PES COLLEGE OF ENGINEERG MANDYA

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

Computer Networks Lab Manual

(P22CSL506)

Preface

This laboratory manual is designed to complement your theoretical understanding of computer networks by providing hands-on experience with real-world networking scenarios. The primary goal of these lab exercises is to bridge the gap between theory and practical implementation, allowing you to develop the skills necessary to design, configure, and troubleshoot computer networks. The lab exercises are crafted to give you practical exposure to key concepts in computer networking. Through hands-on activities, you will gain a deeper understanding of networking protocols, configurations, and troubleshooting techniques. The scenarios presented in the lab exercises are inspired by real-world networking challenges. By working through these scenarios, you will be better prepared to handle the complexities of designing and managing networks in professional settings. Many of the lab activities are designed to be collaborative, encouraging teamwork and communication. Effective communication is a crucial skill in the field of networking, and these exercises provide an opportunity to enhance your ability to work in a team.

<u>Computer Networks Lab Set</u>

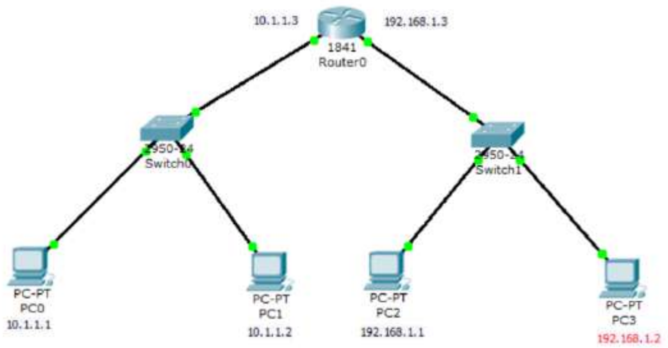
Sl. No	Experiments
	PART A
1.	Simulate a topology with 2 LAN's each having two devices connected to switches. Switches are connected to a common router. Observe the packet flow.
2.	Construct simple LAN using n nodes and understand working of Address Resolution Protocol (ARP).
3.	Perform an experiment to understand the dynamic IP address allocation process observe the routing table at the end of simulation.
4.	Construct a simple LAN by configuring static routing and observe the routing table at the end of simulation.
5.	Simulate a topology where 3 routers are fully connected and each router connected to an end device. Observe the flow of ICMP packets from one network to other using RIP protocol.
6.	Simulate a topology where 3 routers are fully connected and each router connected to an end device. Observe the flow of ICMP packets from one network to other using OSPF protocol.
7.	Simulate a network for browsing and understand DNS protocol.
	PART B
1.	Write a program to implement error detection/ error correction using hamming code.
2.	Write a program to show working of the Stop and wait protocol.
3.	Implementation of CSMA/CD.
4.	Write a program to implement Distance Vector Routing algorithm.
5.	Write program to create a least cost tree using Link State Routing algorithm.
6.	To write a client-server application for chat using TCP.

Course Outcomes: On completion of this course, students are able to:		**Bloom's Level**
Cos	**Course Outcomes with Action verbs for the Course topics**	
CO1	**Understand** the working of various networking components in the simulation environment.	**L1**
CO2	**Analyse** the working principle of the protocols in the TCP/IP protocol suite.	**L2**
CO3	**Implemen**t given networking scenarios and analyse the results.	**L3**

CO	Statement	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	**Understand** the working of various networking components in the simulation environment.	1	1	1										1		1
CO2	**Analyse** the working principle of the protocols in the TCP/IP protocol suite.	2	1	2	2	2								1		2
CO3	**Implement** given networking scenarios and analyse the results.	1	2	2	2	2								1		2

Part A

1. **Simulate a topology with 2 LAN's each having two devices connected to switches. Switches are connected to a common Router. Observe the packet flow.**



Step 1: Click on PC0 → Desktop → IP Config →

IPV4 Address: 10.1.1.1

Subnet Mask: 255.0.0.0

Step 2: Click on PC1 → Desktop → IP Config →

IPV4 Address: 10.1.1.2

Subnet Mask: 255.0.0.0

Step 3: Click on PC2 → Desktop → IP Config →

IPV4 Address: 192.168.1.1

Subnet Mask: 255.255.255.0

Step 4: Click on PC3 → Desktop → IP Config →

IPV4 Address: 192.168.1.2

Subnet Mask: 255.255.255.0

Config done with PC

Step 5: Click on Router → Config → Interface → Fast Ethernet 0/0

IP Address: 10.1.1.3

Subnet Mask: 255.0.0.0

Enable Port Status

Click on → Fast Ethernet 0/1

IP address: 192.168.1.3

Subnet Mask: 255.255.0.4

Enable Port Status

Step 6: Click on PC0 → IP Configuration → Default Gateway → 10.1.1.3

Click on PC1 → IP Configuration → Default Gateway →10.1.1.3

Click on PC2 → IP Configuration → Default Gateway → 192.168.1.3

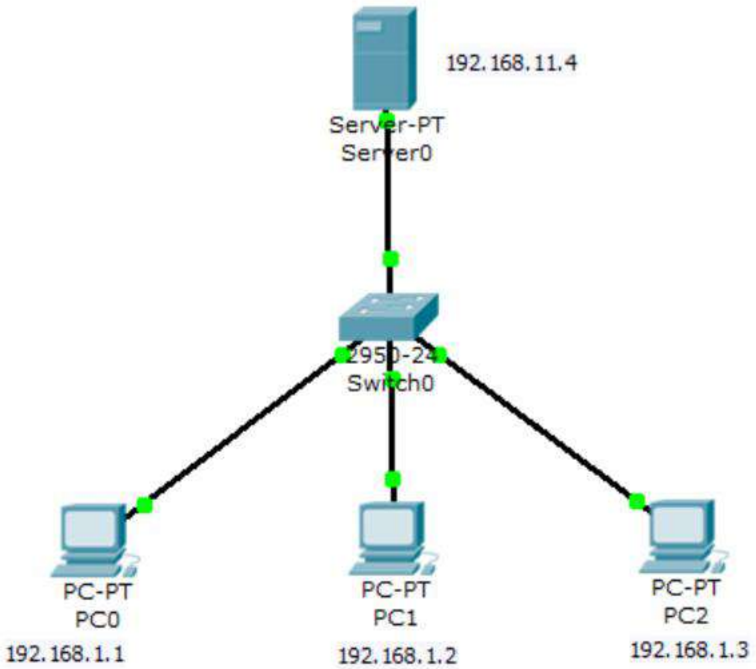
Click on PC3 → IP Configuration → Default Gateway → 192.168.1.3

