Local Area Networks

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Outline

- Introduction
- History
- Ethernet
- Bridging

Introduction

- Wide Area Network
  - WAN : Wide Area Network
  - country, continent
  - PSTN, Internet
- Metropolitan Area Network
  - MAN : Metropolitan Area Network
  - campus, city
  - FDDI, Metro Ethernet
- Local Area Network
  - LAN : Local Area Network
  - company
  - Ethernet
- Personal Area Network
  - PAN : Personal Area Network
  - room
  - Bluetooth

Introduction

- LAN
  - Limited to some buildings
  - Resources Sharing
    - Printers
    - File servers
    - Database Access
    - Internet Access
  - Topology
    - Bus
    - Ring
    - Star

Channel Allocation

- Static Allocation
  - Simple: a portion of the bandwidth is allocated to each user
  - Good performances when users have always data to transmit
  - Bandwidth wasting in normal use
- Dynamic Allocation
  - Complex
  - On demand bandwidth allocation to overcome bandwidth wasting in static allocation
  - Access Methods
    - Random Methods
    - Token-based Methods

Aloha

- Aloha System
- Work of Norman Abramson and his colleagues at Hawaii University in the 70s
- Connect many terminals dispersed over many islands to a mainframe (Menehune) at Oahu island (Hawaii University)
- Radio Networks
- Two frequencies are used
  - The first frequency is used in multiple access by terminals to communicate with the mainframe
  - The second frequency is used by the mainframe to communicate with terminals
- Researchers of Hawaii University had used later the same concept of Aloha to connect Hawaii with NASA-Ames via a satellite channel

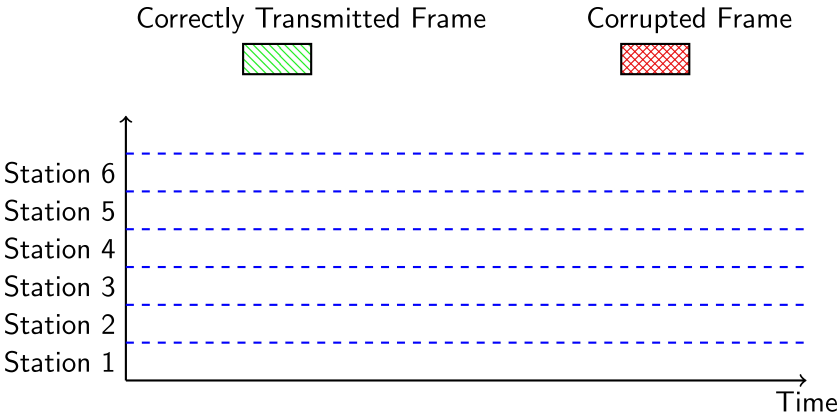
Aloha

- Radio Networks
  - Terminals can access the channel when they have data to transmit using the first frequency
  - Terminals listen on the second frequency waiting for acknowledgment (Waiting Time $>$ 2 times Round Trip Time)
  - If no acknowledgement is received, terminals try to retransmit again after a random time
- Satellite Networks
  - All stations share the rising channel
  - Signal received by the satellite is retransmitted over the falling channel
  - Stations listen on the falling channel and check the success of the transmission
  - Round Trip Time is 270 ms

Aloha

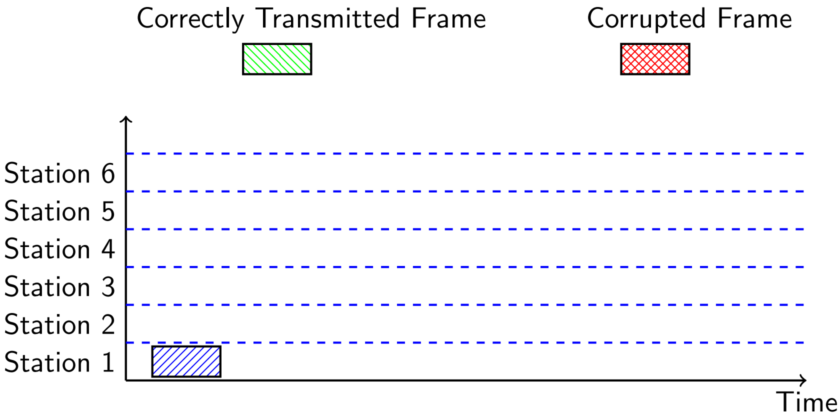
- Easy to implement
  - No synchronization is needed between stations
  - Each station transmits when it has data to transmit
- Bad performances
  - 18% of bandwidth is used in best cases
  - Frequent collisions
  - A collision occurs when two frames are transmitted at the same time (Worst case: the first bit of frame is transmitted with the last bit of a second frame)
    - The two frames are rejected
    - Waiting time before retransmission to prevent a new collision

Aloha



Correctly Transmitted Frame
Corrupted Frame
Station 6
Station 5
Station 4
Station 3
Station 2
Station 1
Time

