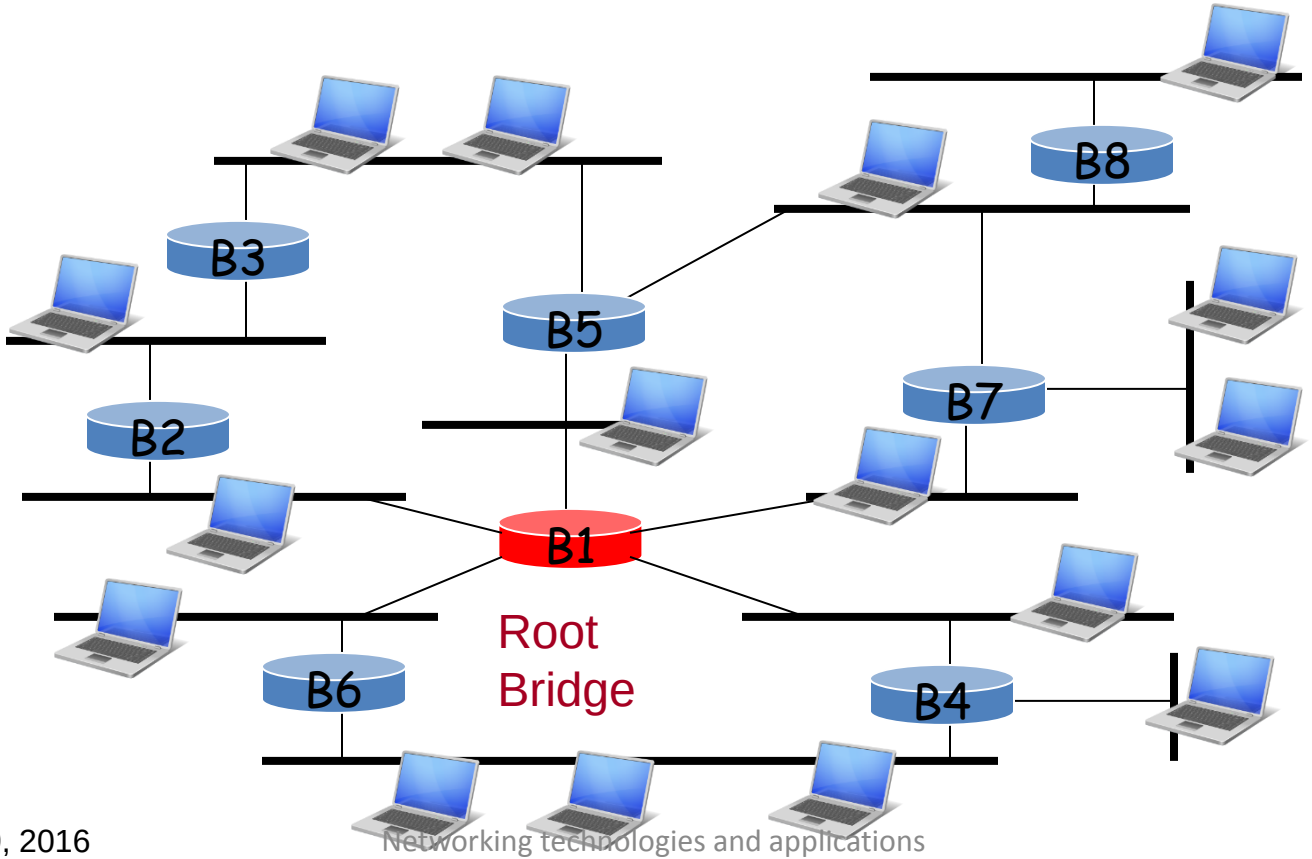


STP operation

- Choosing the root bridge
  - Each bridge has a MAC address and a configurable priority number
    - BID – Bridge Identification (64 bits)

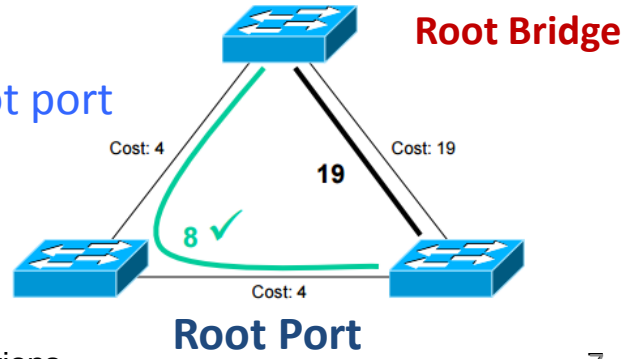
  - The bridge with the lowest priority will be the root
    - In case of equal priorities, the lowest MAC address wins
    - There will be a secondary (backup) root as well
  - Totally automatic, but if the network manager wants a specific device to be the root, it sets a low priority number

