Computer Networks. Unit 4: LANs

Notes of the subject *Xarxes de Computadors, Facultat Informàtica de Barcelona, FIB*

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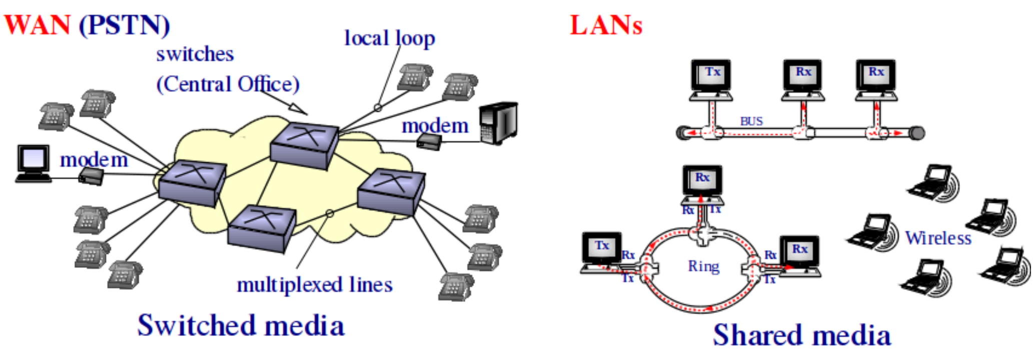
Contents

4 Unit 4: LANs

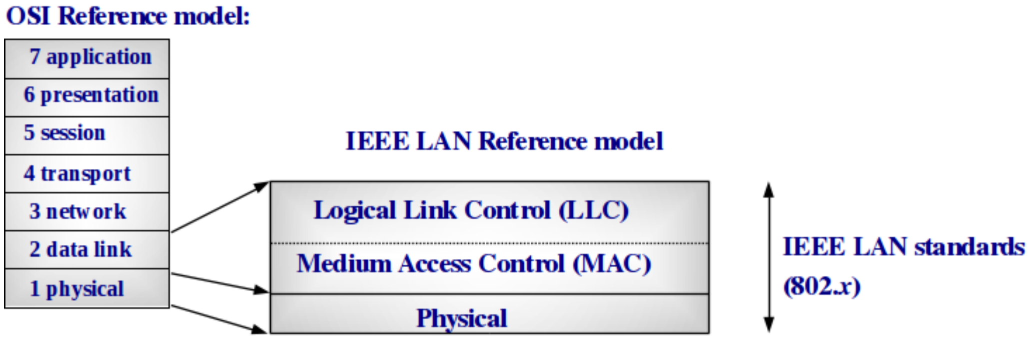
4.1 WAN vs LAN

- **LANs**:
  - **Multy-access** network with shared media
  - Medium Access Control (**MAC**) protocol
  - Ethernet has evolved to a **switched** network

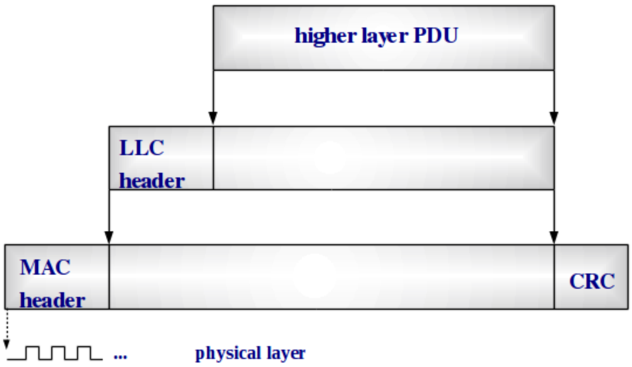


4.2 IEEE LAN Architecture

- **LLC** sublayer (802.2): Generic L2 layer common to all LAN standards (802.x)



4.2.1 LAN encapsulation



4.2.2 LLC header

3 / 4 bytes

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 bits
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Destination SAP| Source SAP    | Control       /
|               |               | 8 or 16 bits  /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SAP: Service Access Point

- Identify the **protocols** handling the frame
- Standardized by **IEEE**
- **SNAP** allows non IEEE protocol IDs