Aloha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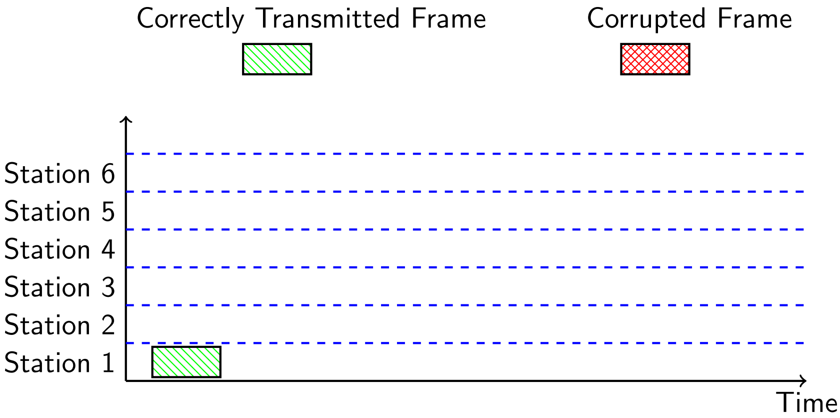
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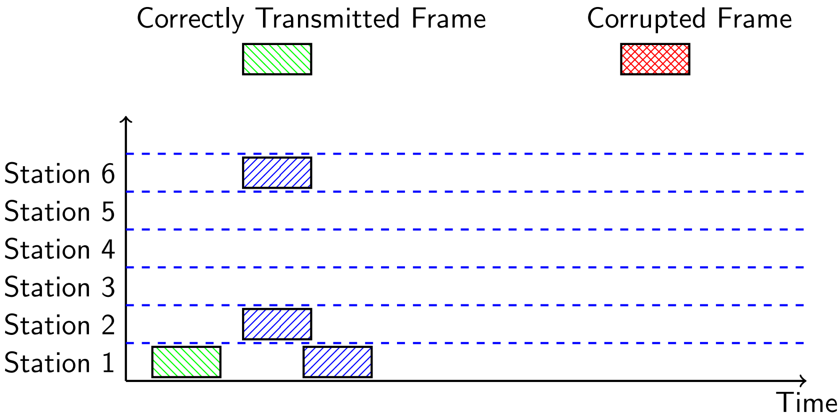
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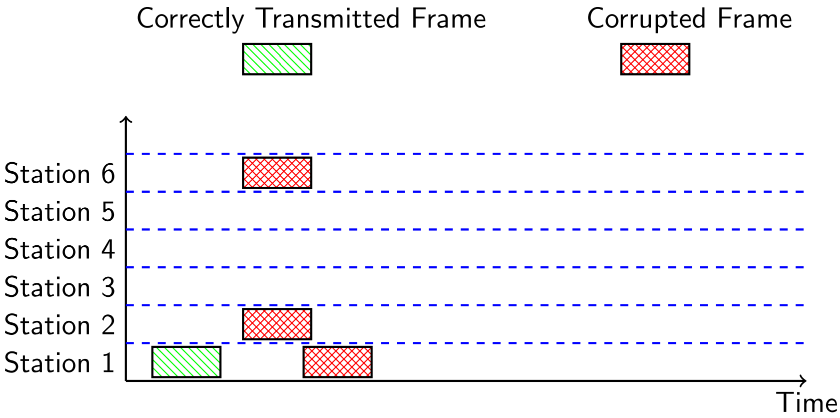

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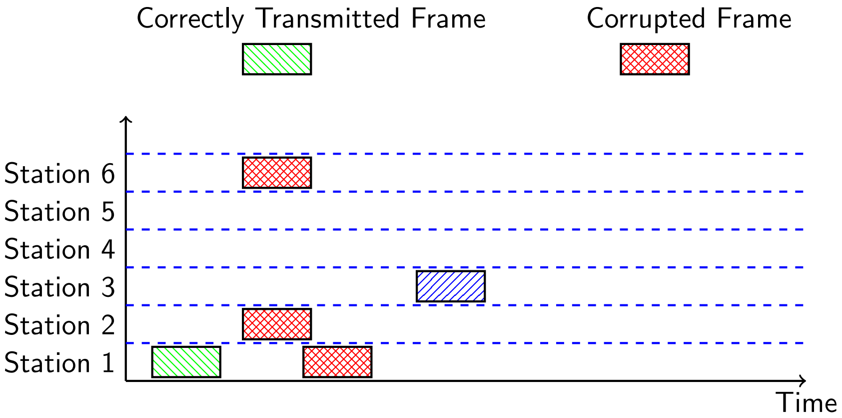
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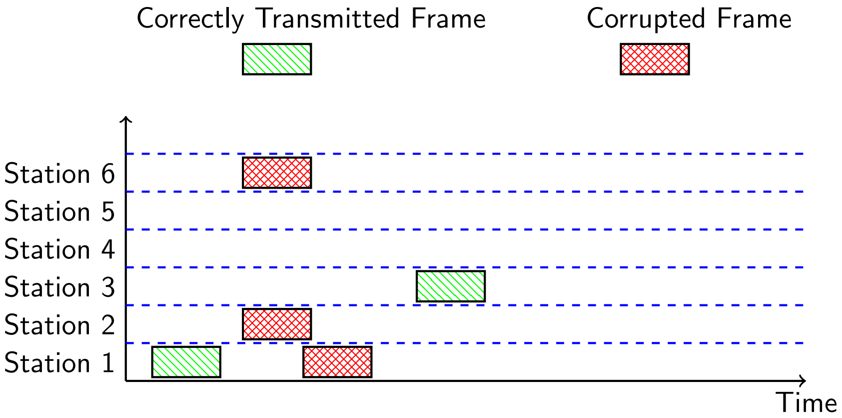

