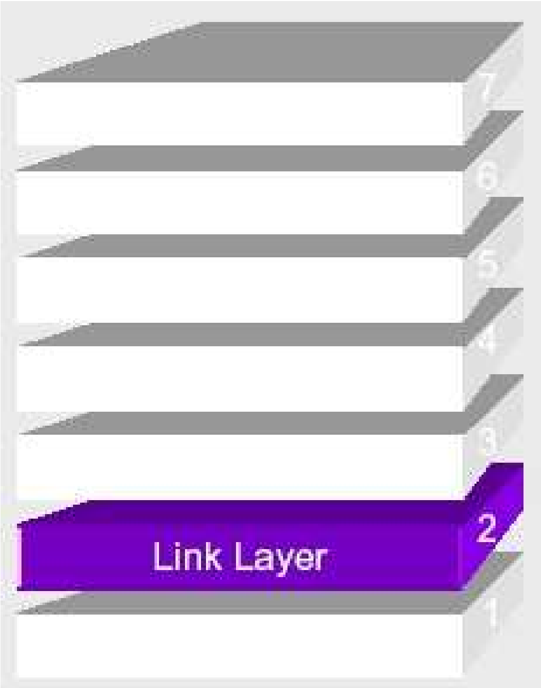
Il livello Data Link



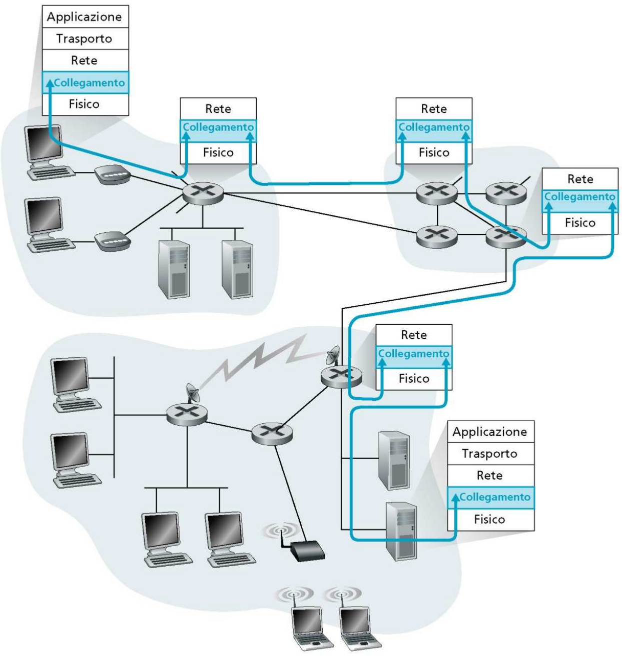
DLL

Il Data Link Level si occupa di fornire al livello di Rete un servizio di trasmissione di flussi di bit.

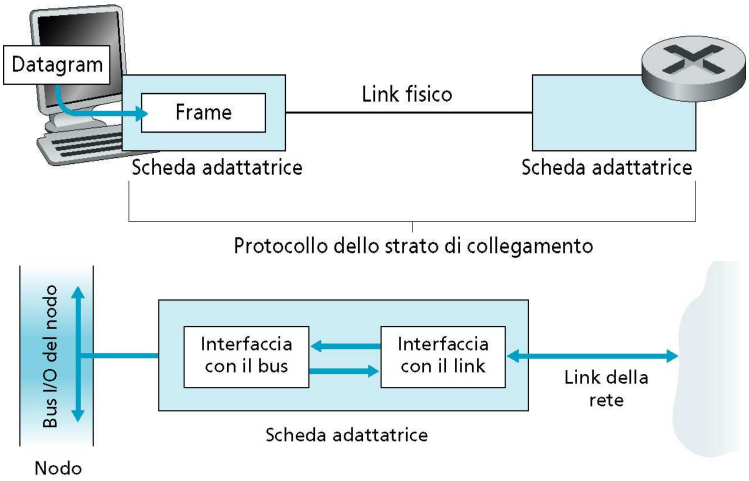
I compiti principali del DDL sono:

- raggruppa i bit dal livello fisico in modo da formare pacchetti (framing)
- gestisce l'accesso al mezzo fisico, nel caso di link broadcast (MAC sublayer);
- fornisce un recapito affidabile (se richiesto);
- gestisce gli errori dovuti al canale di trasmissione
- regola il flusso dei dati tra sorgente e destinazione.

Il livello Data Link

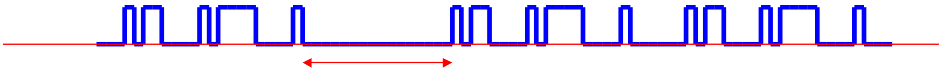


Il livello Data Link



Il protocollo dello strato di collegamento è, di solito, implementato negli adattatori alle due estremità del link

Framing dei dati

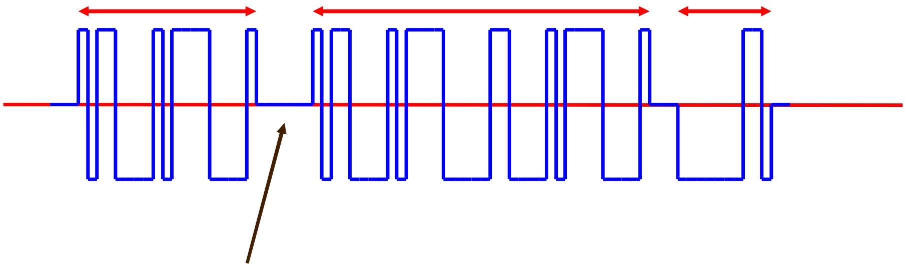


Codifica a due livelli

Il tratto evidenziato è una sequenza di ‘’0’’ o una assenza di comunicazione?

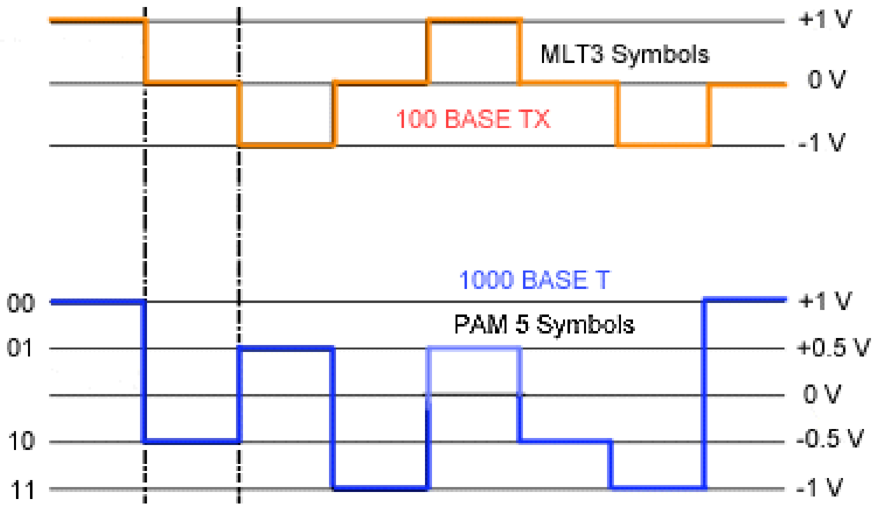
Framing dei dati

Codifica a tre livelli



Ridondanza?

Framing dei dati



Framing dei dati - Codifica 4B5B

Nome	4B	5B	Descrizione
0	0000	11110	hex data 0
1	0001	01001	hex data 1
2	0010	10100	hex data 2
3	0011	10101	hex data 3
4	0100	01010	hex data 4
5	0101	01011	hex data 5
6	0110	01110	hex data 6
7	0111	01111	hex data 7
8	1000	10010	hex data 8
9	1001	10011	hex data 9
A	1010	10110	hex data A
B	1011	10111	hex data B
C	1100	11010	hex data C
D	1101	11011	hex data D
E	1110	11100	hex data E
F	1111	11101	hex data F
I	-NONE-	11111	Idle
J	-NONE-	11000	SSD #1
K	-NONE-	10001	SSD #2
T	-NONE-	01101	ESD #1
R	-NONE-	00111	ESD #2
H	-NONE-	00100	Halt

Codifica 8B10B

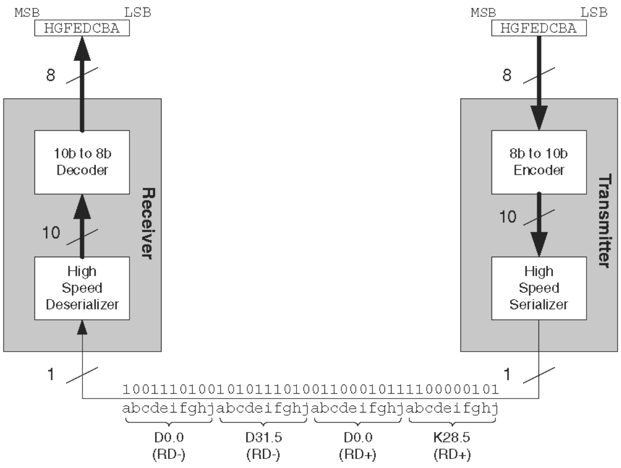
Viene usata per trasmettere 8 bit dati con 10 bit di segnale.

È elettricamente neutra (il numero di bit 1 viene mantenuto uguale al numero di bit 0 trasmessi)

È usata in vari standard:

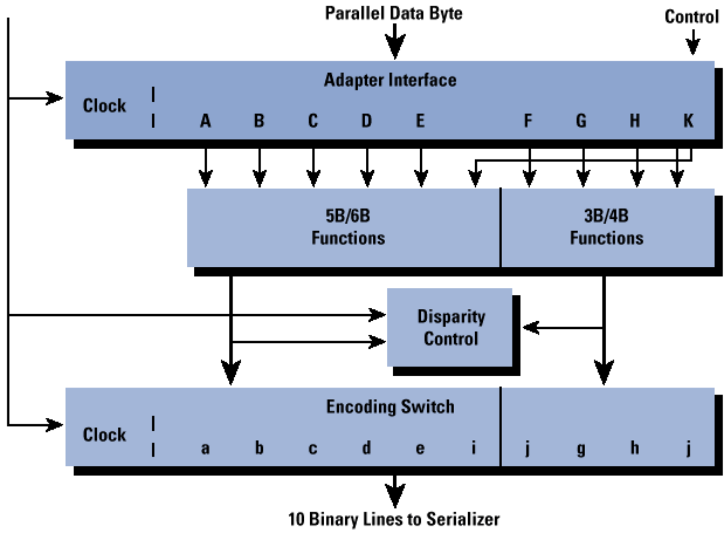
- PCI Express (< 3.0)
- IEEE 1394b (Firewire)
- Serial ATA
- Fibre Channel
- Gigabit Ethernet (alcune versioni)
- DisplayPort Main Link
- DVI e HDMI (Transition Minimized Differential Signaling)
- USB 3.0

Codifica 8B10B



Dx.y : dati (256)
Kx.y: codici di controllo (12)

Codifica 8B10B



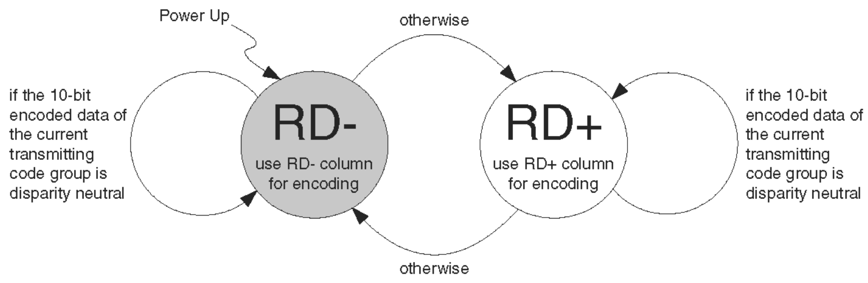
Codifica 8B10B

3b Decimal	3b Binary (HGF)	4b Binary (fghi)
0	000	0100 or 1011
1	001	1001
2	010	0101
3	011	0011 or 1100
4	100	0010 or 1101
5	101	1010
6	110	0110
7	111	0001 or 1110 or 1000 or 0111

Codifica 8B10B

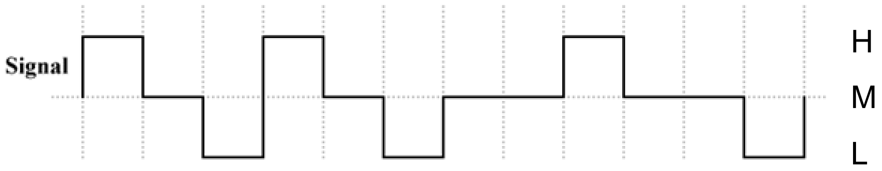
5b Decimal	5b Binary (EDCBA)	6b Binary (abcdei)
0	00000	100111 or 011000
1	00001	011101 or 100010
2	00010	101101 or 010010
3	00011	110001
4	00100	110101 or 001010
5	00101	101001
6	00110	011001
7	00111	111000 or 000111
8	01000	111001 or 000110
9	01001	100101
10	01010	010101
11	01011	110100
12	01100	001101
13	01101	101100
14	01110	011100
15	01111	010111 or 101000
16	10000	011011 or 100100
17	10001	100011
18	10010	010011
19	10011	110010
20	10100	001011
21	10101	101010
22	10110	011010
23	10111	111010 or 000101
24	11000	110011 or 001100
25	11001	100110
26	11010	010110
27	11011	110110 or 001001
28	11100	001110
29	11101	101110 or 010001
30	11110	011110 or 100001
31	11111	101011 or 010100

Codifica 8B10B



La codifica garantisce che, in 20 bit, la differenza tra bit “1” e “0” sia al massimo di 2

Quantità di informazione

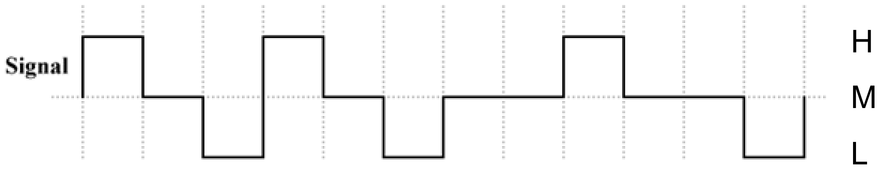


Un simbolo ha tre possibili posizioni H, M, L

Con 2 simboli abbiamo 9 possibili combinazioni (3^2)
HH, HM, HL, MH, MM, ML, LH, LM, LL

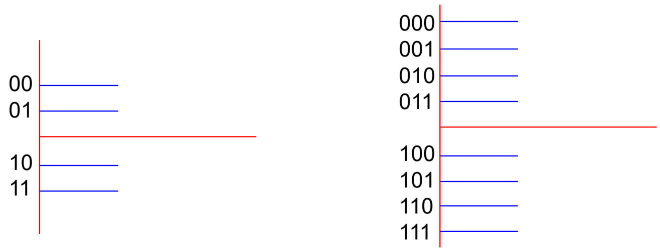
3 simboli -> 27 (3^3)
4 simboli -> 81 (3^4)

Quantità di informazione



simboli	combinazioni	bit	combinazioni
1	3	1	$2^1 = 2$
2	9	3	$2^3 = 8$
3	27	4	$2^4 = 16$
4	81	6	$2^6 = 64$
5	243	7	$2^7 = 128$
6	729	9	$2^9 = 512$

Quantità di informazione

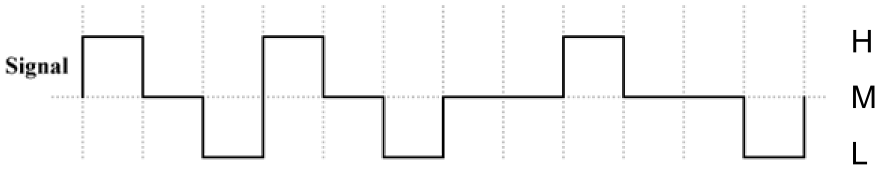


Ogni simbolo trasporta una certa quantità di informazioni, misurabile in bit.

Un sistema a 4 livelli consente di associare 2 bit ad ogni livello
Con 8 livelli avremmo 3 bit, con 16 4 bit, con 32 5 bit …

Quindi per ogni simbolo l'informazione trasportata è $x = \log_2$ n°livelli

Quantità di informazione

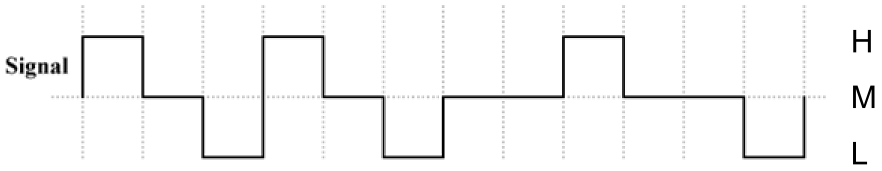


Ogni simbolo trasporta una certa quantità di informazioni, misurata in bit

1 simbolo ha x bit : $x = \log_2 3$ ($2^x=3$)

$x=\log_2 3$ x= 1,5849…. ($x= \ln(3)/\ln(2)$)

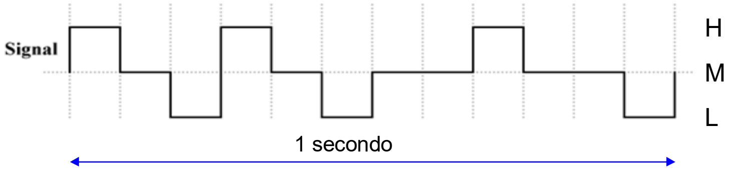
Quantità di informazione



simboli	combinazioni	Informazione (bit)	bit utilizzabili	combinazioni utilizzabili
1	3	1,584963	1	2
2	9	3,169925	3	8
3	27	4,754888	4	16
4	81	6,33985	6	64
5	243	7,924813	7	128
6	729	9,509775	9	512
7	2187	11,09474	11	2048
8	6561	12,6797	12	4096
9	19683	14,26466	14	16384
10	59049	15,84963	15	32768

bitrate

Supponiamo di avere una trasmissione con 12 sps (simboli per secondo)



Simboli per gruppo	Combinazioni per gruppo	Combinazioni utilizzabili	Bit per gruppo	bps
1	3	2	1	12 x 1 = 12 bps
2	9	8	3	6 x 3 = 18 bps
3	27	16	4	4 x 4 = 16 bps
4	81	64	6	3 x 6 = 18 bps
6	729	512	9	2 x 9 = 18 bps
12	531441	524288	19	1 x 19 = 19 bps

Limite teorico: $12 \times \log_2(3) = 19{,}01955001$

Rilevazione e/o correzione degli errori

La rilevazione degli errori consente di individuare la presenza di un errore di trasmissione in una frame, ma NON di correggerlo.

La correzione consente di rilevare e correggere (con alcune forti limitazioni) errori dovuti alla trasmissione.

Entrambi i metodi sono basati sulla presenza di ridondanza nella comunicazione.