Simulation: Select packets and place on PC0 and PC2

Auto capture

Successful

2. Construct simple LAN using 3 nodes and understand the working of Address Resolution Protocol (ARP)



Step 1: Click on PC0 → Desktop → IP Config →

IP Address: 192.168.1.1

Subnet Mask: 255.255.255.0

Step 2: Click on PC1 → Desktop → IP Config →

IP Address: 192.168.1.2

Subnet Mask: 255.255.255.0

Step 3: Click on PC2 → Desktop → IP Config →

IP Address: 192.168.1.3

Subnet Mask: 255.255.255.0

Step 4: Click on Server → Desktop → IP Config →

IP Address: 192.168.1.4

Subnet Mask: 255.255.255.0

Step 5: Click on inspect button (🔍)

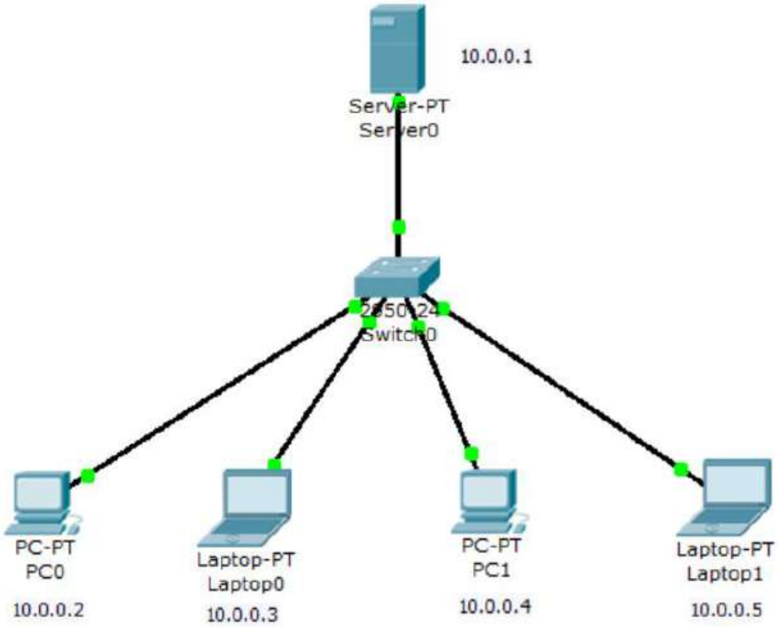
Click on PC → Right click → Select ARP → ARP table for PC0

Simulation: Select packets and place on PC0 and PC2

Auto capture

Successful

3. **Perform the experiment to understand the Dynamic IP Address Allocation process. Observe the routing table at the end of simulation.**



Step 1: Select a Server, a Switch, 2 PC's and 2 Laptops

Step 2: Give the connections

Step 3: Click on Server → In Config select DHCP

Pool Name: Server pool (by default)

Default Gateway : 10.0.0.1

DNS Server: 0.0.0.0

Start IP address: 10 0 0 0

Subnet Mask : 255 0 0 0

Maximum number of users : 50

Save

Step 4: Click on Server → Config → Fast Ethernet → Select IP Config as static and enter the IP Address and Subnet Mask manually (10.0.0.1) → On port status

Step 5: Select PC0 →Desktop →IP Config →DHCP

Requesting IP Address → DHCP Request

Successful

Do the same for Laptop0, PC1 and Laptop1

[IP address and subnet Mask of all changes automatically]

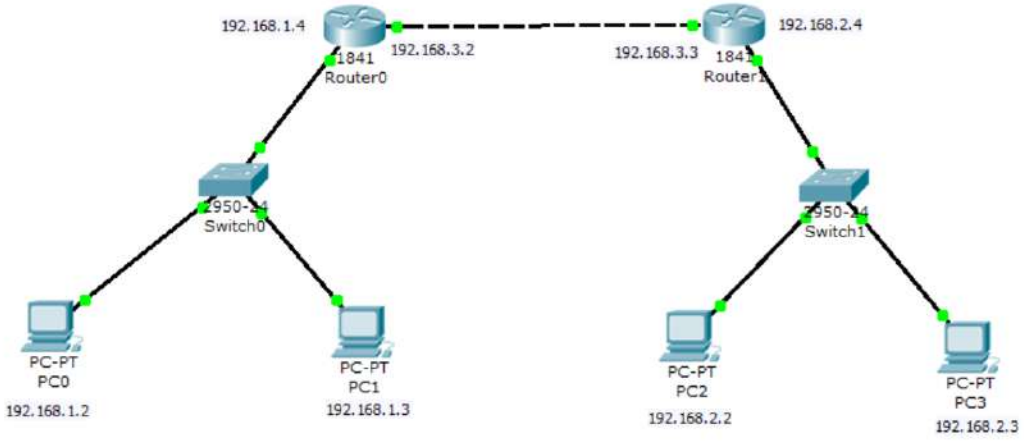
Simulation: Go to simulation mode

Select a packet and place on PC0 and Laptop1

Auto capture

Successful

4. **Construct a simple LAN by configuring static routing and observe the routing table at the beginning and at the end of simulation**