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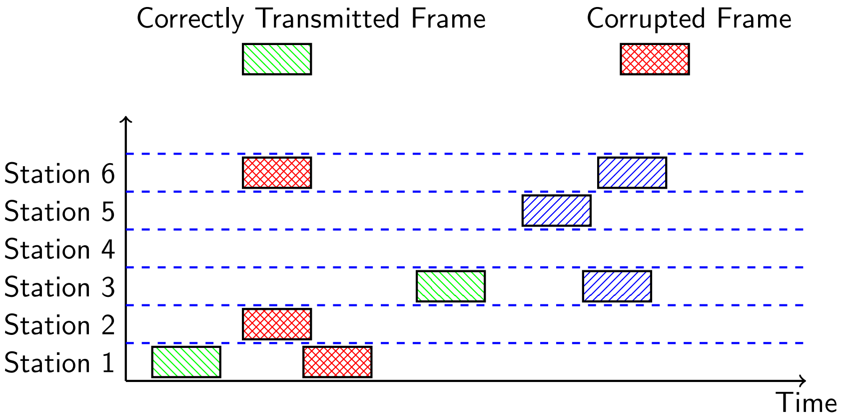

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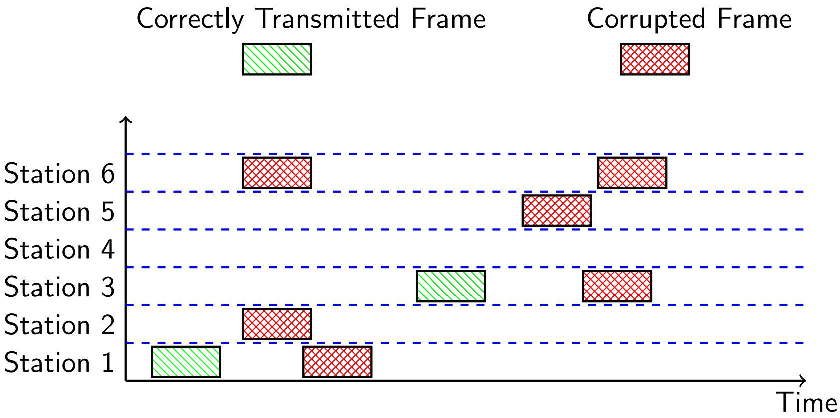
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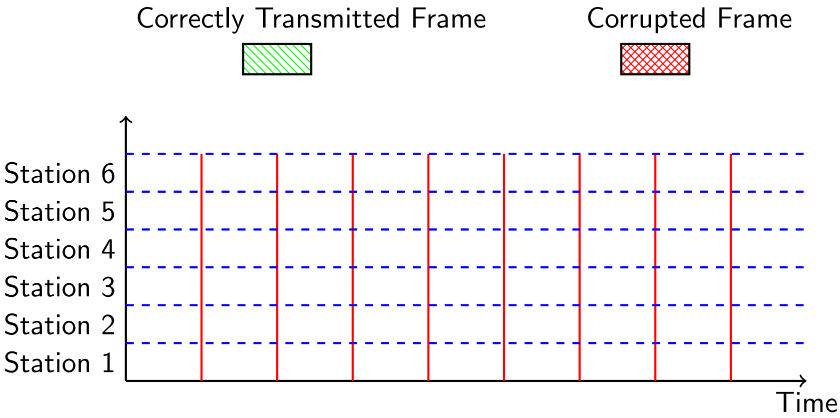
Time

Slotted Aloha

- Slotted ALOHA
- Time is divided in slots
- Transmissions are allowed only at the start of slots
- Stations listen on the output channel, if a collision is detected
  - Retransmission of the frame after random time (integer multiple of a slot size)
- Difficult to implement
- Good performances
  - 36% of bandwidth is used in best cases

Slotted Aloha



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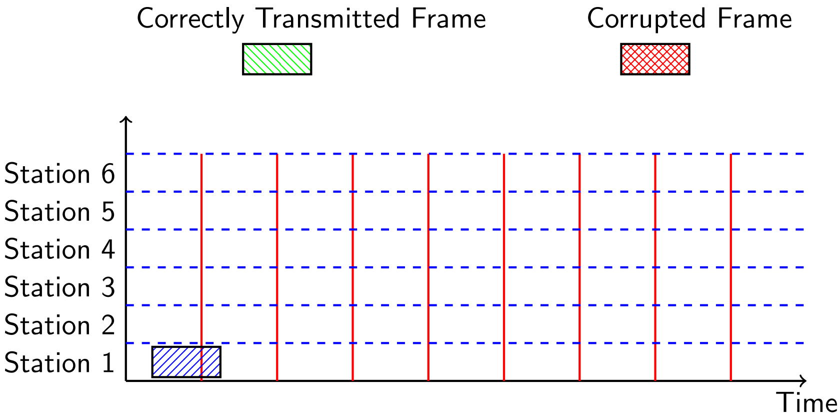

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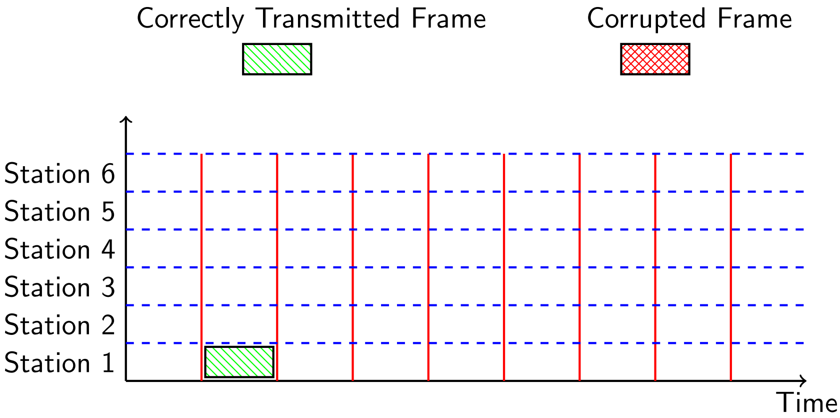

