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Comparative Analysis of Routing Protocols

Sahil Thapar
B.E. EXTC
DJSCOE

Aishwarya Karnik
B.E. EXTC
DJSCOE

Shruti Pawaskar
B.E. EXTC
DJSCOE

Poonam Kadam
Assistant Professor
DJSCOE

ABSTRACT
For end to end IP communication just having the forwarding path is not enough, it is necessary to have the reverse path as well to reach the network. If one can reach one host of one network it doesn't mean one can reach all host of that network. For end to end IP communication router should have route to reach all networks. Initially router has only the route to reach directly connected networks. Router can learn the route of the other network by two processes: Statically and Dynamically. In static Routing protocol the best path selection is done by AD value and in dynamic Routing protocol the best path selection is done through Metric Value. Static Routing protocol is used where it is a simple architecture while dynamic routing protocol is used where complexity increases. It is not advisable to use Dynamic Routing Protocol for simple architecture as processing power is high when we make dynamic entries. In this paper we proposed the use of some specified protocols according to the classification. The emphasis of this paper is not to present protocols in detail but to present main features of wide variety of different protocols depending upon their requirements.

General Terms
Interior Gateway protocol, Exterior Gateway protocol.

Keywords
AD Value, Metric Value, AS Number, Cost, Process ID, LSA Value, LSU Value.

1. INTRODUCTION
The routing protocol ensures the proper information flow between computers in a network .For forwarding a packet a router refers a routing table. Thus the routing table should be populated. Directly connected routes will enter the table automatically, static entry can be done by administrator or routes can be learned dynamically by using routing protocols. Full connectivity is not achieved using directly connected networks. Drawbacks are associated with static entries as they require manual configuration, must be configured on all networks, even failed links are not accounted for and every new network needs to be entered statically. Thus learning the routes dynamically using routing protocol is necessary as it helps routers understand each other better and thus increase their understanding of overall network topology. Routing protocols are those protocols which learn about all the networks, they also learn the best path to reach all the networks and they also select the best path to reach all the network. Routing protocols are used between routers to determine paths and maintain routing tables. Once the path is determined a router can route a routed protocol.

2. CLASSIFICATION OF ROUTING PROTOCOLS

2.1 Interior Gateway Protocol:
Interior Gateway protocol is used for routing within an autonomous system. These Gateway protocols are used to keep a track of the route to reach from one end to another end of a network. They are divided into distance vector routing protocol and link state routing protocol. Examples are RIP, IGRP, EIGRP, OSPF and ISIS. [3]

2.2 Exterior Gateway Protocol:
Exterior Gateway protocol is used for inter autonomous system routing. When there are more than one internet service provider connected to a company. The EGP helps find to have redundancy. Example of EGP is BGP. [3]

2.3 Classful Routing Protocol:
Classfull routing protocols are those protocols with default mask (/8, /16,/24).When we configure them to a network we need to type only the address, no mask is needed as it will consider the default mask.

2.4 Classless Routing Protocol:
Classless routing protocol is any other mask except that of the default mask. When we configure them to network we need to provide it with a mask as mask can be anything.

2.5 Distance Vector Routing Protocol:
Distance Vector Routing Protocols are protocols in which: Updates are periodic. Entire Routing table is not sent as an update Updates are sent to directly connected neighbours only and not to the entire network Distance Vector Routing protocols don't have end to end Visibility of the Entire Networks, directly connected neighbours are the worlds. In distance vector Routing Protocols because updates are periodic hence convergence is slow and because of slow convergence there is a possibility of a patch getting created in the network which carries wrong information.

