**Data link layer**

**Esercizio 1 Elencate almeno tre servizi/funzionalità che possono essere offerti da un protocollo di collegamento.**

1)**FRAMING**: Quasi tutti i protocolli incapsulano il datagramma del livello di rete in un frame del livello di collegamento prima di trasmetterlo. I frame sono formati da un campo di dati dove viene inserito il datagramma e da vari campi. La struttura del frame è definita dal protocollo0.

2)**ACCESSO AL COLLEGAMENTO**: Un protocollo che controlla l’accesso al collegamento specifica le regole con cui immettere i frame nel link.

3)**CONSEGNA AFFIDABILE**: Un protocollo che fornisce un servizio di consegna affidabile garantisce il trasporto senza errori di ciascun datagramma.

4)**RILEVAZIONE E CORREZIONE DEGLI ERRORI:** Gli errori sono causati da attenuazione del segnale o da dei rumori. In questo caso il ricevitore rileva la presenza di errori e li segnala al mittente che ritrasmette o elimina il frame. Un altro modo di agire del ricevente è quello di identificare e correggere errori di bit senza ricorrere alla ritrasmissione.

5)**CONTROLLO DI FLUSSO**: È la stimolazione tra nodi di invio e ricezione degli adiacenti.

6)**HALF DUPLEX e FULL DUPLEX**: Con Half duplex, i nodi ad entrambe le estremità del collegamento possono trasmettere, ma non contemporaneamente.

**Esercizio 2 Cos’è l’indirizzo MAC e quando viene utilizzato? Esattamente un indirizzo MAC a cosa è associato in modo univoco? Quali differenze esistono tra l’indirizzo MAC e l’indirizzo IP, in particolare rispetto alla struttura (o formato) dell’indirizzo e rispetto alla mobilità di un nodo.**

L'indirizzo MAC (Media Access Control) è un identificatore univoco associato all'interfaccia di rete di un dispositivo. Questo indirizzo viene assegnato dal produttore della scheda di rete e viene utilizzato per identificare un dispositivo all'interno di una rete locale. Quindi non esistono due schede di rete con lo stesso indirizzo MAC.

L'indirizzo MAC è composto da 6 byte (48 bit) espressi in notazione esadecimale e di solito viene scritto come una sequenza di 12 cifre esadecimali separate da due punti (ad esempio: 00:1A:2B:3C:4D:5E).

A differenza dell'indirizzo IP, che identifica un dispositivo all'interno di una rete Internet, l'indirizzo MAC viene utilizzato all'interno di una rete locale. Mentre l'indirizzo IP può cambiare quando un dispositivo si sposta da una rete all'altra, l'indirizzo MAC rimane costante per l'intera vita della scheda di rete.

Quando una scheda di rete vuole spedire un frame, inserisce al suo interno l’indirizzo MAC di destinazione e lo immette nella LAN. Ogni scheda di rete controlla se l’indirizzo MAC di destinazione corrisponde al suo e in caso affermativo la scheda di rete estrae il datagramma dal frame e lo passa al livello di rete altrimenti la scheda di rete non farà altro che scartare il frame.

Per determinare l’indirizzo MAC partendo dall’indirizzo IP si usa il protocollo ARP che traduce gli indirizzi IP in indirizzi MAC (molto simile al DNS che traduce i nomi degli host in indirizzi IP, ma nota che ARP traduce solo gli indirizzi IP per i nodi che si trovano nella stessa sottorete).

Nella RAM dei nodi della rete vi è una tabella ARP che contiene la corrispondenza tra indirizzi IP e indirizzi MAC ed inoltre, contiene anche un TTL(time to live) che indica quando bisognerà eliminare tale voce dalla tabella. Da notare che la tabella non contiene necessariamente una voce per ciascun nodo della sottorete.

**Esercizio 4 A cosa serve un protocollo di acceso al mezzo? Descrivete le caratteristiche ideali che dovrebbe avere un tale protocollo. Elencate almeno tre protocolli (o le loro classi) e specificate per ognuno quali caratteristiche ideali possiede.**

**Domanda esame simile**

**a) Quali sono le caratteristiche ideali che i protocolli di accesso al mezzo dovrebbero avere?**

**b) Illustrare la differenza tra un protocollo di accesso al mezzo con partizione del canale ed uno ad accesso casuale specificando quali delle caratteristiche elencate nel punto precedente sono soddisfatte e quali no, motivando le vostre risposte.**

**c) Nel protocollo CSMA/CD descrivere quali sono le operazioni da ripetute collisioni. Descrivere i vantaggi di questa soluzione.**

Un protocollo di accesso al mezzo è un insieme di regole che definisce come i nodi di una rete condivisa accedono al mezzo trasmissivo per inviare e ricevere dati. Tale protocollo è importante per gestire l'accesso al mezzo trasmissivo, in modo che diversi nodi possano trasmettere e ricevere dati senza interferire tra di loro evitando eventuali collisioni.

Un protocollo di accesso al mezzo per un canale broadcast con velocità di R bit/sec dovrebbe avere le seguenti caratteristiche ideali:

1)Quando un solo nodo deve inviare dati può trasmettere a velocità pari a R.

2)Quando M nodi devono inviare dati, ognuno può trasmettere a velocità pari a R/M.

3)Il protocollo è decentralizzato, ovvero, non ci sono nodi principali che coordinano gli altri nodi. (se tali nodi esistessero e non funzionano correttamente quest’ultimi renderebbero inattivo l’intero sistema).

4)Il protocollo è semplice ovvero risulta economico da implementare.

I protocolli ad accesso multiplo si possono classificare in queste categorie:

1)**Protocolli a suddivisione del canale** e sono usati per suddividere la larghezza di banda di un canale broadcast fra i nodi che lo condividono.

Un esempio di tale protocollo è il TDMA che suddivide il tempo in intervalli e poi divide ciascun intervallo in N slots temporali. Ogni slot è assegnato a uno degli N nodi che appartengono alla rete. Ogni volta che un nodo ha un pacchetto da inviare, trasmette i bit del pacchetto durante lo slot di tempo che gli è stato assegnato. In genere le dimensioni degli slot sono tali da consentire la trasmissione di un singolo pacchetto.

Le caratteristiche di questo protocollo sono:

1)Quando un nodo vuole trasmettere, non può farlo alla velocità massima consentita dal canale broadcast.

2)Quando M nodi vogliono trasmettere, ognuno può trasmettere a velocità media di R/M bps (con R velocità massima del canale trasmissivo).

3)Non è completamente decentralizzato poiché bisogna stabilire gli intervalli di tempo in cui i vari nodi possono trasmettere dati. Quindi i nodi non possono trasmettere dati quando vogliono.

4)Il protocollo è semplice da implementare.

Un altro esempio di protocollo a suddivisione del canale è quello FDMA che suddivide il tempo in frequenze differenti e assegna ciascuna frequenza a un nodo N che appartiene alla rete.

2)**Protocolli ad accesso casuale** sono protocolli in cui un nodo trasmette sempre alla massima velocità consentita dal canale. Quando si verifica una collisione i nodi coinvolti ritrasmettono ripetutamente i frame fino a quando raggiungono la destinazione senza collisioni.

La ritrasmissione del frame non è immediata, ma il nodo attende per un certo periodo di tempo casuale, ed ogni nodo coinvolto in una collisione, seleziona un ritardo casuale indipendente da quello degli altri nodi.

Un esempio di protocollo ad accesso casuale è ALOHA il cui funzionamento è il seguente: quando il nodo ottiene un nuovo frame lo trasmette nello slot successivo. Se non c’è collisione il nodo può inviare un nuovo frame nello slot successivo altrimenti se c’è collisione il frame viene ritrasmesso più avanti con un certo ritardo.

I vantaggi sono che un nodo attivo può trasmettere a piena velocità nel canale ed inoltre abbiamo un sistema decentralizzato semplice da realizzare.

Gli svantaggi sono che se c’è una collisione si spreca uno slot a non inviare frame ed inoltre tale soluzione non è efficiente poiché con una rete con N nodi (con N numero molto grande) la probabilità che ci siano delle collisioni è elevata.

Un altro esempio di protocollo ad accesso casuale è CSMA il cui funzionamento è il seguente: prima di trasmettere verifica se il canale è inattivo oppure se è occupato.

Per rilevare le collisioni il nodo che sta trasmettendo rimane (durante la trasmissione) in ascolto del canale. Se sente che un altro nodo sta trasmettendo un frame che interferisce con il suo, arresta la propria trasmissione e aspetta un intervallo di tempo casuale e poi ripete il processo.

In questo caso si possono rilevare ancora le collisioni per via del ritardo di propagazione ovvero il tempo richiesto da un segnale per propagarsi da un nodo ad un altro. Infatti, maggiore è questo ritardo maggiore sarà la possibilità che il nodo non si accorga che è già incominciata la trasmissione da parte di un altro nodo.

Un altro esempio di protocollo ad accesso casuale è CSMA/CD il cui funzionamento è il seguente: all’inizio la scheda di rete riceve il datagramma dal livello di rete e crea il frame, dopodiché se la scheda di rete rileva che il canale è inattivo avvia la trasmissione del frame altrimenti se il canale è occupato la scheda di rete attende e non trasmette fino a quando il canale è inattivo. Se la scheda di rete trasmette l’intero frame senza rilevare collisioni provenienti da altre schede allora ha finito il suo lavoro altrimenti, se rileva collisioni interrompe la trasmissione e attende che il canale sia di nuovo inattivo. Se una volta scaduto il ritardo prova a ritrasmettere ma il canale è ancora occupato allora deve ancora attendere.

3)**Protocollo a rotazione** (c’è ne sono due tipi polling e token-passing)

Nel protocollo a rotazione polling un nodo viene designato come principale e andrà ad interpellare a turno gli altri nodi. Il nodo principale invia un messaggio al nodo 1 e li comunica che può trasmettere un dato numero massimo di frame e dopo che il nodo 1 ha trasmesso, il nodo principale avvisa il nodo 2 che può trasmettere un dato numero massimo di frame.

I vantaggi di questo protocollo sono che elimina le collisioni e gli slot vuoti che c’erano nei protocolli ad accesso casuale e quindi in questo caso si ha un’efficienza più alta.

Gli svantaggi sono che viene introdotto un intervallo di polling ossia il tempo richiesto per dire ad un nodo che ha il permesso di trasmettere, ed un altro svantaggio è che se il nodo principale si guasta l’intero sistema è inutilizzabile.

Nel protocollo a rotazione token-passing non esiste un nodo principale bensì, esiste un frame che è un messaggio di controllo detto token, che circola fra i nodi seguendo un ordine prefissato (da nodo 1 a nodo 2, da nodo 2 a nodo 3, da nodo 3 a nodo 1 e si ricomincia da capo).

Se il nodo che riceve il token non ha pacchetti da inviare invia il token al nodo successivo altrimenti, trasmette i pacchetti e una volta che ha finito invia il token al nodo successivo.

Questo protocollo è decentralizzato e molto efficiente però ha due svantaggi, il primo è che basta che un nodo si guasti per mettere fuori servizio l’intero sistema, il secondo è che se un nodo non riesce più ad inoltrare il token bisogna procedere con metodi di recupero del token per rimetterlo in circolazione per far ripartire il sistema.

**Esercizio 3 Data la sequenza di bit sottostante: S=00101010101000011111**

**Indicate una possibile sequenza di bit trasmessa su un canale di comunicazione non affidabile nel caso si adotti una tecnica di controllo di parità pari:**

**a1) a singolo bit; b1) bidimensionale. Quale vantaggio fornisce la tecnica bidimensionale?**

**Domanda esame simile Data la sequenza di bit D=101011 ed il generatore G=10011**

**a2) Calcolare il corrispondente codice CRC;**

**b2) Scrivere la sequenza di bit che verrà poi trasmessa sul canale**

**c2) Assumete che alla ricezione gli ultimi tre bit della sequenza spedita siano errati il destinatario riesce a rilevare l'errore? motivare la risposta**

**a1) Controllo di parità pari a singolo bit**

Per eseguire il controllo di parità pari a singolo bit, si aggiunge un bit di parità pari alla fine di ogni blocco di dati. Il bit di parità pari viene impostato in modo che il numero totale di bit a valore 1 (compreso il bit di parità) sia pari.

Nel nostro caso, il blocco di dati è costituito dai 20 bit della sequenza S, quindi il bit di parità pari viene calcolato come segue:

* Il numero di bit a valore 1 nella sequenza S è 10
* Il bit di parità pari viene impostato a 0 (poiché 10 è pari)

La sequenza di bit trasmessa con controllo di parità pari a singolo bit sarà quindi:

00101010101000011111 0 con l’ultimo 0 che sarà il bit di parità

Il problema di questo metodo è quando si verifica un numero pari di errori nei bit, in questo caso ci si trova in presenza di un errore non rilevato.

**b1) Controllo di parità pari bidimensionale**

Nel controllo di parità bidimensionale, i dati vengono organizzati in una matrice rettangolare, con un bit di parità pari aggiunto a ogni riga e colonna. Il bit di parità per ogni riga viene impostato in modo che il numero totale di bit a valore 1 nella riga (compreso il bit di parità) sia pari. Il bit di parità per ogni colonna viene impostato in modo che il numero totale di bit a valore 1 nella colonna (compreso il bit di parità) sia pari.

