Networking technologies and applications

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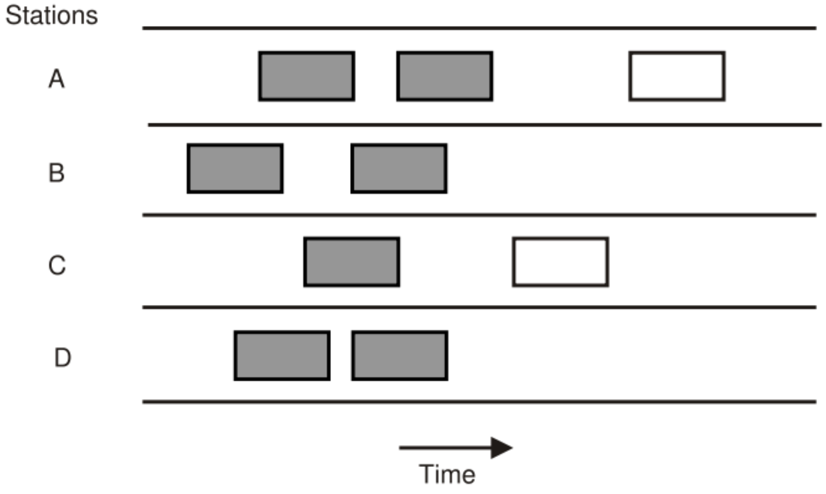
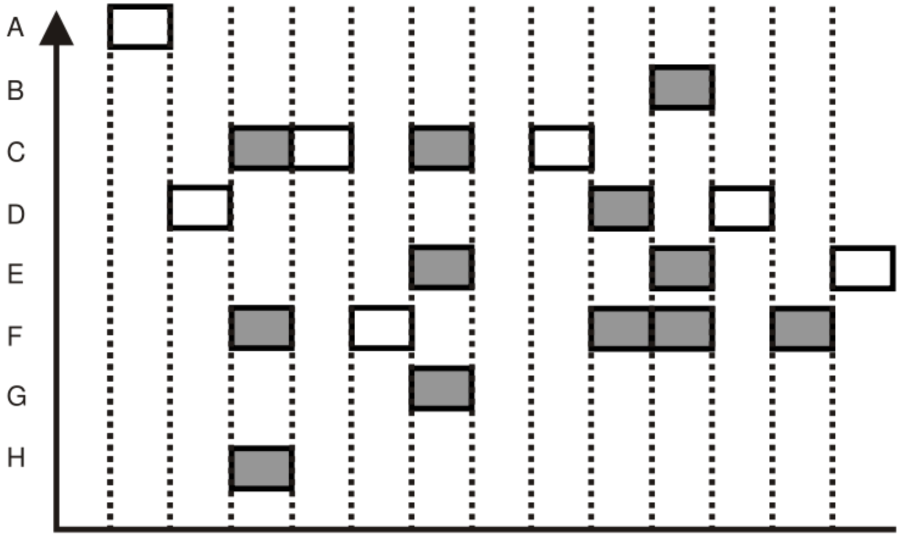
ALOHANET

- Hawaii – no telephone network at the end of the 70's
  - How to connect the computers on different islands to a network, containing the central computer in Honolulu?
- Solution: ALOHANET – low range radio
  - Norman Abramson, University of Hawaii
  - Each user terminal had a small radio device
    - Operated on two frequencies
      - One for the downstream, one for the upstream traffic
    - Downstream data broadcasted by the central computer, no problem
    - Contention on the upstream channel
      - If data reached correctly the central computer, it retransmitted it on the downstream channel
      - If the original sender did not receive it back, it was probably lost
        - Retransmission required
  - If low upstream traffic, the solution is quite efficient
  - If higher traffic, the solution is unusable

Aloha vs. Slotted Aloha





Slotted ALOHA protocol (shaded slots indicate collision)

The evolution of Ethernet

Aloha

The ancestor

Slotted Aloha

Novelty: transmission allowed only at precise moments (slots)

CSMA

CSMA = Carrier Sense Multiple Access

Novelty: It checks first whether the channel is empty or not, it sends data only if it is empty

CSMA/CD

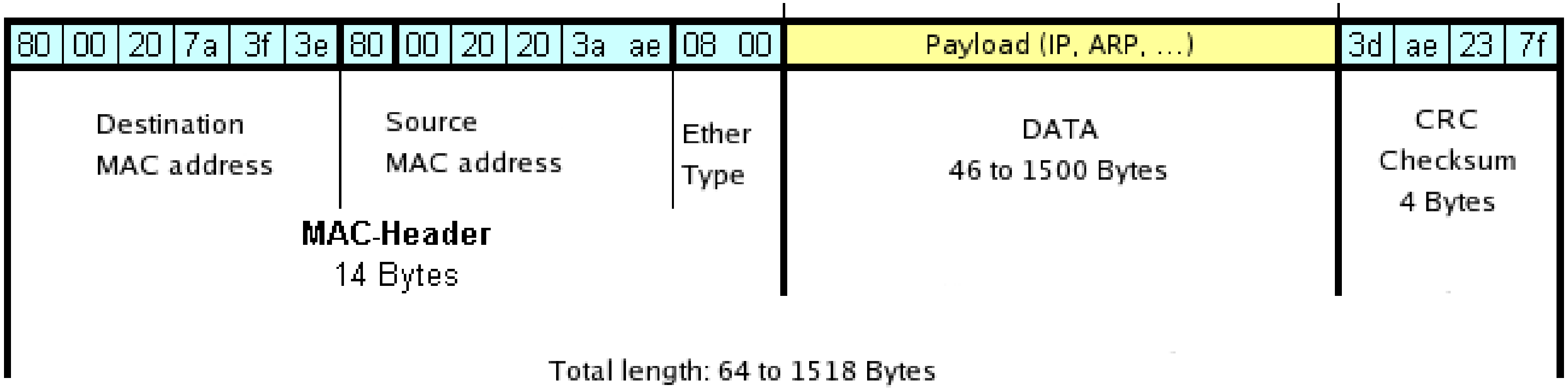
CD = Collision Detection

Novelty: If collisions detected, the transfer is stopped (Ethernet)

Ethernet

- Bob Metcalfe (MIT, Harvard) spends his holiday together with Abramson on Hawaii
  - The first LAN – Metcalfe and Boggs, 1976
- Communication on a shared medium
  - Like a dinner conversation
- Before transmission, hosts on the same Ethernet cable first listen to the channel
  - If busy, they wait for the transmission to end
  - If collision, they detect it
    - Jam signal sent, to ensure that others detect the collision as well
    - Retry after a random back-off time
    - If several collisions, exponentially increasing back-off interval
  - Not possible on Alohanet
    - Two users on the remote islands could not hear each other

