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gd

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Reti di calcolatori

1-2-3 Introduction

TELEX

*qualsiasi trasmissione e ricezione di **segnali che rappresentano messaggi** di qualsiasi natura, attraverso cavi, radio o sistemi ottici e elettromagnetici*

1. **SEGNALAZIONE**
   Processo di selezione del destinatario, apertura e chiusura.
2. **COMMUTAZIONE**
   Processo di interconnessione di canali, unità o reti. **Nodo** gestisce la commutazione tra **mezzi.** **Circuito o pacchetto**
3. **TRAMISSIONE**
   Analogica (infinita e continua) o **numerica** (Discontinua e finita).
   Parallela o **Seriale**
   Asincrona o **Sincrona**
4. **GESTIONE**

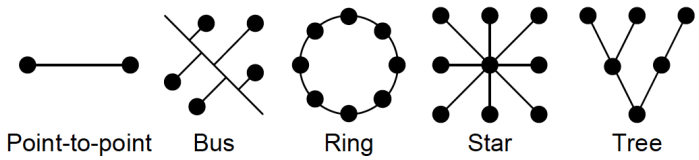
MEZZI E CANALI

1. **MEZZO**
   Mezzo fisico in grado di trasportare informazioni tra due punti
2. **CANALE**
   Aggregato di mezzi.
3. **BANDA**
   (Ampiezza del segnale) **Bitrate**
4. **CAPACITA'**

TOPOLOGIE

$$G = (V, A)$$
$$N = |V| \qquad C = |A|$$

1. **MAGLIA**
   Instradamento complesso e **multi-percorso.**
   $(N-1) < C < \frac{N(N-1)}{2}$
2. **ANELLO (M/B)**
   Mono-direzzionale o pluri-direzionale
   $C = N \;\; C = \frac{N}{2}$
3. **ALBERO**
   Bassa **tolleranza ai guasti.** Riduce i costi e i canali
   $C = N - 1$
4. **STELLA (A/P)**
   Bassa **tolleranza ai guasti.** Riduce i costi e i canali. Gestione **central (a) o broadcast (p).** $C = N$
5. **BUS (A/P)**
   Mono-direzzionale o pluri-direzionale
   $C = N - 1 \;\; C = 1$



METODI MULTIPLAZIONE

1. **FREQUENZA**
   FDM - FDMA
2. **TEMPO**
   TDM - TDMA
3. **CODICE**
   CDM - CDMA
   Come vettori ortogonali. Informazioni come **moltiplicazioni tra codice e payload**
4. **SPAZIO**

STORE AND FORWARD

*Store and forward is a telecommunications technique in which information is **sent to an intermediate** station where it is **kept and sent at a later time** to the final destination or to another intermediate station.*

INFORMATION

*How **much you do not know** from the sender of the message before you have read the message.*

PAYLOAD

$$l = log_2(Alphabet) \cdot L$$

FRAME

*A frame is a digital **data transmission unit** and includes **headers and control parts***

MULTICAST

*IP multicast is a method of sending IP datagrams to a **group of interested receivers in a single transmission.***

DIGITAL AND ANALOG

*Each **digital** communication has a **finite alphabet**, while **analog has not** Both in modulation and demodulation, the states are finite.*

ERROR CORRECTION

*Error control are techniques that enable **reliable delivery** of digital data over **unreliable channels.***

HASH CHECKSUM **INTEGRITY CHECK**

- **PARITA'**
  Rileva unicamente **un** errore.
- **RIPETIZIONE**
- **RIGA-COLONNA**
  Permette di rilevare **errori puntuali**

REASSEMBLY

*Information are rearranged together as of the **fragmentation process** needed for the **integrity check.***

- **OVERHEAD (PCI)**
  Data sent with the purpose of **controlling the transfer** of user information or the **detection and correction of errors.**

STREAMS

Message with no specific size.

- **FRAGMENTATIONS**
  Streams in nowadays networks are possible because of **fragmentation of the informations flow.**

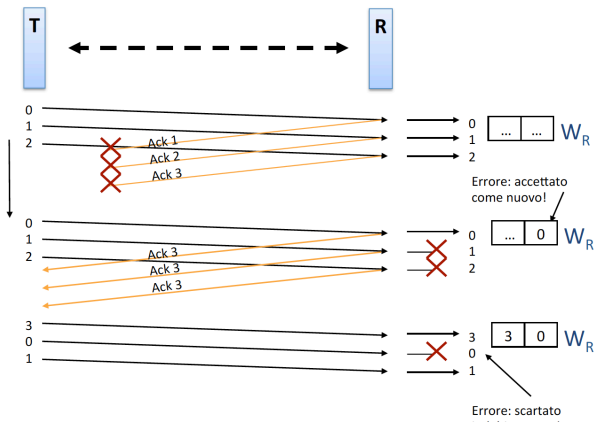
ARQ AUTOREPEAT

*The receiver asks for **fragments** of messages to be re-sent because **integrity checks failed.***

FRAGMENTATION

INTEGRITY AND ACKs

- **ALTERNATING BIT**
  Numerazione PDU **0/1**
- **ALTERNATING BIT 4**
  Numerazione PDU **0/1/2/3** può essere maliziosa per **non sequenziali**
- **SELECTIVE REPEAT**
  the sender sends a **number of frames specified by a window size** even without the need to wait for individual ACK from the receiver as in Go-Back-N ARQ.
  $W_t + W_r \leq 2^k$



A. **STOP AND WAIT**
   Singolo ACK
B. **GO-BACK-N**
   W_T con $n > 1$
C. **SELECTIVE REPEAT**
   W_T e W_R

PROTOCOLLO

1. **SEMANTICA**
2. **STRUTTURA**
3. **TEMPORIZZAZIONE**

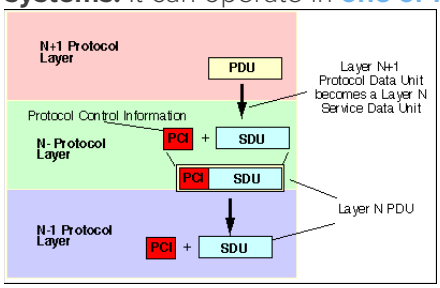
OSI

*The Open Systems Interconnection model is a **conceptual model** that standardizes the communication functions of a telecommunication system without regard to their underlying internal structure and technology.*

INTEROPERABILITY

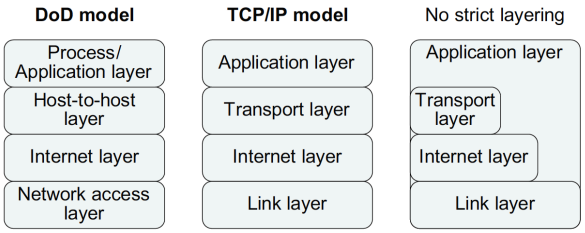
Layer	Function	Example
Application (7)	Services that are used with end user applications	SMTP,
Presentation (6)	Formats the data so that it can be viewed by the user Encrypt and decrypt	JPG, GIF, HTTPS, SSL, TLS
Session (5)	Establishes/ends connections between two hosts	NetBIOS, PPTP
Transport (4)	Responsible for the transport protocol and error handling	TCP, UDP
Network (3)	Reads the IP address form the packet.	Routers, Layer 3 Switches
Data Link (2)	Reads the MAC address from the data packet	Switches
Physical (1)	Send data on to the physical wire.	Hubs, NICS, Cable

- **LAYER**
  A layer serves the **layer above** it and **is served by the layer below it.**
  The **service interface UP** serves the user.
  The **service interface DOWN** is interacting with whatever is needed
  The **peer interface** is interacting with the same layer on the **opposite side.**
- **HEADER**
  Is a piece of information attached to the information by a **single layer.**
- **RELAY**
  Network, data and physical layers serve as **relay system** as to communicate between **end open systems.** It can operate in **one or more of these layers.**



LESS STRUCTURED OSI

OSI is a strict model, therefore is not actually used in telecommunications.