Choosing the root bridge

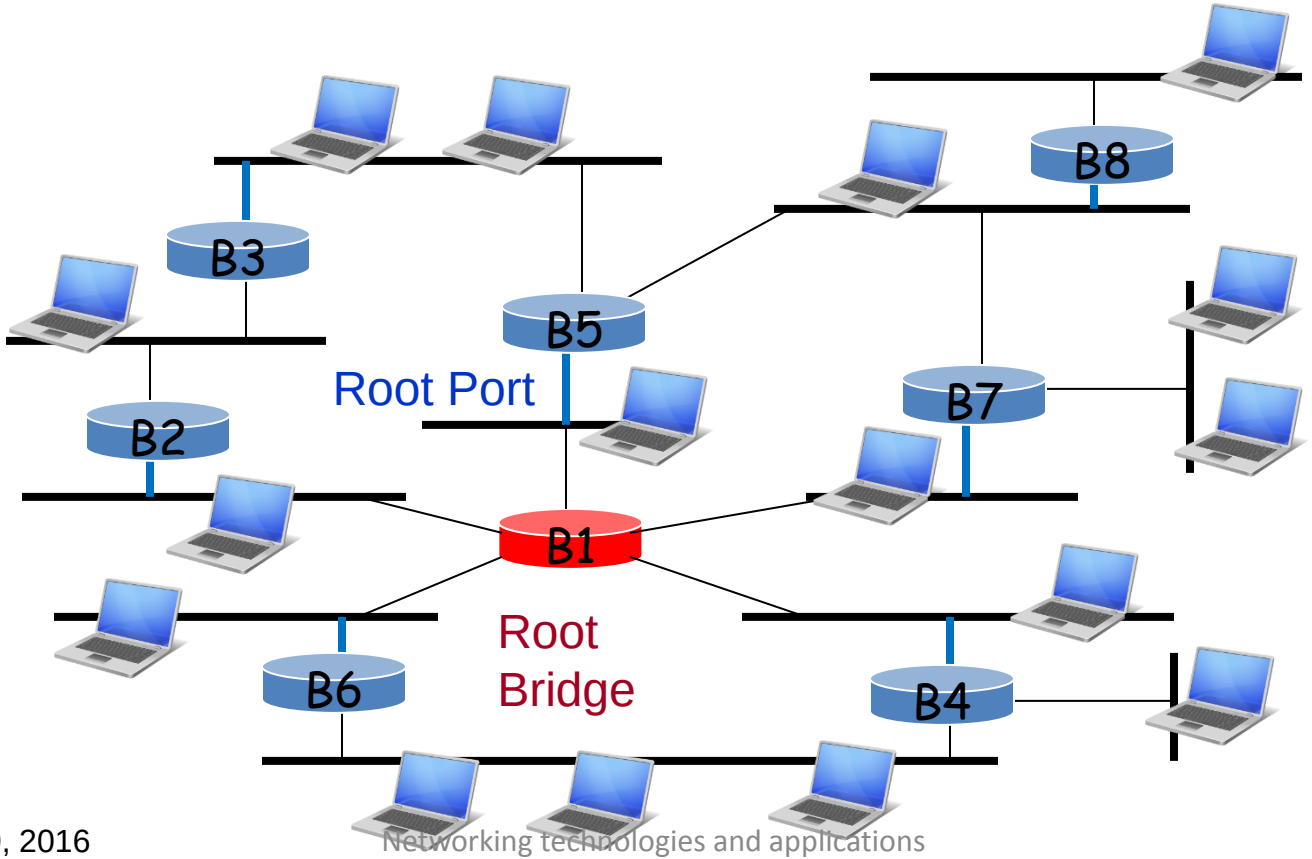


STP operation

- Finding the „cheapest” path to the root bridge
  - BPDU – Bridge Protocol Data Units
    - Sent periodically (2s) among the bridges
  - A bridge calculates the cost of all the possible paths to the root bridge
    - Each port has a *Port Cost*
      - Administrative value, e.g., inversely proportional with the bandwidth
  - Chooses the least-cost path
    - The port belonging to that path will be the root port
    - If several paths with the same cost, the lower Port ID wins