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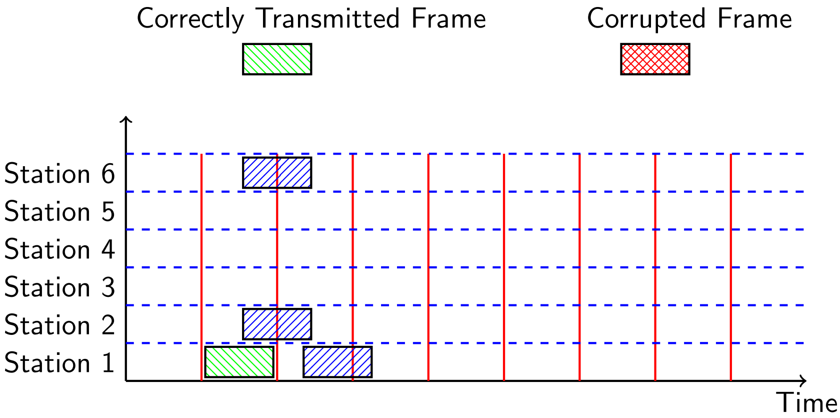

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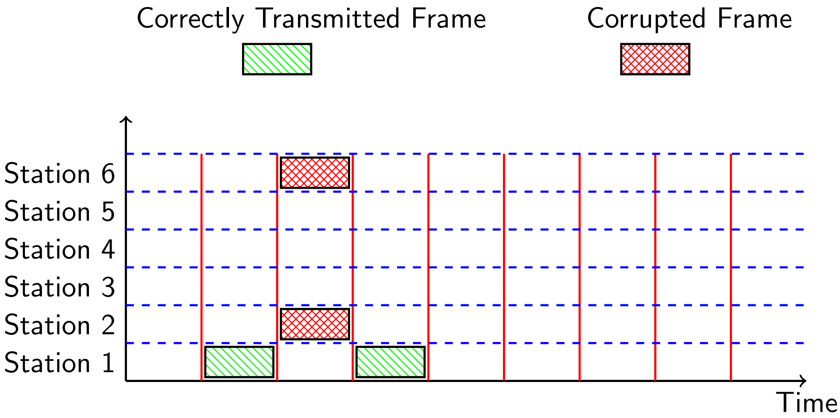

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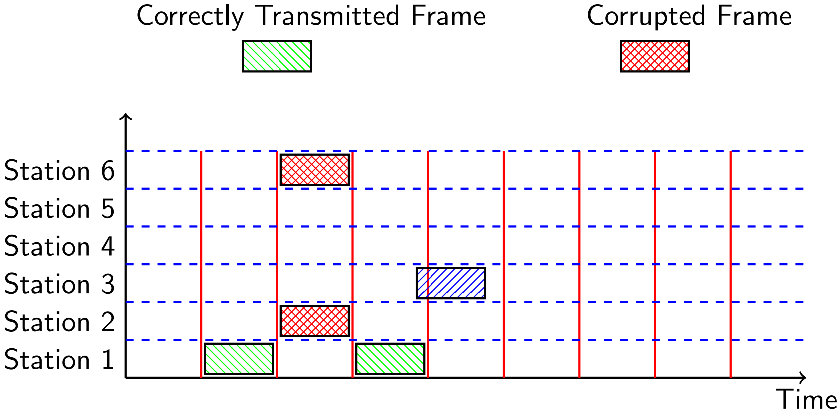

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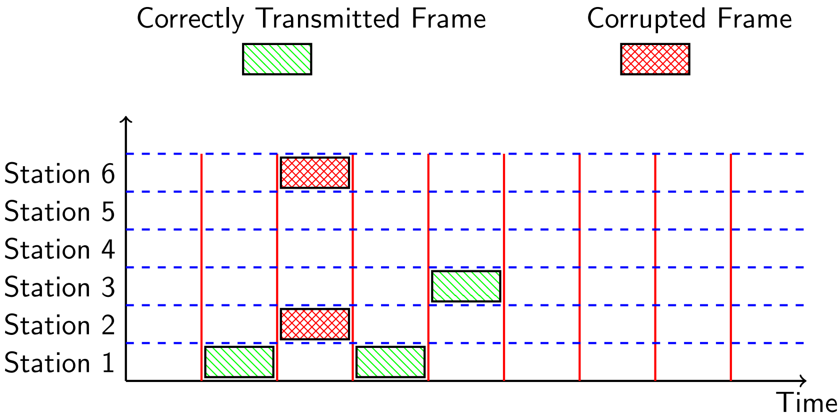

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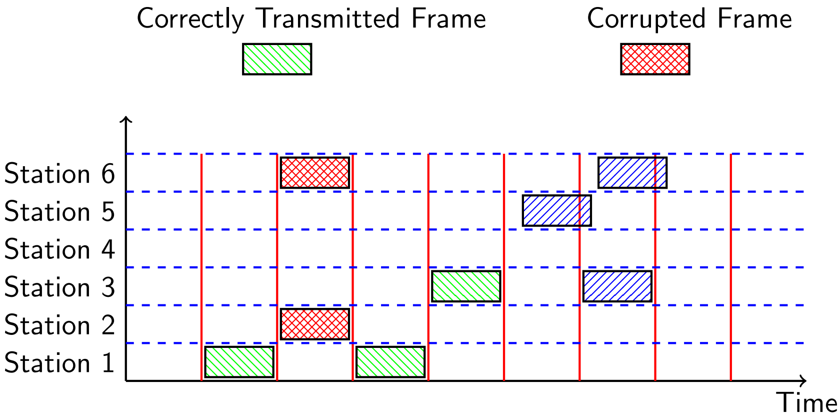

