# Department of Computer Science and Engineering
## Islamic University of Technology (IUT)
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# Laboratory Report

## CSE 4412: Data Communication and Networking Lab

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| **Section** | **: 1 (SWE)** |
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| **Lab No** | **: 7** |

**Title:** Configuration of OSPF in a network topology.

**Objective**:

1. Understand Link State Routing Protocol
2. Understand OSPF
3. Understand the difference between DV and LS routing

**Devices/ software Used**:

1. Cisco Packet Tracer
2. Virtual Routers, PCs, Switches, Servers, Wires etc.

# Theory:

## Link State (LS) Routing

The Link State Routing Algorithm is an **interior protocol** used by every router to share information or knowledge about the rest of the routers on the network. In LS routing, each router in the network maintains a complete and current map of the entire network topology, including all links and network nodes.

With the knowledge of the network topology, a router can make its routing table. Now, for developing the routing table, a router uses a shortest path computation algorithm like **Dijkstra's algorithm** along with the knowledge of the topology. The routing table created by each router is exchanged with the rest of the routers present in the network, which helps in faster and more reliable delivery of data.

When a router detects a change in the network, such as a link failure or a new network node being added, it generates a **Link State Advertisement** (LSA) packet that contains information about the change. This packet is then **flooded** to all other routers in the network so that they can update their network maps accordingly.

Important Points Related to the Link State Routing Algorithm

• The link state routing algorithm exchanges information only when there is a change in the connection.

• It **requires large memory** as it maintains a routing **database**.

• It requires the computation of the shortest path (**Dijkstra's algorithm**), which is an **overhead** for the CPU.

• The information of each router needs to be transmitted all over the network.

**Interior Gateway Protocol** (IGP) is a type of routing protocol used within an autonomous system (**AS**) in a computer network. An autonomous system is a group of routers and networks that are managed by a single entity, such as an organization or a service provider. **IGP**s are designed to allow routers within an autonomous system to communicate with each other and to determine the best path for data to travel between them. They are used to route traffic within a single administrative domain and are typically used in enterprise networks.

There're usually two phases of the link state routing algorithm. The two phases are: **Reliable Flooding** and **Route Calculation**.

**Link-State Database (LSDB)**

The **LSDB** contains information about the state of the network, including information about the routers, the links between them, and the state of those links.

Each router in the network **maintains a copy of the LSDB**, which is constantly updated as new **Link-State Advertisements** (LSAs) are received from neighboring routers.

• Allows each router to build a complete and accurate map of the network topology.

• Helps determining the shortest path between the routers.

• Helps maintaining an up-to-date view of the network topology.

**Link State Packet**

The link state packet is a small data packet containing the information about the routing information. It is used to **advertise information** about the network.

Each router in the network generates LSPs **periodically or in response** to a change in the network topology, such as the addition or removal of a router or a link. The LSPs are then flooded throughout the network, using a reliable flooding mechanism, to ensure that all routers in the network receive the updated information.

## Open Shortest Path First (OSPF)

**OSPF** is one of the Interior Gateway Protocol (IGP), which helps to find the best path for packets as they pass through a set of connected networks while using its own shortest path first (SPF) algorithm.

It is a Link-state routing protocol that is used to distribute routing information about data packets within a large Autonomous System.

Unlike **RIP**, which requires routers to send the entire routing table to neighbors every 30 seconds, **OSPF** sends only the part that has changed and only when a change has taken place.

When routes change, OSPF routers to find a new path between endpoints with no loops (which is why it's called "**open**") and that minimizes the length of the path, which is called the convergence time.

Rather than simply counting the number of routers **hops** between hosts on a network, as **RIP** does, **OSPF** bases its path choices on "**link states**" that take into account additional network information, including IT-assigned cost metrics that give some paths higher assigned costs.
For example, a satellite link may be assigned higher cost than a wireless WAN link, which in turn may be assigned higher cost than a metro Ethernet link.

**Metric:**

The **metric** used in **OSPF** is called the "cost", which is a measure of the relative "expense" of using a particular route. The interface cost is **inversely proportional** to the interface bandwidth and can be also set up explicitly.

In Link State routing protocols, such as OSPF, the costs are used to determine the shortest path between routers in the network. The cost is assigned to each link, and it represents the amount of effort required to send a packet over that link. The lower the cost, the more desirable the link is for routing traffic.