- **APPLICATION**
  Specifies the **shared protocols and interface methods** used by hosts in a communications network. **DOS TELNET BROWSER**
  OVERRIDE: Some or all functions of the lower layers. **NO PHY**
- **TRANSPORT**
  Ensure that the data is delivered exactly the way it was sent, handling **fragmentation and reassembling**. **TCP UDP**
- **INTERNET/NETWORK**
  Methods, protocols and specification that are used to **transport and deliver datagrams.** **IP ICMP IPv6**
- **LINK**
  Transfer data between **nodes and network elements**.
  ETHERNET MAC PHY

MAC

*A media access control address of a computer is a **unique identifier assigned to network interfaces** for communications at the data link layer of a network segment.*

1. **ARBITRATION IN SHARED CHANNELS**
2. **SYGNAL POWER PHY**
3. **IMPLEMENTS ARQ**

PHY

*Provides the **mechanical, electrical, functional, and procedural means** to activate, maintain, and deactivate physical connections for bit transmission between data link entities*

1. **COMMUNICATE WITH MAC**
2. **ELECTRICAL MODULATION**

TIPI DI ERRORE

1. **ERRORE DI CANALE**
    1. RITARDO DI TRASMISSIONE
        Funzione della dimensione pacchetto e velocità trasmissione
    2. RITARDO DI PROPAGAZIONE
        Funzione della dimensione in metri del canale
2. **NODO DI COMMUTAZIONE**
    1. RITARDO DI ELABORAZIONE
    2. RITARDO DI ACCODAMENTO

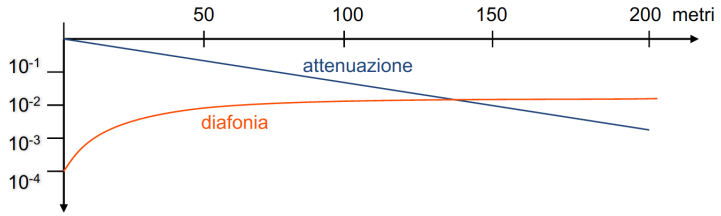
4 Strato fisico

MEZZI TRASMISSIVI

1. **ELETTRICI**
   Doppino o **cavo coassiale** (layers di schermatura)
2. **OTTICI**
   Fibra o **laser**
3. **RADIO**

ELETTRICI

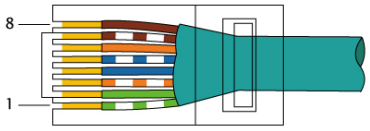
1. RESISTENZA E IMPEDENZA
2. FLESSIBILI
3. RESISTENTI A TRAZIONE
4. GEOMETRIA, ISOLAMENTO, SPAZIATURA
5. ATTENUAZIONE E DIAFONIA
   Rispettivamente **dispersione** potenza e **interferenza energetica**



6. **ATTENUAZIONE LINEARE**
7. **DIAFONIA ASINTOTICA**

DOPPINO

Un doppino ritorto è un cablaggio composto da una coppia di conduttori di rame isolati, utilizzato per la trasmissione delle comunicazioni telefoniche

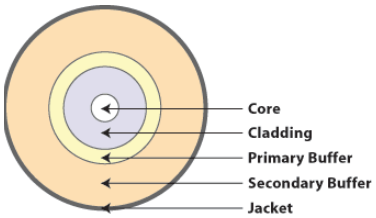


EIA/TIA-568A

1. **ATTENUAZIONE ELETTROMAGNETICA**
2. **TRASMISSIONE DIFFERENZIALE (DOPPIA)**

FIBRA OTTICA

Le fibre ottiche sono filamenti di materiali vetrosi o polimerici, realizzati in modo da poter condurre al loro interno la luce



1. **LEGGE DI SNELL**
2. **NO DISTURBI ELETTROMAGNETICI**
3. **BASSA ATTENUAZIONE**
   (3) $0.8\mu m$ $1.3\mu m 1.55\mu m$
4. **RAGGIO DI CURVATURA**
5. **POINT-TO-POINT**

CANALE RADIOMOBILE

Canale radio propagato nell'etere con almeno TX o RX in movimento

$$\frac{P_R}{P_T} = G_T G_R \frac{\lambda^2}{(4\pi D)^2}$$

1. **FADING & SHADOWING**
   F: Variazione **veloce del segnale in intensità**
   S: Variazione **lenta dell'ampiezza** del segnale

CODIFICHE

1. **CODIFICHE DI LINEA**
   Ottici ed elettrici
2. **MODULAZIONI**
   Digitali, radio e ottici

CODIFICA UNIPOLARE

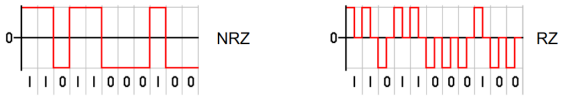
*Uilizza assenza di tensione per **0** e tensione per **1***

1. **SEMPLICE**
2. **SYNCHRO**
3. **SOVRACCARICO LED**

CODIFICA POLARE

*Utilizza **livelli di tensione diversi***

1. **TIPI**
   (3) NRZ No stagnazione su zero **- ZR** Stabile su 0 **- Bifase** Opposti



2. **BIPOLARE**
   (3) NRZ No s

CODIFICA NBMB

*Utilizza **m simboli** per codificare un messaggio di **lunghezza n***

$$n < m$$

$$l = log_2(Alphabet) \cdot L$$

MODULAZIONE

*L'informazione viene impressa su un segnale sinusoidale portante variando **ampiezza, frequenza, sfasamento***

ACCESSO TRASPORTO

*La rete di **accesso** regola la connessione tra utente e provider, **la rete di trasporto tra infrastrutture***

ACCESSO

- **TECNOLOGIE**
  1. DLS (xDSL)

	ADSL	ADSL2	ADSL 2+
Downstream	6 Mb/s	8 Mb/s	24 Mb/s
Upstream	1,5 Mb/s	3.5 Mb/s	3.5 Mb/s

     Modem modula per trasmissione su rete pubblica su **bande adiacenti** alla fonica.
     Splitter divide il segnale voce/dati in base **alle frequenze.**
     POST Splitter divide il segnale utente in voce/dati
     DSLAM Multiplexer connessioni DSL

  2. PON
     Passive optical network, **no elettricità.**
     OLT Optical line **terminator** in centrale
     ONU Network **units** nelle cabine di strada**.**
     ONT Network **terminator** nelle utenze
     ODN Distribution network
  3. HFC
     Mezzo fisico delle **CABLE TV.**
     MODEM Modulare la trasmissione
     CONDIVISIONE Tra utenti stessa area, rispetto a P2P ADSL
  4. BROADBAND
     Roaming Localizzazione nella rete
     Handover Supporto continuità **accesso in mobilità**