Example: RIPV2, RIP

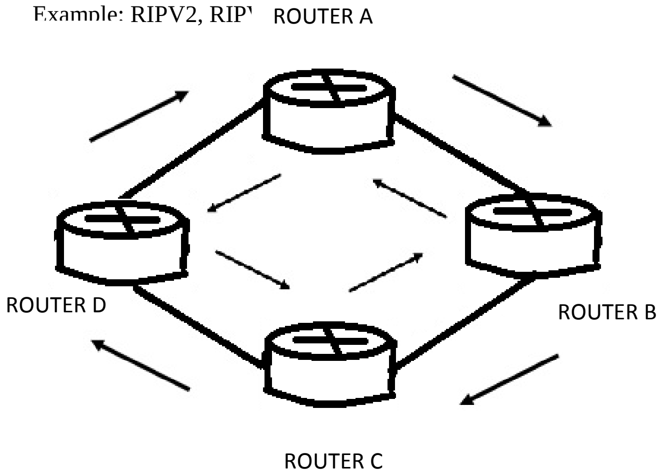

Fig 1: Architecture of Distance Vector Routing Protocol

2.6 Link State Routing Protocol:

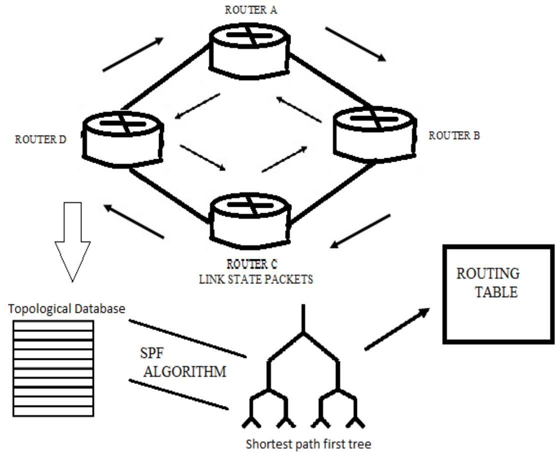

Fig 2: Architecture of Link State Routing Protocol

Link State Routing Protocols are protocols in which updates are triggered, they are not periodic. Updates are Incremental, entire routing table is not sent as an update. Updates are multicasted and not broadcasted Link State Routing Protocols send details like OSPF cost, SPF tree table as a part of their update which help routers build end to end visibility of entire network. Convergence is faster as Compared To distance Vector for 2 Reasons:

1. Updates are triggered.
2. Routers have end to end visibility of the entire network in the form of topology table.

Example: OSPF, ISIS[6]

2.6.1 Operation of Link State Routing Protocol:

When 2 link state routers are up they exchange ‘’hellos’’ between them so that they can acknowledge their neighbours. Every router which are directly connected will exchange information not with everyone and it will send the entire topology table. Process continues till every router has route to reach all networks in their topology table (by using routing protocols like OSPF,ISIS). Topology table is basically that table which contains various routes to reach all networks and Routing table is that table which contains the best path to reach all networks. Now when the router will have same number of networks in Topology table but different paths it will attain Full State. Once it attains the Full State three things will happen:

1. Updates are triggered in an incremental order only when it is down or up

2. SBF is an algorithm which will learn best path in the topology table and put it in the routing table.

3. Previously the hellos which is used to make neighbours will now check whether the other person is alive.

2.7 Advance Distance Vector Routing Protocol:

Advanced Distance Vector Routing Protocol are derived from the combination of link state and distance vector routing protocol. They take the best of link state and distance vector routing protocol. They take the entire operations of link state and simple configuration of distance vector routing protocol.

2.8 Anatomy of Gateway Protocol:

Table 1: Illustrates anatomy of Gateway Protocol

Routing Protocol Type:	CLASS	Type of Routing Protocol
RIP V2	Classless	Distance Vector
RIP V1	Classfull	Distance Vector
IGRP	Classfull	Distance Vector
EIGRP	Classless	Advanced Distance Vector
OSPF	Classless	Link State
ISIS	Classless	Link State
BGP	Classless	Distance Vector

3. DIFFERENT ROUTING PROTOCOLS

3.1 RIP (Routing Information Protocol)

RIP is a distance vector routing protocol whose AD value=120. RIP has a metric which is known as HOP Count. Criteria for Rip is HOP. RIP is further classified into two types: RIP V1 and RIP V2.