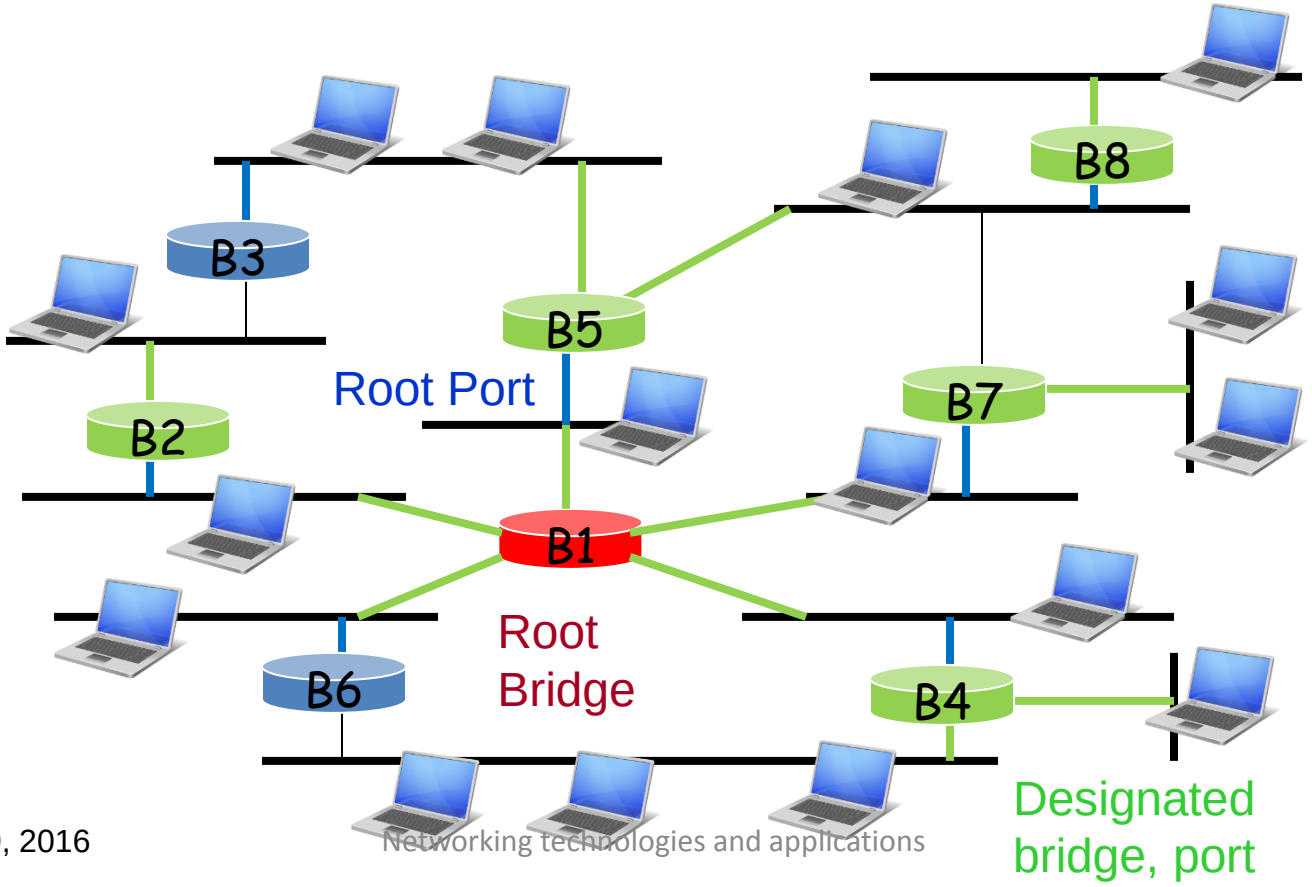
Choosing the root port



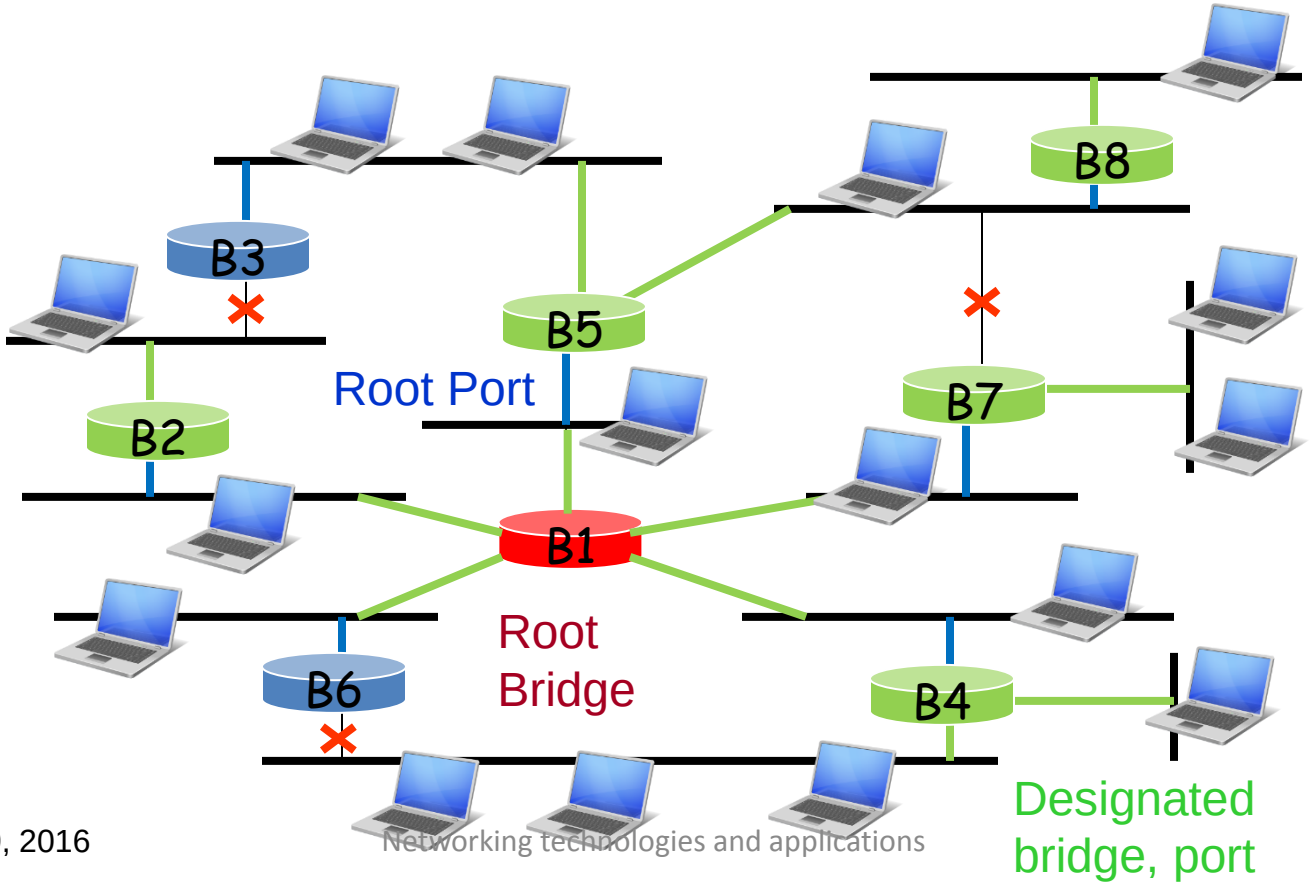
STP operation

- Finding the „cheapest” paths to the root bridge for each LAN segment
  - The bridges calculate together, for each LAN segment, which is the bridge that belongs to the least-cost path towards the root bridge
    - *Designated bridge, designated port*
  - The designated and root ports are switched to *forwarding state*
  - On all the other ports traffic is blocked
    - Only BPDUs pass
- After building the tree, addresses are learned
  - 15 seconds learning time