Ethernet Frame



- The DATA field is at most 1500 bytes
  - Minimum length - 46 bytes
    - If the frame too small, collision detection cannot be used
      - Transmission is terminated very fast, before the first bit reaching the end of the cable
      - Even if there's a collision, the sender is not informed about it
  - Packets that are too small are filled with padding data
    - Bits with no utility

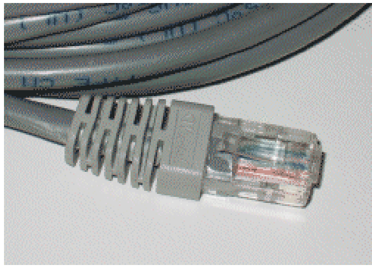
Carrier Extension

- If the speed of the network increases...
  - Either increase the minimum frame size...
  - Or decrease the maximum cable length
    - On a 2500 m cable, for a 1 Gb/s speed, the minimum frame size is 6400 bytes
    - If the minimum size is 640 bytes, the cable can be only 250 m long
  - Very annoying restrictions on a Gigabit network
    - Minimum frame size increased to 512 bytes
- Carrier Extension
  - The sender puts the useless bits after the CRC field
  - The receiver cuts it of, not included in the CRC
    - Serious waste of capacity
- Frame Bursting
  - During a single transmission, several consecutive frames transmitted
  - Increases efficiency considerably

First Ethernet versions

- 10Base5 – thick Ethernet
  - Coaxial cable, 10 Mb/s, 500 m long segments

- 10Base2 – thin Ethernet
  - Coaxial cable, 200 m segments



- 10Base-T
  - Twisted pair, star topology around a hub, 100 m segments

- 10Base-F
  - Optical fiber, 2km long segments

Fast Ethernet

- 100Base-T4
  - 4 twisted pairs
  - One for the upstream, one for the downstream data, the other two can be used as needed
  - Maximum 100 m long segments
- 100Base-TX
  - 2 twisted pairs
  - One for the upstream, one for the downstream, 100 Mb/s duplex speed
- 100Base-FX
  - Multi-mode fiber in both directions
  - 100 Mb/s duplex speed
  - Maximum 2 km between the hub and the stations

Gigabit Ethernet

- IEEE 802.3z (1998), 802.3ab (1999)
- Only point-to-point setups
  - No shared segments, as in traditional 10 Mb/s Ethernet
- Two operation modes:
  - Duplex – traffic in both directions in the same time
    - A central switch links the stations on the periphery
    - All the connections are buffered
      - Any station can send data at any time
      - No need to sense the channel, no contention
      - No need for CSMA/CD, not really Ethernet anymore
  - Half-duplex
    - Stations are connected to a simple hub
    - No buffering, collisions are possible

Gigabit Ethernet

- Different versions
  - 1000Base-SX
    - Multi-mode fiber
    - Maximum 550 m long segments
  - 1000Base-LX
    - Single- or multi-mode fiber
    - Maximum 5000 m long segments
  - 1000Base-T
    - 4 pairs of Cat. 5 UTP cables
    - Maximum 100 m long segments
- IEEE 802.3ae – 10 Gb/s Ethernet (2002)
  - Only on optical cables
- 100 Gb/s Ethernet (2010 -)

Hub

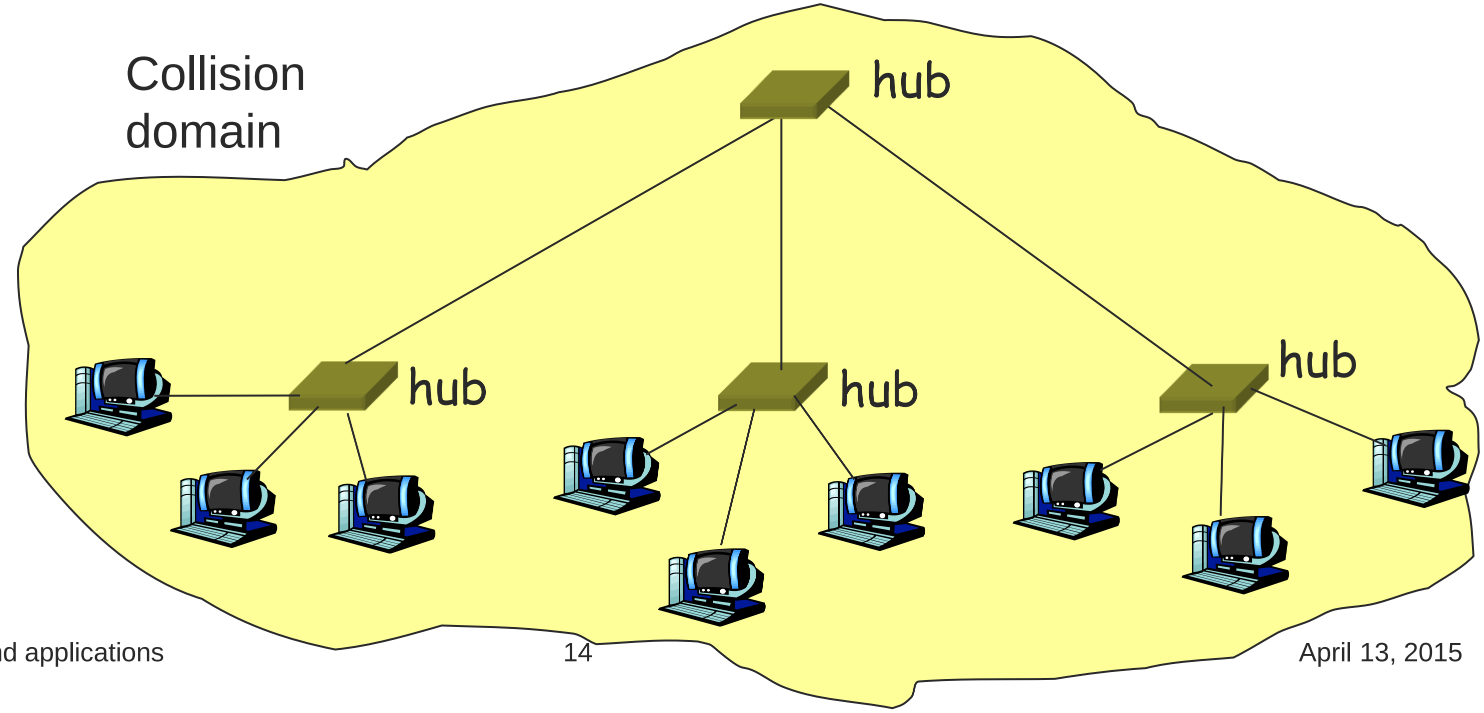
- Physical layer repeater device
  - Repeats the packet on bit level
  - An incoming packet is forwarded immediately on all the other interfaces
    - Everyone receives all the packets
- If many simultaneous transmissions - collision
  - The „collision domain” is not changed
- Usually a hierarchical, tree-like hub topology