Step 1: Select 2 Routers, 2 switches and 4 PC's

Step 2: Give the connections

For Router 0 to Router 1, select the 4th connectivity [---]

While placing the connection, select the fast ethernet 0/1

Step 3: Click on PC0 → Desktop → IP Config → Static →

IP address: 192.168.1.2

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.1.4

Click on PC1 → Desktop → IP Config → Static →

IP address: 192.168.1.3

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.1.4

Click on PC2 → Desktop → IP Config → Static →

IP address: 192.168.2.2

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.2.4

Click on PC3 → Desktop → IP Config → Static →

IP address: 192.168.2.3

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.2.4

Step 4: Click on Router0 → Config → Fast Ethernet 0/0 →

IP address: 192.168.1.4

Subnet Mask: 255.255.255.0

Turn on the port status

Step 5: Click on Router0 → Config → Fast Ethernet 0/1 →

IP address: 192.168.3.2

Subnet Mask: 255.255.255.0

Turn on the port status

Step 6: Click on Router0 → Config → Fast Ethernet 0/0 →

IP address: 192.168.2.4

Subnet Mask: 255.255.255.0

Turn on the port status

Step 7: Click on Router1 → Config → Fast Ethernet 0/0 →

IP address: 192.168.3.3

Subnet Mask: 255.255.255.0

Turn on the port status

Step 8: Click on Router1 → Config → Static

Network: 192.168.1.0

Mask: 255.255.255.0

Next HOP: 192.168.3.2.

Click on add

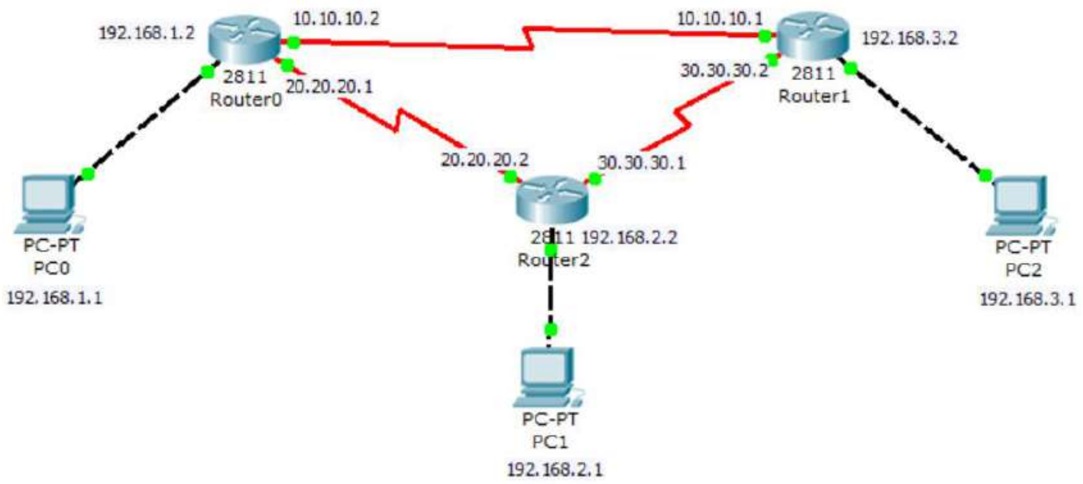
Simulation: Go to simulation mode

Select the packets and place them on PC0 and PC1

Auto capture

Successful

5. Simulate a topology where 3 routers are fully connected and each router connected to end devices. Observe the flow of ICMP packets from 1 network to other using RIP protocol.



Step 1: Select 3 Routers (2811)

Step 2: Click on Router0 → Config → Physical →Select WIC1T or WIC2T

Disable the green button (Right side)

Drag and drop the WIC 2T 2 times into the box

Enable the green button

Repeat the same steps for the other Routers

Step 3: Select 3 PC's and give the connections to Routers and PC's

Step 4: Click on PC0 → Desktop → IP Config → Static

IP address: 192.168.1.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.1.2

Step 5: Click on PC1 → Desktop → IP Config → Static

IP address: 192.168.2.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.2.2

Step 6: Click on PC2 → Desktop → IP Config → Static

IP address: 192.168.3.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.3.2

Step 7: [Based on the respective fast ethernet and serial numbers in your system, provide the IP's]

Click on Router 0 → Config → Interface

Fast Ethernet 0/0:

IP Address: 192.168.1.2

Subnet Mask: 255.255.255.0

Turn on Port status

Serial 0/3/1:

IP Address: 10.10.10.2

Subnet Mask: 255.0.0.0

Turn on Port status

Serial 0/3/0:

IP Address: 20.20.20.1

Subnet Mask: 255.0.0.0

Turn on Port status

Repeat the same process for Router1 and Router2 (For IP's, look at the diagram)

Make sure all the red dots on the connection turns green

Step 6: Click on the Router0 → Config → RIP

Network: 192.168.1.2 → Add

10.10.10.2 → Add

20.20.20.1 → Add

(Add the respective IP's of the Router)