RETI TELEFONICHE

- **1G**
  1. GRANDI CELLE
  2. BASSA QUALITA'
  3. SOLO TELEFONIA
- **2G**
  1. GSM e D-AMPS
  2. 4 BANDE DI FREQUENZA
  3. PICCOLE CELLE (37km)
  4. ENCRYPTION
  5. GPRS - EDGE
     Allocazione dinamica **TDM** in GPRS. Edge **più veloce**
- **3G**
  1. UMTS
  2. VOCE + DATI
  3. CDMA
  4. CELLE STRATIFICATE
     Ombrello + specifiche
- **4G**
  1. OFDMA
     Ad ogni utente sono assegnati più **"micro-canali"** di frequenza per un **tempo limitato**, secondo le richieste di traffico
  2. VOCE + DATI
  3. CDMA
  4. CELLE STRATIFICATE
     Ombrello + specifiche

RETI SATELLITARI

- **GEO**
  35k km - Latenza elevata (3 server)
- **MEO**
  23k km - GPS
- **LEO**
  1km - Dati satellitari

TRASPORTO

- **INTERAMENTE DIGITALE**
- **GERARCHICA**
  1. PDH
     Plesio-Sync con trasmissione **senza store-forward** e sincronia tra TX e RX. **Clock** quasi assenti
  2. SONET/SDH
     Sincronia **perfetta** TX/RX
  3. HFC
     Mezzo fisico delle **CABLE TV.**
     MODEM Modulare la trasmissione
     CONDIVISIONE Tra utenti stessa area, rispetto a P2P ADSL

5 Strato 2 (data-link)

FUNZIONI

Il livello di collegamento (data link) permette il trasferimento di unità dati del livello rete e cerca di fronteggiare i malfunzionamenti dello strato fisico.

1. **DELIMITATORI TRAMA**
2. **MULTIPLAZIONE**
3. **INDIRIZZAMENTO LOCALE**
4. **ERROR CONTROL**
5. **FLOW CONTROL**
6. **LAN**
   Diviso in LLC e MAC
7. **SEQUENCE CONTROL**
8. **ERROR CORRECTION**
9. **DIFFERENTI RETI**
   Private e pubbliche hanno **protocolli di strato 2 differenti** (eg: ATM, LLC, PPP)

TIPI DI STRATO 2

- LAPB (Link Access Procedure Balanced – ISDN e X.25)
- LAPD (Link Access Procedure D-Channel - ISDN)
- LAPF (Link Access Procedure to Frame Mode Bearer Service – Frame Relay)
- LLC 802.2 (Logical Link Control - LAN)
- PPP (Point-to-Point Protocol - ADSL)
- LAPDm (LAP for the mobile D channel - GSM)

CAMPO DI DELIMITAZIONE

*01111110 è la sequenza che **delimina l'inizio e la fine di una PDU**, ma è la combinazione **vietata** nei dati.*

01111110	indirizzo	controllo	dati	CRC	01111110
8	8	8/16	>=0	16	8

1. **BYTE STUFFING**
   Il trasmettitore inserisce un **byte di escape 01111101** prima di ogni byte **01111110 o 01111101** di dati
2. **BIT STUFFING**
   Viene **aggiunto uno 0 dopo 5 1 consecutivi** (non nel delimitatore)

ACCESSO PPP

*Utilizzato per collegamenti punto-punto cablati. **Modem e provider, ADSL, SONET/SDH***

1. **3 LIVELLI**
   Incapsulamento - Link Conn. Protocol **LCP** - Net. Conn. Protocol **NCP**
2. **DELIMITAZIONE PDU**
3. **RICONOSCIMENTO ERRORI**
4. **AUTOCONFIG IP**
5. **CORREZIONE ERRORI E FLUSSO**
6. **GESTIONE MULTIPUNTO**

1. **PPP-LCP**
   Instaura e chiude la connessione, configura la rete.
2. **PPP-NCP**
   Configura **l'indirizzo negoziando.** Ogni livello superiore **ha NCP.**

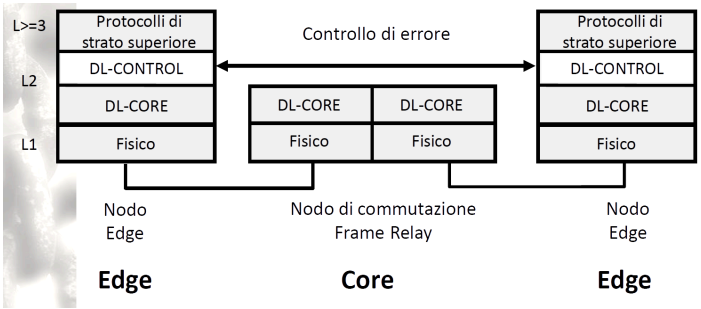
FRAME RELAY

*protocollo di rete ed una tecnica di trasmissione a **commutazione di circuito virtuale** utilizzando il protocollo **LAPF***

1. **64Kbp/s - 54Mbps**
2. **MAX_FRAME= 4MB**

LAP

1. **DL-CORE**
   Utilizzato da **tutti i nodi** della rete. Indirizzo: **numero circuito virtuale**
2. **DL-CONTROL**
   Utilizzato solo da **mittente e destinatario. Controllo errore con retrasmit**



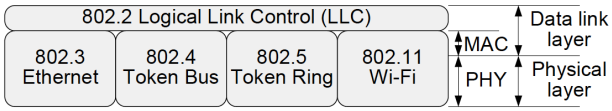
ATM

*Le reti ATM sono reti B-ISDN a pacchetto con servizio di **circuito virtuale.***

1. **FRAME DIMENSIONE FISSA**
   53Byte per cella. **10% Headers.** Due formati per N2N e N2U
   1. GFC
      Generic Flow Control. **ON/OFF** e **Credits**
   2. VPI - VIRTUAL PATH IDENTIFIER
      65535 **vci/path**
   3. VCI - VIRTUAL CIRCUIT IDENTIFIER
      Identifica uno specifico **circuito** in **un path**
   4. PT - PAYLOAD TYPE
      FLAG PTI: Congestione, segnalazione rete
2. **ALTE VELOCITA'**
3. **VELOCITA' ELABORAZIONE**
4. **BASSA LATENZA**
5. **AAL5**
   Strado di adattamento per casting **IP-ATM (strato edge).**
   Segmentazione - Errori - Flusso

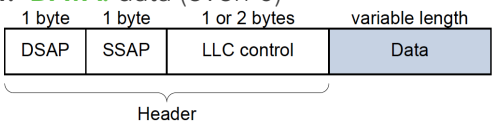
1. **VIOLAZIONE SEPARAZIONE STRATI**
   Ogni 3 PDU, il flag **PTI=1.** Permette la **ricostruzione in strati inferiori.**

LLC



Divided into **2 components**:

1. **LLC**
   1. **DSAP:** RX link to **network layer** protocol.
   2. **SSAP:** TX link to **network layer** protocol.
   3. **LLC CONTROL: control information** (ack, command, responses)
   4. **DATA:** data (even 0)