Choosing the Designated bridge/port



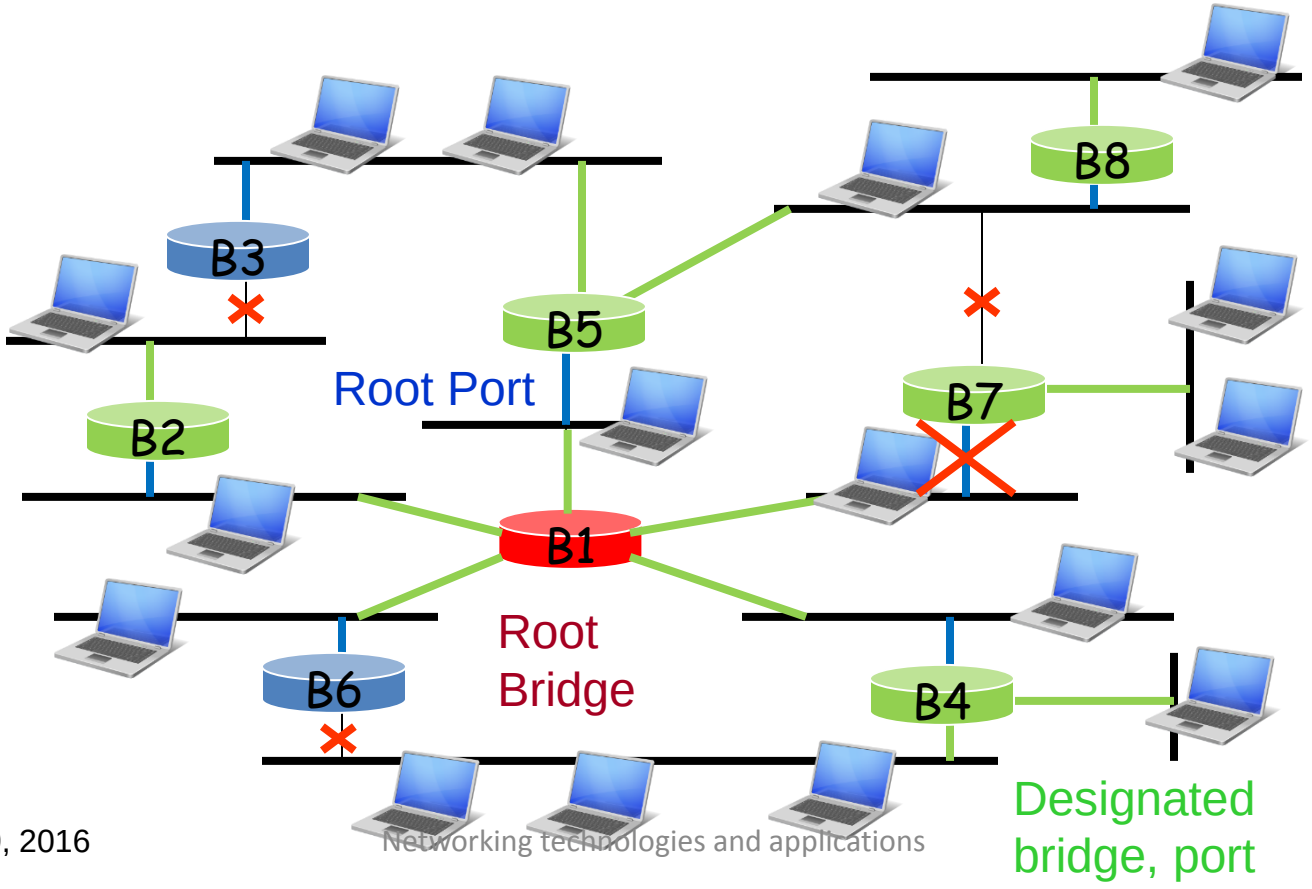
Port blocking



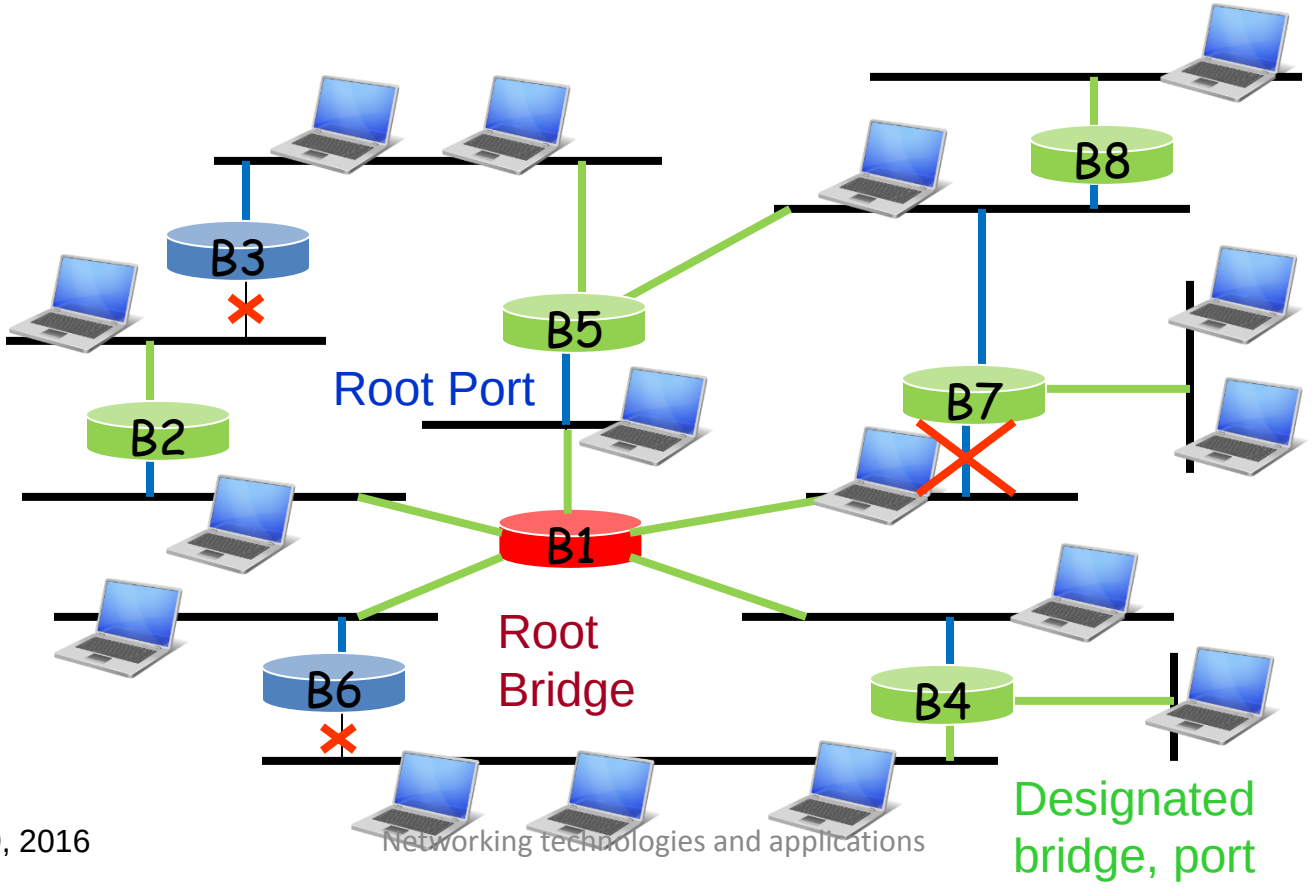
Handling errors

- BPDUs sent periodically
- Two BPDUs missed means an error
  - The bridges recalculate the topology