Repeat the same steps for Router1 and Router2

Simulation: Go to simulation mode

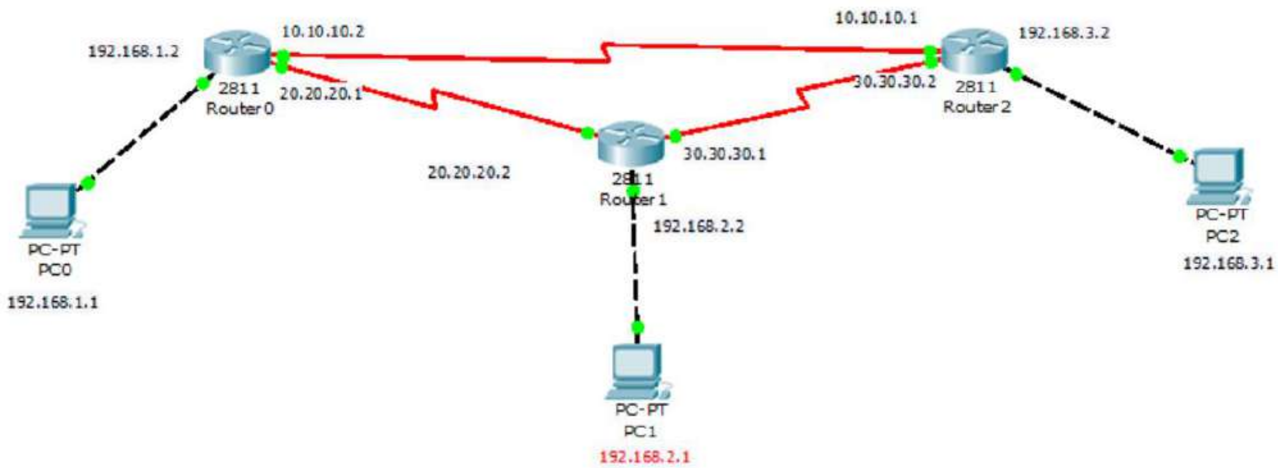
Edit Event list filters → Select only ICMP

Select the packets and place on PC's

Auto capture

Successful

6. **Simulate a topology where 3 routers are fully connected and each router connected to an end device. Observe the flow of ICMP packets from one network to other using OSPF protocol.**



Step 1: Select 3 Routers (2811)

Step 2: Click on Router0 → Config → Physical → Select WIC1T or WIC2T

Disable the green button (Right side)

Drag and drop the WIC 2T 2 times into the box

Enable the green button

Repeat the same steps for the other Routers

Step 3: Select 3 PC's and give the connections to Routers and PC's

Step 4: Click on PC0 → Desktop → IP Config → Static

IP address: 192.168.1.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.1.2

Step 5: Click on PC1 → Desktop → IP Config → Static

IP address: 192.168.2.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.2.2

Step 6: Click on PC2 → Desktop → IP Config → Static

IP address: 192.168.3.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.168.3.2

Step 7: [Based on the respective fast ethernet and serial numbers in your system, provide the IP’s]

Click on Router 0 → Config → Interface

Fast Ethernet 0/0:

IP Address: 192.168.1.2

Subnet Mask: 255.255.255.0

Turn on Port status

Serial 0/3/1:

IP Address: 10.10.10.2

Subnet Mask: 255.0.0.0

Turn on Port status

Serial 0/3/0:

IP Address: 20.20.20.1

Subnet Mask: 255.0.0.0

Turn on Port status

Repeat the same process for Router1 and Router2 (For IP’s, look at the diagram)

Make sure all the red dots on the connection turns green

Step 6: Click on Router 0 → CL I

Router > enable

Router# configure terminal

Router(config)#router ospf 3

Router(config-router)#network 192.168.1.0 0.0.0.255 area 0

Router(config-router)#network 10.0.0.0 0.255.255.255 area 0

Router(config-router)#network 20.0.0.0 0.255.255.255 area 0

Router(config-router)#exit

Router(config)#exit

Click on Router1 → CLI

Router > enable

Router# configure terminal

Router(config)#router ospf 3

Router(config-router)#network 192.168.2.0 0.0.0.255 area 0

Router(config-router)#network 20.0.0.0 0.255.255.255 area 0

Router(config-router)#network 30.0.0.0 0.255.255.255 area 0

Router(config-router)#exit

Router(config)#exit

Click on Router2 → CLI

Router > enable

Router# configure terminal

Router(config)#router ospf 3

Router(config-router)#network 192.168.3.0 0.0.0.255 area 0

Router(config-router)#network 10.0.0.0 0.255.255.255 area 0

Router(config-router)#network 30.0.0.0 0.255.255.255 area 0

Router(config-router)#exit

Router(config)#exit

Simulation: Go to simulation mode

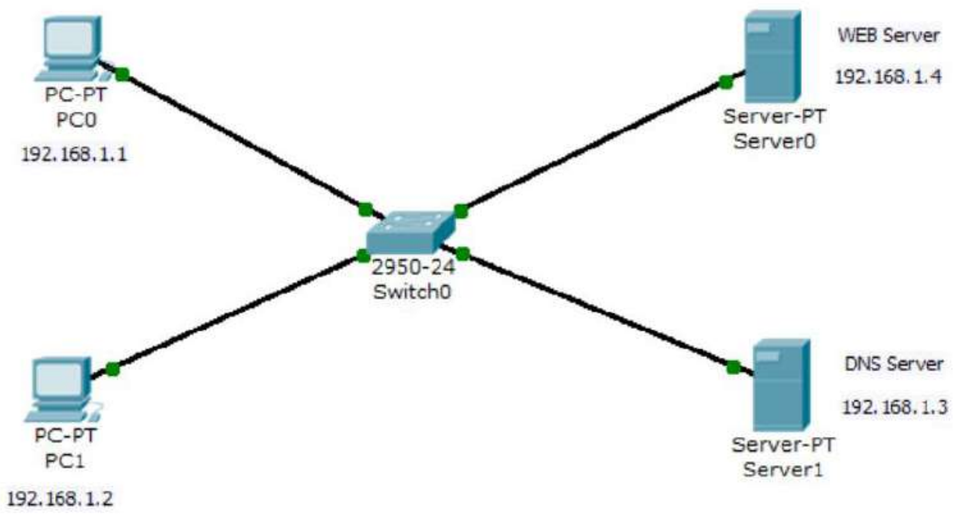
Event List → Edit Filters → Select only ICMP