Per la sequenza S, possiamo organizzare i dati in una matrice rettangolare 3x5 come segue:

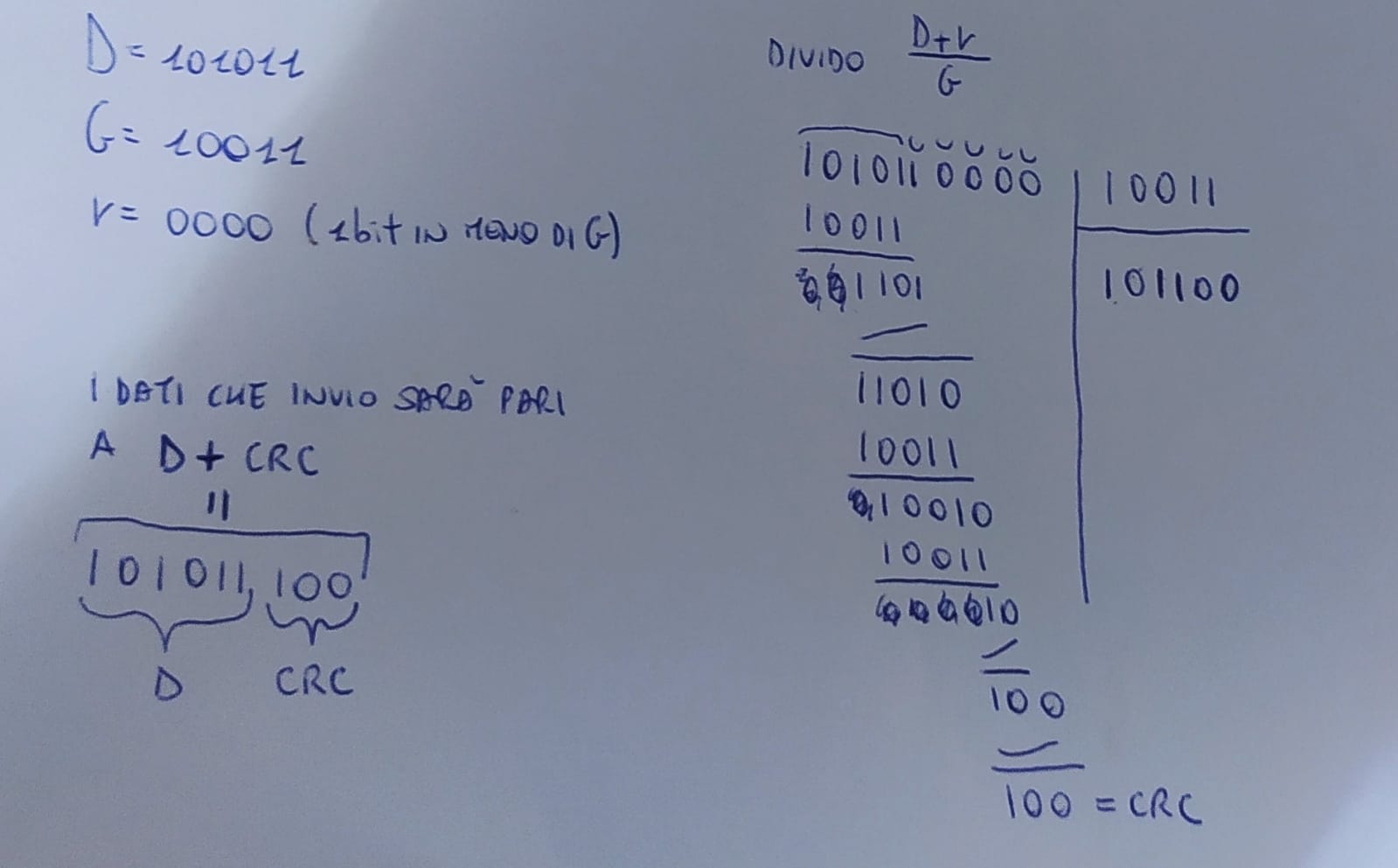
|  |  |  |
| --- | --- | --- |
| **1 0 1 0 1**  **1 1 1 1 0**  **0 1 1 1 0** | Aggiungiamo i bit di parità alle righe e alle colonne | **1 0 1 0 1|1**  **1 1 1 1 0|0**  **0 1 1 1 0|1**  **0 0 1 0 1|0** |

Il vantaggio del controllo di parità bidimensionale rispetto a quello a singolo bit è che può individuare e correggere errori in più di un bit.

**a2)** CRC è una tecnica di rilevazione dell’errore usata al livello di collegamento. Per calcolare il corrispondente codice CRC della sequenza di bit D=101011 ed il generatore G=10011 si esegue una divisione tra D (più un campo r sotto specificato) e G.

In questo caso il mittente aggiunge 4 bit a 0 (la lunghezza del generatore di 5 bit meno 1) alla fine di D che si indicano come r.

**D + r = 101011 0000**



**b2)** La sequenza di bit trasmessa sarà la concatenazione tra la sequenza di bit D e il codice CRC che in questo caso è pari a 101011 100

**c2)** Se alla ricezione gli ultimi tre bit della sequenza spedita sono errati, il destinatario riuscirà a rilevare l'errore poiché, il codice CRC è stato calcolato sulla sequenza completa (D e il bit di CRC stesso), qualsiasi errore introdotto nella trasmissione (anche solo un bit) altererà il valore del codice CRC calcolato dal destinatario.

Il processo di controllo del di correttezza del CRC è semplice: se la divisione (D + CRC) /G ha un resto diverso da 0, il ricevente sa che si è verificato un errore; altrimenti i dati sono considerati corretti.

**Esercizio 5**

**Considerate due stazioni A e B che comunicano a 1 Gbps adottando il protocollo 802.3. In questo caso quanto vale il bit-time? Assumendo l’occorrenza di tre collisioni consecutive, descrivete una possibile sequenza temporale di scambio dei messaggi tra i nodi.**

Il bit-time nel protocollo 802.3 è definito come il tempo richiesto per inviare un singolo bit sulla rete. La sua durata dipende dalla velocità di trasmissione dei dati, quindi nel nostro caso, avendo una velocità di trasmissione di 1 Gbps, il bit-time è pari a 1 nanosecondo (10^-9 secondi).

Consideriamo ora una possibile sequenza temporale di scambio dei messaggi tra due nodi A e B, che comunicano attraverso un hub (dispositivo passivo che inoltra i dati a tutti i dispositivi connessi):

1. Il nodo A inizia a trasmettere un pacchetto di dati a B. La trasmissione richiede un certo tempo per completarsi, pari alla lunghezza del pacchetto diviso per la velocità di trasmissione.
2. Nel frattempo, il nodo B riceve il pacchetto e lo elabora.
3. Tuttavia, il pacchetto di dati inviato da A si scontra con un pacchetto trasmesso contemporaneamente da un altro nodo C, causando una collisione.
4. Il protocollo 802.3 richiede che, in caso di collisione, i nodi in conflitto attendano un tempo casuale prima di ritrasmettere. Questo tempo è selezionato in modo casuale in un intervallo definito dallo standard 802.3.
5. Dopo l'attesa, il nodo A ritrasmette il pacchetto, ma questa volta viene interrotto da una nuova collisione con un pacchetto trasmesso da un altro nodo D.
6. Il nodo A attende nuovamente un tempo casuale prima di ritrasmettere, e questa volta la trasmissione riesce senza collisioni.
7. Il nodo B riceve correttamente il pacchetto e invia una conferma al nodo A per indicare che il pacchetto è stato ricevuto correttamente.
8. Il nodo A riceve la conferma e termina la comunicazione.

Questa sequenza di scambio dei messaggi può variare a seconda del numero di nodi presenti sulla rete e della quantità di traffico dati in transito. Tuttavia, la gestione delle collisioni è un aspetto critico del protocollo 802.3 e richiede una serie di accorgimenti per garantire una trasmissione affidabile dei dati.

**2.Wireless Networks**

**Esercizio 1**

**Illustrate le differenze fra le modalità *infrastruttura* e *senza infrastruttura* (adhoc network).**

Gli host associati a una stazione base sono considerati come operanti in modalità infrastruttura (infrastructure mode), in quanto tutti i tradizionali servizi di rete (come l’assegnamento degli indirizzi e l’instradamento) sono forniti dalla rete attraverso la stazione base. La stazione di base ha il compito di inviare e di ricevere dei dati tra gli host wireless a essa associati.

Un host wireless si dice associato ad una stazione di base quando si trova nell’area di copertura della stazione di base e quando la usa per trasmettere dati verso il resto della rete.

Nelle cosiddette reti ad hoc, gli host wireless non hanno alcuna infrastruttura cui connettersi. In sua assenza, essi stessi devono provvedere ai servizi di instradamento, di assegnazione degli indirizzi, di DNS e altri.

**Esercizio 2**

**Quali sono le differenze fra i seguenti tipi di deterioramenti di segnali trasmessi su canali wireless:**

**1. path loss; 2. multipath propagation; 3. interferenze con altre sorgenti.**

**Il path loss** è l’attenuazione dei segnali quando attraversano determinati ostacoli (come le pareti di una casa). Anche nello spazio libero, l’intensità del segnale si attenua al crescere della distanza percorsa.

**Il multipath propagation** ovvero la propagazione su più cammini si verifica quando una parte delle onde elettromagnetiche si riflette su oggetti e sul terreno, percorrendo cammini di diversa distanza tra il mittente e il ricevente. Tale fenomeno disturba il segnale che giunge al destinatario. Oggetti in movimento possono causare tra il mittente e ricevente possono causare il fenomeno di propagazione multipla, che varia in ogni momento.

**L’interferenza con altre sorgenti** ovvero, ci sono sorgenti radio che trasmettono nella stessa banda di frequenza interferiscono tra loro. Per esempio, i telefoni a 2,4 GHz e le LAN 802.11b trasmettono nella stessa banda di frequenze.

**Esercizio 5**

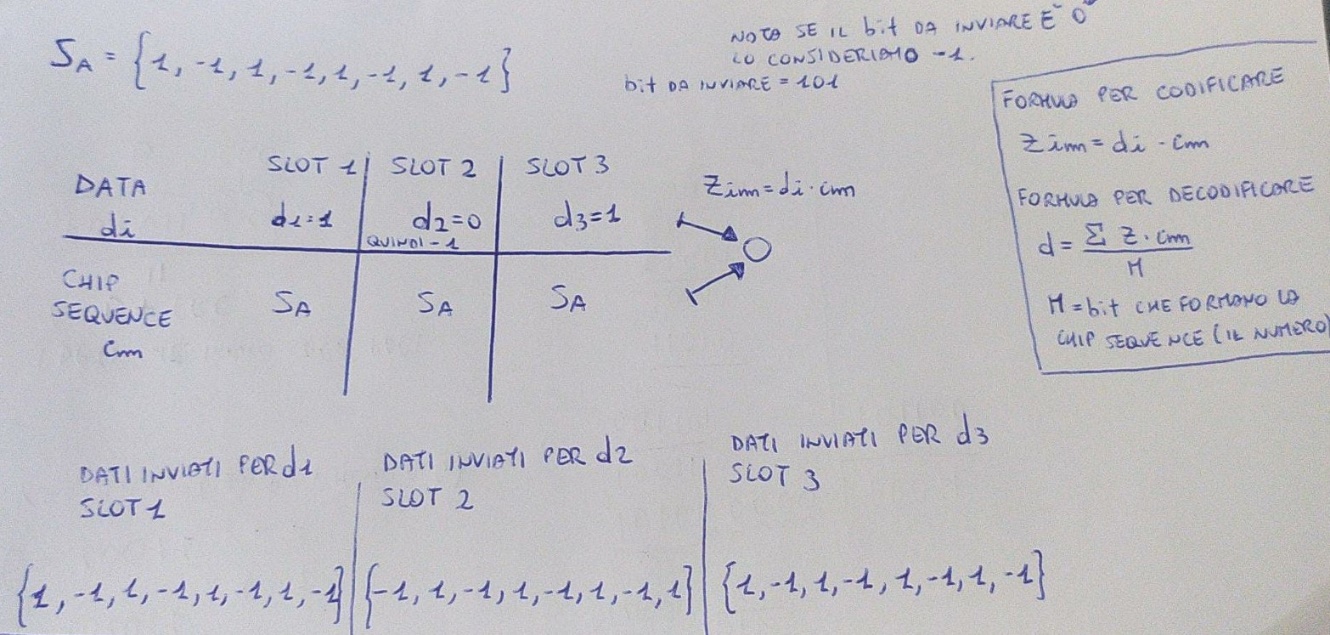
**Considerate due stazioni A e B che comunicano su un canale condiviso tramite la tecnica CDMA.**

**1. Se la chip sequence di A è SA = {1,-1,1,-1, 1,-1,1,-1} come risulterà la codifica della sequenza di bit 101?**

**2. Assumendo che A e B vogliono trasmettere contemporaneamente sullo stesso canale e che A usi la chip sequence SA precedentemente indicata, indicate una possibile chip sequence SB valida per la stazione B.**

CDMA è un protocollo usato per regolare l’accesso su un canale condiviso ed è il più diffuso nelle reti wireless. In tale protocollo ogni bit che viene inviato, viene prima codificato moltiplicandolo per un segnale detto chip sequence che cambia con una frequenza molto superiore rispetto a quella con cui variano i bit dei dati. Il vantaggio di questo protocollo è che risolve il problema dell’accesso multiplo mentre lo svantaggio è che ci sono molte operazioni da fare per inviare un singolo bit. Da notare che più è lunga la chip sequence più sarà grande l’overreding.

**a)** I vari passaggi per codificare i bit 101 con la chip sequence SA



**b)** I vari passaggi per ottenere una possibile chip sequence SB valida per la stazione B

Immagine che contiene testo, lettera

Descrizione generata automaticamente

Siccome le condizioni sono rispettate la chip sequence è valida.

**Domanda simile esame**

**Considerate la tecnica di multiplexing CDMA:**

**a) descrivete a cosa serve, i suoi vantaggi e svantaggi**

**Assumete che a tre nodi trasmittenti A, B, C sono associate le seguenti chip sequence**

**CA = {-1,-1,-1, 1, 1, -1, 1, 1}**

**CB = {-1,-1, 1,-1, 1, 1, 1,-1}**

**CC = {-1, 1,-1, 1, 1, 1,-1, -1}**

**e che i nodi trasmettano contemporaneamente le seguenti sequenze di bit.**

**SA = 10; SB = 01; SC = 00**

**b) Calcolare la sequenza trasmessa sul canale.**

**c) Calcolare come il ricevente può estrarre la sequenza di bit trasmessa dal nodo A.**

**a)** La risposta è nell’altra domanda sul CDMA.

**b)** Qui sotto i vari passaggi

Immagine che contiene testo, lavagna

Descrizione generata automaticamente

**c)** Il ricevente per estrarre la sequenza di bit trasmessa dal nodo A deve utilizzare la chip sequence del nodo A ed eseguire questo calcolo

Immagine che contiene testo

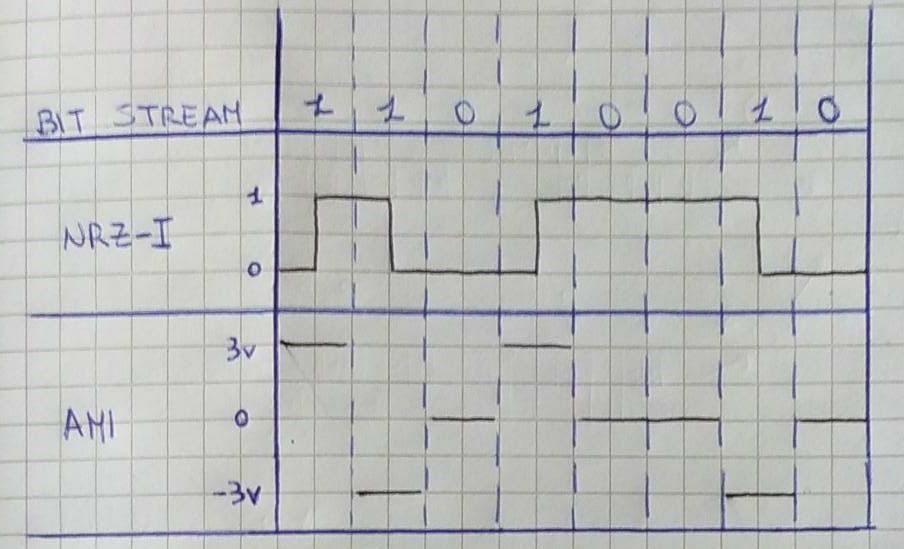
Descrizione generata automaticamente

**Domanda esame**

**Si deve inviare la seguente sequenza di bit S: 11010010 tramite un segnale digitale.**

**Determinare il segnale trasmesso usando le seguenti codifiche:**

**a) NRZ-I; b) AMI; c) Descrivete una possibile tecnica per codificare dati digitali tramite segnali analogici. Mostrate l'applicazione della tecnica scelta sulla sequenza S.**



Una possibile tecnica per codificare dati digitali tramite segnali analogici è per esempio Amplitude shift keying in cui quando invio 0 il segnale trasmesso avrà un’ampiezza nulla mentre quando invio 1 il segnale trasmesso avrà una certa ampiezza.

