APPLICATION NOTE - OSPF

USING OSPF WITH RAPTOR®

Dynamic routing is a networking IP routing mechanism that provides optimal and efficient data routing. Unlike static routing, dynamic routing enables routers such as the iS5 Communications' RAPTOR to select paths according to real-time logical network layout changes and conditions. Dynamic routing protocols allow routers to share information about the network with other routers to let them choose the best path to reach a destination.

There are two types of Dynamic Routing protocols: Interior Gateway Protocols (IGP) and Exterior Gateway Protocols (EGP). The IGPs are designed for routing within an autonomous system. The most used IGP routing protocols are as follows:

- **Open Shortest Path First (OSPF)**
- **Routing Information Protocol (RIP)**
- **Interior Gateway Routing Protocol (IGRP)**
- **Enhanced Interior Gateway Routing Protocol (EIGRP)**

OSPF routing protocol is used in large IP networks. It was developed by the IETF IGP working group and documented in RFC2328. It runs over IP directly with protocol number 89. The protocol uses link-state advertisements and a link-state database to map the network topology. This logical map is used with the link-state algorithm to determine the best route available. It implements Dijkstra's algorithm, also known as the Shortest Path First (SPF) algorithm. When network changes occur in the internetwork, this algorithm determines the best routes using the link-state database and allows OSPF to update its routes faster than RIP. OSPF uses areas to segment the network, which helps it decrease the overall size of the link-state database and speeds up network convergence when the network experiences change.

ADVANTAGES OF OSPF ROUTING

- Less error-prone than static routing
- Allows load balancing among equal-cost paths
- Uses flexible metrics instead of only hop count
- Allows scalability since there is less administrative overhead involved
- Uses multicast rather than the broadcast of its messages to reduce network load
- Enables the exchange of routing information whenever the network experiences a change in topology

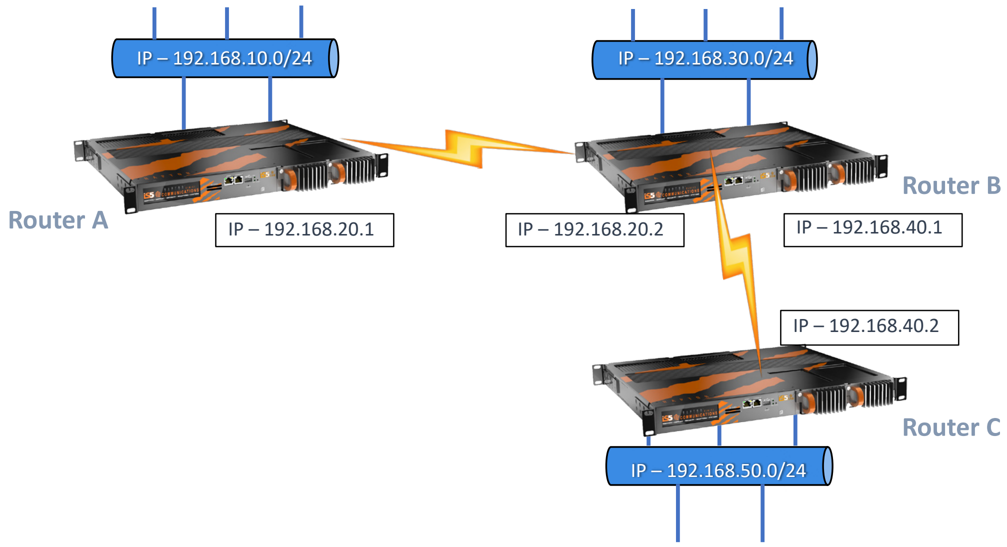
HOW DOES OSPF WORK?

When configured, OSPF listens to neighbors and gathers all link-state data available to build a topology map of all possible paths in its network. It then saves the information in its topology database, also known as its **Link-State Database (LSDB)**. Using the information from this database, OSPF calculates the best shortest path to each network/reachable IP subnet using the **Shortest Path First (SFP)** algorithm.