Select the packets and place on PC's

Auto Capture

Successful

7. **Simulate a network for browsing and understand DNS protocol.**



Step 1: Select 2 PC's, 2 Servers and a Switch

Step 2: Give the connections

Step 3: Click on PC0 → Desktop → IP Config

IP Address: 192.168.1.1

Subnet Mask: 255.255.255.0

Default Gateway: 192.1681.3

Step 4: Click on PC1 → Desktop → IP Config

IP Address: 192.168.1.2

Subnet Mask: 255.255.255.0

Default Gateway: 192.1681.3

Step 5: Click on Server0 (WEB Server) → Desktop

IP Address: 192.168.1.4

Subnet Mask: 255.255.255.0

Click on Server1 (DNS Server) → Desktop

IP Address: 192.168.1.3

Subnet Mask: 255.255.255.0

Step 6: Click on WEB Server → Config → HTTP

Modify the HTML code

Step 7: Click on DNS Server → Config → DNS

Turn on DNS Service

Name: www.abc.com

IP Address: 192.168.1.4 (IP Address of WEB Server)

Add

Step 8: Click on PC0 → Desktop → Web Browser → URL → www.abc.com → Go

Part B

1. Write a program to implement Error Detection/Error Correction using Hamming Code.

Hamming code is a block code that is capable of detecting up to two simultaneous bit errors and correcting single-bit errors. It was developed by R.W. Hamming for error correction. In this coding method, the source encodes the message by inserting redundant bits within the message. These redundant bits are extra bits that are generated and inserted at specific positions in the message itself to enable error detection and correction. When the destination receives this message, it performs recalculations to detect errors and find the bit position that has error.

Program:

```
#include<stdio.h>
int main() {
int data[10];
int dataatrec[10], c, c1, c2, c3, i;
printf("Enter 4 bits of data one by one\n");
scanf("%d",&data[0]);
scanf("%d",&data[1]);
scanf("%d",&data[2]);
scanf("%d",&data[4]);
 // calculate even parity
data[6]=data[0]^data[2]^data[4];
data[5]=data[0]^data[1]^data[4];
data[3]=data[0]^data[1]^data[2];
 printf("\nEncoded data is\n");
for(i=0;i<7;i++)
        printf("%d",data[i]);
 printf("\n\nEnter received data bits one by one\n");
 for(i=0;i<7;i++)
        scanf("%d",&dataatrec[i]);
c1=dataatrec[6]^dataatrec[4]^dataatrec[2]^dataatrec[0];
c2=dataatrec[5]^dataatrec[4]^dataatrec[1]^dataatrec[0];
```

```
c3=dataatrec[3]^dataatrec[2]^dataatrec[1]^dataatrec[0];
c=c3*4+c2*2+c1 ;
   if(c==0) {
printf("\nNo error while transmission of data\n");
   }
else {
printf("\nError on position %d",c);
printf("\nData sent : ");
        for(i=0;i<7;i++)
            printf("%d",data[i]);
printf("\nData received : ");
        for(i=0;i<7;i++)
            printf("%d",dataatrec[i]);
printf("\nCorrect message is\n");
  //if errorneous bit is 0 we complement it else vice versa
if(dataatrec[7-c]==0)
dataatrec[7-c]=1;
 else
dataatrec[7-c]=0;
for (i=0;i<7;i++) {
printf("%d",dataatrec[i]);
}
}
return 0;
}
```

Output:

Case 1 without error

```
[exam1@localhost ~]$ g++ program1.cpp
[exam1@localhost ~]$ ./a.out
Enter 4 bits of data one by one
1 1 0 1

Encoded data is
1100110

Enter received data bits one by one
1 1 0 0 1 1 0

No error while transmission of data
```

Case 2: with error

```
[exam1@localhost ~]$ ./a.out
Enter 4 bits of data one by one
1 1 0 1

Encoded data is
1100110

Enter received data bits one by one
1 1 0 0 1 0 0

Error on position 2
Data sent : 1100110
Data received : 1100100
Correct message is
1100110[exam1@localhost ~]$
```

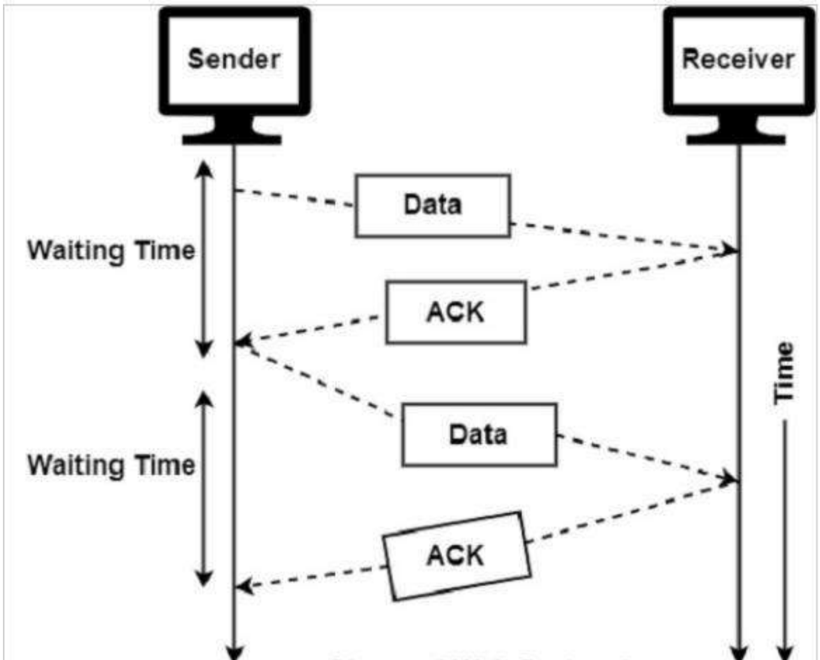
2. **Write a program to show working of the Stop and Wait protocol.**

Stop and wait protocol is the simplest flow control method. In this, the sender will transmit one frame at a time to the receiver. The sender will **stop and wait** for the acknowledgement from the receiver. This time (i.e. the time joining message transmitting and acknowledgement receiving) is the sender's waiting time, and the sender is idle during this time. When the sender gets the acknowledgement (ACK), it will send the next data packet to the receiver and wait for the disclosure again, and this process will continue as long as the sender has the data to send.

