نوتس شبكات لاسلكية

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للطالبة المبدعة

فلسطين حمدان

إرادة - ثقة - تغيير

Hashemite University
Faculty of Engineering
Computer Engineering Department
Wireless Networks (Internal Lab)

Experiment: 1 5/3

Introduction to WIFI Networks.

Beacon frame

Access point ↔ Base Station

1.1 Objectives:

1. Investigating the basic building blocks of Wi-Fi networks.
2. Defining the basic characteristic of Wi-Fi networks.
3. Being able to use the Wi-Fi testers to examine a real life Wi-Fi networks.

سؤال → * types of wifi encryption protocols:-

1) WEP: wired equivalent privacy
2) WPA: Wi-Fi protected Access
3) WPA2: " " " version 2

1.2 Equipment's:

- AirCheck Wi-Fi Air testers.

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2.1 Theoretical Background:

*** Elements of a wireless network**

- **The Basic Service Set (BSS)** of a wireless network is the basic building-block of a wireless LAN it is a set consisting of all the devices associated with a wireless local area network (WLAN).
- **Wireless host:** such as laptop, smartphone, may be stationary (non-mobile) or mobile
- **Base station or AcessPoint:** responsible for sending packets between wired network and wireless host(s) in its "area".
- **Wireless link:** used to connect mobile(s) to base station, this link uses multiple access protocol to coordinate link access, different types of links came with different data rates and transmission distance.

- **Wireless networks modes:**

ببنية تحتية

- **Infrastructure mode:** where there is a base station connects wireless nodes into wired network supporting central connection points for local wireless clients. (in WIFI protocol this base station called the Access point).

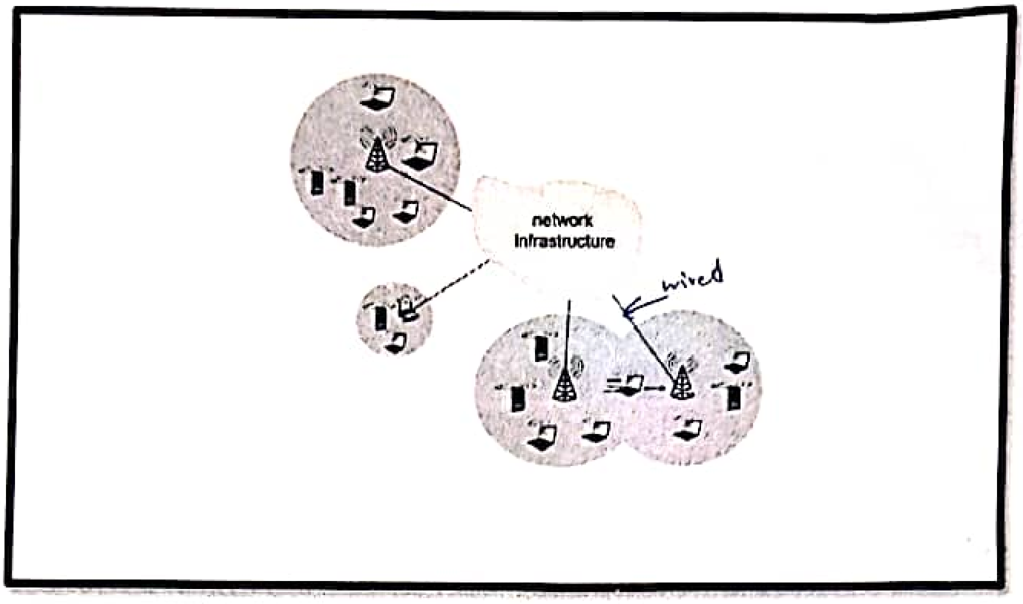


Figure 1: infrastructure mode.

- **Adhoc mode:** mode of connecting devices to one another without the use of a central device like a router (or AP) that conducts the flow of communications. Devices connected to an ad-hoc network, called nodes, each forward data to other nodes.

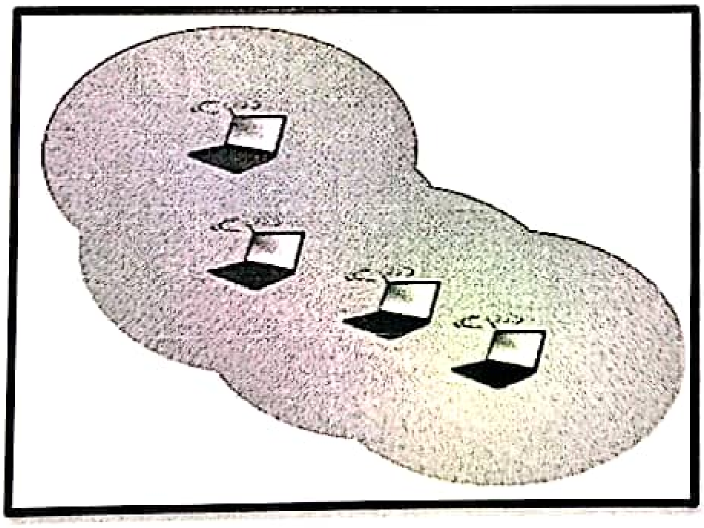


Figure 2: adhoc mode.

Service Set Identifier (SSID): is a case sensitive, 32 alphanumeric character acts as a name that identifies a wireless network, The SSID differentiates one WLAN from another, so all access points and all devices attempting to connect to a specific WLAN must use the same SSID to enable effective roaming. As part of the association process, a wireless network interface card (NIC) must have the same SSID as the access point or it will not be permitted to join the BSS.

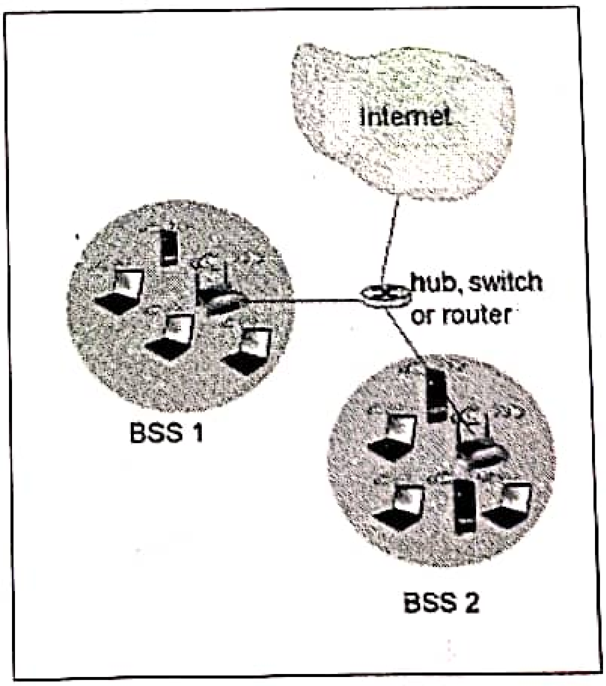
Beacon frame: is one of the management frames in IEEE 802.11 based WLANs(WIFI). It contains all the information about the network including the SSID, the AP MAC address and the encryption type. Beacon frames are transmitted periodically to announce the presence of a wireless LAN. Beacon frames are transmitted by the access point (AP) in an infrastructure basic service set (BSS).

Wireless network taxonomy

	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

802.11 LAN architecture:

- wireless host communicates with base station
  - base station = access point (AP)



- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

AirCheck integrates all Wi-Fi technologies plus interference detection, channel scanning, and connectivity tests. Quickly troubleshoot the most common Wi-Fi pain points, including:

- Coverage problems
- Overloaded networks or channels
- Interference
- Connectivity problems
- Failed access points
- Rogue access points
- Security settings
- Client problems

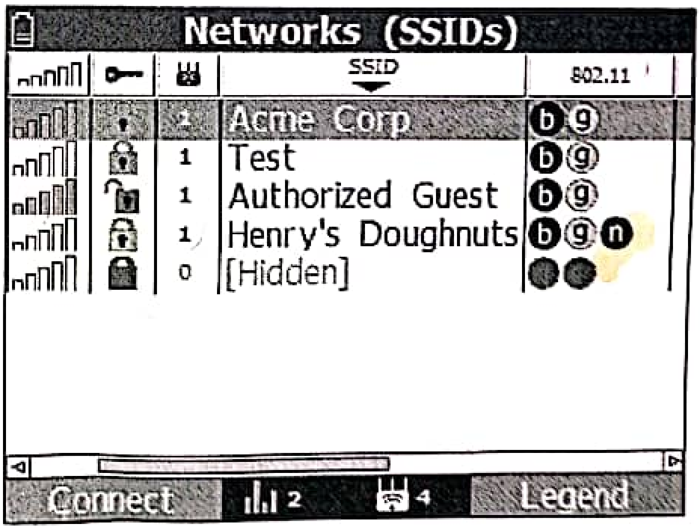
In addition to generating instant reports and documentation, AirCheck Manager software allows you to set up multiple profiles and manage network and security settings for a single unit, or an entire fleet of AirCheck testers.

AirCheck Functions

1- List Networks

Find security issues, rogue APs and coverage problems and view a list of all wireless Networks heard by AirCheck. Instantly see the following for each network:

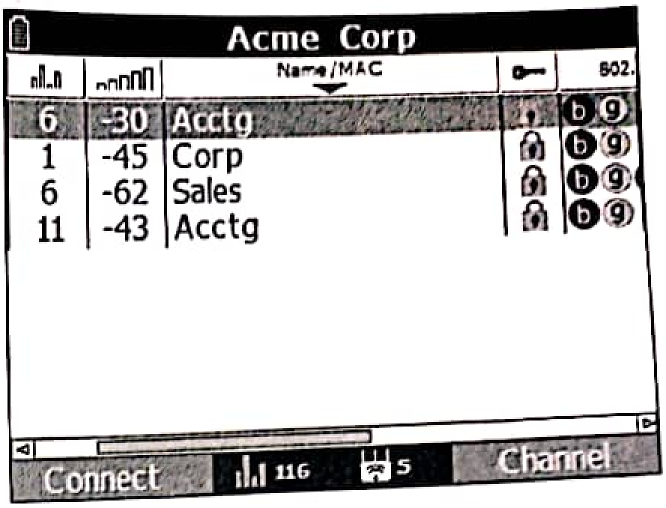
- Signal level
- Security / encryption
- Number of APs in network
- SSID name
- Type of network



2- List Access Points

Find configuration and coverage problems as well as rogue APs. View a list of all physical APs heard by AirCheck including the following information:

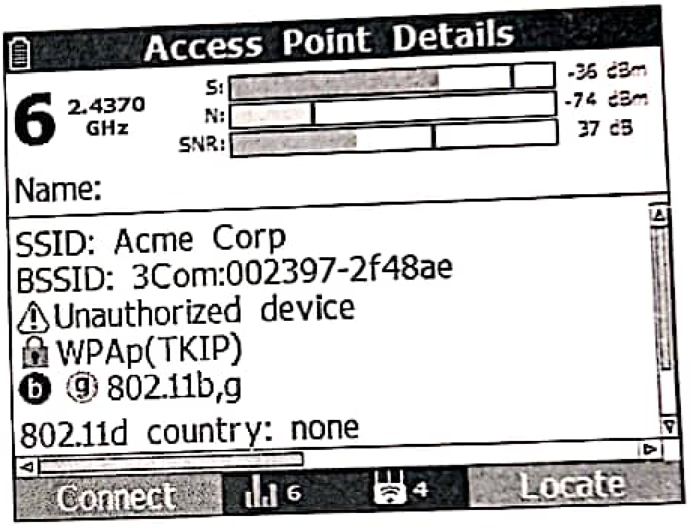
- Channel
- Signal level
- AP name or MAC address
- SSID name (or count of SSIDs for virtual APs)
- Security / encryption
- Type of network



3- Access Point Details

Quickly identify AP configuration problems. View the following information for each Physical AP:

- Signal / noise/ signal-to-noise ratio (current and max)
- SSID and BSSID
- ACL status
- Security / encryption

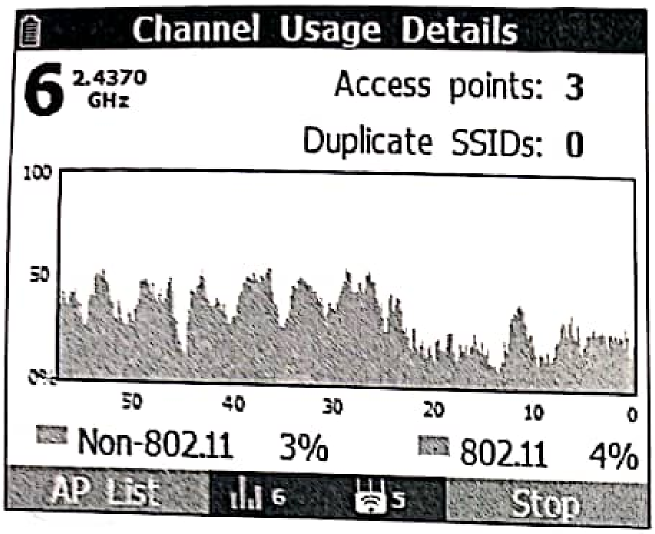


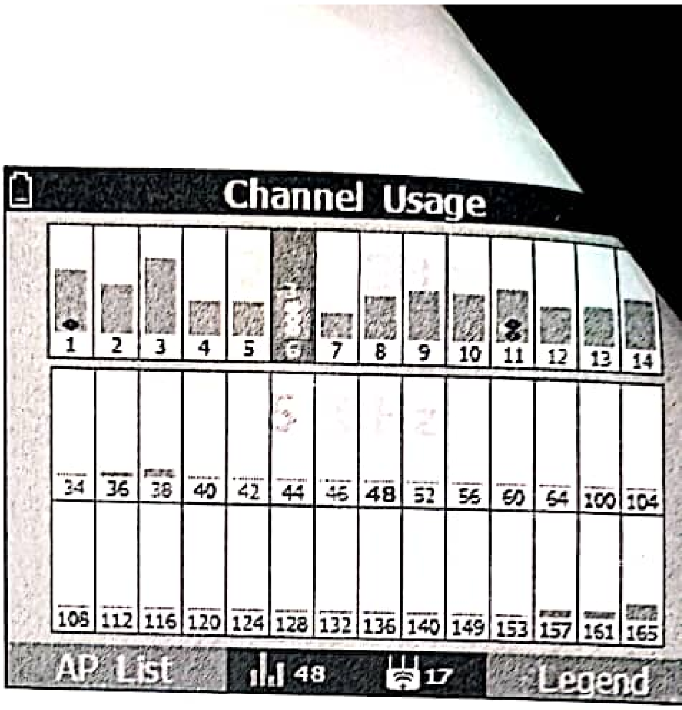
4- Channel Usage

Quickly determine if channels are overloaded due to Wi-Fi traffic (displayed in blue) or interference (displayed in gray). Verify channel-usage pattern or overlap and flag illegal use of channels. With AirCheck, you can also detect the presence of interference. Devices that can cause interference include microwave ovens, cordless phones and headsets, BlueTooth® devices, and analog video cameras.

a. Channel Usage Details

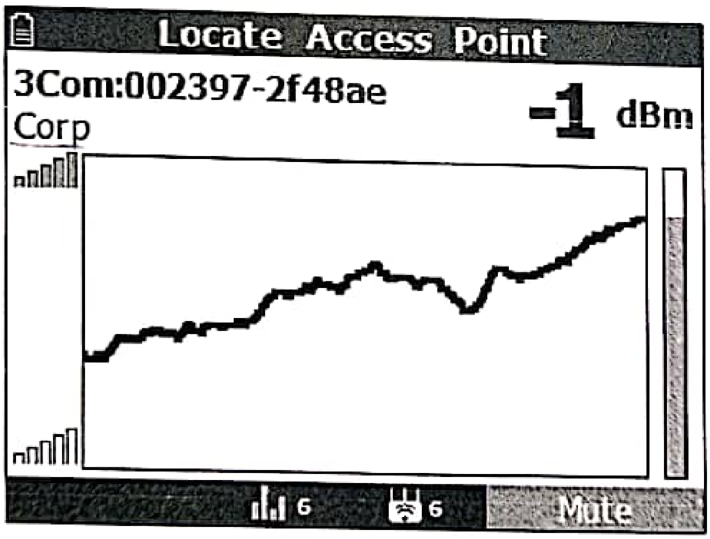
Find overloaded channels and interference. Drill in further to see the level of Wi-Fi traffic and interference over the last 60 seconds on a selected channel, as well as the access points using this channel.





5- Locate Access Points

Track down rogue and other APs by graphing the signal strength over time, or by using an audible indication which can be muted.



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Experiment: 2 12/3

WIFI Networks Survey and Plan

1.1 Objectives:

1. Introduce the AirMagent Surveyor Pro Application.
2. Building the ability to make surveys and plans of Wi-Fi sites and produce heat maps.

1.2 Equipment's:

- Personal computer with ***AirMagent Surveyor pro*** installed on it.
-

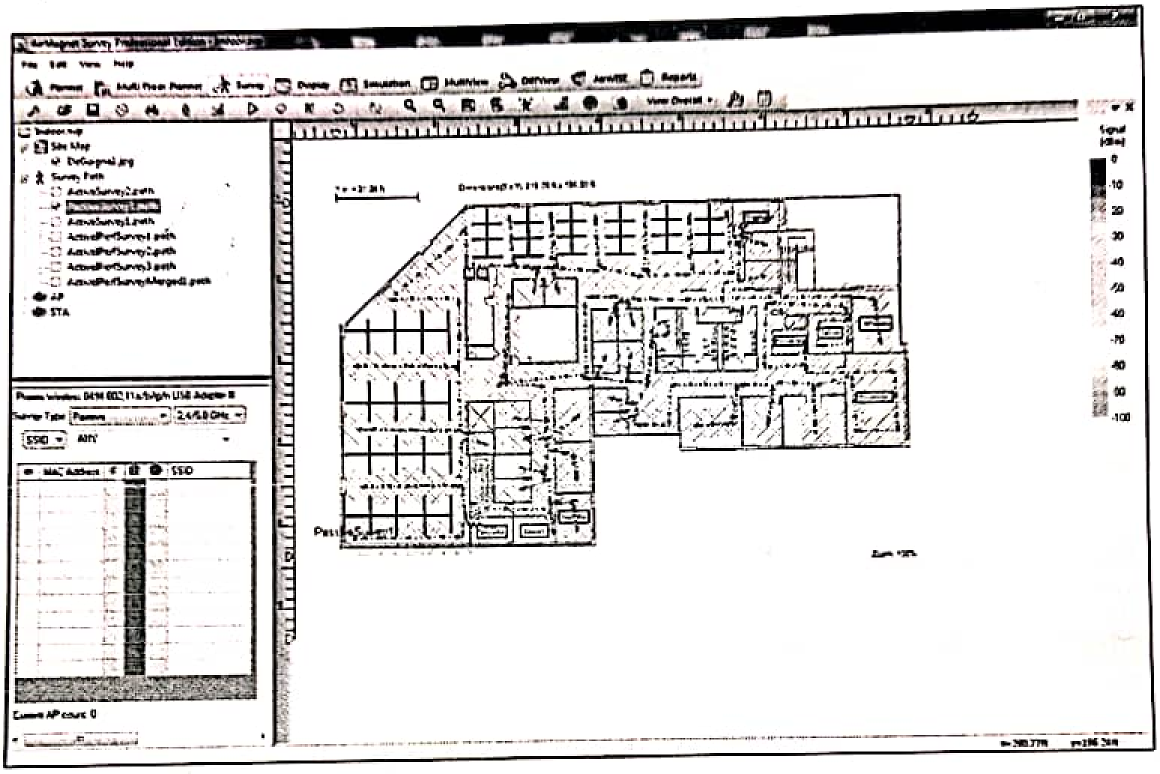
2.1 Theoretical Background:

AirMagnet Survey is a powerful, easy-to-use survey tool for planning, collecting and analyzing WLAN site RF (radio frequency) data crucial for successful WLAN deployment. Wireless network installation is a complex task that involves many invisible and unpredictable variables such as RF signal strength, noise level, data rate, channel allocation, user density, and so on. Since all these factors affect WLAN network performance, it is necessary to perform RF site surveys to fully understand the behavior of radio waves within a facility before installing wireless network access points. Operating at the RF level, AirMagnet Survey enables WLAN professionals to quickly and easily determine the optimal number and placement of WLAN infrastructure devices to provide the best coverage and throughput required by the users in a cost-effective way.

AirMagnet Planner is a wireless network planning tool that accounts for building materials, obstructions, access point configurations, antenna patterns and a host of other variables to provide a reliable predictive map of Wi-Fi signal and performance. The solution offers superior predictive modeling to determine ideal quantity, placement and configuration of APs for optimal security, performance and compliance. AirMagnet Planner includes built-in automated tools to help users with their migration strategy from existing legacy 802.11a/b/g/n networks to 802.11ac technology. When integrated with AirMagnet Survey, users have a powerful solution that combines state-of-the-art predictive modeling with real-world performance data.

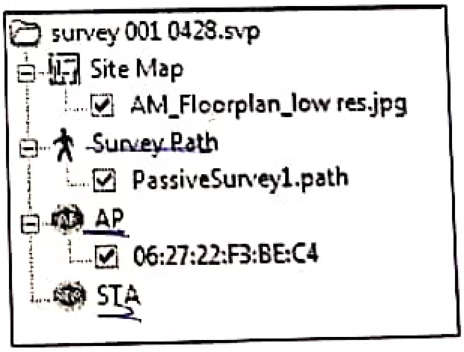
2.2 *Using AirMagnet Survey:*

The Survey view is used for conducting WLAN site surveys whose purposes are to collect RF data in the airwave over the site. Once a Survey project is created, it will be automatically opened on the Display view. The same thing happens when you open a Survey project that you have created earlier. You can open the Survey view simply by clicking on the Navigation Bar. The figure below shows the application's Survey view.



2.3 Survey Project Window

The Project Window displays all the components of the current Survey project opened on the Survey view, as shown in the figure below.

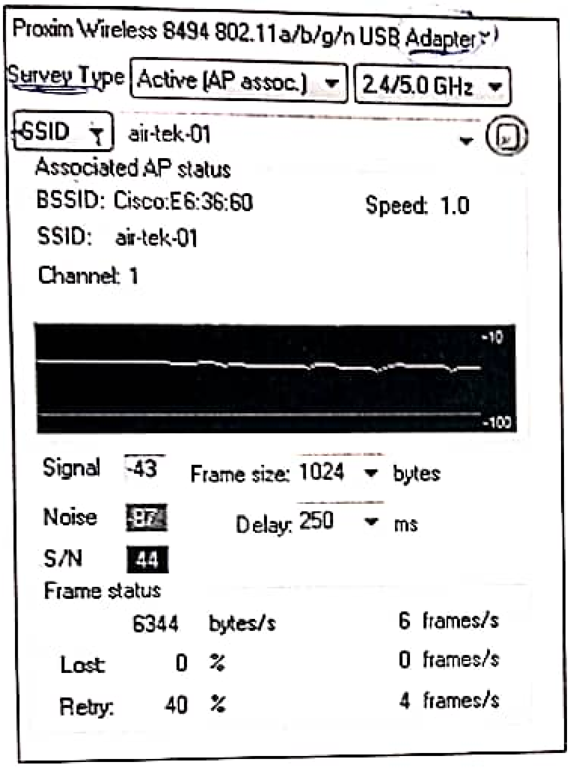


A Data File items are as follows from the top:

- Project file name.
- Floor plan image file name used in the project.
- Survey paths (surveys conducted) listed from first to last for this project.
- Any APs and/or STA (stations) placed on the floor plan.

2.4 Active Survey Data Window

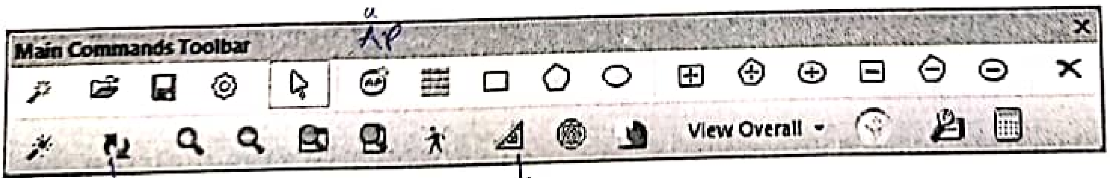
The figure below shows the Data Window when AirMagnet Survey is set in active survey mode. (Availability of some configuration fields depends on adapter support.)



Option	Description
Adapter	The adapter used for the survey is noted at the top of the window.
Survey Type	Options are Active, Passive and Active IPERF.
Media Type	Options are 2.4, 5.0 and 2.4/5.0 GHz
SSID/AP	Enables you to associate to either a specific AP or SSID during the active survey. The associated drop-down enables you to choose a specific device to survey.
BSSID	The name and MAC address of the AP being associated with.
SSID	The name of the network to which the associated AP belongs.
Speed	The rate (in terms of Mbps) at which packets are transmitted.
Channel	The radio channel the AP uses to send and receive RF signals, including the primary and secondary channels, channel bandwidth and the channel span.
Signal	The signal strength for the received packets. The higher the value, the stronger the signal.
Noise	The level of background radio frequency energy in the 2.4-GHz or 5-GHz band. The lower the value, the less the noise.
S/N	The Signal/Noise ratio. Compares the Signal data to the amount of ambient Noise.

2.5 Using AirMagnet Planner

Toolbar: The Toolbar contains frequently used tools, some of which are identical to those found in the File and View menus. The following screen shot of the toolbar shows an undocked view. To undock the toolbar, drag the handle at the far left on the toolbar.



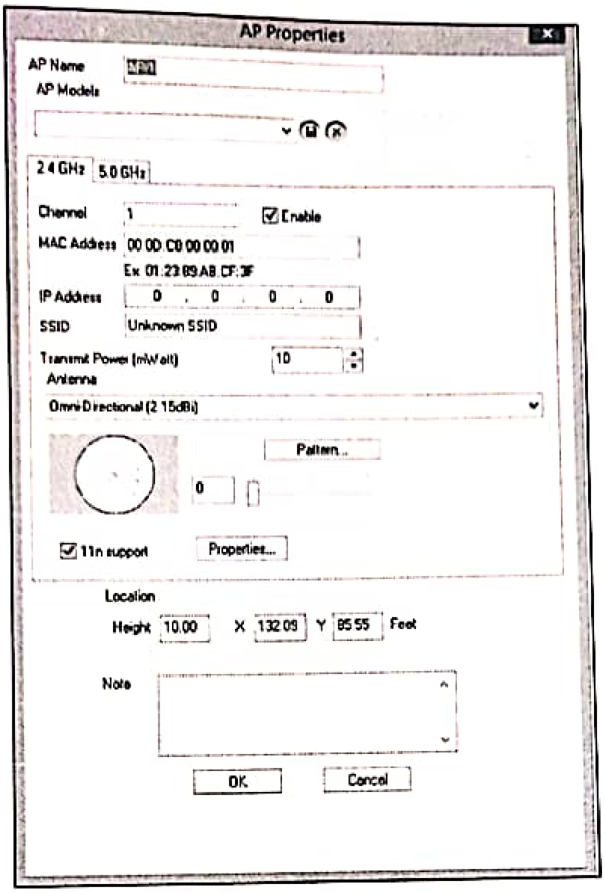
Icon	Tool Name	Description
	Project Wizard	Create a new project.
	Open Project	Browse to open a project.
	Create AP	Allows you to create and place a new AP in the map.
	Measure Mode	Allows you to recalibrate site dimensions to suit your location.
	Create Wall	Allows you to select a wall type and draw the walls of your site.
	Refresh	Generate and refresh the heatmap
	Create Attenuation Areas	
	Create Coverage Areas	
	Create Excluded Areas	

AP Data Properties

AP properties (such as channel and media type) may be viewed using a few different methods, however, the properties can only be edited in the Planner view.

- In the **Planner** view, right-click an AP located on the site map and select **Properties**. This option enables the properties to be edited.
- Expand either the **SSID** or **Channel** tree in the **Data** window. Right-click an AP and select **Properties**. (Edit is available in Display view as well)
- In the **Display** view, right click an AP located on the site map and select **AP Properties**.

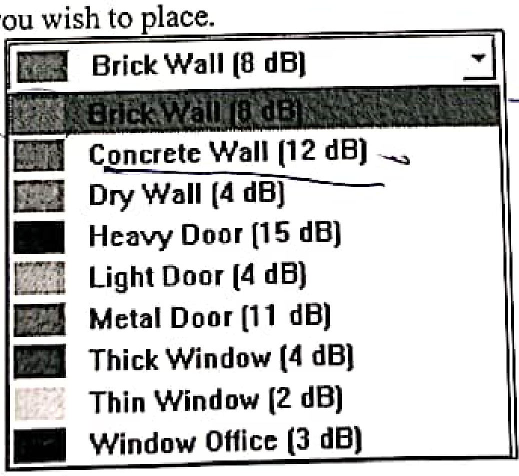
folder
planer
new project
non GPS
meter
closed office



Using the Wall Tool

You should first establish your office's walls and doors. The steps below will walk you through the process of outlining your building.

1. Select the Create Wall tool from the toolbar.
2. You will see a drop-down list appear in the top-right corner of the Map Window. This list contains a number of pre-set wall types that come with inherent dB drop levels (the affect these walls will have upon your wireless network). Select the wall type that you wish to place.



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Experiment: 3
Spectrum analysis

1.1 Objectives:

1. Real time detection and identification of the physical layer signals and interference within the Wi-Fi spectrum.
2. Identify different types of interference in the Wi-Fi spectrum.
3. Locate interference source.

1.2 Equipment's:

- Personal computer AirMagnet Spectrum XT software
- AirMagnet Spectrum XT adapter card
- Non-Wi-Fi devices such as Bluetooth, Zigbee, etc

2.1 Theoretical Background:

AirMagnet Spectrum XT features:

1) It provides a library of spectrum charts and plots. For example, Real-Time FFT (Fast Fourier Transform) graph, Spectrum Density graph, Spectrogram graph, Duty Cycle graph, Channel Power graph, Interference Power graph, etc.

2) Immediately capture and classify interference signals and sources (automatically matches RF signatures and name the source). For example it can detect Bluetooth, cordless phone, microwave ovens, wireless cameras, baby monitors, power signal generators/RF jammers, etc.; in addition to Wi-Fi devices.

3) Locate the interference source using the "find tool" in order to improve the time to fix.

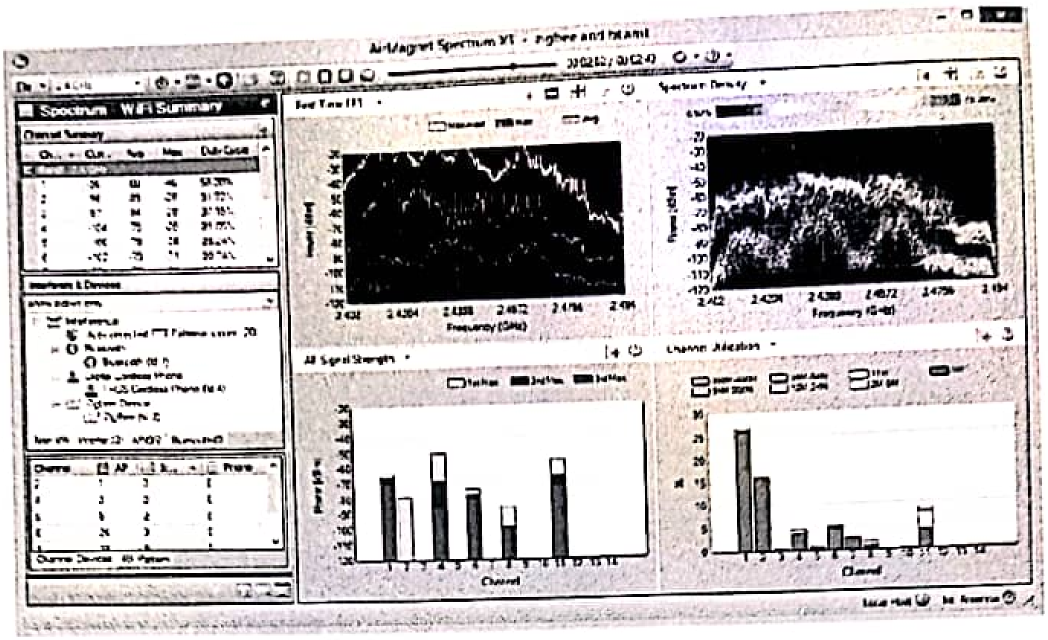
4) Allows the user to record and save live RF spectrum scans and play it back at any time; in addition to instant playback of recent scans.

SUPPORTED BANDS

- **2.4 GHz** - Covers the radio frequency range from 2.402 GHz to 2.842 GHz, which is used by Channels 1 through 14.
- **5.0 GHz Lower** - Covers the radio frequency range from 5.17 GHz to 5.33 GHz, which is used by Channels 44, 48, 52, 56, 60, and 64.
- **5.0 GHz Middle** - Covers the radio frequency range from 5.49 GHz to 5.71 GHz, which is used by Channels 108, 112, 116, 120,124, 128, 132, 136, and 140.
- **5.0 GHz Upper** -Covers the radio frequency range from 5.735GHz to 5.835 GHz, which is used by Channels 157, 161, and 165.
- **4.9 GHz** - Covers bands used by many public safety organizations, from 4.91 to 4.99 GHz.
- **Mixed** - Covers all aforementioned radio frequencies (other than 4.9 GHz) and channels.

MAIN FEATURES

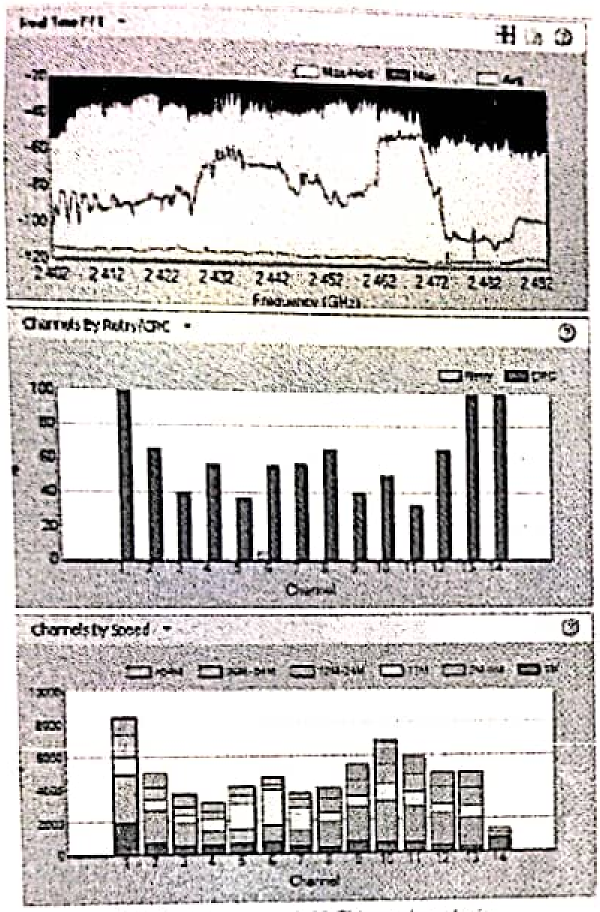
- **Real-Time FFT:** AirMagnet Spectrum XT's FFT graph provides a real-time view into the RF energy in the environment with current, max, max-hold and average RF signal levels.
- Spectrum **Density:** shows the "popularity" of a particular frequency/power reading over time.
- **Channel Power:** shows the current and maximum (aggregated) channel energy readings.
- **Channel Duty Cycle:** shows the percentage of time the RF energy (both 802.11 and non-802.11) is present on the channel.
- **Non- Wi-Fi Devices:** lists all non-Wi-Fi devices whose spectrum information has been detected by the application, along with some key data about each device
- **Wi-Fi Device:** displays comprehensive information about all Wi-Fi devices, such as APs, stations, and phones, detected on the Wi-Fi network.
- **AP Signal Strength:** identifies the three APs with the strongest signal strengths on each available channel in the selected radio band.
- **Channel Occupancy:** shows AP deployment on all available channels in the selected radio band.
- **Channels by Speed:** displays the relative amount of data (in kilobytes) that has been transmitted at each data rate on each available channel in the selected radio band.



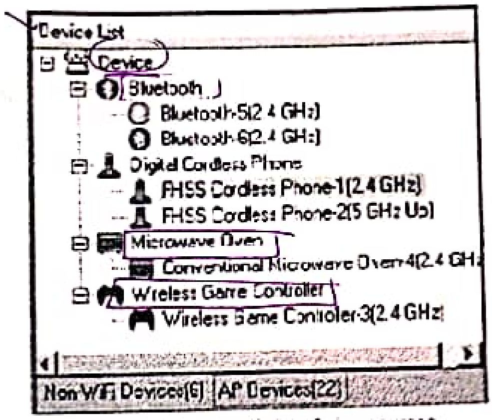
Automatic Identification and Location of Interference sources:

AirMagnet Spectrum XT offers real-time detection and identification of a number of non-WLAN sources that interfere and lower the performance of WLAN networks. The extensive device or source list includes Bluetooth devices, digital and analog cordless phones, conventional and inverter microwave ovens, wireless game controllers, digital video converter, FHSS devices, baby monitors, RF Jammers, radars, motion detectors, ZigBee devices and many more.

Users are also powered with detailed information for the interference source, including peak and average power, first and last seen time, center frequency, impacted channels, number of times the source was detected, and many more. With an additional Bluetooth adapter plugged into the same PC, AirMagnet Spectrum XT provides Bluetooth information such as ID, name, services, etc. for enhanced Bluetooth interferer analysis.
With AirMagnet Spectrum XT's built-in "device locator tool", users can physically locate any Wi-Fi or non-Wi-Fi interference sources operating in the RF environment. The device locator tool operates as a Geiger counter and beeps louder as users get closer to the location of the device.



RF interference and Wi-Fi impact analysis



Detect and classify interfering sources

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Experiment: 4 26/3
Introduction to Arduino

1.1 Objectives:

1. Introduce the Arduino boards.
2. Introduce Arduino (IDE) and the whole process of building a project, writing simple codes, and compiling the project.
3. Code simulation.

1.2 Equipment's:

- Personal computer with ***Arduino IDE*** installed on it.
- Arduino mega boards.

2.1 Theoretical Background:

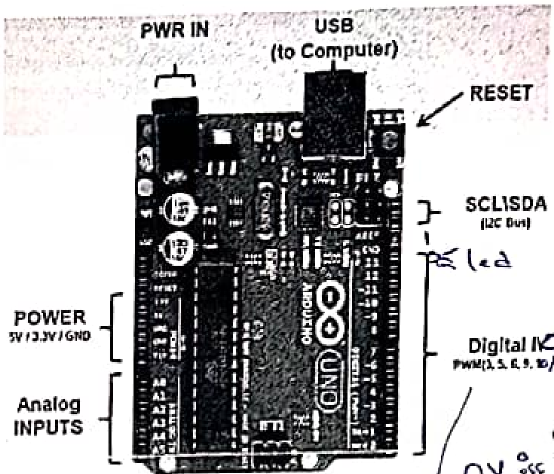
Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. Its products are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form or as do-it-yourself (DIY) kits.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (For prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers can be programmed using C and C++ programming languages. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

2.2 Features of Arduino:

Features of Arduino Uno Board:

- The operating voltage is 5V
- The recommended input voltage will range from 7v to 12V
- The input voltage ranges from 6v to 20V
- Digital input/output pins are 14
- Analog I/O pins are 6
- DC Current for each I/O pin is 40 mA
- DC Current for 3.3V Pin is 50 mA
- Flash Memory is 32 KB
- SRAM is 2 KB
- EEPROM is 1 KB
- CLK Speed is 16 MHz



3.1 Arduino IDE:

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, and Linux) that is written in the programming language Java. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The source code for the IDE is released under the GNU General Public License, version 2.