   1. PDU VARIABILI
   2. NO ERROR CONTROL
   3. NO DELIMITATORI
      Delegato a MAC

CONFRONTO

Protocollo	Delimitazione pacchetti	Multiplazione protocolli strato 3	Rilevazione errore	Correzione errore (protocollo a finestra)
LAPF core + LAPF control	Delimitatore	Mediante circuiti virtuali	SI, in LAPF core	Opzionale in LAP-F control
ATM (core)+ AAL (edge)	Demandato al livello fisico	Mediante circuiti virtuali	SI in AAL (edge)	NO
PPP	Delimitatore	SI	SI	NO
LLC	Demandato a MAC IEEE 802.3	SI	Opzionale	Opzionale
Ethernet MAC	*Silenzi*	*SI*	*SI*	*NO*

6 Protocolli d'accesso reti locali

RETE LOCALE

*Una rete si dice locale se è diffusa su una **piccola estensione** geografica.*

1. **POCO ESTESE**
2. **TOPOLOGIA STELLA**
3. **BROADCAST**
4. **CANALE CONDIVISO**
   Massima velocità di tramissione. **Indirizzo specifico** per target

MULTIPLAZIONE

*Unico segnale in uscita che **combina tutte le sorgenti.***
PROBLEMA CONCENTRATO

1. **STATICA**
   Il canale comune viene **diviso staticamente**
   1. **TIME DIVISION**
   2. **FREQUENCY DIVISION**
   3. **CODE DIVISION**

Alcuni parametri vengono valutati:
1. **THROUGHTPUT**
2. **RITARDO**
3. **NUMERO STAZIONI**

ACCESSO MULTIPLO

*Differenti flussi accedono al canale da **punti differenti***
PROBLEMA DISTRIBUITO

PROTOCOLLI ACCESSO CASUALE

In un protocollo ad accesso casuale, ogni nodo che vuole trasmettere trasmette quando è necessario
NO DETERMINISMO
MAX_VELOCITA' — NO COORDINAMENTO

LAN TYPE

A. **NON-BROADCAST (SWITCHED)**
   ADJACENCY: nodes can only communicate with nodes they are next to
B. **BROADCAST (SHARED MEDIUM)**
   COLLISION-DOMAIN: LAN or a part of a LAN in which there will be a collision if multiple stations transmit at the same time

MAC AS TRAFFICLIGHT
Broadcast networks need MAC for the same reason streets **need traffic** lights and rules of the road to prevent collisions. When **2 or more stations** transmit simultaneously, their signals **will collide and interfere with each othe**r

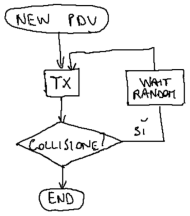
PURE ALOHA

Semplice meccanismo di trasmissione.
***Intelocutori**: TX1 - RX2*
***Master**: TX2 - RX1*

A. **STOP & WAIT**
B. **CONFERMA RICEZIONE**
C. **INIZIO QUALUNQUE ISTANTE**
D. **COLLISIONI**
   Backoff esponenziale: tempo random per ritrasmettere per 2 hosts.
E. **18% THROUGHPUT**

SLOTTED ALOHA

*Divisione del tempo in **slots uguali***

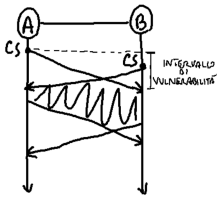


A. SEGMENTAZIONE
B. CONFERMA RICEZIONE
C. INIZIO QUALUNQUE BLOCCO
D. COLLISIONI
   Backoff casuale: ritento in uno **slot a caso**
E. 32% THROUGHPUT

CSMA

*Il Carrier Sense Multiple Access (CSMA) prevede **l'ascolto del canale** (CS) prima della trasmissione*

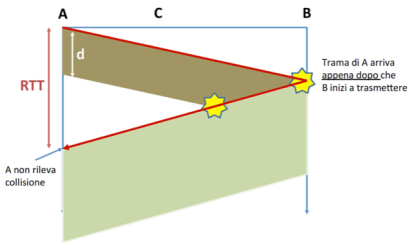
A. 0/1/p PERSISTENTE
   0: Ritento con un tempo casuale
   1: Continua verifica
   p: Trasmetto dopo un tempo random con **probabilità p**
B. COLLISIONI INEVITABILI
   Più **grandi** i frame, **meno** traffico sprecato.
C. INTERVALLO DI VULNETABILITA'
   Dovuto al **tempo di propagazione.** Il canale può essere occupato



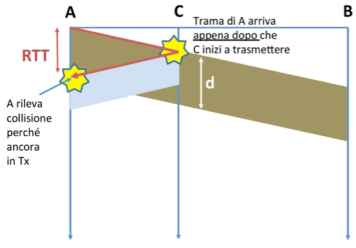
CSMA/CD

*Implementa una **collision detection** al protocollo CSMA*

A. SENSING COLLISIONE
   Se il trasmettitore **non la rileva** la trasmissione è di successo. Se sente collisione **interrompe la propria trasmissione**
   $T_{frame} > 2 \cdot max(T_{prop})$



$d<RTT_{AB}$ A, B, C nello stesso dominio di collisione

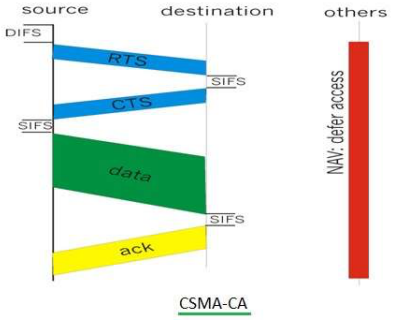


$d>RTT_{AC}$ A, B, C nello stesso dominio di collisione

A. RETI PICCOLE
B. BASSO BITRATE
C. PACCHETTI GRANDI
D. BACKOFF ESPONENZIALE

CSMA/CA

*Collision **avoidance** utilizzata sui canali radio*



A. **DIFS**
   Il canale **attente un tempo DIFS** prima di tentare la trasmissione.
   Altrimenti **backoff casuale**
B. **DECREMENTO BACKOFF**
   Solo se **il canale rimane libero.** A **0 ripete trasmissione**
C. **ACK SIFS**
   Trasmesso con tempo $SIFS < DIFS$ **con priorità su altri frame**
D. **COLLISIONE CONTEMPORANEA**
   Ripeto **raddoppiando** il range di backoff

7 Standard reti locali

LAN

*A local area network is a computer network that interconnects computers within a **limited area***

1. **CSMA-CD-1**
2. **JAMMING-SEQUENCE**
   Informa tutta la LAN **di avvenuta collisione**
3. **DOMINIO COLLISIONE**
   Allora il **tempo minimo di trasmissione** deve essere **maggiore del RTT**
   $RTT \leq T_{TX}$

ETHERNET

Ethernet is a family of computer networking technologies commonly used in LAN, MAN and WAN

IEEE 802. PHYSICAL+DATALINK

LLC

Divided into **2 components**:

1. **LLC**
   1. PDU VARIABILI
   2. NO ERROR CONTROL (OPT)
   3. NO DELIMITATORI
      Delegato a MAC
2. **MAC**
   MAC CONTROL: contains any control information needed for the functioning of the MAC protocol.
   DEST/SOURCE MAC
   LLC PDU: data from the LLC layer
   FCS: frame checksum.The MAC layer **is responsible for detecting errors & discarding** while LLC **keeps track of discarded and ask RT.**

MAC ADDRESS

*Indirizzi di livello 2 di **6Byte***

1. **3Byte COSTRUTTORE + 3SEQ**
2. **FF:FF:FF:FF:FF:FF**
   Broadcast a tutta la lan.
3. **TIPI DI BROADCAST**
   1. SOLLICITATION
   2. AD