Characteristics

It is used in Connection-oriented communication.

- It offers error and flows control.
- It can be used in data Link and transport Layers.
- Stop and Wait ARQ executes Sliding Window Protocol with Window Size 1



Stop and Wait Protocol

Program:

```
#include <iostream>
#include <unistd.h> // for usleep
using namespace std;
int main()
{
    int frames[] = {1, 2, 3, 4};
    // Number of delayed ACKs per frame
    int delaysPerFrame[] = {1, 2, 2, 1};
    cout << "Sender has to send frames : ";
    for (int i = 0; i < 4; i++)
        cout << frames[i] << " ";
    cout << endl << endl;
    cout << "Sender\t\t\t\t\tReceiver" << endl;
    const useconds_t shortDelay = 350000; // 0.35 seconds
    for (int i = 0; i < 4; i++) {
        int frame = frames[i];
        int delayCount = delaysPerFrame[i];
        // Initial send
        cout << "Sending Frame : " << frame << "\t\t";
        usleep(shortDelay);
        cout << "Received Frame : " << frame << endl;
        // Simulate delayed ACKs
        for (int d = 0; d < delayCount; d++) {
            usleep(shortDelay);
            cout << "Delayed Ack" << endl;
            // Retransmit
            usleep(shortDelay);
            cout << "Sending Frame : " << frame << "\t\t";
            usleep(shortDelay);
            cout << "Received Frame : " << frame << " Duplicate" << endl;
        }
        // Final ACK
        usleep(shortDelay);
```

```
        cout << "Acknowledgement : " << frame << endl;
    }
    return 0;
}
```

Output:

```
Sender has to send frames : 1 2 3 4

Sender                   Receiver
Sending Frame : 1        Received Frame : 1
Delayed Ack
Sending Frame : 1        Received Frame : 1 Duplicate
Acknowledgement : 1
Sending Frame : 2        Received Frame : 2
Delayed Ack
Sending Frame : 2        Received Frame : 2 Duplicate
Delayed Ack
Sending Frame : 2        Received Frame : 2 Duplicate
Acknowledgement : 2
Sending Frame : 3        Received Frame : 3
Delayed Ack
Sending Frame : 3        Received Frame : 3 Duplicate
Delayed Ack
Sending Frame : 3        Received Frame : 3 Duplicate
Acknowledgement : 3
Sending Frame : 4        Received Frame : 4
Delayed Ack
Sending Frame : 4        Received Frame : 4 Duplicate
Acknowledgement : 4
```

3. Implementation of CSMA/CD.

Consider a scenario where there are ‘n’ stations on a link and all are waiting to transfer data through that channel. In this case, all ‘n’ stations would want to access the link/channel to transfer their own data. The problem arises when more than one station transmits the data at the moment. In this case, there will be collisions in the data from different stations.

CSMA/CD is one such technique where different stations that follow this protocol agree on some terms and collision detection measures for effective transmission. This protocol decides which station will transmit when so that data reaches the destination without corruption.

Working principal:

Step 1: Check if the sender is ready for transmitting data packets.

Step 2: Check if the transmission link is idle. Sender has to keep on checking if the transmission link/medium is idle. For this, it continuously senses transmissions from other nodes. Sender sends dummy data on the link. If it does not receive any collision signal, this means the link is idle at the moment. If it senses that the carrier is free and there are no collisions, it sends the data. Otherwise, it refrains from sending data.

Step 3: Transmit the data & check for collisions. Sender transmits its data on the link. CSMA/CD does not use an ‘acknowledgment’ system. It checks for successful and unsuccessful transmissions through collision signals. During transmission, if a collision signal is received by the node, transmission is stopped. The station then transmits a jam signal onto the link and waits for random time intervals before it resends the frame. After some random time, it again attempts to transfer the data and repeats the above process.

Step 4: If no collision was detected in propagation, the sender completes its frame transmission and resets the counters.

Program:

```
#include <iostream>
#include <cstdlib> // for rand()
#include <ctime>   // for time()
class Station {
public:
	Station(std::string name) : name(name) {}
	void send() {
	if (carrierBusy()) {
	std::cout << name << " detects carrier busy, deferring transmission." << std::endl;
	return;
	}
std::cout << name << " is sending a message." << std::endl;
if (collisionDetected()) {
std::cout << name << " detects a collision, stopping transmission." << std::endl;
} else {
std::cout << name << " successfully transmitted the message." << std::endl;
}
}
bool carrierBusy() {
// Simulate a random chance of the carrier being busy
return rand() % 2 == 1;
}
bool collisionDetected() {
		// Simulate a random chance of a collision
		return rand()*% 2 == 1;
}
private:
std::string name;
};
int main() {
 Station stationA("Station A");
  Station stationB("Station B"); int i=1;
// Simulate both stations trying to send messages
```

```
while(i<=10){
std::cout<<"Scenario"<<i<<std::endl;
stationA.send();
stationB.send(); i++;
}
return 0;
}
```

