An Anatomy of IGP and BGP Routing Protocols

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Abstract—**Due to the growth of computer networks, the word routing protocol has spread with a notice able speed making a huge impact through the world of networking. Various types of routing protocols have been used in lots of fields; each field uses the protocols that suit its needs with consideration to several metrics such as power and bandwidth consumption. In this paper we propose the idea of routing protocols, starting with an overview of the basics of Interior Gateway Protocols (IGP) and Border Gateway Protocols (BGP). Later, we describe the idea of Link State Routing Protocols (LSRP) and Distance Vector Routing Protocols (DVRP) while making a comparison which should determine the protocol needed for each network topology. The weaknesses and strengths of each routing protocol will be also discussed.**

Keywords-Interior Gateway Protocol (IGP), Border Gateway Protocol (BGP), Link State Routing Protocols (LSRP), Distance Vector Routing Protocols (DVRP).

I. INTRODUCTION

Every Routing Protocol has the main job of providing information of which paths the traffic should follow from the source to the final destination. Such information will determine the specific nodes and links that the traffic will intercept. when node/link failure occurs, the routing protocol must attempt to find an alternative path that should avoid the failure thus, the routing tree of each affected node (any node which originally had the failed node/link in its routing tree) will be updated. Such node/link failure could change logical topology of the network and cause large delays to any sensitive real/time traffic that need to be rerouted. In large networks that span multiple countries and service providers, it's even harder to deal with these node/link failures because of the huge numbers of nodes, links, routes and end devices that has been linked together [4].

Nowadays, routing protocols have been improved to give any network of any size the information needed to reconstruct itself after node/link failures while minimizing traffic delays, and routing loops which can cause large traffic delays and drops. Power consumption rate of the routing protocol is also one factor that should be considered in some specific networks and which could force the network designers to go for a specific routing protocol.

From all the reasons above choosing the right protocol is a hard job to do, every network administrator must consider the most critical criteria when choosing a routing protocol. There are two main types of protocols that will be discussed in details: IGP that has been used within Autonomous Systems (AS) and Exterior Gateway Protocol (replaced with BGP as being the only protocol recommended for exchanging information between AS's [1]), each type of those is divided into other types. Fig1 shows the types of routing protocols. The rest of the paper is organized as follows. Section 2 presents a comparison between IGP and BGP. Section 3 compares DVRP and LSRP while section 4 briefly describes different types of DVRP types. Section 5 describes the LSRP types and Finally, Section 6 concludes the paper.

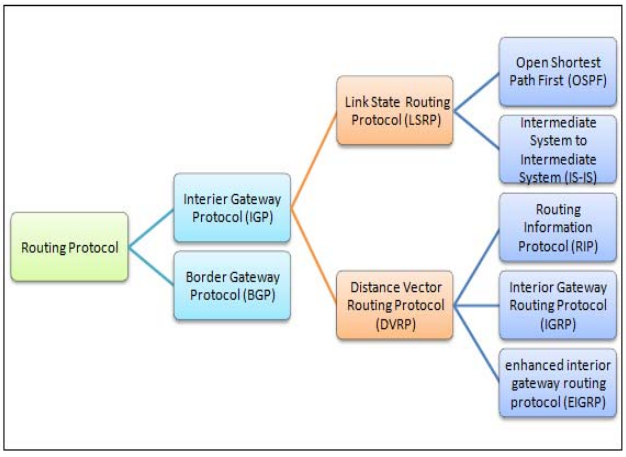

Figure 1. Types of Routing Protocols

II. INTERIOR GATEWAY PROTOCOLS (IGP) VS BORDER GATEWAY PROTOCOLS (BGP)

Fig 1 shows that an IGP has two main categories, the first one is Distance vector routing protocols and the second one is Link state routing protocols. IGP is used to establish and distribute routing information to routers within Autonomous System (AS), the most common routing protocols within this category are RIP (Routing Information Protocol) and OSPF (Open Shortest Path First) [2].

BGP is used to route traffic between ASs within the internet. The protocol takes routing decisions by not only considering the bandwidth, but mainly by considering routing polices published by any AS. Figure 2 demonstrates how BGP works. [3].

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BGP is used widely in the internet. BGP was created to take the place of the Exterior Gateway Protocol (EGP), that it acts and does routing between more than autonomous systems. BGP was designed to allow fully decentralized routing. It is described as a path vector protocol. When BGP connects two nodes in the same AS, it is known as Internal BGP, while External BGP interconnects different ASs [3].

a. BGP Message Types

When BGP wants to start session between two different nodes in the network, it uses a specific type of messages called Open Messages, another type of messages is used when there is more than Border Gateway Message (BGM) system around the network that gives the update of routing this message is called Update Message.