Hub – advantages and drawbacks

- Each station can collide with any other station on the hub
  - Lowers the efficiency of the network
  - Lowers scalability
  - Anyone can see anyone’s traffic
- Different Ethernet versions cannot be joined in the same network
  - If one 10Mbps station in the network, the entire network switches back to 10 Mbps operation mode

Hub

- Not efficient to build a large network using only hubs
  - One large collision domain

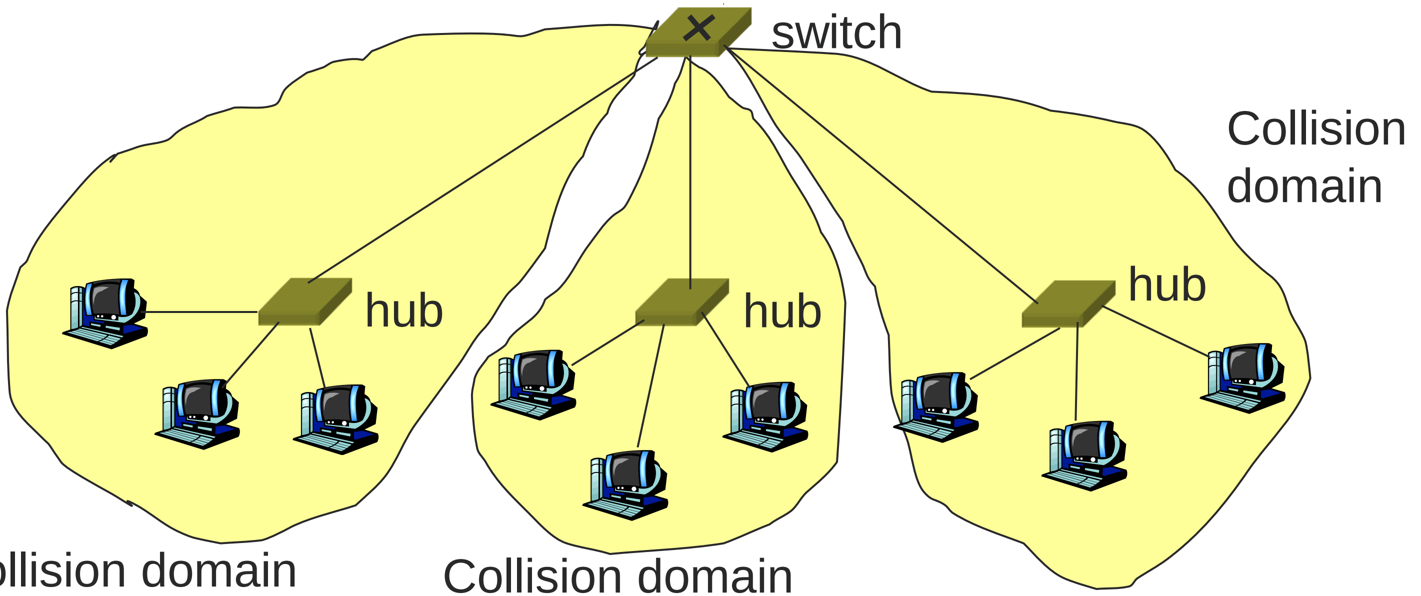


Switch (bridge)

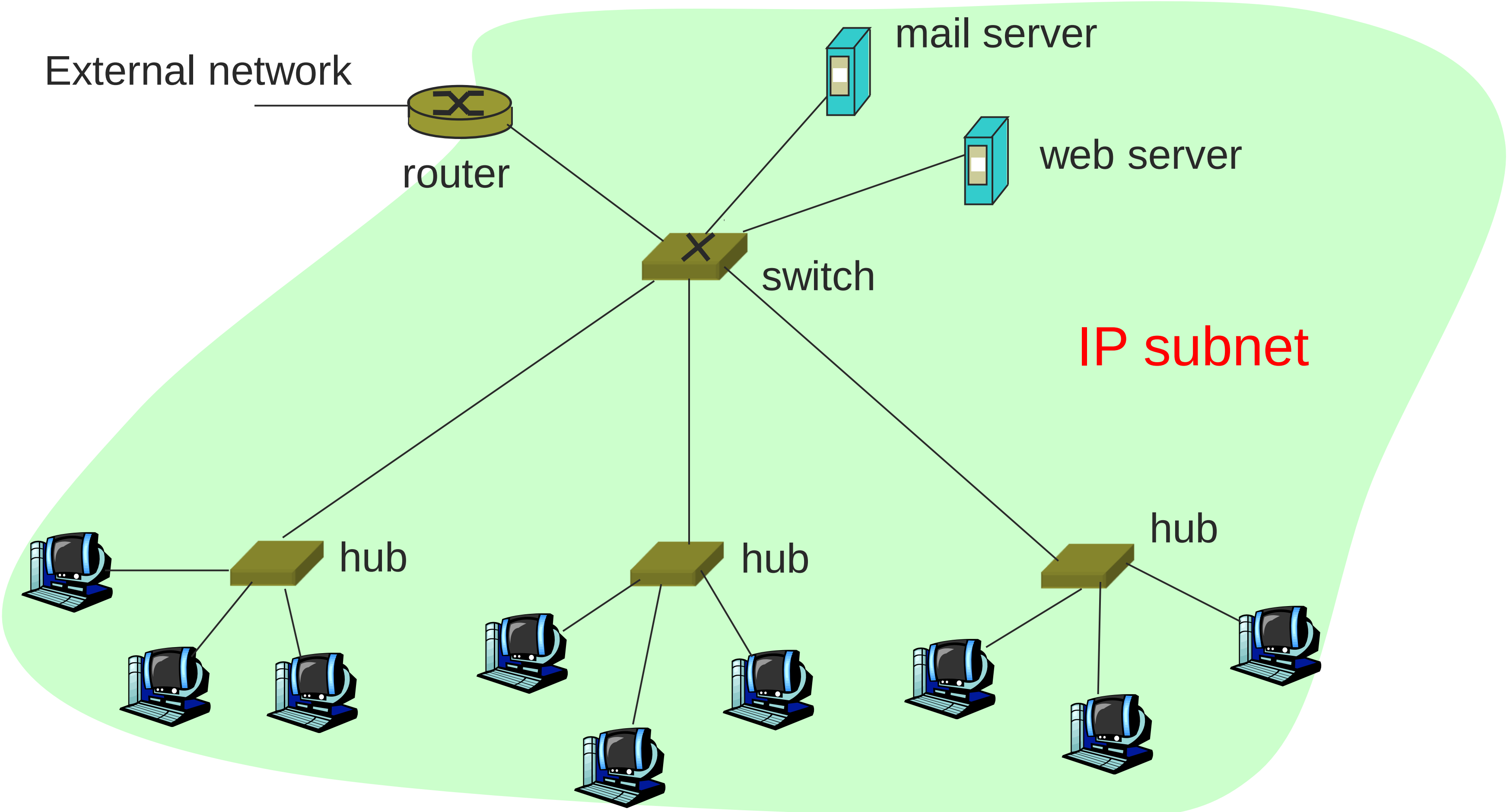
- Link Layer device
  - Checks the MAC header, and forwards selectively
    - switch table: (MAC address, interface, timer)
      - Built from the received packets
      - If one address is unknown, the packet is forwarded to all the interfaces
  - Separates the collision domains
    - Buffers the packets
    - Forwards them only to the appropriate segments