Table 2: Difference between RIP VI and RIP V2

PARAMETER	RIP V1	RIP V2
Class	Classfull	Classless
Mask	Does not send mask as a part of update	Sends mask as a part of update
Authentication	Does not Support	Supports
Updates	Broadcasted	Multicasted

3.1.1 RIP Configuration Example:

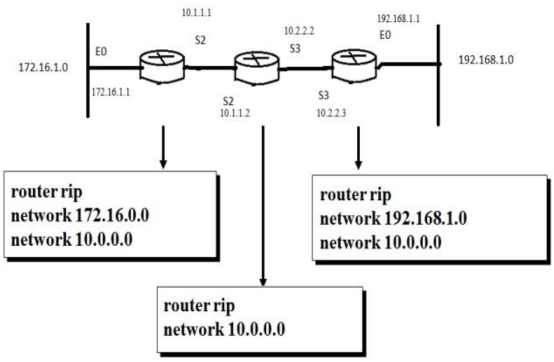

Fig 3: RIP Configuration

3.2 IGRP (Interior Gateway Routing Protocol):

IGRP protocol was developed by cisco systems in mid-1980s. Although RIP was a useful routing protocol for small and moderate size interconnecting networks it has a limitations that the hop count limit was 16 that restricted the size of network and did not allow flexibility in complex environments. IGRP implementations works in IP networks. IGRP was designed to run in any network environments. IGRP is a distance vector routing protocol, it compares the routes using some measurement of distance. IGRP provides features such as: hold downs, split horizons and reverse updates.

3.3 EIGRP (Enhanced Interior Gateway Routing Protocol):

EIGRP is an advanced Distance Vector routing protocol. It is a Hybrid routing protocol. EIGRP is an enhancement of IGRP. Since, IGRP is a distance vector routing protocol, EIGRP would be an advanced distance vector protocol. IGRP uses AS Number i.e. Autonomous System Number. When only this AS number of different routers is same, the communication will take place.

3.3.1 EIGRP Configuration Example:

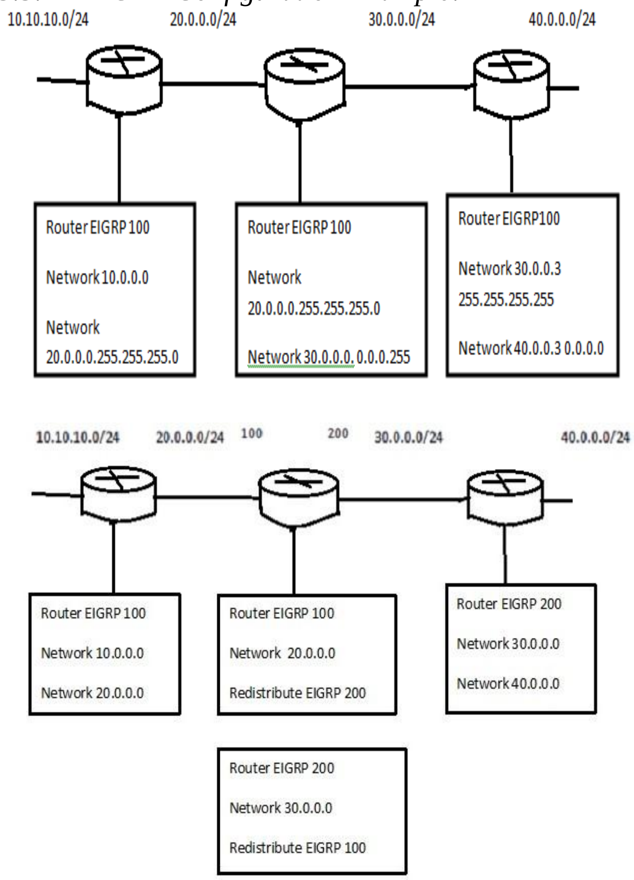

Fig 4: EIGRP Configuration

When one router has two ports with different AS numbers and communication is to be established between ports 100 and 200 then a "redistribute eigrp '200'" is used. If this command is not used the router with port number 100 would only communicate with its own network and not with network with a port having AS Number 200.