Ridondanza

Esempio:

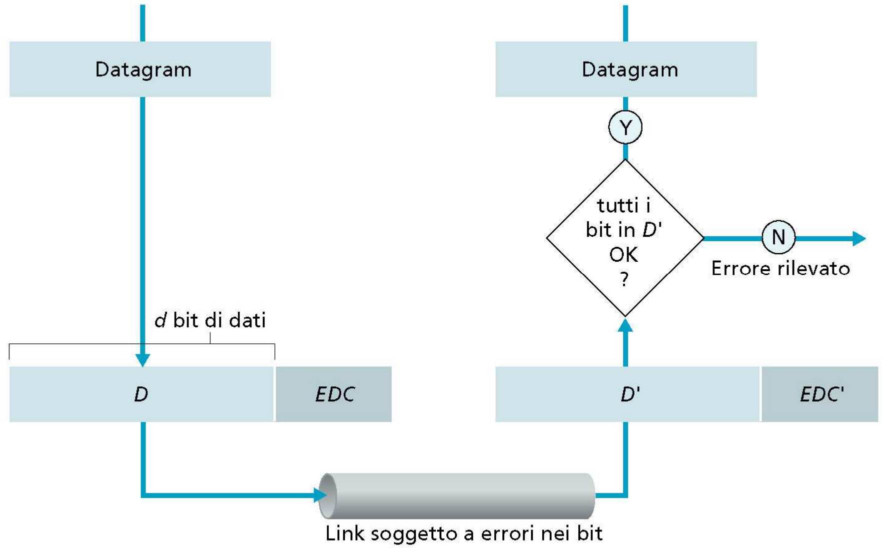
Mario Rossi
nato a Catania
il 15 maggio 2000

CF : RSS MRA 00E15 C351 S

Il CF è una informazione ridondante.

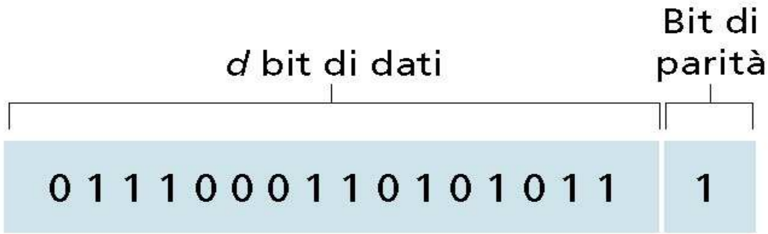
La lettera finale del CF è calcolata in funzione dei caratteri precedenti -> ridondanza

Rilevazione degli errori



Controllo di Parità

Parità pari a un bit



Parità a due dimensioni

Parità di riga

Parità di colonna

$$\begin{array}{cccc|c} d_{1,1} & \dots & d_{1,j} & & d_{1,j+1} \\ d_{2,1} & \dots & d_{2,j} & & d_{2,j+1} \\ \dots & \dots & \dots & & \dots \\ d_{i,1} & \dots & d_{i,j} & & d_{i,j+1} \\ \hline d_{i+1,1} & \dots & d_{i+1,j} & & d_{i+1,j+1} \end{array}$$

Nessun errore

$$\begin{array}{ccccc|c} 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 \\ \hline 0 & 0 & 1 & 0 & 1 & 0 \end{array}$$

Errore correggibile del singolo bit

$$\begin{array}{ccccc|c} 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 \\ \hline 0 & 0 & 1 & 0 & 1 & 0 \end{array}$$

Errore di parità

Errore di parità

Università di Catania

CRC

d bit	*r* bit	
D: bit di dati da spedire	*R*: CRC bit	Schema dei bit

$D \cdot 2^r$ XOR R Formula matematica

1 0 0 1 0 1 1 1

$x^7 + x^4 + x^2 + x^1 + 1$

CRC

1 0 0 1 0 1 1 1

$x^7 + x^4 + x^2 + x + 1$

0 1 0 1 1 0 1 1

$x^6 + x^4 + x^3 + x + 1$

La somma è

$x^7 + x^6 + x^3 + x^2$

1 1 0 0 1 1 0 0

Il prodotto è

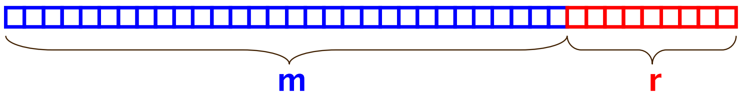
$x^{13} + x^{11} + x^8 + x^7 + x^5 + x^4 + 1$

1 0 1 0 0 1 1 0 1 1 0 0 0 1

CRC

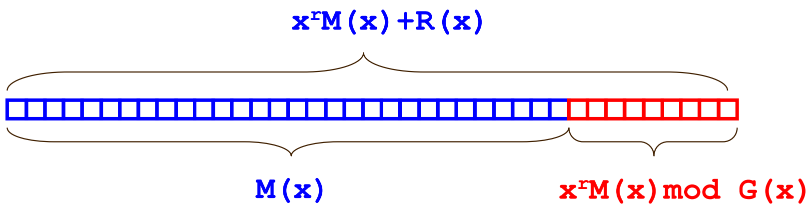
$M(x)$ polinomio con i dati

$G(x)$ polinomio generatore di grado r.

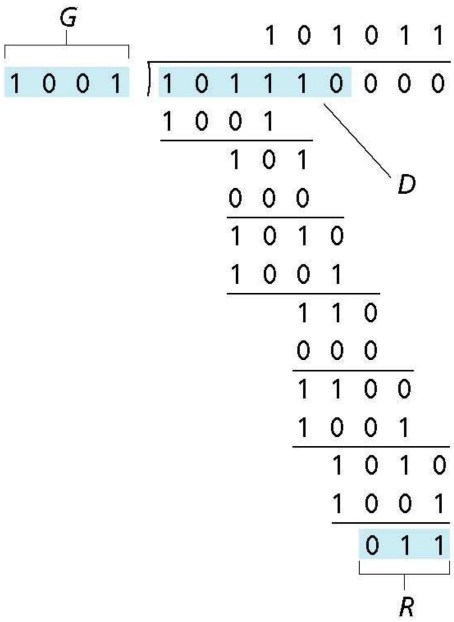


$$R(x) = x^r M(x) \bmod G(x)$$

CRC



CRC



Università di Catania

CRC

```
11010110111110
10011
010011110111110
 10011
00000010111110
  00000
000000101111110
   00000
0000001011111110
    00000
00000010111110
     00000
00000010111110
      10011
…
```

CRC

Polinomi standardizzati :

CRC-12	$x^{12}+ x^{11}+ x^3+ x^2+ x+ 1$
CRC-16	$x^{16}+ x^{15}+ x^2+ 1$
CRC-CCITT	$x^{16}+ x^{12}+ x^5+ 1$
CRC-32	100000100110000010001110110110111

Distanza di Hamming

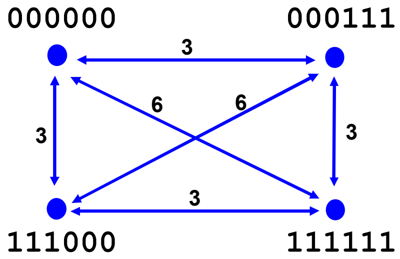
Date due codeword, è possibile definire una distanza tra esse contando il numero di bit diversi tra loro.

```
10001100
11000100
01001000    d = 2
```

Correzione degli errori

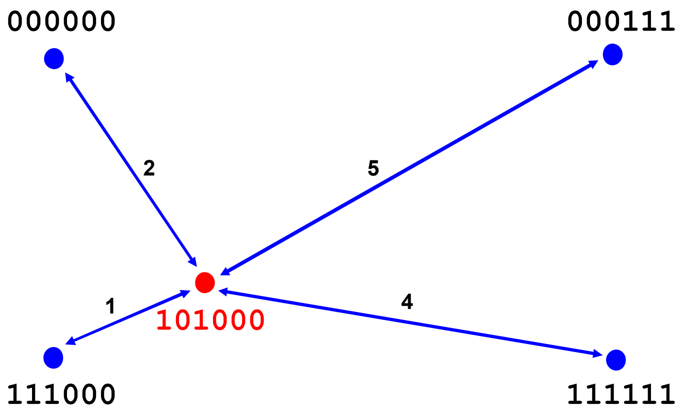
Consideriamo il seguente vocabolario:

```
000000
000111
111000
111111
```



P(e=1) >> P(e=2) >> P(e=3) …

Correzione degli errori



P(e=1) >> P(e=2) >> P(e=3) …

Correzione degli errori

In un vocabolario con distanza ***d=3*** è possibile correggere gli errori singoli.

Per correggere ***e*** errori, è necessario un vocabolario con distanza ***d=2e+1***

Per rilevare ***e*** errori è necessario un vocabolario con distanza ***d=e+1***

La correzione si effettua esclusivamente su base probabilistica.

Correzione degli errori

Esempio: codewords da 10 bit

```
0000000000
0000011111
1111100000
1111111111
```

Parole valide: 4.

Distanza di hamming: **5**

Correzione di errori: 2 bit

Rilevazione di errori: 4 bit.

Esiste un altro vocabolario con la stessa distanza, ma con più parole?

Correzione degli errori

Codewords da 10 bit

```
A 0000000000 :
B 0000011111 :
C 0011100011 :
D 0011111100 :
E 1100100101 :
F 1100111010 :
G 1111000110 :
H 1111011001 :
```

	A	B	C	D	E	F	G	H
A	0	5	5	6	5	6	6	7
B	5	0	6	5	6	5	7	6
C	5	6	0	5	6	7	5	6
D	6	5	5	0	7	6	6	5
E	5	6	6	7	0	5	5	6
F	6	5	7	6	5	0	6	5
G	6	7	5	6	5	6	0	5
H	7	6	6	5	6	5	5	0

Parole valide: 8.

Distanza di hamming: 5

Combinazioni possibili: 2^{10}=1024

Bit di dati: 3

Bit di controllo: 7

Si può far meglio?

Correzione degli errori

Quanta ridondanza serve?

- Dati m bit di dati, quanti bit di ridondanza r servono?

Come costruire un codice per correggere errori singoli?

- Partendo da m bit di dati, sapendo come calcolare r, come costruire operativamente il vocabolario?

Ridondanza

Consideriamo un vocabolario con m bit dati e r bit di controllo

Poniamo **m+r = n**

Le combinazioni possibili (con n bit) sono 2^n , di cui solo 2^m sono valide

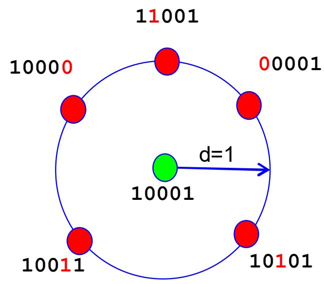
Consideriamo una codeword valida: **10001**

Cambiando un solo bit per volta, possiamo scrivere altre **n** codeword, tutte non valide:

n+1

- 10001
- 00001
- 11001
- 10101
- 10011
- 10000

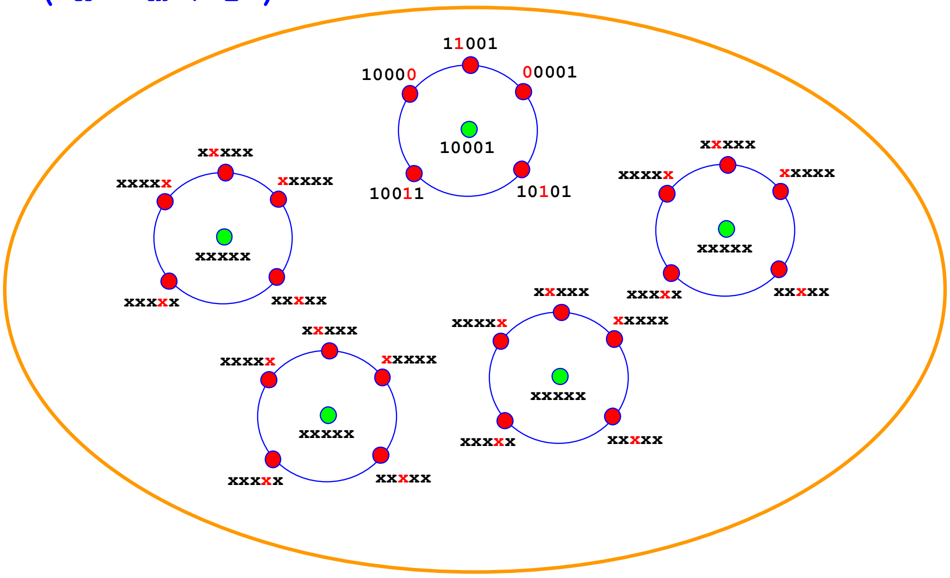
n codeword non valide a distanza 1



Ridondanza

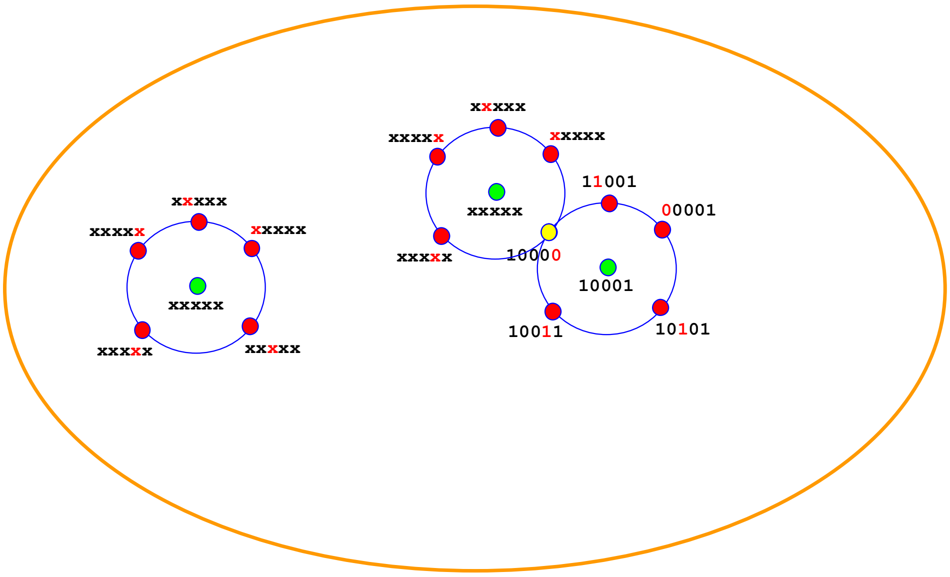
Abbiamo 2^n codeword di cui solo 2^m sono valide.

$(n = m + r)$



Ridondanza

Per correggere 1 errore serve **d=3**



Ridondanza

Se $d=3$, allora $(n+1)2^m \leq 2^n$

Semplificando:

$(m+r+1)2^m \leq 2^{m+r}$

$(m+r+1) \leq 2^r$

$m+1 \leq 2^r - r$

Nota: L'espressione $m+1 \leq 2^r - r$ è valida **solo** per $d=3$.

Esempi:

$m=8 \Rightarrow r=4 \qquad (8+4+1) \leq 2^4 \qquad 13 < 16$

$m=11 \Rightarrow r=4 \qquad (11+4+1) \leq 2^4 \qquad 16 = 16$

Ridondanza

Esercizio:

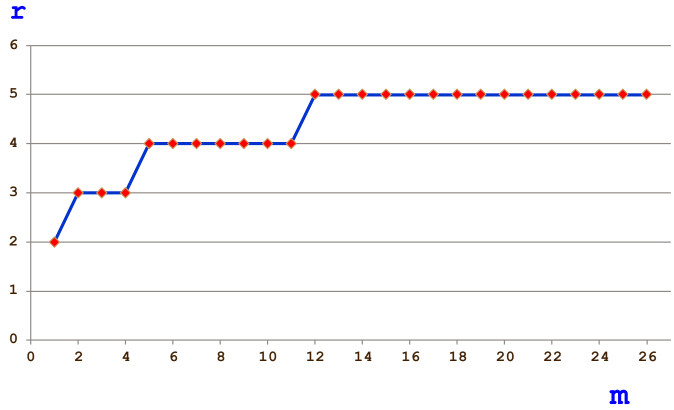
Calcolare r in funzione di m per d=5

$$\cancel{m+1 \leq 2^r - r}$$

Ridondanza

m	r	n
1	2	3
2	3	5
3	3	6
4	3	7
5	4	9
6	4	10
7	4	11
8	4	12
9	4	13
10	4	14
11	4	15
12	5	17
13	5	18

m	r	n
14	5	19
15	5	20
16	5	21
17	5	22
18	5	23
19	5	24
20	5	25
21	5	26
22	5	27
23	5	28
24	5	29
25	5	30
26	5	31
27	6	33



Codici di Hamming

Supponiamo di avere un codice così costruito:

Bit dei dati

00110010000

Bit di controllo

001100100001100

1 2 4 5 8 9

6=2+4

Codici di Hamming

Esempio:

Dati originali 10010001100

xx1x001x0001100

1 2 4 8

$b_1 = 3 \otimes 5 \otimes 7 \otimes 9 \otimes 11 \otimes 13 \otimes 15$

$b_2 = 3 \otimes 6 \otimes 7 \otimes 10 \otimes 11 \otimes 14 \otimes 15$

$b_4 = 5 \otimes 6 \otimes 7 \otimes 12 \otimes 13 \otimes 14 \otimes 15$

$b_8 = 9 \otimes 10 \otimes 11 \otimes 12 \otimes 13 \otimes 14 \otimes 15$

3 = 1+2
5 = 1 +4
6 = 2+4
7 = 1+2+4
9 = 1 +8
10 = 2 +8
11 = 1+2 +8
12 = 4+8
13 = 1 +4+8
14 = 2+4+8
15 = 1+2+4+8

Codici di Hamming

xx1x001x0001100

1 2 4 8

$$b_1 = 3 \otimes 5 \otimes 7 \otimes 9 \otimes 11 \otimes 13 \otimes 15$$

$$b_2 = 3 \otimes 6 \otimes 7 \otimes 10 \otimes 11 \otimes 14 \otimes 15$$

$$b_4 = 5 \otimes 6 \otimes 7 \otimes 12 \otimes 13 \otimes 14 \otimes 15$$

$$b_8 = 9 \otimes 10 \otimes 11 \otimes 12 \otimes 13 \otimes 14 \otimes 15$$

$$b_1 = 1 \otimes 0 \otimes 1 \otimes 0 \otimes 0 \otimes 1 \otimes 0 = 1$$

$$b_2 = 1 \otimes 0 \otimes 1 \otimes 0 \otimes 0 \otimes 0 \otimes 0 = 0$$

$$b_4 = 0 \otimes 0 \otimes 1 \otimes 1 \otimes 1 \otimes 0 \otimes 0 = 1$$

$$b_8 = 0 \otimes 0 \otimes 0 \otimes 1 \otimes 1 \otimes 0 \otimes 0 = 0$$

101100100001100

Codici di Hamming

101100100101100

1 2 4 8

$b_1 = 3 \otimes 5 \otimes 7 \otimes 9 \otimes 11 \otimes 13 \otimes 15$

$b_2 = 3 \otimes 6 \otimes 7 \otimes 10 \otimes 11 \otimes 14 \otimes 15$

$b_4 = 5 \otimes 6 \otimes 7 \otimes 12 \otimes 13 \otimes 14 \otimes 15$

$b_8 = 9 \otimes 10 \otimes 11 \otimes 12 \otimes 13 \otimes 14 \otimes 15$

$b_1 = 1 \otimes 0 \otimes 1 \otimes 0 \otimes 0 \otimes 1 \otimes 0 = 1$

$b_2 = 1 \otimes 0 \otimes 1 \otimes 1 \otimes 0 \otimes 0 \otimes 0 = 1$

$b_4 = 0 \otimes 0 \otimes 1 \otimes 1 \otimes 1 \otimes 0 \otimes 0 = 1$

$b_8 = 0 \otimes 1 \otimes 0 \otimes 1 \otimes 1 \otimes 0 \otimes 0 = 1$

Codici di Hamming

```
1011001001001100
↑ ↑ ↑     ↑  ↑
1 2 4     8  10
```

$b_1 = 1$

$b_2 = 1$

$b_4 = 1$

$b_8 = 1$

2 + 8 = 10 !