![Immagine che contiene grafico

Descrizione generata automaticamente](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4SkGRXhpZgAATU0AKgAAAAgABgALAAIAAAAmAAAIYgESAAMAAAABAAEAAAExAAIAAAAmAAAIiAEyAAIAAAAUAAAIrodpAAQAAAABAAAIwuocAAcAAAgMAAAAVgAAEUYc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDIzOjA0OjAxIDE4OjAxOjU0AAAGkAMAAgAAABQAABEckAQAAgAAABQAABEwkpEAAgAAAAM1MQAAkpIAAgAAAAM1MQAAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkQAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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**Domanda esame**

**Si deve inviare la seguente sequenza di bit S: 11010010 tramite un segnale digitale.**

**Determinare il segnale trasmesso usando le seguenti codifiche:**

**a) NRZ; b) Manchester; c) Quale delle due codifiche permette di risolvere il problema della sincronizzazione fra mittente e ricevente e in che modo?**

**Nota importante in questo esercizio per fare il Manchester manca il clock. Se ci fosse stato il clock avresti dovuto fare l’XOR tra il valore del bit del clock con il valore di S in quell’istante.**

![Immagine che contiene diagramma

Descrizione generata automaticamente](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4Tw8RXhpZgAATU0AKgAAAAgABgALAAIAAAAmAAAIYgESAAMAAAABAAEAAAExAAIAAAAmAAAIiAEyAAIAAAAUAAAIrodpAAQAAAABAAAIwuocAAcAAAgMAAAAVgAAEUYc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDIzOjA0OjAxIDE4OjA3OjA3AAAGkAMAAgAAABQAABEckAQAAgAAABQAABEwkpEAAgAAAAM1MQAAkpIAAgAAAAM1MQAAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkQAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAMjAyMzowNDowMSAxODowMDowMAAyMDIzOjA0OjAxIDE4OjAwOjAwAAAAAAYBAwADAAAAAQAGAAABGgAFAAAAAQAAEZQBGwAFAAAAAQAAEZwBKAADAAAAAQACAAACAQAEAAAAAQAAEaQCAgAEAAAAAQAAKpAAAAAAAAAAYAAAAAEAAABgAAAAAf/Y/9sAQwAIBgYHBgUIBwcHCQkICgwUDQwLCwwZEhMPFB0aHx4dGhwcICQuJyAiLCMcHCg3KSwwMTQ0NB8nOT04MjwuMzQy/9sAQwEJCQkMCwwYDQ0YMiEcITIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIyMjIy/8AAEQgAugEAAwEhAAIRAQMRAf/EAB8AAAEFAQEBAQEBAAAAAAAAAAABAgMEBQYHCAkKC//EALUQAAIBAwMCBAMFBQQEAAABfQECAwAEEQUSITFBBhNRYQcicRQygZGhCCNCscEVUtHwJDNicoIJChYXGBkaJSYnKCkqNDU2Nzg5OkNERUZHSElKU1RVVldYWVpjZGVmZ2hpanN0dXZ3eHl6g4SFhoeIiYqSk5SVlpeYmZqio6Slpqeoqaqys7S1tre4ubrCw8TFxsfIycrS09TV1tfY2drh4uPk5ebn6Onq8fLz9PX29/j5+v/EAB8BAAMBAQEBAQEBAQEAAAAAAAABAgMEBQYHCAkKC//EALURAAIBAgQEAwQHBQQEAAECdwABAgMRBAUhMQYSQVEHYXETIjKBCBRCkaGxwQkjM1LwFWJy0QoWJDThJfEXGBkaJicoKSo1Njc4OTpDREVGR0hJSlNUVVZXWFlaY2RlZmdoaWpzdHV2d3h5eoKDhIWGh4iJipKTlJWWl5iZmqKjpKWmp6ipqrKztLW2t7i5usLDxMXGx8jJytLT1NXW19jZ2uLj5OXm5+jp6vLz9PX29/j5+v/aAAwDAQACEQMRAD8A9I8weS2A33T/AAmrSuMcK3/fJoELG/7tflbp6UeYefkbrSERSS4x8jfpVWaY+U/yN90+n+NA0MMx/uN+n+NRLKcH923U+nr9aQyN5iJV+Ruh9Pb3qOWfagLI2N6jt3I96FqBJvJ/5Zt+n+NMDkL9xup9P8aAGRzBriQBGyqrkce/vTnkOB+7ccj0/wAaBCmUgZMb4H0/xqOCbfbxOqsVZAQQRyMfWgY4O29v3bc+49PrTHm/exrtIYkkDjng+9AD3c7G+RuR7f40okIUfu24Ht/jQAxZTuk+Rj83t6D3pPMbzF+Ruh9Pb3oAJJCI2yjDg9x/jT/Mb/nm35j/ABoAFcgfcbqe49frSecfNUbGzg8ZHt70AKZWx9xuo7j1+tKZWAzsb8xQA22nM8CSiJwr8gHGf51JubcfkPQdx70xDJJ9hRSjAu4Ucjr1/pU2W/55n8xRYZpf8sm+hqypHSmIIseUv+6Kazgbue9JgilNMNw5HWoJpB5b8joaQxhkHqPzpquADyOpoAYzAyryOh/pVe/cLaZz/GgH/fQqo7oZcLD1FR5BXGR1NIRBBHGl/cSCTLPGgK+mC3+P6VO5XaOR27+9DAbKFZGXcBkYzUNj5YsLYI+5BEoU+owMGjoIm3Dc3I61TmBOo2jDlQWyR2+U0IZcYoU+8Oh7+1Mdht+8PzpAVrPA88s3WY4yfYD+lWNy+YPmHAPemxXK1/J/o3DdHXof9oVc3qB94fnR0GRJINpyw+8e/vUauDqJGeFi659T/wDWoQiWSRccMDgjv70pcHjcPzpDG6TuXSbRZflkEShlPBBxVvKhm+YdB3+tN7gUbqRPtViu4EG49f8AYY/0rRLoP41/Oq6IC1sQRN8o6HtVU6tarfT2zRLmFCxOVySAGwB16HNVGHMI0ImZpY41tRtK58wkAEcdO/eo75hDE7LD5hU8KAPapaWwjFmupo5IVksN5kbAMLqV6E/xY7D0psl9D9hmuPszBFICkhRuz0IOcd++Kfs+zHclF1bb1jaLazR+Z90Ed+OO+ATx6U+1mtLx5RCI5BGFJZcEc5x/KlyNK47kjRRiQYjXof4fpVDV41FjlEUESxHgf9NFpQ+JAaEqRIrMUXAGT8tVbORLp5wIMRo2A7LjcTkngjsMc+9Cj1F0HRWkKX9xNhSZI0UrtHGC388/pUV7cJB5cccAaR3RQNnABYDJPQdaEruwXLckSHOVX8qrWUUUdhbKoDKsKANjqMDmkFxlvcxXDAiEhXdkUkDkrkH/ANBP5UspCXdrGEXEkhB49EY/0quWzsFya4eGCF5JNiKB95uAKjt2jurOOcR7VkXcARzjtU20uMS3w7XBZQdsu0cf7K/41BJdCO9aPyV2Rxh3YnnDEjge2DVJXYEtzIsMO8Ipyyr09WA/rTryRbe2ll2BvLQtjHXAzSSFcZZv5kTb1TeCTlehBJwR/ntSROW1KaIgbVhRgPclh/7KKGrNiGX8xhjCxRb5nZVRdvGSQOT2HNXwiqc7R+VK1lcdws5Vms4p9u3zF3YPbNMhuDJO24JtYlUKnurMMH34qlHcCO9A+2aaeP8Aj5P/AKKkrRIGKHsg6k5jkMLfOPun+H2qi2k3sk8js8DRySCVoyTgsFCjtnsKqD5Rl2OHUFSErLbjZHsBIY8cZ/kKp3dvqs6sv2u2X5uqxtn/ANCptw3EUBpuqoU/0y2bbJvBaI9cEev+c1G2kagkLL9rgEe3mMI23PUEfNwc88Ue0iFiN9DvmlMjS2TS5VhI0LFl24xgkn0/U1PBaarb58uWzB2rGTtbkLnH48mh1ItWCwxk1wuP39iDg4+Rj6VU1FdbXTrhjcWZwhIxGw6fjRHkuhl17fXt3F3Y/wDfhv8A4qoIdP1VZ2uPtVr5jMSfkfGenTdjp7ULkQhYrfWl1G5c3FrtaOMAmM84L54z70XVhq1xFskvLYIWB+SN1PBGOQwNF4J31EK1rrKxbEvrXCrtG6Bv1O6mWdnrEdjbx/brQKkSqB9nJ6KB13UXp22Y7EEOj6pHdtONRgyGLLH9nO1WOckDd1OT+Z9TU72mrGeEnUbTerFk/wBFOfukE/f9Dj8abnBvYB0lnrDRtu1S26f8+f8A9nUNno2o2cJji1f5cADdCXwB0A3OcfhS5oWtYCVLHVAz/wDE1T73a1HoP9qoJ9GvJ7qJ5NU+dVOCLcAEAg4IzyM460lOKd7AOuNO1KSPB1dNoZWwbVezA+vtU76fqEgIfVQwPB/0ZaOaHYLFax0a7s4mSLVpdpY/eiVsAHGBnoPb3qVNLvVupJRq8m90VT+4j6AnHb3NDqRbvYQ270a7uIQsmrzEB1IxDGOcj0FTLpmoQQqia1LtXgboEY/meaOeNrWGQ6Xpmp/YbdJdWmQKgBVYY+PxKmrEehzR3DEavd8N5gGyLAY5z/B7n86ftIp6ILD5rSeK+04yahNMPtBwrJGB/qn9FFa5jP8Az0b8h/hSm07WQIt72MZHlN09v8al81v+ebfmP8agGMWVvLX92enqKbuY7vkPX1FJgRvuyPkPX1qOXf5TfJ/Ce9IYxnf+5+tQ+Y3PyfrQAx3fevydj3+lU9SdjYSgx/eG3qO5xVR3QGk0j8/uz+YqESPg4jP3j3HrSEQwTTNf3CNE3lrFGV6dSXz/ACFTu77f9Ueo7j1oYEcpkdGURNyMcEU2yMq6daq8RDiFNwyODgZo6DH7n3N+7P5iq7rKb+3l8vCKGB5HccfyoTAsSu3lsPLPQ55FJucKMRnp6igCCwd2hkJQk+dIOo7MadI7m4UCM8K3ce1D3Agvmf7LnyzgOh6/7Qq/uYDGz9aHsBXjZgpxGT8zd/c0xGb+0UXYctC7EZ9GX/4qhAWZC237n8S9/cUO74wE59M0hCWcjvaqwT+Jh19CR/SrAL+Yx287Rxn3NNqzsBVu95vdNynP2hu//TJ6v5fP3R/31Td7IC2ZU8tvmXp6003CAffX86BlaC/gbyoxKpLEoOe6jJH6Gi21O0u1laGXIjPzAqQfqM9RweR6Gnyu1wHQ39pdybIZ0Z15ZM4YD3B5qSZk8tvnX7p71LTW4is8qA4Lr+dVlmTc/wA6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La codifica Manchester permette di risolvere il problema della sincronizzazione fra mittente e ricevente poiché in questa codifica ci sono molte transizioni tra 0 e 1 mentre negli altri metodi di codifica come NRZ-I non sono presenti molte transizioni e questo porta ad avere il problema del mantenimento della sincronizzazione fra mittente e destinatario.

Per risolvere questo problema usando gli altri metodi di codifica (quindi non usando Manchester) invece di inviare 4 bit alla volta se ne inviano 5 bit. Questi 4 bit vengono tradotti in una sequenza di 5 bit che conterrà un numero di transizioni sufficienti per mantenere la sincronizzazione.

Tale modalità viene chiamata clock recovery ed usata appunto per mantenere la sincronizzazione fra mittente e destinatario.

**Domanda simile esame**

**Nel protocollo 802.3 (Ethernet):**

**a) Quali indirizzi vengono usati per identificare, i vari host nella rete locale? Quali differenze ci sono fra questi indirizzi e gli indirizzi IP? Risposta presente a pagina 1 domanda 2**

**b) Che tipo di protocollo di accesso al mezzo viene usato per coordinare le comunicazioni sullo stesso canale? Descrivetelo in dettaglio, specificando in particolare cosa sono le collisioni e quali azioni correttive prevede il protocollo in caso se ne verifichino.**

**c) Illustrate le principali similitudini e differenze tra router e switch.**

**Esercizio 4**

**d) Illustrare le similitudini e le differenze fra i protocolli 802.3 e 802.11.**

![Immagine che contiene testo, lettera

Descrizione generata automaticamente](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4SM6RXhpZgAATU0AKgAAAAgABgALAAIAAAAmAAAIYgESAAMAAAABAAEAAAExAAIAAAAmAAAIiAEyAAIAAAAUAAAIrodpAAQAAAABAAAIwuocAAcAAAgMAAAAVgAAEUYc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDIzOjA0OjExIDIyOjM3OjA2AAAGkAMAAgAAABQAABEckAQAAgAAABQAABEwkpEAAgAAAAMwNQAAkpIAAgAAAAMwNQAAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkQAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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**Il protocollo 802.3**

**Struttura dei frame Ethernet**:

**1) Campo dati** che contiene il datagramma IP. Dato che l’**unità massima di trasmissione** per Ethernet è di 1500byte, se il datagramma IP supera questo valore, l’host deve frammentare il datagramma. Altrimenti, se il datagramma IP è inferiore alla dimensione minima del campo dati, equivalente a 46 byte, il campo dovrà essere “riempito” fino a raggiungere quel dato valore. Per cui, i dati trasferiti al livellodi rete conterranno oltre al datagramma IP anche i byte di riempimento che verranno rimossi utilizzando il campo lunghezza dell’intestazione del datagramma IP.

**2) Indirizzodidestinazione**è il campo che contiene l’indirizzo MAC della scheda di rete di destinazione. Quando l’host riceve il datagramma trasferisce il contenuto del campo dati del pacchetto al livello di rete. I pacchetti con altri indirizzi MAC vengono scartati.

**3) Indirizzo sorgente** è il campo che include l’indirizzo MAC della scheda che trasmette il pacchetto.

**4) Tipo** che consente a Ethernet di supportare vari protocolli di rete. Occorre tener presente che, oltre a IP, gli host possono supportare vari protocolli di rete e utilizzare diversi protocolli per differenti applicazioni. Per questa ragione, la scheda di rete deve sapere a quale protocollo di rete passare il contenuto del campo dati di ciascun frame ricevuto.