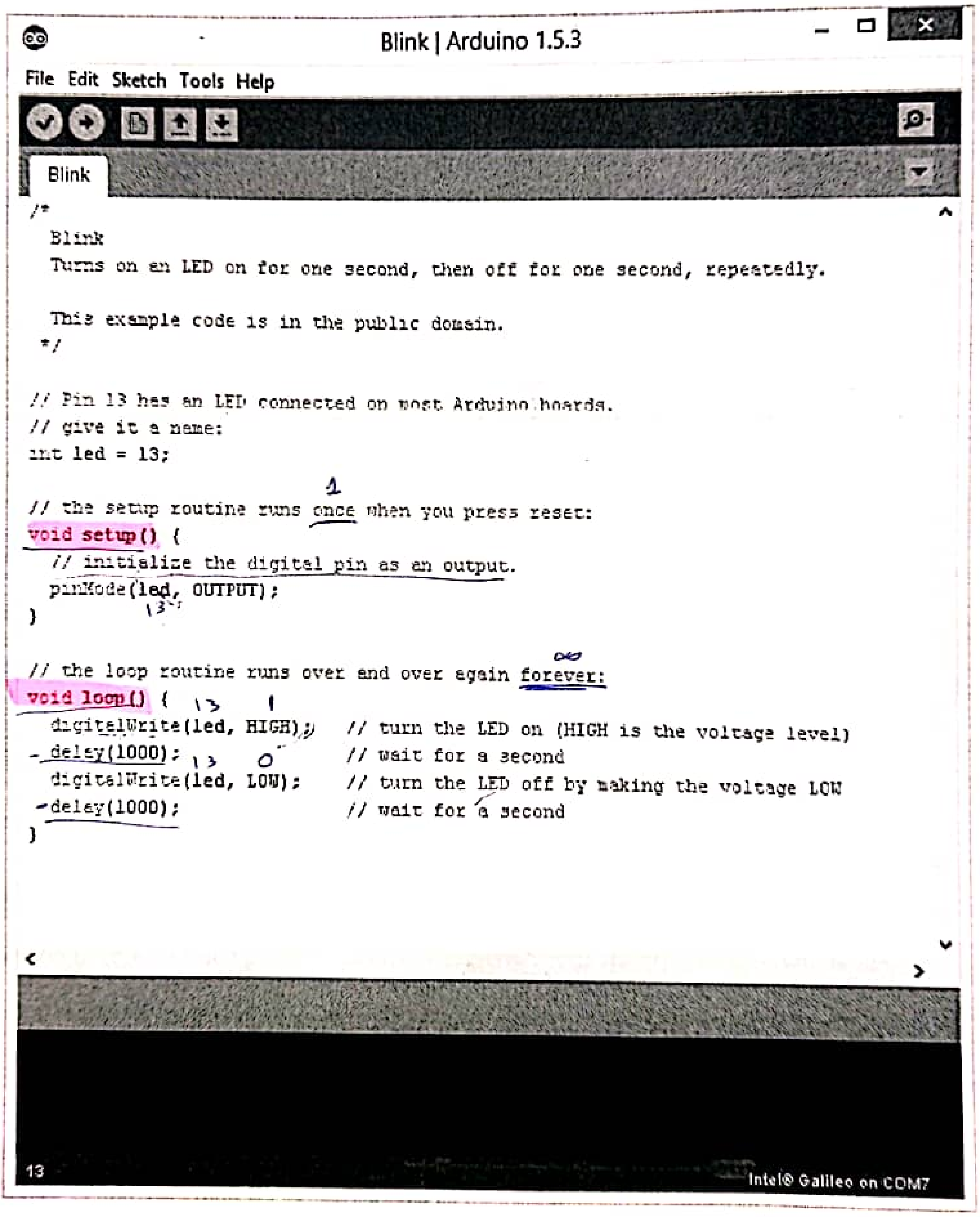
The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

3.2 Sketch:

A sketch is a program written with the Arduino IDE.[59] Sketches are saved on the development computer as text files with the file extension .ino.

A minimal Arduino C/C++ program consists of only two functions:

- setup(): This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch. It is analogous to the function main().
- loop(): After setup() function exits (ends), the loop() function is executed repeatedly in the main program. It controls the board until the board is powered off or is reset. It is analogous to the function while(1).




```
/*
  Blink
  Turns on an LED on for one second, then off for one second, repeatedly.

  This example code is in the public domain.
 */

// Pin 13 has an LED connected on most Arduino boards.
// give it a name:
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);               // wait for a second
  digitalWrite(led, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);               // wait for a second
}
```

Figure 6.1: Arduino IDE with sketch parts

To Configures specific pin to behave either as an input or an output. We use the `pinMode` function like this: `pinMode(pin, mode)` where :

- `pin`: The Arduino pin number to set the mode of.
- `mode`: `INPUT`, `OUTPUT`, or `INPUT_PULLUP`.

To Read a value from a specified digital pin, either HIGH or LOW, we use: `digitalRead(pin)`.

To write either HIGH or LOW value to a specified digital pin, we use: `digitalWrite(pin)`.

3.3 Serial Communication:

Information is passed back and forth between the computer and Arduino using serial communication transferring data one bit at a time, one right after the other. For example, after Compiling (turning your program into ones and zeros) we do the Uploading in which we send the bits through USB cable to the Arduino. The two LEDs near the USB connector blink when data is transmitted:

- RX blinks when the Arduino is receiving data
- TX blinks when the Arduino is transmitting data

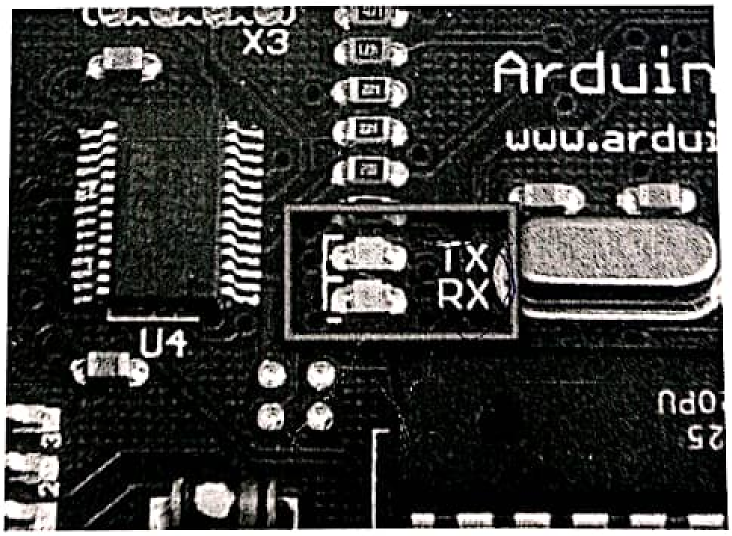


Figure 6.2 TX and RX leds.

We can also send and receive data from the board at run time using serial communication, we first need to setup the baud rate using the function: `Serial.begin(baud_rate)`.

And we do this once in the code in the setup function. Then when we need to write something on the serial we use: `Serial.print()` or `Serial.println()`. and to read from the serial we use: `Serial.read()`. `Serial.available()` is used to check if the serial is one and idel.

At run time the serial monitor is used to send and recive data:

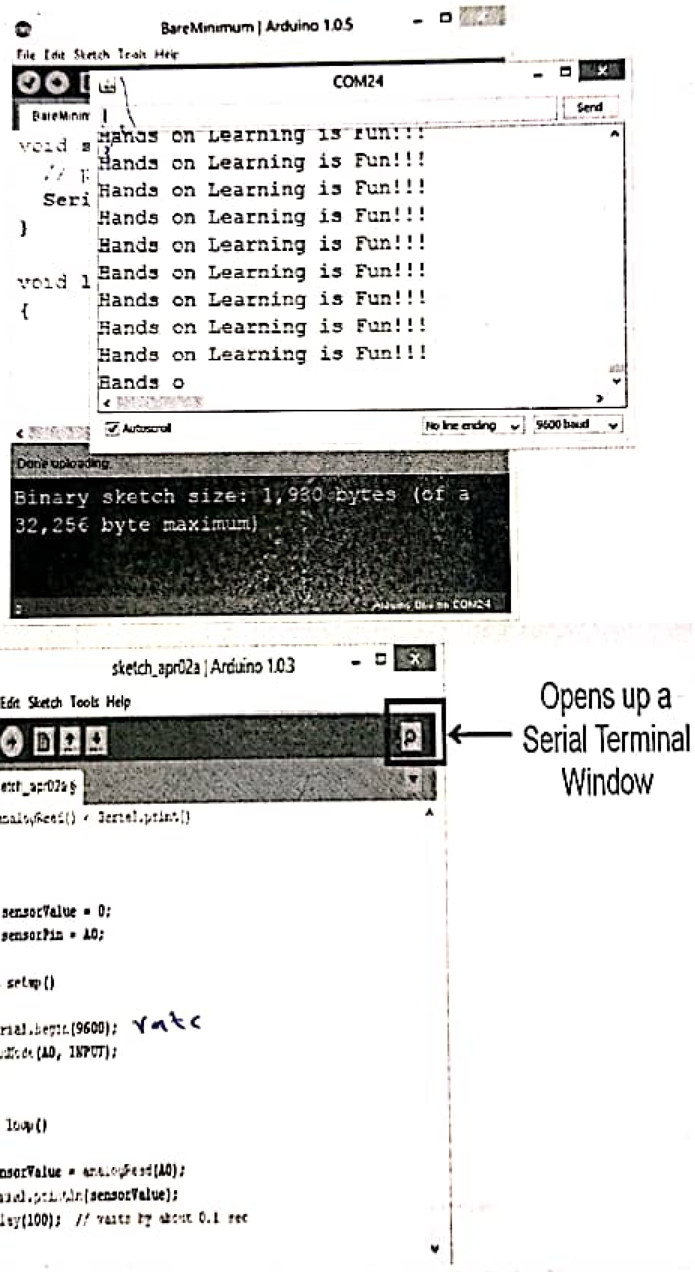
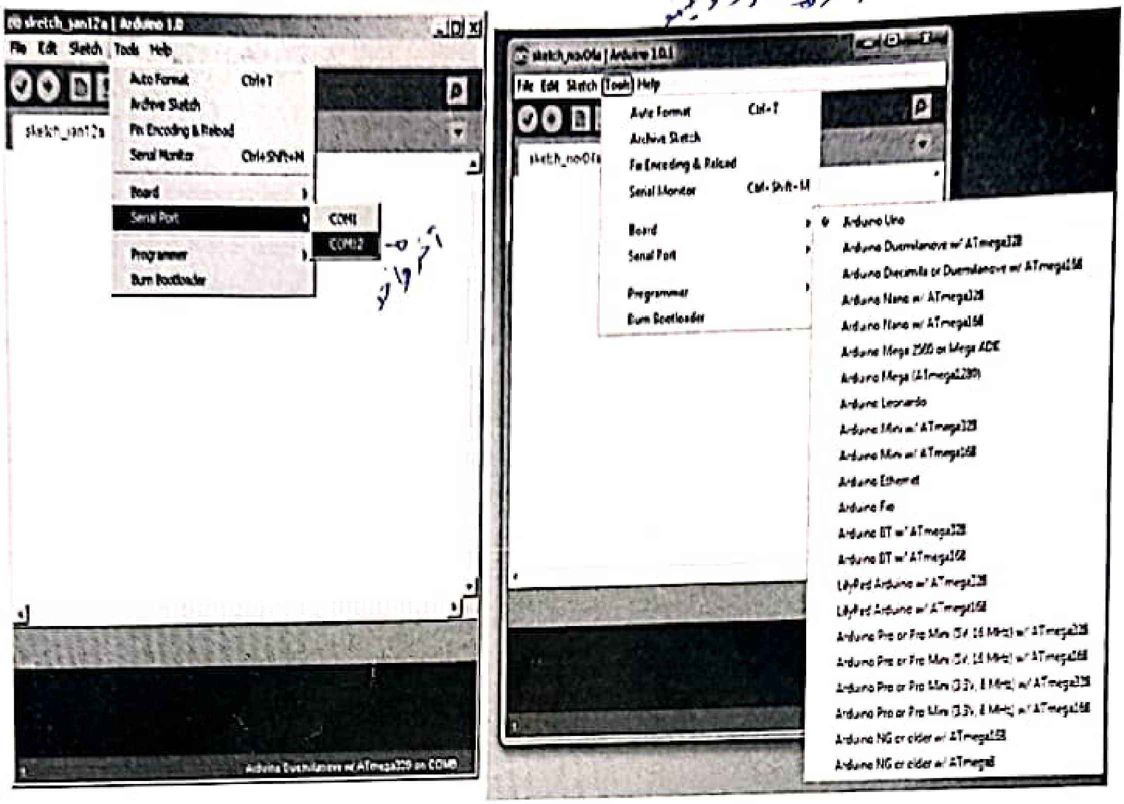
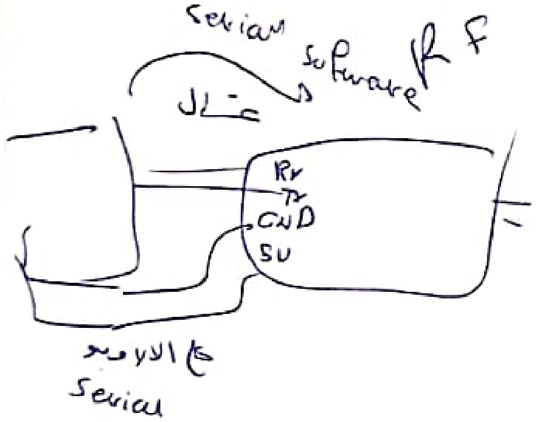


Figure 6.3: Serial monitor.

Finally, after we finish coding we need to choose the port to which our Arduino is connected before uploading the code.





Tx Tran Rx
10 11

tool mega
port
file a
uplode
serial moneter

① device
② ap
③ 2path

Labs

Softwar serial

AT
ok

\r\n

Hashemite University
Faculty of Engineering
Computer Engineering Department
Wireless Networks (Internal Lab)

Experiment: 5
Wireless communication using Arduino boards.

1.1Objectives:

1. To be able to use the Arduino board to send and receive data using RF modules.
2. To be able to use the Arduino board to connect and communicate through Wi-Fi networks.

1.2 Equipment's:

- Personal computer with Arduino IDE installed on it.
- Arduino mega boards.
- NRF24L01 modules
- ESP8266 Wi-Fi transceiver module

2.1 TheoreticalBackground:

RADIO FREQUENCY (RF) INTRO:

RF is an alternating current which if supplied to an antenna, will give rise to an electromagnetic field that propagates through space, Over 40 million systems manufactured each year utilizing low-power wireless (RF) technology for data links, such as: telemetry, control and security, Cordless and cellular telephones, radio and television broadcast stations, hand-held computer and PDA data links, wireless bar-code readers, wireless keyboards for PCs, wireless security systems, consumer electronic remote control, etc.

RF CHARACTERISTICS

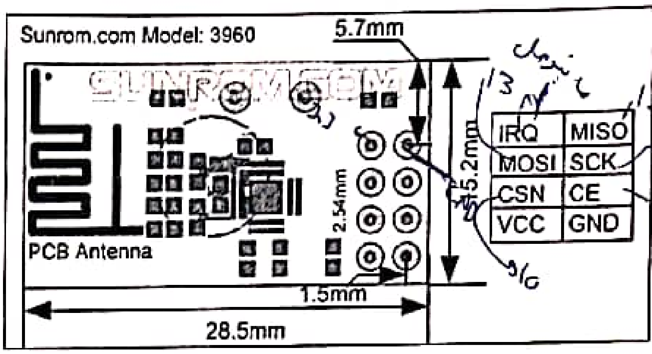
- Low power: Typically transmit less than 1mW of power
- Good operating range: Operate over distances of 3 to 30 meters
- Supports data rate up to 1-2 Mbps
- Penetrates walls
- Does not require a direct transmission path (as opposed to IR)

NRF24L01

- The nRF24L01 is a single chip 2.4GHz transceiver with an embedded baseband protocol engine designed for ultra-low power wireless applications.
- The nRF24L01 is configured and operated through a Serial Peripheral Interface (SPI.)
- The air data rate supported by the nRF24L01 is configurable to 2Mbps. The high air data rate combined with two power saving modes makes the nRF24L01 very suitable for ultra-low power designs.

Connecting the RF module to the Arduino:

- VCC -> 3.3v
- GND -> GND
- CE ->9
- CSN ->10
- SCK ->13
- MISO ->12
- MOSI ->11



Arduino coding:

- #include <SPI.h> // needed Libraries
- #include "RF24.h"
- const uint64_t myAddress= 0xE8E8F0F0EALL; // Write Same Address of Transmitter , the "LL" at he end of the constant is "LongLong" type
- RF24 myRadio (x, y); // Create an instance of a radio, specifying the CE and CS pins (x,y).
- myRadio.begin(); // Start up the physical nRF24L01 Radio
- myRadio.setChannel(x); // set the Radio Channel
- myRadio.setPALevel(RF24_PA_MIN);// Set the PA Level low to prevent power supply related issues
- myRadio.openWritingPipe(myAddress);
- myRadio.openReadingPipe(1, myAddress); // Use the first entry in array 'addresses' (Only 1 right now)
- myRadio.startListening(); //wait for incoming data
- myRadio.write(& buffer, sizeof(buffer));
- myRadio.read(& buffer, sizeof(buffer));

ESP8266:

The ESP8266 is a low-cost Wi-Fi microchip, with built-in TCP/IP networking software, and microcontroller capability. The ESP8266 has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces, it contains a self-calibrated RF allowing it to work under all operating conditions, and requires no external RF parts.

Connecting the ESP8266 module to the Arduino:

After the proper connection of the VCC and GND pins you can connect the RX, TX to any pins then the communication between the Arduino and the ESP8266 module will take place through a serial software interface the baud rate should be synchronized and the each string should end with \r\n which is referred to as "Both NL & CR" in the serial monitor. Below is the list of the basic commands to connect to Wi-Fi network:

Command	Description	Set/Execute	Parameters
AT+RST	restart the module		
AT+CWMODE	wifi mode	AT+CWMODE=<mode>	1= Sta, 2= AP, 3=both
AT+CWLAP	list the AP	AT+CWLAP	
AT+CWJAP	join the AP	AT+ CWJAP=<ssid>,< pwd >	ssid = ssid, pwd = wifi password
AT+CWQAP	quit the AP	AT+CWQAP	
AT+CIFSR	Get IP address	AT+CIFSR	
AT+ CIPMUX	set multiple connection	AT+ CIPMUX=<mode>	0 for single connection 1 for multiple connections
AT+CIPSERVER	set as server	AT+CIPSERVER=<mode>[,<port>]	mode 0 to close server mode, mode 1 to open; port = port
AT+PING	Ping an address	AT+PING=<ip>	
AT+CWSAP	Set the configuration of an ESP32 SoftAP.	AT+CWSAP=<ssid>,<pwd>,<chl>,<ecn>[,<max conn>][,<ssid hidden>]	<ssid>: string parameter showing SSID of the AP. <pwd>: string parameter showing the password. Length: 8 – 63 bytes ASCII. <channel>: channel ID. <ecn>: encryption method; WEP is not supported. 0: OPEN 2: WPA_PSK 3: WPA2_PSK 4: WPA_WPA2_PSK [<max conn>]: maximum number of stations that ESP32 SoftAP can connect. Range: [1,10]. [<ssid hidden>]: 0: broadcasting SSID (default). 1: not broadcasting SSID.

5/3

```
#Include
                 xyz    0000 00000ALL
Const uint64_t ↑ 0X ____        LL
                         CS  CE
RF 24  myRadio ( X, Y );

{ setup()
  Serial.begin(9600);
  myRadio.begin();
receiver  myRadio.openReadingpipe(1, XYZ);
  myRadio.startListening();
sender → myRadio.openwritingpipe(XYZ);
}
loop()
{
sender  myRadio.write("-----", 6);
  myRadio.Read(&S, 10); → char S[5] = "-----";
receiver  Serial.print(S);                Global
                                main     بره ال
}
```

pwd pre work directory

Ls

Cd

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Experiment: 6 14/5
Packet sniffing to Raspberry Pi

1.1 Objectives:

1. Introduce the Raspberry Pi boards.
2. Being able to write and run simple python code in raspberry pi.
3. Being able to sniff and parse packets using scapy in python

1.2 Equipment's:

- Personal computer.
- Raspberry Pi 4 Model B boards.

2.1 Theoretical Background:

Raspberry Pi is an Ultra-low-cost credit-card-sized single-board Linux computer. Raspberry Pi developed by Raspberry foundation (UK), is a small, powerful and lightweight ARM based development board or a computer which is able to perform operations similar to a PC. The powerful graphics capabilities and HDMI video output make it ideal for multimedia applications such as media centers and narrowcasting solutions. With access to the internet, through Ethernet or Wi-Fi and a high definition output, the Raspberry Pi is an incredibly versatile piece of computing kit. The Raspberry Pi is based on a Broadcom chip that is based on ARM. It does not feature a built-in hard disk or solid-state drive, instead relying on an SD card for booting and long-term storage.

This single board computer is inexpensive yet comes packed with Ethernet, USB, a high powered graphics engine, digital I/O ports and enough CPU power to accomplish your projects. The Foundation provides Debian and Arch Linux ARM distributions for download. Tools are available for Python as the main programming language.

2.2 Features of Raspberry Pi board:

Processor	Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
Connectivity	2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN, Bluetooth 5.0, BLE Gigabit Ethernet 2 × USB 3.0 ports 2 × USB 2.0 ports.
GPIO	Standard 40-pin GPIO header (fully backwards-compatible with previous boards)
Video & sound	2 × micro HDMI ports (up to 4Kp60 supported)
SD card support	Micro SD card slot for loading operating system and data storage
Input power	5V DC via USB-C connector (minimum 3A1) 5V DC via GPIO header (minimum 3A1) Power over Ethernet (PoE)–enabled (requires separate PoE HAT)

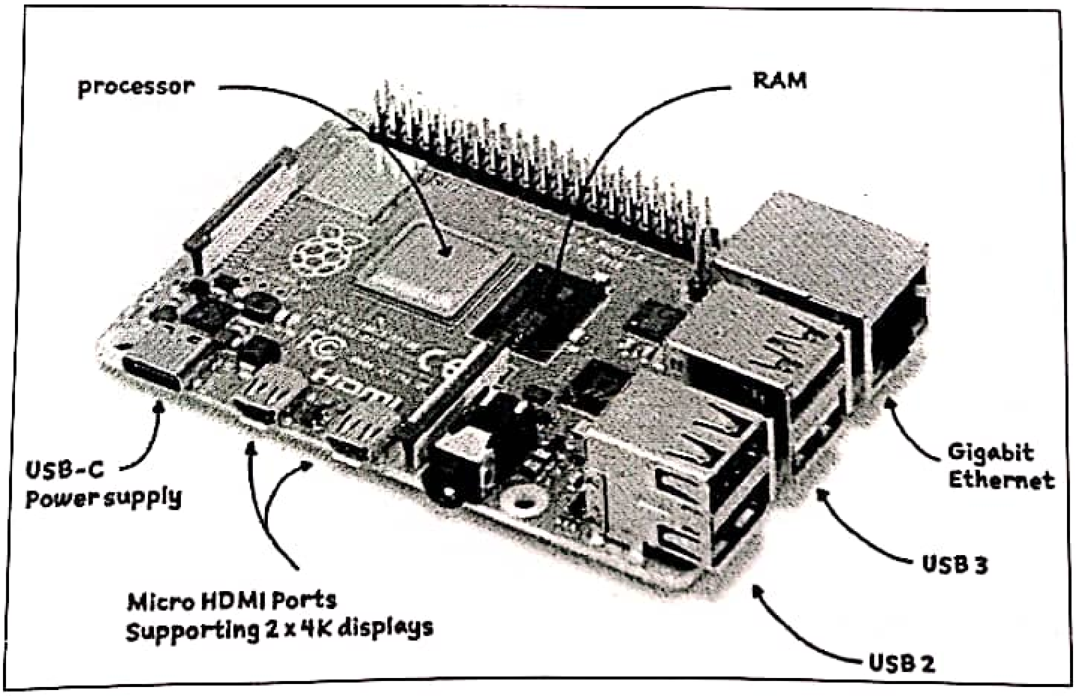


Figure 1: Raspberry Pi Board

3.1 Raspberry Pi OS:

Raspberry Pi OS is a free operating system based on Debian, optimized for the RaspberryPi hardware, and is the recommended operating system for normal use on a Raspberry Pi. The OS comes with over 35,000 packages: precompiled software bundled in a nice format for easy installation on your Raspberry Pi.

Raspberry Pi OS is under active development, with an emphasis on improving the stability and performance of as many Debian packages as possible on Raspberry Pi.

3.2 Python:

Python is a powerful programming language that's easy to use easy to read and write and, with Raspberry Pi, lets you connect your project to the real world. Python syntax is clean, with an emphasis on readability, and uses standard English keywords

3.3 Thonny:

The easiest introduction to Python is through Thonny, a Python 3 development environment. You can open Thonny from the desktop or applications menu. Thonny gives you a REPL (Read-Evaluate-Print-Loop), which is a prompt you can enter Python commands into. Because it's a REPL, you even get the output of commands printed to the screen without using print. In the Thonny application, this is called the Shell window. You can use variables if you need to but you can even use it like a calculator. For example:

```
>>> 1 + 2
3
>>> name = "Sarah"
>>> "Hello " + name
'Hello Sarah'
```

Thonny also has syntax highlighting built in and some support for auto completion. You can look back on the history of the commands you've entered in the REPL with Alt + P(previous) and Alt + N (next)

3.4 Basic Python usage:

Hello world in Python: `print("Hello world")` Simple as that!
Some languages use curly braces {and } to wrap around lines of code which belong together, and leave it to the writer to indent these lines to appear visually nested. However, Python does not use curly braces but instead requires indentation for nesting. For example, a for loop in Python:

```
for i in range(10):
  print("Hello")
```

If statements: You can use `if` statements for control flow:

```
name = "Joe"
if len(name) > 3:
   print ("Nice name,")
   print(name)
else:
   print(name)
   print ("That's a short name,")
```

3.5 GPIO in Python

A powerful feature of the Raspberry Pi is the row of GPIO (general-purpose input/output) pins along the top edge of the board. A 40-pin GPIO header is found on all current Pi boards (unpopulated on Raspberry Pi Zero, Raspberry Pi Zero W and Raspberry Pi Zero 2 W). Prior to the Raspberry Pi 1 Model B+ (2014), boards comprised a shorter 26-pin header. The GPIO header on all boards (including the Raspberry Pi 400) have a 0.1" (2.54mm) pin pitch.

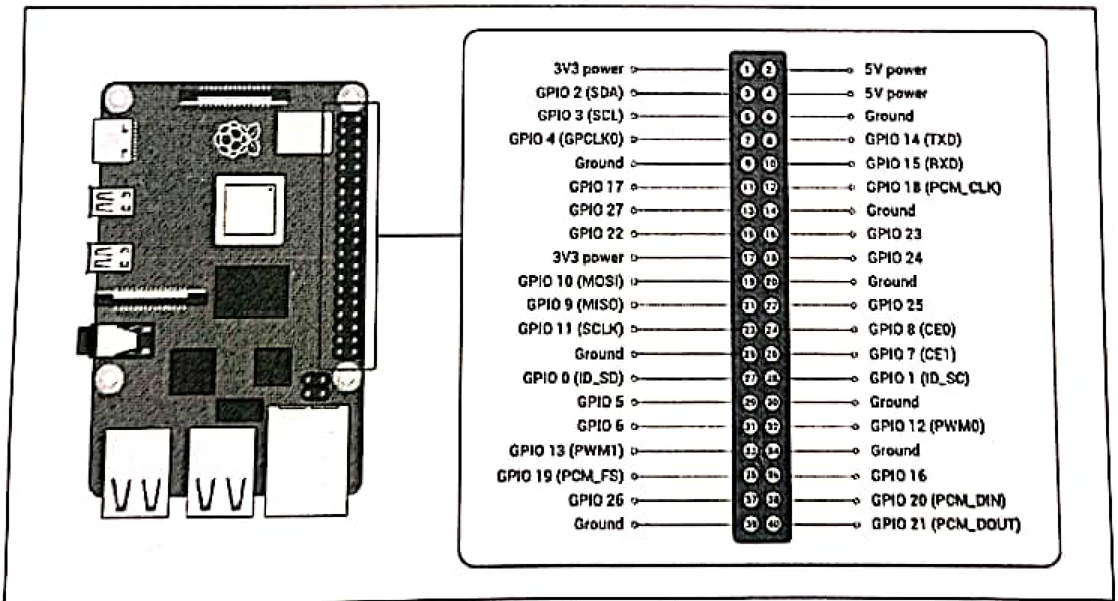


Figure 2: Raspberry Pi board GPIO

Using the GPIO Zero library makes it easy to get started with controlling GPIO devices with Python. The library is comprehensively documented at gpiozero.readthedocs.io.
To control an LED connected to GPIO17, you can use this code:

```
from gpiozero import LED
from time import sleep
led = LED(17)
while True:
    led.on()
    sleep(1)
    led.off()
    sleep(1)
```

Run this in an IDE like Thonny, and the LED will blink on and off repeatedly.
LED methods include on (), off (), toggle (), and blink ().

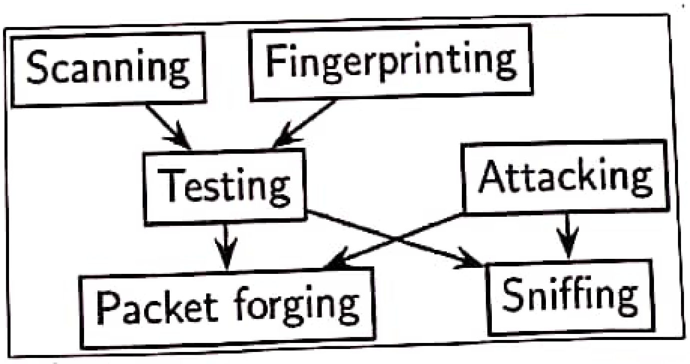
3.6 Python Dictionaries:

A dictionary is a collection which is ordered, changeable and do not allow duplicates. Dictionaries are written with curly brackets, and have keys and values. Dictionary items are presented in (key:value) pairs, and can be referred to by using the key name and The values in dictionary items can be of any data type.

```
thisdict = {
  "brand": "Ford",
  "electric": False,
  "year": 1964,
  "colors": ["red", "white", "blue"]
}
```

4.1 Scapy Library:

Scapy is a Python program that enables the user to send, sniff and dissect and forge network packets. This capability allows construction of tools that can probe, scan or attack networks.



from scapy... import *

Fun (PKt) Prn:

try

PKt[0].show

except

print("failed") sniff(prn=func, store=0)

Sniff function: With "Sniff function" we can easily capture some packets or even clone tcpdump or tshark. Either one interface or a list of interfaces to sniff on can be provided. If no interface is given, sniffing will happen on conf.iface:

```
sniff( iface="wifi0", prn=func1 filter="ip", store =0)
```

interface

prn in the above prototype indicate the name of the function that is used to parse the sniffed packet, while the filter controls the type of the packet to be passed to the parsing function and the store controls wither the packet is to be stored or not.

Packet summary () and show () Methods:

Using the summary () method will give us a quick look at the packet's layers:

```
>>> pkt[0].summary()
'Ether / IP / ICMP 172.16.20.10 > 4.2.2.1 echo-request 0 / Raw'
```

But if we want to see more of the packet contents we use the show () method:

```
>>> pkt[0].show()
###[ Ethernet ]###
  dst= 00:24:97:2e:d6:c0
  src= 00:00:16:aa:bb:cc
  type= 0x800
###[ IP ]###
     version= 4L
     ihl= 5L
     tos= 0x0
     len= 84
     id= 57299
     flags=
     frag= 0L
     ttl= 64
     proto= icmp
     chksum= 0x0
     src= 172.16.20.10
     dst= 4.2.2.1
     \options\
###[ ICMP ]###
        type= echo-request
        code= 0
        chksum= 0xd8af
        id= 0x9057
        seq= 0x0
###[ Raw ]###
```

"192.168.200.1

print

pkt[0][1]. src

.dst

.sport

.dport

my fun (packet)

try

except packet.show

sniff -- prn=myfun

start prog

form scapy.all import * thony

def my-fun(packet)

try:

sport dport IP(packet[0][1]).

print

except print

sniff (pkt. show

مابركز عليه

Wireless Comes of Age

- Guglielmo Marconi invented the wireless telegraph in 1896
  - Communication by encoding alphanumeric characters in analog signal
  - Sent telegraphic signals across the Atlantic Ocean
- Communications satellites launched in 1960s
- Advances in wireless technology
  - Radio, television, mobile telephone, communication satellites
- More recently
  - Wireless LAN networking, cellular technology, WSN, WPN, WMN

Shifting Trends

- The edge of the internet becoming wireless
  - Single-hop networks

  - Multi-hop networks

كل واحد من مراحل عبارة عن hop

Broadband Wireless Technology

- Higher data rates obtainable with broadband wireless technology
  - Graphics, video, audio
- Shares same advantages of all wireless services: convenience and reduced cost
  - Service can be deployed faster than fixed service
  - No cost of cable plant
  - Service is mobile, deployed almost anywhere

** السؤال فاينل

Many Benefits due to Wireless

- Significantly lower cost
  - No cable, low labor cost, low maintenance
- Ease
  - Minimum infrastructure - scatter and play
- Unrestricted mobility
  - Unplugged from power outlet
- Ubiquity
  - Available like water/electricity

ممكن يجي سؤال عنه

Challenges in the Wireless Technologies

- Inherently broadcast and shared
  - Users can impact other users, just by co-location or location vicinity
  - Limited capacity; no adding cables to add capacity
  - Licensing of spectrum, or ‘collisions’ in unlicensed
- Unpredictable Medium
  - Medium is dynamic, even without devices moving
  - Devices may be moving
  - Attenuation with distance, multi-paths, higher error rates, and unpredictable channel responses
- Device limitations: battery capacity or screen sizes
- Politics and Incompatible standards

Q1) List and briefly define 4 benefits due to wireless.

1. lower cost (No cable, low labor cost, low maintenance).
2. Ease (Minimum infrastructure).
3. Unrestricted mobility (Unplugged from the power outlet).
4. Ubiquity (Available).

اجى سؤال الفصل الماضي بالفاينل

Q2) List 4 of the challenges (Disadvantages) in Wireless Technologies.

1. Inherently broadcast and shared.
2. Unpredictable Medium.
3. Device limitations.
4. Politics and Incompatible Standards.

Transmission Fundamentals

Chapter 2

* antenna convert electrical to electromagnetic and electromagnetic to electrical

convert data to signal and send it

electrical to electromagnetic wives we need to use a component called antenna

① time
② freq.

Electromagnetic Signal

wirless (open) بالفضاء space

, destenation collect electromagnet. wive and convert to electrical signal

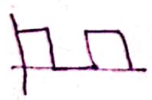
wired, electrical *

- Function of time
- Can also be expressed as a function of frequency
  - Signal consists of components of different frequencies

Type of Signal :

Analog

Digital



Signal: can present in time (function of time) domain and freq domain (function of freq.)

I can convert or switch between time and freq. domain use transformation function laplace, cos, Fourier...

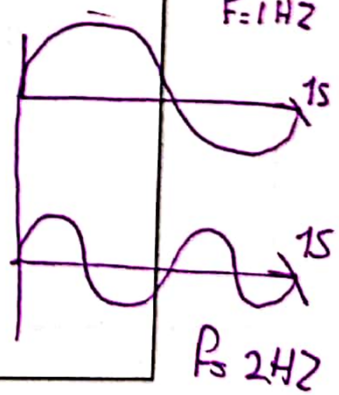
Time-Domain Concepts

- **Analog signal** - signal intensity varies in a smooth fashion over time
  - No breaks or discontinuities in the signal
- **Digital signal** - signal intensity maintains a constant level for some period of time and then changes to another constant level
- **Periodic signal** - analog or digital signal pattern that repeats over time

  - $s(t+T) = s(t) \qquad -\infty < t < +\infty$
    - where T is the period of the signal

Time-Domain Concepts

- Aperiodic signal - analog or digital signal pattern that doesn't repeat over time
- Peak amplitude (*A*) - maximum value or strength of the signal over time; typically measured in volts
- Frequency (*f*)
  - Rate, in cycles per second, or Hertz (Hz) at which the signal repeats



Merge two layers into one layer.

****Q21) Define Digital and Analog Signals.**

Digital signal: signal intensity maintains a constant level for some period and then changes to another constant level.

Analog signal: signal intensity varies in a smooth fashion over time.