3 = 1+2

5 = 1 +4

6 = 2+4

7 = 1+2+4

9 = 1 +8

$\boxed{10 = 2 +8}$

11 = 1+2 +8

12 = 4+8

13 = 1 +4+8

14 = 2+4+8

15 = 1+2+4+8

Codici di Hamming

xx1x110xx0x011xx0x110xx1x000xx0x011xx1x100xx0x001xx0x11
0xx1x011xx1x110xx1x001xx0x011

xx1x110
xx0x011
xx0x110
xx1x000
xx0x011
xx1x100
xx0x001
xx0x110
xx1x011
xx1x110
xx1x001
xx0x011

Codici di Hamming

```
xx1x110
xx0x011
xx0x110
xx1x000
xx0x011
xx1x100
xx0x001
xx0x110
xx1x011
xx1x110
xx1x001
xx0x011
```

```
xxxxxxxxxxxxxxxxxxxxxxxx100101001110xxxxxxxxxxxx101001
010100111010011101010010101011
```

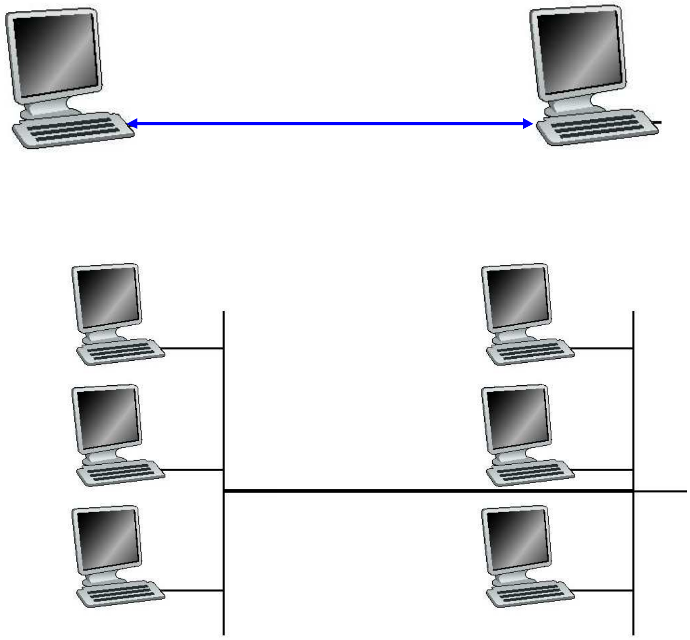
```
xxxxxxxxxxxxxxxxxxxxxxxx100101001110xxxxxxxxxxxx101001
010100000101111101010010101011
```

Codici di Hamming

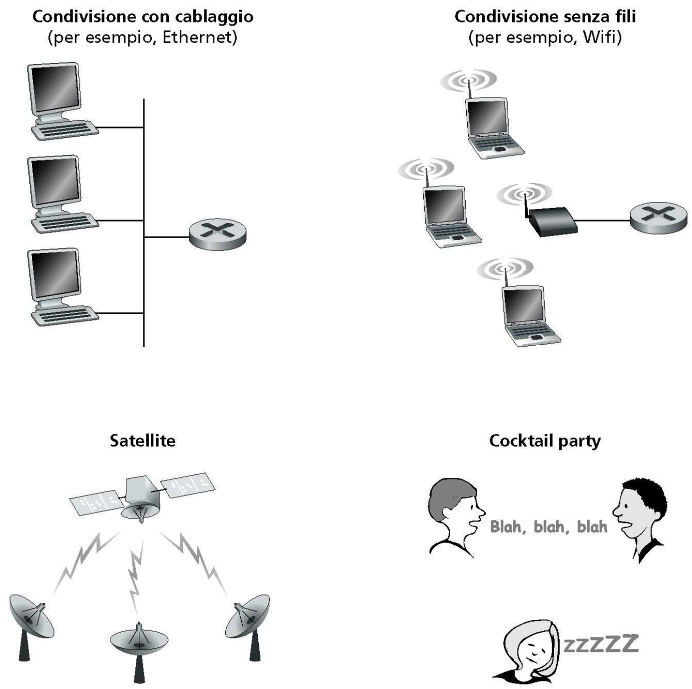
xxxxxxxxxxxxxxxxxxxxxxxx100101001110xxxxxxxxxxxx101001
010100000101111101010010101011

xx1x100
xx0x001
xx0x100
xx1x010
xx0x001
xx1x110
xx0x011
xx0x110
xx1x011
xx1x110
xx1x001
xx0x011

Accesso al Link

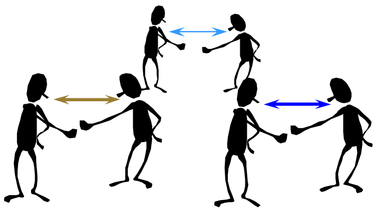


Accesso multiplo



Accesso Multiplo

FDMA
Frequency Division Multiple Access



"Private Conversation"

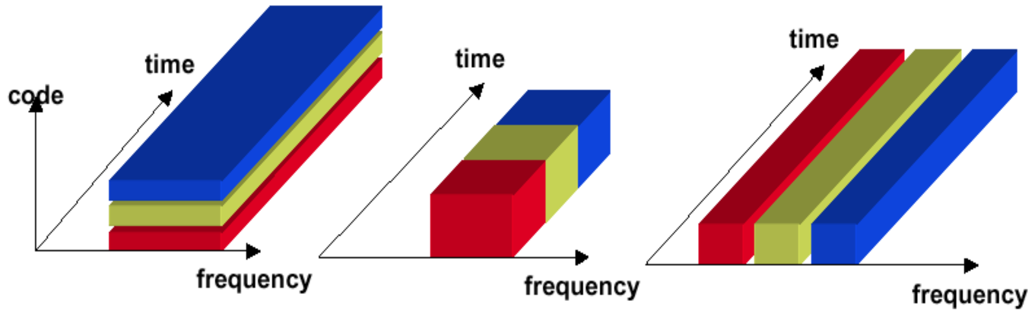
TDMA
Time Division Multiple Access

"Meeting"

CDMA
Code Division Multiple Access

"Cocktail Party"

Accesso Multiplo

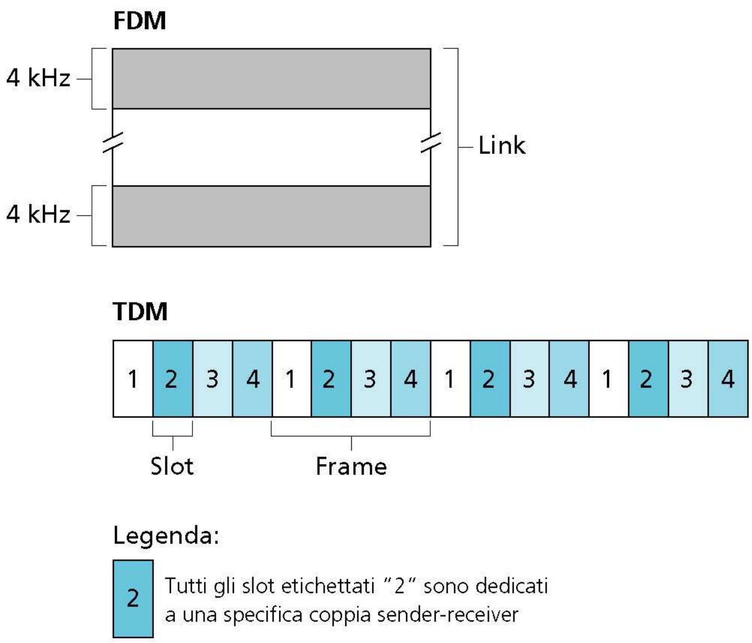


CDMA: Code Division Multiple Access

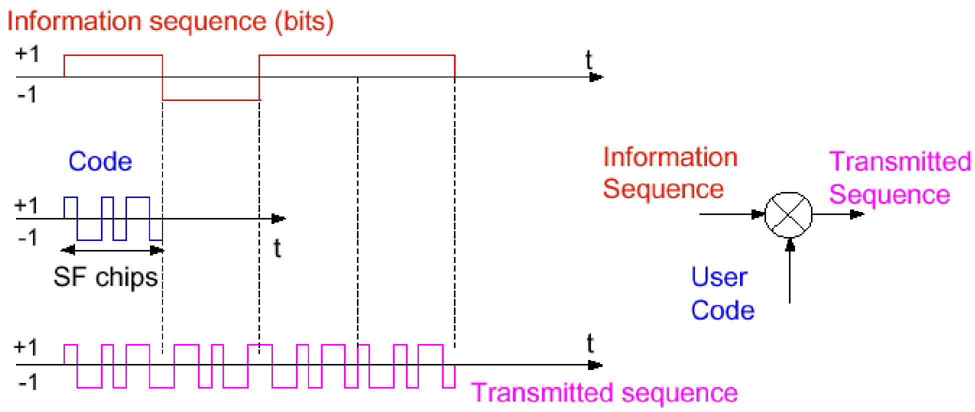
FDMA: Frequency Division Multiple Access

TDMA: Time Division Multiple Access

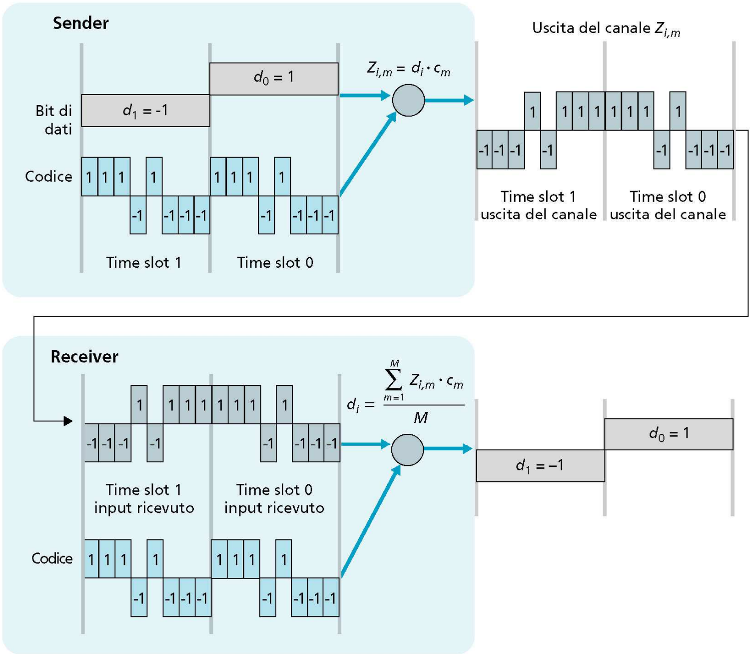
FDM e TDM


FDM
4 kHz
4 kHz
Link
TDM
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Slot
Frame
Legenda:
2
Tutti gli slot etichettati "2" sono dedicati
a una specifica coppia sender-receiver

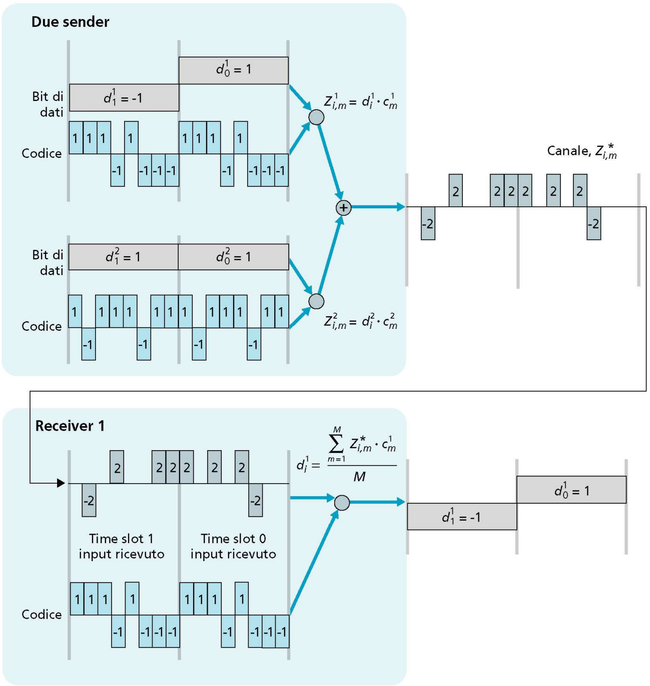
Code Division Multiple Access



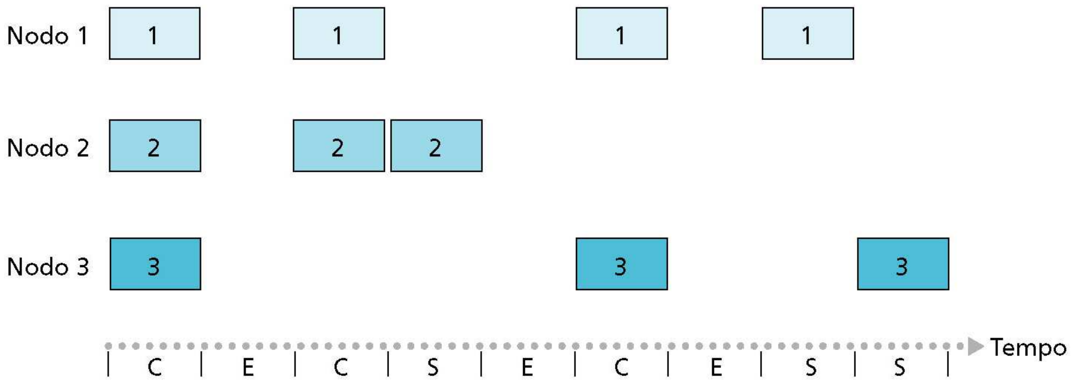
Code Division Multiple Access



Code Division Multiple Access



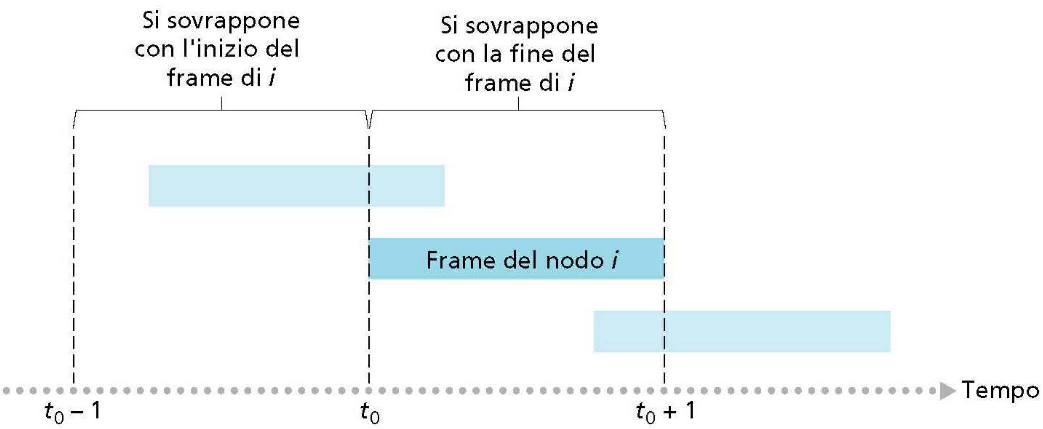
Protocolli ad accesso casuale



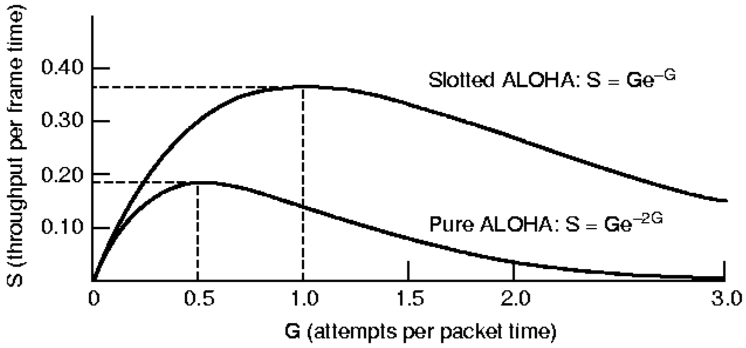
Legenda:

C = Slot con collisione; E = Slot vuoto; S = Slot con successo

ALOHA


Si sovrappone con l'inizio del frame di i
Si sovrappone con la fine del frame di i
Frame del nodo i
Tempo
t0 – 1
t0
t0 + 1

ALOHA



Il throughput massimo si ha per G=0.5 con S=0.184.

Il canale viene quindi utilizzato al più per il 18.4% delle sue potenzialità.

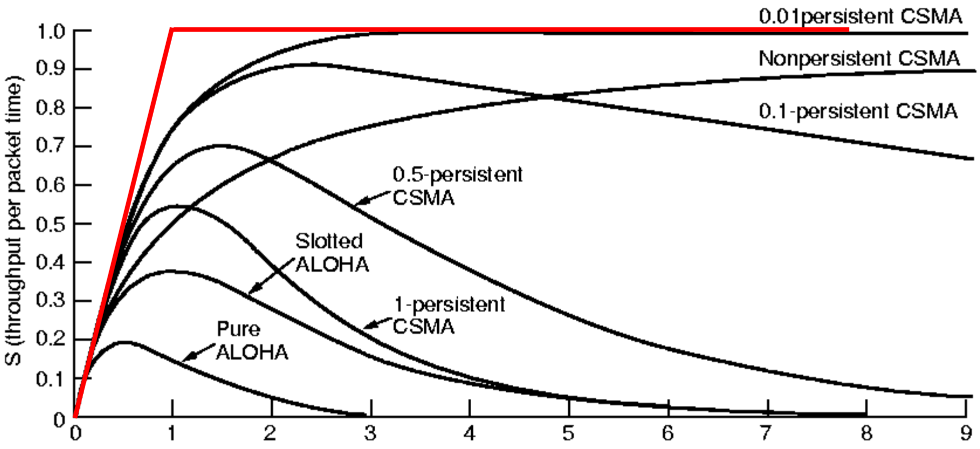
Protocolli CSMA

Il protocollo CSMA 1-persistent prevede la trasmissione non appena scompare la portante.

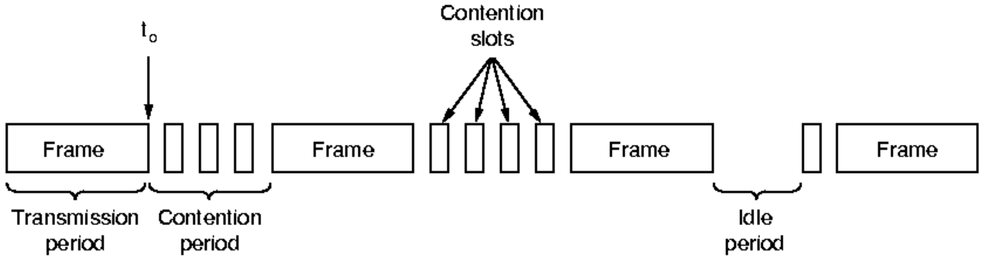
Invece nel protocollo CSMA p-persistent la stazione, dopo aver rilevato il termine della precedente trasmissione, trasmette con probabilità p.

Nel CSMA non-persistent la stazione aspetta un tempo random prima di ricontrollare il canale.