**5) Controllo a ridondanza ciclica (CRC)** è il campo che consente alla scheda di rete ricevente di rilevare la presenza di un errore nei bit del frame.

**6) Preambolo** I frame Ethernet iniziano con un campo di otto byte: sette hanno i bit 10101010 e l’ultimo è 10101011. Il ricevente utilizza i primi sette byte del preambolo per sincronizzarsi con il clock della scheda di rete del mittente. Gli ultimi due bit degli otto byte del preambolo (i primi due 1 consecutivi) avvisano la scheda di rete del ricevente che “le cose importanti” stanno per arrivare.

**Ethernet generico:** A livello di rete, tutte le tecnologie Ethernet forniscono un servizio senza connessione, nel senso che quando una scheda di rete vuole inviare un datagramma a un host della rete, non fa altro che incapsularlo in un frame Ethernet e immetterlo nella LAN, senza alcuna forma di handshake preventivo con il destinatario.

Tutte le tecnologie Ethernet forniscono un servizio non affidabile a livello di rete. In particolare, quando la scheda di rete B riceve un frame da A, lo sottopone a un controllo CRC, ma non invia un acknowledgement né se il frame supera il controllo né in caso contrario: semplicemente lo scarta. Quindi, A non sa se il frame trasmesso abbia superato il controllo CRC. Questa mancanza di affidabilità nel trasporto (a livello di collegamento) aiuta a mantenere Ethernet semplice ed economica, ma significa anche che il flusso dei datagrammi che attraversano il livello di rete può presentare delle lacune.

Come può l’applicazione nell’host B rilevare le lacune dovute ai frame Ethernet scartati? Dipende se l’applicazione sta usando TCP o UDP. Se l’applicazione utilizza UDP, allora l’applicazione nell’host B vedrà delle lacune nei dati. Se, invece, l’applicazione sta usando TCP l’host B non manderà un acknowldegement per i dati contenuti nei frame scartati, forzando il TCP sull’host A ad ritrasmetterli. Si noti che quando TCP ritrasmette delle informazioni, queste, prima o poi, ritorneranno alla scheda di rete che le ha scartate. Per cui Ethernet effettua una ritrasmissione, anche se non ha idea se si tratta di dati nuovi o già trasmessi.

Per Ethernet esistono molte forme differenti con svariate denominazioni come: 10 BASE-T, 10BASE-2, 100BASE-T, 1000BASE-LX e 10GBASE-T. Queste e molte altre tecnologie Ethernet sono standardizzate dai gruppi di lavoro IEEE 802.3 CSMA/CD (Ethernet).

**B vedi anche spiegazione CSMA/CD per rispondere alla domanda)** Tutti i frame trasmessi da un’interfaccia di rete sono ricevuti dalle altre interfacce e il protocollo Ethernet CSMA/CD risolve bene il problema dell’accesso multiplo. I nodi si collegano semplicemente al cavo e si ottiene una rete locale.

Nella maggior parte delle installazioni odierne i nodi Ethernet sono collegati a uno switch con segmenti punto a punto, realizzati con doppini in rame o fibre ottiche

**Lo standard Gigabit Ethernet, detto anche IEEE 802.3z,** ha le seguenti funzionalità:

1) Utilizza il formato del frame standard di Ethernet. Ciò consente una facile integrazione con le infrastrutture Ethernet già installate.

2) Consente sia l’uso di collegamenti punto a punto sia l’uso del canale broadcast condiviso. I collegamenti punto a punto utilizzano switch, mentre i canali broadcast utilizzano hub.

3) Utilizza CSMA/CD per i canali broadcast condivisi. Per riuscire a ottenere un livello accettabile di efficienza è necessario limitare la distanza tra i nodi.

4) Su canali punto a punto può operare in modalità full-duplex a 40 Gbps in entrambe le direzioni.

**Switch:** Il ruolo dello switch è ricevere i frame in ingresso e inoltrarli sui collegamenti in uscita. Lo switch stesso è trasparenteai nodi; cioè, un nodo indirizza un frame a un altro nodo, senza sapere che uno switch riceverà il frame e lo inoltrerà agli altri nodi.

Il filtraggio è la funzionalità dello switch che determina se un frame debba essere inoltrato a una qualche interfaccia o scartato.

L’inoltro consiste nell’individuazione dell’interfaccia verso cui il frame deve essere diretto.

Le operazioni di filtraggio e inoltro di uno switch sono eseguite mediante una tabella di commutazione (switchtable) composta da voci che contengono:

1) L’indirizzo MAC del nodo,

2) L’interfaccia dello switch che conduce al nodo,

3) Il momento in cui la voce per quel nodo è stata inserita nella tabella.

Per comprendere come lo switch esegue filtraggio e inoltro ipotizziamo che un frame con indirizzo di destinazione DD-DD-DD-DD-DD-DD giunga allo switch sull’interfaccia *x*. Lo switch cerca nella sua tabella l’indirizzo MAC DD-DD-DD-DD-DD-DD. I possibili casi sono tre.

1) Non vi è una voce nella tabella per DD-DD-DD-DD-DD-DD e in questo caso lo switch inoltra copie del frame ai buffer di uscita di tutte le interfacce, eccetto *x*. In altre parole, se non vi è una voce per l’indirizzo di destinazione, lo switch manda il frame in broadcast.

2) Vi è una voce nella tabella che associa DD-DD-DD-DD-DD-DD a *x*. In questo caso il frame proviene da un segmento di rete che contiene la scheda di rete DD-DD-DD-DD-DD-DD. Non occorre, quindi, inoltrare il frame a un’altra interfaccia e lo switch esegue la funzione di filtraggio, scartando il frame.

3) Vi è una voce nella tabella che associa DD-DD-DD-DD-DD-DD a *y* ≠ *x*. In questo caso il frame deve essere inoltrato al segmento di LAN collegato all’interfaccia *y*. Lo switch esegue l’inoltro ponendo il frame nel buffer dell’interfaccia *y*.

**Come viene configurata la tabella dello switch all’avvio?**

**L’autoapprendimento** è una proprietà che permette di costruire automaticamente, dinamicamente

e in modo autonomo le proprie tabelle, ovvero senza l’intervento di un operatore o di un protocollo di configurazione. In altre parole, si potrebbe dire che gli switch auto-apprendono. Questa capacità è ottenuta nel seguente modo.

1) La tabella è inizialmente vuota.

2) Di ogni frame che riceve, **lo switch archivia** nella sua tabella **l’indirizzo MAC del campo indirizzo sorgente del frame, l’interfaccia da cui arriva il frame, il momento di arrivo**, registrando in tal modo il segmento LAN su cui risiede il nodo trasmittente. Quando tutti i nodi nella LAN avranno inviato un frame, allora la tabella sarà completa.

3) Quando, dopo un dato **periodo di tempo detto aging time** (tempo di invecchiamento), **lo switch non riceve frame da un determinato indirizzo sorgente, lo cancella dalla tabella**. In questo modo se un calcolatore viene sostituito (da un altro, con una diversa scheda di rete), l’indirizzo MAC del precedente elaboratore viene eliminato automaticamente dalla tabella.

**Gli switch sono dispositivi plug-and-play**, in quanto non richiedono interventi dell’amministratore di rete o dell’utente.

**Ci sono svariati vantaggi relativi all’utilizzo degli switch piuttosto che dei collegamenti broadcast**, come i bus o le topologie a stella basate su hub.

**1) Eliminazione delle collisioni**. In una LAN costituita da switch e senza hub non vi è spreco di banda a causa delle collisioni. Gli switch mettono i frame nei buffer e non trasmettono più di un frame su ogni segmento di LAN in un certo istante.

**2) Collegamenti eterogenei**. Dato che uno switch isola un collegamento da un altro, i diversi collegamenti nella LAN possono funzionare a velocità diverse e possono usare mezzi trasmissivi diversi.

**3)Gestione**. Oltre a fornire una maggiore sicurezza uno switch facilita anche la gestione di rete. Per esempio, se una scheda di rete ha un malfunzionamento e manda continuamente frame Ethernet

uno switch può individuare il problema e disconnettere internamente la scheda di rete non funzionante. L’amministratore di rete non ha pertanto bisogno di essere sul posto per risolvere il problema.

**c) Switch e router a confronto:** I router sono commutatori di pacchetti store-and-forward che inoltranopacchetti usando gli indirizzi a livello di rete. Anche se gli switch sono commutatoridi pacchetto store-and-forward, si distinguono sostanzialmente dai router, in quantoinoltrano i pacchetti utilizzando indirizzi MAC.

Mentre i router sono commutatori dipacchetto di livello 3(livello di rete), gli switch sono commutatori di pacchetto di livello 2(livello di collegamento).

**Quali sono allora i pro e i contro che contraddistinguono i due dispositivi?**

Gli switch sono dispositivi plug-and-play che possono avere capacità di filtraggio e inoltro dei pacchetti relativamente alte ma, devono elaborare pacchetti solo fino al livello 2, mentre i router possono farlo fino al livello 3.

La topologia di una rete di switch è ristretta a un albero per evitare i cicli con i frame broadcast. Inoltre, una rete di switch molto grande richiederebbe delle grandi tabelle ARP nei nodi e nei router generando un considerevole traffico ARP e richiedendo molta elaborazione.

Infine, gli switch non offrono alcuna protezione contro le tempeste di broadcast che consistono in ciò che segue: se un host iniziasse a trasmettere un flusso ininterrotto di pacchetti broadcast, gli switch li inoltrerebbero, provocando il collasso della rete.

Dato che gli indirizzi di rete sono sovente gerarchici (e non lineari come gli indirizzi MAC), generalmente i pacchetti non presentano cicli attraverso i router, anche nel caso in cui la rete presenti percorsi ridondanti.

In ogni modo i pacchetti rischiano di percorrere dei cicli soltanto se le tabelle dei router sono configurate male. IP utilizza uno speciale campo di intestazione del datagramma per limitare la percorrenza dei cicli. Pertanto, i pacchetti non sono vincolati a un albero di copertura e possono utilizzare il miglior percorso fra sorgente e destinazione.

Inoltre, contrariamente agli switch, i router proteggono dalle tempeste di broadcast a livello 2, ma non sono plug-and-play e quindi il loro indirizzo IP e quello degli host a essi collegati deve essere configurato. Inoltre, molte volte presentano un tempo di elaborazione per pacchetto più lungo di quello degli switch, in quanto devono eseguire l’elaborazione fino ai campi del livello 3.

**Quando conviene usare gli uni e quando gli altri?** Generalmente, per le reti costituite al massimo da alcune centinaia di host e da pochi segmenti risultano sufficienti gli switch, in quanto localizzano il traffico e incrementano il throughput aggregato senza richiedere la configurazione degli indirizzi IP. Le reti più grandi, costituite da migliaia di host, invece, includono tipicamente oltre agli switch anche dei router, che forniscono un più efficace isolamento del traffico, evitano le tempeste di broadcast, e utilizzano percorsi più funzionali fra gli host della rete.

**Il protocollo 802.11** conosciuto anche come Wi-Fi è estremamente diffuso. Esistono diversi standard di tale protocollo e le loro caratteristiche sono:

1) Usano lo stesso protocollo di accesso al mezzo, CSMA/CA, e la stessa struttura del frame a livello di collegamento.

2) Tutti possono ridurre la frequenza trasmissiva per raggiungere distanze maggiori.

3) Infine, tali protocolli hanno retrocompatibilità.

Tuttavia, i vari protocolli presentano notevoli differenze a livello fisico.

**Architettura di 802.11:** I componenti che formano l’architettura dell’802.11 sono un BSS (insieme di servizi di base) che contiene una o più stazioni di wireless (PC, tablet, IPhone) e gli AP (access point) che è una stazione base centrale.

Le stazioni hanno indirizzo MAC a 6 byte e ciascuna AP ha un MAC per le interfacce wireless.

Le reti wireless con AP vengono chiamate wireless LAN con infrastruttura, dove “l’infrastruttura” è formata dagli AP, dalla rete Ethernet che li collega e da un router.

**Canali e associazione:** Quando si installa un AP gli si assegna un SSID (ossia un identificatore) e un numero di canale. Prima di inviare o ricevere pacchetti dati 802.11 le stazioni devono associarsi a un AP.

La giungla Wi-Fi è un luogo in cui la stazione wireless riceve un segnale sufficientemente intenso da due o più AP.

Per ottenere l’accesso a Internet, la nostra stazione wireless avrà bisogno di associarsi a una specifica sottorete e quindi a un unico AP. “Associarsi” significa che una stazione wireless crea un cavo virtuale verso l’AP. In particolare, solamente l’AP associato potrà inviare pacchetti di dati verso la nostra stazione wireless e questa potrà inviare pacchetti in Internet soltanto attraverso quel dato AP.

**Come si associa una stazione wireless con un particolare AP? E, cosa più importante, come può sapere quali AP, ammesso che ce ne siano, sono raggiungibili nella giungla?**

Lo standard 802.11 richiede che l’AP invii periodicamente dei frame beacon, che contengono il proprio codice SSID e il proprio indirizzo MAC.

Venuti a conoscenza della presenza di AP attraverso i frame beacon, potremo selezionare quello a cui associarci. Lo standard 802.11 non specifica un algoritmo per selezionare l’AP con il quale associarsi: tale algoritmo viene lasciato ai progettisti firmware e software 802.11 del nostro host wireless. Tipicamente l’host sceglie l’AP i cui frame beacon vengono ricevuti con la potenza di segnale più alta. L’alta potenza di segnale è importante, ma non è la sola caratteristica dell’AP che determinerà le prestazioni ricevute dall’host. In particolare, è possibile che l’AP selezionato abbia un segnale forte, ma sia sovraccarico con altri host associati che dovranno condividere la banda wireless di quell’AP, mentre un AP scarico non venga selezionato a causa di un segnale leggermente più debole.

Il processo di scansione dei canali e di ascolto dei frame beacon è chiamato **scansione passiva**.

Un host wireless può eseguire anche una **scansione attiva**, inviando in broadcast un frame sonda che verrà ricevuto da tutti gli APnel raggio di copertura dell’host wireless. L’AP risponde al frame sonda di richiestacon un frame di risposta. L’host wireless può quindi scegliere l’AP con il quale associarsitra quelli che hanno risposto.

Dopo aver individuato il punto d’accesso con il quale associarsi, l’host wirelessinvia un frame di richiesta di associazione all’AP, il quale risponde con un frame dirisposta di associazione.

Si noti che questo secondo scambio richiesta/risposta è necessario con la scansione attiva, in quanto un AP che risponde all’iniziale frame sondadi richiesta non sa con quale dei (magari molti) AP che rispondono l’host sceglieràdi associarsi.

Una volta associato con un AP, l’host vorrà entrarenella sottorete, nel senso dell’indirizzamento IP, alla quale appartienel’AP. In genere, quindi, l’host invia un messaggio d’identificazione DHCPnella sottorete, tramite l’AP, per ottenere un indirizzo IP su quella sottorete.