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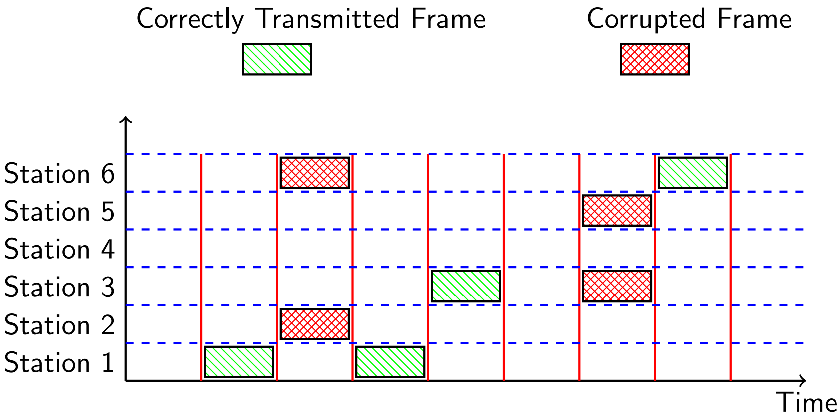
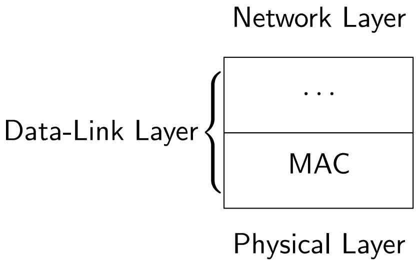


Standardization Organizations

- IEEE
  - Institute of Electrical and Electronics Engineers
- IEEE 802.2 (LLC)
- IEEE 802.3, ISO 8802.3 (Ethernet)
- IEEE 802.4, ISO 8802.4 (Token Bus)
- IEEE 802.5, ISO 8802.5 (Token Ring)

MAC Sub-Layer

- MAC: Medium Access Control
- Sub-Layer of the Data-Link Layer
- Controls multiple accesses to a shared channel of a Local Area Network
- How to control access to the transmission channel?
  - CSMA/CD
  - Token Ring
  - Token Bus



Ethernet

- History
  - Xerox PARC (Palo Alto Research Center)
  - Robert Metcalfe and David Boggs
    - 1973: Invention
    - 1976: Publication, "Ethernet: Distributed Packet-Switching for Local Computer Networks"
    - 1979: Digital Equipment, Intel, Xerox (Standard)

Ethernet

- 10base2
  - Thin Ethernet
  - BNC T Connector (BNC: Bayonet Nut Connector)
  - BNC Terminator
  - 10 Mbps
- 10base5
  - Thick Ethernet
  - DB-15 Connector
  - Yellow Ethernet
  - 10 Mbps
- 10baseT
  - Hub
  - RJ45 Connector (RJ45: Registered Jack-45)
  - 10 Mbps

CSMA

- CSMA: Carrier Sense Multiple Access
- Uses the same concept of Aloha
- Multiple access by sensing the carrier
- All stations listen continuously on the channel
- A station that wants to transmit a frame may transmit its frame if the channel is free
- If the channel is busy, the station delays its retransmission until the channel becomes free

CSMA

- Non persistent CSMA
  - If the channel is busy, the sender waits a random time before restarting the transmission procedure (sensing the carrier)
- Persistent CSMA
  - If the channel is busy, the sender waits until it becomes free to send its frame
- P persistent CSMA
  - Like persistent CSMA, but when the channel becomes free, the sender transmits its frame with a probability p and delays the transmission with a probability (1-p)

CSMA/CD

- CSMA/CD: Carrier Sense Multiple Access/Collision Detection
- Collision Detection
  - The station listens the channel while it is transmitting its frame
  - If the station detects a collision
    - It stops the frame transmission
    - It transmits a 32 bit signal that is different from the FCS correspondent to yet transmitted bits to allow others stations to notice the collision
  - It performs back off algorithm
  - A collision is detected if received bits are different from transmitted bits
  - Collision detection circuit detects a collision if the received voltage is different from an authorized voltage

CSMA/CD

- Analogy with Aloha
  - Why collision detection is not possible with Aloha?
  - Propagation Time $\gg$ Transmission Time
  - Propagation Time (270ms)
  - Transmission Time (51.2 μs for a 64 byte frame at a rate of 10Mb/s)
- LAN
  - Propagation Time is negligible in the case of Local Area Networks
  - Propagation speed in the void $3 * 10^8 m/s$
  - Propagation speed in copper $2 * 10^8 m/s$
  - The frame must have enough size in order a collision could be detected

CSMA/CD

- Minimal Length of an Ethernet Frame
  - $>$ 2 * maximal propagation time
    - Maximal length with 4 repeaters: 2.5km
    - $(2.5km/2 * 10^8) = 12.5\mu s$
    - RTT (Round Trip Time) = 25 μs
  - Minimal transmission time is fixed to 51.2 μs (Propagation time + delay introduced by repeaters)
  - With a rate of 10Mb/s, 51.2 μs corresponds to the transmission of 512 bits
  - The minimal size of an Ethernet frame is 64 bytes
  - 14 bytes for the header + 46 bytes for data + 4 bytes for the CRC
  - Padding is used if data length is smaller than 46 bytes