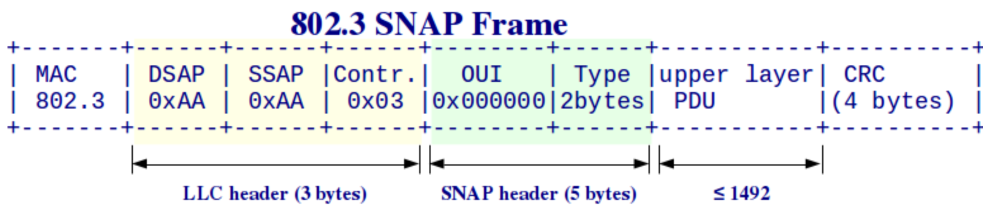
SAP (hex)	Protocol
06	ARPANET Internet Protocol (IP)
08	SNA
42	3IEEE 802.1 Bridge Spanning Tree Protocol
98	ARPANET Address Resolution Protocol (ARP)
AA	SubNetwork Access Protocol (SNAP)
E0	Novell Netware
F0	IBM NetBIOS
FF	Global LSAP

SNAP: used in TCP/IP

Example of some IEEE SAP values.

4.2.3 Ethernet with IEEE Sub-Network Access Protocol (SNAP)

- Used in **TCP/IP**
- **Type** field identifies the Ethernet frame payload.
- Values standarized by **IETF** in RFC1700 (Assigned Numbers - Ether Types)



4.2.4 Types of MACs

- **Token** Passing:

Only the station having the token can transmit. After transmission **the token is passed** to another station.

- Examples: FDDI and Token-Ring

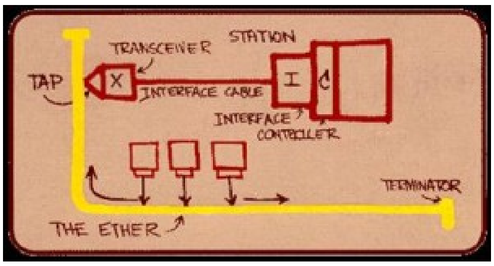
- **Random**:

There is no token. Instead, there is a non null collision probability. In case of **collision**, the frame is retransmitted after a **random backoff time**.

- Examples: Ethernet, WiFi

4.3 Ethernet

- Designed by **Bob Metcalfe** at Xerox in mid-1970s
- Original design: **random** access, **bus** topology
- Initially was commercialized by Digital, Intel and Xerox consortium (**DIX**)
- Standardized by **IEEE** (**802.3**) in 1983
- Nowadays Ethernet is the **leading** LAN technology



Original figure Bob Metcalfe

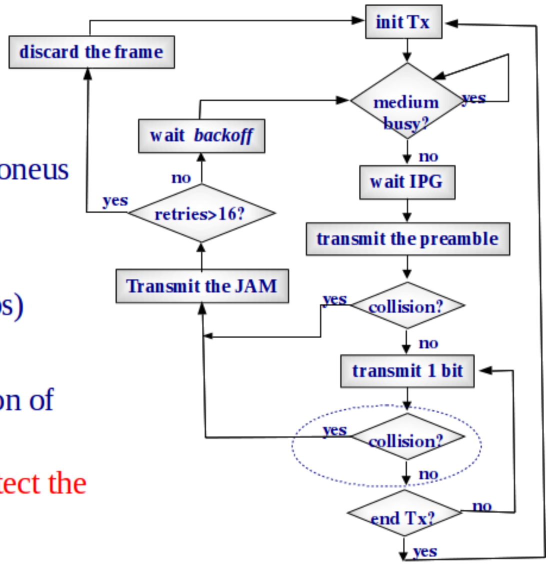
4.4 Ethernet MAC

- Carrier Sense Multiple Access/Collision Detection (**CSMA/CD**)
  - Is a random MAC where the stations **listen** the medium (**carrier sense**) before transmission.
  - When the medium is becomes free the frame is transmitted immediately, and the medium is listened to **detect collisions**.
  - In case of collision, the frame is retransmitted after a **random backoff time**.