Protocolli CSMA

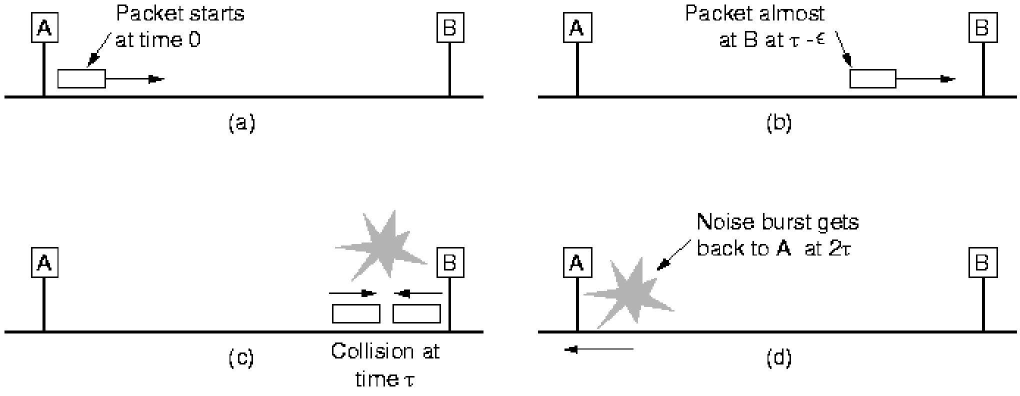


CSMA / CD



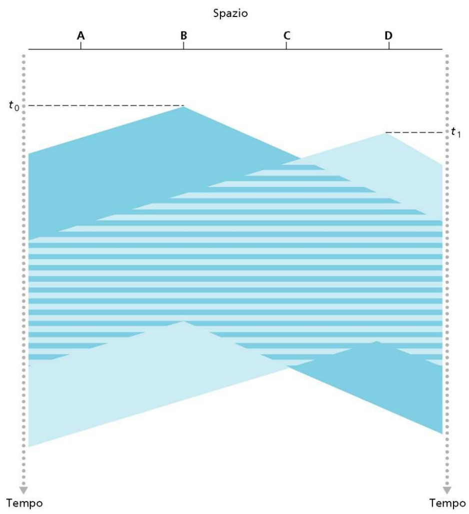
t_o
Contention
slots
Frame
Frame
Frame
Frame
Transmission
period
Contention
period
Idle
period

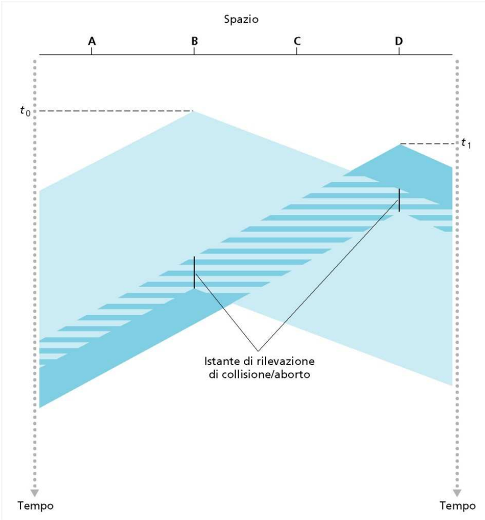
CSMA / CD



A
Packet starts
at time 0
B
(a)
A
Packet almost
at B at τ -ϵ
B
(b)
A
B
Collision at
time τ
(c)
Noise burst gets
back to A at 2τ
A
B
(d)

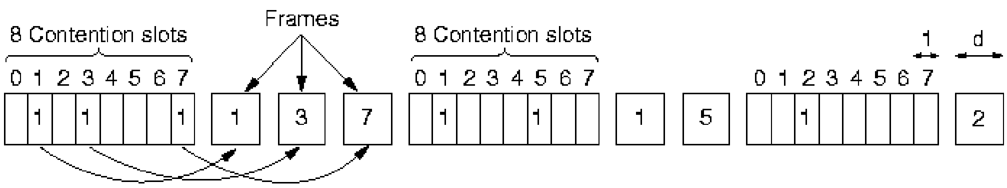
CSMA vs CSMA /CD





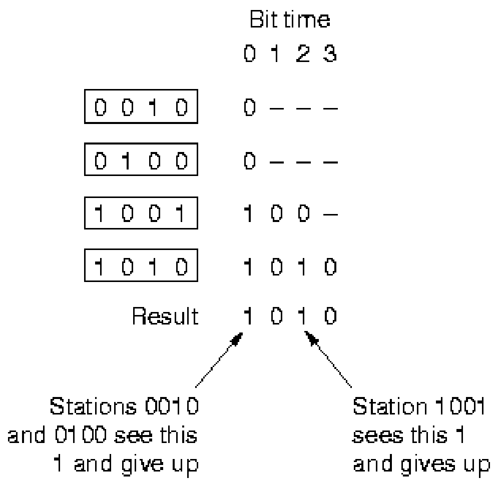
Protocolli senza collisioni

Protocollo a mappa di bit



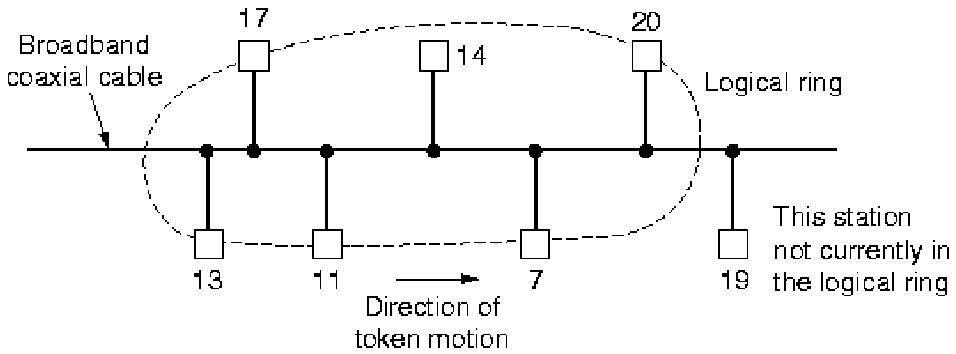
Protocolli senza collisioni

Conteggio binario a ritroso (CSMA/BA CanBus)

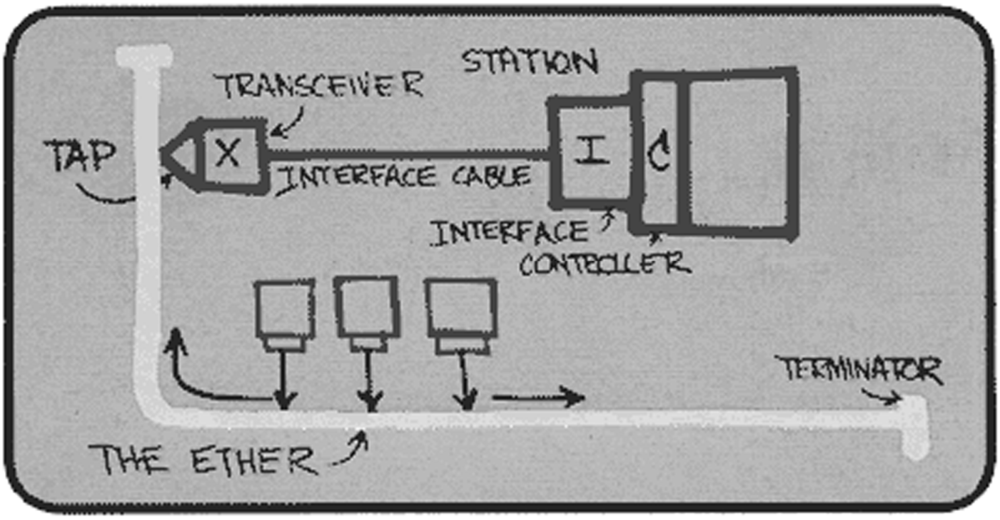


Protocolli a turno

Token Bus



Ethernet


STATION
TRANSCEIVER
TAP
X
I
C
INTERFACE CABLE
INTERFACE
CONTROLLER
TERMINATOR
THE ETHER

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IEEE 802

802.1 High Level Interface (HILI)

802.2 Logical Link Control (LLC) [in ’hibernation’]

802.3 CSMA/CD

802.4 Token Bus [in ’hibernation’]

802.5 Token Ring [in ’hibernation’]

802.6 Metropolitan Area Network (MAN) [in ’hibernation’]

802.7 BroadBand Technical Adv. Group (BBTAG) [in ’hibernation’]

802.8 Fiber Optics Technical Adv. Group (FOTAG) [disbanded]

802.9 Integrated Services LAN (ISLAN) [in ’hibernation’]

IEEE 802

802.10 Standard for Interoperable LAN Security (SILS) [in ’hibernation]

802.11 Wireless LAN (WLAN)

802.12 Demand Priority [in ’hibernation’]

802.14 Cable-TV Based Broadband Comm. Network [disbanded]

802.15 Wireless Personal Area Network (WPAN)

802.16 Broadband Wireless Access (BBWA)

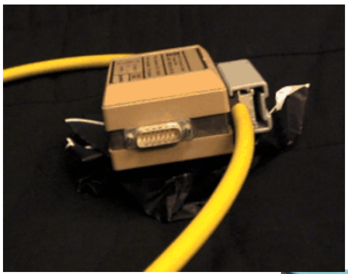
802.17 Resilient Packet Ring (RPR)

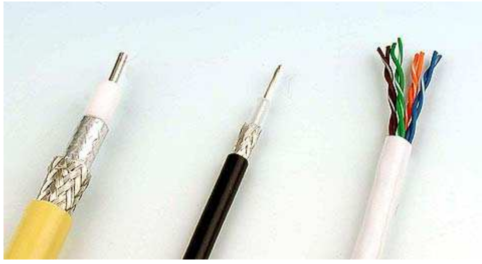
802.18 Radio Regulatory Technical Advisory Group

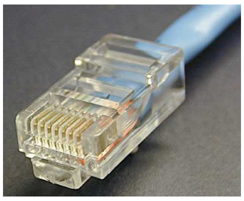
802.19 Coexistence Technical Advisory Group

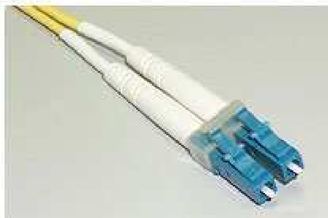
Cablaggi

Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings









Cablaggi

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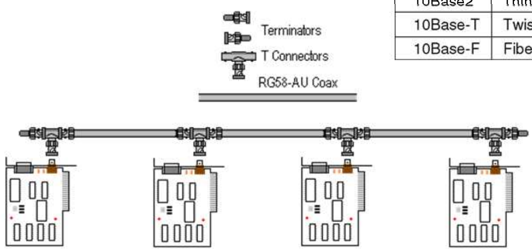
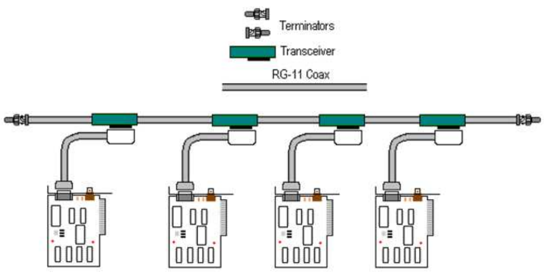
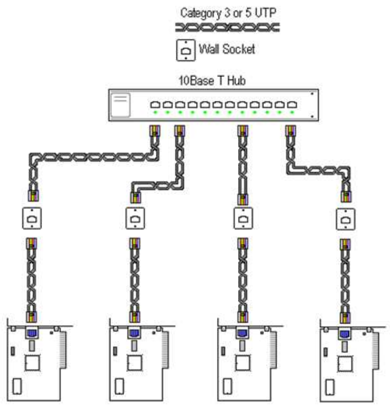
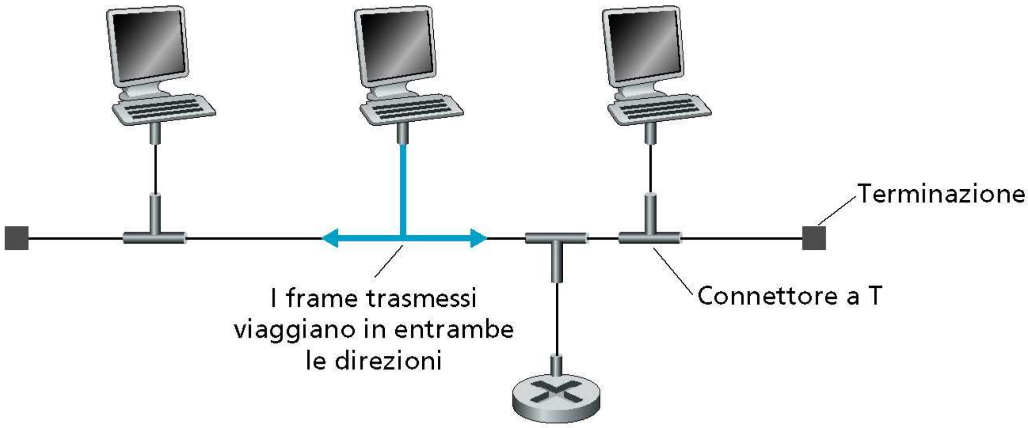


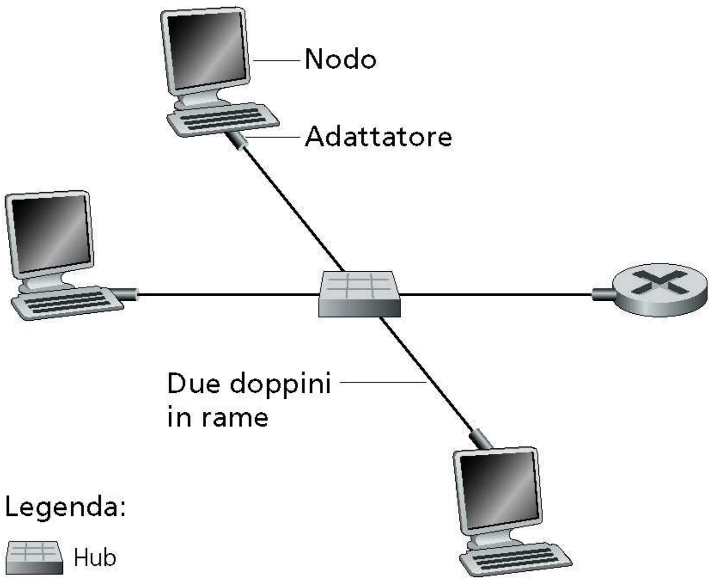




Ethernet 10Base2 - 10Base5

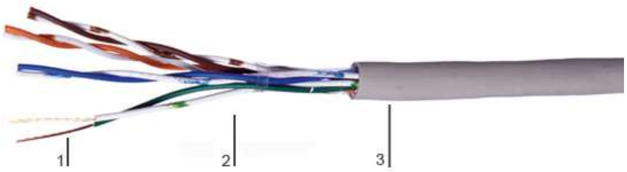


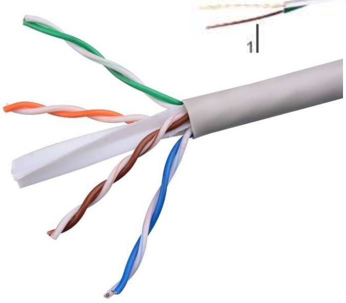
Ethernet 10BaseT

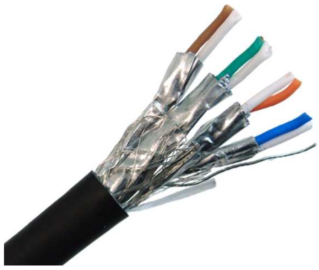


Ethernet 10BaseT

Category	Data Rate	Signal Frequency	Standard
Cat5	100 Mbps	100 MHz	TIA/EIA
Cat5e	100 Mbps /1 Gbps	100 MHz	TIA/EIA-568-B
Cat6	1Gbps / 10 Gbps	250 MHz	TIA/EIA-568-B
Cat6a	1Gbps / 10 Gbps	500 MHz	ANSI/TIA/EIA-568-B.2-10

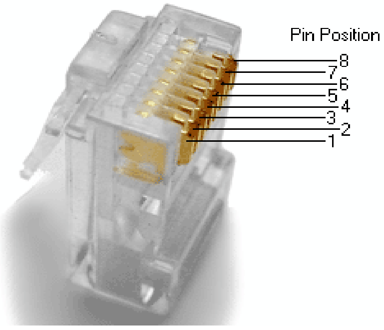


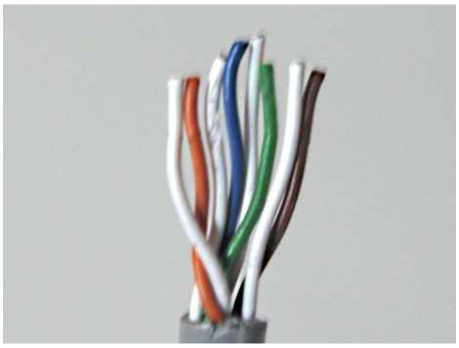




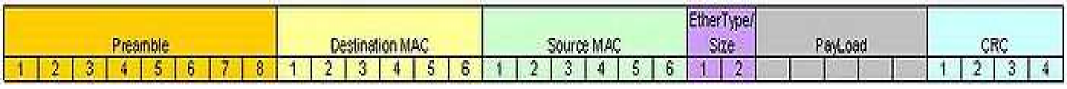
Ethernet 10BaseT

Color	Pin (T568B)	Usage
White/Orange	1	Transmission (Tx+)
Orange	2	Transmission (Tx-)
White/Green	3	Receive (Rx+)
Blue	4	--
White/Blue	5	--
Green	6	Receive (Rx-)
White/Brown	7	--
Brown	8	--





Frame ethernet



Il campo E-type/size indica la lunghezza del campo dati per valori inferiori a 1500, mentre indica il tipo di frame per valori superiori.

Il campo tipo viene utilizzato per il mux/demux sul livello network .