Una volta ottenuto l’indirizzo, l’host viene visto come un altro host con un indirizzo IP in quella sottorete.

Per creare un’associazione con un particolare AP, alla stazione wireless potrebbe essere richiesto di autenticarsi. Le reti 802.11 forniscono diverse possibilità per l’autenticazione e l’accesso.

**Protocollo per regolare gli accessi nel protocollo 802.11:** Una volta che una stazione wireless è associata a un AP, può iniziare a trasmettere e a ricevere frame di dati da e verso l’AP. Ma, poiché stazioni multiple potrebbero voler trasmettere frame di dati contemporaneamente sullo stesso canale, è necessario un protocollo ad accesso multiplo per coordinare le trasmissioni.

**Questo protocollo è chiamato CSMA/CA.**

Come per Ethernet, per ciascuna stazione il CSMA ascolta il canale prima di trasmettere e si astiene dal farlo se rileva che il canale è occupato.

Sebbene sia Ethernet sia 802.11 utilizzino CSMA con accesso casuale, i loro protocolli MAC presentano sostanziali differenze.

La prima è che invece di rilevare le collisioni, 802.11 le previene. Inoltre, essendo il tasso di errore nei bit nei canali wireless piuttosto elevato, 802.11 utilizza uno schema di “avvenuta ricezione/ritrasmissione” a livello di collegamento (ARQ).

Con l’algoritmo di rilevazione di collisioni, le stazioni Ethernet ascoltano il canale durante la trasmissione. Se una stazione che sta trasmettendo rileva la trasmissione di un’altra stazione, prima interrompe la propria trasmissione e poi la ritenta dopo un breve intervallo di tempo di durata casuale.

Al contrario del protocollo Ethernet 802.3, il protocollo MAC 802.11 non implementa la rilevazione delle collisioni. Esistono due fondamentali ragioni per questa scelta.

La prima ragione è la possibilità di rilevare collisioni richiede la capacità di inviare (il segnale proprio della stazione) e ricevere (per determinare se un’altra stazione sta anch’essa trasmettendo) contemporaneamente. Essendo in genere la potenza del segnale ricevuto nettamente inferiore alla potenza del segnale trasmesso dall’adattatore 802.11, risulta molto costoso costruire hardware che possa rilevare una collisione.

La seconda ragione è la possibilità più significativa è il fatto che l’adattatore, anche se fosse in grado di trasmettere e ricevere allo stesso istante (presumibilmente interrompendo la trasmissione quando trova il canale occupato), non potrebbe rilevare tutte le collisioni a causa del problema del terminale nascosto e dell’attenuazione del segnale.

Dato che le reti 802.11 non utilizzano la rilevazione delle collisioni, una volta che una stazione inizia a trasmettere un frame lo trasmette interamente: cioè, non può tornare indietro. Per ridurre il rischio di collisioni, 802.11 implementa numerose tecniche di prevenzione.

Esiste lo schema di conferma di avvenuta ricezione **(acknowledgment scheme)** a livello di collegamento di 802.11. Un frame inviato da una stazione in una rete wireless potrebbe non raggiungere la stazione di destinazione per numerosi motivi. Per contrastare queste possibilità di fallimento, MAC 802.11 utilizza la conferma di avvenuta ricezione a livello di collegamento. Quando la stazione di destinazione riceve un frame che passa il controllo CRC, attende per un breve periodo di tempo, noto come SIFS dopo il quale, invia al mittente un frame di conferma di avvenuta ricezione. Se la stazione trasmittente non riceverà questo riscontro entro un arco di tempo stabilito, presupporrà un errore e ritrasmetterà il frame, utilizzando ancora il protocollo CSMA/CA per accedere al canale. Se il frame di conferma non sarà ricevuto dopo un numero prefissato di ritrasmissioni, la stazione trasmittente passerà oltre e scarterà il frame.

Supponiamo che una stazione (una stazione wireless o un AP) abbia un frame da trasmettere.

1. Se inizialmente la stazione percepisce il canale come inattivo, allora trasmette il suo frame dopo un breve periodo di tempo conosciuto come **DIFS** (*distributed inter-frame space*, spazio distribuito inter-frame ovvero un tempo continuo per il quale il canale è inattivo).

2. Altrimenti, la stazione sceglie un valore casuale di ritardo usando una attesa binaria esponenziale e decrementa questo valore dopo DIFS solo quando il canale viene percepito come inattivo. Se il canale è percepito come occupato, il contatore rimane fermo.

3. Quando il contatore arriva a zero (notiamo che questo può verificarsi soltanto quando il canale è percepito come inattivo), la stazione trasmette l’intero frame e aspetta il frame di conferma.

4. Se riceve la conferma, la stazione sa che il frame è stato ricevuto correttamente e, qualora avesse un altro frame da inviare, riattiva il protocollo CSMA/CA dal passo 2. Se il frame di conferma non viene ricevuto, la stazione trasmittente ritorna al passo 2, ma con un valore di ritardo maggiore.

Nel protocollo Ethernet di accesso, una stazione inizia a trasmettere appena percepisce che il canale è inattivo. Con CSMA/CA, invece, la stazione evita di trasmettere mentre decrementa il contatore, anche se ha rilevato che il canale è inattivo.

**Perché CSMA/CD e CSMA/CA utilizzano approcci differenti?**

Consideriamo uno scenario in cui due stazioni hanno un frame dati da trasmettere, ma non lo fanno in quanto percepiscono che una terza stazione sta trasmettendo. Con CSMA/CD (Ethernet), le due stazioni vorrebbero trasmettere appena rilevano che la terza ha terminato. Questo causerebbe una collisione che però non sarebbe un serio problema in CSMA/CD, in quanto entrambe le stazioni interromperebbero l’invio, evitando l’inutile trasmissione della rimanente parte di frame che ha subìto la collisione.

In 802.11, invece, la situazione è un po’ differente poiché, se le due stazioni rilevano che il canale è occupato, entrambe entreranno immediatamente nello stato di ritardo casuale, con la speranza di scegliere valori di ritardo differenti. Se è così, quando il canale diventa inattivo, una delle due stazioni inizierà la trasmissione prima dell’altra e (se le due stazioni non sono nascoste l’una all’altra) la stazione “perdente” ascolterà il segnale della stazione “vincitrice”, bloccherà il suo contatore e si asterrà dalla trasmissione finché l’altra stazione non avrà terminato la trasmissione. In questo modo viene evitata una collisione.

**Terminali nascosti: RTS e CTS:** Il protocollo MAC 802.11 include anche uno schema di prenotazione che aiuta a evitare collisioni anche in presenza di terminali nascosti.

Le due stazioni sono collocate nel raggio dell’AP al quale sono associate. A causa dell’attenuazione del segnale, anche il raggio di copertura delle stazioni wireless è limitato all’interno dei cerchi laterali più chiari. Quindi, ciascuna delle stazioni wireless è nascosta all’altra, sebbene nessuna sia nascosta all’AP.

Perché i terminali nascosti possono essere problematici?

Supponiamo che la stazione H1 stia trasmettendo un frame e, a metà della trasmissione di H1, la stazione H2 voglia trasmettere un frame all’AP. H2, non rilevando la trasmissione di H1, attenderà un intervallo di tempo DIFS per poi trasmettere il frame, causando una collisione. Il canale risulterà pertanto sprecato durante l’intero periodo di trasmissione di H1 e di H2.

Per evitare questo problema, il protocollo IEEE 802.11 prevede due frame di controllo: RTS (request to send, richiesta di invio) e CTS (clear to send, abilitazione a trasmettere) per riservare l’accesso al canale.

Il trasmittente, quando vuole inviare il frame DATI, invia innanzitutto il frame RTS all’AP, indicando il tempo totale richiesto per la trasmissione del frame DATI e del frame di conferma ACK. L’AP, quando riceve il frame RTS, risponde diffondendo in broadcast il frame CTS.

Questo ha due scopi: comunica al trasmittente il permesso esplicito di inviare e comunica alle altre stazioni di non trasmettere durante il periodo di tempo riservato.

L’utilizzo dei frame RTS e CTS può incrementare le prestazioni per due motivi in quanto risolve il problema del terminale nascosto, in quanto il frame DATI viene trasmesso solamente dopo che il canale è stato prenotato.

Dato che i frame RTS e CTS sono piccoli, una collisione che li coinvolgesse sarebbe di breve durata. Una volta che questi sono stati trasmessi con successo, i successivi frame DATI e ACK dovrebbero essere trasmessi senza collisioni.

Pur contribuendo a ridurre le collisioni, lo scambio dei frame RTS e CTS introduce un ritardo e consuma risorse del canale. Per questo motivo, questi frame sono utilizzati solamente per prenotare il canale per la trasmissione di lunghi frame DATI.

**Pacchetto IEEE 802.11**: I frame 802.11 sono molto simili ai frame Ethernet, ma contengono campi specifici per l’utilizzo nei collegamenti wireless.

**Campi Payload e CRC:** Il campo payload, che consiste in un datagramma IP o di un pacchetto ARP.

È presente un campo CRC di 32 bit che permette al ricevente il rilevamento degli errori nei bit.

**Campi indirizzi:** Il frame 802.11 contiene quattro campi indirizzo, ciascuno dei quali può contenere un indirizzo MAC di 6 byte.Ci sono tre campi indirizzo che sono necessari a scopi d’interconnessione (specialmente per trasportare datagrammi del livello di rete da una stazione wireless, attraverso un AP, all’interfaccia di un router). Il quarto campo indirizzo è impiegato nelle reti ad hoc, ma non in quelle con infrastruttura.

**Campi numero di sequenza, durata e di controllo del pacchetto:** I numeri di sequenza permettono al ricevente di distinguere tra un frame appena trasmesso e la ritrasmissione di un frame.

Il protocollo 802.11 permette alla stazione trasmittente di riservare il canale per un periodo di tempo che include la trasmissione del suo frame dati e quella del frame di conferma e tale valore è incluso nel campo durata (per i frame dati, RTS e CTS).

Il campo di controllo del frame è articolato in molti sottocampi. I campi tipo e sottotipo sono utilizzati per distinguere frame di associazione, RTS, CTS, ACK e dati. I campi verso AP e da AP definiscono la funzione dei diversi campi indirizzo. Il significato di questi cambia a seconda che sia utilizzata una rete ad hoc o con infrastruttura e, in quest’ultimo caso, se il frame è inviato da una stazione o da un AP. Infine, il campo WEP specifica un’eventuale cifratura dei dati.

**ARGOMENTO CHE È IMPORTANTE CHE NON È NELLE DOMANDE**

**VLAN (LAN VIRTUALI)**

Le configurazioni delle LAN via switch, via Ethernet e via ARP hanno 3 inconvenienti:

**1)****Mancanza di isolamento del traffico**. Sebbene la gerarchia localizzi il traffico di un gruppo in un solo switch, il traffico broadcast deve ancora attraversare l’intera rete istituzionale. Le prestazioni della LAN aumenterebbero se si potesse limitare il campo di tale traffico broadcast e forse, ancora più importante, sarebbe limitarlo per ragioni di sicurezza e riservatezza.

**2)** **Uso inefficiente degli switch.** Se invece di 3 gruppi, l’istituzione ne avesse 10, sarebbero necessari 10 switch di primo livello (quelli che raccolgono gruppi di host). Se ogni gruppo fosse piccolo, meno di 10 persone, un singolo switch a 96 porte sarebbe probabilmente sufficiente, ma non fornirebbe isolamento di traffico.

**3) Gestione degli utenti.** Se un dipendente si muovesse tra più gruppi, sarebbe necessario cambiare la posatura della rete per connetterlo a un altro switch. La presenza di dipendenti che appartengono a più gruppi rende il problema ancora più ostico.

**Tali inconvenienti si possono superare usando uno switch che supporta una virtual local area network (VLAN).** Tale switch permette di definire più reti locali virtuali su una singola infrastruttura fisica di rete locale. Gli host all’interno di una VLAN comunicano tra loro come se fossero tutti connessi allo switch. In una VLAN basata sulle porte, le porte dello switch sono divise dal gestore di rete in gruppi, ognuno dei quali costituisce una VLAN le cui porte formano un dominio broadcast (il traffico broadcast proveniente da una porta può raggiungere solo altre porte del gruppo).

Questa VLAN risolve tutti i problemi discussi precedentemente poiché ora 2 frame di due VLAN diverse sono isolati tra di loro. Inoltre, due switch sono sostituibili da un singolo switch e infine se un’utente si muove da un gruppo ad un altro, basta che il gestore di rete semplicemente riconfiguri il software di VLAN in modo che l’utente riceva i frame del gruppo in cui ora appartiene.

Una tabella di associazione tra porte e VLAN viene mantenuta all’interno dello switch; l’hardware dello switch si limita a consegnare frame tra porte appartenenti alla stessa VLAN.

**Isolando completamente le due VLAN, abbiamo introdotto una nuova difficoltà: come trasmettere il traffico dal dipartimento di Ingegneria elettronica a quello di Informatica?**

Un modo sarebbe quello di connettere una porta dello switch VLAN a un router esterno e configurarla in modo che appartenga a entrambe le VLAN. In questo caso, anche se i due dipartimenti condividono lo stesso switch fisico, dal punto di vista logico la configurazione appare come se i due dipartimenti avessero switch separati connessi da un router.

Un datagramma IP che debba transitare dal dipartimento di Ingegneria elettronica a quello di Informatica attraverserebbe prima la VLAN di Ingegneria per raggiungere il router che lo inoltrerebbe all’host destinazione sulla VLAN di Informatica. Fortunatamente, i venditori di switch semplificano la configurazione al gestore di rete fornendo un singolo dispositivo contenente sia uno switch sia un router, in modo che non sia necessario un router esterno separato.

**Supponiamo che i dipartimenti siano ospitati in molti edifici separati dove (naturalmente) debba essere fornito accesso alla rete e che (naturalmente) quest’ultimo faccia parte della VLAN del dipartimento. Come dovrebbero interconnettersi questi due switch?**

Un approccio più scalabile per l’interconnessione tra switch VLAN è noto come VLAN trunking. In questo approccio una porta speciale per ogni switch viene configurata come porta di trunking per interconnettere i due switch VLAN. La porta di trunking appartiene a tutte le VLAN e i frame inviati a qualunque VLAN vengono inoltrati attraverso il collegamento di trunking all’altro switch.

**Questo approccio, tuttavia, solleva un’altra questione: come fa uno switch a sapere che un frame**

**che arriva a una porta di trunking appartiene a una VLAN particolare?**

IEEE ha definito un formato esteso di frame Ethernet per frame che attraversano un trunk VLAN. Tale frame consiste nel frame standard Ethernet con in aggiunta una etichetta VLAN (o tag VLAN) di quattro byte nell’intestazione che trasporta l’identità della VLAN a cui il frame appartiene.