If any error occurs while routing, a message is sent to do what it takes to handle the problem, this type of messages is known as Notification Message, the last type of messages is used to maintain connectivity between nodes; it's called Keep-Alive Message.

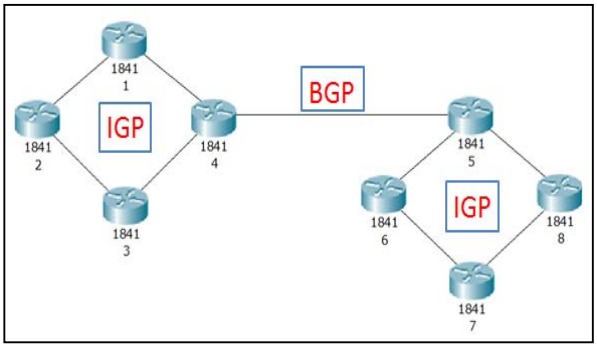

Figure 2. The differences between BGP and IGP

Fig 2 shows that IGP is a great option for routing in small areas, it starts with links between nodes inside the small network delivering information in small area using counted routers. On the other hand, BGP connects small networks that had been already handled with IGP routing protocols using different algorithms, Furthermore, IGP uses more protocols than BGP due to the excessive consumption in small areas.

TABLE I. THE DIFFERENCES BETWEEN IGP AND BGP.

Protocol Properties	IGP	BGP
Operating	Operates within the Autonomous System (AS).	Operates between different Autonomous System (AS).
Routing On	Routing Inside the network.	Routing within Autonomous System.
Administration	Single network administration.	Independent administrative units.

IGP as shown in Table 1 works on a single Autonomous system administrated by a single Authority, links between nodes works efficiently in small areas as well as the routing.BGP works between more than one IGP AS, Therefore it forms a large internetwork that covers and administered by multiple service providers and spans large geographical areas..BGP is used too much in the world of networks and it has some advantages that gave it some reasons to stay among other protocols.

III. DISTANCE VECTOR ROUTING PROTOCOL VS LINK STATE ROUTING PROTOCOL

Distance Vector Routing Protocol is a combination of two main words "Distance" which means how far and how much hops the traffic will take to reach the final destination ,"Vector" is the direction to get to that destination.

The main difference between the Distance vector protocol and link state, is in Distance vector it doesn't have information about the complete network topology and how every node is connected to its neighbors. Distance vector protocols provides any node the information need to reach the directly connected node. This is not the case with Link-State routing protocols where every node has the full map of the topology [1].

The Idea of link state protocol can be demonstrated with a game like puzzle jigsaw ,in this puzzle each point has single node, that single node creates a packet which is represented as a separate point in the puzzle, these kind of packets are distributed everywhere and been received with each router with its own algorithms.

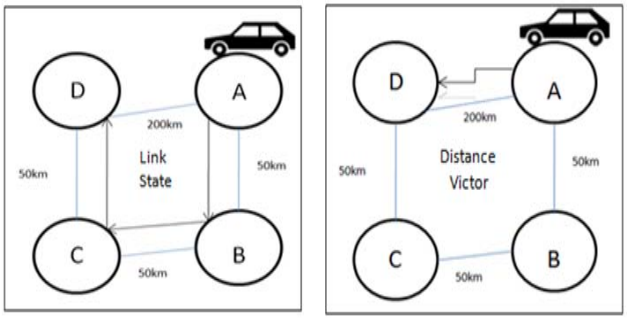

Figure 3. The differences between DVRP and LSRP

The distance for the first car to go from A to D is 200 km, with a Distance Vector protocol the car goes directly from node A to node D to reach the final destination which is node D, in a link state protocol, the nodes will reroute the traffic to take the shortest path, so that the car will go through nodes A, B, C and D (total of 150km instead of 200km). which make the distance vector better in resource consumption, but in other case if the distance between A and B is 100 the link state protocol will definitely have lower cost and will not go through BCD route ,in distance vector it will go through BCD (150 km),in this case Link state will play a better role than Distance vector in resource consumption.

TABLE II. THE DIFFERENCES BETWEEN DVRP AND LSRP

	DVRP	LSRP
Ease of configuration	Yes	No
Complexity	No	Yes
Bandwidth Consumption	High	Low
Resource Consumption	Low	High

From table2 shows the easiness of setting up DVRP in any network which gives it the ability to have a very low consumption rate, DVRP has been used in a lot of areas due to its low complexity and it's been used in most of networks since the routing protocols has started, therefore it preserved first choice for any network administrator, it's like an easy book to read. But nowadays, no one uses DVRP anymore because the network need more resources to establish. On the other hand LSRP has a very high complexity while setting up the network, which cause very high resource consumption but low bandwidth consumption gives it an advantage to be used in more advanced networks.