Switch

- Advantages:
  - Higher scalability
  - More efficient, more secure
  - Buffering and switching tables makes the connection of different Ethernet versions possible inside the same network

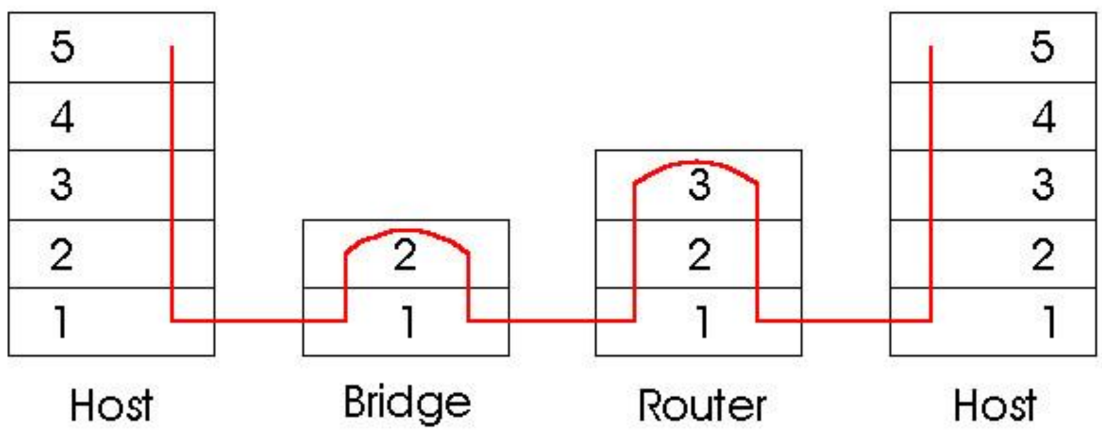


Corporate network



Switch (bridge) vs. router

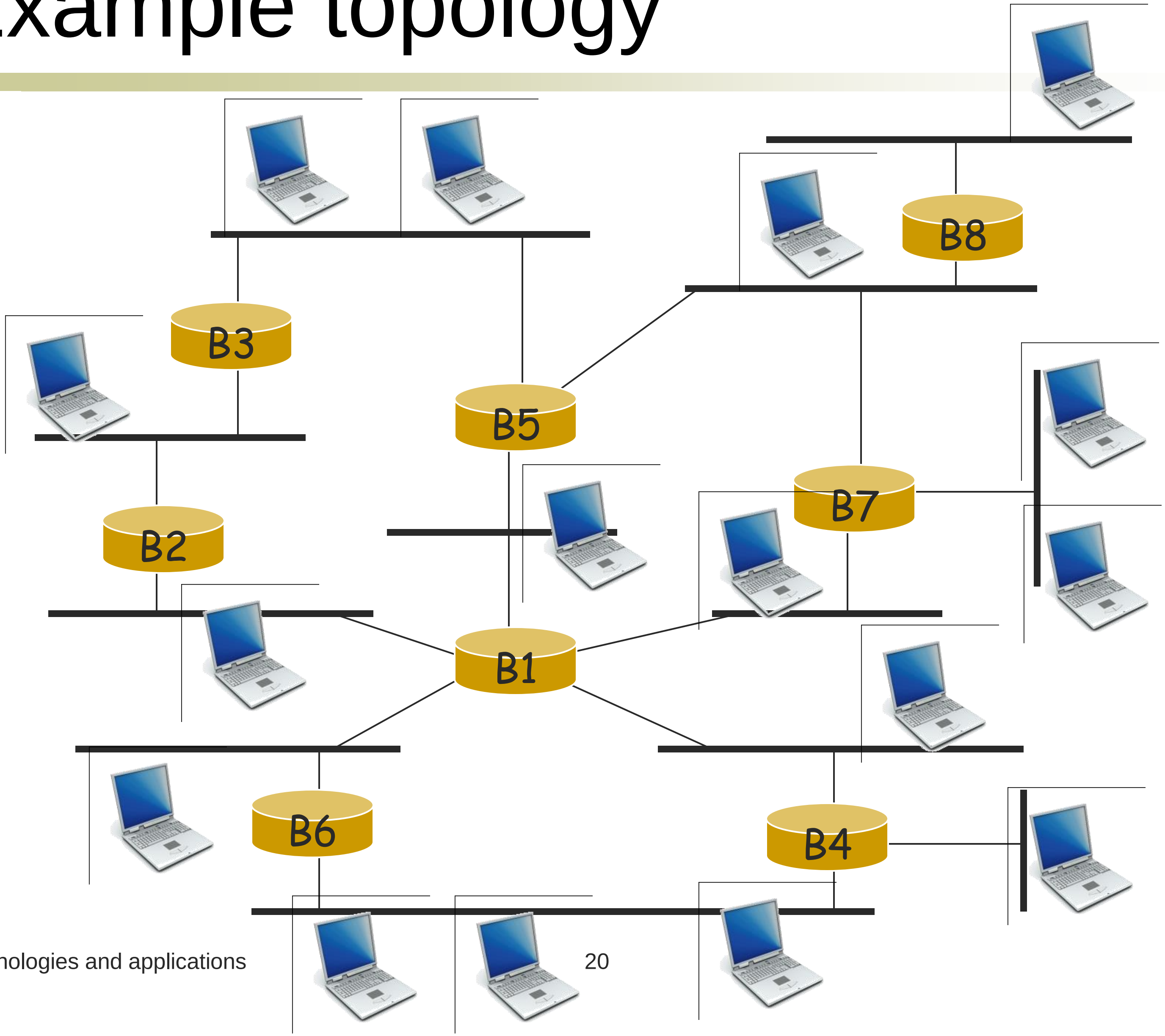
- Intelligent store-and-forward devices
- Router
  - In the network layer (L3), based on IP addresses
  - Stores routing tables, uses routing protocols
- Switch
  - In the data link layer (L2), based on MAC addresses
  - Stores switching tables, uses address learning algorithms