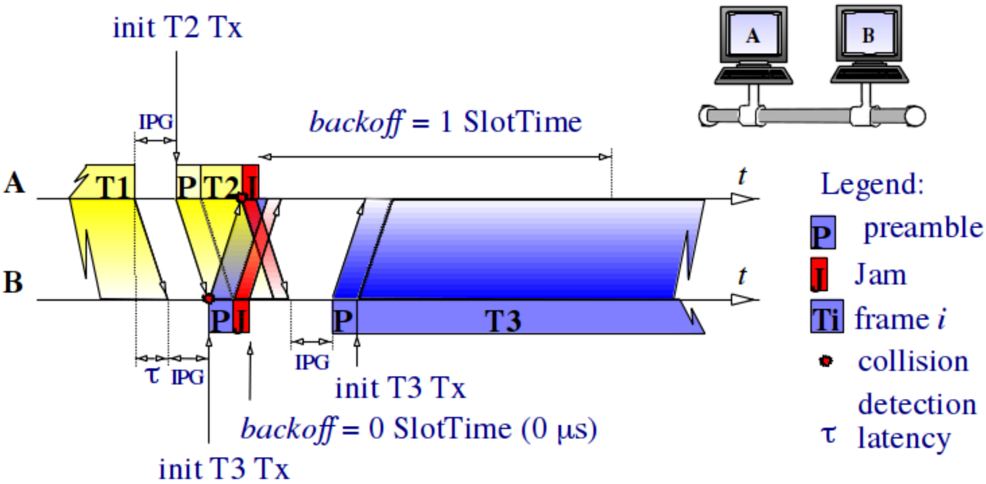
4.5 CSMA/CD

Legend:

- InterPacket Gap (IPG): 96 bits.
- JAM: 32 bits that produce an erroneus CRC.
- *backoff* = $n\,T_{512}$
- T_{512}:*SlotTime* (51,2 µs at 10 Mbps)
- n = random$\{0, 2^{\min\{N,\,10\}}-1\}$,
  - N: number of retransmission of the same frame (1, 2…)
- The transmitting station must detect the collision (no ack is sent).



4.5.1 CSMA/CD: Collision example



4.5.2 Half Duplex and full-duplex

- **Half Duplex**: only one NIC can be simultaneously transmitting into the medium. **CSMA/CD** is used
- **Full Duplex**: When 2 Ethernet NICs are connected **point-to-point**, some Ethernet standards allow a full-duplex Tx. **CSMA/CD** is NOT used (no collisions can occur).
- Ethernet NICs have an **auto-negotiation** mechanism to detect the full-duplex availability and bitrate (backward compatible)

4.6 Ethernet Frame

- DIX

```
+-----------+----------+---------+----------+-----------+----------+
|Preamble   |Destination|Source MAC|Frame type| Payload   | CRC      |
|(8 bytes)  |MAC Address|Address   |(2 bytes) |(46 to     |(4 bytes) |
|           |(6 bytes)  |(6 bytes) |          |1500 bytes)|          |
+-----------+----------+---------+----------+-----------+----------+
```

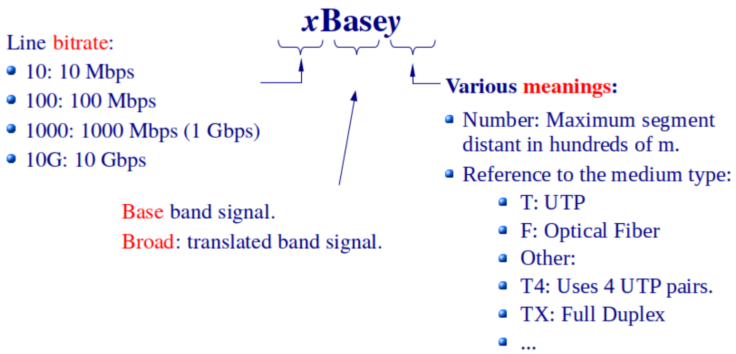
- IEEE

```
+-----------+----------+---------+----------+-----------+----------+
|Preamble   |Destination|Source MAC|Length of | Payload   | CRC      |
|(8 bytes)  |MAC Address|Address   |the frame |(46 to     |(4 bytes) |
|           |(6 bytes)  |(6 bytes) |(2 bytes) |1500 bytes)|          |
+-----------+----------+---------+----------+-----------+----------+
```

- Minimum payload of **46** bytes when **CSMA/CD** is used
- **Length** (IEEE): Payload size (0~1500)
- **Type** (DIX): Identifies the upper layer protocol (IP, ARP, etc.) RFC1700, Assigned numbers. Always > 1500
- TCP/IP with **IEEE encapsulation uses SNAP**
- The **MSS** indicated by TCP would be of **1460 with DIX** and **1452 with IEEE** (8 bytes of LLC+SNAP)

4.7 IEEE Ethernet standards

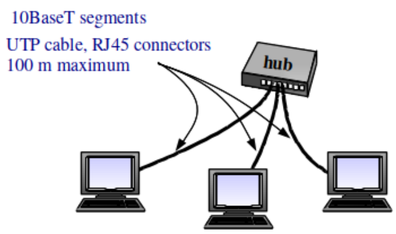
Standard: 802.3xx. Name convention:



Commercial name	bps	Standard	year	Name	Cabling	UTP/OF Pairs	Connector	Codification	segment distance*	
									Half duplex	Full duplex
Ethernet	10Mbps	802.3	1983	10Base5	Coax-thick	-	AUI	Manchester	500m	n/a
		802.3a	1985	10Base2	Coax-thin	-	BNC	Manchester	185m	n/a
		802.3i	1990	10BaseT	UTP-cat3	2	RJ45	Manchester	100m	100m
		802.3j	1993	10BASE-FL	FO	2	SC	on/off Manchester	2000m	>2000m
Fast Ethernet	100Mbps	802.3u	1995	100BaseTX	UTP-cat5	2	RJ45	4B/5B	100m	100m
		802.3u	1995	100BaseFX	FO	2	SC	4B/5B	412m	2000m
		TIA/EIA-785	1999	100BaseSX	FO/led	2	SC	4B/5B	300m	300m
Gigabit-Eth.	1Gbps	802.3z	1998	1000BaseSX	FO	2	SC	8B/10B	275-316m	275-550m
		802.3z	1998	1000BaseLX	FO	2	SC	8B/10B	316m	550-10000m
		802.3z	1998	1000BaseLH	FO	2	SC	8B/10B	n/a	100km
		802.3ab	1999	1000BaseT	UTP-cat. 5e	4	RJ45	PAM5	100m	100m
10Gigabit-Eth.	10Gbps	802.3ae	2002	10GBASE-CX4	InfiniBand	4	CX4	8B/10B	n/a	15m
		802.3ae	2002	10GBASE-SR	FO	2	SC	64B/66B	n/a	26-300m
		802.3ae	2002	10GBASE-LR	FO	2	SC	64B/66B	n/a	10km
		802.3ae	2002	...	FO	2	SC	...	n/a	...

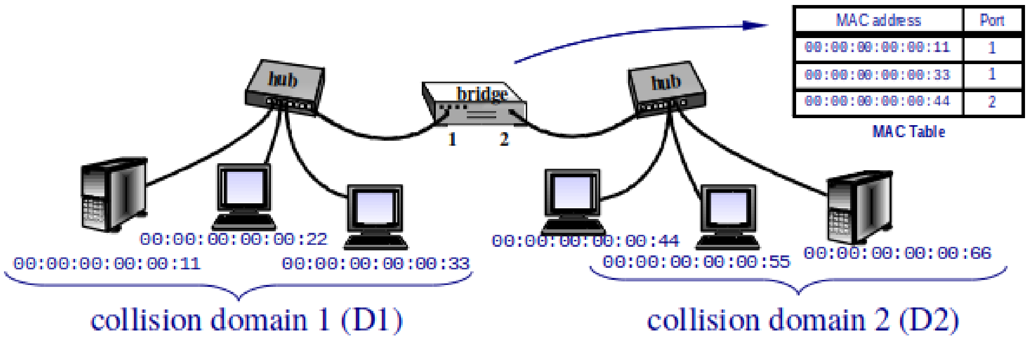
*With OF the distance depends on the OF type.

10BaseT

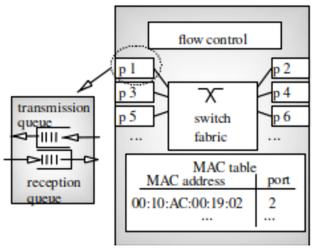


4.8 Ethernet Switches

- CSMA/CD (hub): with many stations **collisions** are inefficient
- Solution: Ethernet **bridge**



- In each **port** there is a NIC
- The **source address** is used to learn which MAC is in each port (**MAC table**)
- If dest. address is not in the table: **flooding** (Tx in all ports). Otherwise, Tx only in 1 port (segments the **collision domain**)
- An Ethernet switch is a **multiport bridge**




```
Switch#show mac-address-table
Address          Dest Interface
------------------------------------
00D0.5868.F583   FastEthernet 2
00E0.1E74.6ADA   FastEthernet 1
00E0.1E74.6AC0   FastEthernet 1
0060.47D5.2770   FastEthernet 3
00D0.5868.F580   FastEthernet 5
```