Output:

```
[exam1@localhost ~]$ vi program3.cpp
[exam1@localhost ~]$ vi program3.cpp
[exam1@localhost ~]$ g++ program3.cpp
[exam1@localhost ~]$ ./a.out

Scenario1
Station A detects carrier busy, deferring transmission.
Station B is sending a message.
Station B detects a collision, stopping transmission.

Scenario2
Station A detects carrier busy, deferring transmission.
Station B detects carrier busy, deferring transmission.

Scenario3
Station A detects carrier busy, deferring transmission.
Station B is sending a message.
Station B successfully transmitted the message.

Scenario4
Station A detects carrier busy, deferring transmission.
Station B detects carrier busy, deferring transmission.

Scenario5
Station A is sending a message.
Station A detects a collision, stopping transmission.
Station B is sending a message.
Scenario6
Station A detects carrier busy, deferring transmission.
Station B is sending a message.
Station B successfully transmitted the message.

Scenario7
Station A is sending a message.
Station A successfully transmitted the message.
Station B is sending a message.
Station B detects a collision, stopping transmission.

Scenario8
Station A is sending a message.
Station A detects a collision, stopping transmission.
Station B detects carrier busy, deferring transmission.

Scenario9
Station A is sending a message.
Station A successfully transmitted the message.
Station B is sending a message.
Station B detects a collision, stopping transmission.

Scenario10
Station A detects carrier busy, deferring transmission.
Station B detects carrier busy, deferring transmission.
```

4. Write a program to implement Distance Vector Routing algorithm.

A **distance-vector routing (DVR)** protocol requires that a router inform its neighbors of topology changes periodically. Historically known as the old ARPANET routing algorithm (or known as Bellman-Ford algorithm).

Bellman Ford Basics – Each router maintains a Distance Vector table containing the distance between itself and ALL possible destination nodes. Distances,based on a chosen metric, are computed using information from the neighbors' distance vectors.

Distance Vector Algorithm –

1. A router transmits its distance vector to each of its neighbors in a routing packet.
2. Each router receives and saves the most recently received distance vector from each of its neighbors.
3. A router recalculates its distance vector when:

- It receives a distance vector from a neighbor containing different information than before.
- It discovers that a link to a neighbor has gone down.

Program:

```
#include<stdio.h>
#include<iostream>
using namespace std;
struct node
{
   unsigned dist[6];
   unsigned from[6];
}DVR[10];
int main()
{
   cout<<"\n\n------------------- Distance Vector Routing Algorithm----------- ";
   int costmat[6][6];
   int nodes, i, j, k;
   cout<<"\n\n Enter the number of nodes : ";
```

```
    cin>>nodes; //Enter the nodes
    cout<<"\n Enter the cost matrix : \n" ;
    for(i = 0; i < nodes; i++)
     {
        for(j = 0; j < nodes; j++)
        {
            cin>>costmat[i][j];
            costmat[i][i] = 0;
            DVR[i].dist[j] = costmat[i][j]; //initialise the distance equal to cost matrix
            DVR[i].from[j] = j;
        }
    }
            for(i = 0; i < nodes; i++) //We choose arbitary vertex k and we calculate the
            //direct distance from the node i to k using the cost matrix and add the distance from k
to node j
            for(j = i+1; j < nodes; j++)
            for(k = 0; k < nodes; k++)
                if(DVR[i].dist[j] > costmat[i][k] + DVR[k].dist[j])
                {   //We calculate the minimum distance
                    DVR[i].dist[j] = DVR[i].dist[k] + DVR[k].dist[j];
                    DVR[j].dist[i] = DVR[i].dist[j];
                    DVR[i].from[j] = k;
                    DVR[j].from[i] = k;
                }
        for(i = 0; i < nodes; i++)
        {
            cout<<"\n\n For router: "<<i+1;
            for(j = 0; j < nodes; j++)
                cout<<"\t\n node "<<j+1<<" via "<<DVR[i].from[j]+1<<" Distance
"<<DVR[i].dist[j];
        }
    cout<<" \n\n ";
    return 0;
}
```

Output:

```
 [exam1@localhost ~]$ vi program4.cpp
[exam1@localhost ~]$ vi program4.cpp
[exam1@localhost ~]$ g++ program4.cpp
[exam1@localhost ~]$ ./a.out


-------------------- Distance Vector Routing Algorithm-----------

 Enter the number of nodes : 4

 Enter the cost matrix :
0 2 999 1
2 0 3 7
999 3 0 11
1 7 11 0


 For router: 1
 node 1 via 1 Distance 0
 node 2 via 2 Distance 2
 node 3 via 2 Distance 5
 node 4 via 4 Distance 1

 For router: 2
 node 1 via 1 Distance 2
 node 2 via 2 Distance 0
 node 3 via 3 Distance 3
 node 4 via 1 Distance 3
 For router: 3
 node 1 via 2 Distance 5
 node 2 via 2 Distance 3
 node 3 via 3 Distance 0
 node 4 via 2 Distance 6

 For router: 4
 node 1 via 1 Distance 1
 node 2 via 1 Distance 3
 node 3 via 2 Distance 6
 node 4 via 4 Distance 0
```

5. Creating a C++ program for the least cost tree using the Link State Routing algorithm requires simulating a network of nodes and performing the Link State algorithm. Below is a simplified example of how you can implement it