  - If there is a blocked port, they will use it
- New topology built in 15 sec
- Then, MAC addresses are learned again
  - In 30 secs the network is operational again

Handling errors



Handling errors



Fiber networks

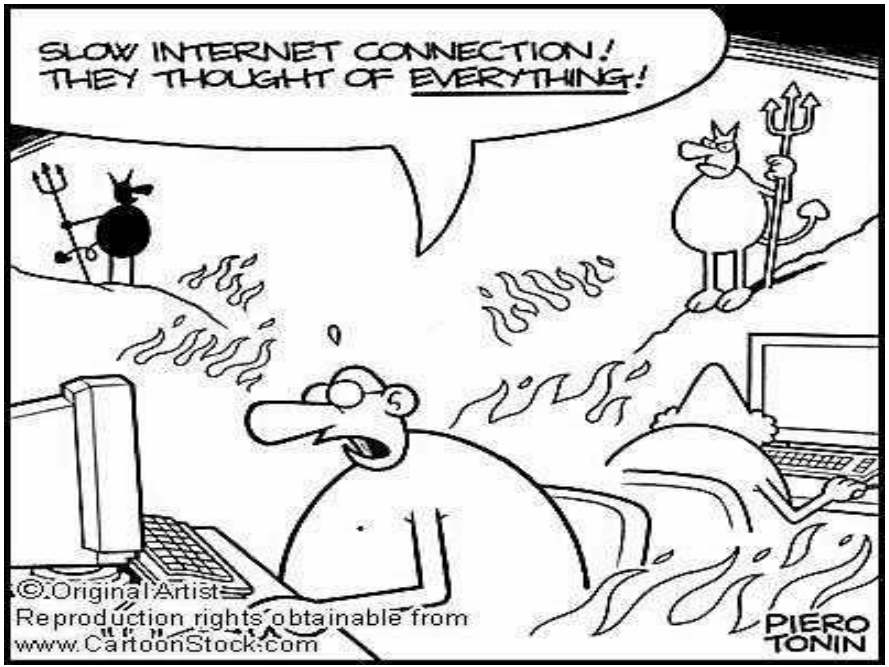
Why fiber?