Campo Ethernet type

0x0800 IPv4

0x0806 ARP

0x0842 Wake-on-Lan

0x8035 RARP

0x809B Ethertalk

0x80F3 AppleTalk Address Resolution Protocol (AARP)

0x8100 VLAN-tagged frame (IEEE 802.1Q)

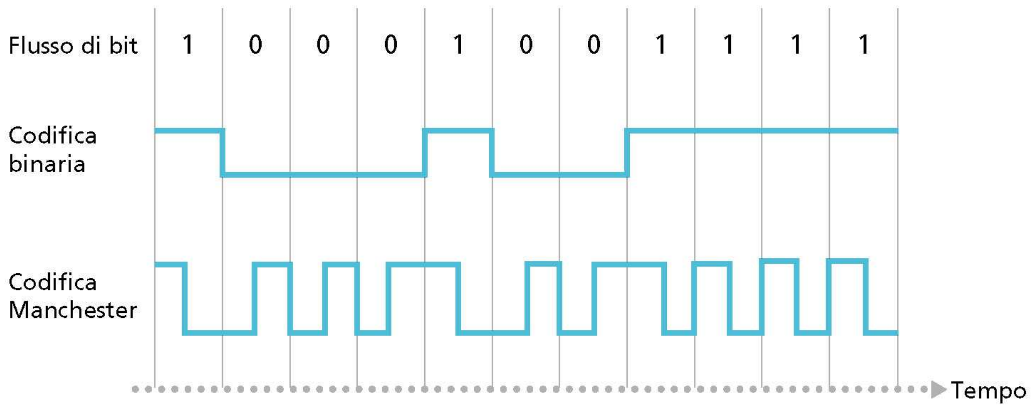
0x8137 Novell IPX

0x8138 Novell

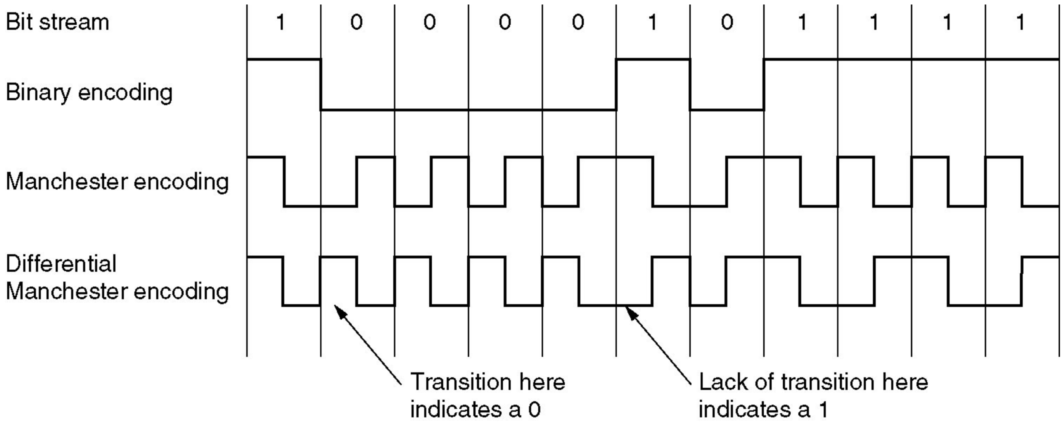
0x86DD IPv6

…

Codifica Manchester



Codifica Manchester



Fast Ethernet

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

100Base-T4 usa la codifica 8B6T e sfrutta tutte le coppie presenti.

100Base-TX usa la codifica 4B5B

Fast Ethernet

TABLE 3.1 Fast Ethernet and FDDI 4B/5B Codes

Four-Bit Data	Five-Bit Encoding
0000 (0)	1 1 1 1 0
0001 (1)	0 1 0 0 1
0002 (2)	1 0 1 0 0
0003 (3)	1 0 1 0 1
0004 (4)	0 1 0 1 0
0005 (5)	0 1 0 1 1
0006 (6)	0 1 1 1 0
0007 (7)	0 1 1 1 1
0008 (8)	1 0 0 1 0
0009 (9)	1 0 0 1 1
1010 (A)	1 0 1 1 0
1011 (B)	1 0 1 1 1
1100 (C)	1 1 0 1 0
1101 (D)	1 1 0 1 1
1110 (E)	1 1 1 0 0
1111 (F)	1 1 1 0 1
S (Set)	1 1 0 0 1
R (Reset)	0 0 1 1 1
Q (Quiet)	0 0 0 0 0
I (Idle)	1 1 1 1 1
H (Halt)	0 0 1 0 0
T (Terminate)	0 1 1 0 1
J (Start 1)	1 1 0 0 0
K (Start 2)	1 0 0 0 1

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Gigabit Ethernet

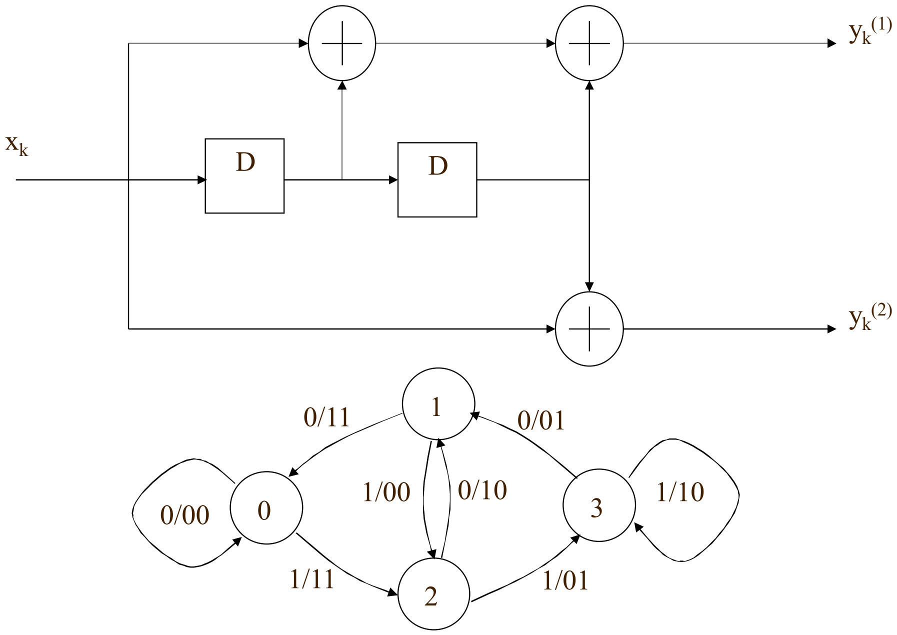
Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

Gigabit Ethernet

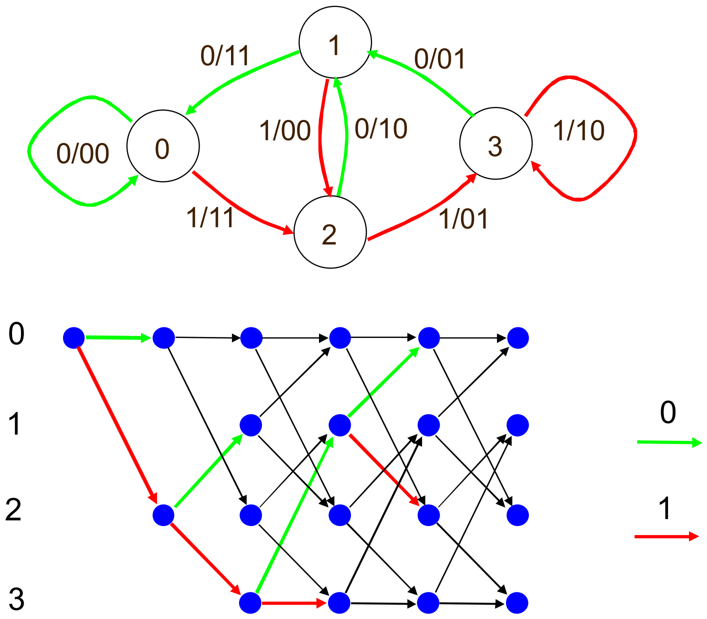
Cinque passi verso 1000BASE-T (cat5)

- rimuovere la codifica 4B5B (100 ->125 Mbps).
- usare le 4 coppie simultaneamente (125 -> 500Mbps).
- trasmissione full duplex (500Mbps full-duplex).
- usare 5 livelli per baud invece che 3 (MLT-3) (5x5x5x5 => 2Gbps full-duplex).
- usare un forward error correction (FEC) per recuperare 6dB.