Time-Domain Concepts

- Period (T) - amount of time it takes for one repetition of the signal
  - $T = 1/f$
- Phase (ϕ) - measure of the relative position in time within a single period of a signal
- Wavelength (λ) - distance occupied by a single cycle of the signal
  - Or, the distance between two points of corresponding phase of two consecutive cycles
  - $\lambda = v \cdot T$

Sine Wave Parameters

- General sine wave:
  - $s(t) = A \sin(2\pi f t + \phi)$
- Figure 2.3 shows the effect of varying each of the three parameters:
  - (a) $A = 1$, $f = 1$ Hz, $\phi = 0$; thus $T = 1$s
  - (b) Reduced peak amplitude; A=0.5
  - (c) Increased frequency; $f = 2$, thus $T = 1/2$
  - (d) Phase shift; $\phi = \pi/4$ radians (45 degrees)
- note: 2π radians = 360° = 1 period

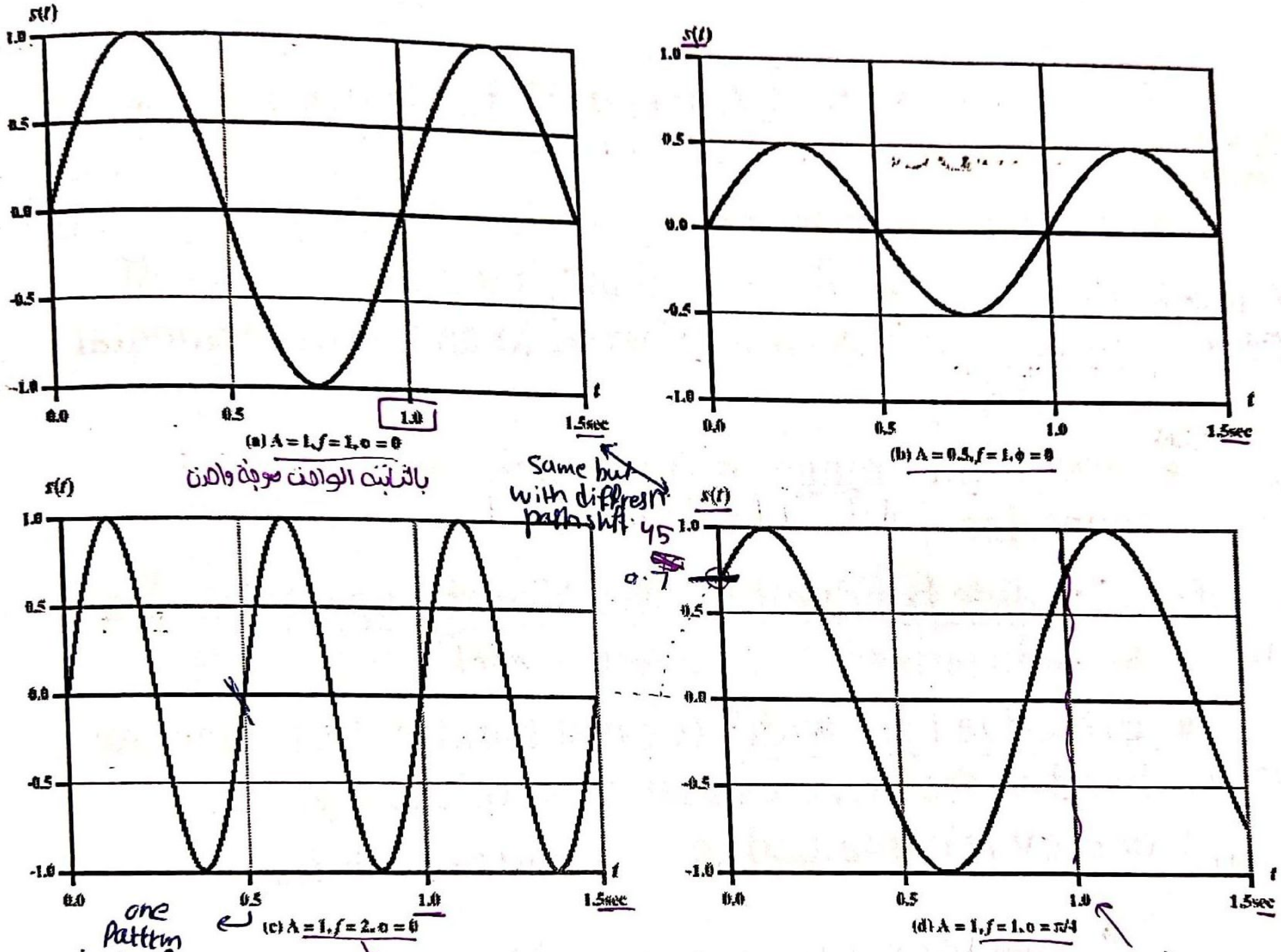


Figure 2.3 $s(t) = A \sin(2\ ft + \phi)$

$1 \sin(2\pi 1 \times 0 + \frac{\pi}{4})$

$\sin(\frac{\pi}{4}) = \sin(45) = 0.707$

لكن اعرف وين ارسم ع ال x-axis بعوض بالمعادلة وبحط بدال t zero

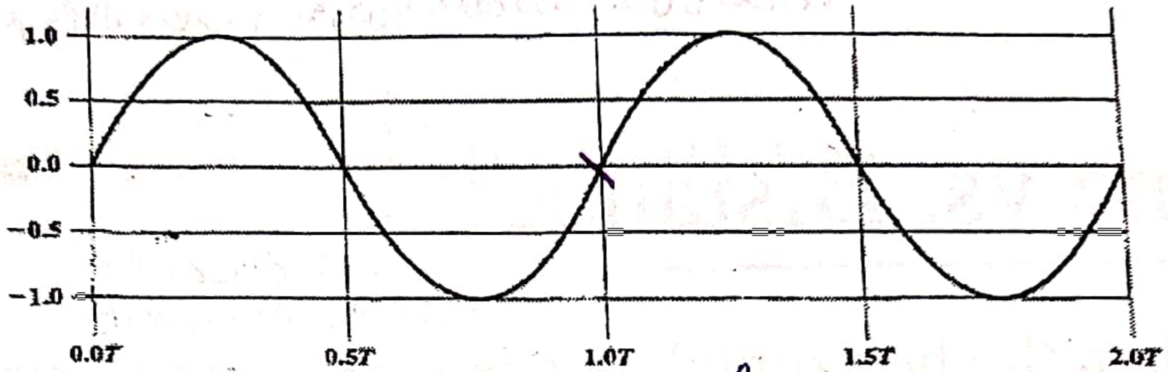
Time vs. Distance

- When the horizontal axis is *time*, as in Figure 2.3, graphs display the value of a signal at a given point in *space* as a function of *time*
- With the horizontal axis in *space*, graphs display the value of a signal at a given point in *time* as a function of *distance*
  - At a particular instant of time, the intensity of the signal varies as a function of distance from the source

Frequency-Domain Concepts

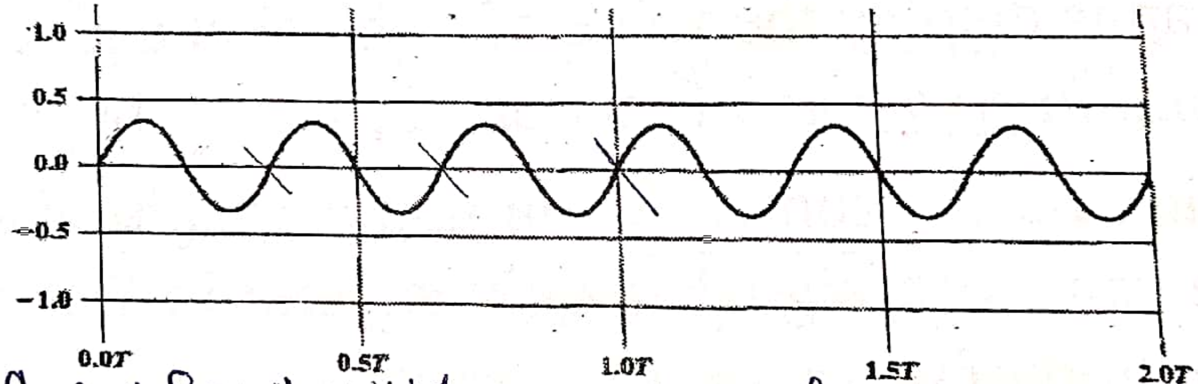
- Fundamental frequency - when all frequency components of a signal are integer multiples of one frequency, it's referred to as the fundamental frequency
- Spectrum - range of frequencies that a signal contains
- Absolute bandwidth - width of the spectrum of a signal
- Effective bandwidth (or just bandwidth) - narrow band of frequencies that most of the signal's energy is contained in

Fundemental Freq →



(a) sin(2πft) 1f

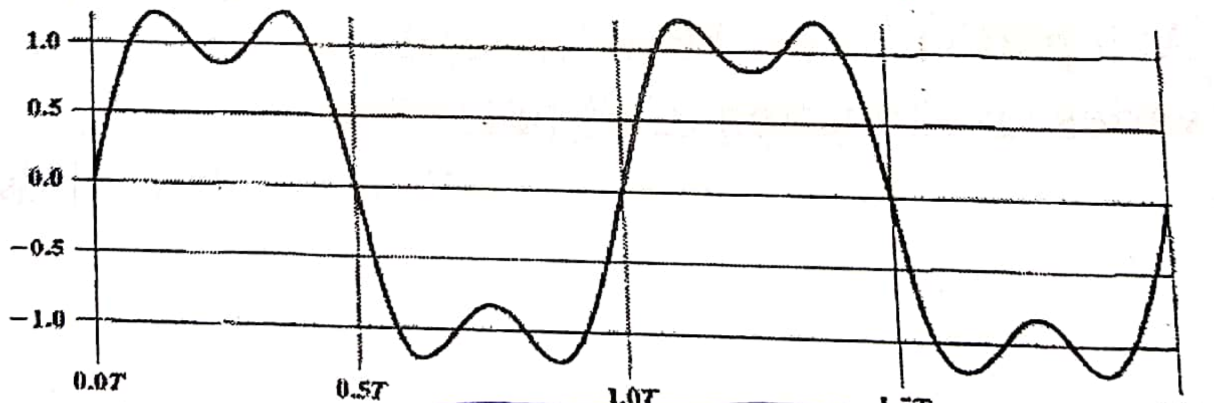
Freq ~~time~~ domain



(b) (1/3)sin(2π(3f)t) 3f ← لما زادت ال Freq ال Amp قلت

period ال اطول نفس ← ال Fundemental Freq. Period = 1T

① الاكثر energy / تحدد الشكل



(c) (4/π) [sin(2πft) + (1/3)sin(2π(3f)t)]

Original signal ← time ~~Freq~~ domain

Freq = 1f

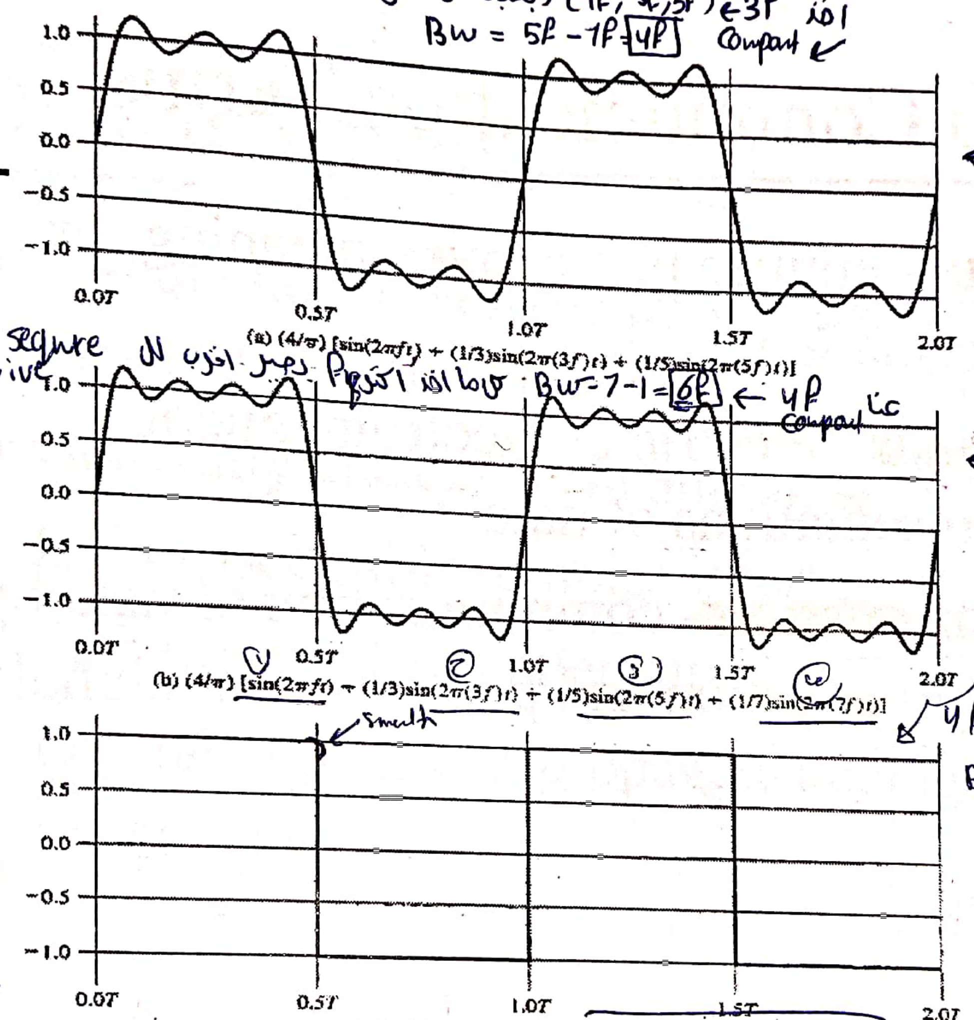
effective = Absolute = BW = 3f − 1f = 2f → original → عبارة عن مجموع 2 Freq. ال signal

Spectrum = 1f and 3f

Frequency-Domain Concepts

- Any electromagnetic signal can be shown to consist of a collection of periodic analog signals (sine waves) at different amplitudes, frequencies, and phases
- The period of the total signal is equal to the period of the fundamental frequency

اخذ 3f ← (1f, 3f, 5f) ونسبة



(a) $(4/\pi)\,[\sin(2\pi ft) + (1/3)\sin(2\pi(3f)t) + (1/5)\sin(2\pi(5f)t)]$

(b) $(4/\pi)\,[\sin(2\pi ft) + (1/3)\sin(2\pi(3f)t) + (1/5)\sin(2\pi(5f)t) + (1/7)\sin(2\pi(7f)t)]$

(c) $(4/\pi)\,\Sigma\,(1/k)\sin(2\pi(kf)t)$, for k odd

Figure 2.5 Frequency Components of Square Wave ($T = 1/f$)

Relationship between Data Rate and Bandwidth

- The greater the bandwidth, the higher the information-carrying capacity
- Conclusions
  - Any digital waveform will have infinite bandwidth
  - BUT the transmission system will limit the bandwidth that can be transmitted
  - AND, for any given medium, the greater the bandwidth transmitted, the greater the cost
  - HOWEVER, limiting the bandwidth creates distortions

Data Communication Terms

- Data - entities that convey meaning, or information
- Signals - electric or electromagnetic representations of data
- Transmission - communication of data by the propagation and processing of signals

Analog Signals

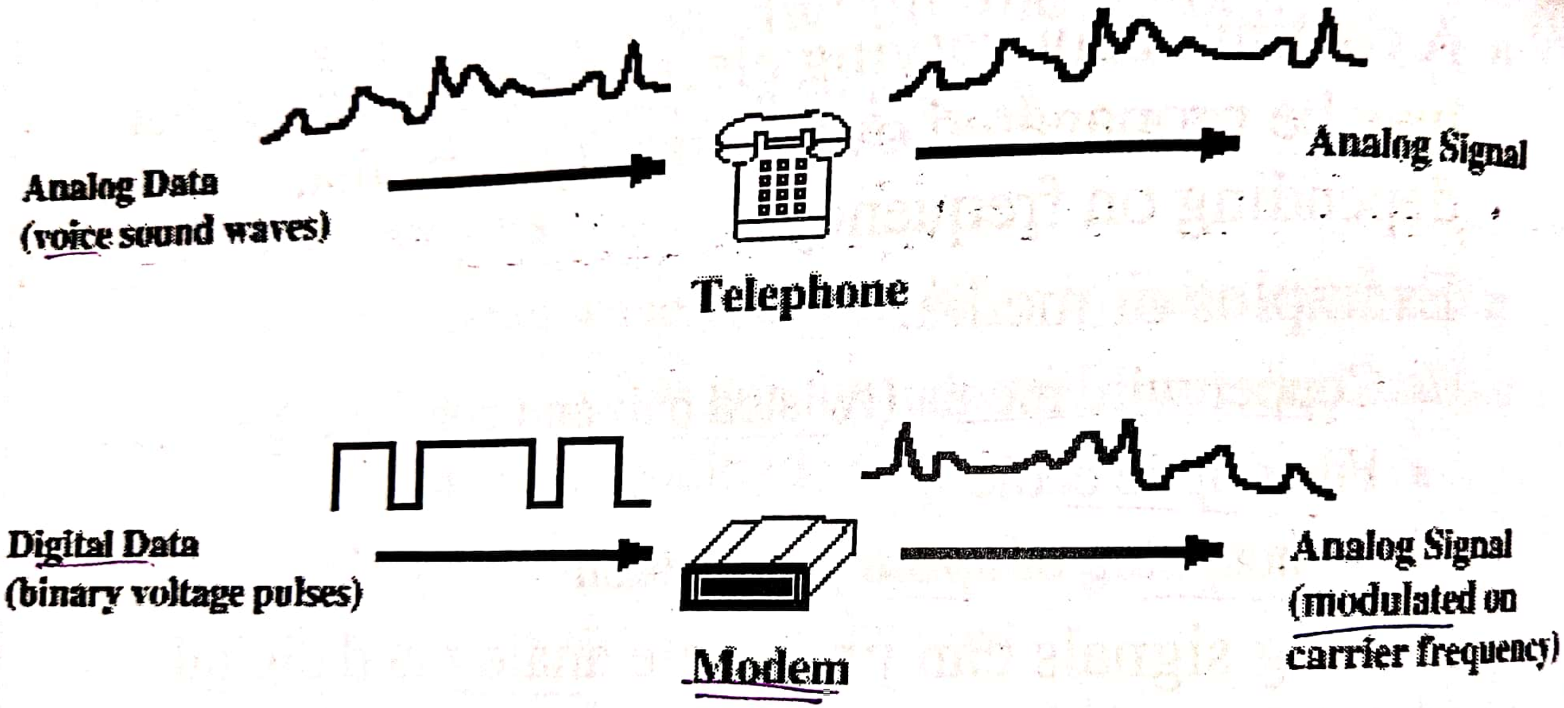
- A continuously varying electromagnetic wave that may be propagated over a variety of media, depending on frequency
- Examples of media:
  - Copper wire media (twisted pair and coaxial cable)
  - Fiber optic cable
  - Atmosphere or space propagation
- Analog signals can propagate analog and digital data

Digital Signals

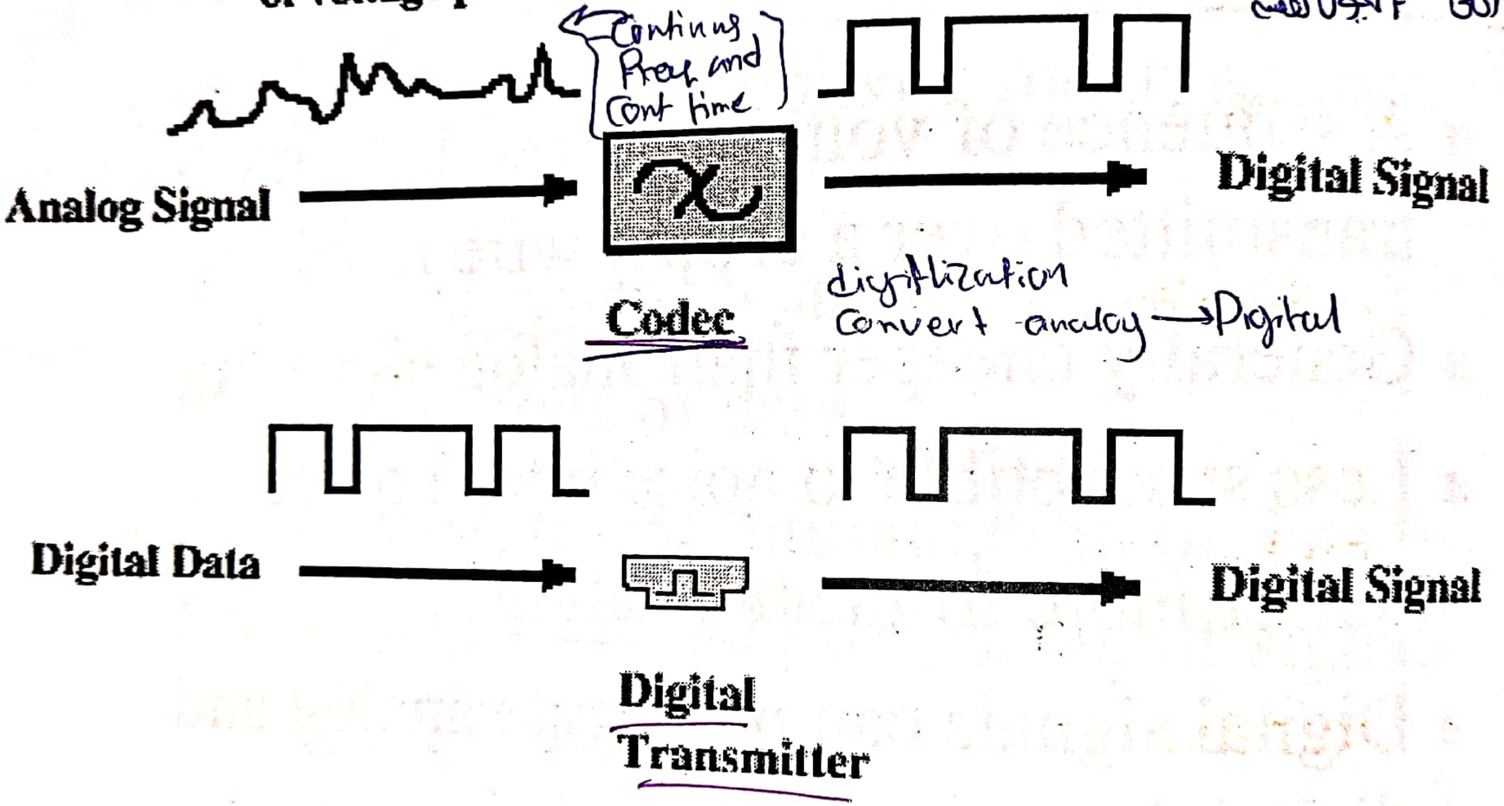
①Binary
②Multi

- A sequence of voltage pulses that may be transmitted over a copper wire medium
- Generally cheaper than analog signaling
- Less susceptible to noise interference
- Suffer more from attenuation
- Digital signals can propagate analog and digital data

Analog Signals: Represent data with continuously varying electromagnetic wave



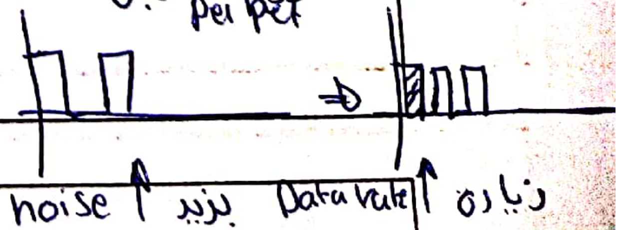
Digital Signals: Represent data with sequence of voltage pulses



About Channel Capacity

- Impairments, such as noise, limit data rate that can be achieved
- For digital data, to what extent do impairments limit data rate?
- Channel Capacity – the maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions

channel capacity ↑ positive
data rate ↑ positive



Concepts Related to Channel Capacity

- **Data rate** - rate at which data can be communicated (bps)
- **Bandwidth** - the bandwidth of the transmitted signal as constrained by the transmitter and the nature of the transmission medium (Hertz)
- **Noise** - average level of noise over the communications path
- **Error rate** - rate at which errors occur
  - Error = transmit 1 and receive 0; transmit 0 and receive 1

السؤال اجى تذكر الkey effect يلي بتأثر ع ال capacity
مع علاقة كل وحدة فيهم
ال noise و ال error rate علاقة عكسية
ال data rate و ال bandwidth علاقة طردية

Q) What key factors affect channel capacity?

اجى سؤال بالفصل الماضي ميد

Bandwidth, noise, and error rate affect channel capacity.

Nyquist Bandwidth

- For binary signals (two voltage levels)
  - $C = 2B$
- With multilevel signaling
  - $C = 2B \log_2 M$
    - M = number of discrete signal or voltage levels

دمير ذا افل

مهم ، سؤال هيبد

Signal-to-Noise Ratio

- Ratio of the power in a signal to the power contained in the noise that's present at a particular point in the transmission
- Typically measured at a receiver
- Signal-to-noise ratio (SNR, or S/N)

$$(SNR)_{dB} = 10\log_{10}\frac{\text{signal power}}{\text{noise power}}$$

- A high SNR means a high-quality signal, low number of required intermediate repeaters
- SNR sets upper bound on achievable data rate

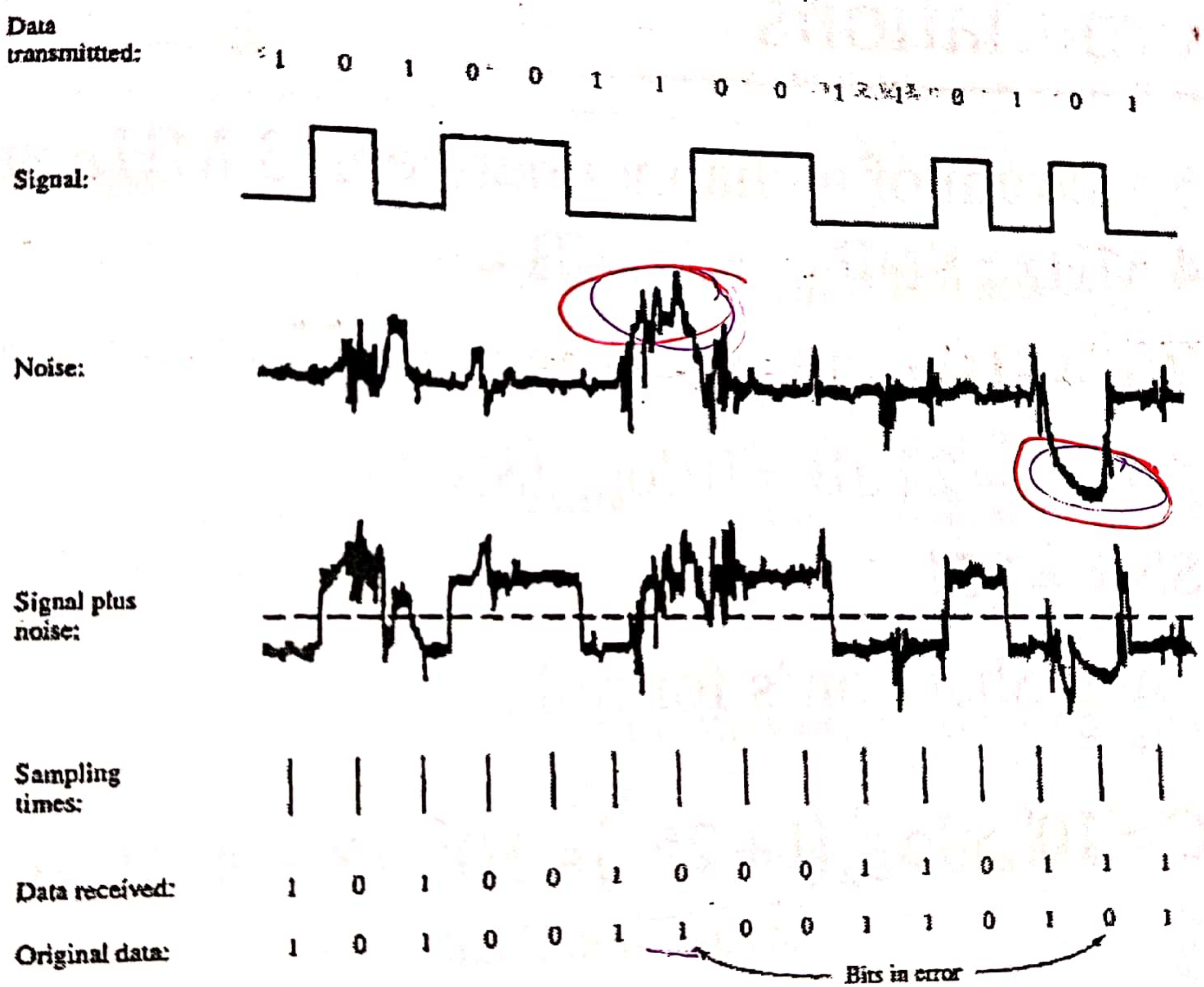


Figure 2.9 Effect of Noise on a Digital Signal

مهم ، سؤال ميد

Shannon Capacity Formula

- Equation:

$$C = B\log_2(1+\mathrm{SNR})$$

- Represents theoretical maximum that can be achieved
- In practice, only much lower rates achieved:
  - Formula assumes white noise (thermal noise)
  - Impulse noise is not accounted for
  - Attenuation distortion or delay distortion not accounted for

Example of Nyquist and Shannon Formulations

- Spectrum of a channel between 3 MHz and 4 MHz ; SNR_{dB} = 24 dB

$$B = 4\,\text{MHz} - 3\,\text{MHz} = 1\,\text{MHz}$$

$$SNR_{dB} = 24\,\text{dB} = 10\log_{10}(SNR)$$

$$SNR = 251$$

- Using Shannon's formula

$$C = 10^6 \times \log_2(1 + 251) \approx 10^6 \times 8 = 8\text{Mbps}$$

3. Damaged REJ.

Q14) A digital signaling system is required to operate at 9600 bps.

a. If a signal element encodes a 4-bit word, what is the minimum required bandwidth of the channel?
b. Repeat part (a) for the case of 8-bit words.

Solution:

Using Nyquist's equation: $C = 2*B*\log_2 M$, we have C = 9600 bps.

a. $\log_2 M = 4$, because a signal element encodes a 4-bit word Therefore, C = 9600 = 2*B*4, and B = 1200 Hz
b. 9600 = 2*B*8, and B = 600 Hz

Example of Nyquist and Shannon Formulations

- How many signaling levels are required?

المطلوب

مهم

لازم تحدد ال level
يلي هي ال M
وعدد ال bit
يلي هي $\log_2 M$

$$C = 2B\log_2 M$$

$$8\times10^6 = 2\times(10^6)\times\log_2 M$$

$$4 = \log_2 M$$

$$M = 16$$

* السؤال يطلب تكتبه
احيانا بصيغة
dB

قوانين shannon و Nyquist حفظ

(Nyquist)

* $C = 2B$ (بحالة ال Binary
لبشو؟ لانه عدد ال
level (بيكون 2)
$\log_2 2 = \boxed{1} \rightarrow 2B \times 1 = 2B$

* $C = 2B \log_2 M$
M → level
$\log_2 M$ → # of bit

مين بالسؤال شو بيعطيك عدد ال bits ولا عدد ال levels

Shannon

$C = B \log_2(1 + SNR)$

التمييز بالقانون حسب اذا هو حدد نستخدم Shannon او Nyquist
او بحال اعطى SNR بيكون shannon

$$(SNR)_{dB} = 10 \log_{10} \frac{S}{N} \rightarrow 10 \log_{10} SNR$$

(10) → power 10 مو power 2

بس بدي اياه بالقانون لهيك اذا اعطى $(SNR)_{dB}$
بطلع $10^{\frac{(SNR)_{dB}}{10}}$

$$\frac{SNR}{10} = \frac{10}{10} \log_{10} SNR$$

$$10^{\frac{SNR}{10}} = 10^{\log_{10} SNR} \rightarrow \boxed{SNR = 10^{\frac{SNR}{10}}}$$

Q) A digital signaling system is required to operate at 9600 bps.
a. If a signal element encodes a 4-bit word, what is the minimum required bandwidth of the channel?

Using Nyquist's equation: C = 2B log2M We have C = 9600 bps a. log2M = 4, because a signal element encodes a 4-bit word Therefore, C = 9600 = 2B × 4, and B = 1200 Hz

b. Repeat part (a) for the case of 8-bit words.

9600 = 2B × 8, and B = 600 Hz

Q) What key factors affect channel capacity?

Bandwidth, noise, and error rate affect channel capacity.

**Q) Given a channel with an intended capacity of 20 Mbps, the bandwidth of the channel is 3 MHz. What signal-to-noise ratio is required to achieve this capacity?

C = B log2 (1 + SNR) 20 × 106 = 3 × 106 × log2(1 + SNR) log2(1 + SNR) = 6.67 1 + SNR = 102 SNR = 101

**Q) Show that doubling the transmission frequency or doubling the distance between transmitting antenna and receiving antenna attenuates the power received by 6 dB.

we have LdB = 20 log (4πd/λ) = 20 log (4πdf/v), where λf = v If we double either d or f, we add a term 20 log(2), which is approximately 6 dB.

**Q) An amplifier has an output of 20 W. What is its output in dBW?

Power (dBW) = 10 log (Power/1W) = 10 log20 = 13 dBW

Classifications of Transmission Media

- Transmission Medium
  - Physical path between transmitter and receiver
- Guided Media
  - Waves are guided along a solid medium
  - E.g., copper twisted pair, copper coaxial cable, optical fiber
- Unguided Media
  - Provides means of transmission but does not guide electromagnetic signals
  - Usually referred to as wireless transmission
  - E.g., atmosphere, outer space

Unguided Media

- Transmission and reception are achieved by means of an antenna
- Configurations for wireless transmission:
  - Directional
  - Omnidirectional

General Frequency Ranges

- Microwave frequency range
  - 1 GHz to 40 GHz
  - Directional beams possible
  - Suitable for point-to-point transmission
  - Used for satellite communications
- Radio frequency range
  - 30 MHz to 1 GHz
  - Suitable for omnidirectional applications
- Infrared frequency range
  - Roughly, $3\text{x}10^{11}$ to $2\text{x}10^{14}$ Hz
  - Useful in local point-to-point multipoint applications within confined areas

within co...

Terrestrial Microwave

- Description of common microwave antenna:
  - Parabolic "dish", 3 m in diameter
  - Fixed rigidly and focuses a narrow beam
  - Achieves line-of-sight transmission to receiving antenna
  - Located at substantial heights above ground level
- Applications:
  - Long haul telecommunications service
  - Short point-to-point links between buildings

Satellite Microwave

- Description of communication satellite:
  - Microwave relay station
  - Used to link two or more ground-based microwave transmitter/receivers
  - Receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink)
- Applications
  - Television distribution
  - Long-distance telephone transmission
  - Private business networks

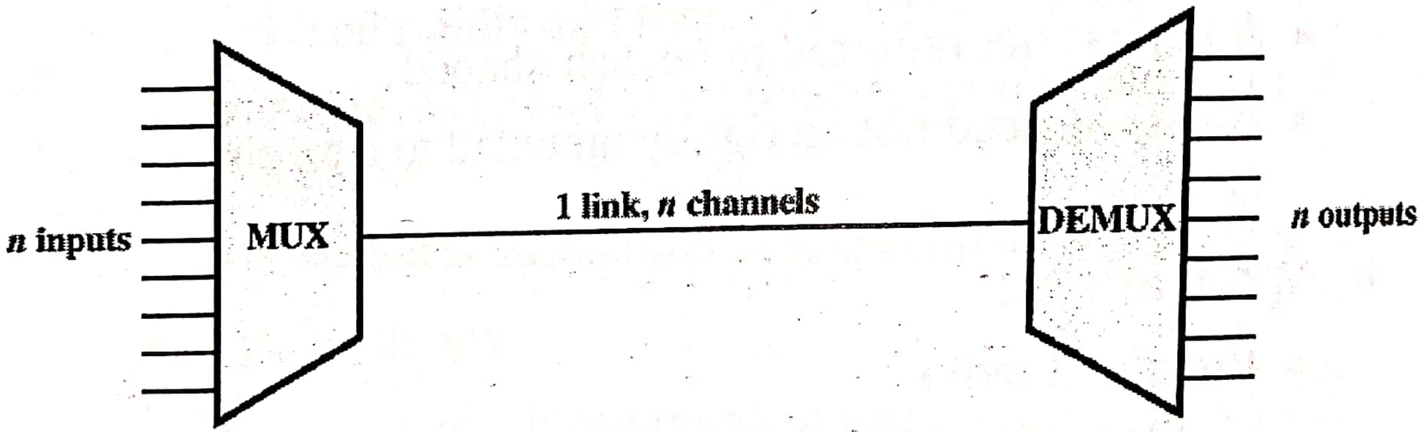
Broadcast Radio

- Description of broadcast radio antennas:
  - Omnidirectional
  - Antennas not required to be dish-shaped
  - Antennas need not be rigidly mounted to a precise alignment
- Applications:
  - Broadcast radio
    - VHF and part of the UHF band; 30 MHZ to 1GHz
    - Covers FM radio and UHF and VHF television

Multiplexing

- Capacity of transmission medium usually exceeds capacity required for transmission of a single signal
- Multiplexing - carrying multiple signals on a single medium
  - More efficient use of transmission medium

Multiplexing



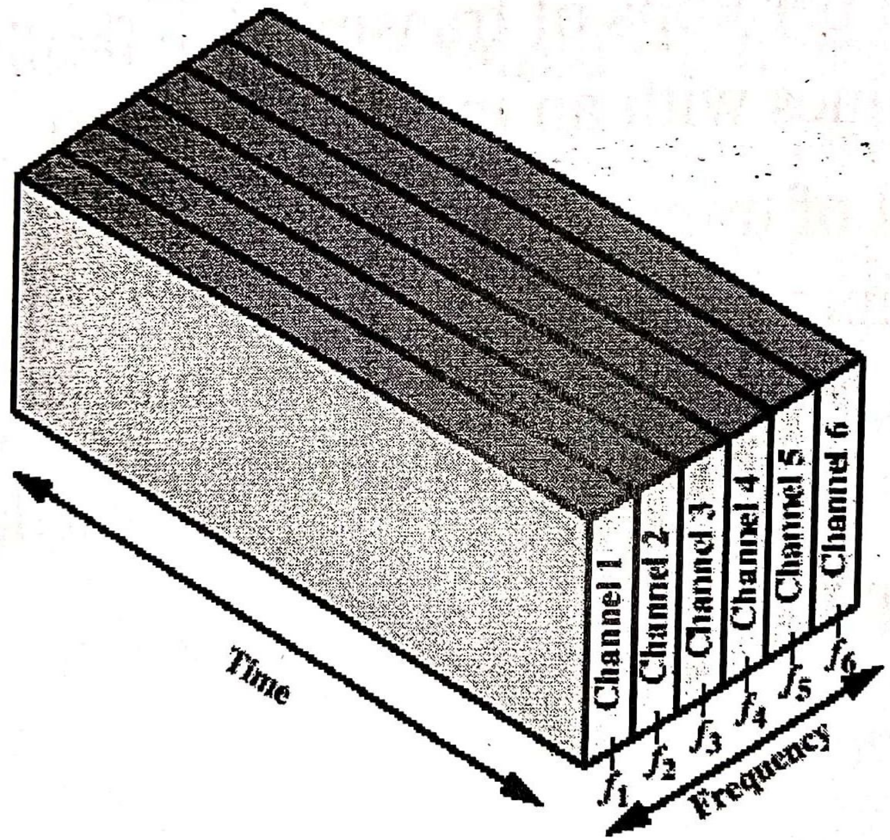
Reasons for Widespread Use of Multiplexing

- Cost per kbps of transmission facility declines with an increase in the data rate
- Cost of transmission and receiving equipment declines with increased data rate
- Most individual data communicating devices require relatively modest data rate support

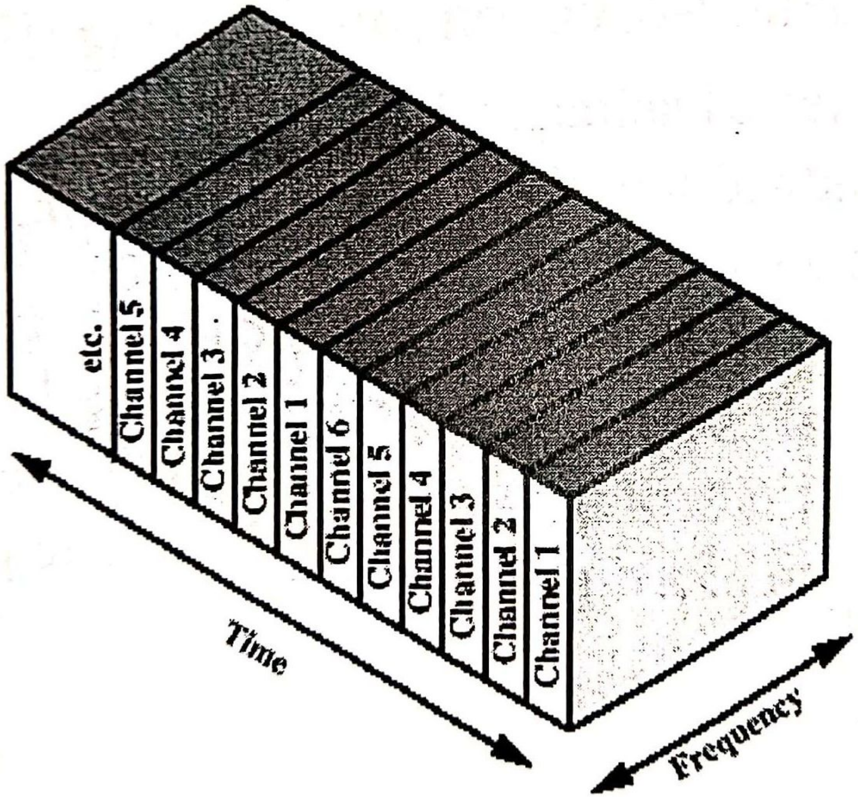
Multiplexing Techniques

- Frequency-division multiplexing (FDM)
  - Takes advantage of the fact that the useful bandwidth of the medium exceeds the required bandwidth of a given signal
- Time-division multiplexing (TDM)
  - Takes advantage of the fact that the achievable bit rate of the medium exceeds the required data rate of a digital signal

Frequency-division Multiplexing



Time-division Multiplexing



←

اقلب الصفحات يلي بدون
نوتس ما اجى عليهم اسئلة
وماركز عليهم كتير الدكتور

Communication Networks

Chapter 3

Types of Communication Networks

- Traditional
  - Traditional local area network (LAN)
  - Traditional wide area network (WAN)
- Higher-speed
  - High-speed local area network (LAN)
  - Metropolitan area network (MAN)
  - High-speed wide area network (WAN)