CSMA/CD

- Maximal Length of an Ethernet Frame
  - 1518 bytes
  - 1500 bytes for data + 18 bytes for control
  - To avoid starvation: Fair Sharing of Bandwidth
- Minimal Time between two successive frame transmissions
  - 9.6 μs
  - IFG : Inter Frame Gap
  - To allow electronic components of the receiver to process the previous frame

Backoff Algorithm after a Collision

- Exponential Backoff Algorithm
  - After collision detection, each station waits a period of time before restarting the corrupted frame retransmission
  - Waiting period is a multiple of the period needed for the transmission of 512 bits (51.2 μs): T = 51.2 μs
  - After the detection of the first collision, each station retransmits its frame after a period randomly selected from 0, 1* T
  - After the detection of the i^{th} collision, each station retransmits its frame after a period randomly selected from 0, 1,. . .,2k -1*T, where k = MIN (i, 10)
  - Maximal number of transmissions is fixed to 16
    - Notification of an error

Performances

- Maximal use
  - Aloha (18%)
  - Slotted Aloha (36%)
  - 1-persistent CSMA (50%)
  - 0.5-persistent CSMA (70%)
  - 0.1-persistent CSMA (90%)
  - non-persistent CSMA (90%)
  - 0.01-persistent CSMA (99%)

Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes
Preamble	SFD	Dest Add	Src Add	Type	Data/Padding	FCS

- Preamble
  - 7 bytes
  - 10101010
  - Synchronization
- SFD
  - 1 byte
  - Start Frame Delimiter
  - 10101011
  - Start of the frame

Frame Format

Preamble	SFD	Dest Add	Src Add	Type	Data/Padding	FCS
7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes

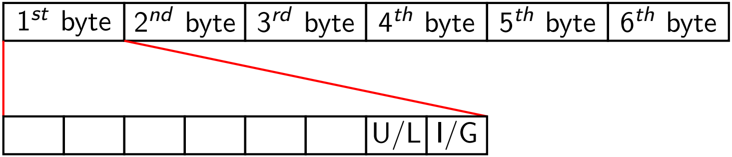
- Dest Add
  - 6 bytes
  - Destination Address
- Src Add
  - 6 bytes
  - Source Address
- Address Format
  - Unicast/Multicast/Broadcast Address
  - Local/Universal Address

Frame Format

- MAC Address Representation
  - 6 group hexadecimal representation separated by comma (:)
  - Examples
    - 00:a0:24:53:b9:03
    - 00:00:c0:4a:d8:c5
  - First three bytes identify the card manufacturer
    - 00:a0:24:53:b9:03; 00:a0:24 3Com
    - 00:00:c0:4a:d8:c5; 00:00:c0 SMC (Std. Microsystems Corp., ex Digital)
  - Last three bytes are assigned by the manufacturer of the card

Frame Format

- MAC Address Format



  - U/L: Universal/Local
    - U/L = 0: Universal Address
    - U/L = 1: Local Address
  - I/G: Individual/Group
    - I/G = 0: Individual Address: Unicast Address
    - I/G = 1: Group Address: Multicast Address
- Broadcast Address
  - FF:FF:FF:FF:FF:FF
  - Group Address
  - Local Address

Frame Format

Preamble	SFD	Dest Add	Src Add	Type	Data/Padding	FCS
7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes

- Type
  - 2 bytes
  - Type of the data transported by the frame
  - 0x800 : IP
  - 0x806 : ARP
- Data
  - 0 - 1500 bytes
  - Data transported by the frame
  - Padding

Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes
Preamble	SFD	Dest Add	Src Add	Type	Data/Padding	FCS

- FCS : Frame Control Sequence
  - CRC
  - 4 bytes
  - Cyclic Redundancy Check

Transmission Order in Ethernet

- Byte Transmission Order
  - From left to right
- Bit Transmission Order in a byte
  - From right to left
  - Low order bit is transmitted first
  - High order bit is transmitted last
- Example:
  - 01:80:C2:00:00:00 multicast address
  - Binary Representation
    - 00000001:10000000:11000010:00000000:00000000:00000000
  - On the wire
    - 10000000:00000001:01000011:00000000:00000000:00000000

Encoding

- Ethernet (10Base5, 10Base2, 10Base-T, 10Base-F)
    - Manchester Encoding
- Fast Ethernet
- 4B/5B Encoding
    - $(0000 \rightarrow 11110, 0001 \rightarrow 01001, \ldots, 1111 \rightarrow 11101)$
- 100BASE-FX : (4B/5B) + NRZI
    - NRZI (Non-Return-to-Zero, Invert-on-one)
        - 1: Transition (1, -1)
        - 0: No transition
- 100BASE-TX : (4B/5B) + MLT-3
    - MLT-3 (Multiple Level Transition - 3 levels) or NRZI-3
        - 1: Transition (0, 1, 0, -1, 0)
        - 0: No transition

Ethernet vs. IEEE 802.3

- Ethernet
  - Product developed by Digital Equipment, Intel, Xerox (De facto Standard)
- IEEE 802.3
  - IEEE Standard uses CSMA/CD 1-persistant access method (like Ethernet)
  - The Type field in Ethernet is replaced by the Length field in IEEE 802.3 frame
  - The Length field (2 bytes) indicates the length of IEEE 802.3 Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes
Preamble	SFD	Dest Add	Src Add	Length	Data/Padding	FCS