3.3.2 The three major types of EIGRP are:

(1) D Internal EIGRP : 90

(2) D ex External EIGRP: 170

(3) Summary:5

3.3.3 Advantages of EIGRP:

EIGRP's Metric is called "Composite Metric". EIGRP makes use of link Bandwidth and Delay. The Delay is the sum of all the delays along the paths. It will calculate mask as earlier and select best path and will note it in the routing table as also would note both the possible paths in the topology table. The bandwidth here would be the lowest bandwidth of links along the paths. EIGRP's scalability is 100 hops.

3.3.4 EIGRP Criterions:

EIGRP is based on 5 criterions to find the best path. They are as follows:

(1) Bandwidth*K1=1

(2) Delay*K3=1

(3) Load*K2=0

(4) Reliability *K4/K5=0

(5) MTU=0

Where, K1, K2, K3, K4, K5 are Metric weights. These 'K' values are called metric weights. They can be changed we usually consider Bandwidth and Delay alone. In case of considering Load we can modify the K2 value.

3.3.5 EIGRP Neighbourship Rule:

Two directly connected EIGRP routers will become neighbours only if: They belong to the same AS value. Their 'K' values match. EIGRP selects next best path at the same time when it selects the best path. This best path is recorded into the routing table. The best path is called as successor and the next best path is called feasible successor.

Packets: There are two types of packets namely: (1) Control Packets (2) Data Packets.

(1) Control Packets: Control Packets are multicast and broadcast. They are used for control between two routers. Example: Hello, Update, Query, Reply etc.

(2) Data Packets: Data Packets are Unicast. They carry data.

EIGRP uses multicast address 224.0.0.10 to exchange control packets. There are 5 types of control packets exchanged in EIGRP, they are Hello, Update, Query, Reply, Acknowledgement ,Hello and Acknowledgement are not reliable (they are UDP based) whereas, Update, Query, Reply are reliable. They use Acknowledgement (TCP Based). EIGRP knows who the fast neighbor and who the slow neighbor is. The neighbor with links less than or equal to T1 are slow neighbors. It sends Hellos after every 60 sec. The neighbors with links greater than T1 are fast neighbours. It sends Hello after every 5 sec.

3.4 OSPF (Open Shortest Path First)

This is a link state routing protocol. The AD value of OSPF is 110 and 10. Path selection criteria here is Bandwidth. The metric is Cost. OSPF would be connected only to its direct users. It will calculate cost on its own with the help of a formulae given as:

Cost = 10^08/Bandwidth[6]

OSPF maintains its topology table.

3.4.1 OSPF Area concept:
OSPF is a highly scalable routing protocol created to work majorly on 1000's of routers and handle 1000's of routes. OSPF routers have end to end visibility of the entire network, all its paths and their cost in form of topology table.

3.4.2 Issues with OSPF are:
(1) Frequent LSA/LSU sending or flapping network.

(2) High bandwidth utilization

(3) High memory utilization

(4) High processor Utilization

3.4.3 The solution to the above problem:
OSPF area is administrator defined area. Within an area no summarization takes place. The internal as well as border routers would exchange LSA/LSU's directly without summarization [6]. All the area internal routers would have full visibility of all the area internal routers their paths and their cost. LSA/LSU exchange can be done within an area but to exchange LSA/LSU outside the area 'Filtering' is done.