MAC Table in a CISCO Switch

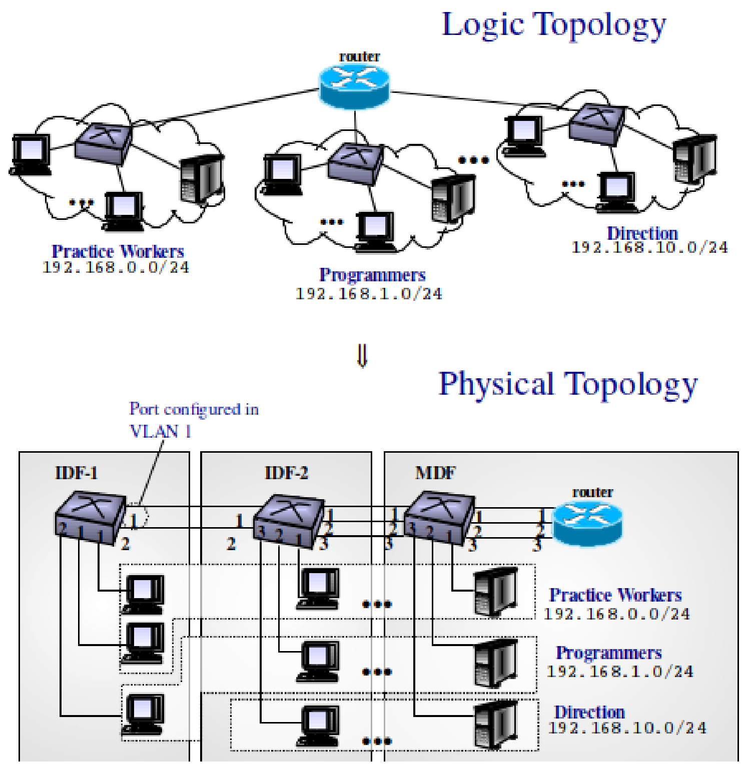
Edge and *backbone* CISCO switches.

4.8.1 Ethernet switch capabilities

- Each port is different a **collision domain**
- Different ports can **Tx/Rx simultaneously**
- Ports can have **different bitrates**
- Ports can be **full-duplex**
- There can be ports **half or full duplex**
- Link **aggregation**: several links can be aggregated acting as a single link of higher capacity
- **Security**: stations see only traffic of their collision domain

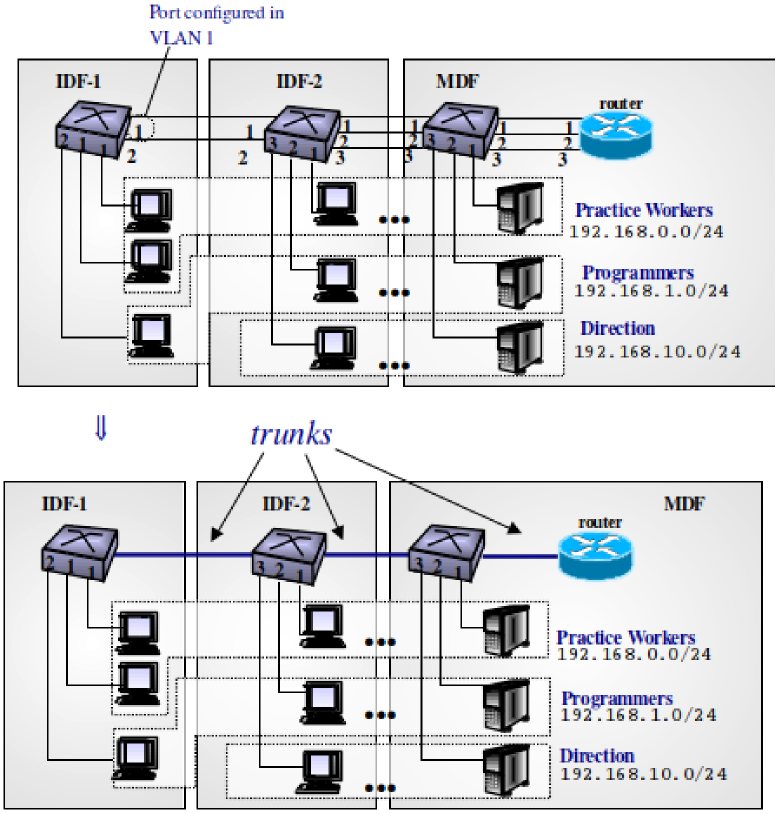
4.9 Virtual LANs, VLANs

- **Motivation**: Adapt logic to physical topology
- The switch **isolates** different VLANs: Each VLAN is equivalent to a different switch