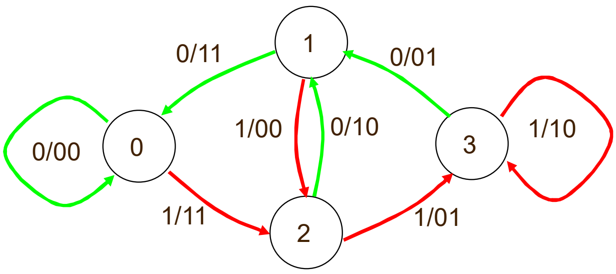
Gigabit Ethernet

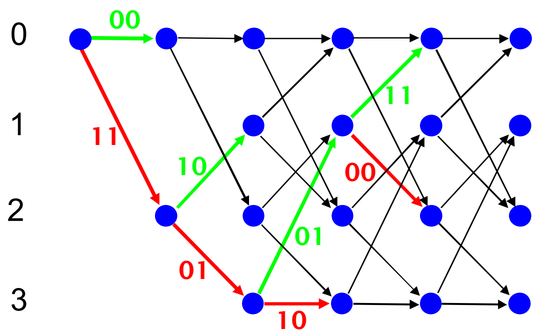


Gigabit Ethernet

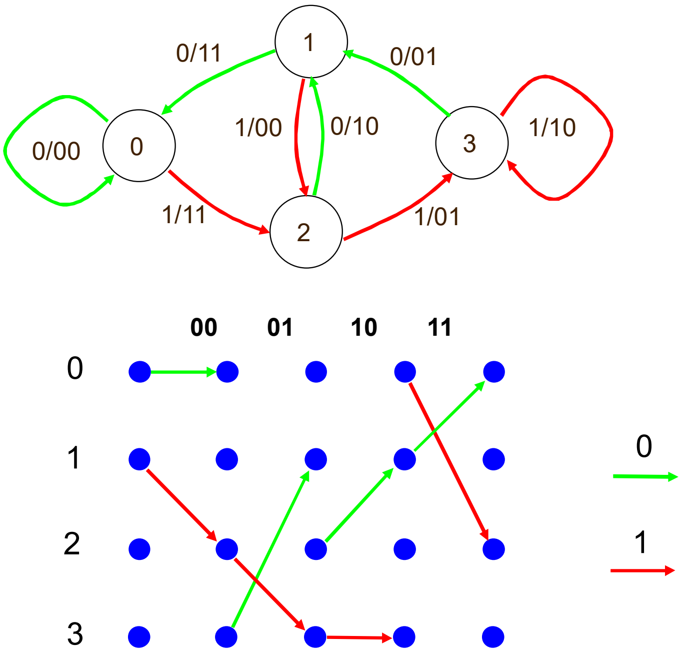


Gigabit Ethernet



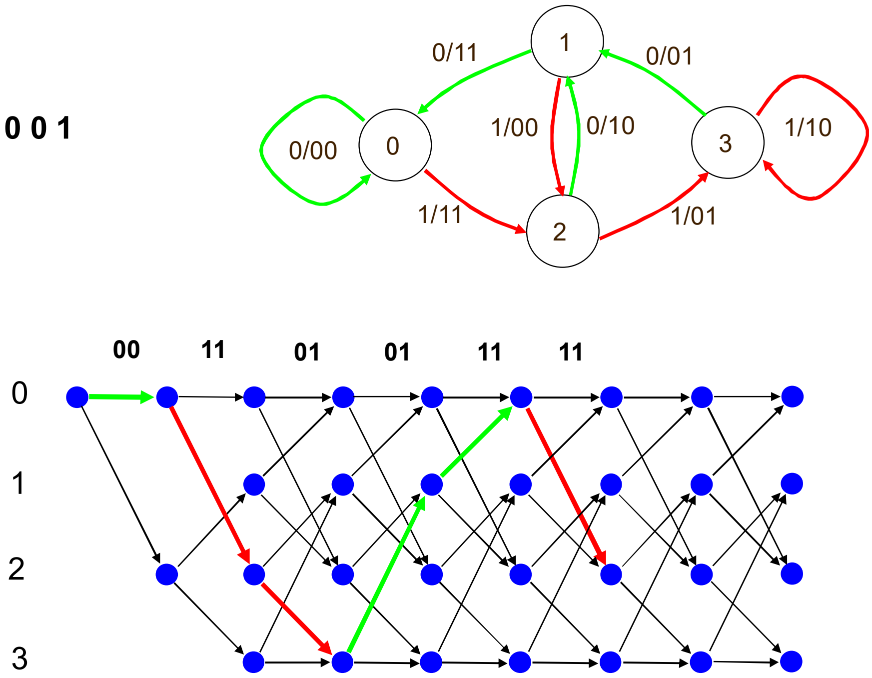


Gigabit Ethernet

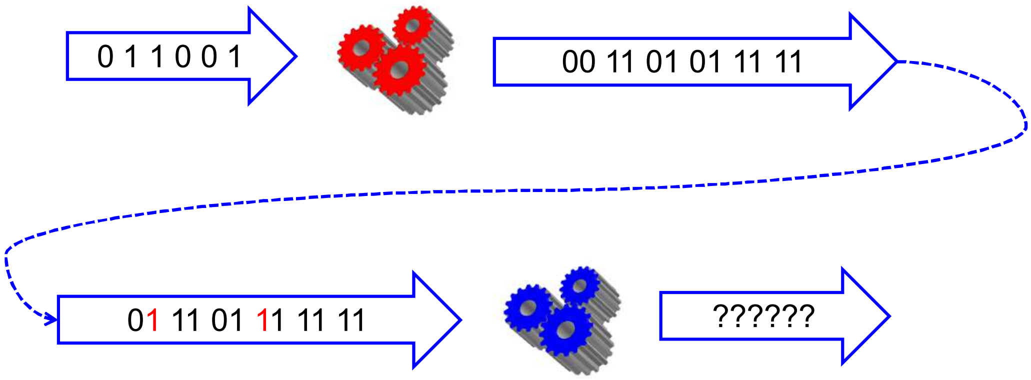


Gigabit Ethernet

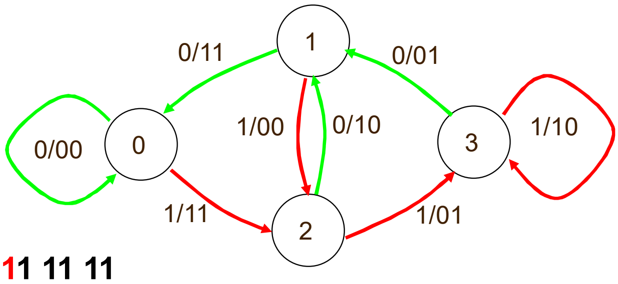
0 1 1 0 0 1



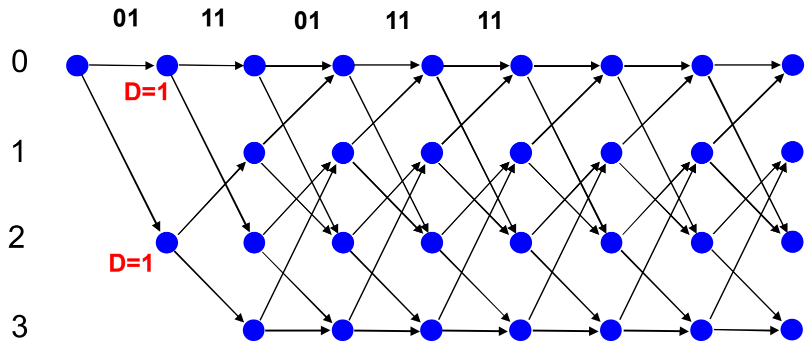
Gigabit Ethernet



Gigabit Ethernet

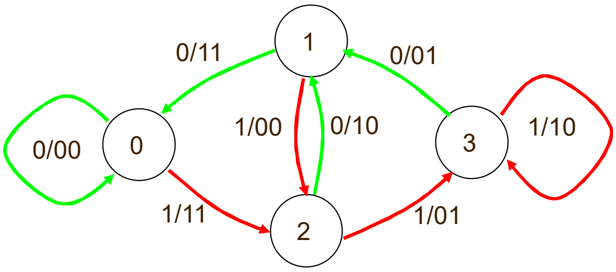


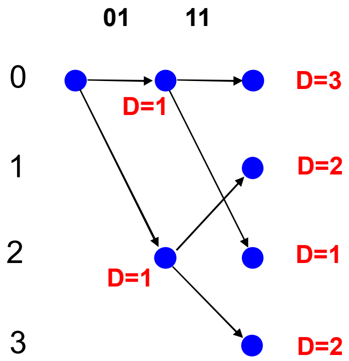
01 11 01 11 11 11



Gigabit Ethernet

01 11 01 11 11 11





00 00

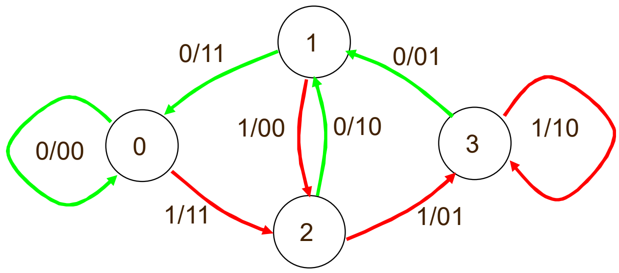
11 10

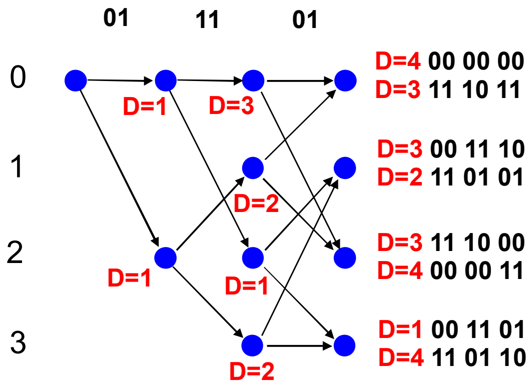
00 11

11 01

Gigabit Ethernet

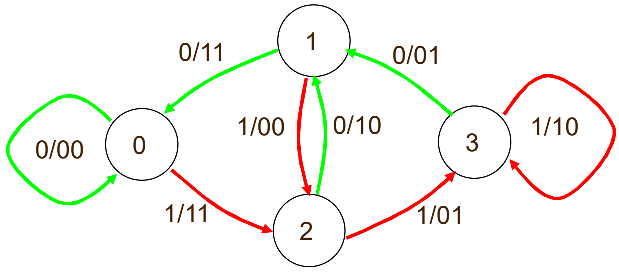
01 11 01 11 11 11

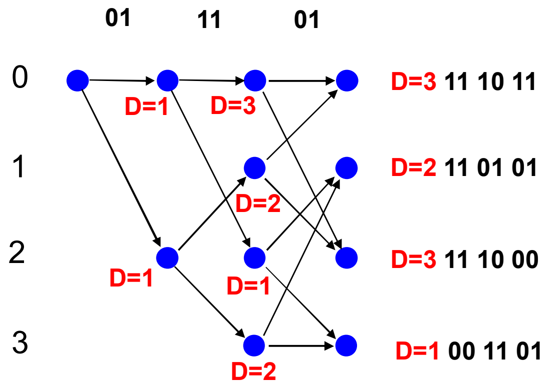




Gigabit Ethernet

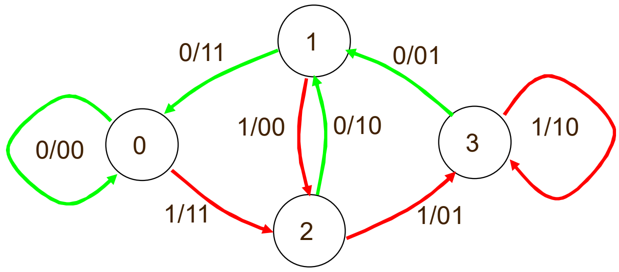
01 11 01 11 11 11

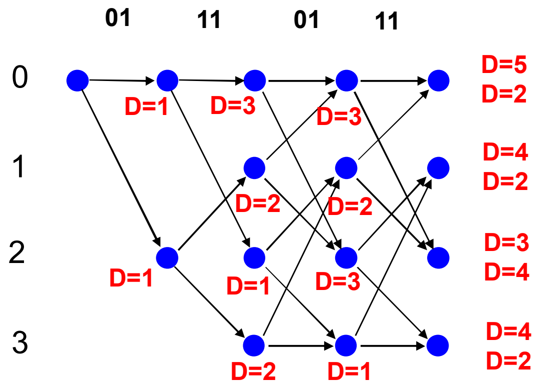




Gigabit Ethernet

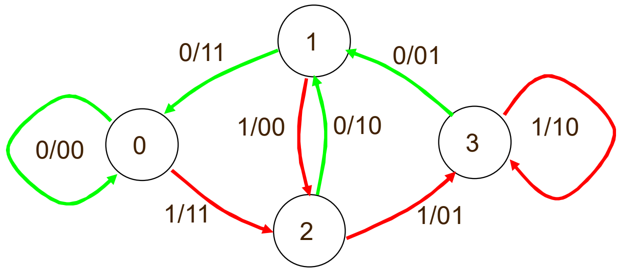
01 11 01 11 11 11

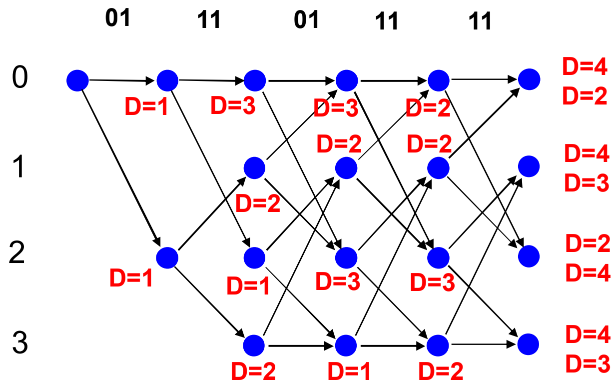




Gigabit Ethernet

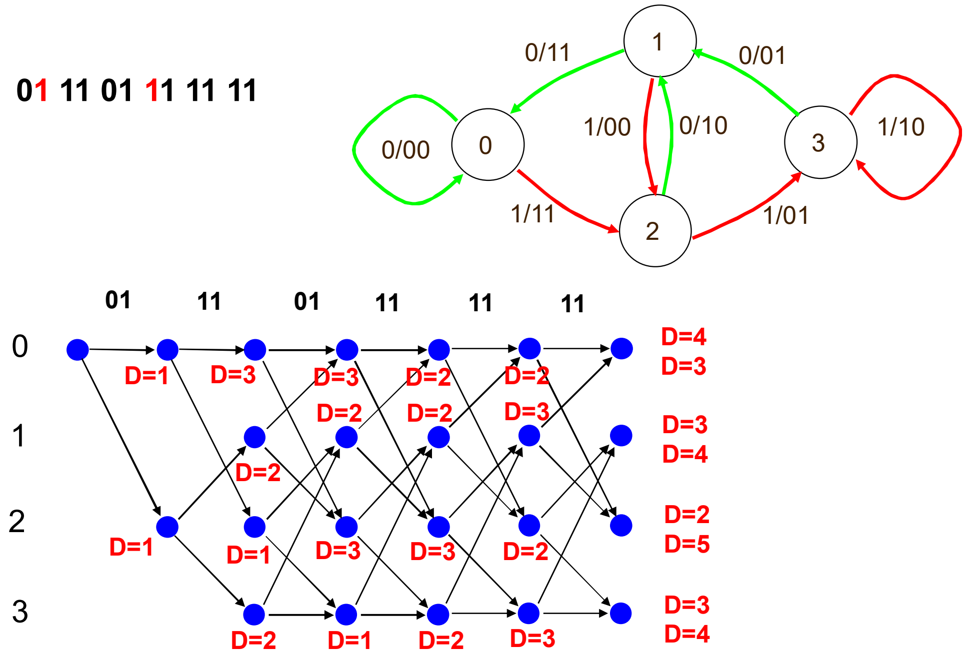
01 11 01 11 11 11





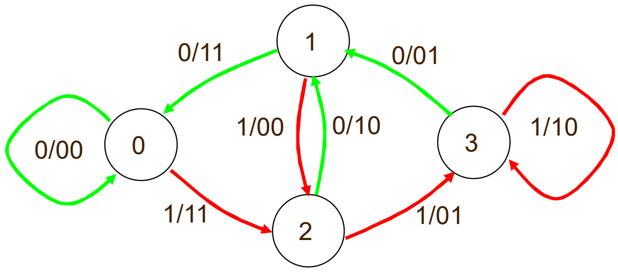
Gigabit Ethernet

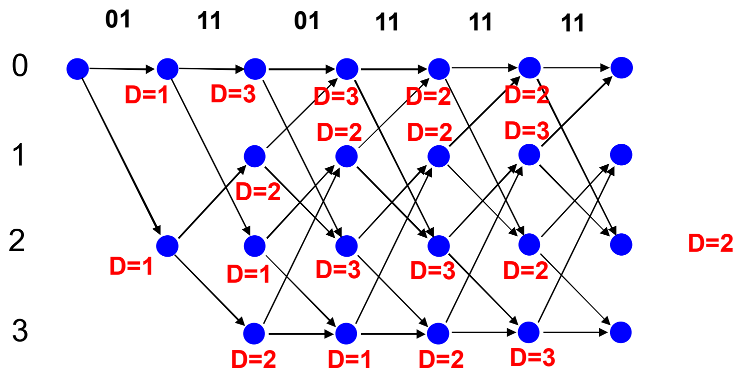
01 11 01 11 11 11



Gigabit Ethernet

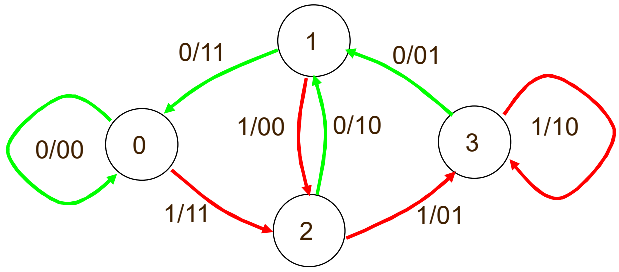
01 11 01 11 11 11

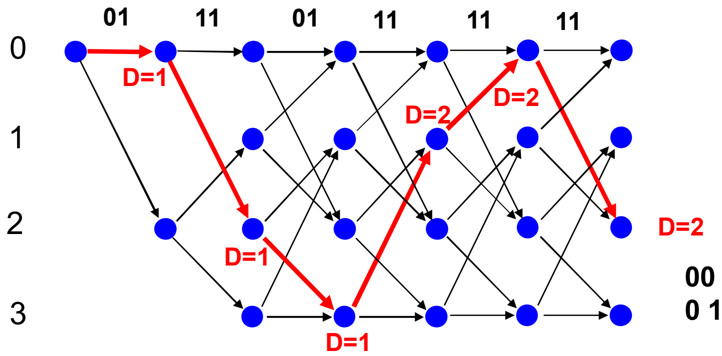




Gigabit Ethernet

01 11 01 11 11 11



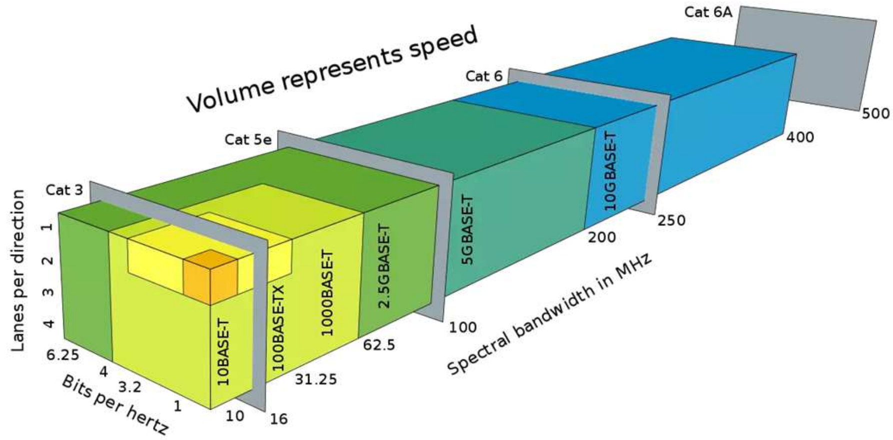


00 11 01 01 11 11
0 1 1 0 0 1

Riepilogo 10 – 100 - 1000

Tecnologia	Massima lunghezza del link	Codifica	Topologia del mezzo		Bit rate (bps)
10Base5 10Base2	500 m 185 m	Manchester Manchester	bus bus	50-ohm coax 50-ohm coax	10 M 10 M
10BaseT	100 m	Manchester	star	2 pair UTP cat. 3,4,5	10
100BaseFL 100BaseT2	2000 m 100 m	Manchester PAM 5x5	star star	Multi-mode fiber* 2 pairs UTP cat. 3,4,5	10 M 100 M
100BaseT4	100 m	8B/6T	star	4 pairs UTP cat. 3,4,5	100 M
100BaseTX	100 m	4B/5B with MLT-3	star	2 pairs UTP cat. 5	100 M
100BaseFX 1000BaseT	412/2000 m 100 m	4B/5B with NRZI PAM 5x5	star star	Multi-mode fiber* 4 pairs UTP Cat 5	100 M 1000 M
1000BaseSX	275 m	8B/10B	star	Multi-mode fiber†	1000 M
1000BaseLX	316/550 m	8B/10B	star	Multi-modeFiber‡	1000 M
1000BaseCX	25 m	8B/10B	star	Twinax	1000 M

Oltre 1Gbps

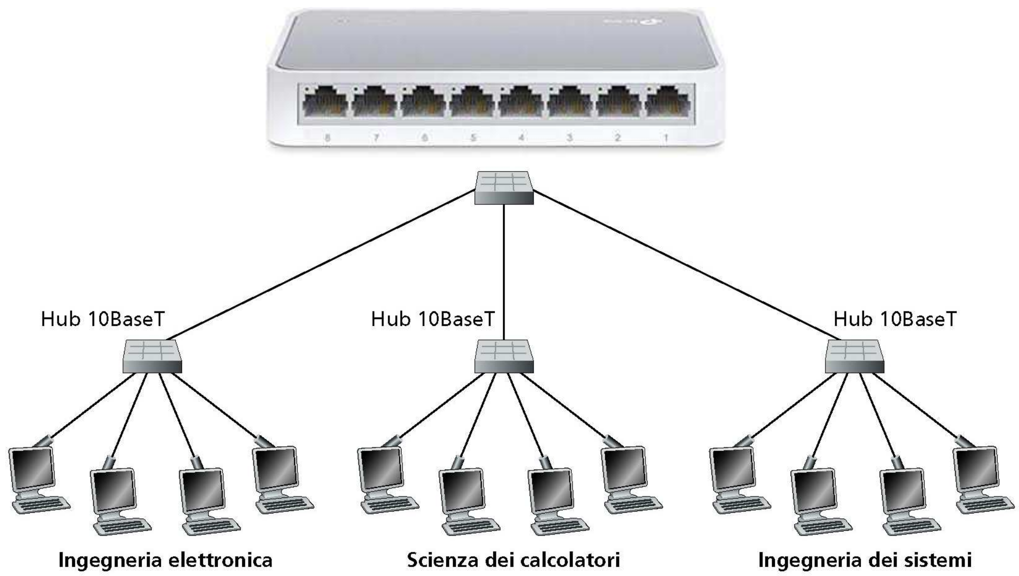


Volume represents speed
Cat 3
Cat 5e
Cat 6
Cat 6A
Lanes per direction
1
2
3
4
6.25
4
3.2
1
Bits per hertz
10
16
31.25
62.5
100
200
250
400
500
Spectral bandwidth in MHz
10BASE-T
100BASE-TX
1000BASE-T
2.5GBASE-T
5GBASE-T
10GBASE-T

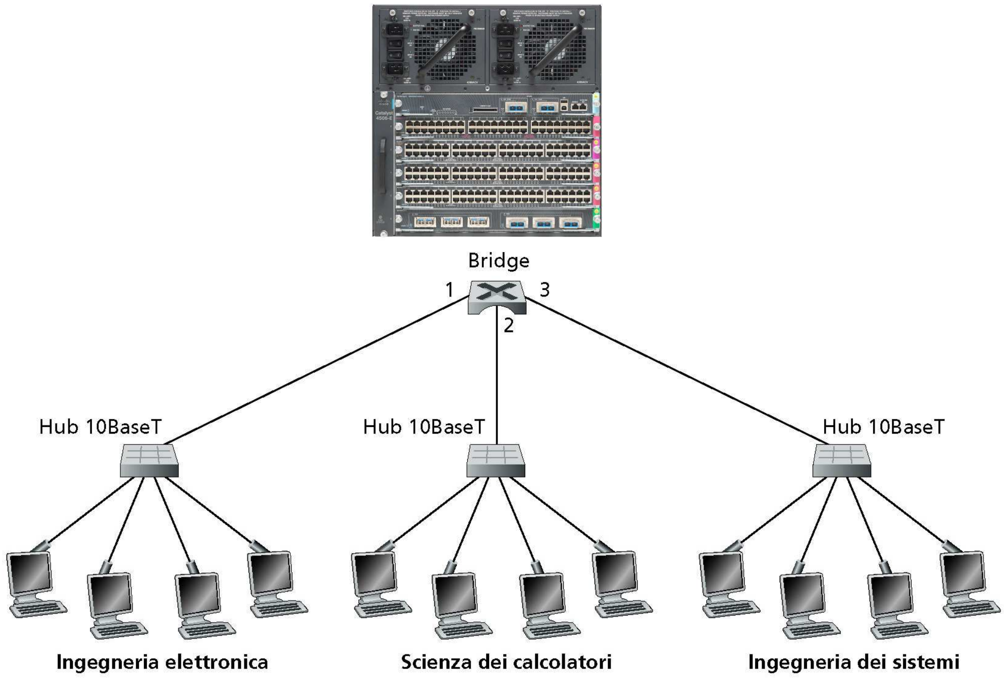
40 Gbps

Standard	Transfer speed[a]	Channels per direction[b]	Bits per Hertz per channel[c]	Spectral bandwidth[d]	Cable req. 100 m	Cable spec 100 m
10BASE-T	10 Mbit/s	1	1	10 MHz	Cat 3	16 MHz
100BASE-TX	100 Mbit/s	1	3.2	31.25 MHz	Cat 5	100 MHz
1000BASE-T	1000 Mbit/s	4	4	62.5 MHz	Cat 5e	100 MHz
2.5GBASE-T	2500 Mbit/s	4	6.25	100 MHz	Cat 5e	100 MHz
5GBASE-T	5000 Mbit/s	4	6.25	200 MHz	Cat 6	250 MHz
10GBASE-T	10000 Mbit/s	4	6.25	400 MHz	Cat 6A[e]	500 MHz
25GBASE-T	25000 Mbit/s	4	6.25	1000 MHz	Cat 8 (30 m)	1600/2000 MHz
40GBASE-T	40000 Mbit/s	4	6.25	1600 MHz	Cat 8 (30 m)	1600/2000 MHz

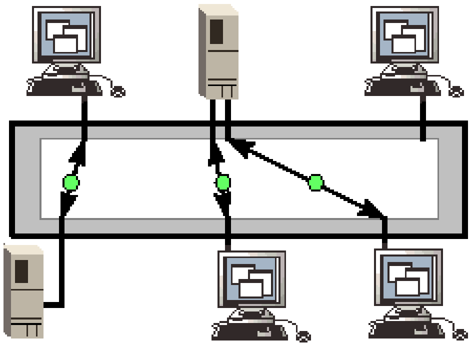
Hub Ethernet



Bridge Ethernet

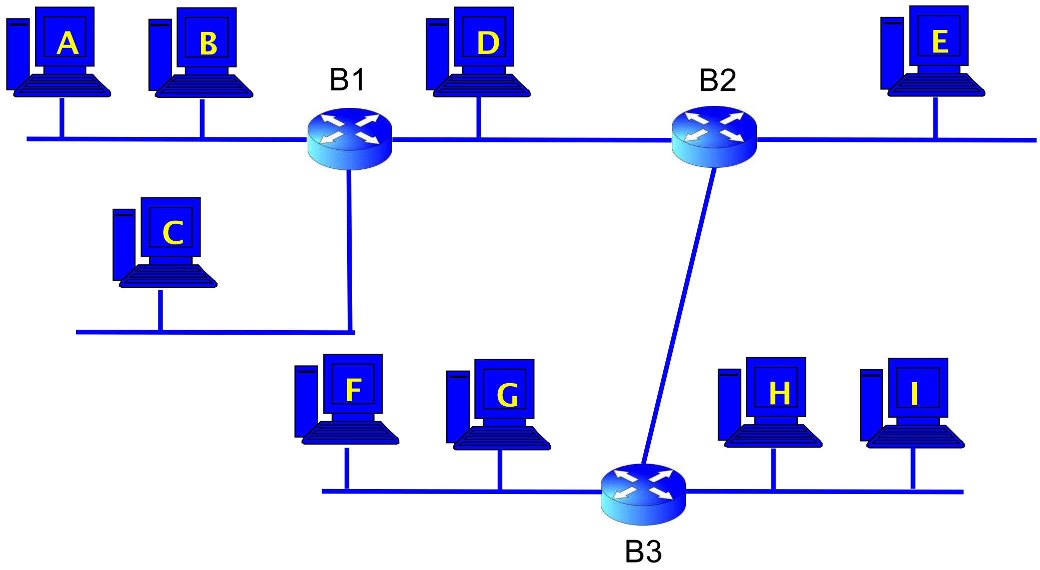


Bridge

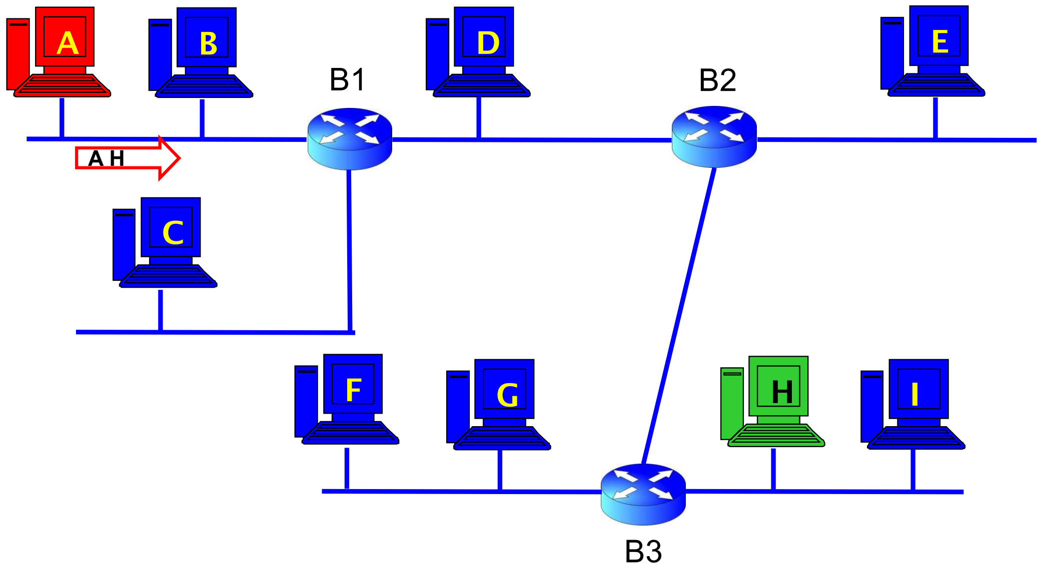


Indirizzo	Interfaccia	Tempo
62-FE-F7-11-89-A3	1	9:32
7C-BA-B2-B4-91-10	3	9:36
.....	.....	.....