3.4.4 3.4.4 OSPF Configuration Example:

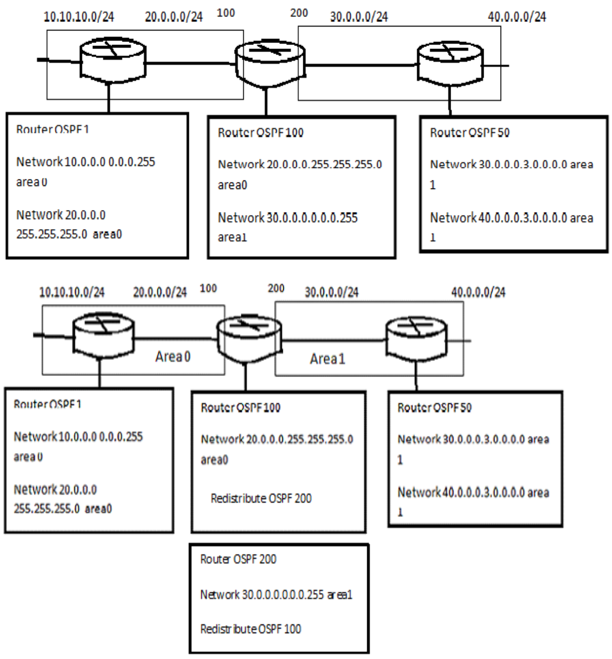

Fig 5: OSPF Configuration

OSPF uses Process ID for individual routers. Two area won't exchange routing tables unless they are connected to the backbone area. Like EIGRP OSPF too uses "Redistribute OSPF Process ID" to establish communication between different processes ID.

3.4.5 Router ID concept:
In OSPF routers are identified by their Router ID (RID). RID is the highest IP of loop back interface when OSPF starts. In absence of loop back interface, it is the highest IP of active interface when OSPF starts. Once RID is elected, it will remain as the RID and will not change even if interface with higher IP comes up.

3.4.6 Neighbourship:
OSPF behavior on multi-access network is slightly different. OSPF elects DR and BDR and all other router will act as DR others. DR is the router with highest OSPF priority. If all the routers have same priority election goes on RID. The router with highest RID becomes DR. Post neighbourship formation Hellos are exchanged to elect DR and BDR. Routers will send details like DR IP, BDR IP, OSPF Priority and RID as part of their hellos which helps routers elect DR and BDR. Initially, all routers would claim themselves to be DR and BDR but eventually by exchanging hellos appropriate router will become DR and BDR. If there is a topology change seen on DR other router, it will send updates to DR and BDR using multicast address 224.0.0.6. IN turn DR will send this update to DR others using multicast address 224.0.0.5. This is the address on which DR others listen. In case DR fails to send this update to DR others within a stipulated time then BDR will become DR and send it once BDR becomes DR it remains DR and will not change even if original DR comes up. This is how BDR becomes DR. Now the original DR will work as DR others [6]. For OSPF neighbourship: (1) Two routers should belong to the same area (2) Their Hello and Dead time should match. EIGRP and OSPF operations are similar and full state of OSPF is called as converged in EIGRP.

3.5 ISIS (Intermediate System Intermediate System)
ISIS is a link state protocol, which enables very fast convergence with large scalability. ISIS provides high flexibility. Leading edge feature such as MPLS Traffic Engineering is incorporated in ISIS. The features included in ISIS are classless behavior, fast convergence, rapid flooding of new information. ISIS is similar to OSPF in terms that it multicasts to establish neighbourship and uses the same algorithm as OSPF to find shortest path. The ISIS protocol uses four different metric. The default metric is cost and is supported by all routers. Delay, expense, and error are optional metrics. ISIS uses topology table that contains routes and the shortest path to a subnet. Unlike OSPF it does not have backbone area concept instead has level 2 routers. ISIS area and backbone routers: IS-IS has two layer hierarchy .The backbone (level 2).The area (level 1).An IS can be Level 1 router (intra-area routing).Level 2 router (inter-area routing) Level 1-2 router (intra and inter area routing) For each level (1 and 2) a DIS (Designated IS) will be elected on LANs .Level 1 routers have neighbours only in the same area. Level 2 router can have neighbour in other areas. Level 1-2 routers have neighbours in any area. Level 1 routers can exchange information with other level one router. Level 2 routers can exchange information between Level 2 routers. Level1-2 routers are required to exchange information between Level 1 and Level 2 routers. ISIS routers does not have backbone area. ISIS areas does not terminate on routers they terminate on links. ISIS requires links to be bidirectional this is to help create new neighbours so that it can exchange information and learn new topologies. The neighbours are created and maintained using hello protocol.