IV. DISTANCE VECTOR ROUTING PROTOCOL (DVRP) TYPES

a. RIP

Routing Information Protocol is one of distance vector Routing protocol and the oldest among other types. the path with the least hop count is considered while the maximum allowable hop count is 15 so any destination beyond 15 hops will be unreachable. The main advantage of RIP is that it's easy to deploy in small networks [4].

RIP has a high convergence time in a medium-sized network; there are 2 main versions of RIP, RIP v1 and RIP version 2.. RIP sends full routing schedules to all links that are active at periodic intervals. This table below summarizes the differences between these versions [5].

TABLE III. THE DIFFERENCES BETWEEN RIP TYPES.

	RIPv1	RIPv2
Best for	Small network	Small network
Supports VLSM	No	Yes
Classes	Full	Classless

The table above shows that RIP v2 is an enhanced version of RIP v1 that tried to overcome the drawbacks of RIP v1.RIP v1 has two main drawbacks, it doesn't support Variable Length Subnet Mask (VLSM) that could become an critical issue if subnetting was used in the network, also being class-full (A B C) in routing tables gives it more time than others to deal with routing, RIP v2 as mentioned above came to overcome the problems of supporting VLSM and had a new level in routing when it became classless.

b. IGRP

The Interior Gateway Routing Protocol (IGRP) is an interior distance-vector routing protocol. It was developed to overcome and improve the drawbacks of RIP it also uses single routing metric. IGRP exchanges its routing information with other routers within its Autonomous System. Routes are customized by IGRP using multiple metrics including bandwidth Hop count, delay, reliability and length. These metrics are distilled down to a single metric that is used for comparison purposes in choosing the better router available [6].

Also it's important to know the main characteristics for IGRP, IGRP only supports IP routing, IGRP sends full schedule of the updates of the topology every 90 second after each update, IGRP uses the algorithm to choose the best path in routing. This algorithm is well known in the world of networking and it's the base of a lot of protocol and it's called Bellman-Ford Distance Vector Algorithm.

c. EIGRP

The Enhanced Interior Gateway Routing Protocol (EIGRP) came after the IGRP to overcome the limitation of its predecessor , it's a combination of link state routing protocol (with the concept of shortest path)with the metrics of IGRP, The algorithm is known as Diffusing-Update Algorithm Finite-State Machine (DUAL FSM), it adjusts routing table entries based on changes in the network topology [6].

EIGRP packet types

- **Hello/ACKs:** Hellos are multicast to discovery and recovery neighbors, a hello without data is used as an acknowledgment (ACK).
- **Updates:** Used to transfer reachability of destinations.
- **Queries:** This is a response packet to a received query.
- **Replies:** Sent in response queries to indicate the originator
- **Requests:** Used to get information from one or more neighbors.

After the brief summary for the IGP's protocols, the table below shows the differences between each of the three types and how can they suit different networks.

TABLE IV. THE DIFFERENCES BETWEEN DVRP TYPES.

Protocol	RIP	IGRP	EIGRP
Suits	Small networks	Large networks	Large networks
Convergence time	Slow	Slow	Fast
Ease of configuration	Easy	Easy	Easiest
100% loop free	No	No	Yes
VLSM	No	No	Yes
Bandwidth consumption	High	High	Low
Resource consumption	Low	High	Low
Multi-path Support	No	Yes	Yes
Proprietary	No	Yes	Yes
Routers Non-IP Protocols	No	No	Yes

From the table above RIP works efficiently in small networks and has a very comfort ease in setting up it also provides very low power consumption but its high bandwidth consumption is one of its drawbacks, also RIP is one of the oldest routing protocol that almost cannot be seen in any network so its advantages and disadvantages is visible for any network administrator. IGRP suits large networks, it's easier than RIP in configurations because it came after it to correct or improve this weak point that faced RIP, also it has a high bandwidth consumption and a high power consumption which can be

considered as a weakness, but it's obvious that the best protocol that fulfills the needs of a good working network is EIGRP ,no wonder it came after IGRP to be one of the best choices due to its fast convergence time, ease of configuration and for the very low bandwidth and resource consumption.

V. LINK STATE ROUTING PROTOCOL (LSRP) TYPES

a. Open Shortest Path First (OSPF)

OSPF is a link-state routing protocol, OSPF is divided into two parts. The first part is (Open), which means that its work in public as open source. The second part is (SPF) which is based on an algorithm for calculating the shortest path [2].