Program:

```
#include <iostream>
#include <vector>
#include <climits>
using namespace std;
const int INF = INT_MAX;
class Network {
public:
    int numNodes;
    vector<vector<int>> costMatrix;
    Network(int nodes) : numNodes(nodes) {
        costMatrix.resize(nodes, vector<int>(nodes, INF));
    }
    void addLink(int node1, int node2, int cost) {
        costMatrix[node1][node2] = cost;
        costMatrix[node2][node1] = cost;
    }
    void printLeastCostTree(int source, const vector<int>& parent) {
        cout << "Least Cost Tree:" << endl;
        for (int i = 0; i < numNodes; ++i) {
            if (i != source) {
                cout << "Node " << i << " -> Node " << parent[i]
                     << " (Cost: " << costMatrix[i][parent[i]] << ")"
                     << endl;
            }
        }
    }
    void linkStateRouting(int source) {
        vector<int> distance(numNodes, INF);
        vector<bool> inTree(numNodes, false);
```

```
        vector<int> parent(numNodes, -1);
        distance[source] = 0;
        for (int i = 0; i < numNodes - 1; ++i) {
            int u = getMinDistanceVertex(distance, inTree);
            inTree[u] = true;
            for (int v = 0; v < numNodes; ++v) {
                if (!inTree[v] &&
                    costMatrix[u][v] != INF &&
                    distance[u] + costMatrix[u][v] < distance[v]) {
                    parent[v] = u;
                    distance[v] = distance[u] + costMatrix[u][v];
                }
            }
        }
        printLeastCostTree(source, parent);
    }
    int getMinDistanceVertex(const vector<int>& distance,
                             const vector<bool>& inTree) {
        int minDistance = INF;
        int minVertex = -1;
        for (int v = 0; v < numNodes; ++v) {
            if (!inTree[v] && distance[v] < minDistance) {
                minDistance = distance[v];
                minVertex = v;
            }
        }
        return minVertex;
    }
};

int main() {
    int numNodes = 4;
    Network network(numNodes);
    // Add links with their costs
```

```
    network.addLink(0, 1, 4);
    network.addLink(0, 2, 2);
    network.addLink(1, 2, 5);
    network.addLink(1, 3, 10);
    network.addLink(2, 3, 1);
    int sourceNode = 0;
    network.linkStateRouting(sourceNode);
    return 0;
}
```

Output:

```
Least Cost Tree:
Node 1 -> Node 0 (Cost: 4)
Node 2 -> Node 0 (Cost: 2)
Node 3 -> Node 2 (Cost: 1)
```

6. To write echo Client-Server application using TCP.

Program:

```
// TCP server side
//Include headers
#include<stdio.h>
#include<netinet/in.h>
#include<netdb.h>
#include<arpa/inet.h>
#include<unistd.h>
//Define server port
#define SERV_TCP_PORT 5035
int main(int argc,char**argv)
{
  //variable declaration
       int sockfd,newsockfd;
       socklen_t clength;
       struct sockaddr_in serv_addr,cli_addr;
       char buffer[4096];
   // create socket
       sockfd=socket(AF_INET,SOCK_STREAM,0);
   //Initialize server addres structure
       serv_addr.sin_family=AF_INET;
       serv_addr.sin_addr.s_addr=INADDR_ANY;
       serv_addr.sin_port=htons(SERV_TCP_PORT);
       printf("\nStart");
 // bind socket
       bind(sockfd,(struct sockaddr*)&serv_addr,sizeof(serv_addr));
       printf("\nListening...");
       printf("\n");
//Listen incoming connection
       listen(sockfd,5);
// accept connection from client
       clength=sizeof(cli_addr);
```

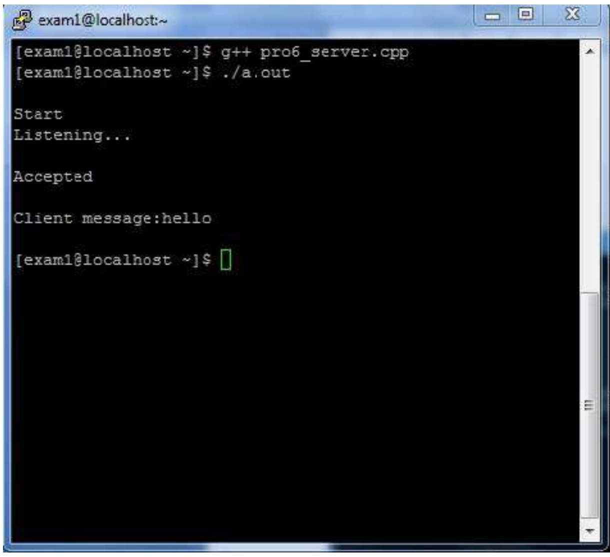
```
	newsockfd=accept(sockfd,(struct sockaddr*)&cli_addr,&clength);
	printf("\nConnection Accepted");
	printf("\n");
//Read client message
	read(newsockfd,buffer,4096);
	printf("\nClient message:%s",buffer);
//echo back to client
	write(newsockfd,buffer,4096);
	printf("\n");
//close sockets
	close(sockfd);
	close(newsockfd);
	return 0;
}

//TCP client side
#include<stdio.h>
#include<sys/types.h>
#include<sys/socket.h>
#include<netinet/in.h>
#include<netdb.h>
#include<unistd.h>
#include<arpa/inet.h>
#define SERV_TCP_PORT 5035
int main(int argc,char*argv[])
{
	int sockfd;
	struct sockaddr_in serv_addr;
	struct hostent *server;
	char buffer[4096];
	sockfd=socket(AF_INET,SOCK_STREAM,0);
	serv_addr.sin_family=AF_INET;
	serv_addr.sin_addr.s_addr=inet_addr("127.0.0.1");
	serv_addr.sin_port=htons(SERV_TCP_PORT);
```

```
    printf("\nReady for sending...");
    connect(sockfd,(struct sockaddr*)&serv_addr,sizeof(serv_addr));
    printf("\nEnter the message to send\n");
    printf("\nClient: ");
    fgets(buffer,4096,stdin);
    write(sockfd,buffer,4096);
    printf("Serverecho:%s",buffer);
    printf("\n");
    close(sockfd);
    return 0;
}
```

Output:

At Server Terminal



At Client Terminal