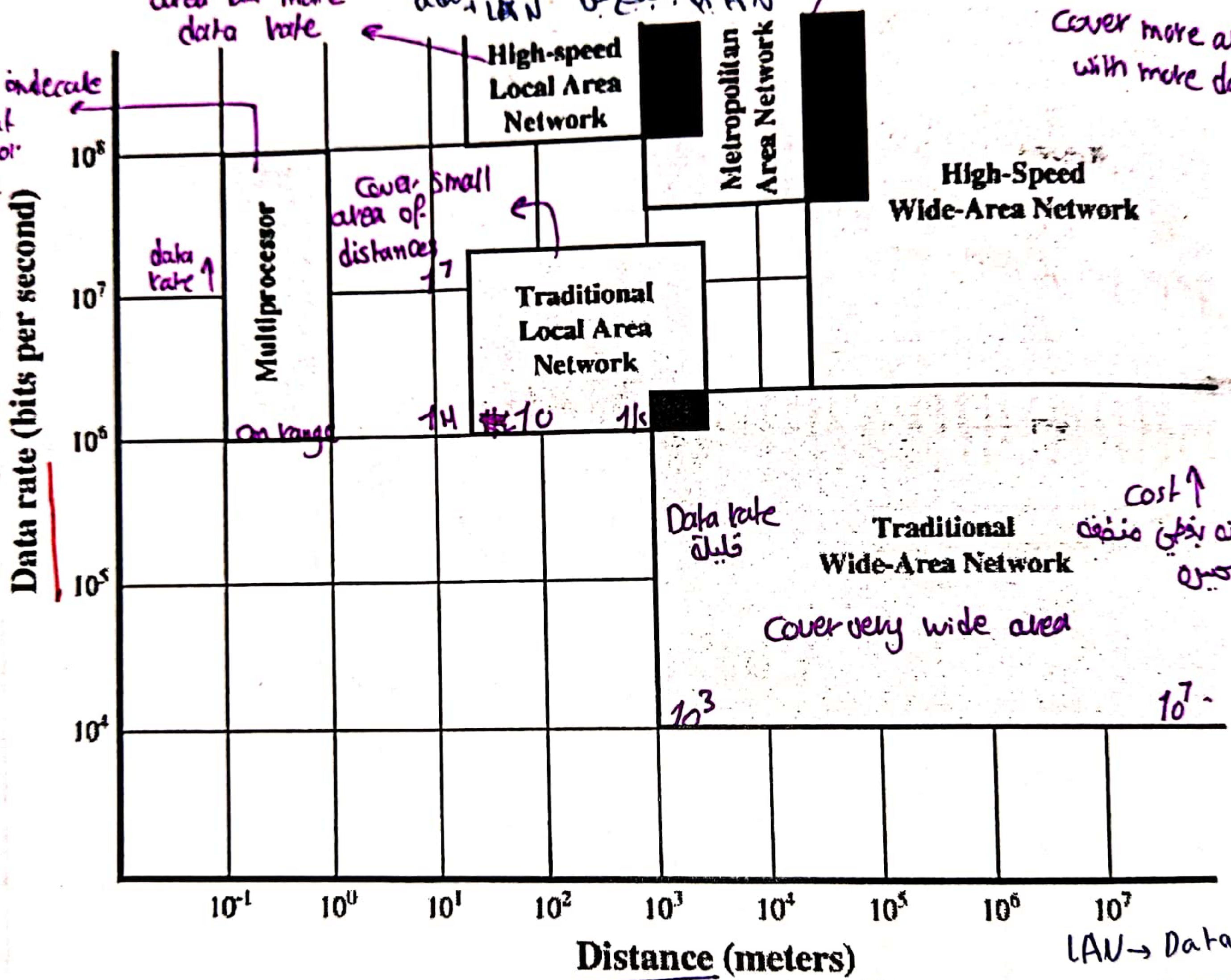


Figure 3.1 Comparison of Multiprocessor Systems, LANs, MANs, and WANs

Characteristics of WANs

- Covers large geographical areas
- Circuits provided by multiple carriers
- Consists of interconnected switching nodes
- Traditional WANs provide modest capacity
  - 64,000 bps common
  - Business subscribers using T-1 service – 1.544 Mbps common
- Higher-speed WANs use optical fiber and transmission technique known as asynchronous transfer mode (ATM)
  - 10s and 100s of Mbps common

Characteristics of LANs

- Like WAN, LAN interconnects a variety of devices and provides a means for information exchange among them

  within building like university

  base on shared link not switching link
- Traditional LANs
  - Provide data rates of 1 to 20 Mbps
- High-speed LANS
  - Provide data rates of 100 Mbps to 1 Gbps

Differences between LANs and WANs

- Scope of a LAN is smaller
  - LAN interconnects devices within a single building or cluster of buildings
- LAN usually owned by one organization that owns the attached devices
  - For WANs, most of network assets are not owned by same organization
- Internal data rate of LAN is much greater

one company

↑cost WAN
↑ Data rate LAN

The Need for MANs

- Traditional point-to-point and switched network techniques used in WANs are inadequate for growing needs of organizations
- Need for high capacity and low costs over large area
- MAN provides:
  - Service to customers in metropolitan areas
  - Required capacity
  - Lower cost and greater efficiency than equivalent service from telephone company

Switching Terms

- Switching Nodes:
  - Intermediate switching device that moves data
  - Not concerned with content of data
- Stations:
  - End devices that wish to communicate
  - Each station is connected to a switching node
- Communications Network:
  - A collection of switching nodes

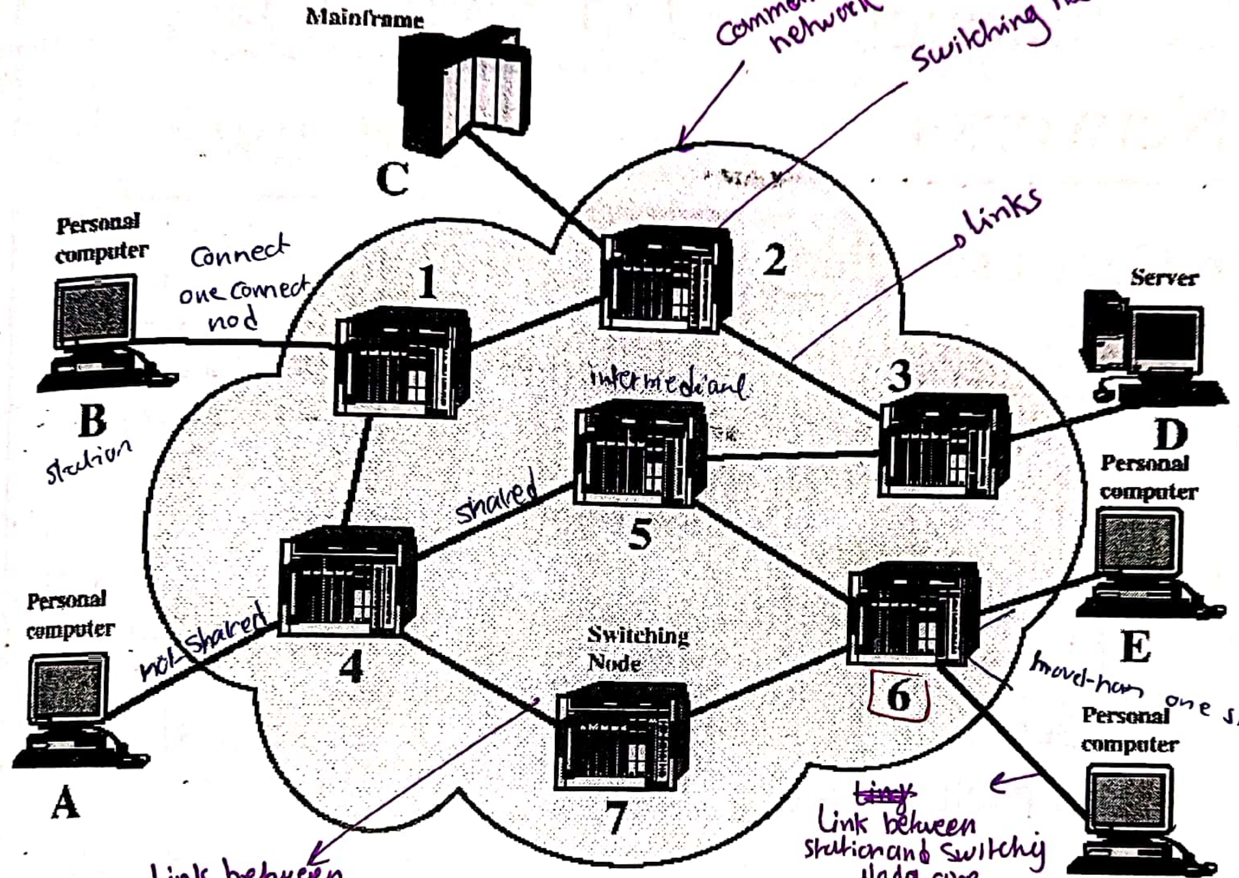


Figure 3.3 Simple Switching Network

end user = station

* each station connect with network through switching node (label by number)

* not fully connected

I ain't have seperated link or connection of each pair of station

I can't support this

not provid uniq bath for every station

no Folling (goal)

C - D 2, 3

B → D

1, 2, 3 node

Observations of Figure 3.3

Observations of Figure 3.3

- Some nodes connect only to other nodes (e.g., 5 and 7)
- Some nodes connect to one or more stations
- Node-station links usually dedicated point-to-point links
- Node-node links usually multiplexed links
  - Frequency-division multiplexing (FDM)
  - Time-division multiplexing (TDM)
- Not a direct link between every node pair
  - Network is not fully connected
  - More than one path is desirable for each pair of stations

Techniques Used in Switched Networks

- Circuit switching
  - Dedicated communications path between two stations
  - E.g., public telephone network
- Packet switching
  - Message is broken into a series of packets
  - Each node determines next leg of transmission for each packet

Phases of Circuit Switching

Phases of Circuit Switching

- Circuit establishment
  - An end to end circuit is established through switching nodes (dedicate path)
  - Routing information, Availability, Cost
- Information Transfer
  - Information transmitted through the network
  - Data may be analog voice, digitized voice, or binary data
- Circuit disconnect
  - Circuit is terminated (requested by one of the stations)
  - Each node deallocates dedicated resources

* adv: ① less delay
② transparent path (connection) any node or link failler we can find directly
③ sheap intermediant node

what type of delay that use in circuit switch?
① call setup time (delay)
② propagation delay: time needed to cost over distance — distance / speed
③ transmission delay: time nedded to put data over link — data size / data rate

Characteristics of Circuit Switching

- Can be inefficient:
  - Channel capacity dedicated for duration of connection (some connections can be blocked)
  - Utilization not 100% (idle connection)
  - Delay prior to signal transfer for establishment (for call setup)
- Once established, network is transparent to users
- Information transmitted at fixed data rate with only propagation delay

* disadv: ① line efficency low (not use full resource) because the link dedicated
② fixed data rate, Two user should connect in the same data link. and call setup time
③ not full connected (blocked) connection busy

Components of Public Telecommunications Network

- Subscribers - devices that attach to the network; mostly telephones
- Subscriber line - link between subscriber and network
  - Also called subscriber loop or local loop
- Exchanges - switching centers in the network
  - A switching centers that support subscribers is an end office
- Trunks - branches between exchanges

packetize data and each packe contain payload and control then send over network.

How Packet Switching Works

- Data is transmitted in blocks, called packets
- Before sending, the message is broken into a series of packets:
  - Typical packet length is 1000 octets (bytes)
  - Packets consists of a portion of data plus a packet header that includes control information
- At each node in a route, packet is received, stored briefly and passed to the next node

① Virtual cct ② datagram cct
reserve the link and all packet should go in the same path
packet go to different path and inter node should forward the packet to go the next hop.

variable لا يفصل packets

protocol الـ حسب overhead

informal الـ تكون
SID, DID, time, address, MAC, security inf .....
error detection

stored so we don't have delay because the heavy trafic

header الـ و payload الـ fixed size حسب البروتوكل تكون عندي

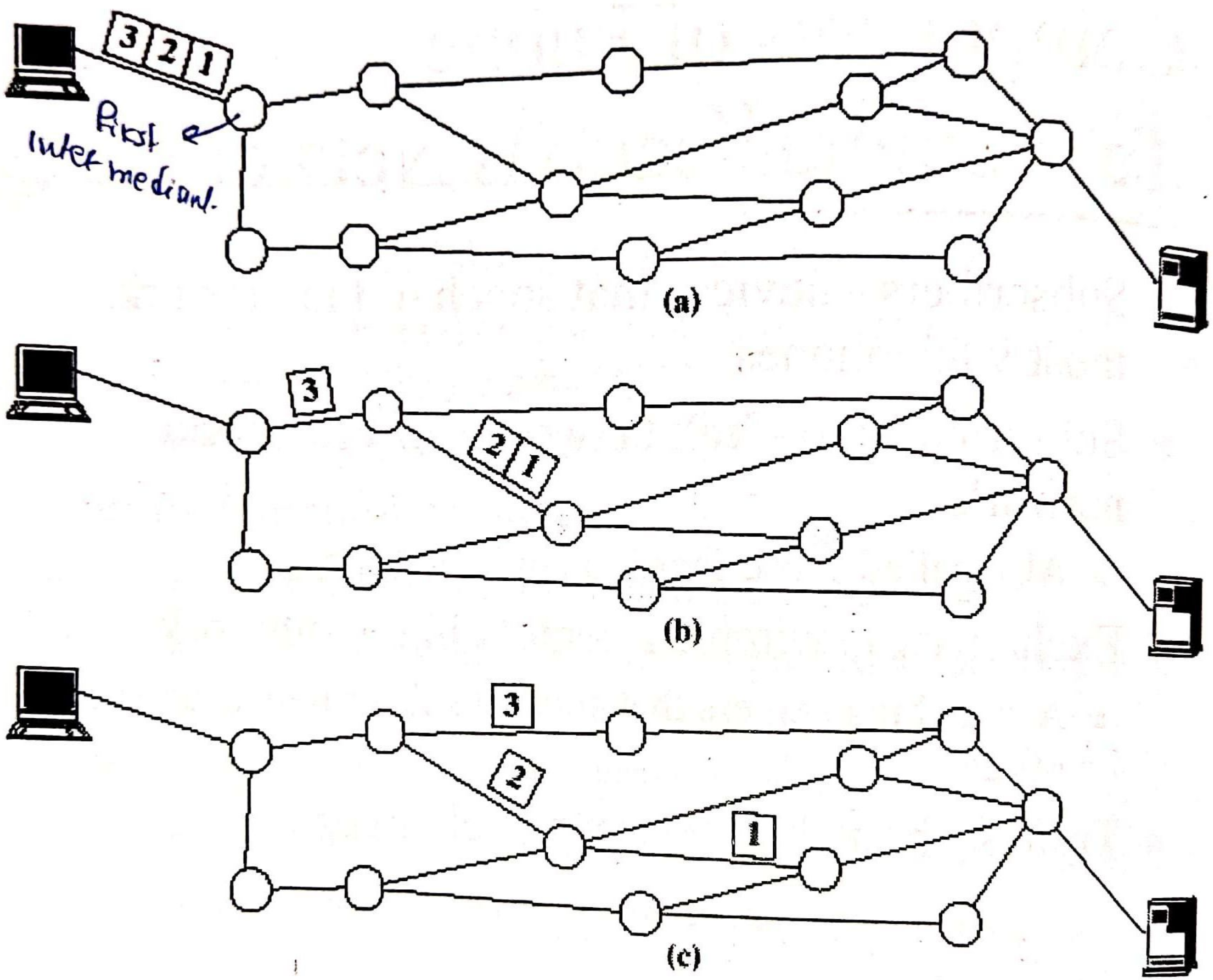


Figure 3.7 Packet Switching: Datagram Approach

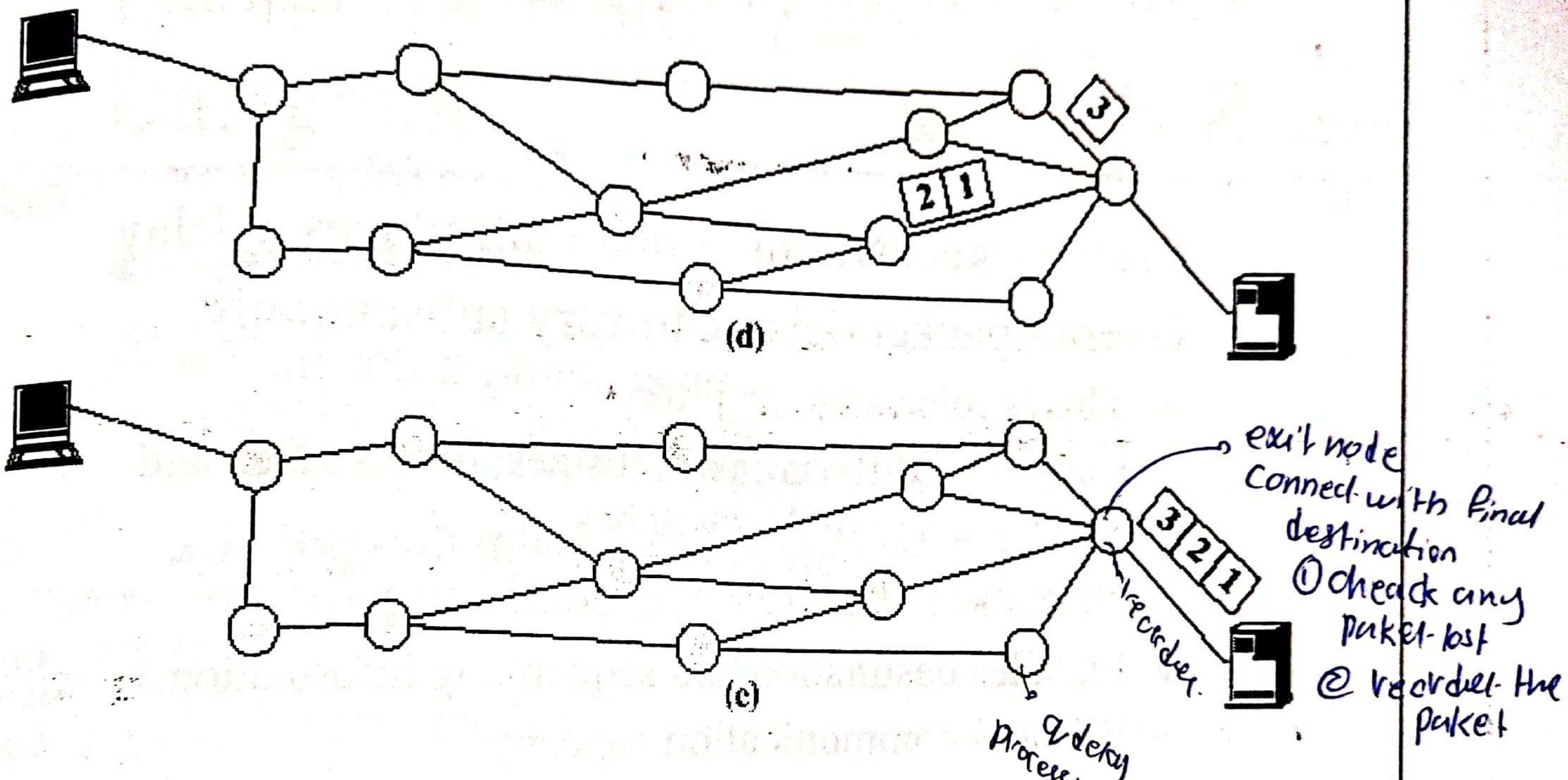


Figure 3.7 Packet Switching: Datagram Approach

circuit switch ... send the packe

Packet Switching Advantages

- Line efficiency is greater
  - Many packets over time can dynamically share the same node to node link
- Packet-switching networks can carry out data-rate conversion
  - Two stations with different data rates can exchange information
- Unlike circuit-switching networks that block calls when traffic is heavy, packet-switching still accepts packets, but with increased delivery delay
- Priorities can be used

Disadvantages of Packet Switching

buffer delay ، process delay عندنا هان

- Each packet switching node introduces a delay
- Overall packet delay can vary substantially:
  - This is referred to as jitter
  - Caused by differing packet sizes, routes taken and varying delay in the switches

header overhead ايضا control inform نرسل

- Each packet requires overhead information
  - Includes destination and sequencing information
  - Reduces communication capacity

smart بدنا intermedent node

- More processing required at each node (intelligent node)

datagram and Virtual cct

paket الحوشي رح يرسلوا ال data ع شكل

Packet Switching Networks -

Packet Switching Networks - Datagram

- Each packet treated independently, without reference to previous packets
- Each node chooses next node on packet's path
- Packets don't necessarily follow same route and may arrive out of sequence
- Exit node restores packets to original order
- Responsibility of exit node or destination to detect loss of packet and how to recover

Packet Switching Networks – Datagram

- Advantages:
  - (1) Call setup phase is avoided (ماعنا)
  - Because it's more primitive (simple), it's more flexible
  - Datagram delivery is more reliable
    - Node failure
    - Link congestion

بيعت ال data directly

ازا صار عندي node failure ال intermediate بترسل ال packet ل node ثانية عادي

اما ال virtual لازم نمشي بنفس ال path وازا صار عند fail لازم ارجع لل source لاتي يغير ال path

ال path
وإذا صار عند fail
لازم ارجع لل source
لتى يغير ال path

Packet Switching Networks – Virtual Circuit

send packet in the same path

- Preplanned route established before packets sent
- All packets between source and destination follow this route
- Routing decision not required by nodes for each packet
- Emulates a circuit in a circuit switching network but is not a dedicated path
  - Packets still buffered at each node and queued for output over a line
  - Packets from other connections can share the same path

الاختلاف انه ال virtual circuit بتبعت pakel عكس ال circuit switching

وكمان ال path مابكون dedicated لإلها فقط ع عكس ال circuit switching

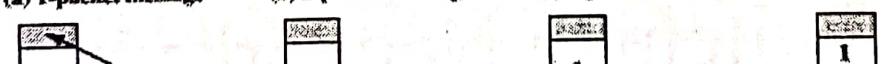
Packet Switching Networks – Virtual Circuit

- Advantages:
  - Packets arrive in original order
  - Packets arrive correctly (e.g. retransmission)
  - Packets transmitted more rapidly without routing decisions made at each node

less processing

مثل ال datagram لانه عندي process intermediat

(a) 1-packet message (b) 2-packet message (c) 5-packet message (d) 10-packet message



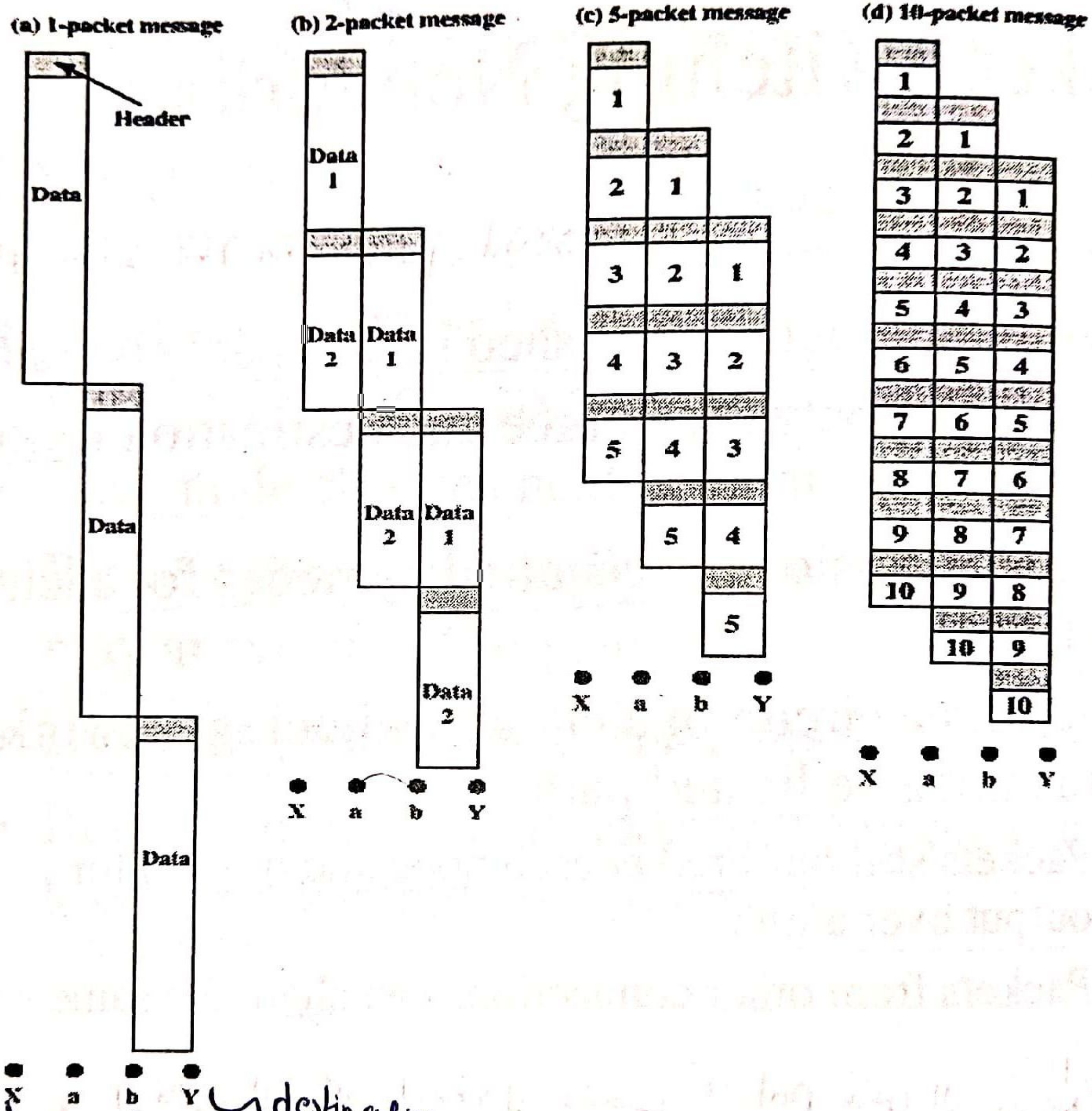
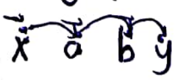


Figure 3.9 Effect of Packet Size on Transmission Time

Effect of Packet Size on Transmission

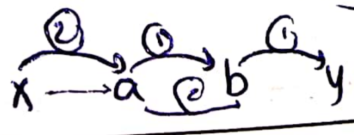
transmission delay = packet size / data rate

- Breaking up packets decreases transmission time because transmission is allowed to overlap
  يقرب ب عدد ال packet اذا بدي احسب لكل ال paket
- Figure 3.9a
  - Entire message (40 octets) + header information (3 octets) sent at once
    40 byte — overhead — byte
    اذا بدي ارسلها مرة واحدة ال size كم
  - Transmission time: 129 octet-times
    Paket size = 43 byte
    and I want to send it over network have 2 intermediate network
- Figure 3.9b
  $\frac{40}{2} = 20$
  - Message broken into 2 packets (20 octets) + header (3 octets)
    user data — constant
    23 bytes x 4
  - Transmission time: 92 octet-times
    ال transmission بنحسب عند كل node بتعمل forward



one packet size = 23 byte

قل ال transmission delay



بزيادة ال packet size بنزيد ال transmission delay ولكن ليس forever

4 transmission

x بيبعث 2, a بتبعث وحدة, b بتبعث وحدة = 4

Effect of Packet Size on

Effect of Packet Size on Transmission

- Figure 3.9c
  - Message broken into 5 packets (8 octets) + header (3 octets)
  - Transmission time: 77 octet-times
- Figure 3.9d
  - Making the packets too small, transmission time starts increases
  - Each packet requires a fixed header; the more packets, the more headers

Q6) Explain the difference between datagram and virtual circuit operation.

1. In virtual circuit, we have a call setup to establish a path for all the packets, then all the packets go through the same path. They reach the destination ordered. This is faster than datagram switching.
2. In the datagram approach, each packet is treated independently, and doesn't follow the same path as the one before, the packets reach the destination unordered, it is slower than virtual circuit, but it does not require setup phase, and it is more reliable in case of failure.

***Q26) What is the difference between Circuit switching and Virtual Circuit switching? Which one has a higher efficiency?**

1. Circuit switching: does not split data into packets, it streams the data. Path is dedicated and other connections can't use the resources until it is released. It is faster (less delays) but less efficient.

2. Virtual circuit switching: splits data into packets and sends them. Path is not reserved, other connections may send data through it, which introduces delay (buffering delay at switching nodes). It is slower but more efficient.

* delay for circit switching = call setup + propagation delay + Transmission delay

$\Rightarrow C + N$ (Number of hope) $\times D$ (propagation delay) $+ L$ (message length) $/ B$ (data rate)

delay for datagram packet =

$D_1 + D_2 + D_3 + D_4$

$\downarrow$

N (number of hope) * $\frac{P \text{ (fixed packet size)}}{B \text{ (data rate)}}$ + D (prop. delay)

$D_2 = D_3 = D_4 \Rightarrow \frac{P}{B} + D$

$\rightarrow$ ~~##P~~ $N * \frac{P}{B} + D + \left(\frac{P}{B} + B\right) + \left(\frac{P}{B} + D\right) + \left(\frac{P}{B} + D\right)$

Virtual $\longrightarrow$ زي ال datagram

ولكن بعمل ال call setup

Q7: Define the following parameters for a switching network:
N = number of hops between two given end systems
L = message length in bits
B = data rate, in bits per second (bps), on all links
P = fixed packet size, in bits
H = overhead (header) bits per packet
S = call setup time (circuit switching or virtual circuit) in seconds
D = propagation delay per hop in seconds
For $N = 4, L = 3200, B = 9600, P = 1024, H = 16, S = 0.2, D = 0.001$, compute the end-to-end delay for circuit switching, virtual circuit packet switching, and datagram packet switching. Assume that there are no acknowledgments. Ignore processing delay at the nodes.

Circuit Switching

$T = C_1 + C_2$ where
C_1 = Call Setup Time

-8-

C_2 = Message Delivery Time
$C_1 = S = 0.2$
C_2 = Propagation Delay + Transmission Time
$= N \times D + L/B$
$= 4 \times 0.001 + 3200/9600 = 0.337$
$T = 0.2 + 0.337 = 0.537$ sec

Datagram Packet Switching

$T = D_1 + D_2 + D_3 + D_4$ where 4 Ds -> number of hops
D_1 = Time to Transmit and Deliver all packets through first hop
D_2 = Time to Deliver last packet across second hop
D_3 = Time to Deliver last packet across third hop
D_4 = Time to Deliver last packet across forth hop

here are $P - H = 1024 - 16 = 1008$ data bits per packet. A message of 3200 bits equires four packets (3200 bits/1008 bits/packet = 3.17 packets which we round p to 4 packets).

$D_1 = 4 \times t + p$ where 4 -> number of packets
t = transmission time for one packet
p = propagation delay for one hop
$D_1 = 4 \times (P/B) + D$
$= 4 \times (1024/9600) + 0.001$
$= 0.428$
$D_2 = D_3 = D_4 = t + p$
$= (P/B) + D$
$= (1024/9600) + 0.001 = 0.108$
$T = 0.428 + 0.108 + 0.108 + 0.108$
$= 0.752$ sec

For virtual circuit delay, add call setup time to datagram delay (0.752 + 0.2 = 0.952)

Protocols and the TCP/IP Suite

Chapter 4

Key Features of a Protocol

- Syntax
  - Concerns the format of the data blocks
- Semantics
  - Includes control information for coordination and error handling
- Timing
  - Includes speed matching and sequencing

data of the user that I need to change or delivery to the final distination (Content of data and how to present the data)

header

user data + Control information

Agents Involved in Communication

- Applications program of sofware that run over user station and generat data
  - Exchange data between computers (e.g., electronic mail)
- Computers user station
  - Connected to networks
- Networks connect of diffrant links and nods
  - Transfers data from one computer to another

1

TCP/IP Layers

stands for Internet protocol

split communication stack in 5 layers

5 layers

- assign different protocol to each layers and each layers assign to do something function

low 1) ■ Physical layer

2) ■ Network access layer

3) ■ Internet layer (IP)

4) ■ Host-to-host, or transport layer (TCP)

higher 5) ■ Application layer

TCP/IP Physical Layer

- Covers the physical interface between a data transmission device and a transmission medium or network
- Physical layer specifies:
  - Characteristics of the transmission medium
  - The nature of the signals
  - The data rate
  - Other related matters (modulation, encoding, ..)

how to access the channel? data link layer
type of connection

TCP/IP Network Access Layer

- Concerned with the exchange/access of data between an end system and the network to which it's attached
- Routing within the same network
- Other services like priorities
- Not concerned about the type of transmission medium
- Protocol used depends on type of network:
  - Circuit switching
  - Packet switching (e.g., ATM)
  - LANs (e.g., Ethernet)
  - Others

responce for the type of Network communication not for transmission medim

using MAC address

and exchange

use MAC address

and how to exchang the packet within the same type of network

- LANs (e.g., Ethernet)
- Others

change the الراوتر بعدل MAC address to the final distination or to the next router

TCP/IP Internet Layer

end station موجود بال and router not in Intermediary

- Uses internet protocol (IP) — version 4 → connect two diffrent networks; version 6
- Provides routing functions to allow data to traverse multiple interconnected networks
- Not concerned about the type of the network
- Implemented in end systems *and* routers
- IPv4, IPv6

responsiple for rout the packet through different type of network

ما بتهتم بنوع ال transmission medium communicator ولا بنوع ال network

مسؤولة عن نقل ال IP packet باستخدام ال different network ل

لا الnode تكون بداخل ال network فقط تكون اوالها 2 network اول ما تكون اولها Layer 3

عدد الاجهزة اكثر من 2^{32} 4G

solution for the problem that have local address for many divice

another solution IPv6 2^{128}

So I can support many device

سبب التسمية لوجود أشهر
TCP and IP 2 protocol
in layer 4 in layer 3

TCP/IP Host-to-Host, or Transport Layer

. not consider about the type of transmission medium
. not consider about the type of communication network
. not consider about how to delivy the packet through different network

- Commonly uses transmission control protocol (TCP) direct logic link between two station
- Provides reliability during data exchange:
  - Completeness/ correctness
  - Ordering/ sequencing

how to deliy the data in correct way and completeness within time implementation and how to represent the data

Tcp: Connection orianted
UDp: " less
↳ ما عنو correctness and completeness بال
بيهتم بال time
(Faster processing)

↳ send in the sam order and recive completly using connection and error detection and with time

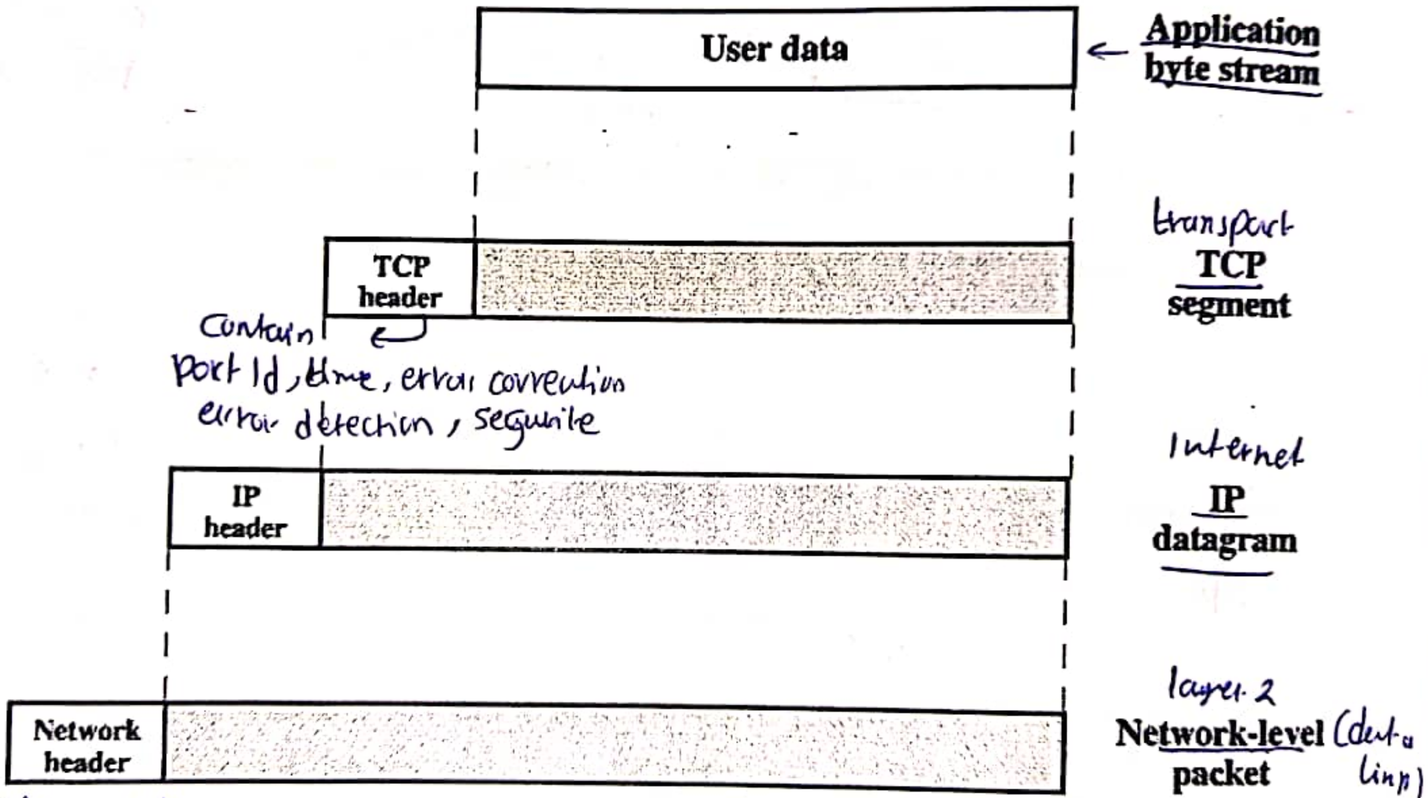
TCP/IP Application Layer

- Logic supports user applications:

how to generate the packet from different user application

- Simple mail transfer protocol (SMTP)
  - Provides a basic electronic mail facility
- File Transfer Protocol (FTP)
  - Allows files to be sent from one system to another
- TELNET
  - Provides a remote logon capability

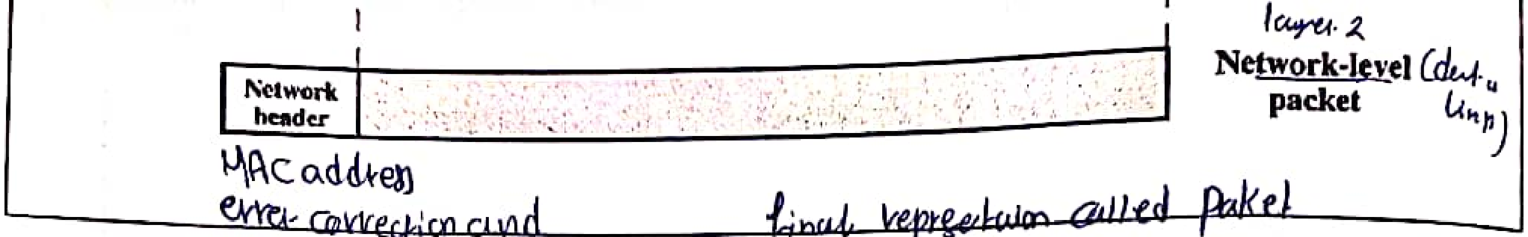
Protocol Data Units (PDUs)



MAC address
error correction and
error detetion
schedaling

final represetation called paket

has several



MAC address
error correction and
error detection
scheduling
final representation called packet

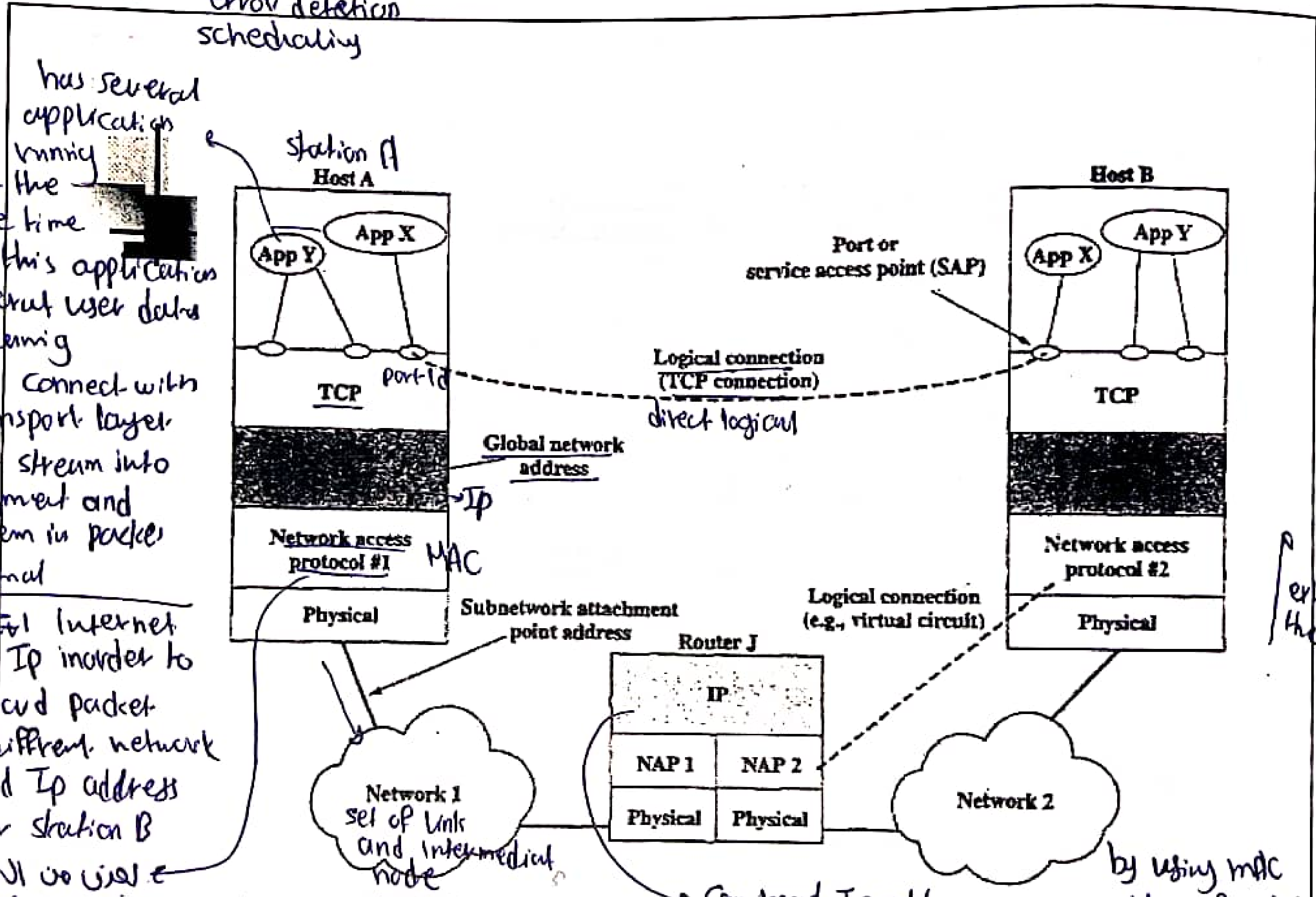


Figure 4.1 TCP/IP Concepts

has several application running at the same time and this applications general user data streaming and connect with transport layer split stream into segment and put them in packet format

Internet add Ip inorder to Forward packet in different network add Ip address for station B

الـ Ip بيعرف ان الـ station موجود B
في الـ network
غير عنوان الـ MAC
الـ address للـ router الي connect networks

Can read Ip address and understand the final station is B

So change the MAC address from it's address created to MAC // for B

by using MAC address for station B it's forward the massage.