4.9.1 VLAN Trunking

- The port configured as trunk belongs to **all VLANs**
- VLANs are distinguished by **tagging**



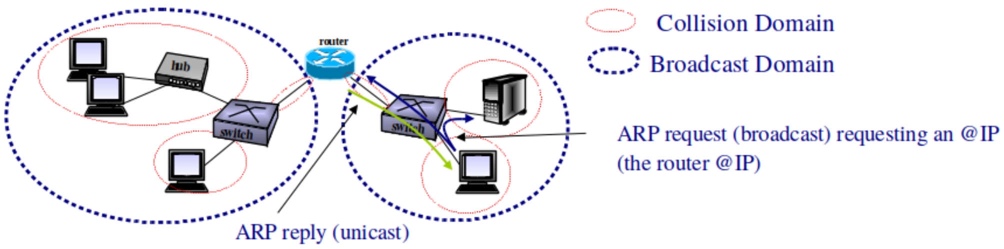
- IEEE-802.1Q (VLAN tagging)

```
+-----------+-----------+---------+---------+---------+---------+-----------+---------+
|Preamble   |Destination|Source MAC| TPID    | TCI     |Length of| Payload   | CRC     |
|(8 bytes)  |MAC Address|Address  |         |         |the frame|(46 to     |(4 bytes)|
|           |(6 bytes)  |(6 bytes)|(2 bytes)|(2 bytes)|(2 bytes)|1500 bytes)|         |
+-----------+-----------+---------+---------+---------+---------+-----------+---------+
```

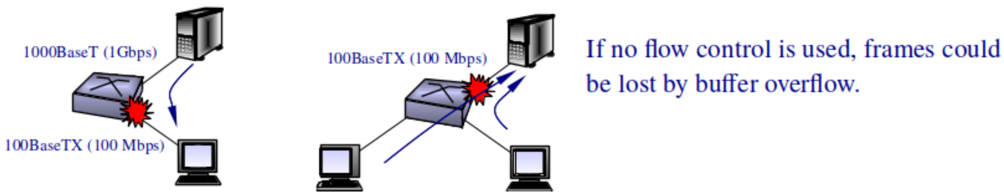
- Tag Protocol Identifier (TPID): 8100 for Ethernet
- Tag Control Information (TCI): **VLAN ID** (12 bits)

4.10 Broadcast domains

- Set of stations that will received a **broadcast frame** sent by any of them
- ARP cannot solve an @IP out of the broadcast domain
- **Hubs and switches** does not partition broadcast domains
- To leave the broadcast domain a **router** is required

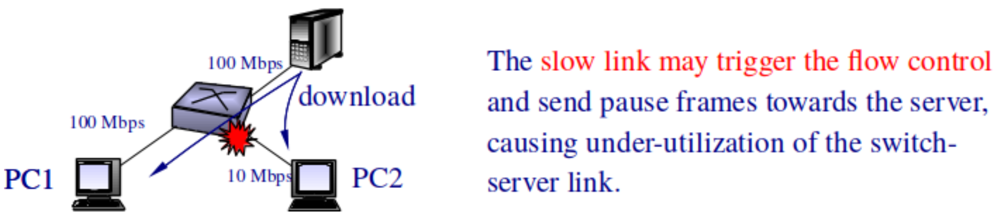


4.11 Switch flow control



- Flow control techniques
  - **Jabber signal** (**half duplex, CSMA/CD**): The switch sends a signal into the port which need to be throttled down, such that CSMA see the medium busy
  - **Pause frames** (**full duplex**): The switch send special pause frames indicating the time that the NICs receiving the frame must be silent

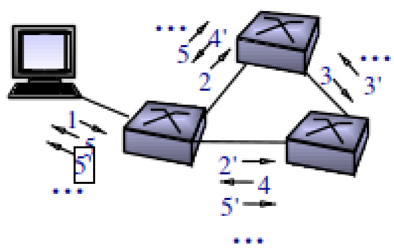
Flow Control head of line blocking



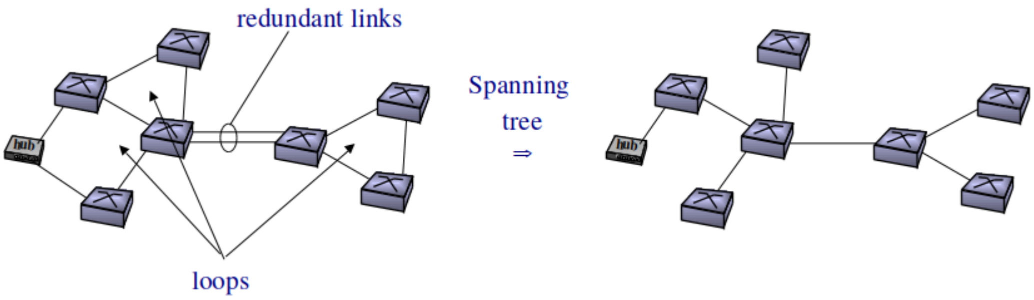
- We shall assume an **ideal flow control in the problems**, which allow achieving the maximum throughput