OSPF then constructs **three tables** for storing information:

- **Neighbor Table**—contains all discovered OSPF neighbors with whom routing information is interchanged
- **Topology Table**—contains the entire road map of the network with all available OSPF routers and calculated best and alternative paths.
- **Routing Table**—contains the current working best paths that forward data traffic between neighbors

Figure 1.0 - OSPF Network Convergence



After configuration, the router exchanges information with networks they are directly connected to. For example, in Figure 1, router A is only aware of network 192.168.10.0, which is directly attached to router A's LAN interface. Router A will advertise network 192.168.10.0 to router B. Once received, Router B then updates its routing table to forward packets destined for 192.168.10.0 network to 192.168.20.1 IP address. Router B knows that 192.168.20.1 can be reached as its WAN interface is a directly attached network.

Router C advertises its network, 192.168.50.0, to router B. The latter then records this new information in the routing table. In addition, router B advertises both networks 192.168.30.0 and 192.168.50.0 to router A and networks 192.168.30.0 and 192.168.10.0 to router C. Routers A, B, and C now all have the full internetworks information as well as the knowledge on how to reach each LAN IP segment.

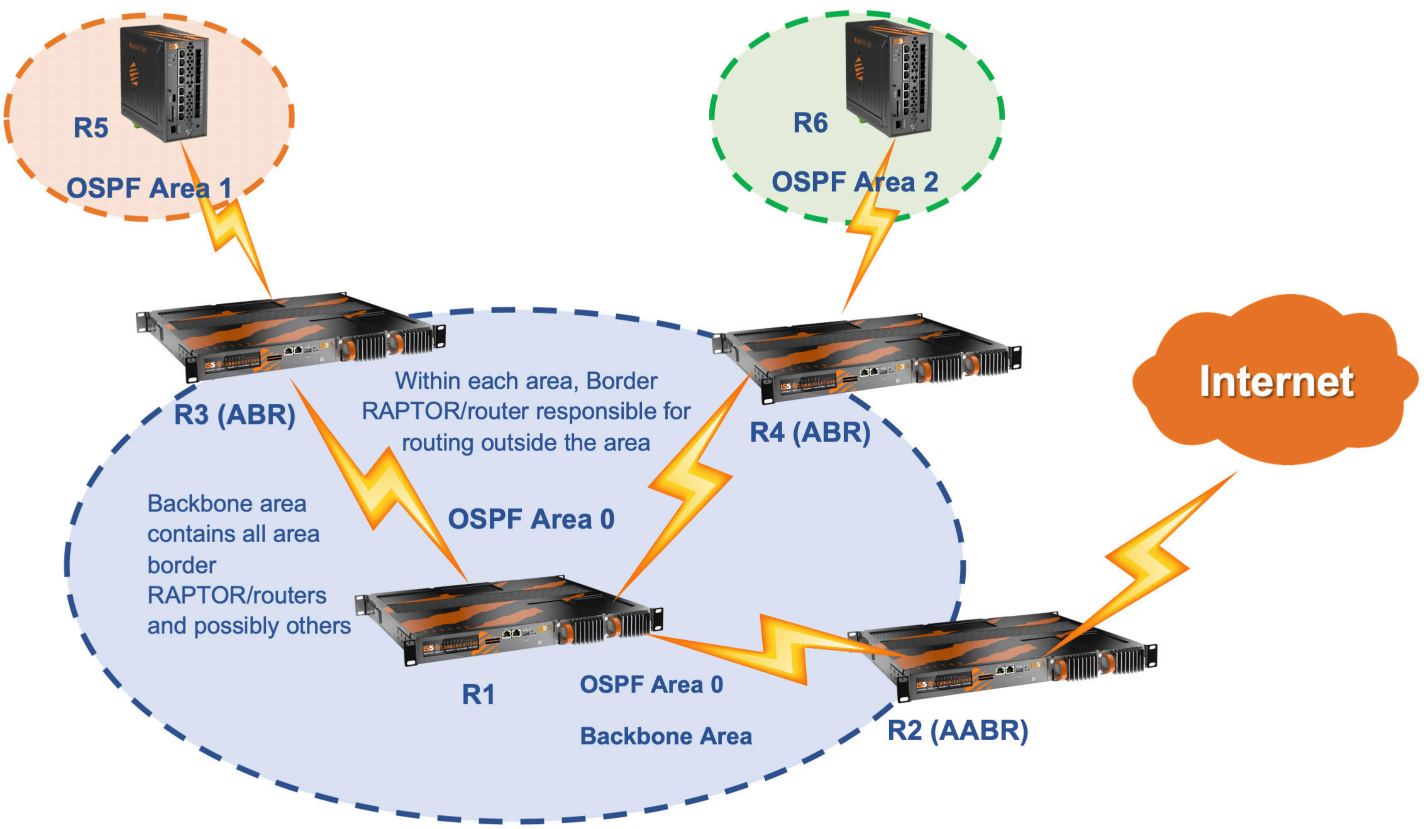
ABOUT OSPF AREAS

OSPF offers a unique feature called **Routing Areas.** A routing area is a logical aggregation of OSPF networks, routers, and links that have the same **Area ID**. A router within an area must maintain a topological database for the area to which it belongs. The idea of partitioning the OSPF network into areas is to simplify administration and optimize available resources. Resource optimization is crucial for large networks with a plethora of networks and links. Having many routers exchange the link-state database could flood the network and reduce its efficiency. The concept of routing areas was created due to this need.

OSPF - FOUR TYPES OF ROUTERS

The OSPF routing network itself can contain multiple areas. The main area is called the **"Area 0"**, or the backbone area, and the rest of the areas must connect to **Area 0**.

Figure 2.0 - OSPF Areas, Area 0 (Backbone Area), ABR (Area Border Router) and ASBR (Autonomous System Border Router)



WORKING INSIDE THE AREA

a. Designated Router (DR)