Layers of the OSI Model

open system Interconnection

7 layers

1) ■ Application
2) ■ Presentation
3) ■ Session
4) ■ Transport
5) ■ Network
6) ■ Data link
7) ■ Physical

OSI Application Layer

generat user data

- Provides access to the OSI environment for users
- Provides distributed information services

transport layer - presentation
session
transport

OSI Presentation Layer

split data into packet

- Provides independence to the application processes from differences in data representation (syntax)

represent user data in certain packet format

OSI Session Layer

mange session

manage port id, session, time from each application

- Provides the control structure for communication between applications
- Establishes, manages, and terminates connections (sessions) between cooperating applications

the way more proffesional in OSI

OSI Transport Layer

transfer data correctness

- Provides reliable, transparent transfer of data between end points
- Provides end-to-end error recovery and flow control

OSI Network Layer (deliver packet to final destination)

routing packet from network

- Provides upper layers with independence from the data transmission and switching technologies used to connect systems
- Responsible for establishing, maintaining, and terminating connections

OSI Data link Layer

just for access channel
not exchange
access channel

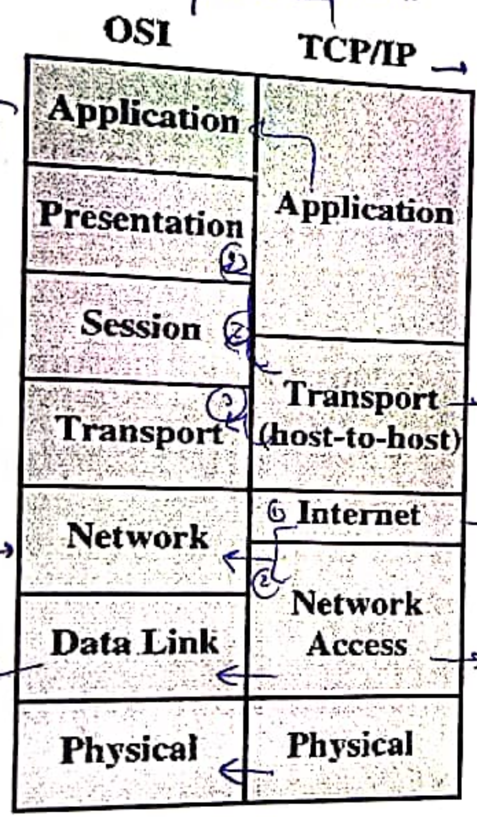
- Provides for the reliable transfer of information across the physical link
- Sends blocks (frames) with the necessary synchronization, error control, and flow control

OSI Physical Layer

type of transmission medium

- Concerned with transmission of unstructured bit stream over physical medium
- Deals with accessing the physical medium:
  - Mechanical characteristics
  - Electrical characteristics
  - Functional characteristics
  - Procedural characteristics

Comparison of OSI and TCP/IP



What is the better? both of them do the same task
the TCP/IP less complex and less header (overhead)
5 layers
and it's the design first

TCP/IP Architecture Dominance

Q8) **What are some advantages to layering as seen in the TCP/IP architecture?

TCP is less complex than OSI model because it uses less layers.

Q9) List the major disadvantages of the layered approach to protocols and give a solution to it.

1. Having many layers requires us to add lots of headers and control information, which is an overhead that takes away from the capacity of the channel.
2. Encapsulation and decapsulation take time.
3. It makes the system more complex.

One solution could be merging multiple layers into one layer, that way it removes complexity and overhead.

**** Q10) A TCP segment consisting of 1500 bits of data and 160 bits of header is sent to the IP layer, which appends another 160 bits of header. This is then transmitted through two networks, each of which uses a 24-bit packet header. The destination network has a maximum packet size of 800 bits. How many bits, including headers, are delivered to the network layer protocol at the destination?**

Data plus transport header plus internet header equals 1820 bits. This data is delivered in a sequence of packets, each of which contains 24 bits of network header and up to 776 bits of higher-layer headers and/or data. Three network packets are needed. Total bits delivered = $1820 + 3 \times 24 = 1892$ bits.

b. (EIRP)=Pt x Gt = 0.1 W x 351.85 = 35.185 W

c.

$$\frac{P_t}{P_r} = \frac{(4\pi)^2(d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$ = 32,654,616 * 1000 = 32,654,616,000

10 log(32,654,616,000) = 105 dBm

The transmitter power, in dBm is 10 log (100) = 20 dBm

The available received signal power is 20 – 105 = -85 dBm design first

TCP/IP Architecture Dominance

- TCP/IP protocols matured quicker than similar OSI protocols
  - When the need for interoperability across networks was recognized, only TCP/IP was available and ready to go
- OSI model is unnecessarily complex
  - Accomplishes in seven layers what TCP/IP does with fewer layers

Internetworking Terms

- Internet – collection of communication networks, interconnected by bridges/routers
- Intranet – internet used by an organization for internal purposes
  - Provides key Internet applications
  - Can exist as an isolated, self-contained internet
- Bridge – an IS used to connect two LANs that use similar LAN protocols
- Router – an IS used to connect two networks that may or may not be similar

****Q25) What is the difference between the bridge and router?**

Bridge: used to connect two LANs that use similar LAN protocols.

Router: used to connect two networks that may or may not be similar.

Antennas and Propagation

Chapter 5

Introduction

- An antenna is an electrical conductor or system of conductors
  - Transmission - radiates electromagnetic energy into space
  - Reception - collects electromagnetic energy from space
- In two-way communication, the same antenna can be used for transmission and reception

convert signal from electrical wave to electromagnetic wave in transmission and reverse in the reception (collect electromagnetic wave and conve it to electrical signal) in the same antenna

any wirless device antenna

Radiation Patterns

- Radiation pattern
  - Graphical representation of radiation properties of an antenna
  - Depicted as two-dimensional cross section
- Beam width (or half-power beam width)
  - Measure of directivity of antenna
- Reception pattern
  - Receiving antenna's equivalent to radiation pattern

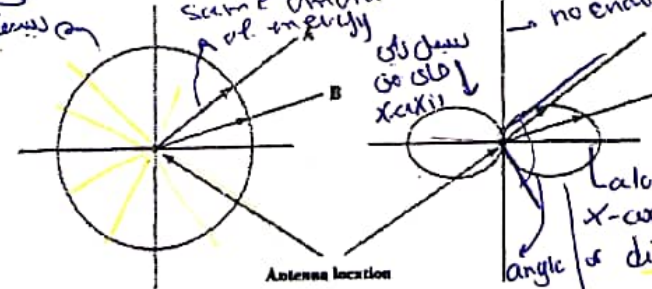
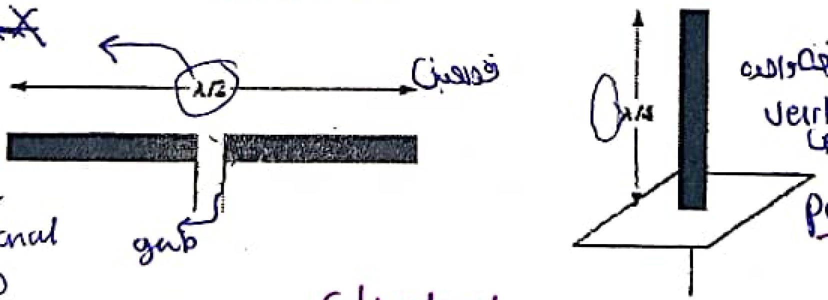


Figure 5.1 Idealized Radiation Patterns

Types of Antennas

- Isotropic antenna (idealized) (omnidirectional)
  - Radiates power equally in all directions
- Dipole antennas
  - Half-wave dipole antenna (or Hertz antenna)
  - Quarter-wave vertical antenna (or Marconi antenna)



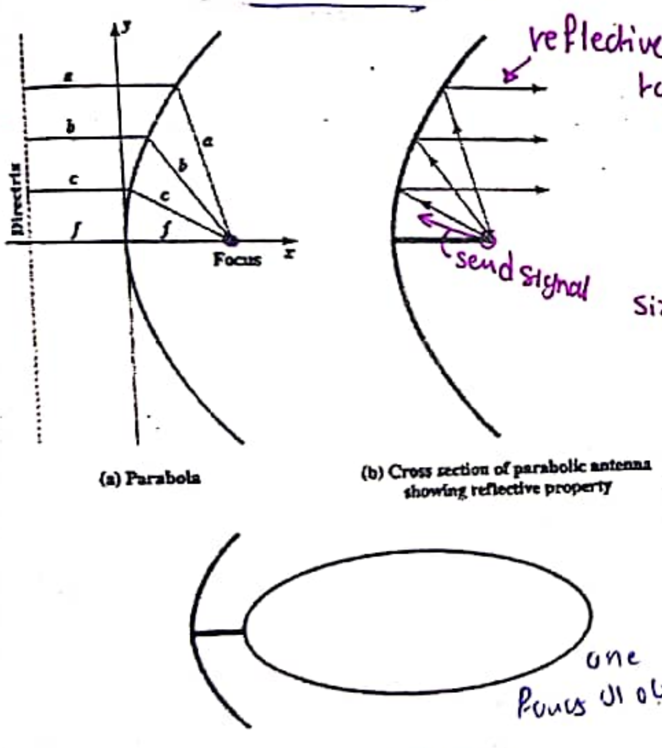
(a) Half-wave dipole (directional antenna) (b) Quarter-wave antenna

Figure 5.2 Simple Antennas

cross section
circul تدخين شكلها
in the same amount of energy of signal and in all direction
certain angle of direction through angle direction
for any direction I can transimate or recive (function of space)
2 base of condoctor with small gab between them total length = λ/2
$\lambda = T \times C = \frac{C}{F}$ (C = speed of light, F = freq)
one base of conductor, the length = λ/4
portable device
vertical
gab

Types of Antennas

- Parabolic Reflective Antenna



(a) Parabola

(b) Cross section of parabolic antenna showing reflective property

(c) Cross section of parabolic antenna showing radiation pattern

Figure 5.4 Parabolic Reflective Antenna

Table 5.1 Antenna Beamwidths for Various Diameter Parabolic Reflective Antennas at f = 12 GHz [FREE97]

Antenna Diameter (m)	Beam Width (degrees)
0.5	3.5
0.75	2.33
1.0	1.75
1.5	1.166
2.0	0.875
2.5	0.7
5.0	0.35

size — angle — directivity ↑ directivity (angle)

directivity ↑
① f ↑
② surface area ↑
③ chap of antina

كل ما كان ال area لل parabolic antenna اكبر كل ما كان ال Beam width اصغر

كل ما قلت ال angle ال directivity بتكون اعلى

[illegible]

$10 \log(R) = dB$

$10 \log_{10}(R) = 3 \rightarrow \log_{10}(R) = 0.3$

$10 \log_{10}(R) = 3$

$R = 10^{0.3} = ②$

(c) Cross section of parabolic antenna showing radiation pattern

Figure 5.4 Parabolic Reflective Antenna

Antenna Gain

- Antenna gain
  - Power output, in a particular direction, compared to that produced in any direction by a perfect omnidirectional antenna (isotropic antenna)
  - if an antenna has a gain of 3dB, then it improves upon the isotropic antenna in that direction by 3dB, or a factor of 2
  - At the expense of other directions.
- Effective area
  - Related to physical size and shape of antenna

Antenna Gain

- Relationship between antenna gain and effective area:

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

- G = antenna gain
- A_e = effective area
- f = carrier frequency
- c = speed of light ($\leq 3 \times 10^8$ m/s)
- λ = carrier wavelength

Table 5.2 Antenna Gains and Effective Areas [COUC01]

Type of Antenna	Effective Area A_e (m^2)	Power Gain (relative to isotropic)
Isotropic	$\lambda^2/4\pi$	1
Infinitesimal dipole or loop	$1.5\lambda^2/4\pi$	1.5
Half-wave dipole	$1.64\lambda^2/4\pi$	1.64
Horn, mouth area A	$0.81A$	$10A/\lambda^2$
Parabolic, face area A	$0.56A$	$7A/\lambda^2$
Turnstile (two crossed perpendicular dipoles)	$1.15\lambda^2/4\pi$	1.15

Turnstile (two crossed perpendicular dipoles)	$1.15\lambda^2/4\pi$	1.15

Propagation Modes

1) Ground-wave propagation

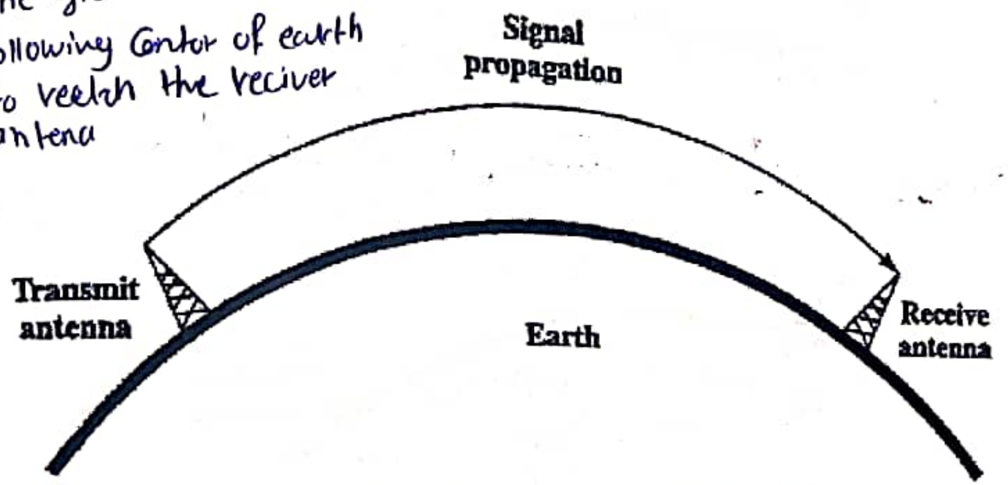
2) Sky-wave propagation

3) Line-of-sight propagation

Ground Wave Propagation

the way of signal transfer.

signal transsmit above the graund of earth following contor of earth to reach the reciver antena



(a) Ground wave propagation (below 2 MHz)

Freq. of signal should be below 2 MHz

- the signal can travel very long distance using this way

becouse 3 reson ① when signal travel above the ground with signal below 2 MHz reduce current from the ground this current give inf power to signal to travel long distance (current indection)

② Signal when hit the edge of large opject size signal will bend to world earth surface (difraction)

③ when signal travel to world the sky it will be skaterd because the freq small so it hit the small size opstical from the sky

Wave Propagation

... this way
because 3 reson ① when signal travel above the ground with signal below 2 MHz reduce current from the ground this current give inf power to signal to travel long distance (current indection)
② signal when hit the edge of large object size signal will bend to world earth surface (difraction)
③ when signal travel to world the sky it will be skaterd because the freq small so it hit the small size opstical from the sky

Ground Wave Propagation

- Follows contour of the earth:
  - The electromagnetic wave induces a current in the earth's surface
  - Diffraction انثناء الموجة الى الارض
- Can Propagate considerable distances
- Frequencies up to 2 MHz
- Example:
  - AM radio

low density

different layer with different density in sky

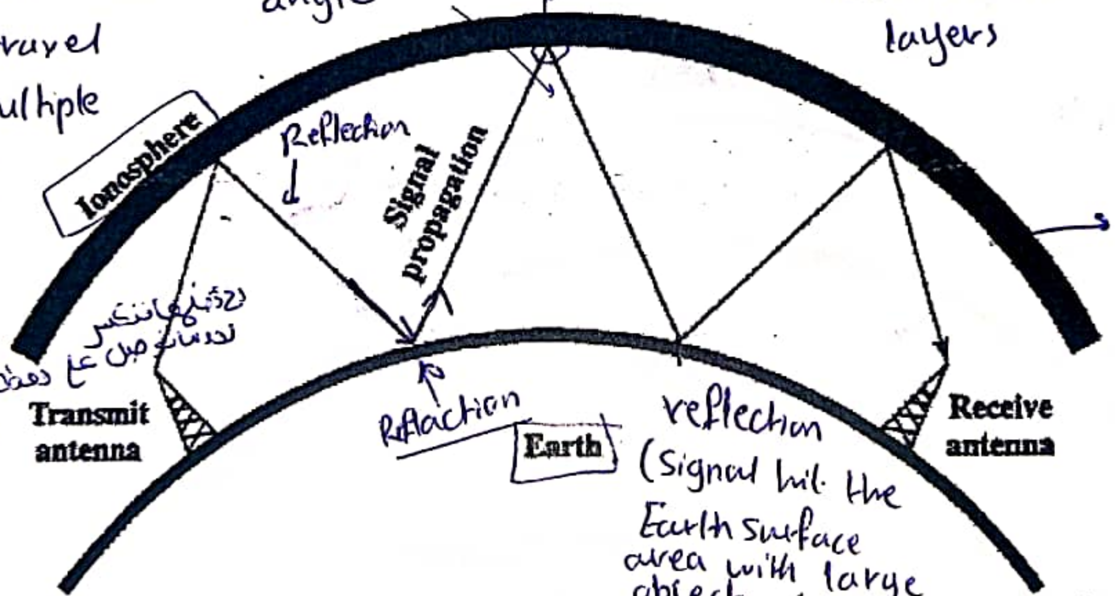
higher layer close to the Earth

Sky Wave Propagation

refraction: change for signal direction for travel diffrent desity of layers

critical angle

signal travel by pulse in multiple hups fourth and back between Earth surface and Ionospher



Reflection

Reflaction

reflection (Signal hit the Earth surface area with large object (chang direction to oppesite direction angle equal

density

Earth

(b) Sky wave propagation (2 to 30 MHz)

scatting

2M freq

ionsphere

Sky Wave Propagation

- Signal reflected from ionized layer of atmosphere back down to earth
- Signal can travel a number of hops, back and forth between ionosphere and earth's surface
- in Ground Reflection effect caused by in sky refraction
- Frequencies up to 30 MHz
- Examples
  - Amateur radio
  - International Broadcast radio

2 antenna (transit and Recive) see each other in order to communicat

Line-of-Sight Propagation

strate line — Device لازم ال وال Tran يشوفوا بعض

maximum distance can be reach between two antenna using line of sight propagation called (optical horizon)

street forward line

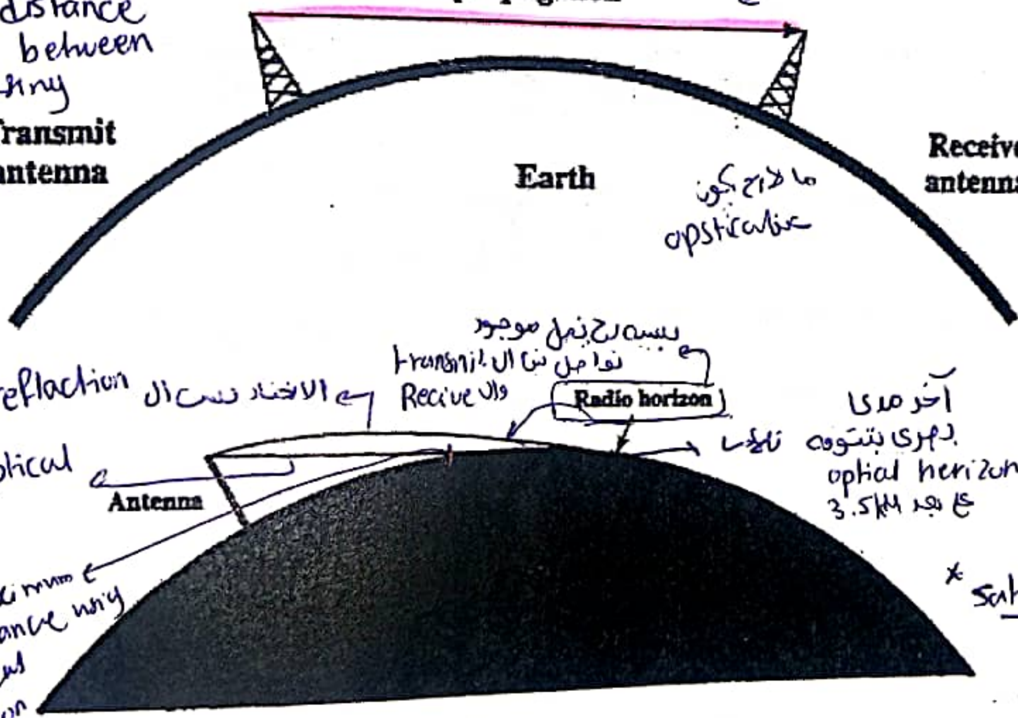


Figure 5.7 Optical and Radio Horizons

taure
* microwave sterial communcation above ground

* satallit comunication

reflaction ال الانحناء

Maximum distance using optical horizon

up 30MHz

Radio horizons larger that optical horizons

طبعا ع افتراض انه ال receiver وال ما الرفع hight

Figure 5.7 Optical and Radio Horizons

Radio horizons larger that optical horizons up 30MHz

طبقا ع الافتراض انه ال receiver مالو hight العالي

Line-of-Sight Propagation

- Transmitting and receiving antennas must be within line of sight:
  - Satellite communication – signal above 30 MHz not reflected by ionosphere
  - Ground communication – antennas within *effective* line of site due to refraction (radio horizon)
- Refraction – bending of microwaves by the atmosphere
  - Velocity of electromagnetic wave is a function of the density of the medium
  - When wave changes medium, speed changes
  - Wave bends at the boundary between mediums

LOS

Line-of-Sight Equations

- Optical line of sight

  $$d = 3.57\sqrt{h}$$

  [km] [m] → high of transmitter.

  assuming the reciver antenna doesn't have any hight above ground

- Effective, or radio, line of sight

  $$d = 3.57\sqrt{Kh}$$

  [km] [m] K constant.

  - d = distance between antenna and horizon (km)
  - h = antenna height (m)
  - K = adjustment factor to account for refraction, rule of thumb K = 4/3

بسبب الRefraction
عاكبر من ١ لانه تكون
عند extend for signal

Line-of-Sight Equations

- Maximum distance between two antennas for LOS propagation:

$$d = 3.57\left(\sqrt{Kh_1} + \sqrt{Kh_2}\right)$$

Example 5.2 The maximum distance between two antennas for LOS transmission if one antenna is 100 m high and the other is at ground level is:

$$d = 3.57\sqrt{Kh} = 3.57\sqrt{133} = 41 \text{ km}$$

Now suppose that the receiving antenna is 10 m high. To achieve the same distance, how high must the transmitting antenna be? The result is:

$$41 = 3.57\left(\sqrt{Kh_1} + \sqrt{13.3}\right)$$

$$\sqrt{Kh_1} = \frac{41}{3.57} - \sqrt{13.3} = 7.84$$

$$h_1 = 7.84^2/1.33 = 46.2 \text{ m}$$

This is a savings of over 50 m in the height of the transmitting antenna. This example illustrates the benefit of raising receiving antennas above ground level to reduce the necessary height of the transmitter.

LOS Wireless Transmission Impairments

effict quality of sevivel.

factor effictive the equalty of receive signal

1. Attenuation and attenuation distortion
2. Free space loss energy ضياع
3. Noise unwanted signal
4. Atmospheric absorption
5. Multipath signal travel in diffrent way
6. Refraction

Amp ← اول ① power signal bel the thresould to detect signal at receiver antenna

Attenuation

- Strength of signal falls off with distance over transmission medium
- Attenuation factors for unguided media:
  - Received signal must have sufficient strength so that circuitry in the receiver can interpret the signal
  - Signal must maintain a level sufficiently higher than noise to be received without error
    - Use repeaters or amplifiers
  - Attenuation is greater at higher frequencies, causing distortion
    - Amplify high frequencies more than lower frequencies.

signal will be spreading into free space with distance

Free Space Loss

- Signal dispersion (spreading) with distance.
- Free space loss, ideal isotropic antenna: (omidirectional)

collect part of signal

the loss in directional anntena less than omidirectional anntena

Power transite / power recive

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi fd)^2}{c^2}$$

directional

- Free space loss equation can be recast:

$$L_{dB} = 10\log\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right)$$

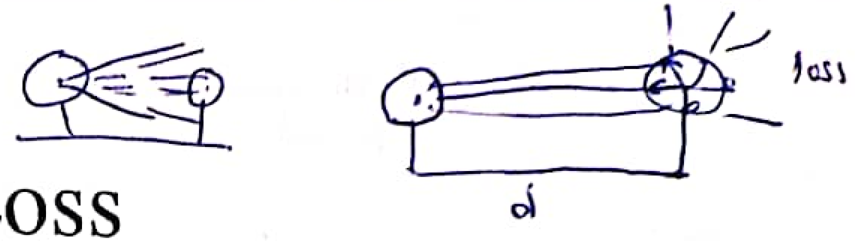
dB → 10 log

$$= -20\log(\lambda) + 20\log(d) + 21.98\ \text{dB}$$

$$= 20\log\left(\frac{4\pi fd}{c}\right) = 20\log(f) + 20\log(d) - 147.56\ \text{dB}$$

Hz   Meter

$\frac{(4\pi)^2}{c^2}$



Free Space Loss

- Free space loss accounting for gain of other antennas:

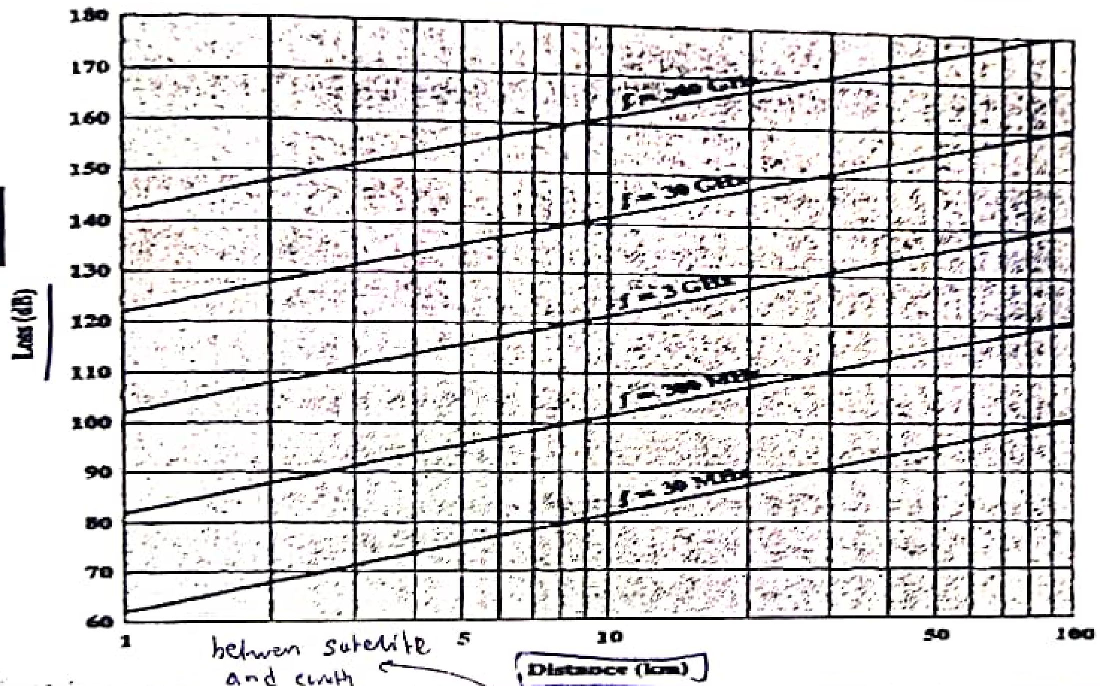
$$\frac{P_t}{P_r} = \frac{(4\pi)^2 (d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

- Free space loss accounting for gain of other antennas can be recast as:

$$L_{dB} = 20\log(\lambda) + 20\log(d) - 10\log(A_t A_r)$$

$$= -20\log(f) + 20\log(d) - 10\log(A_t A_r) + 169.54\text{dB}$$

$L_{dB} = L_{dB} - G_{TdB} - G_{RdB}$



different curve with different freq

Increase distance increase loss by using a certain freq. and if I increase freq the loss will increase

omidirection

between satellite and earth

Example 5.3 Determine the isotropic free space loss at 4 GHz for the shortest path to a synchronous satellite from earth (35,863 km). At 4 GHz, the wavelength is $(3 \times 10^8)/(4 \times 10^9) = 0.075$ m. Then,

using omidirection antenna

$$L_{dB} = -20 \log(0.075) + 20 \log(35.853 \times 10^6) + 21.98 = 195.6 \text{ dB}$$

Now consider the antenna gain of both the satellite- and ground-based antennas. Typical values are 44 dB and 48 dB respectively. The free space loss is:

$$L_{dB} = 195.6 - 44 - 48 = 103.6 \text{ dB}$$

Now assume a transmit power of 250 W at the earth station. What is the power received at the satellite antenna? A power of 250 W translates into 24 dBW, so the power at the receiving antenna is $24 - 103.6 = -79.6$ dBW.

losses

$P_T - L_{DB} = R_P$

$10 \log(250) - 103.6 = -79.6$ dBw

Free Space Propagation

Now assume a transmit power of 250 W at the earth station. What is the power received at the satellite antenna? A power of 250 W translates into 24 dBW, so the power at the receiving antenna is 24 − 103.6 = −79.6 dBW.

الطاقة اقل من 1w (اذا سالبة) 1w losses

الساتلايت استقبل اقل من

$P_T - L_{dB} = R_P$ | $\frac{P_T}{P_r} = L$

$10\log_{10}(250) - 103.6 = -79.6\ dBW$

Free Space Propagation

- Isotropic Source creates electromagnetic energy of power P.
  - A spherical wave is created towards all directions
  - The energy of the source is equally distributed over the surface area of the sphere,

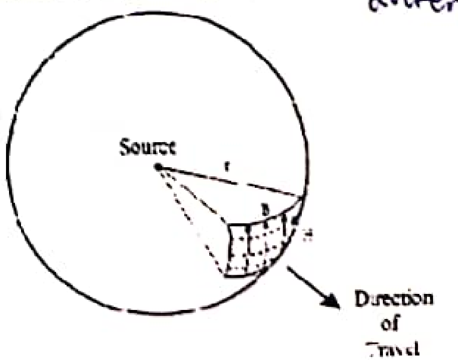
$$A = 4\pi r^2$$

- Therefore, at any point on the sphere, the power is equal to

we use omidirection antenna

$$P_r = \frac{P}{4\pi r^2}$$

resive power antenna spherical



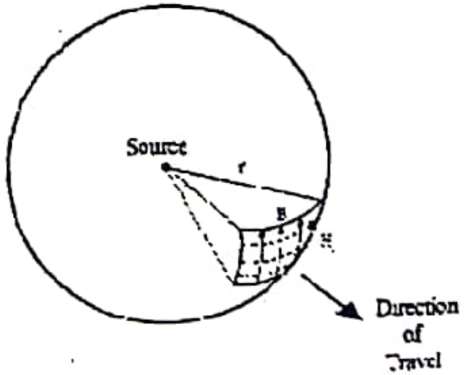
Free Space Propagation

- If the receiver has an effective area A_e , then the received power will be:

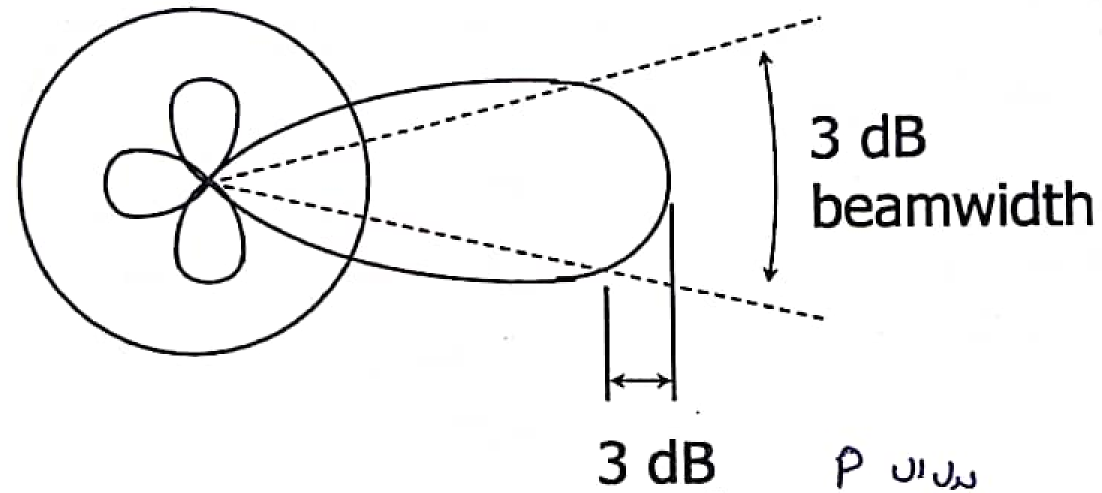
$$P_r = \frac{P}{4\pi r^2} \cdot A_e$$

size of reciver antenna

بنعوض قيمتها من قانون ال antenna gean



Free Space Propagation



بدل ال P

- Effective Isotropic Radiated Power $(EIRP) = P_t G_t$

- Effective area of an antenna: $$A_e = \left(\frac{\lambda^2}{4\pi}\right) G$$

وغيرنا ال receiver ال directional والtransmitter

Free Space Propagation

- Received power is equal to

$$P_r = P_t G_t \left[\frac{\lambda}{4\pi r} \right]^2 G_r$$

- Attenuation is equal to

اهم القانون

(vecived signal strength)

بحسب كم ال signal رح استقبلها ع ال reciver

اذا عكسته رح يعطيني ال losses

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi r} \right)^2$$

↳ distance

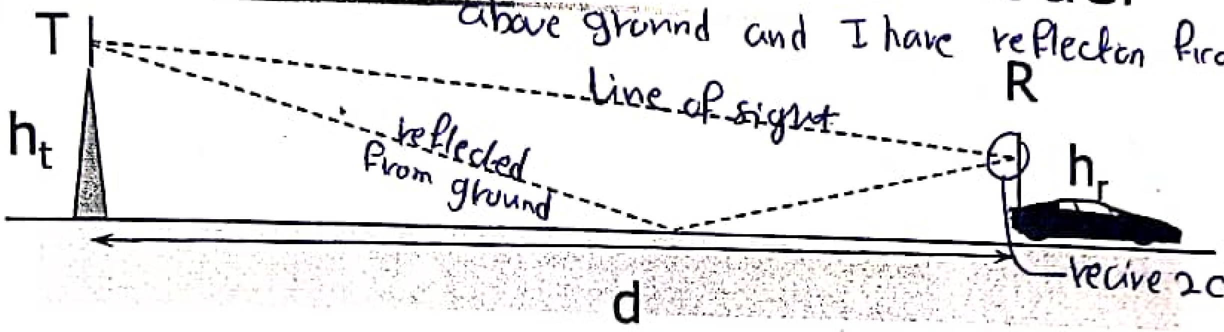
- or

$$PL[dB] = 20 \log_{10} \left(\frac{\lambda}{4\pi r} \right)$$

$\frac{(4\pi r)^{d}}{G_t G_r \lambda}$ = losses

the equation when we have open space between receive and Transmitte

2-Ray Ground Reflection Model



- then $$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$$
- Note:
  - No longer depends on wavelength (d>>ht)
  - Drops off as 1/r4 instead of 1/r2

Categories of Noise

any unwanted signal

① ■ Thermal Noise

② ■ Intermodulation noise

③ ■ Crosstalk

④ ■ Impulse Noise

Thermal Noise

- Thermal noise due to agitation of electrons
- Present in all electronic devices and transmission media
- Cannot be eliminated
- Function of temperature
- Uniformly distributed across the frequency spectrum (white noise)
- Particularly significant for satellite communication

Thermal Noise

- Amount of thermal noise to be found in a bandwidth of 1Hz in any device or conductor is:

power in 1Hz Bandwidth we show that the amount of thermal

$$N_0 = kT \, (\text{W/Hz})$$

- N_0 = noise power density in watts per 1 Hz of bandwidth
- k = Boltzmann's constant = 1.3803 x10^{-23} J/K   1.4
- T = temperature, in kelvins (absolute temperature)

t in c tc+273

Thermal Noise

- Noise is assumed to be independent of frequency
- Thermal noise present in a bandwidth of B Hertz (in watts):

1HZ اكثر من

$$N = kTB$$

or, in decibel-watts:

$$N = 10\log k + 10\log T + 10\log B$$
$$= -228.6\,\text{dBW} + 10\log T + 10\log B$$

**** Q17) What is the thermal noise level of a channel with a bandwidth of 10 kHz carrying 1000 watts of power operating at 50°C? Compare the noise level to the operating power.**

N = kTB = 4.46 * 10^-17

SNR = 1000 / (4.46 * 10^-17) = 2.243 * 10^19

T(k) = T(c)+273.15=50+273.15

T(k) = 323.15

N = -228.6 dBW + 10log(T)+10log(B)

N = -228.6 dBW + 25.09 + 40 = -163.51

NdB = -163.51

**** Q18) If the received signal level for a particular digital system is -151 dBW and the receiver system effective noise temperature is 1500 K, what is *Eb/No* for a link transmitting 2400 bps?**

(Eb/N0) = SdBW - 10log (Data Rate) - 10log (temp) + 228.6 dBW

(Eb/N0) = −151 dBW – 10 log 2400 – 10 log 1500 + 228.6 dBW = 12 dBW

(Eb/N0) = 12 dBW

مهم جدا

Noise Terminology

transimal two signal with different frequencies in the same transmission medium

- **Intermodulation noise** – occurs if signals with different frequencies share the same medium
  - Interference caused by a signal produced at a frequency that is the sum or difference of original frequencies

I receive the 2 signal with other 2 signal (sum and difference)

$f_1, f_2 \rightarrow f_1, f_2, f_1+f_2, f_1-f_2$

4 signal

- **Crosstalk** – unwanted coupling between signal paths with same freq.