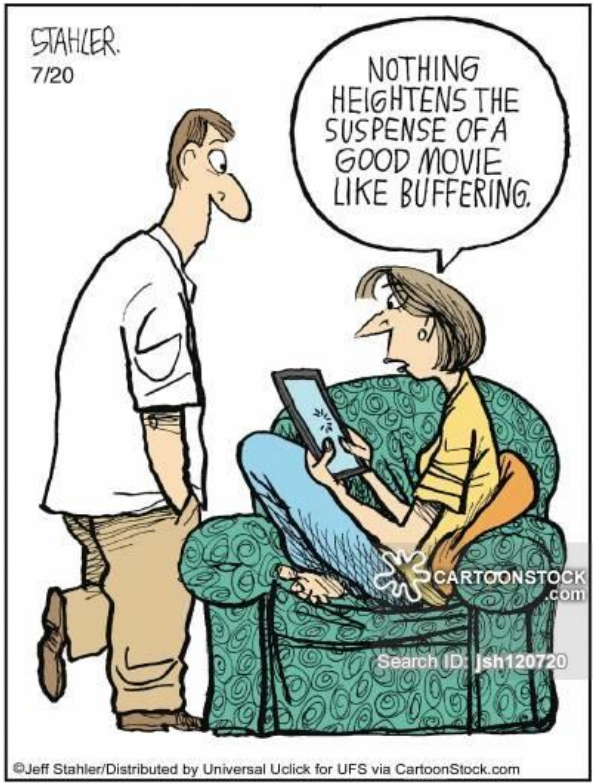
- Today the killer application is not web browsing anymore, but multimedia
  - MPEG-1 – ISO/IEC standard
    - Moving Pictures Experts Group
    - 50:1 – 100:1 compression rate
    - 1.5 Mbps, VHS quality image
  - MPEG-2
    - DVD quality image
    - High resolution, high color depth, high movement video (e.g., sport events) – 4-8 Mbps
    - HDTV – 14 Mbps, **8K UHD TV – 50 Mbps** (7680 x 4320, 60 fps)
- The ADSL speeds are far from being enough
  - Only in case of very short loops

Why fiber?

- HFC (Hybrid Fiber Coax)
  - The traditional 300-550 MHz coaxial cables replaced with 850 MHz cables
    - Additional 300 MHz → 50 new 6 MHz wide channels
    - With QAM-256, 40 Mbps per channel → 2 Gbps new bandwidth
    - 500 houses on a segment → each subscriber gets 4 Mbps downstream, which might be enough for an MPEG-2 stream
  - Sounds nice, but...
    - All the cables should be changed to 850 MHz coax
    - New CMTS, new fiber nodes, two-way amplifiers
    - Nearly the entire network has to be changed
- Why not bringing the fiber as close to the subscriber as possible?

Slow speed is today a torture!





Speed is important!

MGM, Paramount Pictures, Warner Brothers and Universal Studios announce a common plan to support on-line movie renting”

2002 december 9

„Hollywood’s Latest Flop”, Fortune Magazine:

„The data files are huge. At 952 megabytes, Braveheart took just less than five hours to download using our DSL line at home. Video-on-demand? Hardly. In the same time we could have made 20 roundtrips to our neighborhood Blockbuster”

Estimated minimum download time for the Braveheart movie

Technology	Minutes	Hours	Days
Modem 56 kb/s			2
FedEx		12	
DSL 1 Mb/s		2.5	
Cable 2.5 Mb/s		1	
BLOCKBUSTER	45		
FTTH	0.4		