4.12 Spanning Tree Protocol (STP)

- loops can produce a **broadcast storm** and the network blocks:



- Solution: IEEE 802.1D **Spanning Tree Protocol (STP)**



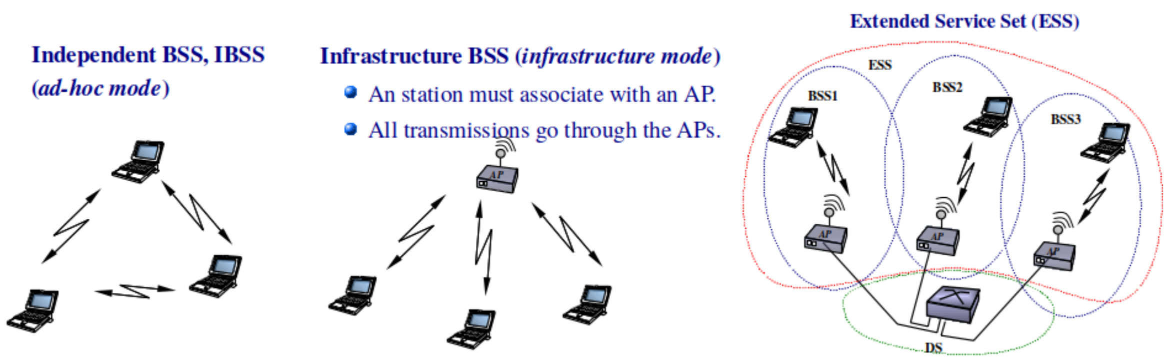
4.13 Wireless LANs (WiFi)

ISM: Industrial Scientific and Medical, **no license required**

Year	standard	max bitrate	ISM band
1997	802.11	2 Mbps	2,4 GHz
1999	802.11a	54 Mbps	5 GHz
1999	802.11b	10 Mbps	2,4 GHz
2003	802.11g	54 Mbps	2,4 GHz
2009	802.11n	600 Mbps	2,4/5 GHz
2013	802.11ac	6,9 Gpbs	5 GHz

4.13.1 802.11 Components

- Basic Service Set, **BSS**: Identifies a WiFi Network
  - Service Set identifier (**SSID**) or Network name
  - BSS Identifier (**BSSID**): 48 bits number (MAC address of the AP)
- Distribution System (**DS**): Exchange frames with other networks. (e.g. an Ethernet switch)



- Practical example:

```
sudo iw wlan0 scan
```

4.13.2 802.11 MAC

- In WiFi collisions cannot be detected while transmitting
- Carrier Sense Multiple Access with **Collision Avoidance CSMA/CA**: In contrast to CSMA/CD, always wait a random backoff before Tx
- **Acks** are used to detect whether a unicast transmitted frame collided
- **Collisions of broadcast frames** is not detected
- **802.11 Addresses**
  - Designed to be compatible with Ethernet

– Use non overlapping ranges with Ethernet
– The frame may have up to **4 addresses**

2	2	6	6	6	2	6	Variable: 0-2312	4
Frame Control	Duration	**Address 1**	**Address 2**	**Address 3**	Seq Ctrl	**Address 4**	Payload	FCS

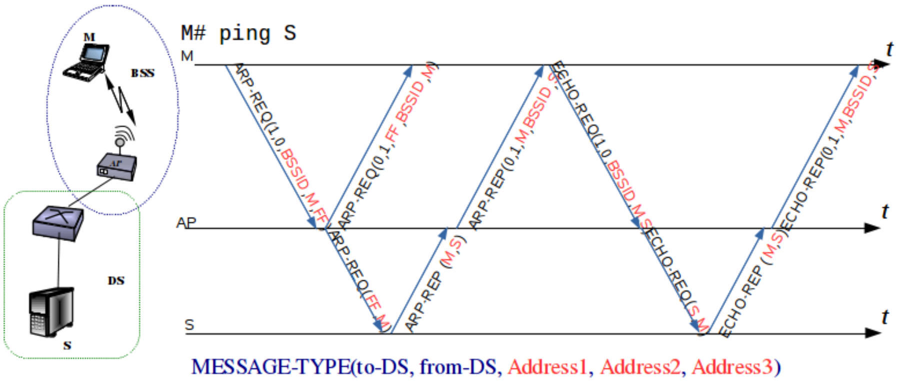
General data frame format

4.13.3 802.11 Addresses

Use **3/4 addresses** depending on the **to-DS/from-DS** bits of the frame control field