Ethernet 18 bytes	IPv4 20 bytes	UDP 8 bytes

ETHETNET FRAME

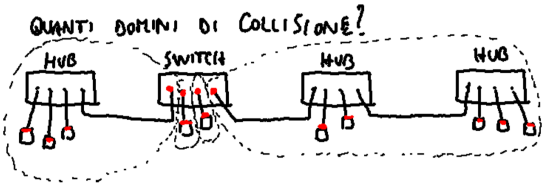
8 bytes	6 bytes	6 bytes	2 bytes	46-1500	4 bytes
Preamble	Destination address	Source address	Ethertype	Data	FCS

HEADER: 18B
SDU MIN 46B MAX 1500B

1. **PREAMBLE 8B**
   it consists of 8 bytes of alternating "1"s and "0"s, ending in 11, as to **synchronise clocks**
2. **SFD 8B**
   Segnala **l'inizio del pacchetto**
3. **DEST/SOURCE MAC 6Bx2**
4. **ETHERTYPE 2B**
   Defines versioning of upper layers **(LCC)**
   802.3: Il campo per il tipo di protocollo diventa superfluo perchè il sottostrato di livello superiore è **sempre LLC.**
5. **INTERPACKET GAP 4B**
   Segnala la **fine del frame**

LAN SWITCH

*Multiport node that allow stations to attach directly and **forward incoming packet to their correct MAC destination or broadcast***



1. **RETI LIVELLO 2**
2. **ADDRESS LEARNING**
   (Mac, Physical Port)
3. **NO MAC**
4. **SPANNING TREE**
   Crea un **albero ricoprente** per **evitare loop. Bridge_id per gli switch**
5. **STORE-FORWARD**
   Rallenta le **prestazioni** di rete
6. **NO COLLISIONI**
   Implementa il CS
7. **DOMINIO COLLISIONE**
   Tra switch e host
8. **vLAN**
   Tag aggiunto al pacchetto

GIGABIT ETHERNET

*Utilizza il **frame 802.3.** Flow control, jumbo-frame, full-duplex.*

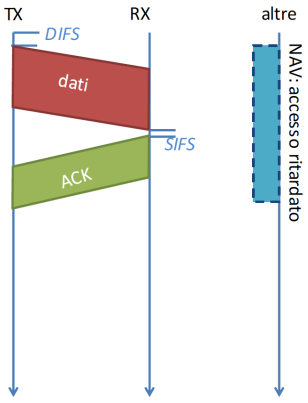
10GBIT ETHERNET

*Utilizza il **frame 802.3.** Flow control, jumbo-frame, full-duplex.*
PARALLEL CHANNELS

WIFI

*Certificazione di **interoperabilità e aderenza allo standard**, rilasciata da una associazione di produttori chiamata WiFi Alliance*

1. **COMUNICAZIONE UNICA CON AP**
   Funzionamento analogo allo **switch**
2. **DOPPIA BANDA**
   2,4Ghz (condivisa **14 canali - 3 overlapped**) e 5GHz (unica **23 canali**)
3. **HALF-DUPLEX**
4. **DCF -> CSMA/CA**
   - Trasmettitore
     - Se canale libero per DIFS
       - Trasmette una trama
     - Se canale occupato
       - Aspetta per un tempo casuale e trasmetti
       - Se fallisce (no ACK) backoff esponenziale (CA)
   - Ricevitore
     - Se dati ricevuti correttamente manda ACK dopo SIFS
   - Altre stazioni
     - Nessuna azione per un tempo pari alla durata dello scambio di trame (NAV)



5. **TERMINALE NASCOSTO:**
   A,B non si vedono ma vedono AP.
   1. RTS
      Durata scambio all'AP
   2. CTS
      Durata **rimanente** scambio dall'AP. Se **CTS viene sentito** rimando lo scambio
6. **VELOCITA' UNIFORME**
   Tutti alla più lenta per via di **CTS.**

8 Network Layer

INTERNET LAYER

HEADER $(20 \pm 40)Bytes$ [+20Bytes TCP]

The header has a **fixed-length component of 20 bytes** plus a **variable-length** component consisting of options that can be up to 40 bytes

1. 4b. **VERSION:** Indicates **version number**
2. 4b. **IHL: Length of the header** MIN 5 (20 bytes) MAX 15 (60 bytes)
3. 8b. **TOS:** Species **priority, delay, throughput,** reliability...
4. 16b. **TOTAL LENGTH: Total length** MIN **28B** MAX 15 **65535B**
5. 8b. **TTL:** Maximum hops to pass, **decrements it by 1.** 6°OF SEP
6. 8b. **PROTOCOL: TCP = 6; UDP = 17; ICMP = 1**
7. 16b. **HEADER CHECKSUM:** Verifies the **integrity of the header** of the IP packet.Since some header fields change, the **header checksum is recomputed and verified** at each point that the IP header is processed
8. 32b. **SOURCE/DEST ADD:** Written down in binary or dotted-decimal.
9. (40Bytes). **OPTIONS:** Allows the packet to **request special treatment** such as route to be taken by the packet, timestamp at each router, etc.

DATA MIN 8B MAX 65KB

Must contain an **integer number of bytes.**

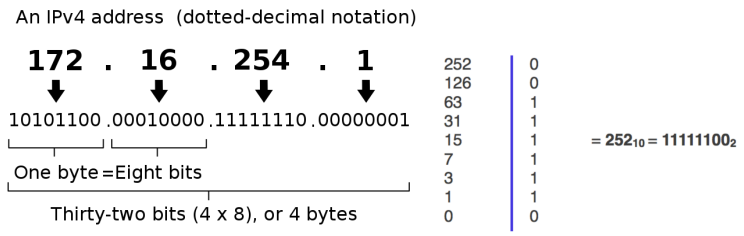
FRAGMENTATION

*Divisione del pacchetto in base alla **MTU** del **link layer***

1. **IDENTIFICATORE**
   Tutti i **frammenti** lo condividono
2. **FLAG 3bit**
   Indica se il frammento è **l'ultimo**
   1. RESERVED (0)
   2. 0 FRAGMENT - 1 DON'T
   3. 1 FRAGMENTS - 0 SINGLE
3. **OFFSET**
   Indica la posizione del frammento. $O = Byte_{cum}/8$

IP ADDRESS

A.B.NETWORK_ID[C].HOST_ID[D]



RESERVED ADRESSES

0.0.0.0. **NULL ADDRESS**
172.16.0.0 to 172.31.255.255 **LAN**
192.168.0.0 to 192.168.255.255 **LAN**
10.0.0.0 to 10.255.255.255 **LAN**

SUBNETTING

SUBNET: *small part of the network*

$$2^{HostBits} - 2$$

$$a.b.c.d/x \quad x = 32 - n$$

1. **ACTUAL HOST ADDRESS**
   Actual host acting
2. **NETWORK IP**
   Network IP address with **host bits set to 0.** **Calcolo di validità**
3. **BROADCAST IP ADDRESS**
   Network IP address with all **host bits set to 1**
4. **MASK IP ADDRESS**
   All **network address are 1, all host are 0.**
   $256 - 2^n$

ROUTES

*Esistono **dirette e indirette***

1. **DIRETTE**
   Network direttamente connessi col router
2. **INDIRETTE STATICHE**
   Manualmente configurate e **non connesse direttamente**
3. **INDIRETTE DINAMICHE**
   Dinamicamente configurate e **non connesse direttamente**

ROUTING TABLE

*Is a data table stored in a router or a networked computer that **lists the routes** to particular network destinations*

CIDR BLOCK

CIDR is principally a bitwise, prefix-based standard for the representation of IP addresses and their routing properties.