2 signal use the same freq and I receive both

مثلا زي الراديو لما يحصل تداخل بين قناتين

- **Impulse noise** – irregular pulses or noise spikes
  - Short duration and of relatively high amplitude
  - Caused by external electromagnetic disturbances, or faults and flaws in the communications system

It's don't have the certain reason, dont efect in analog system

لما الـ data rate عالية

مثلا الـ amplituted بتقل مثلا الـ 1 دفعة واحدة لـ 3 بعرف انه spikes

تكون الـ noise spikes قريب

من الـ normal spikes

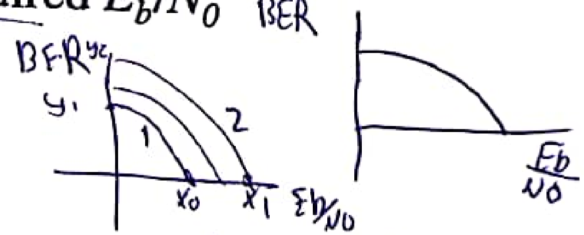
* Minor effect on analog signals, but Major effect on digital signals

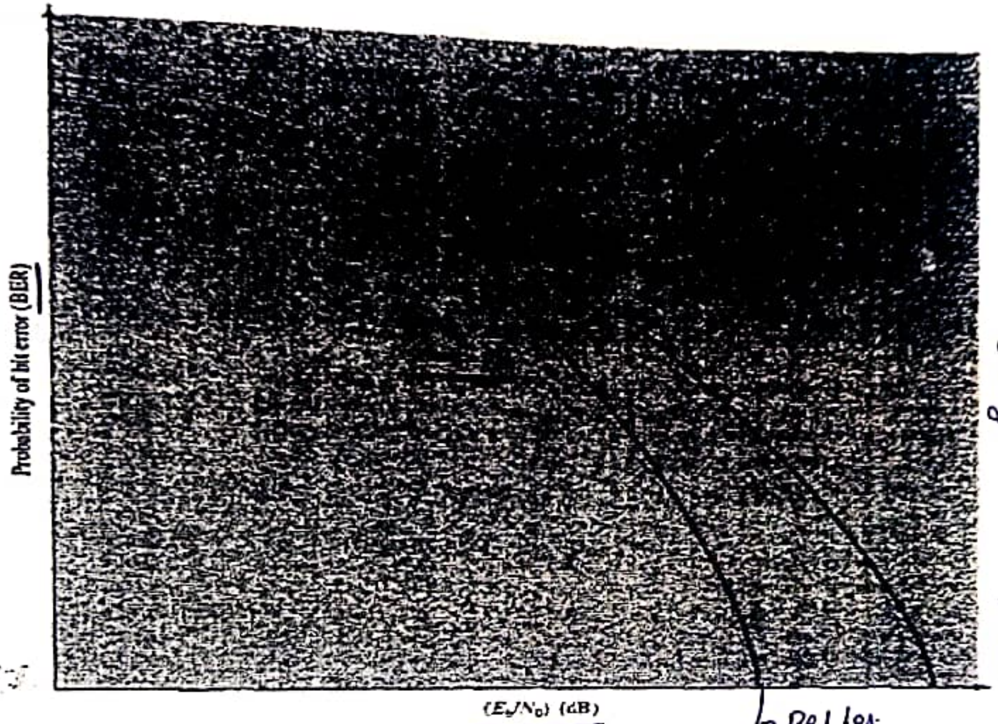
Expression E_b/N_0

- Ratio of signal energy per bit to noise power density per Hertz

$$\frac{E_b}{N_0} = \frac{S/R}{N_0} = \frac{S}{kTR}$$

- The bit error rate (BER) for digital data is a function of E_b/N_0 (inverse relationship)
  - Given a value for E_b/N_0 to achieve a desired error rate: parameters of this formula can be selected
  - As bit rate R increases, transmitted signal power S must increase to maintain required E_b/N_0





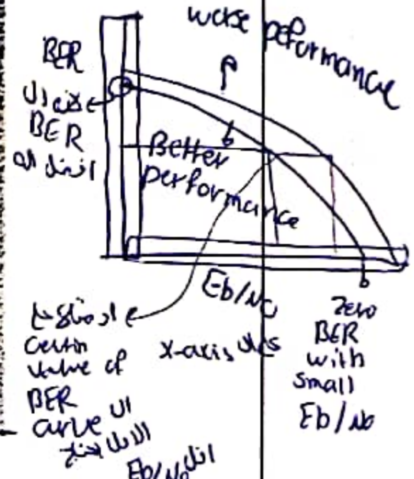


Figure 5.9 General Shape of BER Versus E_b/N_0 Curves

Example 5.6 Suppose a signal encoding technique requires that $E_b/N_0 = 8.4$ dB for a bit error rate of 10^{-4} (one bit error out of every 10,000). If the effective noise temperature is 290°K (room temperature) and the data rate is 2400 bps, what received signal level is required to overcome thermal noise?

We have

$$8.4 = S_{dBW} - 10 \log 2400 + 228.6 \text{ dBW} - 10 \log 290$$
$$= S_{dBW} - (10)(3.38) + 228.6 - (10)(2.46)$$
$$S = -161.8 \text{ dBW}$$

Other Impairments

$$\ldots 10 \log 2400 + 228.6 \text{ dBW} - 10 \log 290$$

$$= S_{dBW} - (10)(3.38) + 228.6 - (10)(2.46)$$

$$S = -161.8 \text{ dBW}$$

Other Impairments

- Atmospheric absorption – water vapor (22 GHz) and oxygen (60 GHz) contribute to attenuation
- Multipath – obstacles reflect signals so that multiple copies with varying delays are received
- Refraction – bending of radio waves as they propagate through the atmosphere

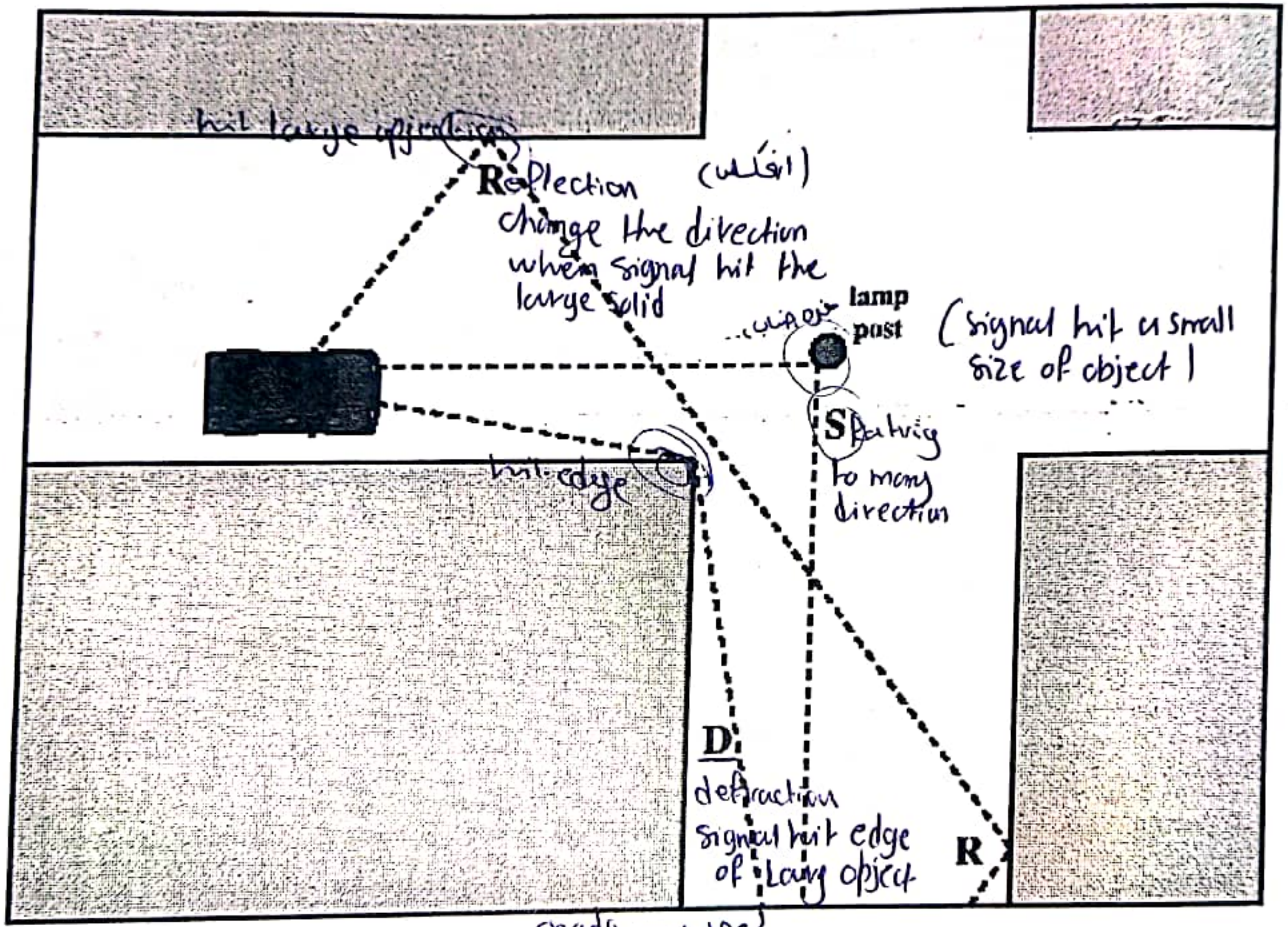


Figure 5.10 Sketch of Three Important Propagation Mechanisms: Reflection (R), Scattering (S), Diffraction (D) [ANDE95]

so I can recive multiple copy of signal

so I can recive multiple copy of signal

Multipath Propagation

- **Reflection** - occurs when signal encounters a surface that is large relative to the wavelength of the signal
- **Diffraction** - occurs at the edge of an impenetrable body that is large compared to wavelength of radio wave
- **Scattering** – occurs when incoming signal hits an object whose size in the order of the wavelength of the signal or less

**** Q12) What is the difference between diffraction and scattering?**

Diffraction: occurs at the edge of an impenetrable body that is large compared to the wavelength of a radio wave.

Scattering: occurs when an incoming signal hits an object whose size is in the order of the wavelength of the signal or less.

Reflection: occurs when a signal encounters a surface that is large relative to the wavelength of the signal.

Q13) Name and briefly describe four types of noise.

1. Thermal Noise: due to agitation of electrons, Present in all electronic devices and transmission media, cannot be eliminated, white noise, particularly significant for satellite communication.
2. Intermodulation noise: occurs if signals with different frequencies share the same medium, so we also receive the sum and difference of these signals.
3. Crosstalk: unwanted coupling between signal paths.
4. Impulse Noise: irregular pulses or noise spikes, short duration and of relatively high amplitude, Caused by external electromagnetic disturbances, or faults and flaws in the communications system.

**** Q14) What factors determine antenna gain?**

1) Frequency of the signal (f)
2) Effective Area of the antenna (A)

**** Q15) What is the primary cause of signal loss in satellite communications?**

Free space loss.

**** Q16) A microwave transmitter has an output of 0.1 W at 2 GHz. Assume that this transmitter is used in a microwave communication system where the transmitting and receiving antennas are parabolas, each 1.2 m in diameter.**
a. What is the gain of each antenna in decibels?
b. Taking into account antenna gain, what is the effective radiated power of the transmitted signal?
c. If the receiving antenna is located 24 km from the transmitting antenna over a free space path, find the available signal power out of the receiving antenna in dBm units.

a. From Table 5.2, G = 7A/λ^2 = 7Af^2/c^2 = (7×π×(0.6)^2×(2×10^9)^2]/(3×10^8)^2 = 351.85

then GdB = 25.46 dB

The Effects of Multipath Propagation

- Multiple copies of a signal may arrive at different phases:
  - If phases add destructively, the signal level relative to noise S/N declines, making detection more difficult
- Intersymbol interference (ISI)
  - One or more delayed copies of a pulse may arrive at the same time as the primary pulse for a subsequent bit

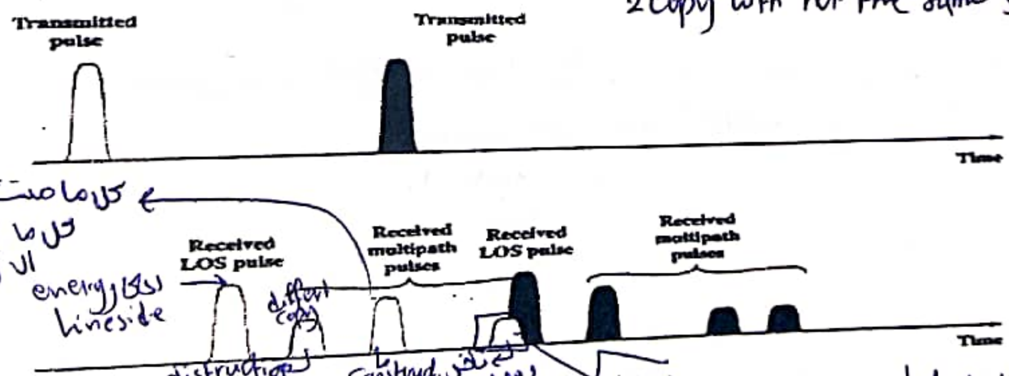


Figure 5.12 Two Pulses in Time-Variant Multipath

Compensation Mechanisms

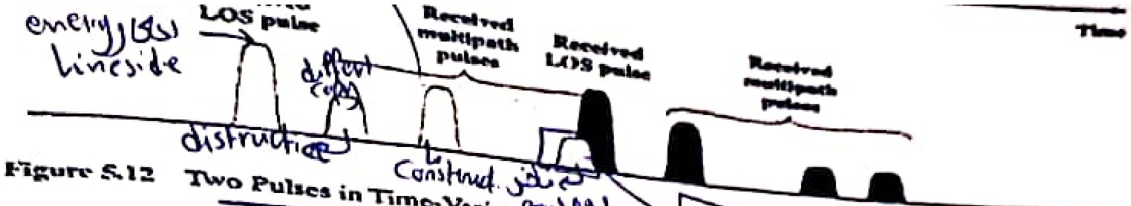


Figure 5.12 Two Pulses in Time-Variant Multipath

Error Compensation Mechanisms

- Forward error correction
- Adaptive equalization
- Diversity techniques

Forward Error Correction

- Transmitter adds error-correcting code to data block
  - Code (FEC) is a function of the data bits
- Receiver calculates error-correcting code from incoming data bits:
  - If calculated code matches incoming code, no error occurred
  - If error-correcting codes don't match, receiver attempts to determine bits in error and correct

Adaptive Equalization
base in hardware

extra hardware cccl.1

- Can be applied to transmissions that carry analog or digital information
  - Analog voice or video
  - Digital data, digitized voice or video
- Used to combat intersymbol interference
- Involves gathering dispersed symbol energy back into its original time interval
- Techniques:
  - Lumped analog circuits — order. to spread multi-path copy base in phase shift
  - Sophisticated digital signal processing algorithms — dis.

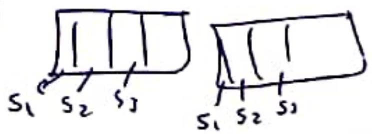
  ① Extra HW
  ② Process increase cost

base in space of freq or time

Diversity Techniques

- Diversity is based on the fact that individual channels experience independent fading events:
- (1) Space diversity – techniques involving physical transmission path
- (2) Frequency diversity – techniques where the signal is spread out over a larger frequency bandwidth or carried on multiple frequency carriers
- (3) Time diversity – techniques aimed at spreading the data out over time

Send signal over diffrent freq.



correction بعمل
error بحالة صار
time بال
diversity

10 bit
First backet

Coding and Error Control

Chapter 8

Coping with Data Transmission Errors

3 methodes

- ① Error detection codes — detect having error in recive data
  - Detects the presence of an error
- ② Automatic repeat request (ARQ) protocols → retransmission I ask the sender to retransmestion the same backet because the prevoy one hes error
  - Block of data with error is discarded
  - Transmitter retransmits that block of data
- ③ Error correction codes, or forward correction codes (FEC) — correct error at the receiver without asking sender to repet transission
  - Designed to detect and correct errors

the numer of error smaly we can correct in receiver. either detect

Error Detection Probabilities

- Definitions:
  - P_b : Probability of single bit error (BER)
  - P_1 : Probability that a frame arrives with no bit errors
  - P_2 : While using error detection, the probability that a frame arrives with one or more undetected errors
  - P_3 : While using error detection, the probability that a frame arrives with one or more detected bit errors but no undetected bit errors

$P_1 = (1 - P_b)^{F}$

$P_2 = 1 - P_1$

$P_3 = 0$

Error Detection Probabilities

- With no error detection:

$$P_1 = (1 - P_b)^F$$

$$P_2 = 1 - P_1$$

$$P_3 = 0$$

  - F = Number of bits per frame

F → number of packet per frame

P_b → usually major in reciver (given)

$P_3 = 0$ → لانه مو مستخدم اي error detection schem

يعني كل مليون bit لما يستقبلها عندي → 1 bit error

Example 8.1 A defined objective for ISDN (Integrated Services Digital Network) connections is that the BER on a 64-kbps channel should be less than 10^{-6} on at least 90% of observed 1-minute intervals. Suppose now that we have the rather modest user requirement that on average one frame with an undetected bit error should occur per day on a continuously used 64-kbps channel, and let us assume a frame length of 1000 bits. The number of frames that can be transmitted in a day comes out to 5.529×10^6, which yields a desired frame error rate of $P_2 = 1/(5.529 \times 10^6) = 0.18 \times 10^{-6}$. But if we assume a value of P_b of 10^{-6}, then $P_1 = (0.999999)^{1000} = 0.999$ and therefore $P_2 = 10^{-3}$, which is about three orders of magnitude too large to meet our requirement.

one frame only with error

1 packet per day with error

1 packet with error/day

n. bit/day = 64 K × 60 × 60 × 24 = y → 5.5296×10^9 → number of bit per day ÷ number of frame per day → $\frac{5.5296 \times 10^9}{1000} = 5.5296 \times 10^6$

n. frames/day = $\frac{y}{1000}$ = z

P_2 (user) = $\frac{1}{z}$

P_2 (company) = $1 - P_1$ (→ BER)

$P_2 = 1 - (1 - 10^{-6})^{1000} = 10^{-3}$

Error Detection Process

add extra bit along to original data

1 packet with error/day 1 packet per day with error

N. bit/day = 64K x 60 x 60 x 24 = y [5.5296 x 10^9] number of bit per day ÷ number of frame per day → 5.5296x10^9 / 1000 = 5.5296x10^6

N. frames/day = y/1000 = z

P2 user = 1/z

P2 (company) = 1 − (P1) ← BER

P2 = 1 − (1 − 10^-6)^100 = 10^-3

Error Detection Process

- Transmitter — add extra bit along to original data
  - For a given frame, an error-detecting code (check bits) is calculated from data bits — unique of for certain original data
  - Check bits are appended to data bits
- Receiver — separate original data from check bits
  - Separates incoming frame into data bits and check bits
  - Calculates check bits from received data bits
  - Compares calculated check bits against received check bits
  - Detected error occurs if mismatch

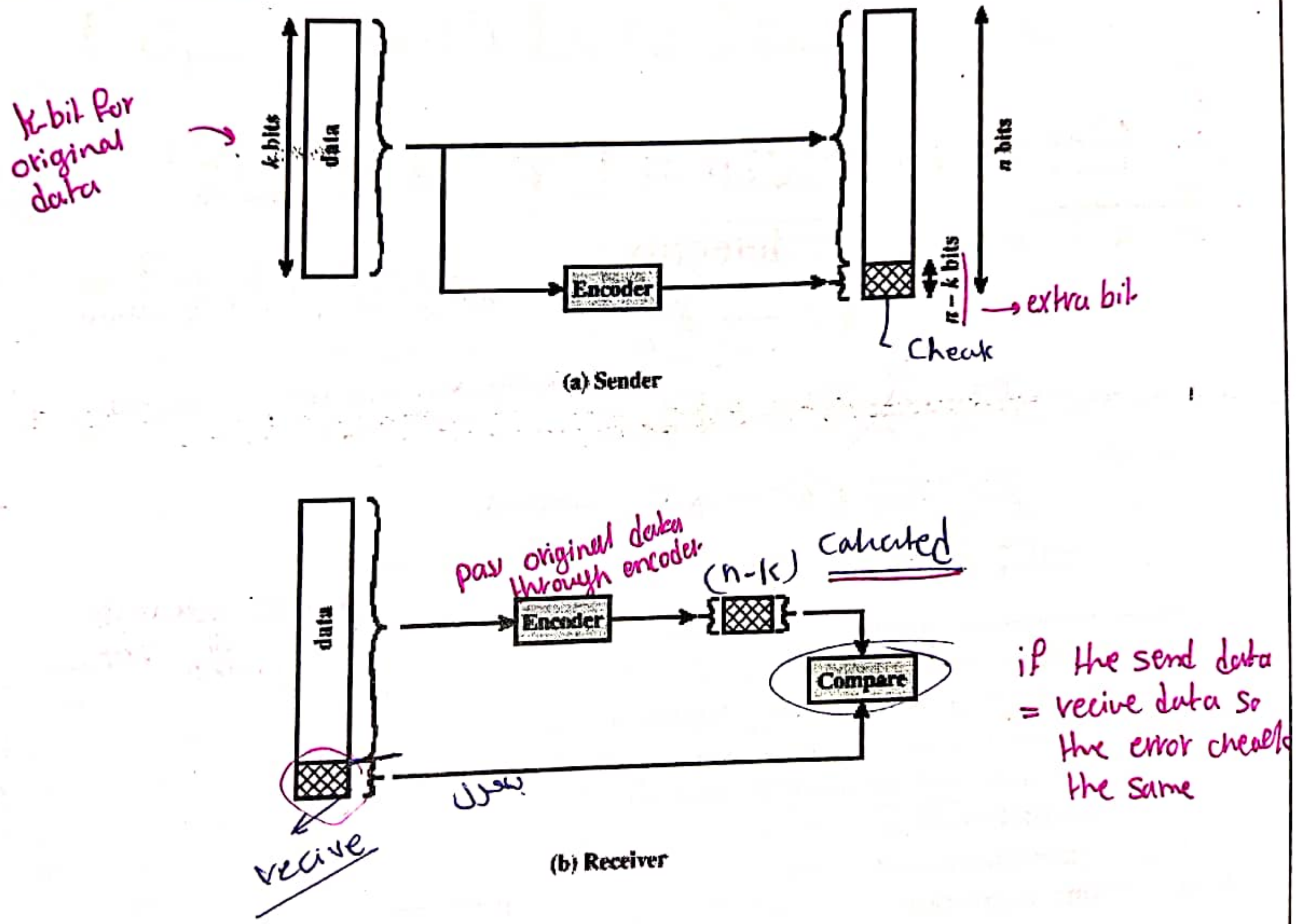


Figure 8.1 Error Detection Process

Parity Check

- Parity bit appended to a block of data
- Even parity
  - Added bit ensures an even number of 1s
- Odd parity
  - Added bit ensures an odd number of 1s
- Example, 7-bit character [1110001]
  - Even parity [11100010]
  - Odd parity [11100011]

Cyclic Redundancy Check (CRC)

- Transmitter
  - For a *k*-bit block, transmitter generates an (*n*-*k*)-bit frame check sequence (FCS)
  - Resulting frame of *n* bits is exactly divisible by predetermined number

$T = 2^{n-k} D + \frac{R}{P}$ remainder

- Receiver
  - Divides incoming (original) frame by predetermined number → size: extra bit + 1

    $\frac{TR}{P}$ < R = 0 → no error; R ≠ 0 → with error
  - If no remainder, assumes no error

$2^{n-k} D + R$

Data bits = D

CRC using Modulo 2 Arithmetic

- Exclusive-OR (XOR) operation:

1111	1111	11001
+ 1010	− 0101	× 11
0101	1010	11001
		11001
		101011

- Parameters:
  - T = n-bit frame to be transmitted
  - D = k-bit block of data; the first k bits of T
  - F = $(n-k)$-bit FCS; the last $(n-k)$ bits of T
  - P = pattern of n–k+1 bits; this is the predetermined divisor
  - Q = Quotient
  - R = Remainder

CRC using Modulo 2 Arithmetic

- For T/P to have no remainder, start with:

$$T = 2^{n-k} D + F$$

- Divide $2^{n-k}D$ by P gives quotient and remainder

$$\frac{2^{n-k} D}{P} = Q + \frac{R}{P}$$

- Use remainder as FCS:

$$T = 2^{n-k} D + R$$

CRC using Modulo 2 Arithmetic

- Does R cause T/P have no remainder?

$$\frac{T}{P} = \frac{2^{n-k}D + R}{P} = \frac{2^{n-k}D}{P} + \frac{R}{P}$$

- Substituting,

$$\frac{T}{P} = Q + \frac{R}{P} + \frac{R}{P} = Q + \frac{R+R}{P} = Q$$

  - No remainder, so T is exactly divisible by P

no error

* an error results in reversal of bit, equivalent to XOR data bit with 1
receive packet ← $T_r = T$ XOR E.
(T: transmit packet — E: Error pattern)
* If there is error, $E \neq 0$, it won't be detected if and only if T_r is divisible by P

* occure when E is divisible by P
* which is unlikely to happen

— XOR 0 → نفسه
— XOR 1 → toggel

Example

$\frac{T}{P}$ XOR $\frac{E}{P}$ → بتعطي ال zero; no remainder → 0; 0 = E

Example 8.3

1. Given

original bit value → k

Message $\underline{D}$ = 1010001101 (10 bits)
Pattern P = 110101 (6 bits) — predetermined number
FCS R = to be calculated (5 bits) — Extra bit — لازم يكون اقل بواحد

Thus, $n = 15$, $k = 10$, and $(n - k) = 5$.

2. The message is multiplied by 2^5, yielding 101000110100000.
3. This product is divided by P:

```
                   1 1 0 1 0 1 0 1 1 0  ← Q
P → 1 1 0 1 0 1 ) 1 0 1 0 0 0 1 1 0 1 0 0 0 0 0  ← 2^(n-k) D
                  1 1 0 1 0 1
                    1 1 1 0 1 1
                    1 1 0 1 0 1
                      1 1 1 0 1 0
                      1 1 0 1 0 1
                        1 1 1 1 1 0
                        1 1 0 1 0 1
                          1 0 1 1 0 0
                          1 1 0 1 0 1
                            1 1 0 0 1 0
                            1 1 0 1 0 1
                              0 1 1 1 0  ← R
```

اذا ال size نفس
جمع ال P ال بدها 1
اذا اقل بدها 0
كل ما اضيف bit وصار 6 ← 1
" وظلت 5 ← 0

[The] remainder is added to 2^5D to give T = 101000110101110, which is transmitted.
(1010001101 = نفس ال T ; 01110 = R)

Example (cont.)

Reciver

5. If there are no errors, the receiver receives *T* intact. The received frame is divided by *P*:

نفس ال packet يلي انبعتت

```
                       1 1 0 1 0 1 0 1 1 0  ← Q
P → 1 1 0 1 0 1 / 1 0 1 0 0 0 1 1 0 1 0 1 1 1 0  ← T
                  1 1 0 1 0 1
                    1 1 1 0 1 1
                    1 1 0 1 0 1
                        1 1 1 0 1 0
                        1 1 0 1 0 1
                            1 1 1 1 1 0
                            1 1 0 1 0 1
                                1 0 1 1 1 1
                                1 1 0 1 0 1
                                  1 1 0 1 0 1
                                  1 1 0 1 0 1
                                            0  ← R
```

Because there is no remainder, it is assumed that there have been no errors

Wireless Transmission Errors ①

- Error detection requires retransmission
- Retransmission inadequate for wireless applications:
  - Error rate on wireless link can be high, results in a large number of retransmissions
  - Long propagation delay compared to transmission time (ex. Satellite communication)

- Energy consumption

Block Error Correction Codes

simillar to error detection (add extra bit)

- Transmitter
  - Forward error correction (FEC) encoder maps each k-bit (original) block into an n-bit block codeword
  - Codeword is transmitted; analog for wireless transmission
- Receiver
  - Incoming signal is demodulated
  - Block passed through an FEC decoder

pass this packet to decoder in order to check they have error or not

output ① correct ② recived with error and this error corrected ③ recived with error and can't be corrected ④ reciced with error and this error can't detected

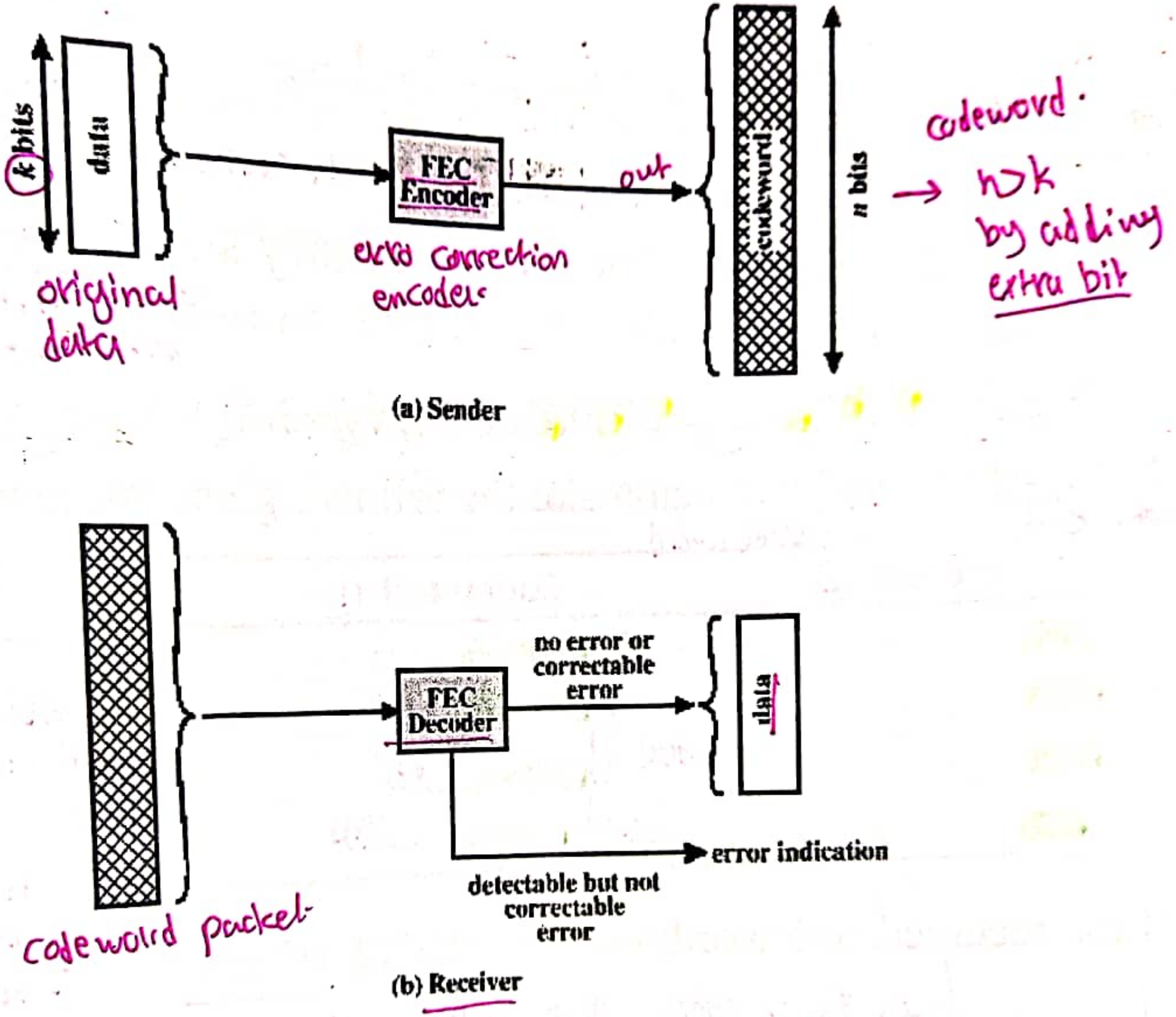


Figure 8.5 Forward Error Correction Process

FEC Decoder Outcomes:

4 possible outcomes

1. ■ No errors present
   - ■ Codeword produced by decoder matches original codeword
2. ■ Decoder detects and corrects bit errors

   detectable and correctable
3. ■ Decoder detects but cannot correct bit errors; reports uncorrectable error

   → detectable and not correctable
   capability ... higher than correct.
   (discard packet and ask sender to retransmit the packet)
4. ■ Decoder cannot detect bit errors, even though there are errors

   ↳ can't detect and correct
   (similar to first one packet receive with no error)

Q15) If we increase the frequency, what is the effect of the received signal for:

a. Free space loss, ideal isotropic antenna? Decrease the power of received signal.
b. Free space loss accounting for a gain of other antennas? Increase the power of received signal.

Q16) Why would you expect a CRC to detect more errors than a parity bit?

1. Parity bit can only detect single-bit errors, while CRC can detect multiple-bit errors.
2. CRC adds a longer check sequence to the data, increasing the likelihood of error detection, whil parity bit added only one bit to the sequence.
3. The CRC has more bits and therefore provides more redundancies. That is, it provides more information that can be used to detect errors.

Q17) In an *(n, k)* block ECC, what do n and *k* represent?

1. "n" represents the total number of bits in a codeword or block.
2. "k" represents the number of data bits or symbols in the block.

Q18) What two key elements comprise error control?

1. Error Detection: identifies errors in transmitted data.
2. Error Correction: rectifies identified errors, enabling accurate recovery of the original data.

Q19) What is the purpose of using modulo 2 arithmetic rather than binary arithmetic in computing an FCS?

1. Modulo 2 arithmetic scheme is easy to implement in circuitry.
2. Modulo 2 arithmetic yields a remainder one bit smaller than binary arithmetic.
3. Modulo 2 arithmetic simplifies the error detection process, offers efficient computation, and provides reliable error detection capabilities.

Q20) Consider a frame consisting of two characters of four bits each. Assume that the probability of bit error is (10^-3), independent for each bit.

a. What is the probability that the received frame contains at least one error?
b. Now add a parity bit to each character. What is the probability?

Solution:

8.2 a. We have:

Pr [single bit in error] = 10^{-3}

Pr [single bit not in error] = $1 - 10^{-3} = 0.999$
Pr [8 bits not in error] = $(1 - 10^{-3})^8 = (0.999)^8 = 0.992$
Pr [at least one error in frame] = $1 - (1 - 10^{-3})^8 = 0.008$

b. Pr [at least one error in frame] = $1 - (1 - 10^{-3})^{10} = 1 - (0.999)^{10} = 0.01$

Block Code Principles

in order to check correctness of data

- Hamming distance – for 2 n-bit binary sequences, the number of different bits:

  # of different bit between two pattern

  - E.g., v_1=011011; v_2=110001; $d(v_1, v_2)$=3
- For K=2 and n=5, we can make the following assignment:

  original data size → K; codeword → n

Data block (2)	Codeword (5)
00	00000
01	00111
10	11001
11	11110

min HD : 3
MAX HD : 4

H. distance between 3 and 4; I select the max. in order to increase # of different bit

- If the received codeword has the value of: 00100 ?

data recive with error can detected and corrected

Hamming distance (Cont.)

Hamming distance (Cont.)

Invalid Codeword	Minimum distance	Valid codeword	Invalid codeword	Minimum distance	Valid codeword
00001	1	00000	10000	1	00000
00010	1	00000	10001	1	11001
00011	1	00111	10010	2	00000 or 11110
00100	1	00000	10011	2	00111 or 11001
00101	1	00111	10100	2	00000 or 11110
00110	1	00111	10101	2	00111 or 11001
01000	1	00000	10110	1	11110
01001	1	11001	10111	1	00111
01010	2	00000 or 11110	11000	1	11001
01011	2	00111 or 11001	11010	1	11110
01100	2	00000 or 11110	11011	1	11001
01101	2	00111 or 11001	11100	1	11110
01110	1	11110	11101	1	11001
01111	1	00111	11111	1	11110

d(00000, 00111) = 3; d(00000, 11001) = 3; d(00000, 11110) = 4;
d(00111, 11001) = 4; d(00111, 11110) = 3; d(11001, 11110) = 3;

5 bit = 2^5 = 32 [4, 28 x

Max number of correctable errors: $t = \left\lfloor \frac{d_{min} - 1}{2} \right\rfloor$ ← lower int number $\left\lfloor \frac{3-1}{2} \right\rfloor = 1$ I can correct just one error

t = dmin or more: can't detect an correct.
t = dmin - 1: error detect but not correct.

00000 / 00000 / ادا ال error 00001 / نفسه !! similar to other codeword

ال output (2) افرب ال 00 — data recive with error can detected and corrected

اذا HD = 1: I can detect and correct.

invalid → لانها مو من ال table بنلاقيها — detect for error

اذا كانت 2 HD: *حسبنا ال اولها وكلن الكودوورد لحتى 2 ال valid data

3 out come (I detect error but I can't correct them)

اذا كنا 3: 60111 error to 3 → 00000 convert to other valid code word. I can't detect and I can't correct (4 outcome) حسب عدد ال error و عدد ال minHD

اذا كان 3 او 4 ما رح يكون نتلقة ال invalid ال يتحول ل valid

Block Code Principles

- Redundancy – ratio of redundant bits to data bits
- Code rate – ratio of data bits to total bits
- Coding gain – the reduction in the required E_b/N_0 to achieve a specified BER of an error-correcting coded system

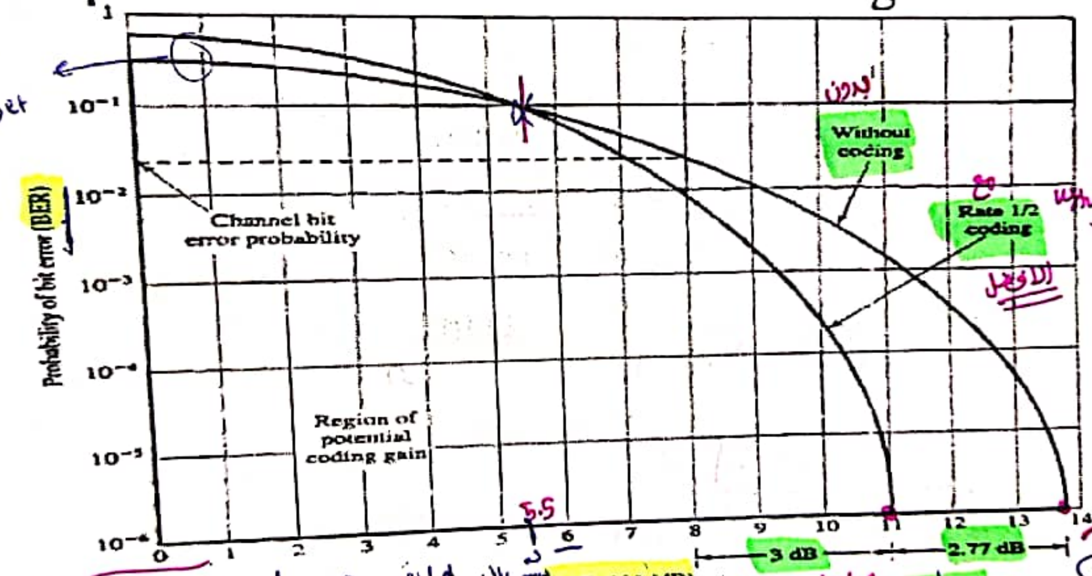


Figure 8.6 How Coding Improves System Performance

FEC Design

Q31) What are three key factors related to satellite communications performance?