A DR is elected by the routers on multi-access segments (e.g. Local Area Network) based on its priority (Router ID, priority). The DR routers send Link State Advertisements (LSAs) and exchange information with all other routers in the same area. Every router in the same area creates an adjacency with the DR and BDR.

Using the Multicast IP address 224.0.0.5 the DR sends updates to all Area Routers. Except DR, all OSPF routers use the Multicast address 224.0.0.6 to send Link State Advertisements (LSAs) and Link State Update (LSU) packets to the DR router.

b. Backup Designated Router (BDR)

A BDR is a router that becomes a DR if the existing DR fails. The BDR has the second-highest priority (with the DR having the top priority value) in the OSPF network. A new BDR is elected when the existing BDR becomes a DR.

c. Area Border Routers (ABR)

Routers that are located on the borders of each area and are connecting to more than one OSPF area are called ABR. It stores and maintains separate routing tables regarding the backbone and the topologies of the area to which it is connected. They are accountable for summarizing the IP addresses of each area and suppressing updates among areas to prevent fault containment.

d. Autonomous System Boundary Router (ASBR)

Autonomous System Border Router (ASBR) is a router that is running multiple protocols and works as a gateway to routers outside the OSPF domain as well as those running with different IP routing protocols. Using the process named as redistribution, the ASBR imports and translates different routing protocol routes into OSPF.

OSPF Packets

OSPF sends packets to neighbors to establish and maintain adjacencies, send and receive requests, ensure reliable delivery of LSAs-Link-state advertisements between neighbors, and to describe link-state databases. The latter is generated from all the LSAs that an area router sends and receives. The link-state database then calculates the shortest-path spanning-tree using the Shortest Path First (SPF) algorithm.

There are Five types of OSPF packets:

- Hello
- Database description
- Link-State Request
- Link-State Update
- Link-State Acknowledgement

Version	Type (1-5)	Packet Length
Router ID		
Area ID		
Checksum		Authentication Type
Authentication		
Authentication		

Hello packet

This Hello packet is sent by the router to discover OSPF neighbor router and to establish bidirectional communications with them.