In OSPF, the cost of a link is calculated as a function of the bandwidth of the link. The formula used to calculate the cost is: **Cost = 10^8 / Bandwidth**

For example, if the bandwidth of a link is 10 Mbps, the cost is calculated as follows:

Cost = 10^8 / 10,000,000 = 10. This means that the cost of the link is 10.

Similarly, if the bandwidth of a link is 1 Gbps (1000 Mbps), the cost is calculated as follows:

Cost = 10^8 / 1,000,000,000 = 1. This means that the cost of the link is 1.

The reference bandwidth of 100 Mbps is used as the default value in OSPF, but it can be changed to a different value to adjust the cost calculation

**Areas:**

An autonomous system can be divided into areas; these help in **reducing** the link state advertisements (**LSA**) and other **overhead traffic** that will be otherwise sent to the network.
There are five types of OSPF areas: Backbone Area (area 0), Standard Area, Stub Area, Totally Stubby Area, and No So Stubby Area (NSSA).

An area is a **logical collection** of OSPF networks, routers, and links that have the **same area identification**. A router within an area must maintain a topological database for the area to which it belongs. The router does not have detailed information about network topology outside of its area, which **thereby reduces the size of its database**.

**Link State Advertisement (LSA):**

When a router detects a change in the network, such as a link failure or a new network node being added, it generates a **Link State Advertisement** (LSA) packet that contains information about the change. This packet is then **flooded** to all other routers in the network so that they can update their network maps accordingly.

**OSPF Implementation:**

OSPF is a complex protocol that is made up of several protocol handshakes, database advertisements, and packet types.

OSPF is an **interior gateway routing protocol** **based on the open standard** that uses link-states rather than distance vectors for path selection. OSPF propagates link-state advertisements (**LSAs**) rather than routing table updates. Because only LSAs are **exchanged** instead of the entire routing tables, OSPF networks **converge** in a timely manner.

OSPF uses a link-state algorithm to build and calculate the shortest path to all known destinations. Each router in an OSPF area contains an identical link-state database, which is a list of each of the router-usable interfaces and reachable neighbors.

At a high level, OSPF operation consists of **three** main elements: **neighbor discovery**, **link-state information exchange**, and **best-path calculation**.

OSPF uses the shortest path first (**SPF**) or **Dijkstra's algorithm**. The input information for SPF calculation is link-state information, which is exchanged between routers using several different OSPF message types. These message types help improve convergence and scalability in multi-area OSPF deployments.

OSPF also <u>supports several different network types</u>, which enables you to configure OSPF over a variety of different underlying network technologies.

<u>**Multiple OSPF processes can run on the same router.**</u>

**Performance:**

Performance of OSPF is largely **dependent** on the **size** of the network and the **frequency of updates.** In large networks, frequent updates can lead to **high overhead** and **slower convergence time**.

However, optimizing OSPF configurations and utilizing hierarchy through areas can help <u>mitigate these issues and improve overall network performance and stability</u>. Compared to other routing protocols, the performance of OSPF is generally considered to be **superior** due to its ability to **adapt quickly to changes** in network topology and **efficiently calculate the shortest path** between routers. Additionally, OSPF's support for **load balancing** across multiple equal-cost paths further enhances its performance capabilities and ensures optimal utilization of available network resources.

**Update Message:**

Update messages in OSPF are crucial for maintaining routing information. OSPF updates its messages through a process called **flooding**. In flooding, a router sends an update message to all of its neighboring routers.

Flooding in OSPF is responsible for **validating and distributing link-state updates** to the link-state database (**LSDB**) whenever a change or **update** occurs to a link. Changes or updates are key concepts regarding when flooding occurs. **Flooding** is part of the LSDB synchronization mechanism within OSPF. The goal of this mechanism is to keep the LSDBs of the routers in an OSPF domain **synchronized** within time in the presence of topological changes.