STP

- Spanning Tree Protocol
  - Part of the IEEE 802.1D standard
  - 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

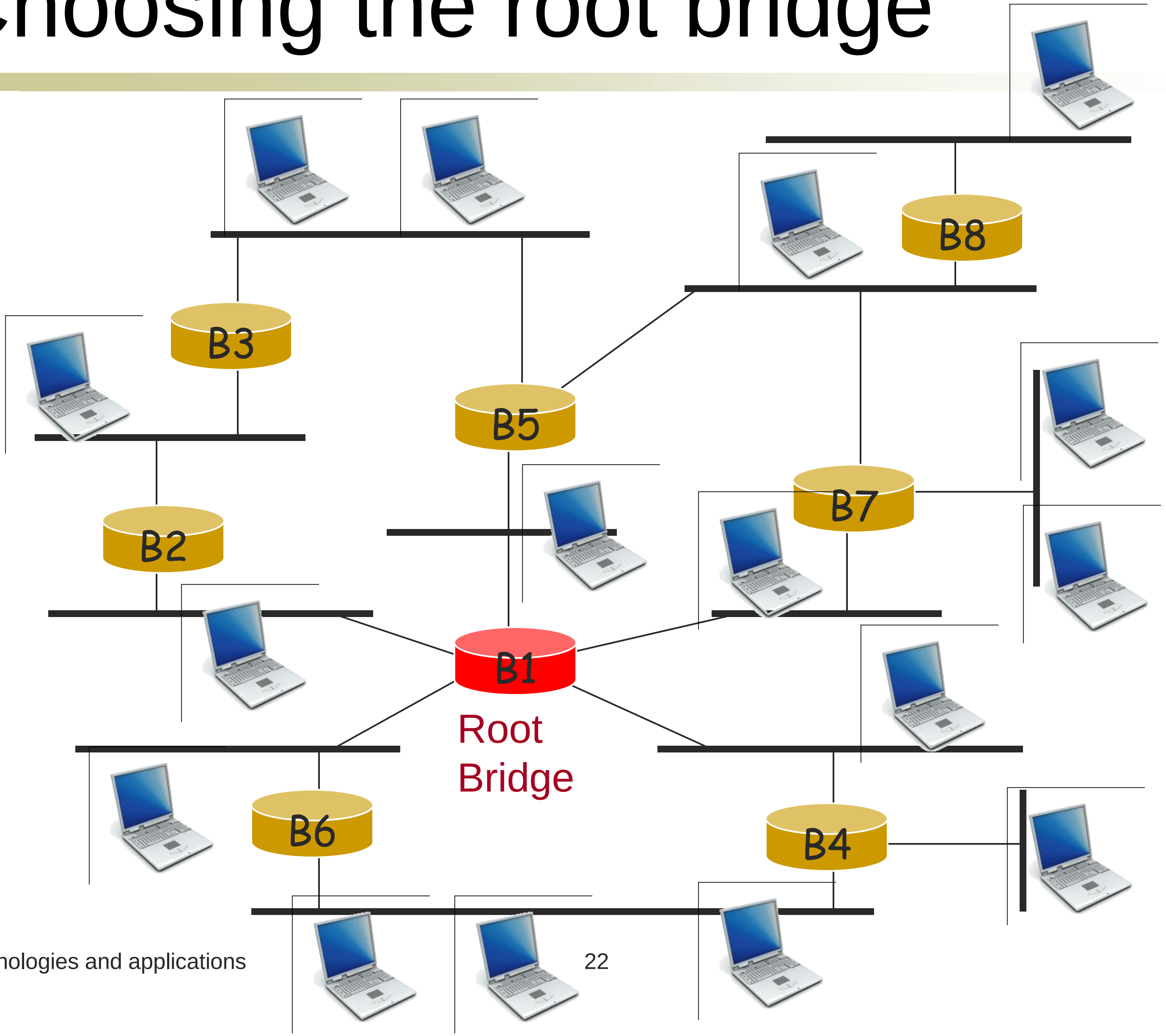
Example topology



STP operation