A.B.C.D/X
The number following the slash is the prefix length, **the number of shared initial bits**, counting from the most-significant bit of the address.

AS ROUTING

*Within the Internet, an autonomous system (AS) is a collection of **connected Internet Protocol routing** prefixes under the control of one or more network operators. **BGP***

EX ROUTING

1. **ALLOCARE IL NUMERO DI IP**
   $IP = H_{osts} + 2_{net} + 1_R = H_{hosts} + 3$
2. **NETMASK**
   $/N_m = 32 - log_2(IP) \quad \&\& \; D = 256 - IP$
3. **DOPPIO ADDRESS ROUTER**
   Per ogni **interfaccia**
4. **BROADCAST IP ADDRESS**
   Network IP address with all **host bits set to 1**
5. **MASK IP ADDRESS**
   All **network address are 1, all host are 0.**
   $256 - 2^n$

EX CLASSFUL ADDRESSING

Prefix Range	Address Class
0–127	A
128–191	B
192–223	C
224–239	D
240–255	E

Reserved private IPv4 network ranges[8]

Start	End	Number of addresses
10.0.0.0	10.255.255.255	16 777 216
172.16.0.0	172.31.255.255	1 048 576
192.168.0.0	192.168.255.255	65 536

EX ROUTE AGGREGATION AND STATIC ROUTING

1. **ROUTER INTERFACE**
   Si riferisce sempre a quella **connessa e interfacciata** con la subnet
2. **AGGREGAZIONE**
   Per ogni **classe con next-hop comune e aggregabile.** **Costo indifferente**
3. **MOST SPECIFIC ROUTES**
   Sempre **la più piccola**
4. **BACKUP ROUTE**
   Sempre da specificare

EX SNIFFING AND ANALYSIS

1. **PING**
2. **ARP**
3. **DNS**
4. **HTTP CACHE**

8b Various Net/Link app

ARP LAYER

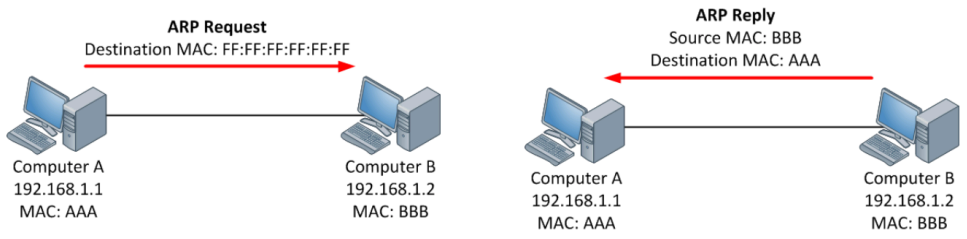
The Address Resolution Protocol is a request and response protocol whose **messages are encapsulated by a link layer protocol.**

LINK/NETWORK LAYER

- **LOCAL NETWORK**
- **LIMITING FACTORS**
- **MINIMISES THE OVERHEAD WITH CACHE**

ARP PROCEDURE

- **2 COMPUTER CONNECTED BY ETHERNET**
- **LOOK FOR DESTINATION IP'S MAC**
- **IF IP IN CACHE STOP; ELSE BROADCAST ARP REQUEST**
  To MAC address **FF:FF:FF:FF:FF:FF** asking a **reply only rom the specified ip to the source IP and Mac address** with a **payload asking for Mac.**
- **GET ARP RESPONSE**
  With the Mac address



DHCP

*A DHCP server enables computers to **request IP addresses** and networking parameters automatically, reducing the need for a network administrator or a user to configure these settings manually.*

APPLICATION LAYER

- **IP - GATEWAY - SUBMASK**
- **DNS**
- **NTP**
- **NO SECURITY**
- **ARBITRATION BASED ON DELAYS**

ICMP

*It is used by network devices, including routers, to send **error messages and operational information.***

LIBRARY OF PREDEFINED MESSAGES

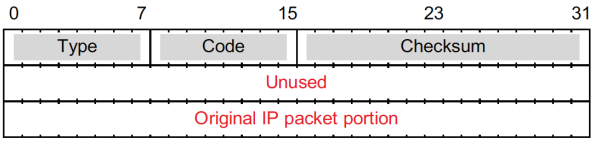
NETWORK

1. **ENCAPSULATED IN IP**
   Protocol field is set to 1
2. **PING + TRACEROUTE**
   Incremental TTL **trace route the way message is delivered.**
3. **NO SWITCHES AND ROUTERS**
   Can't be pinged

Sometimes the ip return **failures**

A. **TRANSIENT FAILURES**
   Such invalid checksum, are **generally ignored**
B. **SEMI-PERMANENT FAILURES**
   Need to **be reported immediately:** TTL=0, destination unreachable, etc

ICMPV4 FORMAT



1. 8b. **TYPE:** Indicates **message's type**
2. 8b. **CODE:** Describe the **purpose of message**.
3. 16b. **CHECKSUM:** Detect errors in the ICMP message, similar to ipv4
4. 32b. **UNUSED:** Contains all zero
5. ?. **IP PACKET PORTION:** Contains original **IP header and 8B of data**

DHCP WORKING

- **IP: 0-0-0-0/0 - MAC: VENDOR ONE**
- **BROADCAST ANYONE FOR DHCP ADDRESS**
- **OFFER FROM DHCP SERVERS**
- **CLIENT REQUEST TO A SINGLE SERVER**
- **ACKNOWLEDGMENT OF ADDRESS**

1. **DISCOVERY**
2. **OFFERING**
3. **REQUEST**
4. **ACKNOWLEDGMENT**

PING

*ping is a **software utility** used to test the reachability of a host on an Internet Protocol (IP) network*

RFC 1122 states that "every host must implement an ICMP Echo server"

- **2 QUERY MESSAGES**
  An **ICMP Echo Request** message is a probe sent by a user to a destination system, which responds with an **ICMP Echo Reply message**

TRACEROUTE

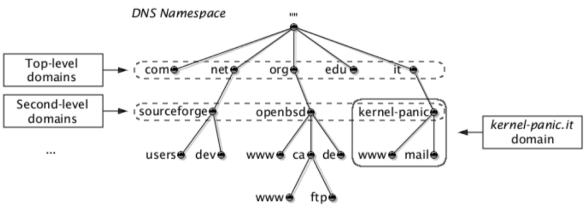
*Traceroute is a diagnostic tool for **displaying the route** (path) and measuring **transit delays of packets** across an Internet Protocol (IP) network.*

- **INCREASING TTL**
- **3 ICMP PER HOP**
- **PATH MAY CHANGES DURING THE PROCESS**

DNS

Hierarchical decentralized naming system *for computers, services, or other resources connected to the Internet or a private network.*

- **HIERARCHY OF DNS SERVERS**
- **REGULATED BY IANA**



GLUE RECORDS

A glue record is simply the ***association of a hostname*** *(nameserver, or DNS) with an* ***IP address*** *at the registry.*

- **CLIENT BASED QUERIES**
  Every time you ask for a server, the **root server, secondary root server,** will give you **only a piece** as to resolve address.