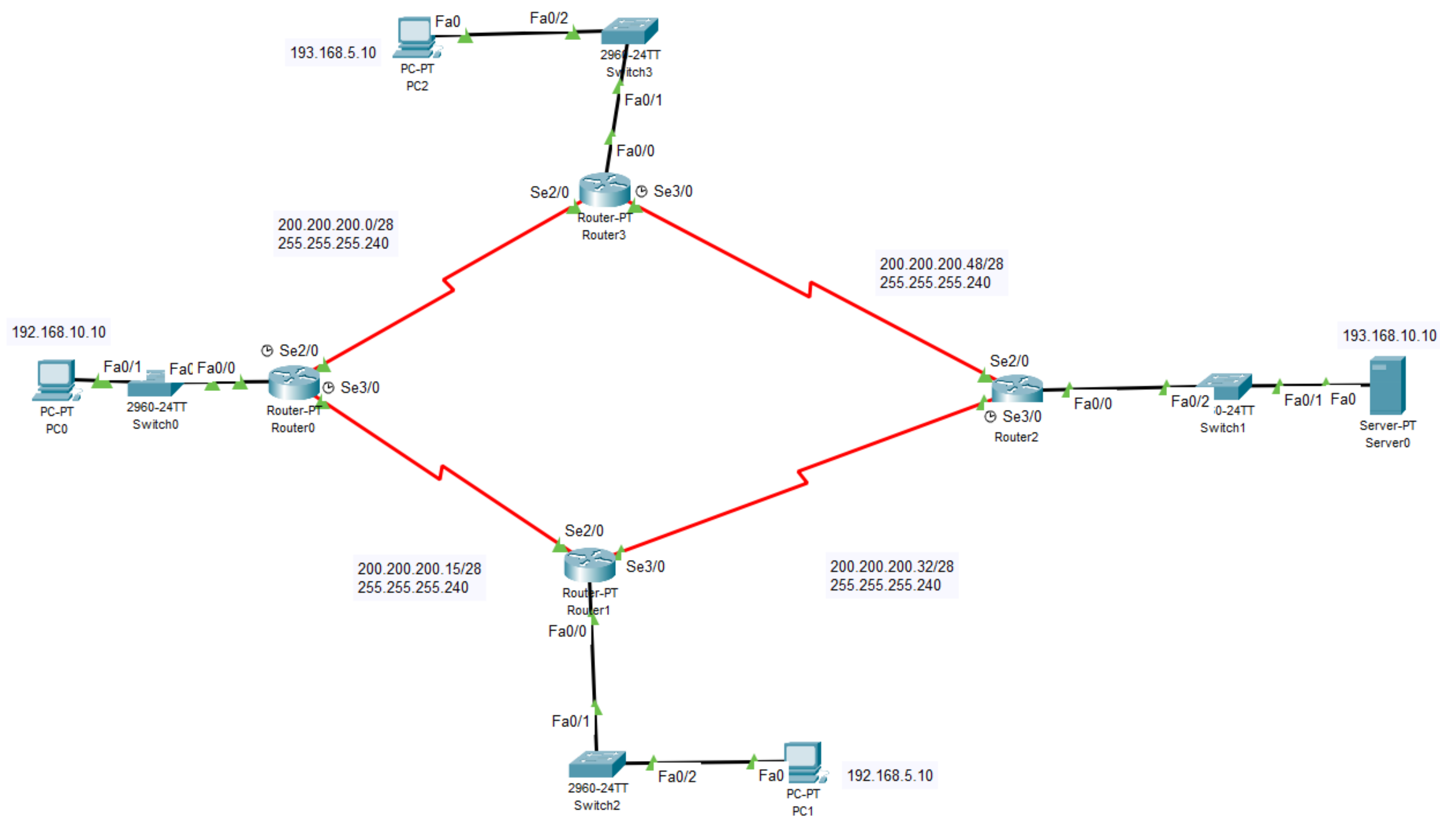
The **primary goal of flooding** is to ensure that every router receives the changed or updated LSA within the flooding scope (area or domain).
When a **DR** (**Designated Router**) is present, only non-DRs flood to the DR. The DR then floods to everyone as required.

## Convergence of Forwarding Tables:

**Forwarding tables** of routers are a type of routing table that contains information about the **next-hop router** to which packets should be forwarded for each destination network, as well as the **outgoing interface** and any necessary metrics or preferences.

To understand how it works, it's important to note that when a change occurs in the network topology, routers must communicate with each other to recalculate their forwarding tables. The **convergence process** is initiated by the exchange of link-state advertisements (LSAs) among routers, allowing them to update their internal databases and perform shortest-path calculations.