Ethernet vs. IEEE 802.3

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes
Preamble	SFD	Dest Add	Src Add	Typ/Len	Data/Padding	FCS

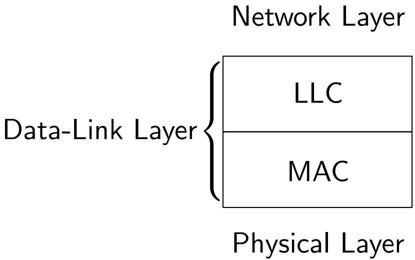
- Cohabitation
  - Ethernet and IEEE 802.3 may be used simultaneously over the same bus
  - How can we distinguish between an Ethernet frame and a IEEE 802.3 frame?
  - Type/Length field
  - If Type/Length field $\geq$ 1536
    - Ethernet frame
    - Type field
  - If Type/Length field $<$ 1536
    - IEEE 802.3 frame
    - Length field

Switched Ethernet

- An Ethernet switch is a hub with a processor, memory, and a high speed internal bus
  - When the switch receives a frame over a giving port, he withdraws the frame and looks over which port he must send it. If this port is busy, he stores the frame in his memory until the port becomes free
- It allows good bandwidth use
- It causes a problem when the traffic is addressed to a single specific station (server and many clients)
  - Use 100Base-TX for the port connected to the server and 10BaseT for other ports
  - It doesn't allow a network parser to listen to traffic over the network
  - Promiscuous mode is Ethernet allows the capture of the whole traffic

LLC Sub-Layer

- Logical Link Control
- IEEE 802.2 Standard
- Common Sub-Layer for all MAC Sub-Layers: IEEE 802.3, IEEE 802.4, IEEE 802.5



LLC Sub-Layer - Frame Format

1 byte	1 byte	1 byte	43-1497 bytes
DSAP	SSAP	Control	Data/Padding

- Frame Format
  - DSAP : Destination Service Access Point
  - SSAP : Source Service Access Point
  - Control : 3 frame types
    - I (Information)
    - S (Supervisory)
    - U (Unnumbered)

LLC Sub-Layer

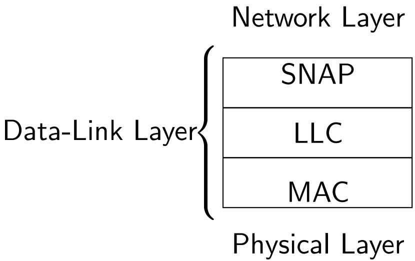
- Services offered by the LCC Sub-Layer to the Network Layer
  - LLC Type 1 :
    - Connectionless service without acknowledgement
  - LLC Type 2 :
    - Connection oriented service
  - LLC Type 3 :
    - Connectionless service with acknowledgement

SAP

- Service Access Point
  - 0000 0000 : 00 Null LSAP
  - 0101 0101 : AA SNAP
  - 0100 0010 : 42 Bridge Spanning Tree Protocol
  - 0100 0000 : 40 Individual LLC sublayer management
  - 1100 0000 : 30 Group LLC sublayer management
  - 0010 0000 : 20 SNA Path Control
  - 0110 0000 : 60 DoD IP protocol
  - 0111 1111 : EF OSI network protocol
  - 1111 1111 : FF Global DSAP

SNAP

- Sub Network Access Protocol
- LLC
  - DSAP : 0xAA
  - SSAP : 0xAA
  - Control : 0x03



SNAP

3 bytes	2 bytes	38-1492 bytes
OUI	Type	Data/Padding

- SNAP
  - OUI (Organizationally Unique Identifier, 3 bytes) : 0x000000
  - Type (2 bytes) : Ethernet Type

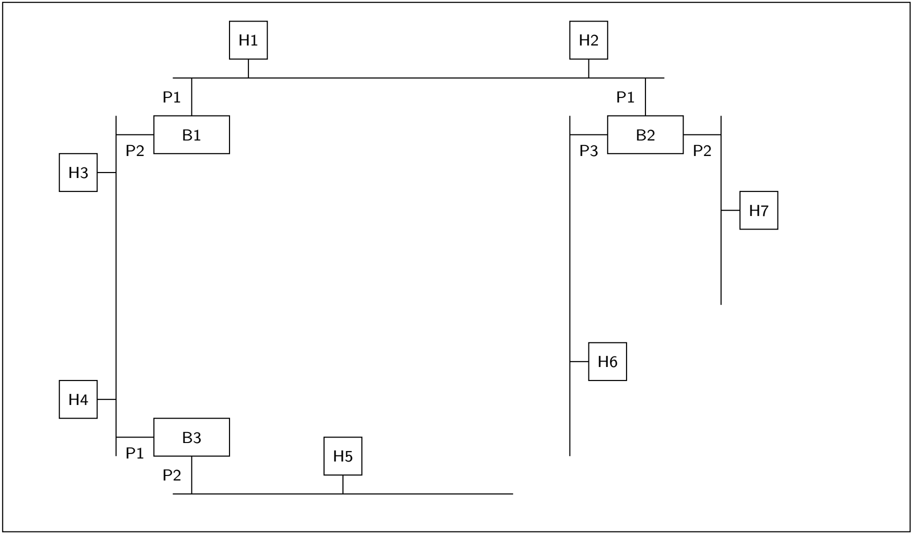
Bridging

- Interconnection between two or more networks at the Data-Link Layer
- Bridge: equipment allowing the interconnection between two or more networks at the Data-Link Layer level
- Advantages
  - Allowing communication between two equipments belonging to two different networks using two different MAC technologies
    - IEEE 802.3 and IEEE 802.5
  - Increasing the rate and reducing the collision probability on an Ethernet network by separating the network in two parts

Transparent Bridges

- Bridge operates in auto-learning mode
- When the bridge receives a frame on a giving port, it uses the source address field of the frame to locate the sender station
- After that the bridge reads the destination address of the frame and looks in its table to see to which port the destination station is attached and sends the frame on that port
- If the bridge does not find a correspondent output port, it sends the frame on all its ports except the port on which it had received this frame
- Problem: infinite circulation (looping) of some frames!!!