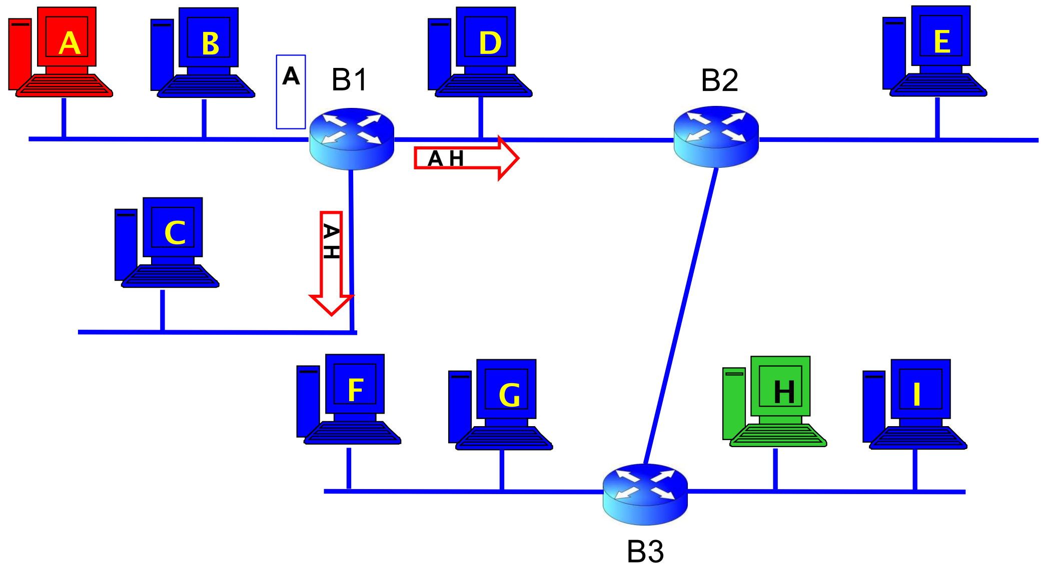
Bridge



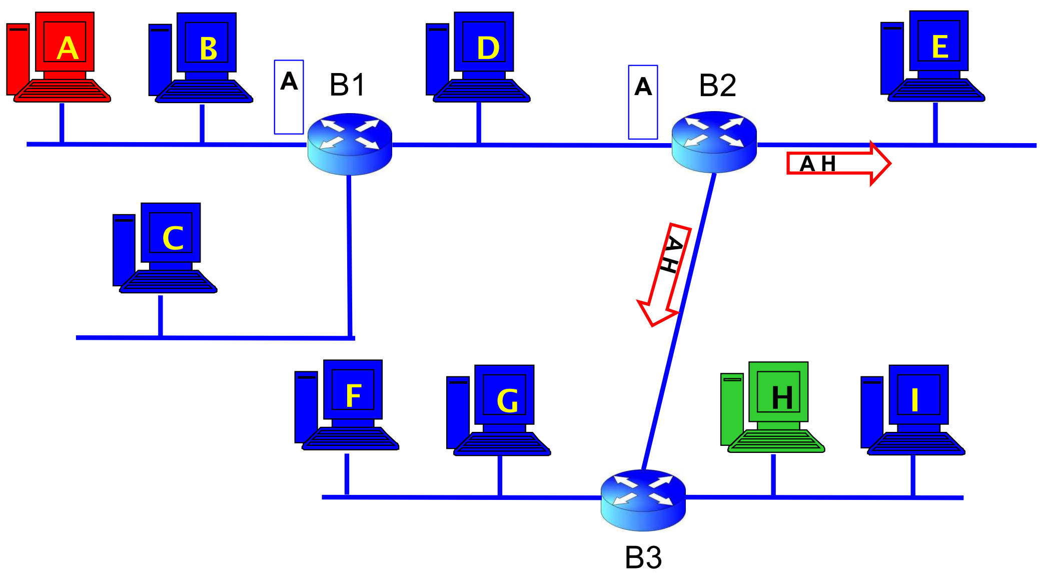
Bridge



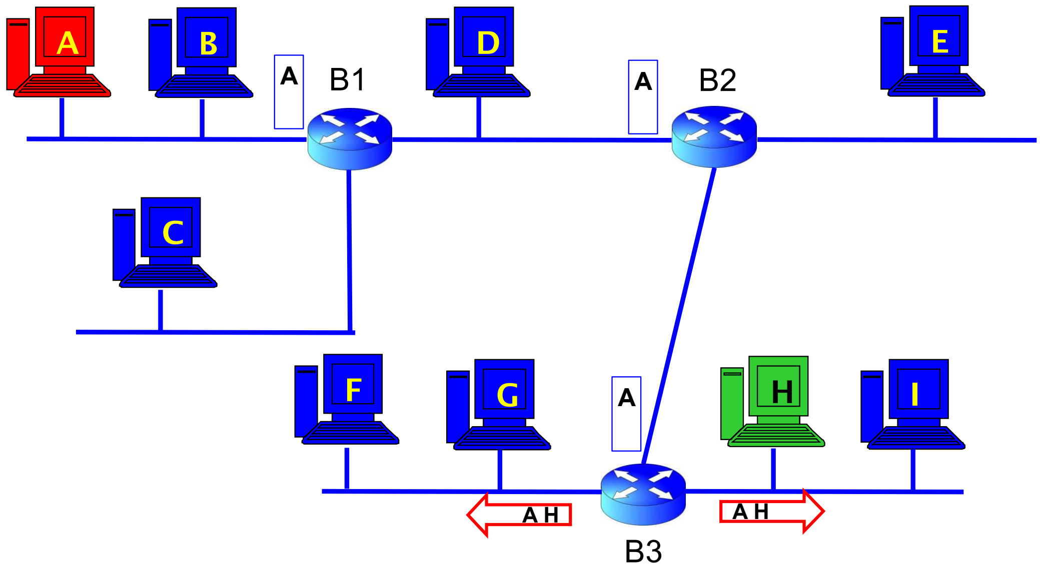
Bridge



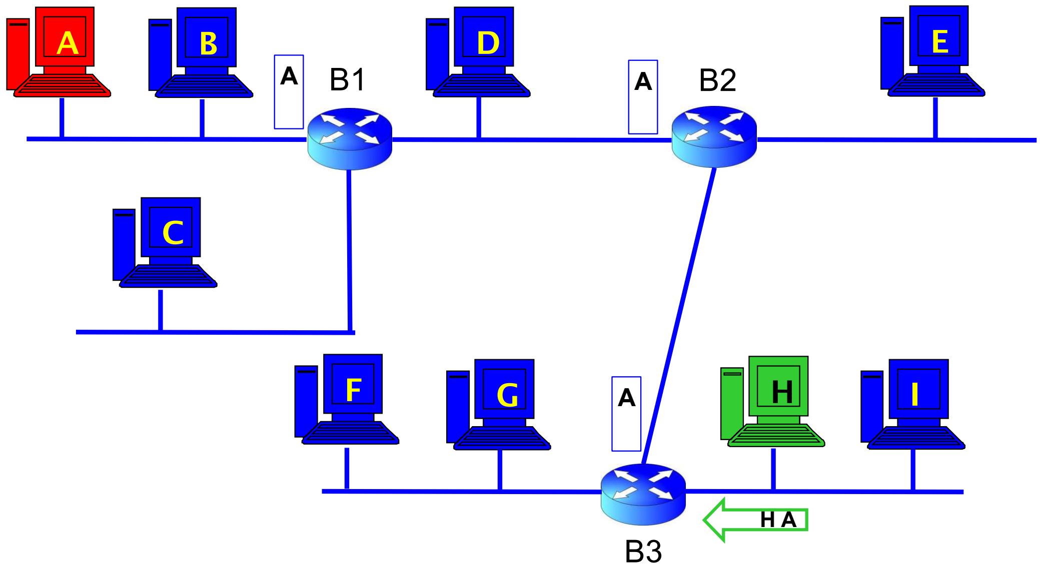
Bridge



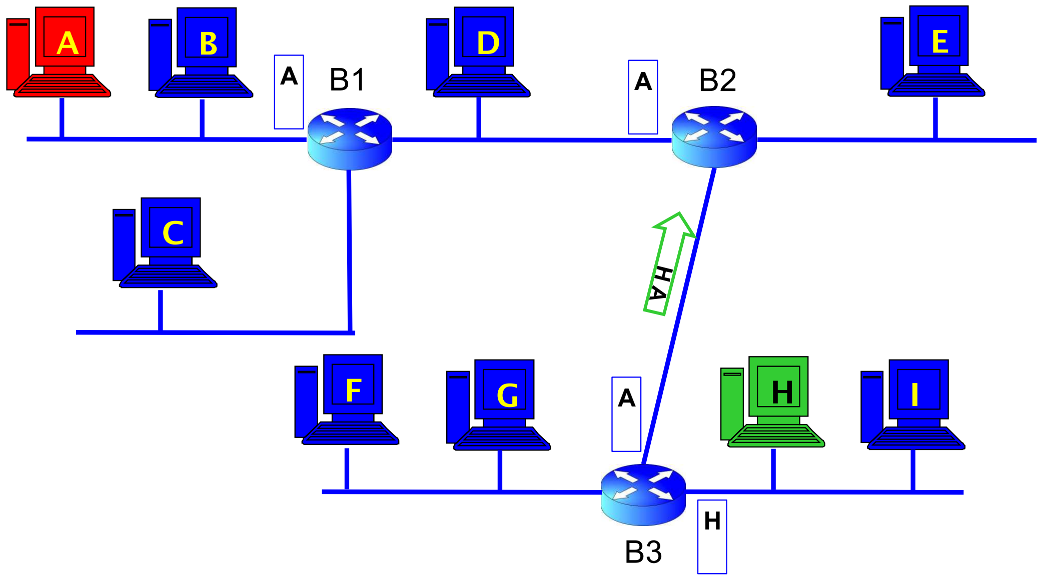
Bridge



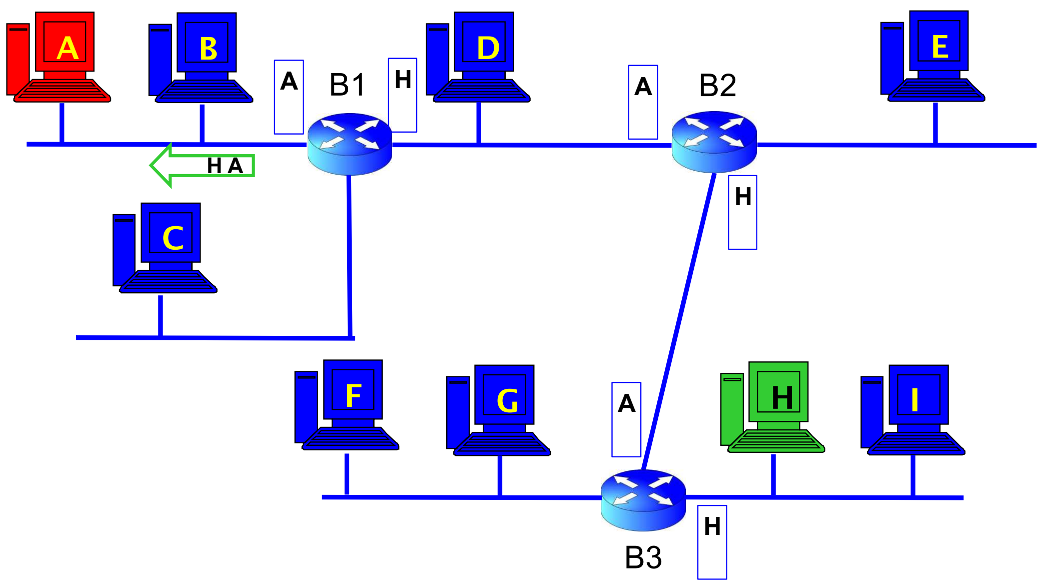
Bridge



Bridge



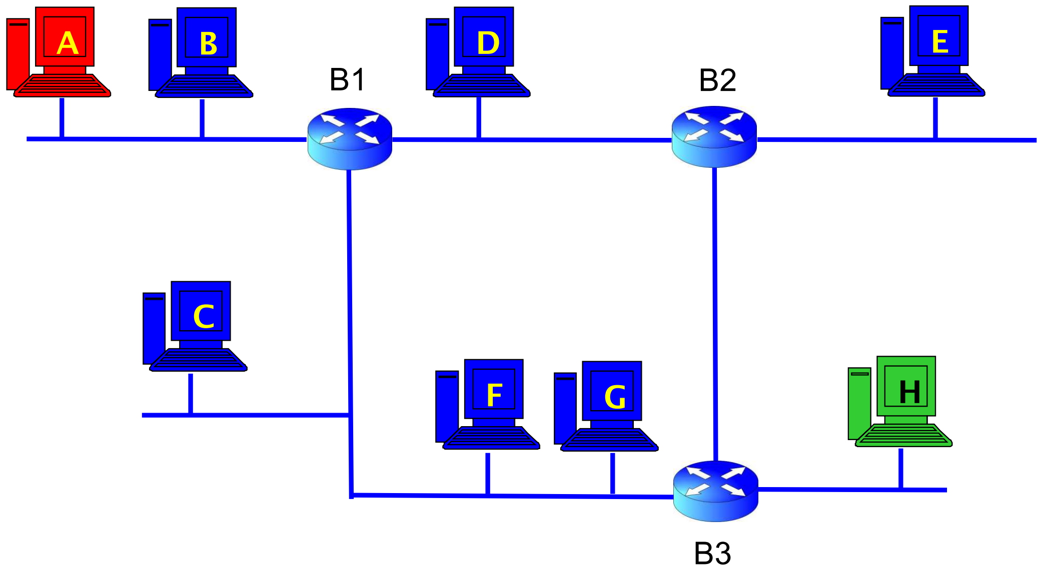
Bridge



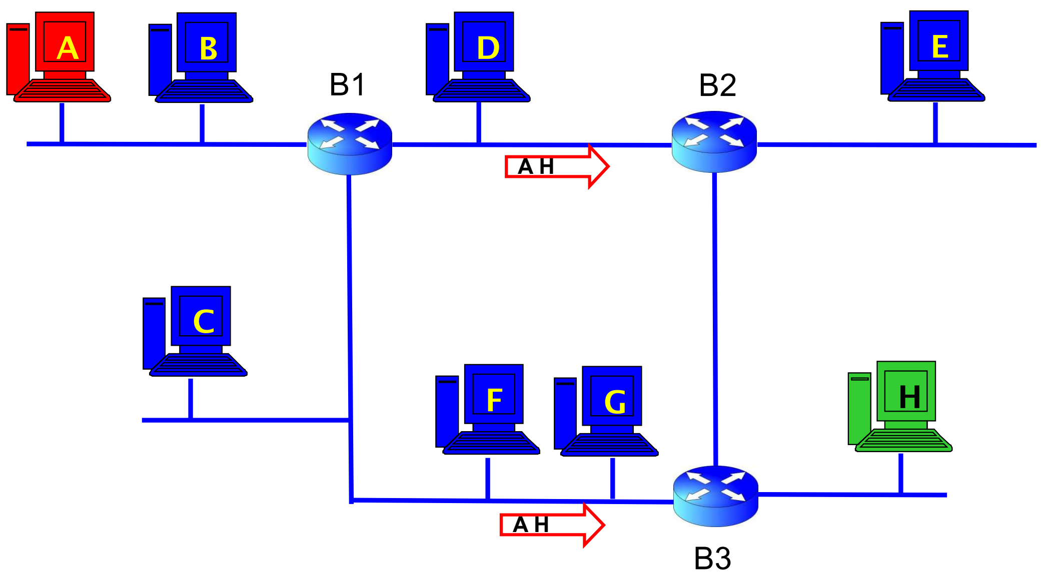
Bridge

Indirizzo	Interfaccia	Tempo
01-12-23-34-45-56	2	9:39
62-FE-F7-11-89-A3	1	9:32
7C-BA-B2-B4-91-10	3	9:36
.....	.....	.....