L’etichetta VLAN è aggiunta al frame dallo switch sul lato di trasmissione del trunk, mentre viene analizzata e rimossa dallo switch sul lato ricevente. L’etichetta VLAN consiste di un campo TPID (tag protocol identifier) di due byte (con un valore fisso esadecimale di 81-00) e un campo tag control information di due byte, contenente il campo di identificazione della VLAN a 12 bit e un campo di priorità a 3 bit, simile al campo TOS del datagramma IP.

**ARGOMENTO CHE È IMPORTANTE CHE NON È NELLE DOMANDE**

**Mobilità all’interno di una sottorete IP**

**Caso di spostamento di un host da un ap ad un altro ap che appartiene allo stesso switch**

Immagine che contiene diagramma

Descrizione generata automaticamente

Per aumentare la copertura di una LAN wireless, aziende e università dispongono spesso vari BSS all’interno di una stessa sottorete IP.

**Nasce quindi un problema relativo alla mobilità all’interno dei BSS:**

**Come può una stazione wireless muoversi da un BSS a un altro durante la stessa sessione TCP?**

La Figura mostra due BSS interconnessi con l’host H1, che si sposta da BSS1 a BSS2. Dato che in questo esempio il dispositivo che connette i due BSS non è un router, tutte le stazioni all’interno di queste, inclusi gli AP, apparterranno alla stessa sottorete IP. Quindi, quando H1 si sposta da BSS1 a BSS2, può mantenere il suo indirizzo IP e tutte le sue connessioni TCP aperte.

Se il dispositivo d’interconnessione fosse stato un router, allora H1 avrebbe dovuto cambiare l’indirizzo IP e chiudere tutte le connessioni TCP, oppure usare un protocollo di mobilità a livello di rete come, per esempio, IP mobile.

H1 è in una connessione in cui riceve frame da AP1 però, quando si sposta e cambia AP(AP2) i frame continuano ad arrivare a AP1. Come risolvere tale problema?

Quando H1 cambia AP (da AP1 a AP2) quest’ultimo, manda un broadcast per far aggiornare le porte dello switch in cui comunica che lo stream di frame che è diretto a lui deve essere rindirizzato appunto ad AP2 e non più ad AP1.

Il protocollo 802.11 inoltre, grazie ad un campo del frame control permette lo stand-by dell’AP in caso di non utilizzo, consentendo un risparmio energetico.

**Esistono due altri protocolli IEEE 802, Bluetooth e Zigbee (definiti negli standard IEEE 802.15.1 e IEEE 802.15.4)**

**Protocollo 802.15: Personal Area Network (Bluetooth)**

Le reti 802.15.1 sono reti ad hoc, nel senso che non è necessaria alcuna infrastruttura (cioè un AP) per interconnettere i dispositivi 802.15.1.

Di conseguenza, questi dispositivi devono organizzarsi da soli, dapprima in una **piconet** composta da otto elementi attivi. Un elemento è scelto come principale (master) e gli altri operano in modalità slave. Il nodo master regola la piconet (il suo orologio ne determina il tempo) e può trasmettere in ogni slot dispari, mentre lo slave può trasmettere solamente dopo che il master ha comunicato con lui nello slot precedente e anche in quel caso può trasmettere solo al master.

Oltre agli slave, la rete può avere fino a 255 dispositivi che, però, possono comunicare solo dopo che il nodo master ha modificato il loro stato da “in sosta” ad “attivo”.

La rete 802.15.1 opera nella banda a 2,4 GHz in modalità TDM, con slot di tempo di 625 microsecondi. In ogni slot, si può trasmettere in uno tra 79 canali, cambiando il canale in modo pseudo-casuale da uno slot all’altro. Questa strategia, conosciuta come **FHSS.**

**Protocollo 802.15.4 (Zigbee)**

Zigbee ha come obiettivo applicazioni a energia, velocità e cicli di attività inferiori a quelli di Bluetooth. Benché tendenzialmente si pensi che una rete sia migliore tanto più sia grande e veloce, non tutte le applicazioni di rete hanno bisogno di una grande larghezza di banda e quindi di costi elevati sia in termini economici che di energia.

Nelle reti Zigbee esistono due tipi di nodi: i cosiddetti “dispositivi a funzionalità ridotte” (*reduced-function*) che operano come slave sotto il controllo di un solo “dispositivo a funzionalità completa” (*full-function*).

Un dispositivo full-function può operare come un dispositivo master in Bluetooth controllando più dispositivi slave, e più dispositivi full-function possono inoltre essere configurati per formare una rete mesh nella quale fanno instradamento di frame per comunicare tra loro.

Zigbee condivide con altri protocolli a livello di collegamento molti meccanismi: frame beacon e riscontri a livello di collegamento simili a 802.11, protocolli di accesso casuale a rilevamento di portante con backoff esponenziale binario simili a 802.11 ed Ethernet e allocazione degli slot temporali garantita e fissata simile a DOCSYS.

**Esercizio 3**

**Supponete ci siano due ISP che forniscono accesso WiFi dove ogni ISP adotta il suo access point con il proprio blocco di indirizzi IP.**

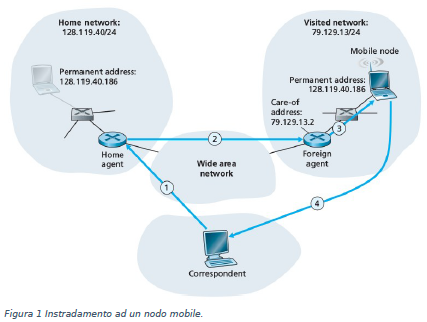
**1. Assumete che accidentalmente ciascun ISP ha configurato il proprio access point per operare sul canale 11. In tal caso la comunicazione tramite il protocollo 802.11 è totalmente compromessa? Discutete cosa accade quando due stazioni associate a differenti ISP tentano di trasmettere contemporaneamente.**

**2. Ora assumete che gli access point operino su canali diversi. Come cambia la precedente risposta?**

**3.Mobility in Networks**

**Esercizio 1**

**Descrivete nel dettaglio i passi numerati nella Figura 1. Quale tipo di instradamento è rappresentato nella figura? Specificate i/il punto/i nella comunicazione dove si utilizza la tecnica di tunneling.**



**Esercizio 2**

**Descrivete come cambia la Figura 1 se ipotizziamo che anche il nodo corrispondente sia mobile, connesso ad una visited network e usi un instradamento diretto.**

**Esercizio 3**

**Quali sono le funzionalità/servizi forniti dal protocollo IP mobile? Riuscite a trovare delle analogie tra (alcuni) servizi di IP mobile e le modalità attivo/passiva del protocollo 802.11?**

**Esercizio 4**

**Spiegate cos’è la procedura di handoff, quando può essere richiesta ed in quali condizioni permettono di non interrompere una connessione stabilita a livello di trasporto.**

**Domanda esame**

**a) Come si può gestire la mobilità di un nodo? Descrivete i concetti di home network (rete di appartenenza o domestica), foreign network (rete ospitante) e il care of address (COA indirizzo di mediazione).**

**b) Come si stabilisce una connessione tramite instradamento diretto tra un nodo corrispondente A ed un nodo mobile B che si trova su una rete ospitante? Se dopo aver stabilito una connessione tra A e B, quest'ultimo si sposta su un'altra rete, quale problema insorge? Descrivete una possibile soluzione affinché la connessione aperta venga mantenuta**

**Domanda esame**

**a) Descrivete i concetti di home network (rete di appartenenza o domestica), foreign network (rete ospitante) e il care of address (COA indirizzo di mediazione).**

**b) Assumete che durante una connessione tramite instradamento indiretto tra un nodo corrispondente A ed un nodo mobile B che si trova su una Tete ospitante il nodQ B si sposti su una diversa rete ospitante. Quali accorgimenti si possono adottare per mantenere aperta, anche dopo lo spostamento, la stessa connessione?**

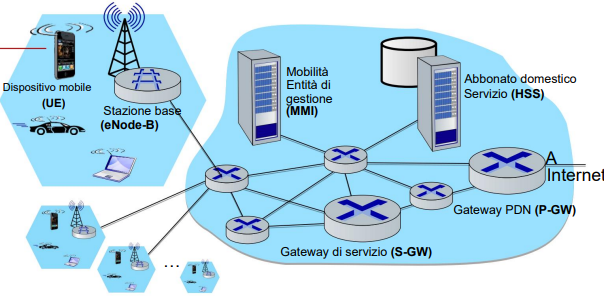
**Appunti relativi a Mobility in Networks**

**Reti Wireless Mobile (4G/5G)**

Sono la soluzione per le reti mobili di grandi estensioni.

La quarta generazione di sistema cellulare è il 4G e presenta, due importanti innovazioni rispetto ai sistemi 3G: nucleo di rete completamente basato su IP e rete di accesso migliorata.

**Architettura 4G: nucleo di rete completamente basato su IP**



In gergo l’utente che utilizza il dispositivo viene indicato attraverso UE (User Equipment)

Le principali componenti dell’architettura 4G sono le seguenti:

**1) eNodeB** gestisce le risorse radio wireless e i dispositivi mobili nella sua area di copertura (“cella”) coordina l'autenticazione del dispositivo con altri elementi.

Il suo ruolo nel piano dei dati è quello di trasmettere i datagrammi tra UE (utente) (attraverso la rete di accesso radio LTE) e P-GW. I datagrammi dell’UE sono incapsulati nell’eNodeB e inviati in tunneling al P-GW attraverso il nucleo di rete completamente basato su IP.

Nel piano di controllo, eNodeB gestisce le segnalazioni di controllo registrazione e mobilità per conto dell’UE quindi ci sono nuovi protocolli per la gestione della mobilità, sicurezza e autenticazione.

**2)** Il **Packet Data Network Gateway** (**P-GW**) assegna gli indirizzi IP agli UE e si occupa del QoS.

Essendo anche un endpoint, svolge le operazioni di incapsulamento/ decapsulamento durante l’inoltro di un datagramma a / da un UE.

**3)** Il **Serving Gateway (S-GW)** è il nodo di appoggio della mobilità nel piano dei dati: tutto il traffico UE passerà attraverso S-GW, che svolge anche le funzioni di fatturazione e intercettazione del traffico.

**4)** Il **Mobility Management Entity (MME)** esegue la connessione e la gestione della mobilità per conto dell’UE residente nella cella che controlla. Riceve informazioni sulla sottoscrizione UE dall’HHS.

**5) Home Subscriber Server (HSS)** contiene le informazioni dell’UE quali la capacità di roaming, il profilo della qualità di servizio e le informazioni di autenticazione.

LTE utilizza una combinazione di multiplexing a divisione di frequenza e di tempo sul canale di downstream noto come multiplexing a divisione di frequenza ortogonale (OFDM).

Il termine “ortogonale” deriva dal fatto che i segnali inviati su canali a frequenze diverse vengono creati in modo da generare bassa interferenza anche quando le frequenze sono molto vicine.

In LTE a ogni nodo mobile attivo vengono allocati uno o più time slot da 0,5 ms in una o più frequenze di canale. Più time slot vengono allocati, sulla stessa frequenza o su frequenze differenti, più un nodo mobile è in grado di raggiungere tassi di trasmissione elevati.

La riallocazione degli slot tra i nodi mobili può essere effettuata anche ogni millisecondo. Inoltre, possono essere usati diversi schemi di modulazione per variare il tasso di trasmissione.

La decisione di quale nodo mobile è autorizzato a trasmettere in un dato slot su una fissata frequenza è determinata dagli algoritmi di scheduling forniti dai costruttori di apparati LTE e/o dagli operatori di rete. Lo scheduling opportunistico permette al controller dell’interfaccia di rete di ottimizzare il mezzo wireless facendo corrispondere il protocollo di livello fisico alle condizioni di canale tra il mittente e il ricevente e basando la scelta dei riceventi sulle condizioni del canale.

**Gestione della mobilità (mobilità offerta dai canali wireless)**

Un nodo mobile è un nodo che cambia nel tempo il suo punto di connessione con la rete.

**Che cos’è un utente mobile dal punto di vista del livello di rete?**

L’utente che si sposta in diverse reti di accesso senza chiudere le connessioni attive.

**Quanto è importante che l’indirizzo del nodo mobile resti invariato?**

Dipende dalle applicazioni in esecuzione, ad esempio, per il guidatore sarebbe conveniente mantenere lo stesso indirizzo IP.

Se l’entità mobile è in grado di mantenere il proprio indirizzo IP quando si sposta, la mobilità diventa trasparente dal punto di vista dell’applicazione. Questa trasparenza è molto importante poiché un’applicazione non si deve preoccupare di un potenziale cambio d’indirizzo IP, mentre lo stesso codice applicativo serve connessioni mobili e non mobili.

D’altra parte, l’utente potrebbe semplicemente smettere di lavorare in ufficio con il proprio portatile, portarlo a casa, accenderlo e lavorare da lì.

Se il computer ha primariamente la funzione di client in un’applicazione client-server (per esempio, e-mail, Web, collegamento a host remoto), lo specifico indirizzo IP utilizzato non risulta tanto importante. In particolare, potrebbe andar bene l’indirizzo temporaneamente assegnato al computer dall’ISP di casa. DHCP fornisce già questa funzionalità.

Per illustrare i problemi di cui occorre tenere conto per consentire agli utenti mobili di mantenere le connessioni attive mentre si muovono tra reti diverse ricorriamo a un’analogia. Immaginiamo un ventenne che lascia la casa dei genitori e inizia a spostarsi fra diversi ostelli e/o appartamenti, cambiando sovente indirizzo. Se un amico volesse mettersi in contatto con lui, come potrebbe reperire il suo indirizzo? La cosa più semplice è rivolgersi ai familiari, supponendo che il ragazzo li informi costantemente dei propri spostamenti. La casa dei genitori, con il suo indirizzo permanente, diventa quindi il luogo che gli altri possono raggiungere come primo passo per mettersi in contatto con lui. La comunicazione dell’amico può avvenire sia in modo indiretto (per esempio, con una mail inviata prima alla casa dei genitori che provvederebbero a inoltrarla al figlio) sia diretto (per esempio, inviare una mail all’amico utilizzando l’indirizzo ottenuto dai genitori).

In una rete, il luogo permanente in cui risiede un nodo mobile (come un portatile o un palmare) è detto rete di appartenenza (*home network*) e le entità che gestiscono la mobilità per conto del nodo mobile all’interno di questa sono conosciute come agenti domestici (*home agent*).

La rete in cui il nodo mobile viene a trovarsi occasionalmente costituisce la rete ospitante (*foreign network* o *visited network*) mentre l’entità al suo interno che si occupa della mobilità è detta agente ospitante (*foreign* *agent*).

Per i professionisti “mobili”, la rete di appartenenza è costituita dalla rete della loro azienda, mentre la rete ospitante potrebbe essere quella del collega o del cliente che sta visitando.

Il corrispondente è l’entità che desidera comunicare con il nodo mobile.

Gli agenti ospitanti sono localizzati presso i router (per esempio, processi in esecuzioni sui router), ma potrebbero anche essere eseguiti su altri host della rete.