Data transfer over the fiber

- Three main components:
  - Source of light
    - LED (light emitting diode), laser
  - Fiber
    - Very thin glass fiber
  - Light detector
    - If it detects a light pulse – logical 1 bit
    - If not – logical 0 bit
- The digital data has to be transformed to light pulses, and vice versa
- The transfer speed is only limited by the speed of the conversion
  - Actual speeds today on a single fiber ~10-50 Gbps

Fiber categories

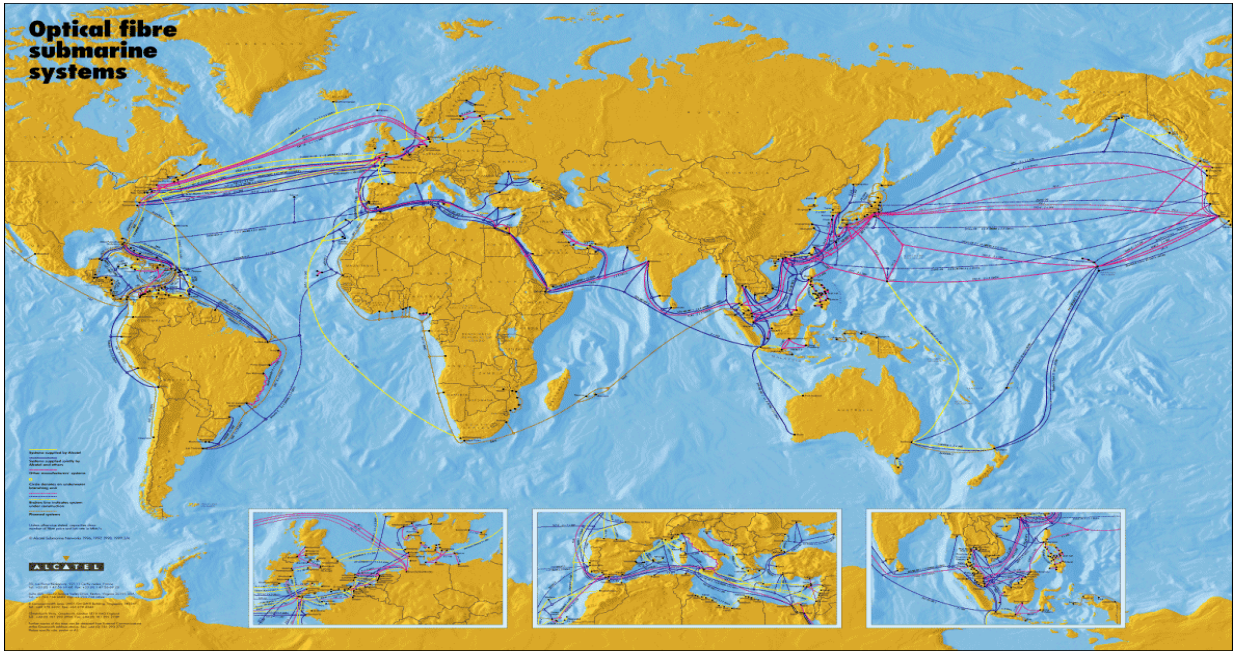
- Multi-mode fiber

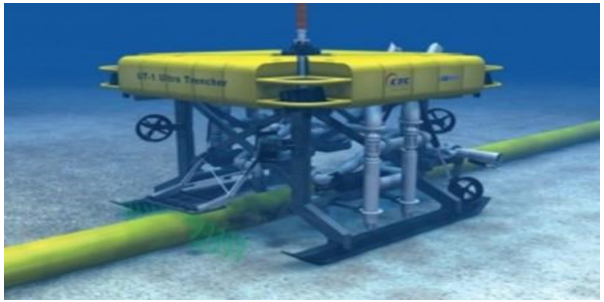
  - Light pulses are spread inside the fiber
  - Many rays of light reflected under different angles
  - Cheap solution, but suitable only for small distances (500 m)

- Single-mode fiber

  - The diameter of the fiber is very small, a single ray of light is transmitted inside the fiber, no reflections
  - Much more expensive, needs much higher capacity lasers
  - Suitable for much larger distances
    - 50 Gbps on 100 km without amplifiers
    - Very important for transatlantic cables, where amplifiers are hard to install
  - The core network is built only with single-mode fibers

Submarine optical systems





WDM – Wavelength Division Multiplexing

- Many wavelengths (colors) on the same fiber
- At the beginning only 2 colors
  - Today up to 160
  - On a 10 Gbit/s fiber a theoretical speed of 1.6 Tbit/s