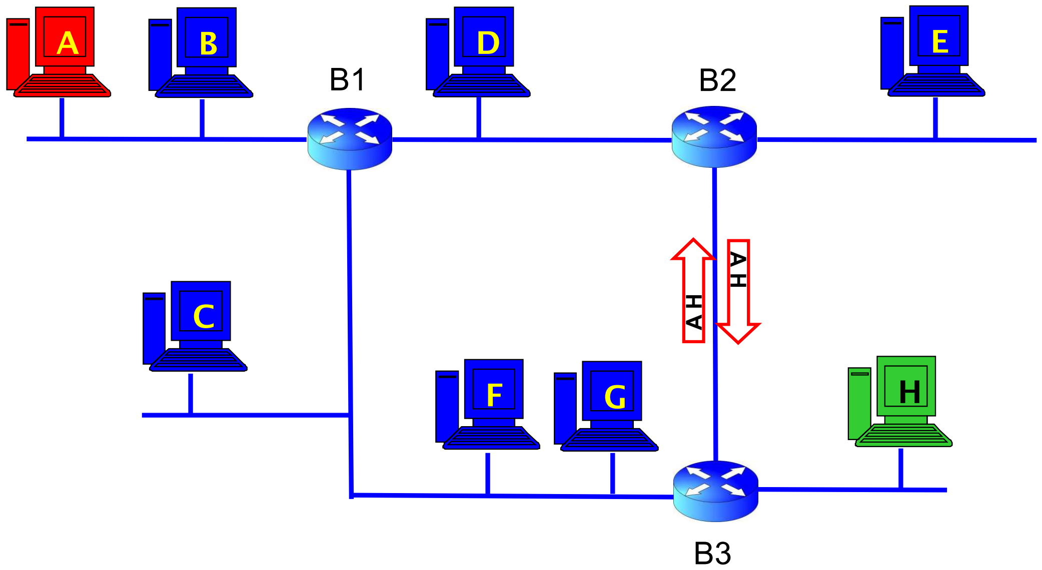
Bridge



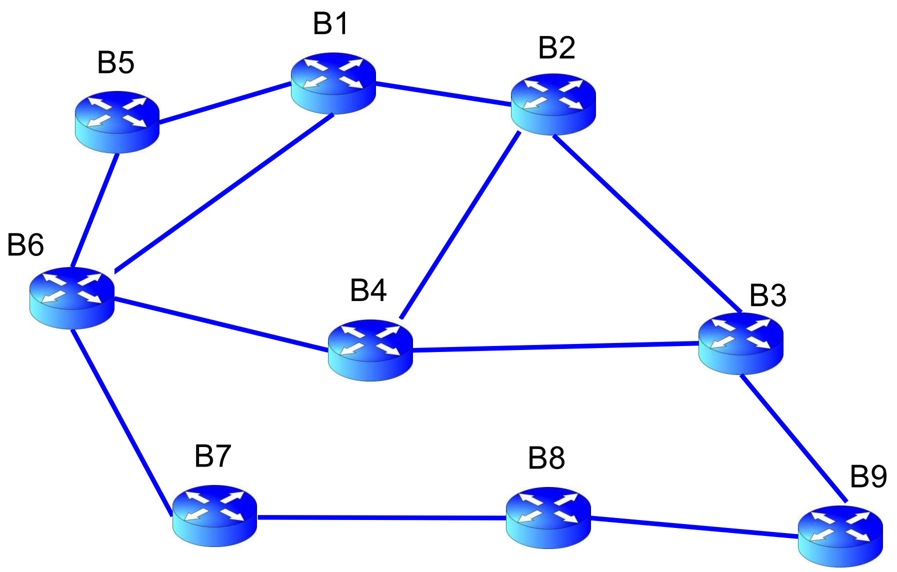
Bridge



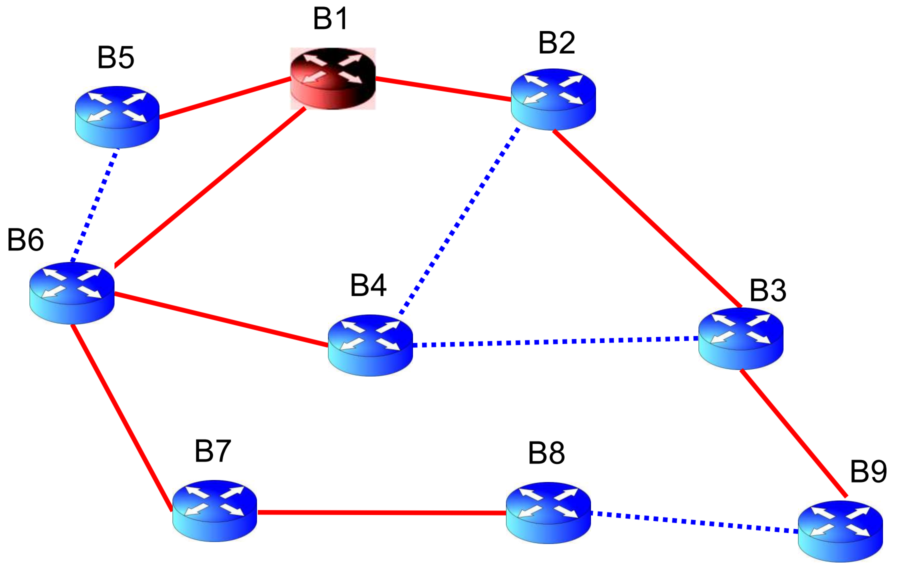
Bridge



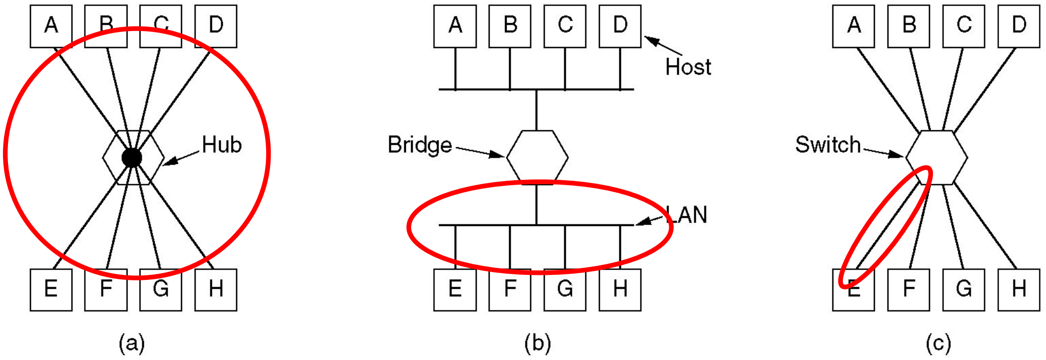
Spanning Tree Protocol (IEEE 802.1d)



Spanning Tree Protocol (IEEE 802.1d)

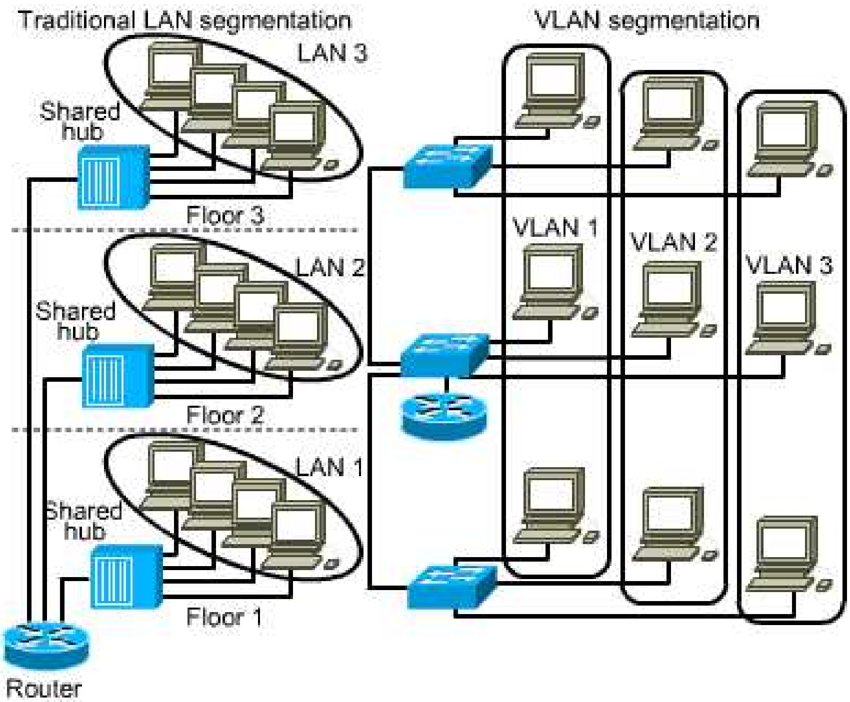


Repeaters, Hubs, Bridges, Switches



Domini di collisione

VLAN


Traditional LAN segmentation
VLAN segmentation
LAN 3
Shared hub
Floor 3
LAN 2
Shared hub
Floor 2
LAN 1
Shared hub
Floor 1
Router
VLAN 1
VLAN 2
VLAN 3

VLAN

Le VLAN sono LAN logiche separate realizzate in una stessa struttura fisica. I pacchetti broadcast (livello 2) sono confinati all'interno della VLAN

La connessione tra VLAN differenti deve essere realizzata attraverso routing di livello 3.

Lo standard IEEE 802.1Q definisce le specifiche per le VLAN.

VLAN

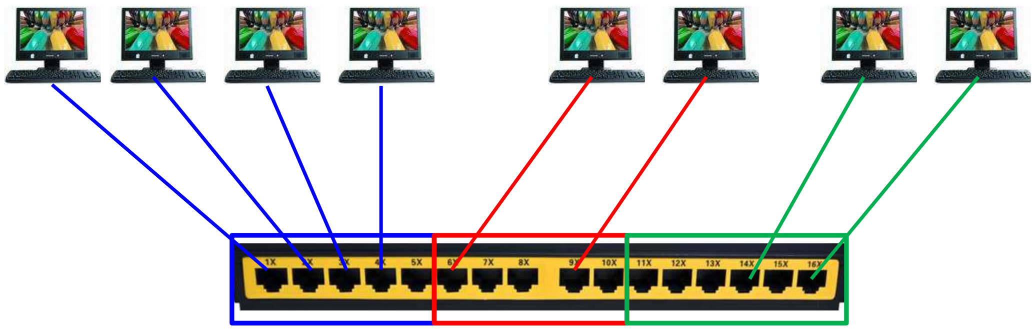
Scopo delle VLAN:

- risparmio: riutilizzo delle linee e degli apparati preesistenti;
- flessibilità: facile spostamento fisico degli utenti;
- aumento di prestazioni: il traffico broadcast viene confinato;
- sicurezza: gli utenti di VLAN differenti non vedono i reciproci frame dati.

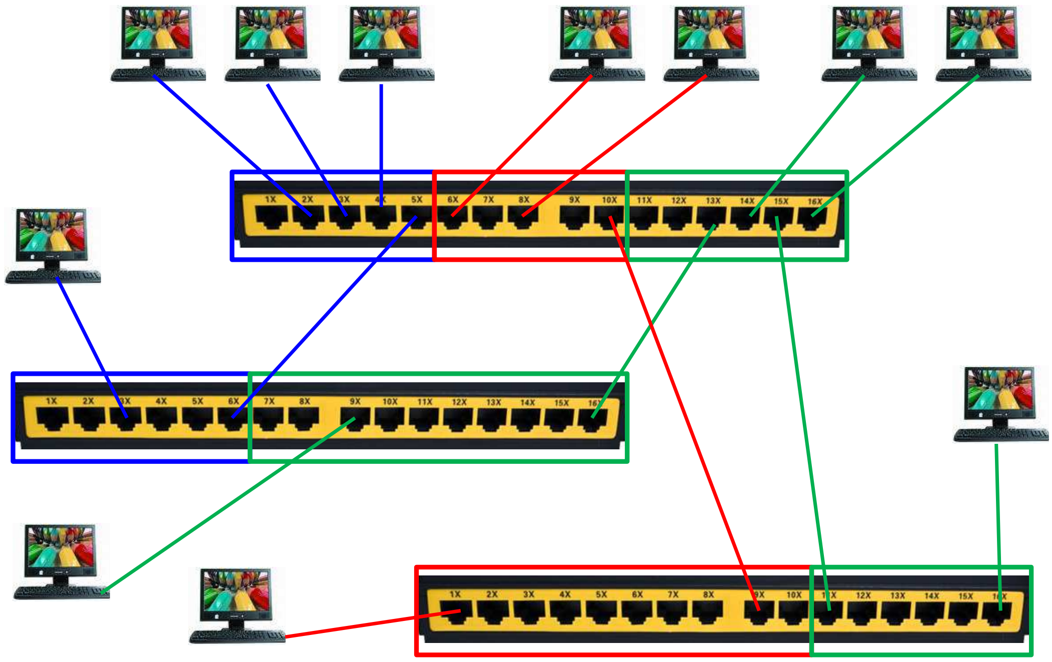
Port based VLAN (untagged)

Lo switch viene logicamente partizionato in più parti, assegnando le singole porte alle varie VLAN.

Per realizzare una VLAN untagged è sufficiente uno switch che supporti il protocollo 802.1Q.

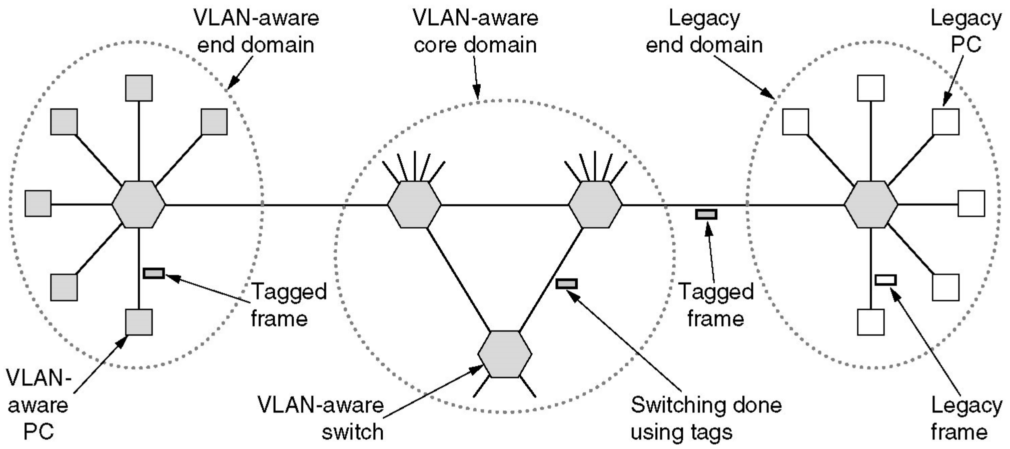


Untagged VLAN



Reti di Calcolatori - 130

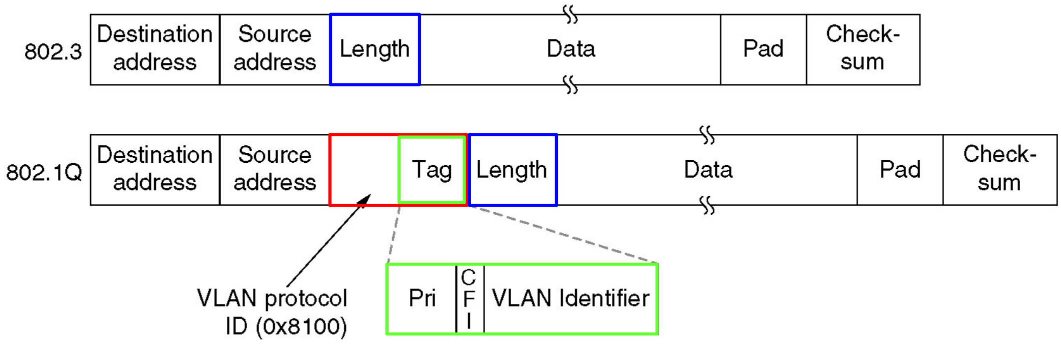
IEEE 802.1Q Standard



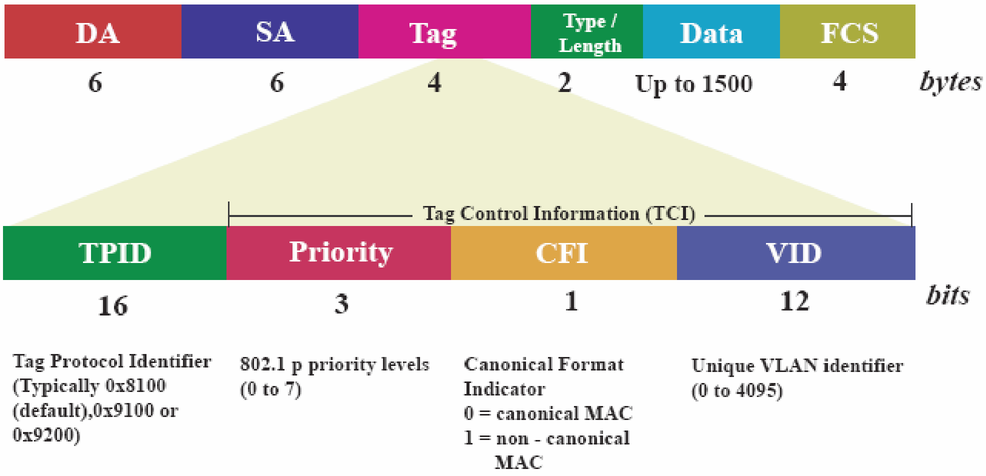
Tagged VLAN

Lo standard 802.1Q consente di utilizzare gli stessi link fisici per VLAN differenti.

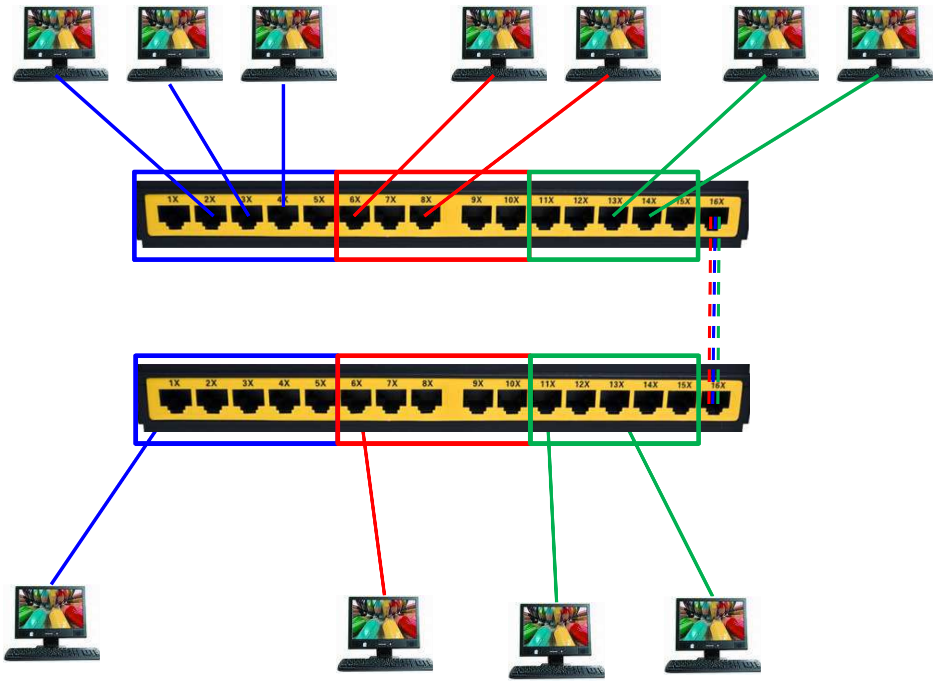
802.1Q inserisce 4 byte nel frame ethernet, per poter associare il frame ad una VLAN.



Tagged VLAN

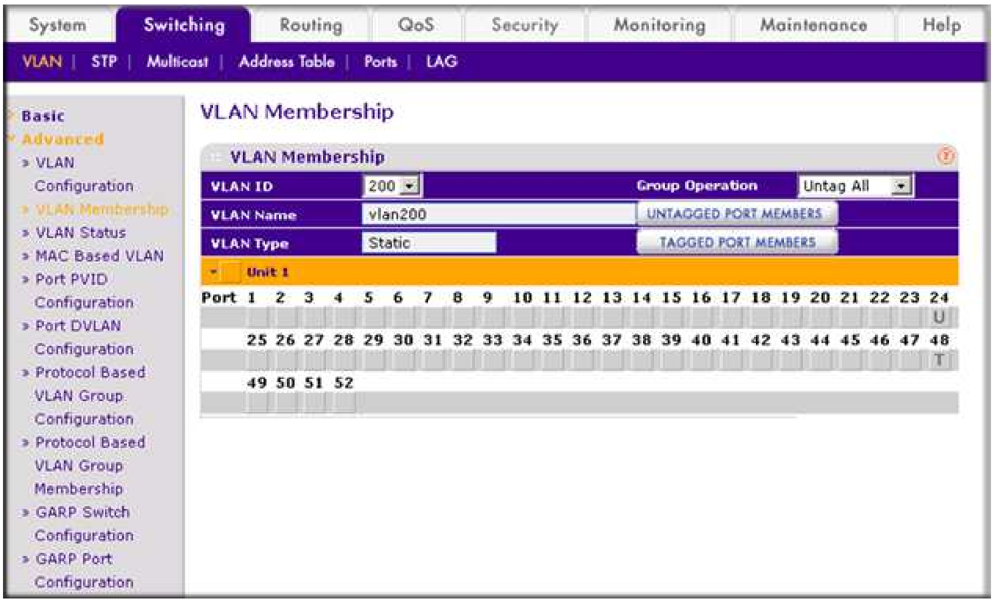

DA
SA
Tag
Type / Length
Data
FCS
6
6
4
2
Up to 1500
4
bytes
Tag Control Information (TCI)
TPID
Priority
CFI
VID
16
3
1
12
bits
Tag Protocol Identifier (Typically 0x8100 (default),0x9100 or 0x9200)
802.1 p priority levels (0 to 7)
Canonical Format Indicator
0 = canonical MAC
1 = non - canonical MAC
Unique VLAN identifier (0 to 4095)

Tagged VLAN



Reti di Calcolatori - 134

VLAN



System
Switching
Routing
QoS
Security
Monitoring
Maintenance
Help
VLAN | STP | Multicast | Address Table | Ports | LAG
Basic
Advanced
» VLAN Configuration
» VLAN Membership
» VLAN Status
» MAC Based VLAN
» Port PVID Configuration
» Port DVLAN Configuration
» Protocol Based VLAN Group Configuration
» Protocol Based VLAN Group Membership
» GARP Switch Configuration
» GARP Port Configuration
VLAN Membership
VLAN Membership
VLAN ID
200
Group Operation
Untag All
VLAN Name
vlan200
UNTAGGED PORT MEMBERS
VLAN Type
Static
TAGGED PORT MEMBERS
Unit 1
Port 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
U
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
T
49 50 51 52