**Indirizzamento**

Quando un nodo è ospitato in una rete, tutto il traffico diretto all’indirizzo permanente del nodo deve essere instradato verso quella rete.

La rete ospitante avverta tutte le altre reti vicine che il nodo mobile si trova attualmente al suo interno dicendo che possiede percorsi specifici per l’indirizzo permanente del nodo mobile. A loro volta le reti vicine dovranno propagare queste informazioni attraverso la rete come parte della normale procedura di aggiornamento delle informazioni di instradamento e delle tabelle d’inoltro. Quando il nodo mobile esce da una rete e si connette a un’altra, la nuova rete ospitante dovrà comunicare una nuova specifica rotta per questo nodo, mentre la vecchia dovrà cancellare le sue informazioni di instradamento.

In questo modo le altre reti conoscono la localizzazione del nodo mobile, verso il quale instradano facilmente il datagramma usando le tabelle di inoltro.

Un aspetto negativo è il seguente se il gestore della mobilità deve essere il responsabile dei router di rete, questi dovrebbero dimensionare le tabelle d’inoltro per milioni di nodi potenziali e aggiornarle quando i nodi si muovono.

Un approccio alternativo è di portare le funzionalità di mobilità dal nucleo della rete alla sua periferia. Una modalità intuitiva di questo approccio utilizza la rete di appartenenza del nodo mobile. Nello stesso modo in cui i genitori tengono d’occhio gli spostamenti del figlio, gli agenti nella rete di appartenenza del nodo mobile possono monitorare la rete nella quale il nodo mobile si trova a risiedere. È certamente necessario un protocollo tra il nodo mobile (o l’agente ospitante che lo rappresenta) e l’agente domestico per aggiornare la localizzazione del nodo stesso.

Vediamo ora l’agente ospitante:

L’approccio concettualmente più semplice è porre l’agente ospitante nei router agli estremi nella rete visitata. Un compito di questo agente è la definizione di un **indirizzo di mediazione**, detto **COA** (*care-of address*) per il nodo mobile. La parte di rete del COA sarà quella della rete ospitante.

Gli indirizzi associati alla modalità mobile sono quindi due: quello **permanente** (analogo all’indirizzo della famiglia del ragazzo) e il COA (analogo all’attuale indirizzo del nostro amico).

Il secondo ruolo dell’agente ospitante è di informare l’agente domestico che il nodo mobile risiede nella sua rete e di essere a conoscenza del suo COA. Vedremo tra breve che il COA sarà utilizzato per “reinstradare” il datagramma al nodo mobile attraverso il suo agente ospitante. Sebbene abbiamo separato le funzionalità del nodo mobile e dell’agente ospitante, è importante notare che il nodo mobile può anche assumere le responsabilità dell’agente ospitante. Per esempio, il nodo mobile potrebbe ottenere il COA nella rete ospitante (utilizzando un protocollo come DHCP) e comunicare all’agente domestico il proprio COA.

**Instradamento verso il nodo mobile**

Abbiamo fin qui analizzato come un nodo mobile ottenga il COA e come l’agente domestico possa venire a conoscere tale indirizzo. Ma il problema è risolto solo in parte. Come dovrebbe essere indirizzato e inviato il datagramma al nodo mobile?

In questo caso esistono due approcci: l’instradamento indiretto e quello diretto.

**Instradamento indiretto verso il nodo mobile**

Consideriamo il caso del corrispondente che voglia inviare il datagramma a un nodo mobile. Nell’approccio dell’**instradamento indiretto**, il corrispondente non fa altro che indirizzare il datagramma all’indirizzo permanente del nodo e inviarlo nella rete, inconsapevole dell’effettiva localizzazione del nodo. La mobilità, quindi, è completamente trasparente al corrispondente. (passo 1).

L’agente domestico oltre alla responsabilità di interagire con l’agente ospitante per monitorare il COA del nodo mobile, ha un’altra funzione molto importante: il controllo dei datagrammi in entrata indirizzati ai nodi che fanno parte della rete di appartenenza, ma che si trovano al momento in una rete esterna. L’agente intercetta questi datagrammi e li invia al nodo mobile con un processo articolato in due passi. Il datagramma è innanzitutto inviato all’agente ospitante del nodo mobile, utilizzando il COA di quest’ultimo (passo 2) e poi viene inoltrato al nodo mobile stesso (passo 3).

Consideriamo ora un nodo mobile che invia un datagramma al corrispondente. Si tratta di una funzione relativamente semplice, in quanto il nodo può indirizzare il datagramma direttamenteal destinatario utilizzando il proprio indirizzo permanente come indirizzo sorgente, e l’indirizzo del corrispondente come indirizzo di destinazione. Conoscendo l’indirizzo del corrispondente, non è necessario instradare il datagramma attraverso l’agente domestico (passo 4).

Lo standard IP mobile utilizza l’approccio dell’instradamento indiretto.

Immagine che contiene diagramma

Descrizione generata automaticamente

Elenco delle funzionalità richieste a livello di rete per supportare la mobilità.

**Protocollo da nodo mobile ad agente ospitante**. Il nodo mobile si registra presso l’agente ospitante quando si collega alla rete esterna e si cancella quando l’abbandona.

**Protocollo di registrazione da agente ospitante ad agente domestico.** L’agente ospitante registra il COA del nodo presso l’agente domestico. L’agente ospitante non avrà bisogno di rimuovere il COA quando il nodo lascerà la sua rete, in quanto la successiva registrazione di un nuovo COA (quando il nodo mobile si sposta in una nuova rete) cancellerà automaticamente quella precedente.

**Protocollo dell’agente domestico per l’incapsulamento del datagramma.** Riguarda l’incapsulamento e l’invio del datagramma originale del corrispondente all’interno del datagramma indirizzato al COA.

**Protocollo di decapsulamento del datagramma dell’agente ospitante.** Riguarda l’estrazione del datagramma originale del corrispondente dal datagramma incapsulato e suo invio al nodo mobile.

**Instradamento diretto verso un nodo mobile**

L’instradamento indiretto comporta un’inefficienza conosciuta come **problema dell’instradamento triangolare** (*triangle routing problem*), in quanto datagrammi indirizzati al nodo mobile devono prima essere instradati all’agente domestico e poi alla rete ospitante, anche in presenza di percorsi più efficienti tra il corrispondente e il nodo mobile.

Nel caso peggiore, immaginiamo un professore in visita presso il collega di un’altra università. I due sono seduti alla stessa scrivania e si scambiano dati attraverso la rete. In tal caso i datagrammi dell’uno sono instradati all’agente domestico dell’altro e poi rimbalzati indietro alla rete ospitante.

L’**instradamento diretto** supera l’inefficienza insita nell’instradamento triangolare, ma al costo di una maggiore complessità.

In questo approccio un **agente corrispondente**, nella rete del corrispondente, ottiene innanzitutto il COA del nodo mobile.

Questo può essere fatto con una richiesta all’agente domestico, assumendo che (come nel caso dell’instradamento indiretto) il nodo mobile disponga di un valore aggiornato del suo COA e che questo sia noto al suo agente domestico. È anche possibile che il corrispondente svolga la funzione di agente corrispondente, così come il nodo mobile potrebbe svolgere la funzione di agente ospitante (passi 1 e 2). L’agente corrispondente, poi, invia tramite un tunnel i datagrammi direttamente al COA del nodo mobile, in modo analogo a come faceva l’agente domestico (passi 3 e 4).

Immagine che contiene diagramma

Descrizione generata automaticamente

Così, l’instradamento diretto risolve il problema dell’instradamento triangolare ma, al contempo, introduce due ulteriori, fondamentali problemi.

1) La necessità di un **protocollo di localizzazione dell’utente mobile** tramite il quale l’agente corrispondente possa interrogare l’agente domestico per ottenere il COA del nodo mobile (passi 1 e 2).

2) Quando il nodo mobile si sposta da una rete a un’altra, come sono inviati i dati alla nuova rete? Per risolvere questo problema nel caso dell’instradamento indiretto era sufficiente aggiornare il COA presso l’agente domestico. Con l’instradamento diretto, l’agente domestico è interrogato dall’agente corrispondente solo una volta, all’inizio della sessione. In questo modo, aggiornare il COA nell’agente domestico non sarà sufficiente per risolvere il problema dell’instradamento dei dati verso la nuova rete del nodo mobile. Una soluzione potrebbe essere un nuovo protocollo per avvisare il corrispondente del cambio di COA.

**IP MOBILE**

IP mobile è uno standard flessibile, che supporta diverse modalità operative (per esempio, con o senza agenti ospitanti), vari modi con cui gli agenti e i nodi mobili si rilevano l’un l’altro, l’utilizzo di COA singoli o multipli e varie forme d’incapsulamento.

L’architettura di IP mobile contiene molti elementi che abbiamo considerato in precedenza, inclusi i concetti di agente domestico, ospitante, indirizzamento, incapsulamento e recupero dei datagrammi.

L’attuale standard che specifica, l’utilizzo dell’instradamento indiretto, consiste di tre parti principali.

• **Ricerca dell’agente.** IP mobile definisce i protocolli utilizzati dagli agenti per informare i nodi mobili dei propri servizi e dai nodi mobili per richiederli.

• **Registrazione presso l’agente domestico.** IP mobile definisce i protocolli utilizzati dal nodo mobile e/o dall’agente ospitante per registrare e cancellare i COA presso l’agente domestico del nodo.

• **Instradamento indiretto dei datagrammi**. Lo standard definisce anche il modo in cui i datagrammi sono inviati al nodo mobile dall’agente domestico, incluse le regole per l’invio dei datagrammi, la gestione degli errori e varie forme d’incapsulamento.

Nello standard IP mobile i problemi della sicurezza sono posti in primo piano. Per esempio, è necessaria l’autenticazione dei nodi mobili per evitare che utenti malintenzionati registrino indirizzi contraffatti, che potrebbero portare all’invio di tutti i datagrammi a un indirizzo IP per essere re-instradati a un malintenzionato.

**Ricerca dell’agente:** Il nodo IP mobile che giunge in una nuova rete, per connettersi a una rete ospitante o per ritornare alla sua rete di appartenenza deve apprendere l’identità dell’agente di quella rete. In realtà, questa è la ricerca di un nuovo agente, con un nuovo indirizzo di rete, che consenta al livello di rete del nodo mobile di accorgersi dello spostamento in una nuova rete.

Questo processo è conosciuto come **ricerca dell’agente** (*agent discovery*) e può essere realizzato tramite un avviso (dell’agente da scoprire) o una richiesta (all’agente interessato).

Con l’**avviso dell’agente** (*agent advertisement*) un agente rende noti i suoi servizi utilizzando un’estensione del protocollo esistente di ricerca di un router.

L’agente invia periodicamente, in broadcast, un messaggio ICMP che contiene 9 nel campo tipo (ricerca router) su tutti i collegamenti cui è connesso. Il messaggio di ricerca del router contiene l’indirizzo IP del router (che è l’agente), in modo da permettere ai nodi mobili di conoscere l’indirizzo IP dell’agente. Questo messaggio contiene anche un’estensione dell’avviso dell’agente mobile che contiene informazioni addizionali necessarie al nodo mobile.

Con la **richiesta dell’agente** (*agent solicitation*), il nodo mobile che vuole informazioni riguardo agli agenti, senza aspettare di ricevere un avviso dell’agente, può inviare in broadcast un messaggio di richiesta dell’agente, che è semplicemente un messaggio ICMP che contiene 10 nel campo tipo. L’agente che riceve questa richiesta invierà in unicast un avviso dell’agente direttamente al nodo mobile, che potrà quindi procedere come se avesse ricevuto un avviso non richiesto.

**Registrazione presso l’agente domestico:** Una volta che il nodo IP mobile ha ricevuto il COA, l’indirizzo deve essere comunicato all’agente domestico. Ciò può avvenire tramite l’agente ospitante (che poi registra il COA presso l’agente domestico) o direttamente dal nodo stesso. Consideriamo il primo caso, che prevede quattro fasi.

1) In seguito alla ricezione dell’avviso dell’agente ospitante, il nodo mobile gli invia il messaggio di registrazione IP mobile. Il messaggio di registrazione, trasportato in un datagramma UDP e inviato alla porta 434, contiene la comunicazione del COA da parte dell’agente ospitante, l’indirizzo dell’agente domestico (HA), l’indirizzo permanente del nodo mobile (MA), il tempo di scadenza della registrazione richiesto e l’identificazione di registrazione a 64 bit. Il tempo di scadenza è il numero di secondi per i quali la registrazione risulta essere valida. Se la registrazione non viene rinnovata entro il tempo specificato, perde validità. L’identificatore di registrazione svolge il ruolo del numero di sequenza e sarà utilizzato per confrontare la risposta di registrazione ricevuta con la richiesta iniziale, come vedremo in seguito.

2) L’agente ospitante riceve il messaggio di registrazione e memorizza l’indirizzo IP permanente del nodo mobile. Ora sa che deve prestare attenzione ai datagrammi d’incapsulamento il cui indirizzo di destinazione corrisponde a quello permanente del nodo mobile. L’agente ospitante, quindi, invia un messaggio di registrazione IP mobile (ancora, in un datagramma UDP) alla porta 434 dell’agente domestico. Il messaggio contiene COA, HA, MA, il formato d’incapsulamento richiesto, la scadenza di registrazione richiesta e l’identificazione di registrazione.

3) L’agente domestico riceve la richiesta di registrazione e ne controlla autenticità e correttezza. Successivamente, associa l’indirizzo IP permanente del nodo mobile al COA; d’ora in poi, i datagrammi indirizzati al nodo mobile che arriveranno all’agente domestico saranno incapsulati e inviati al COA. L’agente domestico invia una risposta di registrazione IP mobile contenente HA, MA, la scadenza corrente e l’identificazione di registrazione della richiesta.

4) L’agente ospitante riceve la risposta di registrazione e la invia al nodo mobile.

**Gestione della mobilità nelle reti cellulari**

Ci concentriamo sulla mobilità, utilizzando l’architettura delle reti cellulari GSM.

Come IP mobile, GSM adotta un instradamento indiretto inviando dapprima la chiamata del corrispondente alla rete di appartenenza dell’utente mobile e da lì alla rete visitata.

Nella terminologia GSM, la rete di appartenenza dell’utente mobile è identificata come **home PLMN** (*home public land mobile network,* rete di appartenenza mobile di area pubblica).

La homePLMNdi GSM è anche detta **rete di appartenenza**. Questa è costituita dal fornitore di servizi cellulari con cui l’utente mobile ha un contratto (cioè, il gestore di telefonia mobile).

La PLMN visitata, alla quale faremo riferimento come **rete visitata**, è la rete in cui l’utente mobile di volta in volta risiede.

La rete di appartenenza mantiene un database detto **HLR** (home location register) che contiene il numero telefonico permanente del telefono cellulare e le informazioni sul profilo degli utenti.