When several routers that run OSPF have interfaces attached to the same network, the Hello packet classifies the designated router-DR. The designated router-DR is adjacent to all routers on the network. The DR role is to generate and flood the LSAs on behalf of the network. In a broadcast network environment, such as Ethernet, the DR reduces the amount of generated router protocol traffic. The DR is also responsible for maintaining the network topology database that is copied in all other routers that are within the same OSPF area on the network. The concept of a DR does not exist for point-to-point connections.

Database description packet

After the Hello packets are exchanged, and two-way communications are established, the DR and other area routers are neighbors. At this point, the router knows which neighbors it must establish adjacencies with and then starts forming OSPF adjacencies. The most critical OSPF protocol function of synchronizing databases between routers is bringing up an adjacency. Database description packets are sent using the exchange database protocol, which in turn, exchanges a description of the link-state databases between adjacent partners using the database description packet.

Link-state update packet

Until the router databases are fully synchronized, they request and exchange more information from adjacent routers using link-state request and link-state update packets.

The router, whose router identifier is numerically higher, assumes the primary role, and the other assumes the secondary role. The primary router sends its database descriptions one at a time and the secondary router acknowledges each one, including in the acknowledgement its database descriptions. The records are then compared according to type, advertising router, and link-state ID. A sequence number in the record determines whether the record is newer or older. If the new description indicates that this record is newer than the recipient already has in its database, this description is saved.

Link-state request packet

Once all descriptions are received, the neighbors send out database requests for complete information about the records that were requested. These requests are followed by flooding of link-state updates containing the requested information. Each link-state update packet is acknowledged, either explicitly with a link-state acknowledgment packet or implicitly in the link-state packets. The routers are fully adjacent when the link-state databases are fully synchronized.

There are eight OSPF adjacency states; they are Down, Init, Attempt, 2-way, Exstart, Exchange, Loading, and Full. On RAPTOR, 2-way is represented by *WAY2 and means that the RAPTOR is fully adjacent only with the DR or the backup designated router (BDR). When the adjacency state is *FULL, this means that many neighbor states might be *WAY2, and therefore, an individual router might know about a neighbor but not be fully adjacent to it.

Link-state acknowledgment packet

Each newly received LSA must be acknowledged by its recipient to verify its delivery. This is done by sending a link-state acknowledgment packet, which contains one or more acknowledgements. An acknowledgment packet is either sent immediately or delayed, based on a specified time interval.

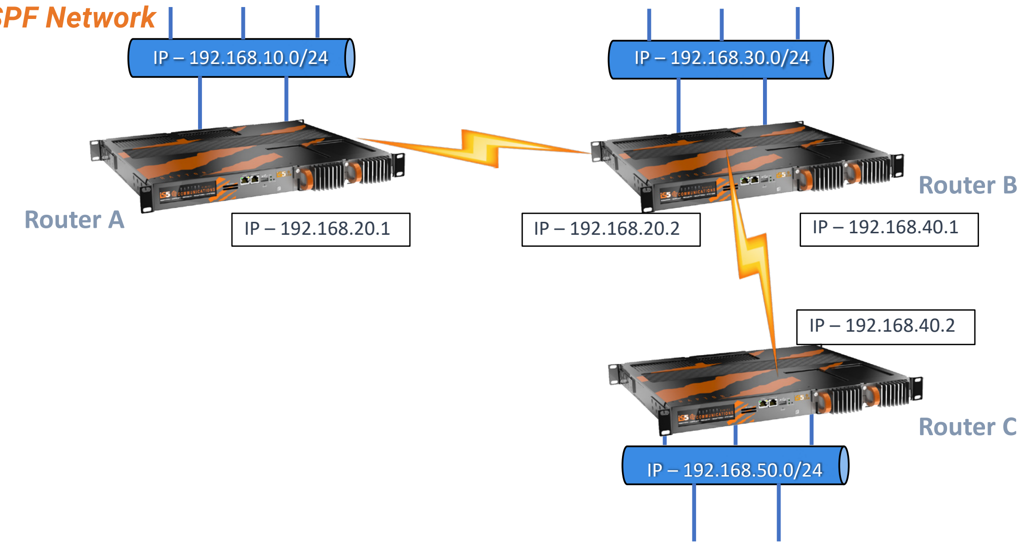
RAPTOR OSPF basic configuration

The steps are:

1. Enable OSPF on a RAPTOR using the **router ospf** in global configuration prompt.
2. Configure the Router ID using command **router-id IP_ADDRESS**.
3. Define which interfaces OSPF runs on and which networks to advertise. Use the command network IP_ADDRESS WILDCARD_MASK(optional) AREA_ID command from the OSPF configuration mode.

NOTE: To establish a neighbor relationship, the OSPF process number doesn't have to be the same on all routers, but for routers to become neighbors, the Area ID must be the same on all neighboring routers.

Figure 3.0 - OSPF Network



RAPTOR A Configuration

Enable OSPF on a router.

```
RAPTOR-A # configure terminal
RAPTOR-A (config)# router ospf
```

Router ID Configuration.

```
RAPTOR-A (config-router)#router-id 192.168.10.1
```

Next, you need to configure which interfaces OSPF will run and what networks will be advertised.

```
RAPTOR-A (config-router)#network 192.168.10.1 area 0.0.0.0
RAPTOR-A (config-router)#network 192.168.20.1 area 0.0.0.0
```

RAPTOR B Configuration

Enable OSPF on a router.

```
RAPTOR-B # configure terminal
RAPTOR-B(config)# router ospf
```

Router ID Configuration.

```
RAPTOR-B (config-router)#router-id 192.168.30.1
```

Next, you need to configure which interfaces OSPF will run and what networks will be advertised.

```
RAPTOR-B (config-router)#network 192.168.20.2 area 0.0.0.0
RAPTOR-B (config-router)#network 192.168.30.1 area 0.0.0.0
RAPTOR-B (config-router)#network 192.168.40.1 area 0.0.0.0
```

RAPTOR C Configuration

Enable OSPF on a router.

```
RAPTOR-C # configure terminal
RAPTOR-C(config)# router ospf
```

Router ID Configuration.

```
RAPTOR-C (config-router)#router-id 192.168.50.1
```

Next, you need to configure which interfaces OSPF will run and what networks will be advertised.

```
RAPTOR-B (config-router)#network 192.168.50.1 area 0.0.0.0
RAPTOR-B (config-router)#network 192.168.40.2 area 0.0.0.0
```

To display the status of adjacencies and OSPF route, we can use the following command - in RAPTOR.

```
show ip ospf neighbor
show ip route ospf
sh ip route
```

CONCLUSION

OSPF routing protocols allow RAPTOR to automatically discover each connected IP Network and adjust to convergency in the internetwork. OSPF protocols are used to free the administrator from entering multitudes of static routes for traffic flow and fault tolerance.

ABOUT iS5 COMMUNICATIONS INC.

iS5 Communications Inc. (“iS5Com”) is a global provider of integrated services and solutions, and manufacturer of intelligent Industrial Ethernet products. Our products are designed to meet the stringent demand requirements of utility sub-stations, roadside transportation, rail, and industrial applications. iS5Com’s services and products are key enablers of advanced technology implementation such as the Smart Grid, Intelligent Transportation Systems, Intelligent Oil Field, and Internet of Things. All products have the ability to transmit data efficiently without the loss of any packets under harsh environments and EMI conditions.

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For more information, visit: is5com.com

toll free: +1-844-520-0588 | fax: +1-289-401-5206 | info@is5com.com

technical support: +1-844-475-8324 | support@is5com.com

Address: 5895 Ambler Dr, Mississauga, ON L4W 5B7