There are five types of OSPF packets, each of them is used for a specific function, first of all the protocol needs to discover neighbors and exchange neighbor capabilities, and this is accomplished using **Hello Packets**, after that the protocol needs to trade the Link-Sate advertisements (LSA) headers and choose a number for the database, and that will be **Database Description Packets** function, then to demand a particular LSA that was working during the exchange process. It will need the **Link State Request Packet** function, after that the protocol will dispatch the whole LSA to the adjacent node which requested that specific LSA, and that will be the **Link-State update packets** function, at last the protocol needs to acknowledge the LSA which was received, and that will be the **Link-State acknowledgment packet** function.

b. Intermediate System to Intermediate System (IS-IS)

IOS is the developer of IS-IS routing protocol. IS-IS is a link-state protocol and behaves much like OSPF. It uses Open System Interconnection (OSI) protocols to deliver its packets, to locate the network topologies, IS routers use routing information exchanging.

There are four types of IS-IS packets, each of them is used for a specific function, first of all the protocol needs to organize neighbors and sends a packet every 10 seconds, and that will be through the **IS-IS Hello packet** function, after that the protocol needs to gather all the information needed about one router, and that will be through the **Link State Packet** function, then the protocol will request and confirm the link state information, and this is done using the **Partial Sequence Number Packet** function, at last the protocol will distribute the complete link state database, and that will be **Complete Sequence Number Packet** function.

OSPF and IS-IS belong to the same family (Link State Protocol) and both use the same algorithm to calculate the best path, support the same variable to calculate the subnet masks length, discover the adjacent router, use the same multitask to check the routing updates, and support authentication [2].

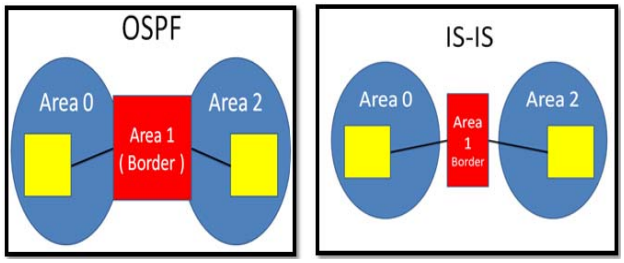

Figure 4. Differences between IS-IS and OSPF

Fig 4 shows that OSPF connects links together in direct way, but in IS-IS links are connected together with a separate area (Border) which makes the difference between the two types, also the other difference between them is that the area (Border) on OSPF falls within the scope of the area 0 and area 2, but on the other side the IS-IS area (Border) falls outside the scope of area 0 and area 2.This area border was the main advantage of IS-IS to recover and overcome the drawback of OSPF

TABLE V. THE DIFFERENCES BETWEEN OSPF AND IS-IS

Protocol Properties	OSPF	IS-IS
The complexity	Complex	Simple.
Encapsulation	Runs on top of IP.	Runs directly over L2.
Media support	Supports NBMA and point-to-multipoint links.	Does not support NBMA and point to point multi links.
Packet Encoding	Encoded.	Mostly TLV encoded.
Area Architecture	Area boundaries fall within a router.	Area boundaries fall on links.
Database Granularity	The database node is characterized to be LSAdvertisement.	Database node is characterized to beLSPacket.
Neighbor Establishment	The subnet needs hello and holding timers to match all the routers.	To full the Maximum transmission unit IS-IS needs padding of hello packets.
Neighbor Adjacency Establishment	Synchronizing neighbors needs a complex and multistate process.	Synchronizing neighbors needs regular flooding techniques.
Designated Routers and Adjacency	Chooses the DR and a backup DR to adjacent all the routers.	All routers are adjacent.
LAN Flooding	Multicast send is used by OSPF, using acknowledgment from designated router.	Multicast link state packet is used by IS-IS, using complete sequence number packet from designated router.
Database Size	The router size and the Network determines the database size.	The LSP count determines the database size.
Specs	Very good enforcement guide.	Very poor enforcement hints.

The above comparison shows that OSPF routers may belong to many areas and it is complex which means that the OSPF routers will need a high power consumption, OSPF runs on top of IP which retain more security advantage, OSPF area boundaries falls within routers which means that there will be no delay on receiving or sending packets, one last thing, to match all the routers on the same subnet, OSPF needs hello and holding timers, and that will make it hard during time changing.

On the other hand IS-IS routers belong to exactly one area and it is simple, so the power consumption for IS-IS routers is low, and because IS-IS runs directly above layer 2 it may lose the security advantage, IS-IS area boundaries falls within links which means that sometimes it may cause a delay while sending and receiving packets, one last thing is that IS-IS does not need holding timers to match all the routers, and that will give the advantage for IS-IS protocols.

VI. CONCLUSION

The results that have been found after making this paper about protocols types are that IGP has more benefits in small areas than the BGP ,also IGP protocols are used more than BGP protocols in variety of applications and among the two types the best protocol is EIGRP because it provides a better performance than RIP , OSPF and IS-IS, it has a good impact in the world of networking due to its fast convergence time ,improved scalability and for sure the great handling of routing loops ,also IGRP has a great impact in HTTP application which gives it the power to be in the lead of routing protocols .Its effective and could replace any other protocol.

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