TYPES OF QUERIES

RECURSIVE QUERY
With a recursive name query, client requires that the DNS server **respond** to the client with either the requested **resource record or an error no redirects**

ITERATIVE QUERY
Client allows the DNS server to **return the best answer** it can give based on its cache or zone data. No answer: the **best possible information it can return is a referral**

11 Transport Layer

TRANSPORT LAYERS

Transport layer protocols have some characteristics in common

1. **USABLE PRIMITIVES**
   For the **app layer.** Abstract the connection and its problems
2. **MULTIPLEX CONNECTIONS**
   With different ports
3. **LISTENING SOCKETS**
   Allow accepting connections in a **unified manner**
4. **END-TO-END**
   They are only implemented at **end systems.**

UNIQUE IDENTIFIER

SOURCE DESTINATION IP	PROTOCOL FIELD VALUE	SOURCE AND DESTINATION PORT

DEMULTIPLEXING

DEMUX *is the* ***reverse of the multiplex (MUX) process*** *– which split the unique signal input into* ***different streams***

LOWER TO HIGHER

MULTIPLEXING

MUX *or Multiplexing is the process in which multiple Data Streams, coming from different Sources, are combined and Transmitted* ***over a Single Data Channel*** *or Data Stream.*

HIGHER TO LOWER

PORT NUMBERS

Port is an ***endpoint of communication*** *in an OS.*

2^{16} = 65, 536

1. **0-1023**
   Well knowns
2. **1024-49151**
   Registered ports
3. **49151-65536**
   Dynamic ports
4. **EPHEMERAL PORTS**
   Port dynamically assigned to client and freed up when no longer needed

UDP

A. **MESSAGE DATAGRAM ORIENTED**
   Small messages (eg: **DNS, DHCP**)
B. **CONNECTIONLESS**
   Establishing a connection before sending data is not required
C. **STATELESS**
   Neither side keeps track of the connection
D. **UNRELIABLE**
   No **ACK** or **retransmissions.**

1. **UNRELIABLE**
2. **ERROR CONTROL (opt)**
3. **DATA INTEGRITY VERIFICATION**
   UDP checksum applies to the entire UDP datagram plus a pseudo header pre fixed at the time of checksum computation
4. **NO FLOW-CONGESTION CONTROL**
5. **NO FEEDBACK MESSAGE**

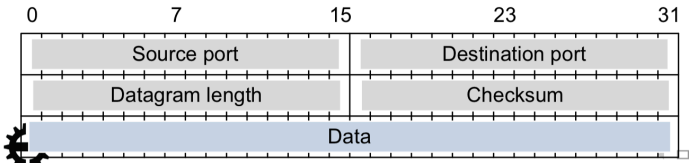
TCP

A. **BYTE STREAMS ORIENDED**
   Data bytes are **delivered in-order** to an application process
B. **CONNECTION ORIENTED**
   A connection must be **established** between hosts
C. **STATEFUL**
   Both sender and receiver **keep track of the state** of the session
D. **RELIABLE**
E. **FULL-DUPLEX**
   Both hosts can send infos in the **same channel**

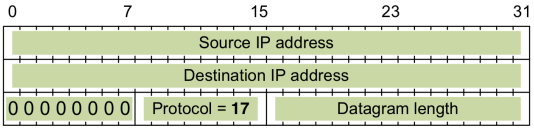
1. **FLOW AND CONGESTION CONTROL**
   TCP regulates the rate at which the sending host transmits data
2. **ERROR CONTROL (mandatory)**
   TCP checksum applies to the entire TCP segment plus a pseudo header pre fixed at the time of checksum computation. **Trigger resending when not passed**
3. **FEEDBACK BASED**

UDP DATAGRAM STRUCTURE

8B HEADER



1. 16bits. SRC & DST PORTS
2. 16bits. DATAGRAM LENGTH
3. 16bits. CHECKSUM
   If the length of the datagram is not a multiple of 16 bits, the datagram will be padded out with "0"s to make it a multiple of 16 bits.
   PSEUDO-HEADER DURING COMPUTATION



A. CORRUPTED
   Notify via ICMP
B. NO COMPUTATION OF HEADER
   Fill with all 0 the **checksum field. Then set to all 1**

TCP PACKET

20B HEADER

1. 16b. SRC & DST PORTS
2. 32b. SEQUENCE NUMBER
   Identifies the position of the first data byte of this segment in the sender's byte stream. **IF SYN=1 THEN SN=ISN+1 with ISN $2^{32} - 1$**

3. 32b. ACK NUMBER
   If the **ACK bit is set to 1**, identifies the **sequence number of the next data byte** that the sender expects to receive Also indicates that the sender has **successfully received all data up to** (*but not including*) this value
4. 4bits. HEADER LENGTH
   Specifies the length of the TCP header in 32-bit words
5. 9bits. CONTROL BITS
   - ECN Explicit congestion **notification.**
   - CWR Sending host has received a TCP **segment with ECE=1.**
   - ECE Host is Congestion-capable
   - URG Urgent data
   - ACK Ack number is correct
   - PSH Pass the already received data to the application
   - RST drop all buffers and reset the connections
   - SYN used to establish a TCP connection
   - FIN end the connection
6. 16bits. WINDOW
   Bytes the receiver of this segment is **ready to accept**
7. 16bits. CHECKSUM
8. 16bits. URGENT POINTER
   If the URG bit is set to 1, **specifies a positive offset that must be added** to the **Sequence number** field value of the segment to yield the sequence number of the last byte of urgent data
9. ?. OPTIONS
10. ?. PADDING

ACKS

A. **PIGGYBACKED**
A data segment from host A to host B can also contain an ACK for data sent in the direction from B to A and **data**. **REDUCE HEADERS AND TRAFFIC**

B. **CUMULATIVE ACK(N)**
ACKs for complex packets can be sent together when **everything has been received up to N-1.**

C. **NEGATIVE NAK(N)**
Retransmit N

D. **DELAYED**
3:Sent when no ACK for the **previous segment**, or no message in the last **500ms** or there is a gap in **SN.**

E. **DUPLICATE**
1:Out of **order** packet. Ack signals the **expected packet**

3WAY HANDSHAKE

A. **A->B SYN SEGMENT**
With no app-data and **SYN=1 and SEQ=ISN(A)**
Client: active open

B. **B->A SYN/ACK SEGMENT**
With no app-data and **SYN=1 and ACK=ISN(A)+1 and SEQ=ISN(B).**
Server: passive open

C. **A->B ACK SEGMENT**
With no app-data and **SYN=0 and ACK=ISN(B)+1**

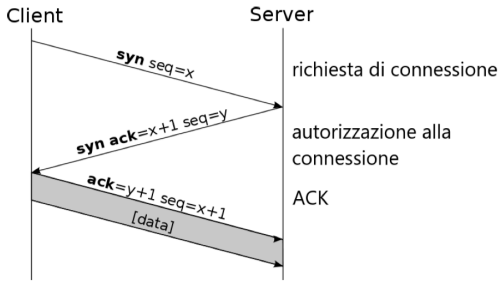
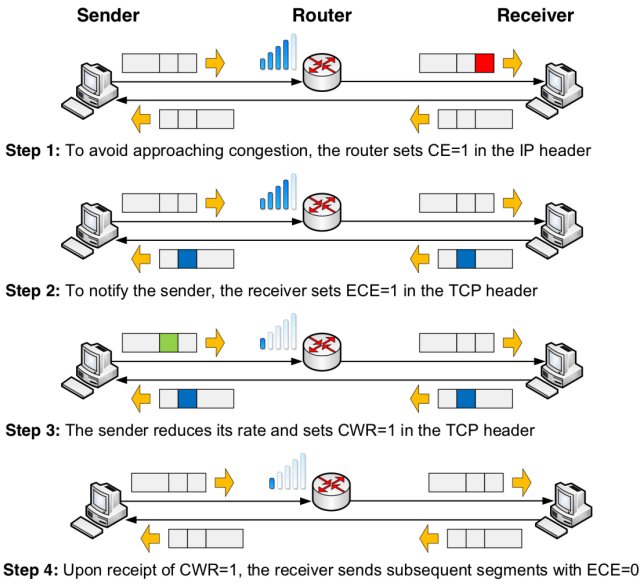