1. Distance between earth station antenna and satellite antenna.
2. Atmospheric attenuation.
3. For downlink, terrestrial distance between earth station antenna and "aim point" of satellite.

Q32) What are the primary causes of atmospheric attenuation for satellite communications?

- oxygen, water, angle of elevation, and higher frequencies.

Q33) The Space Shuttle is an example of a LEO satellite. Sometimes, it orbits at an altitude of 250 km.

a. Using a mean earth radius of 6378.14 km, calculate the period of the shuttle orbit.
b. Determine the linear velocity of the shuttle along this orbit.

Solution:

9.2 a. a = 6378.14 + 250 = 6628.14 km

$T^2 = (4\pi^2 a^3)/\mu = (4\pi^2) \times (6628.14)^3/(3.986004418 \times 10^5) = 2.88401145 \times 107\ s^2$

T = 5370.3 s = 89 min 30.3 s

b. The linear velocity is the circumference divided by the period

$(2\pi a)/T = (41645.83)/(5370.3) = 7.775$ km/s

Q34) A satellite at a distance of 40,000 km from a point on the earth's surface radiates a power of 10 W from an antenna with a gain of 17 dB in the direction of the observer. The satellite operates at a frequency of 11 GHz. The receiving antenna has a gain of 52.3 dB. Find the received power.

Solution:

9.4 received_power = transmitted_power + transmitted_gain + received_gain − path_loss

From Equation (2.2):

path_loss = $20 \log (4\pi d/\lambda) = 20 \log [4\pi d/(c/f)]$

$= 20 \log [(4\pi \times 4 \times 10^7)/(2.727 \times 10^{-2}) = -205.3$ dB

received_power = 10 + 17 + 52.3 − 205.3 = −126 dBW

FEC Design

- The design of a block code involves a number of considerations:
- For given values of *n* and *k*, we would like the largest possible value of d_{min}.
- The code should be relatively easy to encode and decode, requiring minimal memory and processing time.
- The number of extra bits, (n - k), needs to be small, to reduce bandwidth.
- The number of extra bits, (n - k), needs to be large, to reduce error-rate.

Hamming Code

- Designed to correct single bit errors
- Family of (n, k) block error-correcting codes with parameters:
  - Block length: $n = 2^m - 1$
  - Number of data bits: $k = 2^m - m - 1$
  - Number of check bits: $n - k = m$
  - Minimum distance: $d_{min} = 3$
- Single-error-correcting (SEC) code
  - SEC double-error-detecting (SEC-DED) code

$\frac{3-2}{1} = 1$

Hamming Code Process

- **Encoding**: *k* data bits + (*n* -*k*) check bits
  - Check bits: XORed the positions of ones in the data bits
  - Inserted in the positions that are a power of 2
- **Decoding**: compares received (*n* -*k*) bits with calculated (*n* -*k*) bits using XOR:
  - Resulting (*n* -*k*) bits called *syndrome word*
  - Syndrome range is between 0 and $2^{(n-k)}-1$
  - Each bit of syndrome indicates a match (0) or conflict (1) in that bit position

First step

① in transmitter he will shift data bit with ~~Right~~ left side and empty position or location to the power of 2

bit 1 —— 1z ① shift left ② بخليه فاضي power of 2 واي مكان

... 2^4 2^3 2^2 2^1 2^0

... 16 8 4 2 1 ← اماكن لازم تكون فاضية

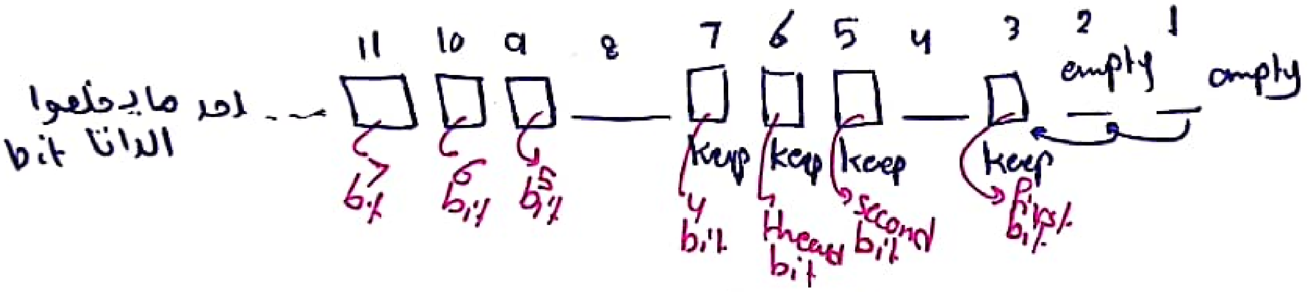
بنبلش من 1 مو zero

power of two

شيفك ← (✓) location 1 بطفها shift ← (✓) location 2 بعدها shift بخليه فاضي

لوين location 3

يعني ال bit الموجود ب location 1 ← عملها location 2 ← بخليه 3



بعدين بشوف الاماكن باللي فيها ones هنا ب position 3, 7 — وبعدها XOR location of ones

ال output بيكون ال extra bit وال cheak bit اللي بحطه محل ال empty bit

size of number لازم يكون نفس ال size for extra bit ← # of empty position

وهاد بعتمد على ال k bit

عدد موجود ال extra bit

هناك عندي 4 empty bit يعني 4 extra bit

اذا عندي واحد ب location 3 بكتب

0011 four bit

وبعمل XOR وال output بحطه بالاماكن 2 power

Reciver he know the bit that in power of 2 is extra bit
he will extract them from packet

then **XOR** location of **ones**.

لـ 2 تكون عنه calculeld extra bit (مدل حسبهم عن طريق xor location of 1) و receive extra bit (مدل الموجودين د location 2) رح يعمل بينهم (XOR)

result ال ⊕ بنسميه **Syndrome**

0 → no error.

one 1 → error in Extra bit. (power of 2)

more than 1 → error in data

Hamming Code

- Hamming Code generates a syndrome with the following characteristics:
  - If the syndrome contains all 0s, no error has been detected.
    الرقمين نفس التي
  - If the syndrome contains one and only one bit set to 1, then an error has occurred in one of the check bits. No correction is needed.
    معناه we have error بس موجود بال extra ما حاجة لتصحيح
    وما موجود بالمكان power of 2 zero والباقي
  - If the syndrome contains more than one bit set to 1, then the syndrome indicates the position of the data bit in error. This data bit is inverted for correction.
    عندي error وهاد ال error صار بال data
    How to correct? just flip bit.

Example:

8-bit data block: 00111001

Table 8.2 Layout of Data Bits and Check Bits

(a) Transmitted block

Bit Position	12	11	10	9	8	7	6	5	4	3	2	1
Position Number	1100	1011	1010	1001	1000	0111	0110	0101	0100	0011	0010	0001
Data Bit	D8	D7	D6	D5		D4	D3	D2		D1		
Check Bit					C8				C4		C2	C1
Transmitted Block	0	0	1	1	0	1	0	0	1	1	1	1
Codes			1010	1001		0111				0011		

(b) Check bit calculation prior to transmission

Position	Code
10	1010
9	1001
7	0111
3	0011
XOR = C8 C4 C2 C1	0111

Example (cont.)

(c) Received block

Bit Position	12	11	10	9	8	7	6	5	4	3	2	1
Position Number	1100	1011	1010	1001	1000	0111	0110	0101	0100	0011	0010	0001
Data Bit	D8	D7	D6	D5		D4	D3	D2		D1		
Check Bit					C8				C4		C2	C1
Received Block	0	0	1	1	0	1	1	0	1	1	1	1
Codes			1010	1001		0111	0110			0011		

(d) Check bit calculation after reception

Position	Code
Hamming	0111
10	1010
9	1001
7	0111
6	0110
3	0011
XOR = syndrome	0110

Cyclic Codes

- Can be encoded and decoded using linear

Q24) Suppose an 8-bit data word stored in memory is (11000010). Using the Hamming algorithm, determine what check bits would be stored in memory with the data word. Show how you got your answer.

Solution:

Position	12	11	10	9	8	7	6	5	4	3	2	1
Bit	D8	D7	D6	D5	C8	D4	D3	D2	C4	D1	C2	C1
Block	1	1	0	0		0	0	1		0		
Codes	1100	1011						0101				

Check bit calculation:

Position	Code
12	1100
11	1011
5	0101
XOR = C8 C4 C2 C1	0010

Q25) For the 8-bit word 00111001, the check bits stored with it would be 0111. Suppose when the word is read from memory, the check bits are calculated to be 1101. What is the data word that was read from memory?

Solution:

8.15 The Hamming Word initially calculated was:

bit number:

12	11	10	9	8	7	6	5	4	3	2	1
0	0	1	1	0	1	0	0	1	1	1	1

Doing an exclusive-OR of 0111 and 1101 yields 1010 indicating an error in bit 10 of the Hamming Word. Thus, the data word read from memory was 00011001.

Q26) How many check bits are needed if the Hamming error correction code is used to detect single-bit errors in a 1024-bit data word?

Solution:

8.16 Need $n - k$ check bits such that $2^{(n-k)} - 1 \geq 1024 + (n - k)$. The minimum value of $n - k$ that satisfies this condition is 11.

- Or: $(Log_2 1024) + 1 = 11$

5. Electrical noise generated by the earth's heat near its surface adversely affects reception.

Q9) Write down the equation for finding the Max number of correctable errors.

- Max number of correctable errors: $t = \left\lfloor \frac{d_{min}-1}{2} \right\rfloor$

Q10) Write down the equation for finding the number of detectable but not correctable errors.

- Number of detectable but not correctable errors $= d_{min} - 1$

Cyclic Codes

- Can be encoded and decoded using linear feedback shift registers (LFSRs)
- For cyclic codes, a valid codeword ($c_0, c_1, \ldots, c_{n-1}$), shifted right one bit, is also a valid codeword ($c_{n-1}, c_0, \ldots, c_{n-2}$)
- Takes fixed-length input (k) and produces fixed-length check code (n-k)
  - In contrast, CRC error-detecting code accepts arbitrary length input for fixed-length check code

السلايدات يلي عليهم نجمة الدكتور ما شرحهم
وكانوا من ضمن وحدة من مواضيع البرزنتيشن و ما جاب سيرة عنهم بالفاينل ، مو خطأ تقرأهم

BCH Codes

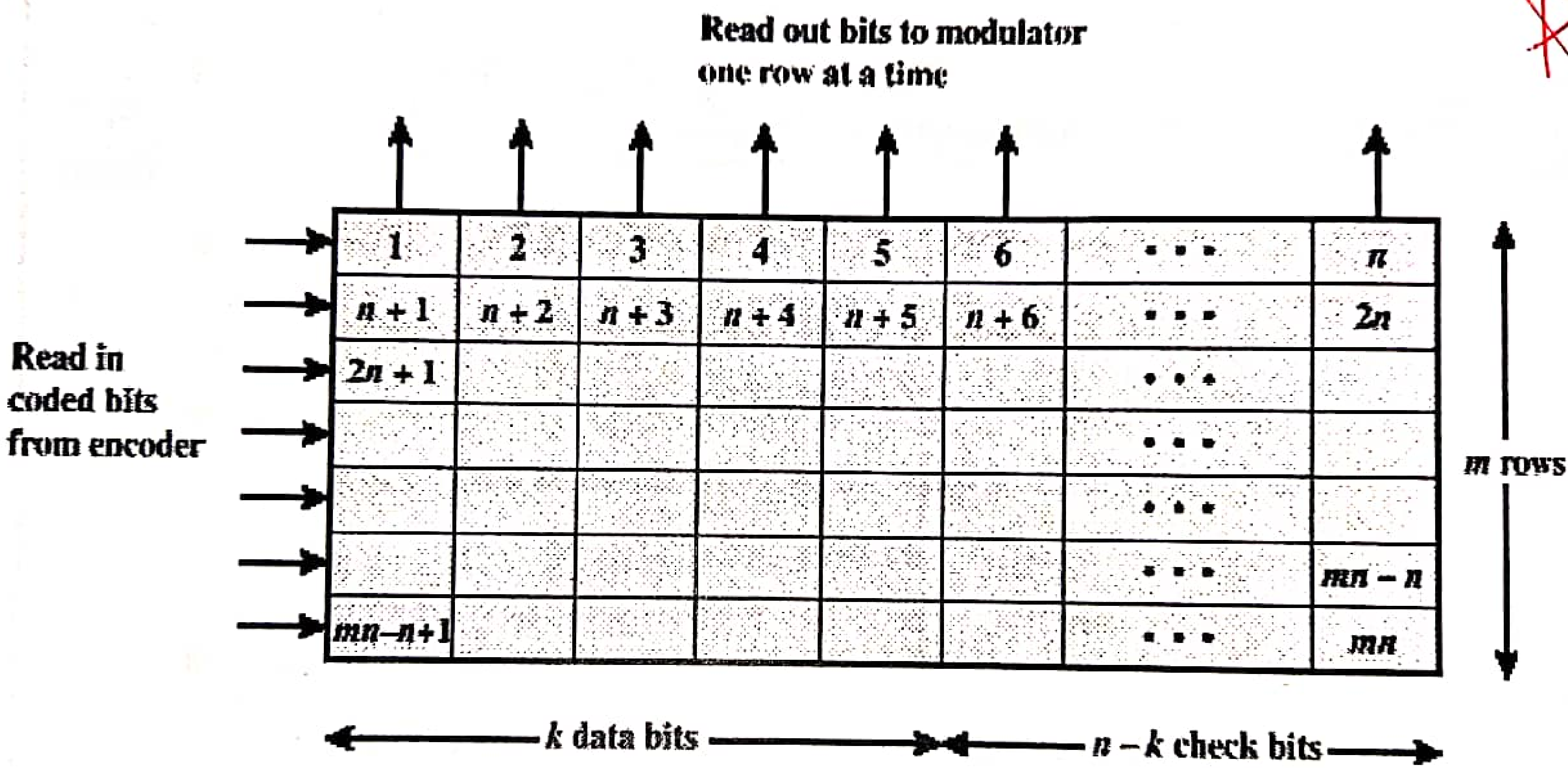
- For positive pair of integers m and t, a (n, k) BCH code has parameters:
  - Block length: $n = 2^m - 1$
  - Number of check bits: $n - k$ £ mt
  - Minimum distance: $d_{\min}$ ³ $2t + 1$
- Correct combinations of t or fewer errors
- Flexibility in choice of parameters
  - Block length, code rate

Reed-Solomon Codes

- Subclass of nonbinary BCH codes
- Data processed in chunks of m bits, called symbols
- An (n, k) RS code has parameters:
  - Symbol length: m bits per symbol
  - Block length: $n = 2^m - 1$ symbols $= m(2^m - 1)$ bits
  - Data length: k symbols
  - Size of check code: $n - k = 2t$ symbols $= m(2t)$ bits
  - Minimum distance: $d_{min} = 2t + 1$ symbols

Block Interleaving

- Data written to and read from memory in different orders
- Data bits and corresponding check bits are interspersed with bits from other blocks
- At receiver, data are deinterleaved to recover original order
- A burst error that may occur is spread out over a number of blocks, making error correction possible

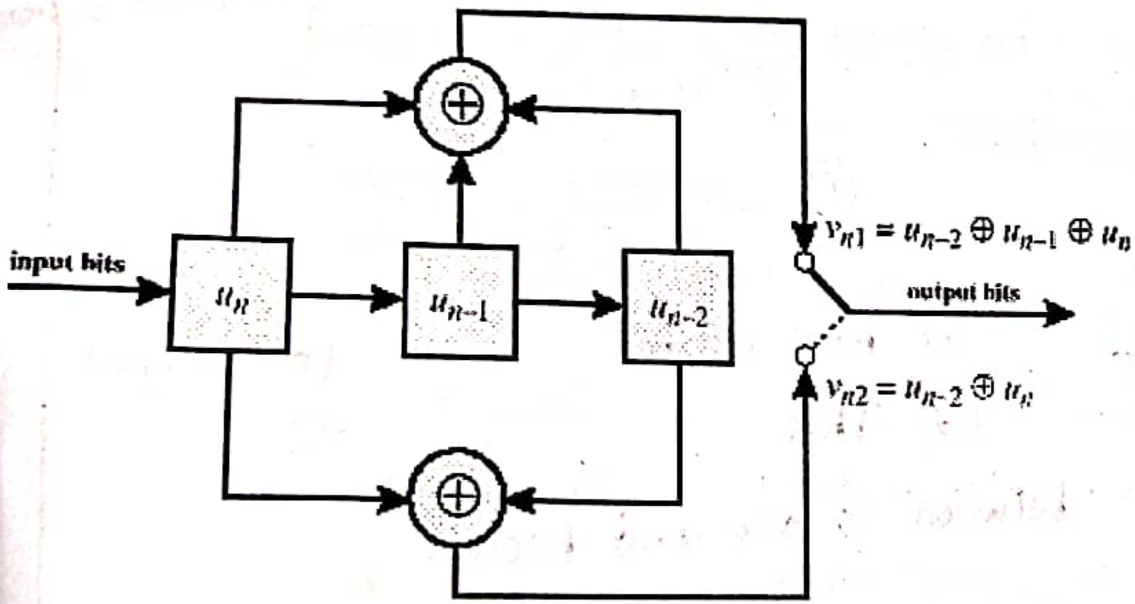


Note: The numbers in the matrix indicate the order in which bits are read in.
Interleaver output sequence: $1, n + 1, 2n + 1, \ldots$

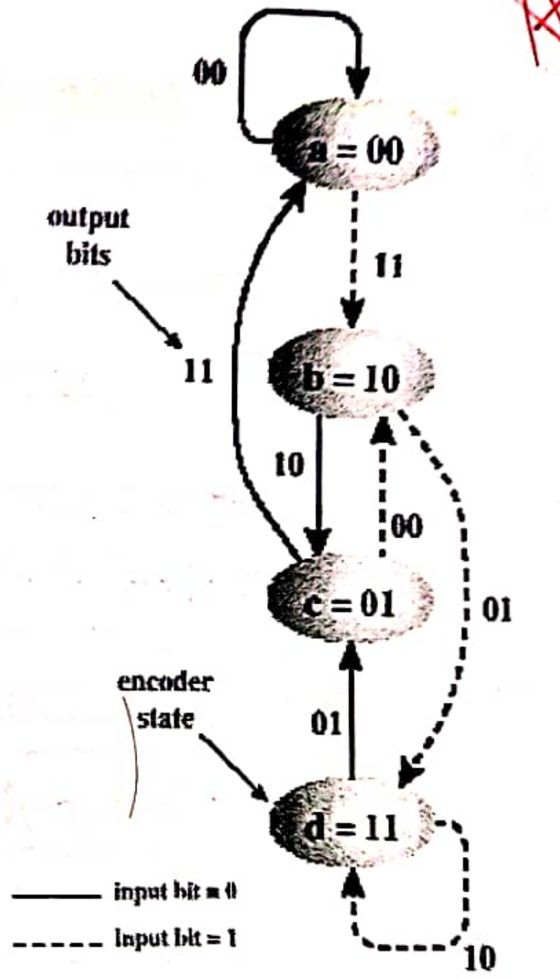
Figure 8.8 Block Interleaving

Convolutional Codes

- Generates redundant bits continuously
- Error checking and correcting carried out continuously
  - (n, k, K) code
    - Input processes k bits at a time
    - Output produces n bits for every k input bits
    - K = constraint factor
    - k and n generally very small
  - n-bit output of (n, k, K) code depends on:
    - Current block of k input bits
    - Previous K-1 blocks of k input bits



(a) Encoder shift register



(b) Encoder state diagram

Figure 8.9 Convolutional Encoder with $(n, k, K) = (2, 1, 3)$

Decoding

- Trellis diagram – expanded encoder diagram
- Viterbi code – error correction algorithm
    - Compares received sequence with all possible transmitted sequences
    - Algorithm chooses path through trellis whose coded sequence differs from received sequence in the fewest number of places
    - Once a valid path is selected as the correct path, the decoder can recover the input data bits from the output code bits

ARQ

Automatic Repeat Request

retransition
number of error higher the capibility of error schem

- Mechanism used in data link control and transport protocols
- Relies on use of an error detection code (such as CRC)

① we have error
② ARR
retransmit agin

2 mechanism

① - Flow Control

between sender and Reciver

② - Error Control

I need to restrict number of packet that intransiat between sender and reciver.

Flow Control

- Assures that transmitting entity does not overwhelm a receiving entity with data
- Protocols with flow control mechanism allow multiple PDUs in transit at the same time
- PDUs arrive in same order they are sent
- Ex: Sliding-window flow control:
  - Transmitter maintains list (window) of sequence numbers allowed to send # of packet transmited like 10 packet
  - Receiver maintains list allowed to receive

* avoid having droping packet.
* avoid having consution in transmission medium
* recive in the same order.

send first packet. 9 باقي
send second packet 8 باقي

window size shrend
unless he recived acknolgment
expanding لل window ال

Flow Control

- Reasons for breaking up a block of data before transmitting:
  - ① Limited buffer size of receiver
  - Retransmission of PDU due to error requires smaller amounts of data to be retransmitted
  - On shared medium, larger PDUs occupy medium for extended period, causing delays at other sending stations

idea why we breaking message int Block data of packet?

① If I recive packet with error ther is no need to transtuted all massege just I transimted the packet contain recived error.

② In order to avoid having extra delay like Transited delay depend in paket size

③ If we transimted large size maybee we can't store in buffer.

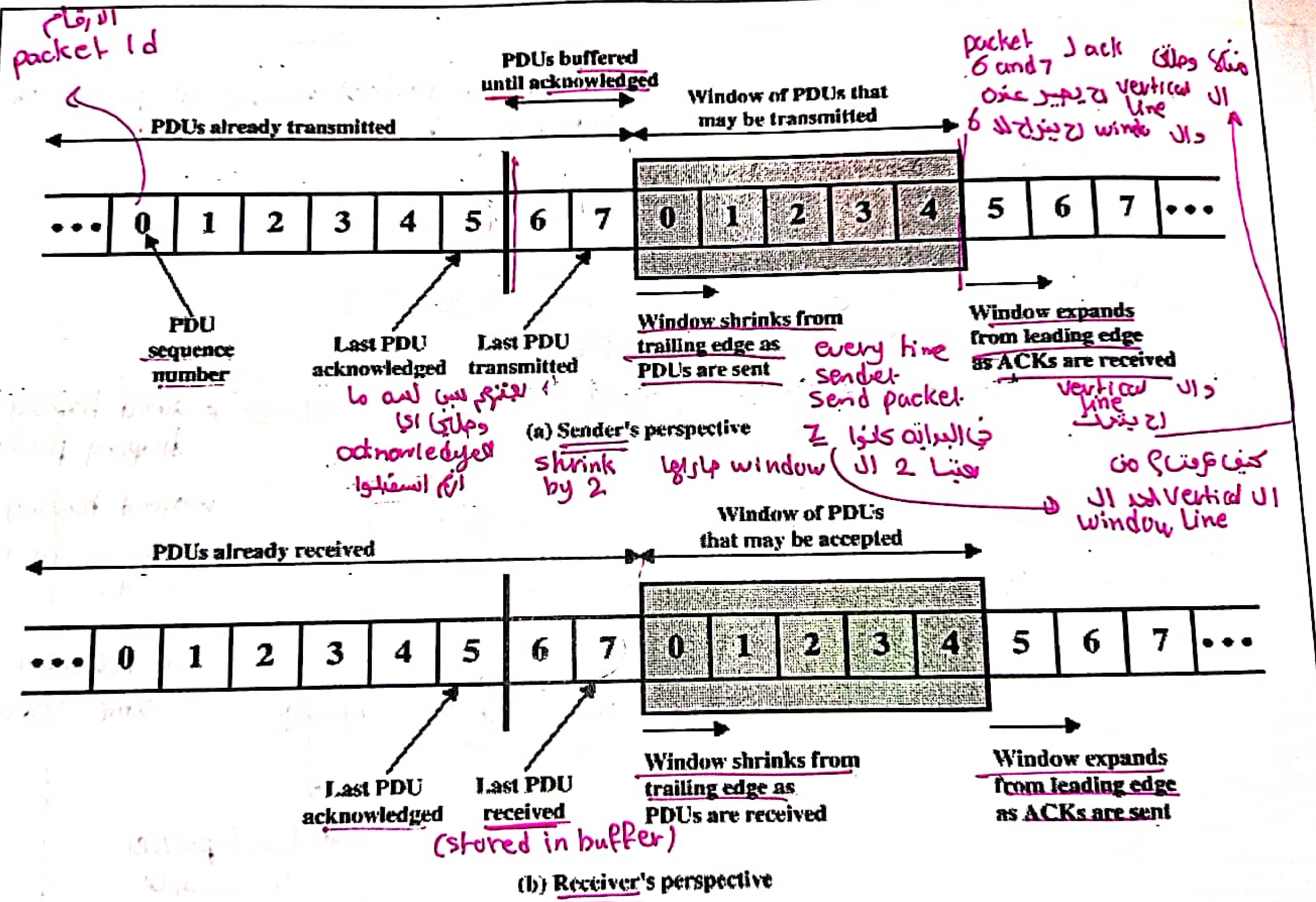
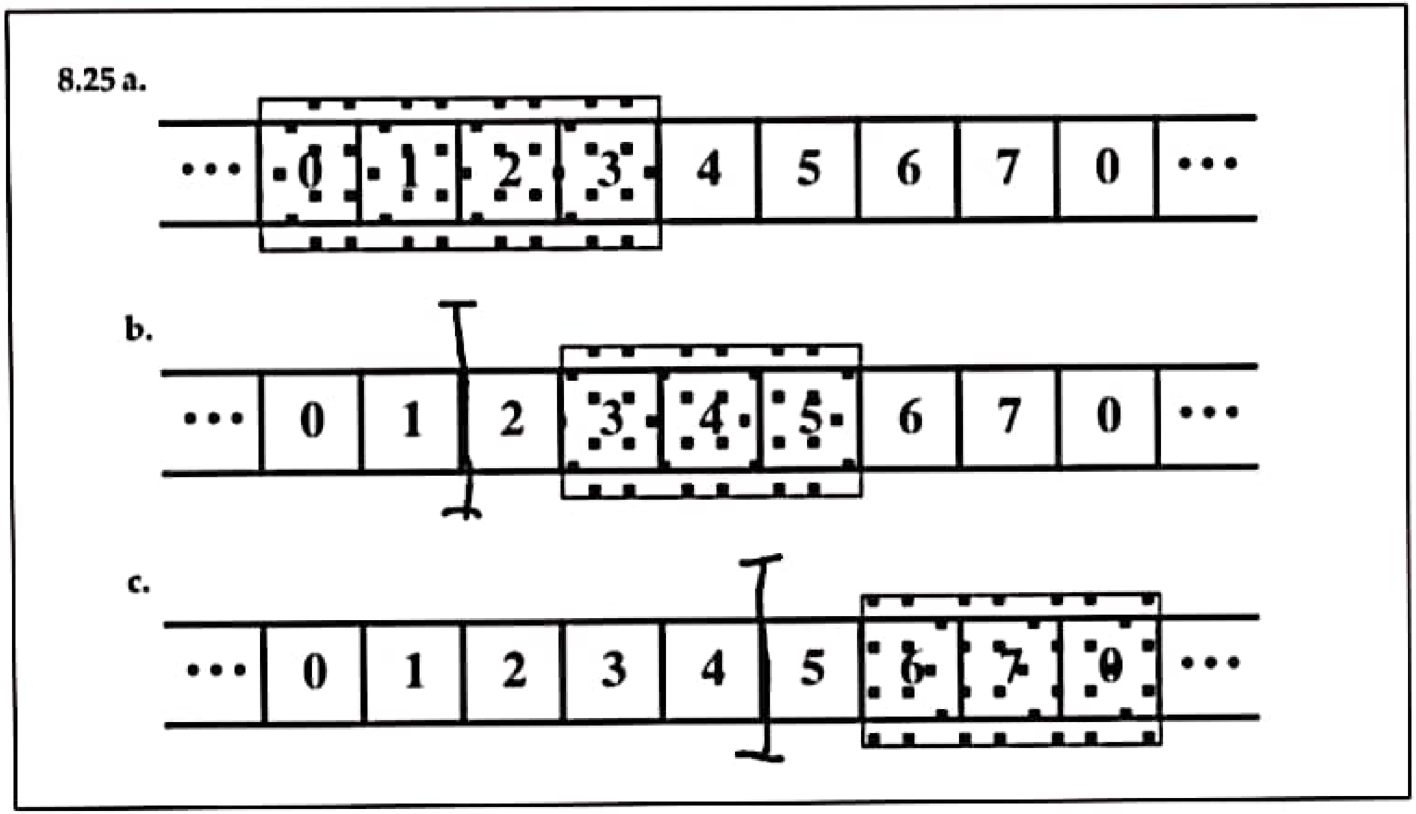


Figure 8.17 Sliding-Window Depiction

Q27) Two neighboring nodes (A and B) use a sliding-window protocol with a 3-bit sequence number. As the ARQ mechanism, Go-back-N is used with a window size of 4. Assuming A is transmitting, and B is receiving, show the window positions for the following succession of events:

a. Before A sends any frames.
b. After A sends frames 0, 1, 2 and receives an acknowledgment from B for 0 and 1
c. After A sends frames 3, 4, 5 and B acknowledges 4 and the ACK is received by A.

Solution:



Sliding Window Protocol

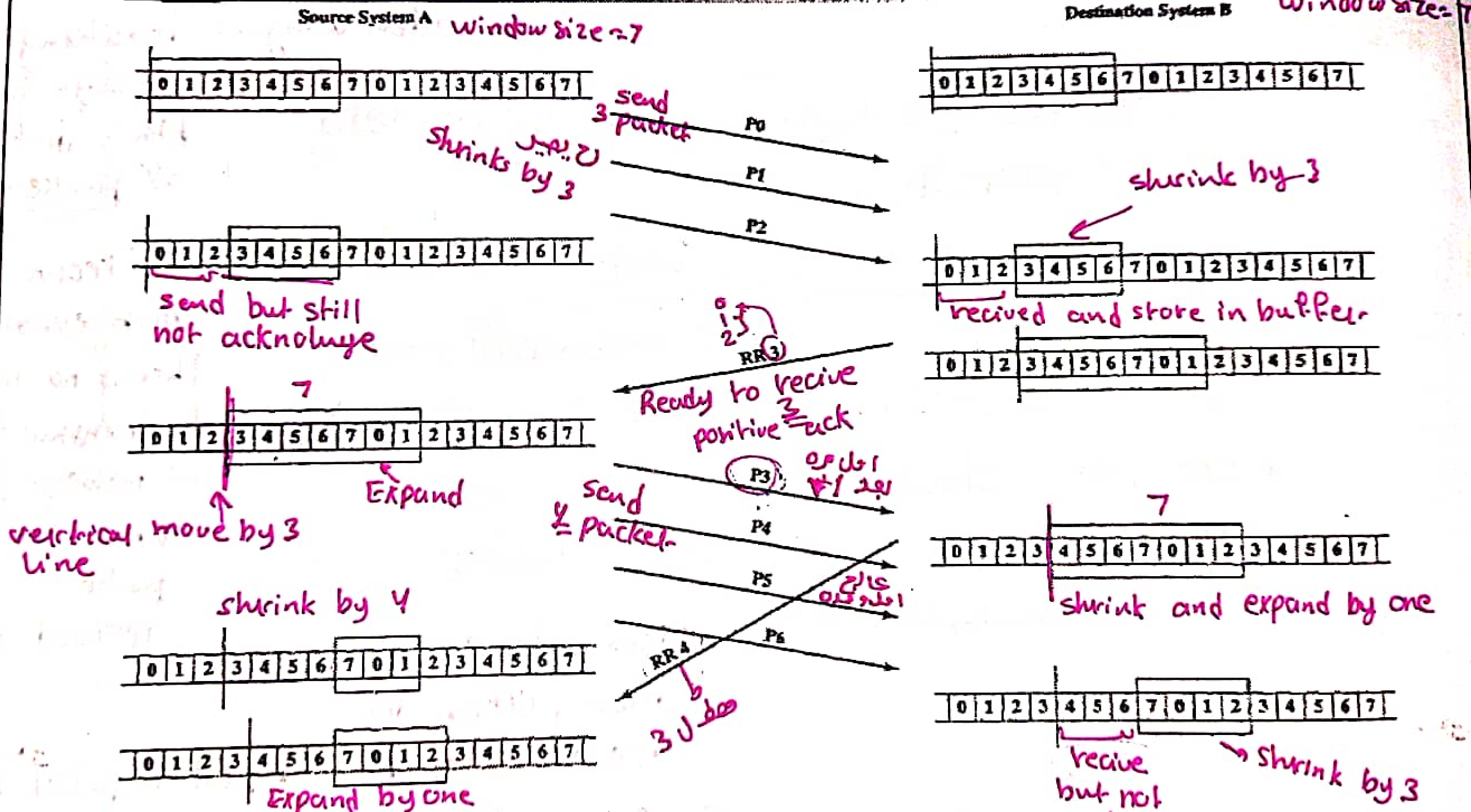


Figure 8.18 Example of a Sliding-Window Protocol

Error Control

ARR

- Mechanisms to detect and correct transmission errors

- Types of errors:
  - Lost PDU : a PDU fails to arrive
  - Damaged PDU : PDU arrives with errors

loss packet

packet Recive error

Error Control Requirements

1. ■ Error detection — to detect error
   ■ Receiver detects errors and discards PDUs
2. ■ Positive acknowledgement
   ■ Destination returns acknowledgment of received, error-free PDUs
3. ■ Retransmission after timeout (timer)
   ■ Source retransmits unacknowledged PDU
4. ■ Negative acknowledgement and retransmission
   ■ Destination returns negative acknowledgment to PDUs in error

loss packet maybe for packet or acknolgment

after certain time I not recived ~~transmitted~~ any thing, control masse to retransmition.

Go-back-N ARQ

- Acknowledgments
  - RR = receive ready (no errors occur) positive ack
  - REJ = reject (error detected) negative ack [damaged / loss]
- مهم Contingencies
  - Damaged PDU
  - Damaged RR
  - Damaged REJ

loss : استقبل 1,2,3 وبعدها 5

عرف انه في شي اهملها loss

رح يبعث REJ (4)

ال damaged بنعرف عن ال error detection

Q13) List the Contingencies of Go-back-N ARQ.

1. Damaged PDU.
2. Damaged RR.
3. Damaged REJ.

Q14) A digital signaling system is required to operate at 9600 bps.

Go-back-N ARQ

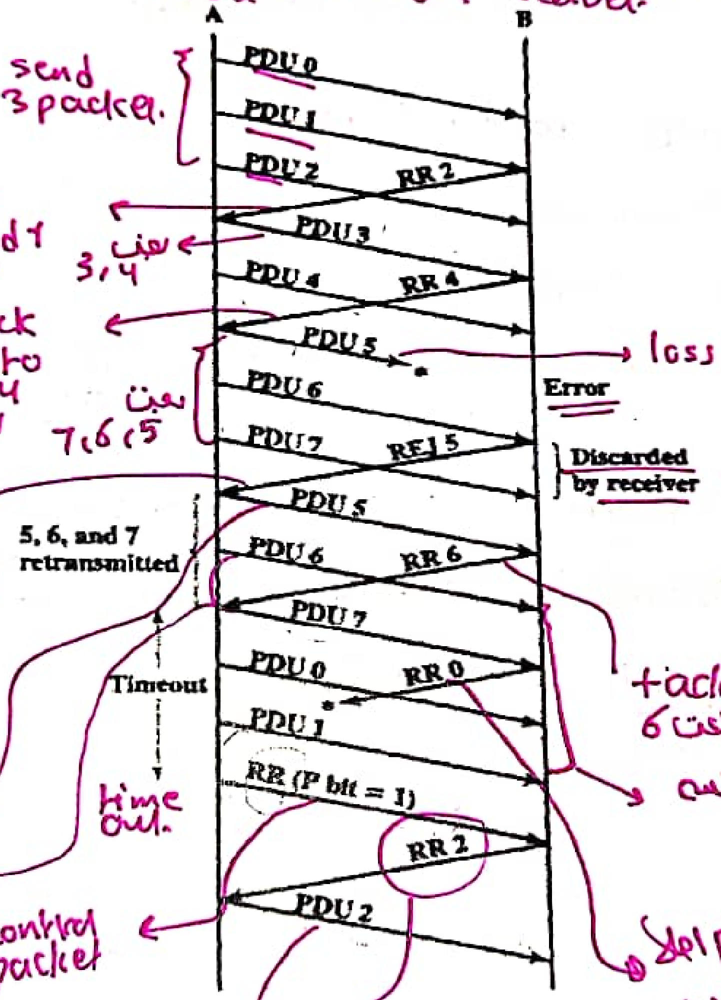


Figure 8.19 Go-back-N ARQ

Q21) For P = 110011 and M = 11100011, find the CRC

Solution:

```
              10110110
110011/1110001100000
       110011
        101111
        110011
         111000
         110011
          101100
          110011
           111110
           110011
    CRC =   11010
```

Q22) Calculate the Hamming pairwise distances among the following codewords:

a. (00000,10101,01010)
b. (000000,010101,101010,110110)

Solution:

إنتبه! الجداول مو صح 100%

8.9

a.

	00000	10101	01010
00000	0	2	2
10101	3	0	5
01010	2	5	0

b.

	000000	010101	101010	110110
000000	0	3	3	4
010101	3	0	6	6
101010	3	6	0	3
110110	4	6	3	0

Q23) For the Hamming code shown in the Table below, show what happens when a check bit rather than a data bit is received in error.

If the syndrome contains one and only one bit set to 1 , then an error has occurred in one of the check bits. No correction is needed.

8.13 The transmitted block and check bit calculation are shown in Table 8.2a and b. Now suppose that the only error is in C8. Then the received block results in the following table:

Position	12	11	10	9	8	7	6	5	4	3	2	1
Bits	D8	D7	D6	D5	C8	D4	D3	D2	C4	D1	C2	C1
Block	0	0	1	1	1	1	0	0	1	1	1	1
Codes			1010	1001		0111				0011		

The check bit calculation after reception:

Position	Code
Hamming	1111
10	1010
9	1001
7	0111
3	0011
XOR = syndrome	1000

The nonzero result detects and error and indicates that the error is in bit position 8, which is check bit C8.

Satellite Communications

Ex. los — both station must see togather.