## Diagram of the experiment:



## Configuration of Routers:

RIP works with **classful addressing**, that's why we don't have to work with subnet masks. But, OSPF works with **classless addressing**. So, we have to provide masks. Here, we provide something called **wildcard**. Which is basically the complement of the subnet mask.

Here's the configuration of "Router0":

```
Router>
Router>
Router>en
Router#config t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 1
Router(config-router)#network 200.200.200.0 0.0.0.15 area 0
Router(config-router)#
00:09:42: %OSPF-5-ADJCHG: Process 1, Nbr 200.200.200.50 on Serial2/0 from FULL to DOWN, Neighbor Down: Interface down or detached

00:09:42: %OSPF-6-AREACHG: 200.200.200.0/0 changed from area 1 to area 0

Router(config-router)#network 200.200.200.15 0.0.0.15 area 0
Router(config-router)#network 192.168.10.0 0.0.0.255 area 0
Router(config-router)#
00:11:04: %OSPF-6-AREACHG: 192.168.10.0/0 changed from area 1 to area 0

Router(config-router)#end
Router#
```

Here, the process ID is 1 and it's under area 0. OSPF uses areas so we need to specify the area. The number "1" is a process ID and we can choose any number we like. It doesn't matter and if we want, we can use a different number on each router.

Here, the wildcard for IP & Mask 200.200.200.0 255.255.255.240 is 0.0.0.15. Which is the same for IP & Mask 200.200.200.15 255.255.255.240. On the other hand, the wildcard is 0.0.0.255 for IP & Mask 192.168.10.0 255.255.255.0.

Here's the configuration of "Router1":

```
Router>
Router>
Router>
Router>en
Router#config t
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 1
Router(config-router)#network 200.200.200.15 0.0.0.15 area 0
Router(config-router)#network 200.200.200.32 0.0.0.15 area 0
Router(config-router)#
00:26:22: %OSPF-5-ADJCHG: Process 1, Nbr 200.200.200.49 on Serial3/0 from FULL to DOWN, Neighbor Down: Interface down or detached

00:26:22: %OSPF-6-AREACHG: 200.200.200.32/0 changed from area 1 to area 0

Router(config-router)#network 192.168.5.0 0.0.0.255 area 0
Router(config-router)#
00:26:55: %OSPF-6-AREACHG: 192.168.5.0/0 changed from area 1 to area 0

Router(config-router)#end
Router#
```

Similarly, the routers will be configured following the same format.

For “Router0”:

```
Router#show ip ospf neighbor


Neighbor ID     Pri   State           Dead Time   Address         Interface
200.200.200.33    0   FULL/  -        00:00:38    200.200.200.18  Serial3/0
200.200.200.50    0   FULL/  -        00:00:30    200.200.200.2   Serial2/0
```

For “Router1”:

```
Router#show ip ospf neighbor


Neighbor ID     Pri   State           Dead Time   Address         Interface
200.200.200.17    0   FULL/  -        00:00:31    200.200.200.17  Serial2/0
200.200.200.49    0   FULL/  -        00:00:33    200.200.200.34  Serial3/0
```

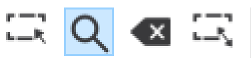
For “Router3”:

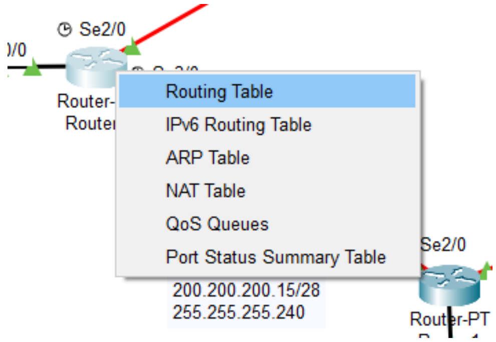
```
Router#show ip protocols

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 200.200.200.50
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    200.200.200.48 0.0.0.15 area 0
    200.200.200.0 0.0.0.15 area 0
    193.168.5.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    200.200.200.17       110      00:26:41
    200.200.200.33       110      00:00:08
    200.200.200.49       110      00:27:11
    200.200.200.50       110      00:26:17
  Distance: (default is 110)
```

## Observation:

How to get the routing tables:






The screenshots of routing table of each router are shown below:

Routing Table for Router0

| Type | Network | Port | Next Hop IP | Metric |
|---|---|---|---|---|
| O | 192.168.5.0/24 | Serial2/0 | 200.200.200.2 | 110/193 |
| C | 192.168.10.0/24 | FastEthernet0/0 | --- | 0/0 |
| O | 193.168.5.0/24 | Serial2/0 | 200.200.200.2 | 110/65 |
| O | 193.168.10.0/24 | Serial2/0 | 200.200.200.2 | 110/129 |
| C | 200.200.200.0/28 | Serial2/0 | --- | 0/0 |
| C | 200.200.200.16/28 | Serial3/0 | --- | 0/0 |
| O | 200.200.200.32/28 | Serial2/0 | 200.200.200.2 | 110/192 |
| O | 200.200.200.48/28 | Serial2/0 | 200.200.200.2 | 110/128 |

Routing Table for Router1

| Type | Network | Port | Next Hop IP | Metric |
|---|---|---|---|---|
| C | 192.168.5.0/24 | FastEthernet0/0 | --- | 0/0 |
| O | 192.168.10.0/24 | Serial3/0 | 200.200.200.34 | 110/193 |
| O | 193.168.5.0/24 | Serial3/0 | 200.200.200.34 | 110/129 |
| O | 193.168.10.0/24 | Serial3/0 | 200.200.200.34 | 110/65 |
| O | 200.200.200.0/28 | Serial3/0 | 200.200.200.34 | 110/192 |
| C | 200.200.200.16/28 | Serial2/0 | --- | 0/0 |
| C | 200.200.200.32/28 | Serial3/0 | --- | 0/0 |
| O | 200.200.200.48/28 | Serial3/0 | 200.200.200.34 | 110/128 |

Routing Table for Router2

| Type | Network | Port | Next Hop IP | Metric |
|---|---|---|---|---|
| O | 192.168.5.0/24 | Serial3/0 | 200.200.200.33 | 110/65 |
| O | 192.168.10.0/24 | Serial2/0 | 200.200.200.50 | 110/129 |
| O | 193.168.5.0/24 | Serial2/0 | 200.200.200.50 | 110/65 |
| C | 193.168.10.0/24 | FastEthernet0/0 | --- | 0/0 |
| O | 200.200.200.0/28 | Serial2/0 | 200.200.200.50 | 110/128 |
| O | 200.200.200.16/28 | Serial3/0 | 200.200.200.33 | 110/128 |
| C | 200.200.200.32/28 | Serial3/0 | --- | 0/0 |
| C | 200.200.200.48/28 | Serial2/0 | --- | 0/0 |

Routing Table for Router3

| Type | Network | Port | Next Hop IP | Metric |
|---|---|---|---|---|
| O | 192.168.5.0/24 | Serial3/0 | 200.200.200.49 | 110/129 |
| O | 192.168.10.0/24 | Serial2/0 | 200.200.200.1 | 110/65 |
| C | 193.168.5.0/24 | FastEthernet0/0 | --- | 0/0 |
| O | 193.168.10.0/24 | Serial3/0 | 200.200.200.49 | 110/65 |
| C | 200.200.200.0/28 | Serial2/0 | --- | 0/0 |
| O | 200.200.200.16/28 | Serial2/0 | 200.200.200.1 | 110/128 |
| O | 200.200.200.32/28 | Serial3/0 | 200.200.200.49 | 110/128 |
| C | 200.200.200.48/28 | Serial3/0 | --- | 0/0 |

**Advantages**:

• Open Short Path First is easily scalable, meaning with a very little amount of hassle, we can scale it to use in a very big network.

• Open Shortest Path First Protocol has full support for subnets.

• Use of Hello Packets: Open Short Path First sends small hello packets to verify link operations and ignores transferring large tables.

• OSPF Supports route tagging: In Open Short Path First, routes can be tagged to ease interoperation with arbitrary values.

• Routing: Open Short Path First is able to route packets based on their type of service field.

**Disadvantages:**

• It is a processor-intensive protocol to use.

• Because it maintains more than one copy of routing information, it consumes more memory.

• It is a more complex protocol to understand and learn compared to other Internet Protocols.

**Challenges:**

- It took a lot of time to gather all the necessary information and compile it into a comprehensive report.
- Familiarity issues.