Scenario	Usage	to-DS	from-DS	Address1	Address2	Address3	Address4
STA→STA	Ad-hoc	0	0	DA	SA	BSSID	-
STA→AP	Infrastructure	1	0	BSSID	SA	DA	-
AP→STA	Infrastructure	0	1	DA	BSSID	SA	-
AP→AP	WDS	1	1	RA	TA	DA	SA

Legend: Destination Address (DA), Source Address (SA), Receiver Address (RA), Transmitter Address (TA)



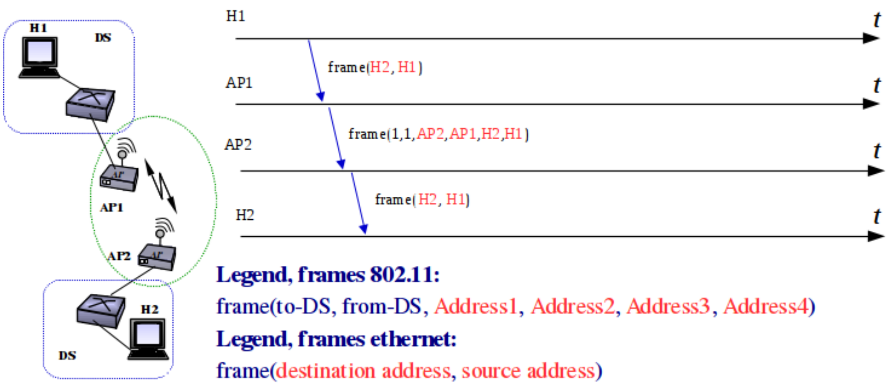
MESSAGE-TYPE(to-DS, from-DS, Address1, Address2, Address3)

Transmission with an **AP in bridge mode**

4 addresses

Scenario	Usage	to-DS	from-DS	Address1	Address2	Address3	Address4
STA→STA	Ad-hoc	0	0	DA	SA	BSSID	-
STA→AP	Infrastructure	1	0	BSSID	SA	DA	-
AP→STA	Infrastructure	0	1	DA	BSSID	SA	-
AP→AP	WDS	1	1	RA	TA	DA	SA

Legend: Destination Address (DA), Source Address (SA), Receiver Address (RA), Transmitter Address (TA)



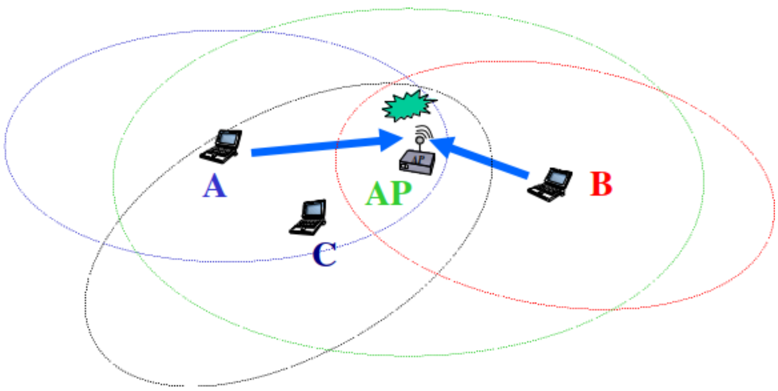
Legend, frames 802.11:
frame(to-DS, from-DS, Address1, Address2, Address3, Address4)
Legend, frames ethernet:
frame(destination address, source address)

Transmission with **APs in WDS mode**

4.13.4 Hidden Node Problem

- When **A** transmits to AP, **B** cannot detect the transmission using the carrier sense mechanism
- If **B** transmits, a **collision** will occur at AP

- Solution **802.11 RTS/CTS**



802.11 RTS/CTS

- Upon receiving a RTS/CTS, the station use a **virtual carrier sensing**
- RTS/CTS is only used for unicast Tx