Chapter 9

Satellite-Related Terms

- Earth Stations – antenna systems on or near earth
- Uplink – transmission from an earth station to a satellite
- Downlink – transmission from a satellite to an earth station
- Uplink frequency is greater than downlink cause Earth station has more power to compensate free space loss.
- Transponder – electronics in the satellite that convert uplink signals to downlink signals

Ways to Categorize Communications Satellites

- ① **Coverage area** — cover sevilal country within one Content
  - Global, regional, national → use in one country
    - Global: very large area
    - regional: accross contures
    - national: one country
- ② **Service type**
  - Fixed service satellite (FSS) — point-to-point. ما بتحركوا T and Reciver
  - Broadcast service satellite (BSS) — one to many; one Trans. to many Reciver; one earth station transmitted signal and satellite station forward this signal to many earth station. EX. satellite TV
  - Mobile service satellite (MSS) — both T and R move; ↳ both earth stations can move or mobile (like mobile service ثريا)
- ③ **General usage**
  - Commercial, military, amateur, experimental

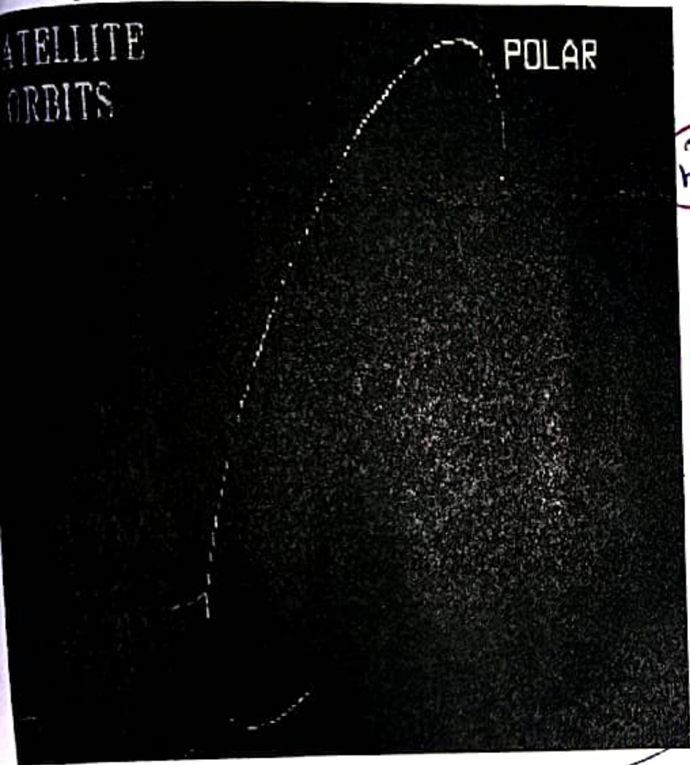
Q28) List and briefly define three different ways of categorizing communications satellites.

1. Coverage area: Categorizing satellites based on the area they cover, such as global, regional, or national. The larger the area of coverage, the more satellites must be involved in a single networked system.
2. Service type: Categorizing satellites based on the specific services they provide. It includes Fixed service satellites (FSS), Broadcast service satellites (BSS), and Mobile service satellites (MSS).
3. General usage: Categorizing satellites based on their general usage, which can be commercial, military, amateur, or experimental.

Classification of Satellite Orbits

- Circular or elliptical orbit
  - Circular with center at earth's center
  - Elliptical with one foci at earth's center
- Orbit around earth in different planes
  - Equatorial orbit above earth's equator
  - Polar orbit passes over both poles
  - Other orbits referred to as inclined orbits
- Altitude of satellites
  - Geostationary orbit (GEO)
  - Medium earth orbit (MEO)
  - Low earth orbit (LEO)

Satellite Orbits



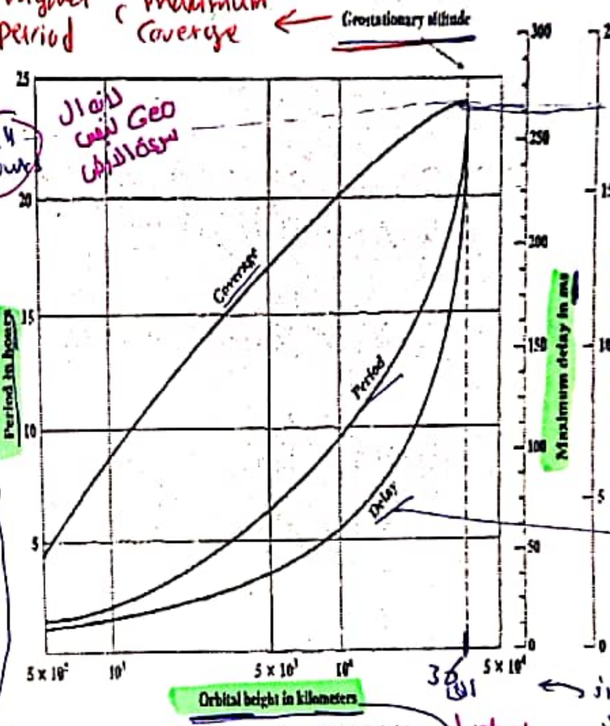


Figure 9.2 Satellite Parameters as a Function of Orbital Height

Geometry Terms

Geometry Terms

- Elevation angle (θ): the angle from the horizontal to the point on the center of the main beam of the antenna when the antenna is pointed directly at the satellite
- Minimum elevation angle is preferred
- Coverage angle (β): the measure of the portion of the earth's surface visible to the satellite
- Distance from satellite and farthest point:

$$d = \frac{(R + h)\sin\beta}{\cos\theta} = \frac{R\sin\beta}{\sin\alpha}$$

- Round-trip transmission delay:

$$\frac{2h}{c} \le t \le \frac{2(R + h)\sin\beta}{c(\cos\theta)}$$

Figure Coverage and Elevation Angles

Minimum Elevation Angle

why can't have the Elevation angle =0

- Reasons affecting minimum elevation angle of earth station's antenna (>0°)

1. - Buildings, trees, and other terrestrial objects block the line of sight.
2. - Atmospheric attenuation is greater at low elevation angles
3. - Electrical noise generated by the earth's heat near its surface adversely affects reception

Q8) List the Reasons affecting the minimum elevation angle of the earth station's antenna.

1. Buildings, trees, and other terrestrial objects block the line of sight.
2. Atmospheric attenuation is greater at low elevation angles.
3. Electrical noise generated by the earth's heat near its surface adversely affects reception.

Q9) Write down the equation for finding the Max number of correctable errors.

GEO Satellite Characteristics

- The most common type of satellite communication
- Usually, the satellite is in a circular orbit 35,863 km above the earth's surface
- Diameter of coverage is about 16,000 km
- Rotate at exactly the same angular speed as the earth
- So, they remain above the same spot on the equator as the earth rotates.

GEO Orbit

- **Advantages:**
  - No problem with frequency changes
  - Tracking of the satellite is simplified
  - Large coverage area

- **Disadvantages:**
  - Weak signal after traveling over 35,000 km
  - Polar regions are poorly served
  - Signal sending delay is substantial (round trip delay 500 ms)

Solve the problem of GEO

LEO Satellite Characteristics

- Often in polar orbit under 2000 km — small delay 20 msecond
- Orbit period ranges from 1.5 to 2 hours — faster than GEO
- Diameter of coverage is about 8000 km — smaller
  لانه اقرب لسطح الارض
- Round-trip signal propagation delay less than 20 ms
- Maximum satellite visible time up to 20 min
- System must cope with large Doppler shifts
  problem

LEO Categories

freq حسب ال

- Little LEOs
  - Frequencies below 1 GHz
  - 5MHz of bandwidth
  - Data rates up to 10 kbps
  - Aimed at paging, tracking, and low-rate messaging

little bandwidth
and little Data rate

text message

- Big LEOs
  - Frequencies above 1 GHz
  - Support data rates up to a few megabits per sec
  - Offer same services as little LEOs in addition to voice and positioning services

multimedia

LEO Orbit

- Advantages:
  - Reduced propagation delay
  - Strong received LEO signal compared with GEO
  - Localized small coverage so that the spectrum can be conserved (reused)
- Disadvantages:
  - Many satellites are needed for broad coverage over 24 hours
  - Problem with frequency changes

Freq reuse overlapping circles

the freq

coverage area ↓

in order to increase the coverage I need many leo

in order to find solution and advant between LEO and GEO we use MEO

MEO Satellite Characteristics

in middle between GEO and LEO

- Inclined orbit at an altitude in the range of 5000 to 12,000 km
- Orbit period of 6 hours
- Diameter of coverage is 10,000 to 15,000 km
- Round trip signal propagation delay less than 50 ms
- Maximum satellite visible time is a few hours

Table 9.1 Orbital Comparison for Satellite Communications Applications

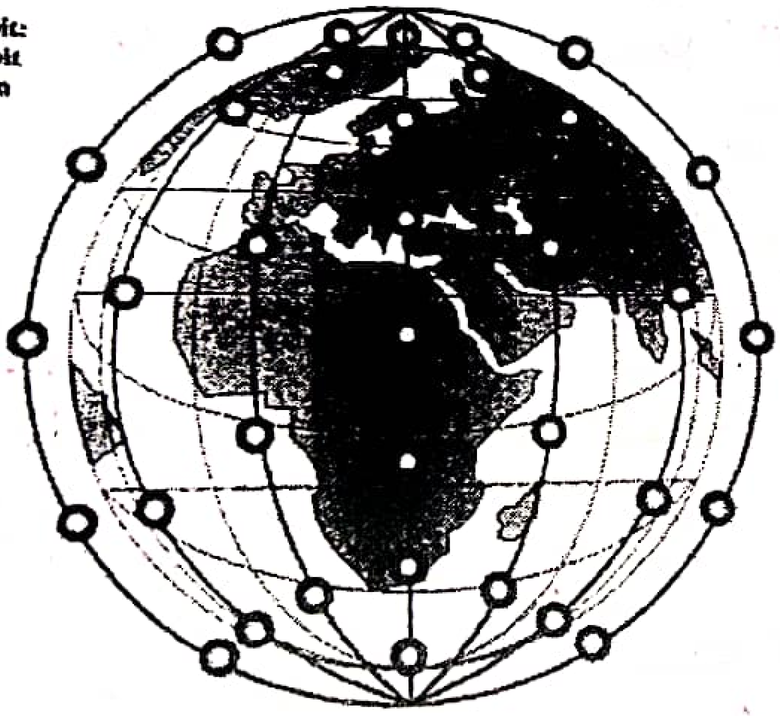
Orbits	LEO	MEO	GEO
Orbital period	1.5 to 2 h	5 to 10 h	24 h
Altitude range	500 to 1500 km	8000 to 18,000 km	35,863 km
Visibility duration	15 to 20 min/pass	2 to 8 hr/pass	Permanent
Elevation	Rapid variations; high and low angles	Slow variations; high angles	No variation; low angles at high latitudes
Round-trip propagation delay	Several milliseconds	Tens of milliseconds	≈250ms
Instantaneous ground coverage (diameter at 10° elevation)	≈6000 km	≈12,000 to 15,000 km	16,000 km
Examples of systems	Iridium Globalstar Teledesic Skybridge, Orbcomm	Odyssey Inmarsat	Intelstat Interspoutnik Inmarsat

The LEO MEO GEO table in the slides is important.

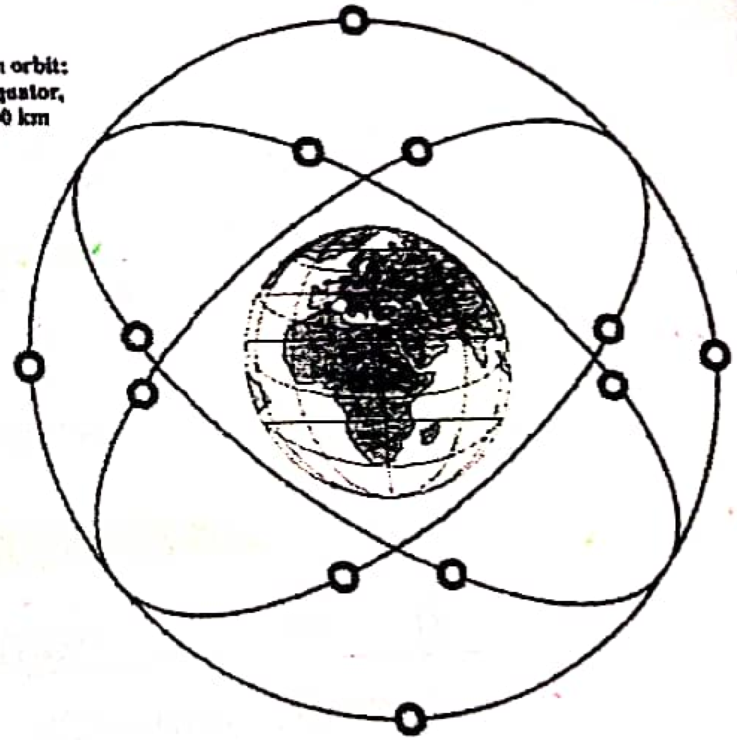
Orbits	LEO	MEO	GEO
Orbital period	1.5 to 2 h	5 to 10 h	24 h
Altitude range	500 to 1500 km	8000 to 18,000 km	35,863 km
Visibility duration	15 to 20 min/pass	2 to 8 hr/pass	Permanent
Elevation	Rapid variations; high and low angles	Slow variations; high angles	No variation; low angles at high latitudes
Round-trip propagation delay	Several milliseconds	Tens of milliseconds	≈250ms
Instantaneous ground coverage (diameter at 10° elevation)	≈6000 km	≈12,000 to 15,000 km	16,000 km
Examples of systems	Iridium Globalstar Teledesic Skybridge, Orbcomm	Odyssey Inmarsat	Intelstat Interspoutnik Inmarsat

LEO and MEO Satellite

(a) Low earth orbit: often in polar orbit at 500 to 1500 km altitude



(b) Medium earth orbit: inclined to the equator, at 5000 to 18,000 km altitude



Q29) List and briefly define three different ways of classifying satellite orbits.

1. Circular or elliptical orbit: with the center of the circle at the center of the earth, or elliptical, with the earth's center at one of the two foci of the ellipse.
2. Altitude of satellites: classified as geostationary orbit (GEO), medium earth orbit (MEO), and low earth orbit (LEO).
3. Orbit around Earth in different planes: An equatorial orbit is directly above the Earth's equator. A polar orbit passes over both poles. Other orbits are referred to as inclined orbits.

Q30) Explain what GEO, LEO, and MEO satellites are (including what the acronyms stand for). And compare the three types with respect to factors such as size and shape of orbits, signal power, frequency reuse, propagation delay, number of satellites for global coverage, and handoff frequency.

- LEO, GEO, and MEO stand for Low Earth Orbit, Geostationary Orbit, and Medium earth orbit, respectively.

- LEO satellites: Lower orbits, typically 700 to 1,400 km altitude. Faster orbital speed. Lower signal power is required. Shorter propagation delay compared to GEO satellites. More difficult to track due to speed and smaller coverage area. Frequent handoffs due to rapid movement

- GEO satellites: Circular orbit above the equator at approximately 35,838 km altitude. Signal strength is relatively weak compared to LEO satellites. Frequency reuse is more challenging due to broader antenna beam coverage. The propagation delay is about 1/4th of a second. Inadequate coverage near the north and south poles. Tracking and handoff are not required as GEO satellites appear stationary relative to the Earth.

- MEO satellites: Moderate orbits, typically ranging from 8,000 to 20,000 kilometers above the Earth. Moderate orbital speed. Moderate signal power is required. Moderate propagation delay compared to GEO and LEO satellites. Less difficult to track compared to LEO satellites, but still requires tracking systems. Occasional handoffs may be necessary depending on orbit characteristics.

Frequency Bands Available for Satellite Communications

Band	Frequency Range	Total Bandwidth	General Application
L	1 to 2 GHz	1 GHz	Mobile satellite service (MSS)
S	2 to 4 GHz	2 GHz	MSS, NASA, deep space research
C	4 to 8 GHz	4 GHz	Fixed satellite service (FSS)
X	8 to 12.5 GHz	4.5 GHz	FSS military, terrestrial earth exploration, and meteorological satellites
Ku	12.5 to 18 GHz	5.5 GHz	FSS, broadcast satellite service (BSS)
K	18 to 26.5 GHz	8.5 GHz	BSS, FSS
Ka	26.5 to 40 GHz	13.5 GHz	FSS

Satellite Link Performance Factors

- ① Distance between earth station antenna and satellite antenna (attribute) كل ما كانت اقل كل ما كانت أوضح
  - Free space loss propagation model
- For downlink, terrestrial distance between earth station antenna and "aim point" of satellite (نفس السنتر) لحالة horizontal
  - Displayed as a satellite footprint (Figure 9.6) بنعين ال diameter (coverage area)
- Atmospheric attenuation
  - Affected by oxygen, water, angle of elevation, and
  - higher frequencies ↑ Atmo.

اذا كنت لبنفس ال converge area ح استقبل good signal

مثلا انا ب اوروبا بدي استقبل القنوات نايا من الفايل سات نايا انا اجلا برا ال coverage out-side (aim point)

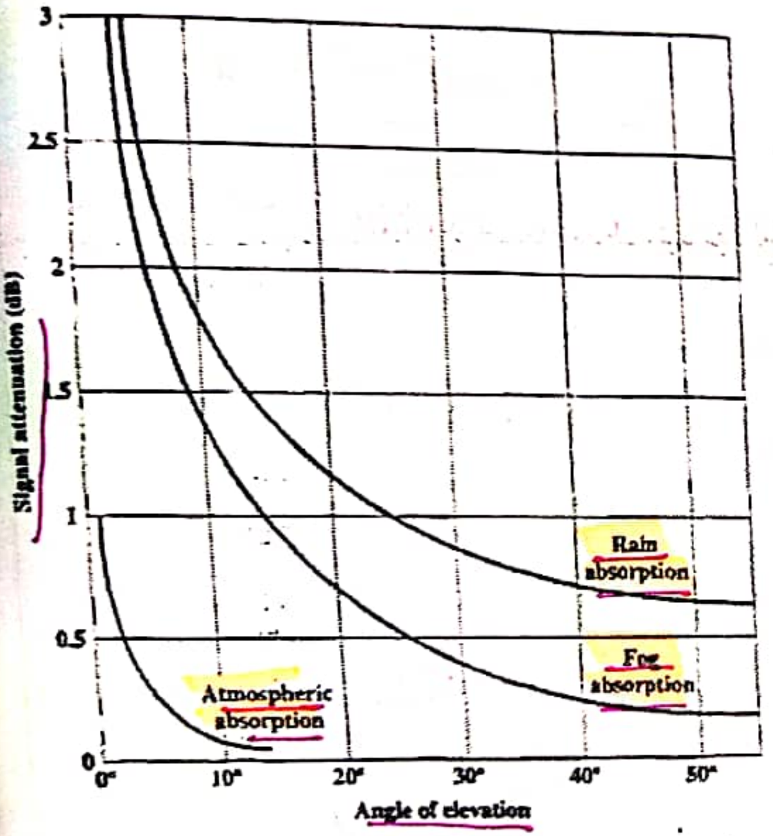


Figure 9.7 Signal Attenuation Due to Atmospheric Absorption (C Band)

كل ما كانت ال elevation angle مغيرة
باتجاه ال zero كل ما كان
ال absorption عالي من
ال atmospheric

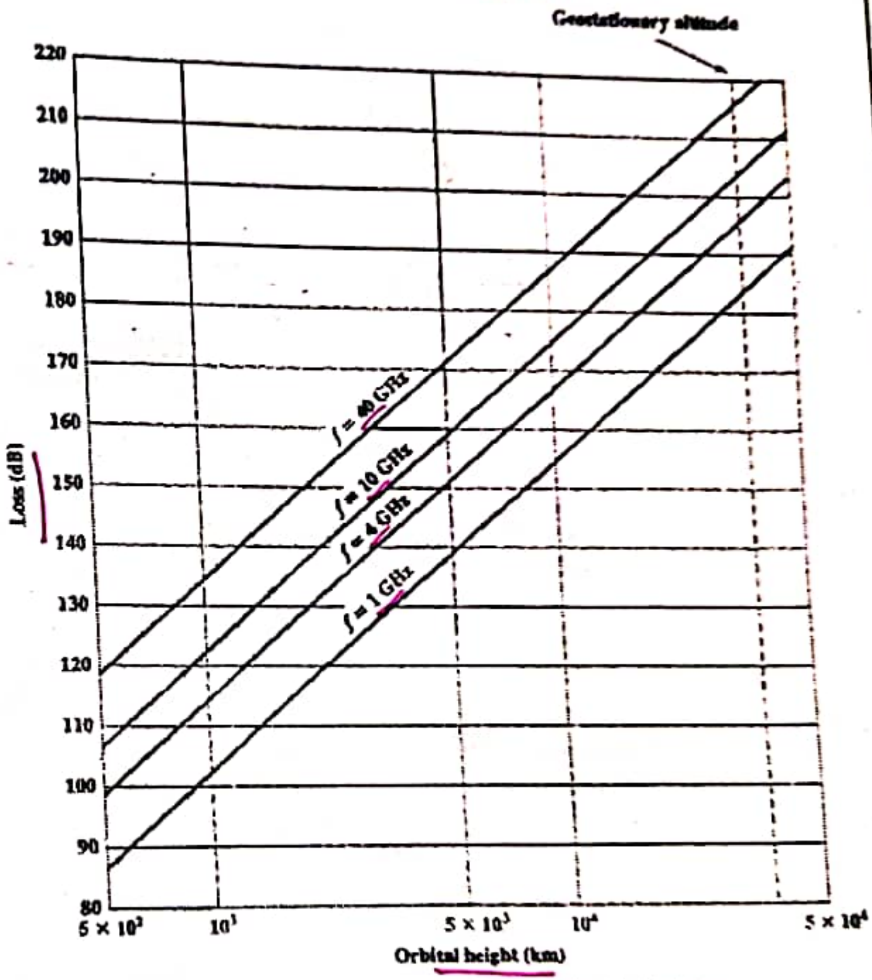


Figure 9.5 Minimum Free Space Loss as a Function of Orbital Height

كل ما بزيد ال hight ال loss رح يزيد

↑loss ↑f ← omidrection

↓loss ↑f ← directional

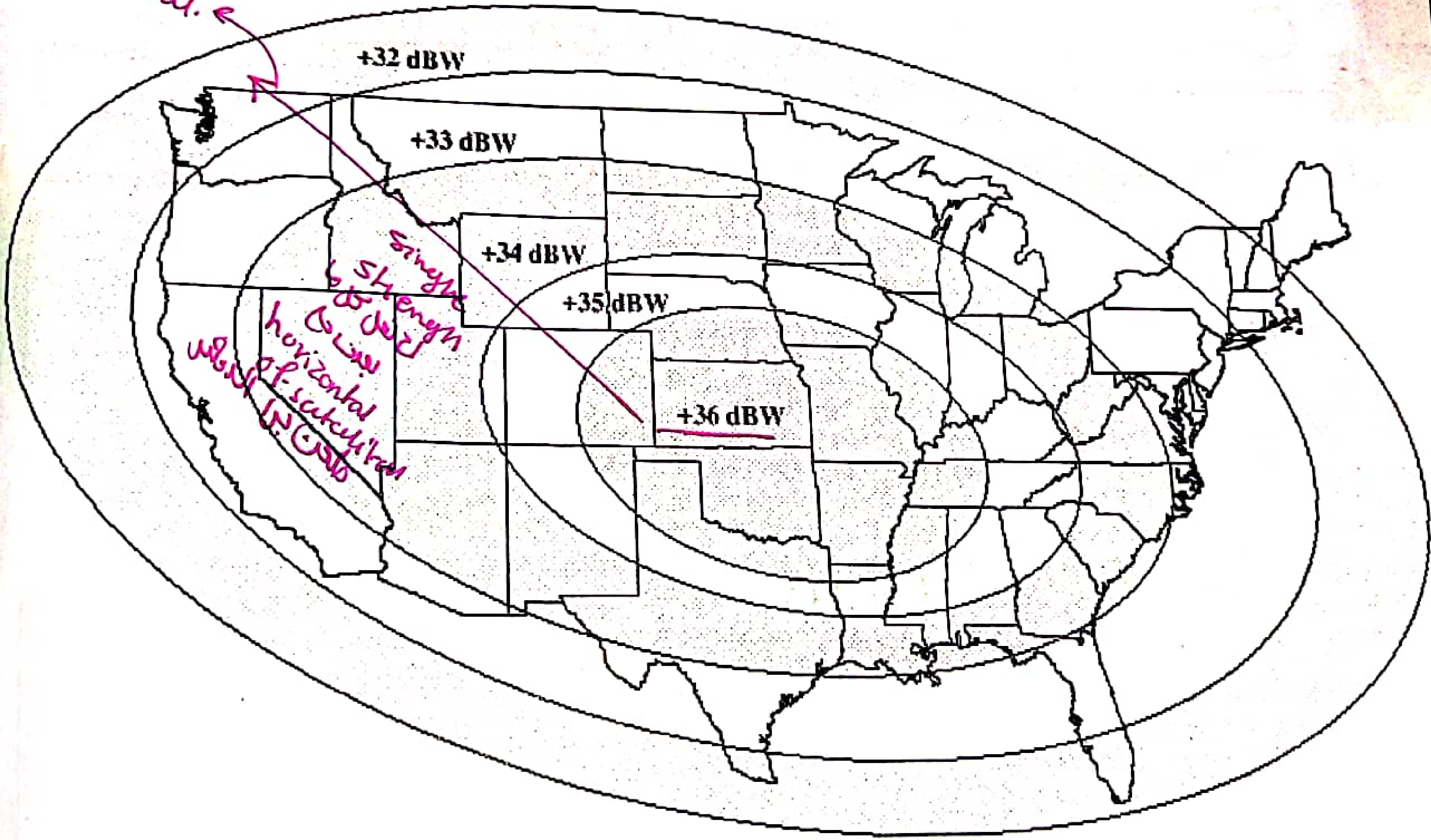


Figure 9.6 Typical Satellite Footprint

Satellite Network Configurations

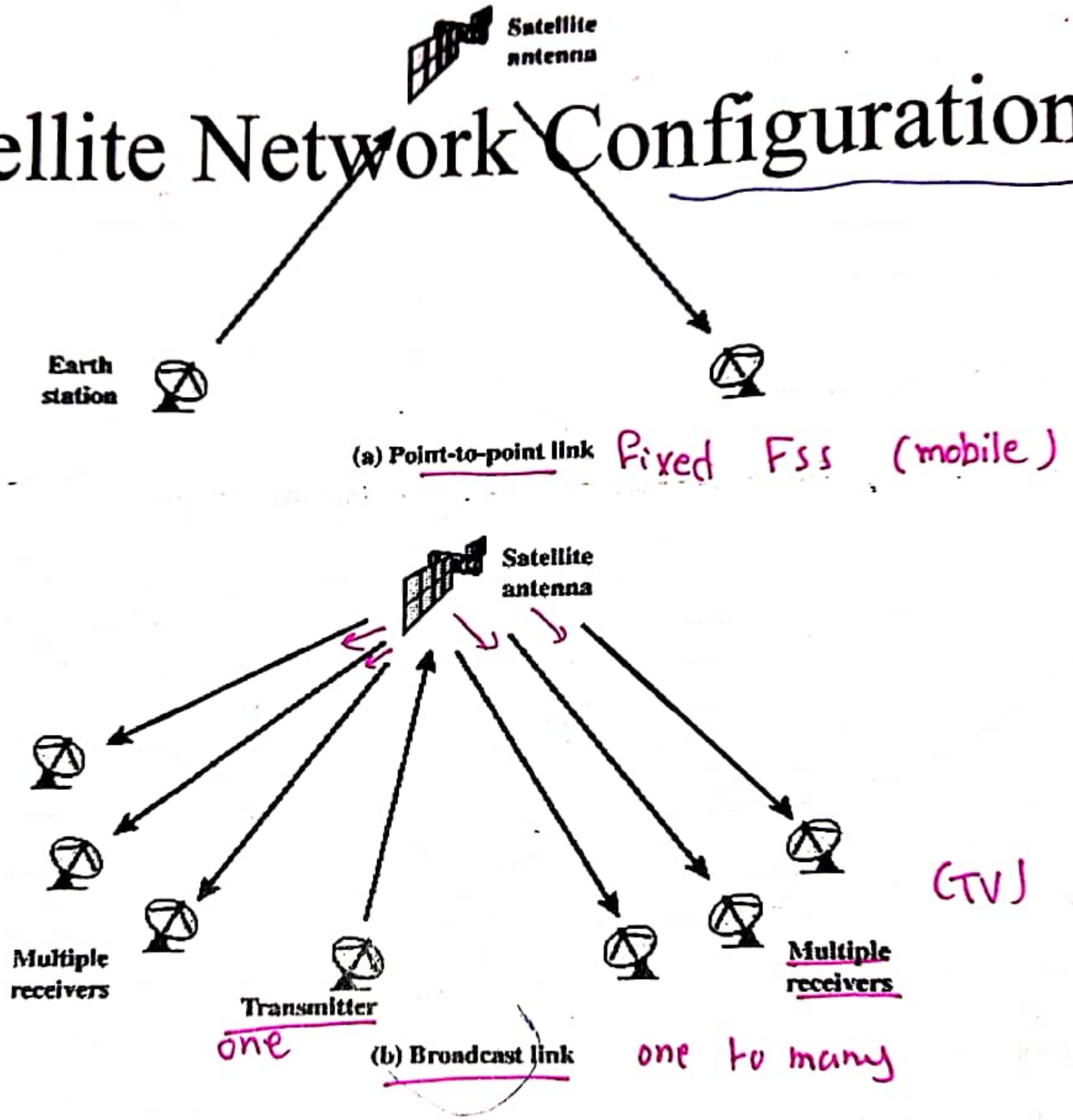


Figure 9.8 Satellite Communication Configurations

Figure 9.8 Satellite Communication Configurations

Capacity Allocation Strategies

So resource limit so we use multiplixing increase # of user reduce cost

1 ■ Frequency division multiple access (FDMA)

2 ■ Time division multiple access (TDMA)

3 ■ Code division multiple access (CDMA)

Frequency-Division Multiplexing

- Alternative uses of channels in point-to-point configuration:
  - 1200 voice-frequency (VF) voice channels
  - One 50-Mbps data stream
  - 16 channels of 1.544 Mbps each
  - 400 channels of 64 kbps each
  - 600 channels of 40 kbps each
  - One analog video signal
  - Six to nine digital video signals

Ex. For Divison the freq. to channel and each chennel has freq.

Frequency-Division Multiple Access

- Factors which limit the number of subchannels provided within a satellite channel via FDMA:

noise between this slot

① - Thermal noise
② - Intermodulation noise
③ - Crosstalk

Forms of FDMA

2 type of assigment:

① ▪ Fixed-assignment multiple access (FAMA)

- The assignment of capacity is distributed in a fixed manner among multiple stations
- Demand may fluctuate
- Results in the significant underuse of capacity

ممكن

→ waste the capacity

لا يكون في user ما استخدموا their capacity

② ▪ Demand-assignment multiple access (DAMA)

(dynamic)

- Capacity assignment is changed as needed to respond optimally to demand changes among the multiple stations

حسب ال needed

for capacity

حسب ال demand

user need alot → so the capacity ↑

" " less → " " ↓

FAMA-DAMA

pass on time

- FAMA – logical links between stations are preassigned
- FAMA – multiple stations access the satellite by using different frequency bands
- Uses considerable bandwidth
- DAMA – set of subchannels in a channel is treated as a pool of available links:
  - For full-duplex between two earth stations, a pair of subchannels is dynamically assigned on demand
  - Demand assignment performed in a distributed fashion by earth stations or satellite

Reasons for Increasing Use of TDM Techniques

Freq Cold Fashion

compare to FTMA

① ■ Cost of digital components continues to drop

② ■ Advantages of digital components:

- ■ Use of error correction reduce (error)

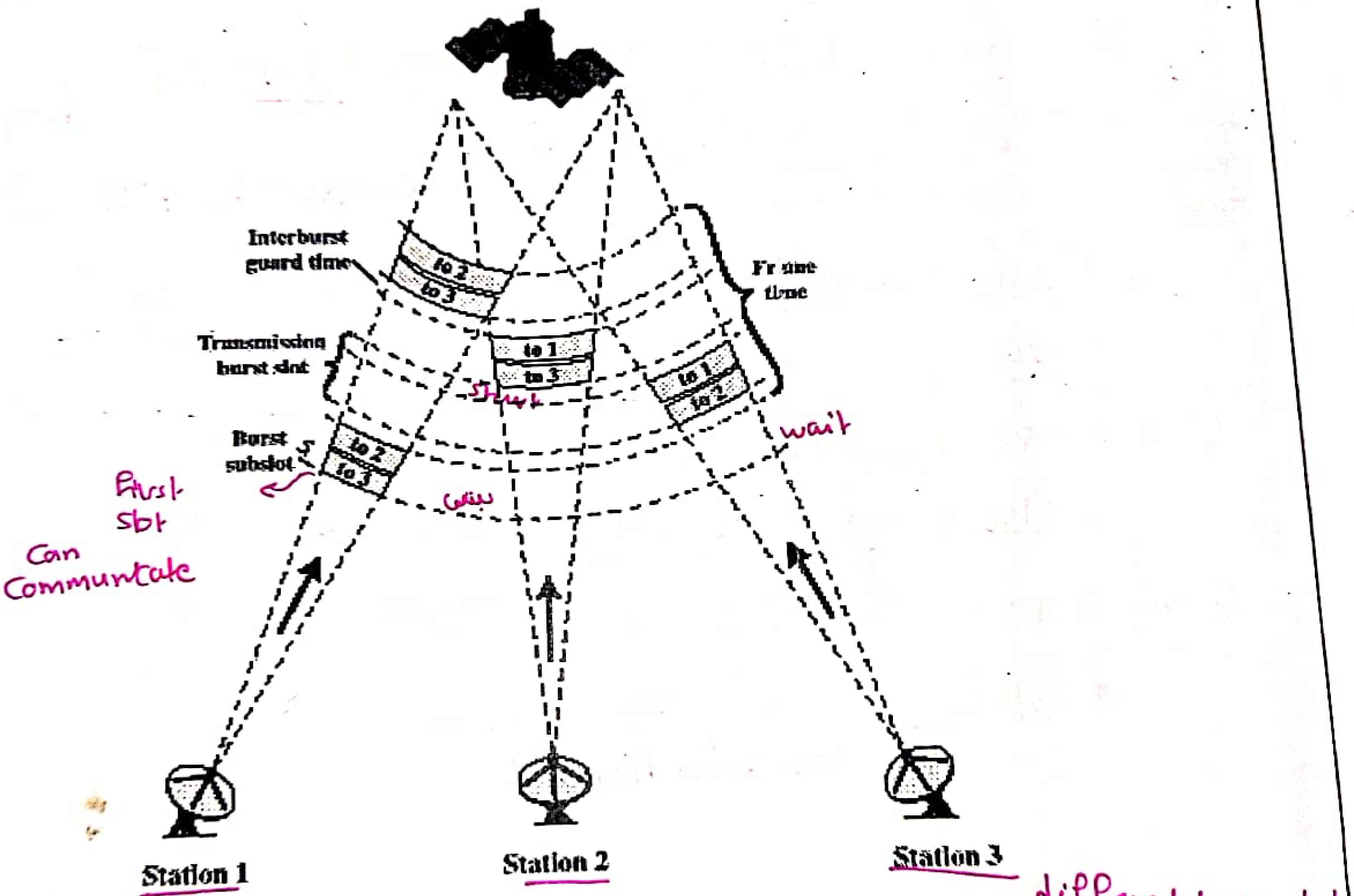
③ ■ Increased efficiency of TDM:

- ■ Lack of intermodulation noise

less sufer from noise

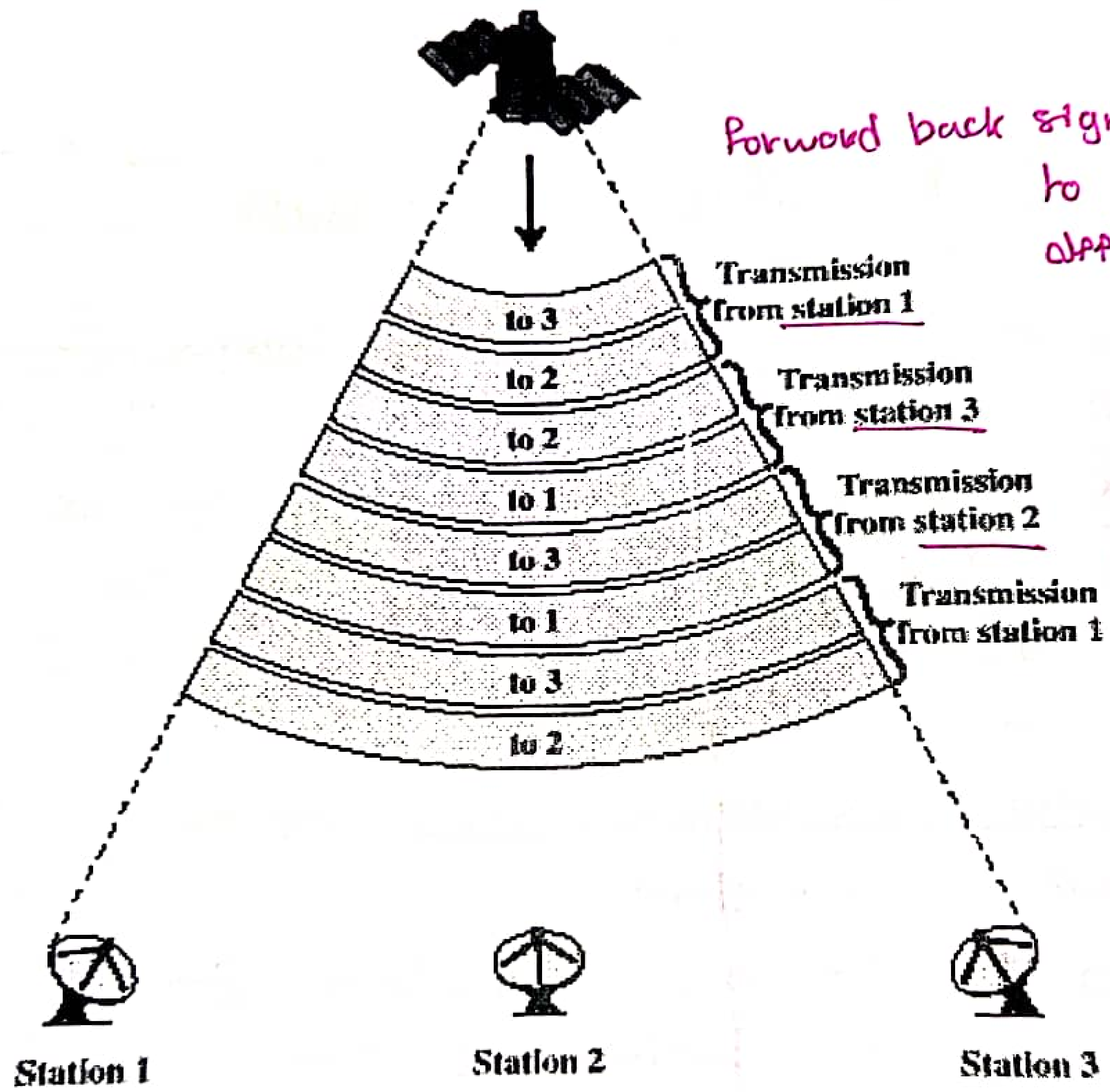
FAMA-TDMA Operation

- Transmission in the form of repetitive sequence of frames:
  - Each frame is divided into a number of time slots
  - Each slot is dedicated to a particular transmitter
- Earth stations take turns using uplink channel
  - Sends data in assigned time slot
- Satellite repeats incoming transmissions
  - Broadcast to all stations
- Stations must know which slot to use for transmission and which to use for reception



(a) Uplink

Figure 9.14 FAMA-TDMA Operation



(b) Downlink

Figure 9.14 FAMA-TDMA Operation