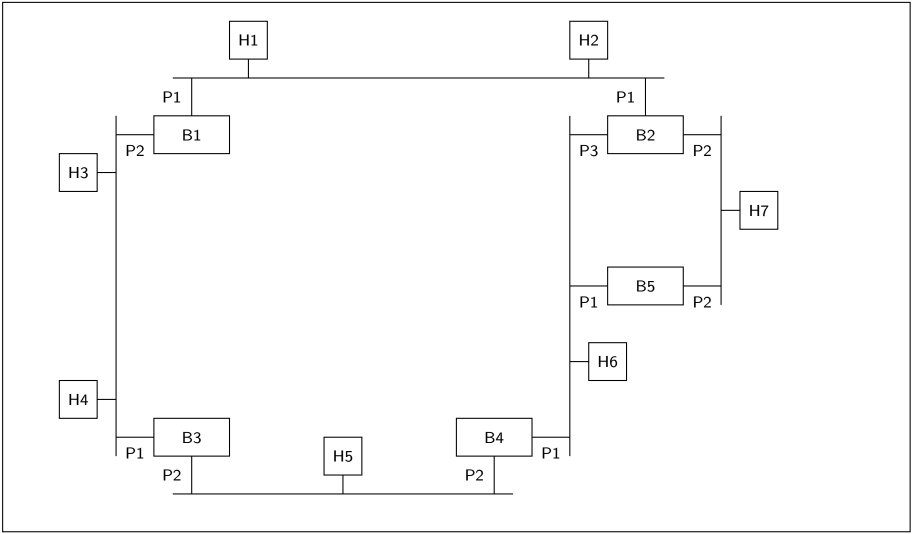
Transparent Bridges



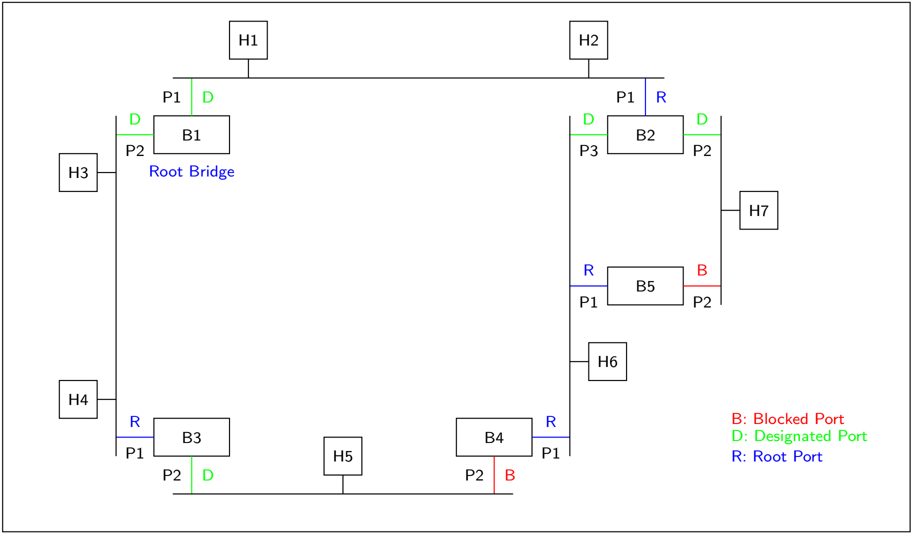
Spanning Tree Bridges

- To resolve the problem of loops with transparent bridges, Spanning-Tree Algorithm is used
- Construct a spanning tree that contains all networks
  - Choose the bridge having the highest priority as the root bridge of the tree
  - When two bridges have the same priority, the bridge having the biggest address will be selected as the root bridge
  - Bridges exchange messages periodically to maintain the tree by adding new bridges/networks and withdrawing non-operational bridges/networks
  - Bridges will block some ports to avoid loop configuration
  - Non-efficient solution pas

Spanning Tree Protocol



Spanning Tree Protocol



Source Routing Bridges

- Sender station must add to the frame the route to fellow in order to arrive to the destination
- Route is composed by a list of networks and bridges that must be traversed by the frame to arrive to the destination
- If the destination does not belong the local network, the most significant bit of the destination address must be set to allow bridges to process only frames that are addressed to distant networks
- The bridge selects frame that have the most significant bit of the destination address set and looks if it is on the list of the route of the frame, if it is the case, it sends the frame on the network mentioned after it on the list

Source Routing Bridges

- How stations know routes to other stations?
  - Each station broadcasts a message to ask routes for all other stations
  - Each station answers the previous message
  - When the response goes through a bridge , it adds its address and the address of the network to the message
  - Many responses arrive to the source station
  - Source station selects the bets route to each other station
- Problems
  - You have to learn the route before sending a new frame
  - The mechanism should be implemented by stations