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

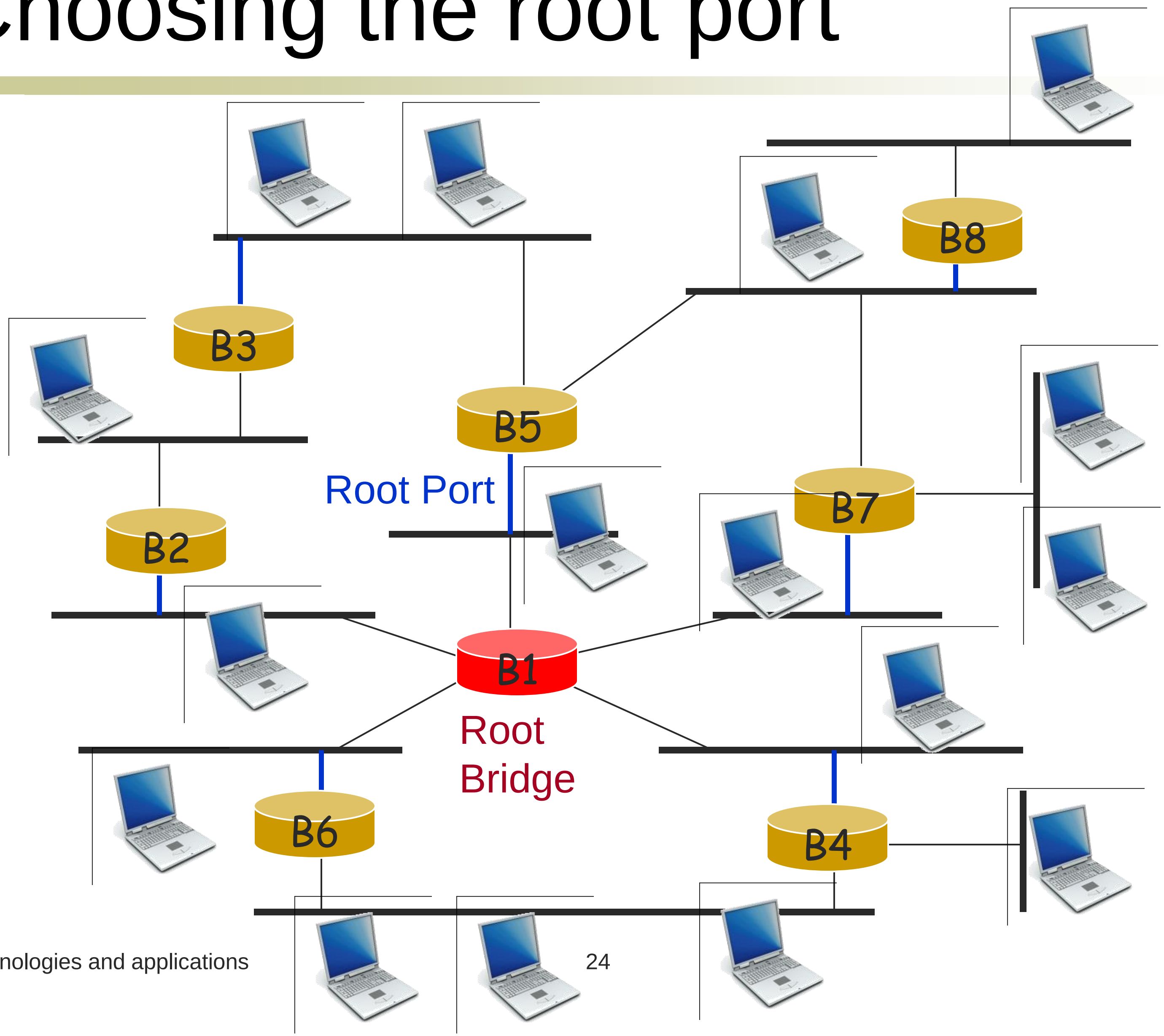
Choosing the root bridge



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

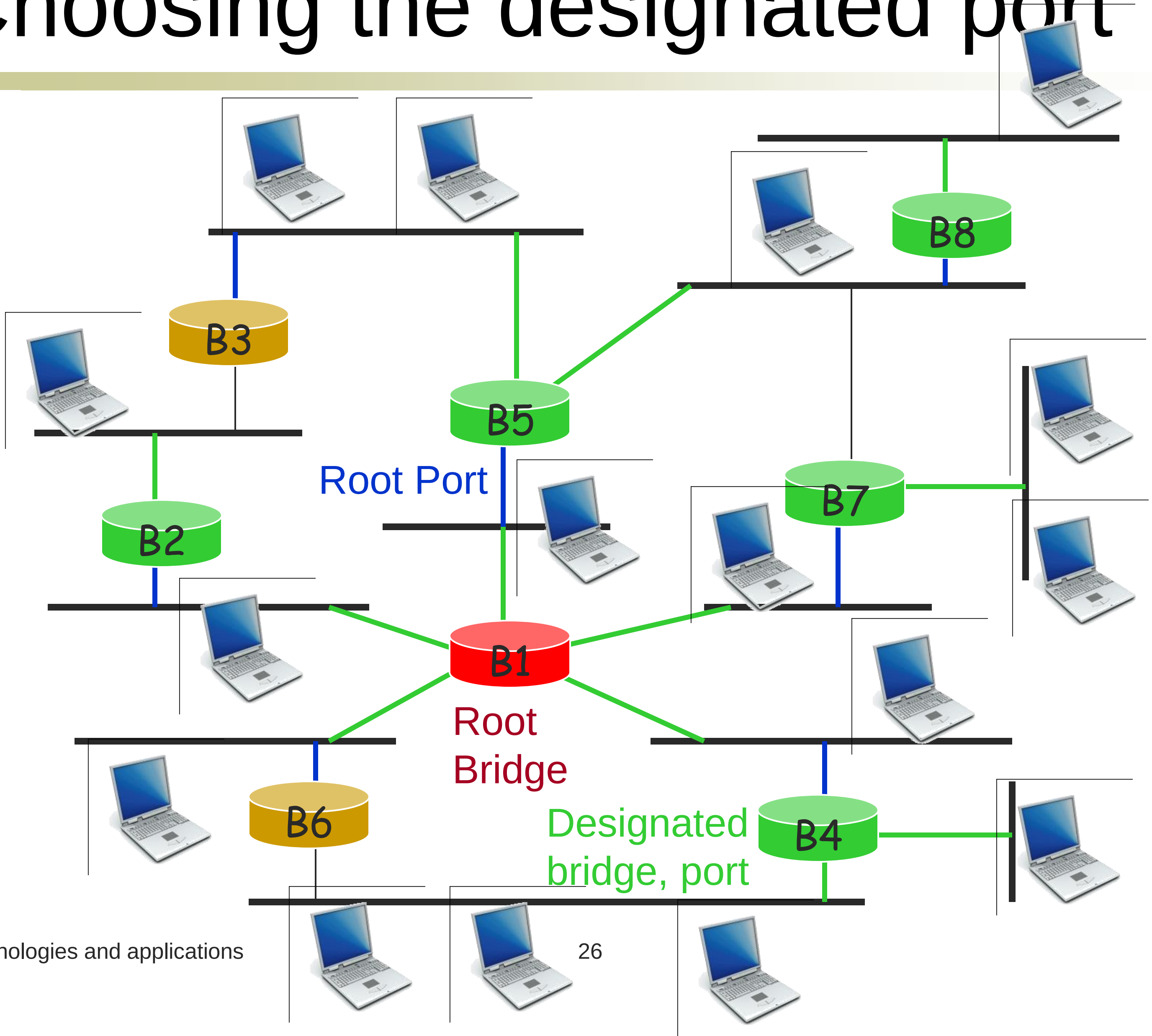