L’HLR contiene anche informazioni sulla localizzazione corrente di questi utenti. Quindi, se al momento l’utente mobile sta operando nella rete cellulare di un altro fornitore, HLR conterrà le informazioni necessarie per ottenere l’indirizzo nella rete visitata al quale instradare le chiamate verso l’utente.

Uno switch speciale nella rete di appartenenza, il **GMSC** (gateway mobile services switching center) viene contattato da un corrispondente per le chiamate dirette agli utenti mobili. Qui, ci riferiremo al GMSC con il termine più evocativo di **MSC di appartenenza** (home MSC).

La rete visitata mantiene un database detto **VLR** (*visitor location register*), che contiene una voce per ogni utente mobile che si trova attualmente nella parte della rete da lui servita. Queste voci nascono e muoiono ogni volta che l’utente entra o lascia la rete. VLR è solitamente localizzato nell’MSC che coordina l’instaurazione delle chiamate da e per la rete visitata.

**Consideriamo un semplice esempio di come sono instradate le chiamate dirette a un utente GSM**

1)Il corrispondente compone il numero di telefono dell’utente mobile. Questo numero non si riferisce a una particolare linea o locazione in quanto, ovviamente, il numero di telefono è fisso e l’utente è mobile. Si suppone che la prima parte del numero sia sufficiente per identificare globalmente la rete di appartenenza dell’utente.

La chiamata viene instradata dal corrispondente attraverso la rete pubblica commutata verso l’MSC della rete di appartenenza. Questo è il primo tratto della connessione.

2)L’MSC di appartenenza riceve la chiamata e interroga l’HLR per determinare la localizzazione dell’utente. In questo semplice caso, l’HLR restituisce il **MSRN** (numero di roaming della stazione mobile), a cui faremo riferimento come numero di roaming.

Notiamo che questo è diverso dal numero di telefono permanente, che è associato alla rete di appartenenza dell’utente mobile. Il numero di roaming è effimero: è assegnato temporaneamente all’utente quando visita una rete. Questo numero ha un ruolo simile al COA di IP mobile ed è invisibile al corrispondente e all’utente. Se HLR non ha il numero di roaming, restituisce l’indirizzo del VLR della rete visitata. In questo caso), l’MSC di appartenenza avrà bisogno di interrogare il VLR per ottenere il numero di roaming dell’utente mobile. Ma come è possibile che l’HLR ottenga questo numero o l’indirizzo del VLR? Che cosa accadrà a questi valori quando l’utente si sposterà in un’altra rete? Considereremo questi importanti aspetti tra breve.

3) Dato il numero di roaming, l’MSC di appartenenza imposta la seconda tratta della connessione verso l’MSC della rete visitata. La chiamata è completata in quanto instradata lungo il percorso che va dal corrispondente all’MSC di appartenenza all’MSC visitato, fino alla stazione base, che serve l’utente mobile.

**Handoff in GSM**

Quando la stazione mobile cambia la sua associazione da una stazione base a un’altra nel corso di una chiamata si verifica un **handoff**, cioè un passaggio di mano.

Ci sono numerose situazioni in cui si può verificare un handoff. Per esempio:

1) Il segnale tra la stazione base attuale e quella mobile potrebbe subire un tale deterioramento che la chiamata rischia di cadere, oppure

2) Una cella potrebbe essere sovraccarica per l’alto numero di chiamate. Questa congestione può essere risolta passando delle stazioni mobili a celle vicine, meno congestionate.

Lo standard GSM non specifica un particolare algoritmo per decidere se iniziare l’handoff.

Le fasi dell’handoff sono:

1) La vecchia stazione base (BS) comunica all’MSC visitato che sta per essere eseguito un handoff e la nuova stazione BS (o il gruppo di possibili BS) cui l’utente mobile sarà associato.

2) L’MSC visitato inizializza un percorso verso la nuova BS, allocando le risorse necessarie per re-instradare la chiamata e segnalandole che l’handoff sta per essere eseguito.

3) La nuova BS alloca e attiva un canale radio per la stazione mobile.

4) La nuova BS trasmette all’MSC visitato e alla vecchia BS che il percorso da MSC visitato alla nuova BS è stato stabilito e che la stazione mobile dovrà essere informata dell’imminente handoff. La nuova BS fornirà tutte le informazioni di cui la stazione mobile avrà bisogno per associarsi.

5) La stazione mobile è informata che dovrà eseguire l’handoff. Notiamo che, fino a questo punto, la stazione mobile è inconsapevole che la rete ha preparato le basi per l’handoff (cioè l’allocazione del canale nella nuova BS e l’allocazione di un percorso da MSC visitato alla nuova BS).

6) Le stazioni mobili e la nuova BS si scambiano uno o più messaggi per completare l’attivazione del nuovo canale, nella nuova BS.

7) La stazione mobile invia un messaggio di completamento dell’handoff alla nuova BS, la quale lo invierà all’MSC visitato. A sua volta, questo re-instraderà la chiamata attiva alla stazione mobile attraverso la nuova BS.

8) Le risorse allocate lungo il percorso verso la vecchia BS vengono rilasciate.

**4.Multimedia networking**

**Esercizio 1**

**Si assuma che Victor Video guardi un video di 4 Mbps, Facebook Frank una nuova immagine da 100 Kbyte ogni 20 secondi e Martha Music stia ascoltando audio in strearning a 200 kbps. Calcolare il consumo di banda delle diverse applicazioni multimediali durante un periodo complessivo di 4000 sec.**

**Esercizio 2**

**Considerate la figura riportata di seguito. Supponete che il video sia codificato a un bit rate fisso e che quindi ogni blocco del video contenga frame che vengono riprodotti nella stessa quantità di tempo, *Δ*. Il server trasmette il primo blocco video al tempo t0, il secondo blocco al tempo t0 + *Δ*, il terzo a t0 + 2*Δ* e così via. Quando il client inizia la riproduzione, ogni blocco dovrebbe essere riprodotto *Δ* unità di tempo dopo quello precedente.**

**(a) Supponete che il client inizi la riproduzione non appena arriva il primo blocco al tempo t1. Nella figura sottostante, quanti blocchi video, compreso il primo, arriveranno al client in tempo per essere riprodotti? Spiegate il ragionamento che avete fatto.**

**(b) Supponete ora che il client inizi la riproduzione al tempo t1 + *Δ*. Quanti blocchi video, compreso il primo, arriveranno al client in tempo per essere riprodotti? Spiegate il ragionamento che avete fatto.**

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**Esercizio 3**

**Riprendete il semplice modello di streaming HTTP mostrato nella Figura 7.3 del libro, nel quale B denota la grandezza del buffer dell'applicazione client e Q denota il numero di bit che deve essere memorizzato nel buffer prima che l'applicazione client inizi la riproduzione. Sia r inoltre il tasso di consumo del video. Assumete che il server invii bit a un tasso costante finché il buffer del client non sia pieno.**

**(a) Supponete x < r. Come discusso nel testo, in questo caso la riproduzione avrà periodi alternati di continuità e di blocco. Determinate la lunghezza di questi due tipi di periodi, in funzione di Q, r, e x.**

**(b) Supponete ora x> r. A quale tempo t1 il buffer dell'applicazione client si riempie?**

**Esercizio 4**

**Considerate un sistema DASH con N versioni video, a N bit rate e qualità diversi, e N versioni audio, a N bit rate e qualità diversi. Supponete di voler dare la possibilità all' utente di scegliere in ogni istante quale delle N versioni video e audio voglia.**

**(a) Se i file che creiamo mescolano audio e video, in modo che il server invii solo uno stream in un dato istante, quanti file deve memorizzare il server (ognuno a un URL diverso)?**

**(b) Se invece il server invia separatamente gli stream audio e video e il client li sincronizza, quanti file deve memorizzare il server?**

**Esercizio 5**

**Considerate la sottostante figura che descrive l’arrivo di una sequenza di pacchetti in coda. Assumendo che al più un solo pacchetto può lasciare la coda in ogni slot di tempo, rispondete alle seguenti domande:**

**(a) Assumendo un servizio FIFO, indicate l'istante in cui i pacchetti da 2 a 12 lasciano la coda. Per ciascun pacchetto, qual è il ritardo tra l'arrivo e l'inizio dello slot nel quale viene trasmesso? Qual è la media di questo ritardo su tutti e 12 i pacchetti?**

**(b) Assumete ora un servizio a priorità: i pacchetti con numero dispari sono ad alta priorità, mentre quelli con numero pari a bassa priorità. Indicate l'istante in cui i pacchetti da 2 a 12 lasciano la coda. Per ciascun pacchetto, qual è il ritardo tra l'arrivo e l'inizio dello slot nel quale viene trasmesso? Qual è la media di questo ritardo su tutti e 12 i pacchetti?**

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**Domanda esame**

**Una Content Distribution Network (CDN):**

**a) A cosa serve?**

**b) Attraverso quali passaggi la richiesta di un video, originariamente indirizzata ad un provider di contenuti, viene inoltrata a un nodo della CDN, descriveteli in dettaglio?**

**c) Illustrare le differenze fra le architetture enter-deep e bring-home di una CDN. Quale delle due scegliereste per limitare il costo del loro mantenimento?**

**d)Quali tecniche si possono usare per determinare a quale specifico nodo della CDN inoltrare la richiesta?**

a) Un Content Distribution Network (CDN) è un sistema distribuito di server che offre un servizio di distribuzione efficiente dei contenuti su Internet. La sua principale funzione è quella di ridurre la latenza e migliorare le prestazioni fornendo i contenuti agli utenti finali da un server che si trova fisicamente più vicino a loro. Invece di dover richiedere i contenuti direttamente al server di origine, i clienti si connettono a un server nella CDN, che offre una copia in cache dei contenuti desiderati o può richiederli al server di origine a nome del cliente.

b) Quando viene fatta una richiesta di un video a un provider di contenuti, il processo di inoltro verso un nodo della CDN avviene attraverso i seguenti passaggi:

1. Risoluzione del nome: Il client che fa la richiesta invia un DNS (Domain Name System) lookup per tradurre il nome del dominio nella CDN nell'indirizzo IP corrispondente.
2. Selezione del nodo: Il client si connette al nodo CDN più vicino alla sua posizione geografica, utilizzando l'indirizzo IP ottenuto dalla risoluzione del nome. Questa selezione può avvenire tramite algoritmi di routing basati sulla latenza o sulla prossimità geografica.
3. Caricamento dei contenuti: Il nodo CDN selezionato verifica se ha già una copia in cache del video richiesto. Se la copia è presente, il nodo CDN invia il video direttamente al cliente. In caso contrario, il nodo CDN invia una richiesta al server di origine del contenuto per ottenere il video.
4. Distribuzione dei contenuti: Una volta che il nodo CDN ha ottenuto il video dal server di origine, lo memorizza nella sua cache e inizia a distribuirlo ai clienti che ne fanno richiesta. In questo modo, il nodo CDN funge da punto di consegna dei contenuti per i clienti che si trovano nella sua zona di responsabilità.

c) Per determinare a quale specifico nodo della CDN inoltrare la richiesta, possono essere utilizzate diverse tecniche, tra cui:

* Latenza: La scelta del nodo CDN può essere basata sulla latenza di rete tra il client e i diversi nodi disponibili. Un client può selezionare il nodo CDN con la latenza più bassa, cioè quello che offre la connessione più veloce.
* Prossimità geografica: La selezione del nodo può essere basata sulla posizione geografica del cliente e dei nodi della CDN. Un client può essere indirizzato al nodo più vicino fisicamente alla sua posizione per ridurre la latenza e migliorare le prestazioni complessive.
* Algoritmi di bilanciamento del carico: La CDN può utilizzare algoritmi di bilanciamento del carico per distribuire le richieste tra i suoi nodi in base alla disponibilità delle risorse o al carico corrente di ciascun nodo. In questo modo, le richieste dei clienti vengono distribuite in modo equo tra i nodi della CDN.

Queste tecniche possono essere combinate o utilizzate separatamente, a seconda delle esigenze specifiche della CDN e dei criteri di ottimizzazione delle prestazioni.

**Domanda esame**

**a) Descrivere le caratteristiche della tecnica di streaming dinamico adattativo su http (DASH), in questa tecnica a cosa serve il file manifest?**

**b) Descrivere nel dettaglio almeno una tecnica di Forward Error Correction (FEC) usata per tollerare l'eventuale perdita/ritardo dei pacchetti con payload nultimediale**

a) Il Dynamic Adaptive Streaming over HTTP (DASH) è una tecnica di streaming che consente la consegna di contenuti multimediali su Internet in modo adattivo e scalabile. Le caratteristiche principali di DASH includono:

1. Adattabilità: DASH suddivide il contenuto multimediale in segmenti di breve durata e li codifica a diversi livelli di qualità o bit rate. Durante la riproduzione, il client può selezionare dinamicamente il bit rate appropriato in base alla larghezza di banda disponibile e alle condizioni di rete in tempo reale. Ciò consente di adattare la qualità del video alle capacità di rete e alle prestazioni del dispositivo del cliente.
2. Segmentation: Il contenuto multimediale è suddiviso in segmenti di durata fissa. Questi segmenti possono essere suddivisi in segmenti più piccoli o raggruppati in segmenti più grandi, a seconda delle esigenze. Ogni segmento è disponibile in diversi livelli di qualità e viene scaricato in base alla richiesta del client.
3. File Manifest: Il file manifest, spesso in formato XML o JSON, gioca un ruolo fondamentale in DASH. Esso fornisce un elenco di URL per i segmenti di contenuto multimediale disponibili a diversi bit rate. Il client utilizza il file manifest per selezionare i segmenti da scaricare e riprodurre. Inoltre, il file manifest può contenere informazioni sulla durata dei segmenti, le modalità di adattamento dinamico, le preferenze di riproduzione, le restrizioni di sicurezza e altro ancora.

b) Una delle tecniche di Forward Error Correction (FEC) utilizzate per tollerare la perdita o il ritardo dei pacchetti con payload multimediale è la tecnica di codifica a blocco. In particolare, una tecnica comune è la Reed-Solomon FEC.

La Reed-Solomon FEC è una tecnica di codifica a blocco che aggiunge ridondanza ai dati inviati per consentire la correzione degli errori. I dati originali vengono divisi in blocchi più piccoli e vengono aggiunti byte di ridondanza ai blocchi. Questi byte di ridondanza contengono informazioni di correzione degli errori che possono essere utilizzate per ricostruire i dati persi o corrotti durante la trasmissione.

Durante la decodifica, i pacchetti ricevuti vengono utilizzati per calcolare i parametri matematici che rappresentano la sindrome dell'errore. Utilizzando tali parametri, il ricevitore può identificare e correggere gli errori, ricostruendo i dati originali. La quantità di ridondanza aggiunta dipende dalla tolleranza agli errori richiesta e può essere regolata per adattarsi alle condizioni di rete specifiche.

La tecnica di codifica a blocco Reed-Solomon FEC è ampiamente utilizzata in applicazioni di streaming multimediale per garantire una corretta riproduzione anche in presenza di pacchetti persi o corrotti durante la trasmissione.