Figura 14.1: Three-way handshake di TCP.[3]

ECN - CE



A. **TOS IPv4 FIELDS**
ECT capable and **CE** experienced

CONNECTION CLOSE

A. B->A FIN=1
   Server active close
B. A->B FIN=1
   Client: passive close
C. B->A ACK FIN SEGMENT
D. A->B FIN=1 ACK
E. TIME_WAIT=2*MSL
   ACK Received and **Buffering** period

TCP FAST RETRANSMIT

1. DUPLICATE ACKs
2. TIMEOUTS - FAST RETRANSMIT
   After **3 identical ACKs** TCP performs a **retransmission** of what appears to be the missing segment, without waiting for the retransmission timer to expire

FLOW CONTROL

*Process of managing the **rate of data transmission** between two nodes, providing a mechanism for the **receiver** to **control the transmission speed***

HW/SW E2E/H2H

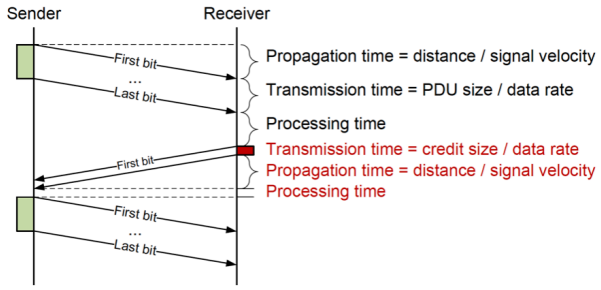
- CONGESTION CONTROL
  Prevents overloading by acting on **middle-point nodes and the sender**
- COMPROMISE
  High throughput, resource utilisation and low control overhead
- SYNCHRONISES DIFFERENT SPEEDS

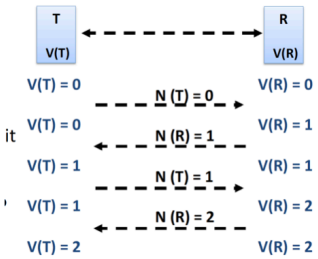
STOP AND WAIT GO BACK N=1

*Stop-and-wait flow control is the simplest form of flow control. In this method, the **receiver indicates its readiness** to receive data for each frame, the message is broken into multiple frames.*

SEND FRAMES AFTER ACKs (Credit)

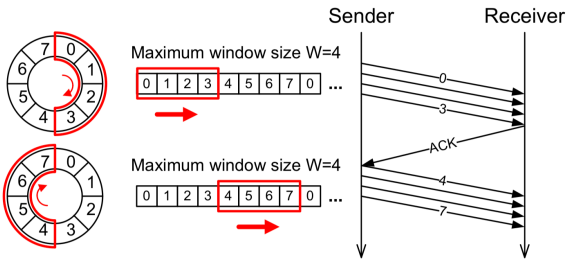
A. PROPAGATION TIME
B. TRANSMISSION TIME
C. PROCESSING TIME
D. SAME FOR ACK





SLIDING WINDOW GO BACK N>1 SELECTIVE REPEAT

*Generalisation of **stop-and-wait** for **more than 1 PDU***



SILLY WINDOW SYNDROME

*each ACK advertises a **small amount of space available** and each segment carries a small amount of data*

- **RECEIVER HEURISTIC**
  ACK WITH ON: Instead of sending a window advertisement immediately, the receiver waits until the available space **reaches either 50% of the total buffer size or a maximum-sized segment**
- **SENDER HEURISTIC**
  CLUMPING: **collect** the data transferred in each call before transmitting it in a **single, large segment.** **NAGLE ALGORITHM**

SLOW START CONGESTION

*To probe the network path and to determine **how much bandwidth is available,** TCP uses an algorithm called slow start*

$$TCP_{rate} = \frac{cwndw}{RTT}$$

1. **CWND=IWindow**
2. **INCREMENT**
   For every ACK received that acknowledges new data, the **cwnd is incremented** by the number of **bytes in the sender's MSS**
3. **CWND>SSTRESH || PACKET LOSS**
   Congestion avoidance: linear increment over exponential.

13 Application Layer

APP LAYER

*Application Layers interact with the **network layer** by telling where to forward the message and with the **transportation layer protocols.***

STREAM vs MESSAGE

1. **ASYMMETRICAL DESIGN**
   Client request server replies or vice versa
2. **P2P SYSTEM**
3. **HYBRID SYSTEMS**
4. **HIGH LEVEL INTERACTION**
5. **NOT INCLUDED**
   Encryption (usually), error correction, identification of connections

HTTP PROTOCOL

POST HEAD GET OPTIONS (PUT DELETE PATCH)

Request_type=one of <GETIPOSTITRACEIDELETE...> **Target** /HTTP <version>
Options (option=value)
empty_line
Message body empty_line

SMTP *Simple mail transfer protocol sends email through internet.*

1. **MAIL**
   Specifies the **return path**
2. **RCPT**
   Specifies the **recipients**
3. **DATA**
   Specifies the **message**
4. **AUTH**
   Authentication in **plaintext.** In **SMTPs** connection is **TSL encrypted** and auth are **base64 encoded**

- **BINARY ARE WEIGHTY (ATTACHMENTS)**
- **NO ENCRYPTION**
- **SECURITY CONCERNS**

POP3 *Post Office Protocol version 3 - used to manipulate emails*

1. **LIST, QUIT, DELETE, MOVE**

- **CAN'T FETCH HEADER**
  In IMAP you can just fetch the header.
- **READ/NOT READ**
- **NO FOLDERS**
- **NO FILTERS**
-

FTP *File transfer protocol is used to manipulate files*

1. **CONTROL PORT (21)**
   Carries control messages. **Plaintext unencrypted protocol**
2. **DATA PORT**
   Carries data transfer. **Active / passive** *(preferred)*

Note finali

Alcuni dei contenuti presenti nelle seguenti dispense sono stati liberamente tratti dai materiali didattici disponibili al Politecnico di Torino.
Le dispense sono state elaborate dal sottoscritto come complemento allo studio e non intendono in alcun modo sostituire la completezza dei libri di testo e delle lezioni dalle quali sono state liberamente tratte.
Le dispense sono state scritte per l'esame di **Reti di Calcolatori dell'A.A. 2017-18, docente Guido Marchetto**, corso di laurea in Ingegneria Gestionale L8.
E' doveroso quindi citare alcuni delle fonti da cui sono stati liberamente tratti alcune parti di esercizi e/o metodologie di soluzione:

- Guido Marchetto, Whiteboard e appunti del corso di Reti di Calcolatori.
- wikipedia.org