Choosing the root port



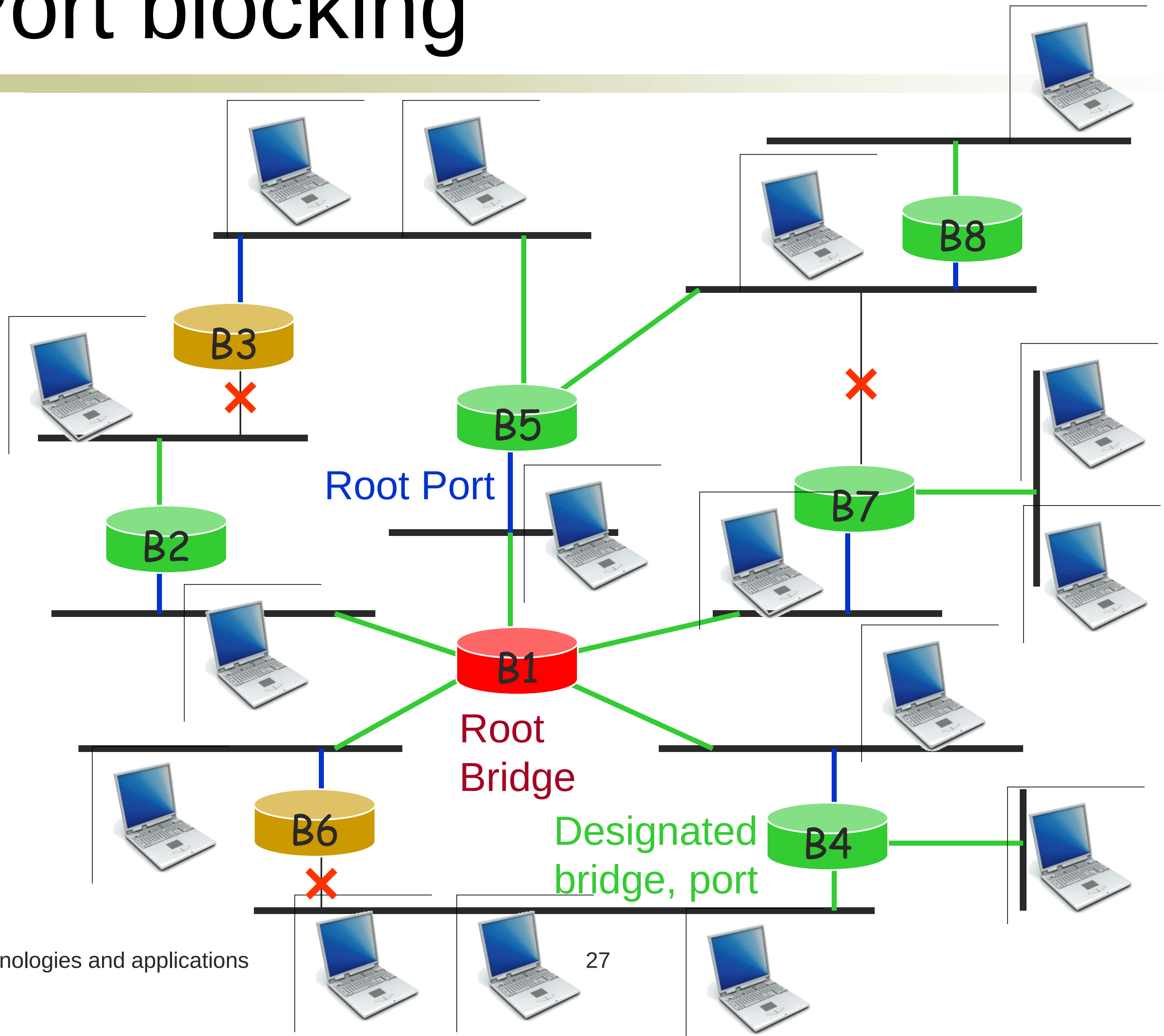
STP operation

- Finding the „cheapest” paths to the root bridge
  - 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 port



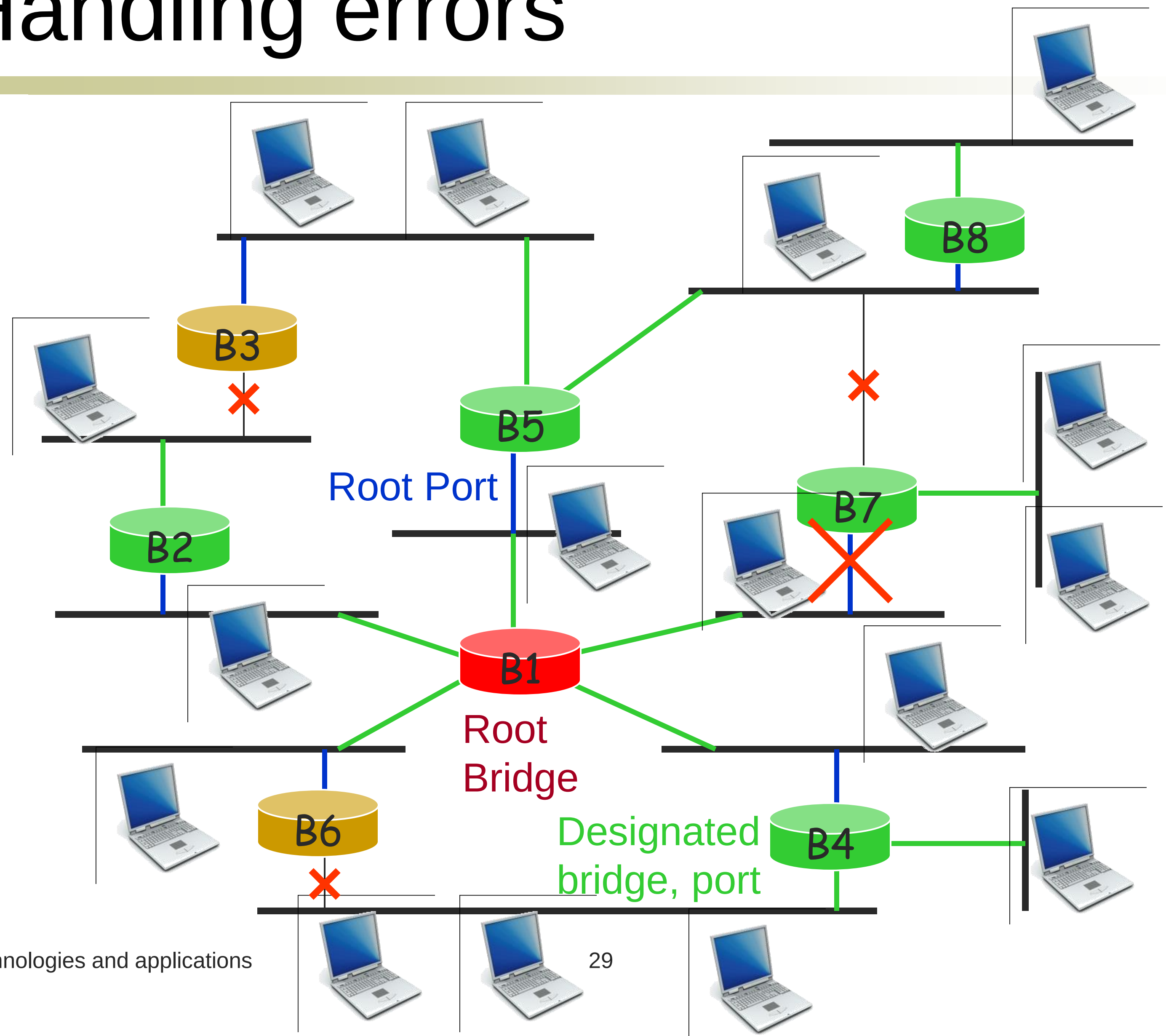
Port blocking



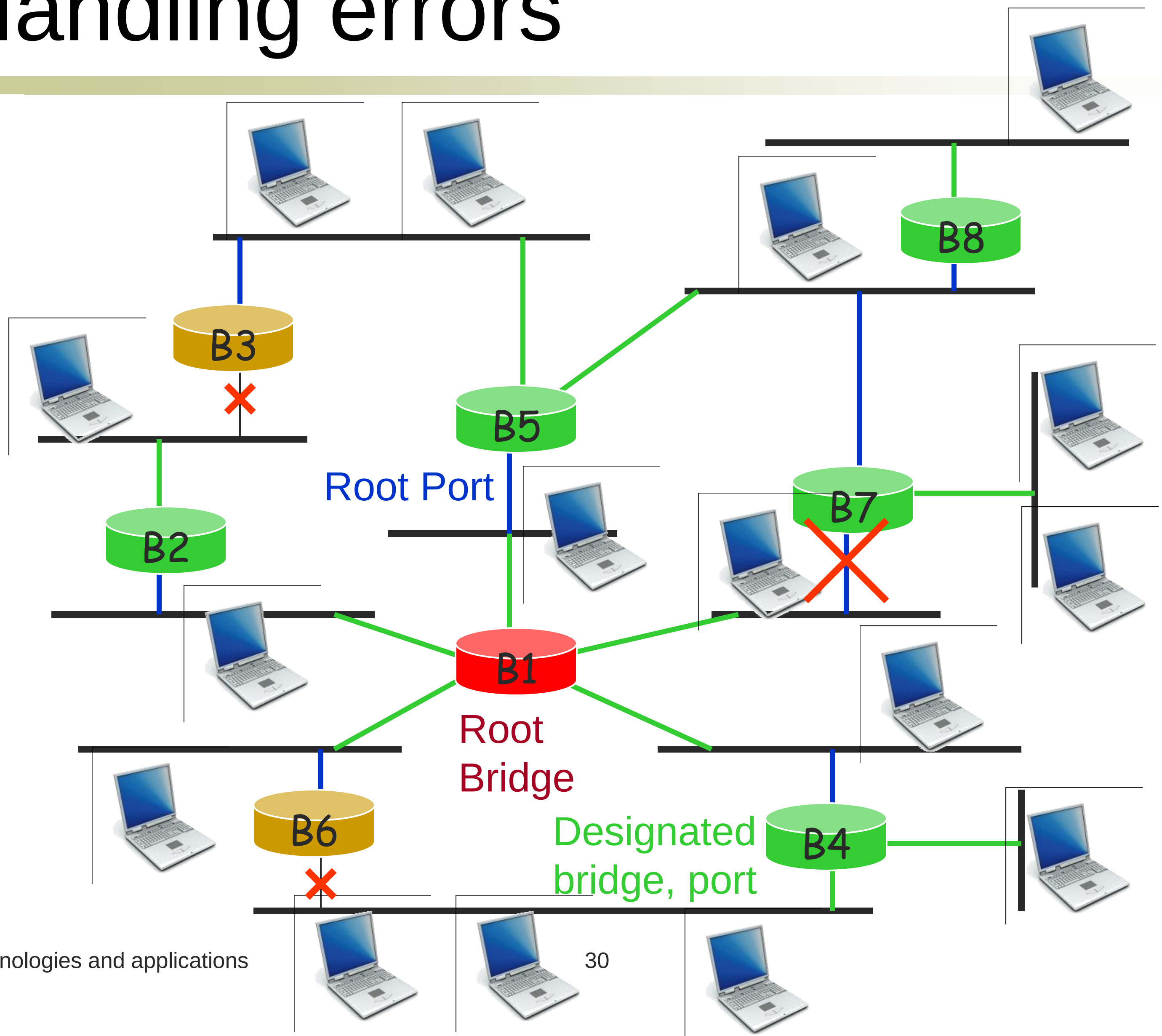
Handling errors

- 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



Too many wires

Bluetooth

- II. Harald Blaatand („Bluetooth”)
  - 940 – 981 AC
  - Viking king, united Denmark and Norway
- Ericsson initiative (1994)
  - Joining mobile phones, PDAs, other devices through a wireless connection
  - cheap devices with low radio range, low capacity
- SIG – Special Interest Group
  - Ericsson, IBM, Intel, Nokia, Toshiba

Bluetooth

- Initial goal – get rid of the wires
  - PAN – Personal Area Network
    - Many intelligent devices in our proximity
  - Competition on the WLAN domain as well
    - with IEEE 802.11
- Bluetooth SIG specification – 1999
  - 1500 pages document
  - Describes everything, from the physical layer to the application layer
- IEEE 802.15 standard (2002)
  - Describes only the physical and data link layer

Bluetooth network

- Piconet
  - One master and maximum 7 slave nodes
    - Slaves in a 10 meter range from the master
- Many piconets form a scatternet
- Besides the active slaves, at most 255 parked nodes
  - The master sends them to a „sleeping" mode
    - Battery is spared
    - Do nothing, wait for the activation from the master
- The main idea is to build a cheap architecture
  - Bluetooth chips cheaper than 5 USD
    - Dummy slaves, do what the master orders
  - Piconet – frequency division multiplexing – FHSS
    - The master controls the clock, assigns the time slots
    - Two slaves communicate only through the master
    - A master in a piconet can be a slave in the other