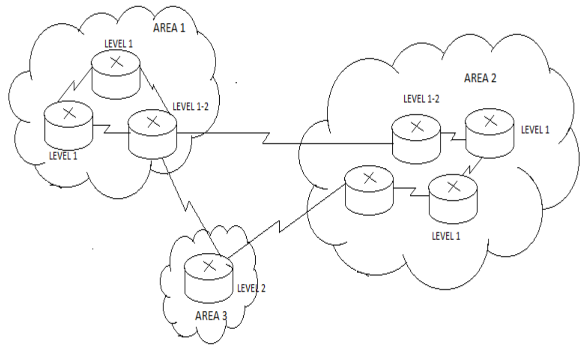

Fig 6: Isis Architecture

3.6 BGP (Border Gateway Protcol):

It is the only routing protocol on the internet. BGP is an exterior routing protocol. BGP is a unicast routing protocol. BGP is used to transfer data and information between different host gateways, the internet or autonomous systems .Currently BGP version 4 is used. It is the successor of BGP version 3 and version2. BGP replaces EGP protocol used in 1990s. The BGP routing protocol was created to overcome the drawbacks of EGP. BGP runs on the top of TCP. BGP uses TCP port 179 and maintains neighbour or peer relationship. Two system connected on the TCP exchange message to form a connection and exchange connection parameter. Using TCP BGP initially exchanges entire routing table and then incremental updates. The keep alive are exchanged using TCP. BGP has wealth of path attributes. It does not only use matric to select the best path. Metric is one of the attribute. BGP does not do load balancing. IT selects only one best path to connect to a network.

3.6.1 Path vector routing:

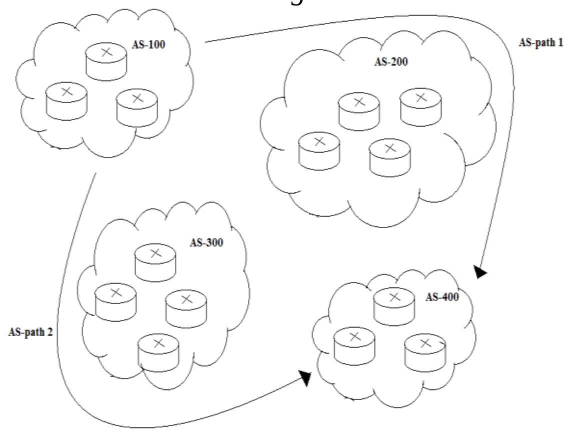

Fig 7: BGP Architecture

BGP is a path vector routing protocol. It is similar to distance vector routing protocol. By default BGP finds the best path to a network using best AS-path. AS-path is the number of autonomous system required to transverse to reach a particular network. The figure illustrates that to reach a network 190.0.30.0/24, AS-100 has two AS-paths. One is through AS-200 and other through AS-300. The best AS-path is the one which requires minimum number of autonomous system to be traversed. AS number is an ID required for an entity to connect over the internet

3.6.2 BGP neighbour relationship

In BGP neighbours are manually configured. This is to prevent the network from attacks. Neighbours start in idle state.BGP routing protocols are available in two flavors: IBGP and EBGP. IBGP is used between routers in the same autonomous system. EBGP is used between routes in different autonomous system.

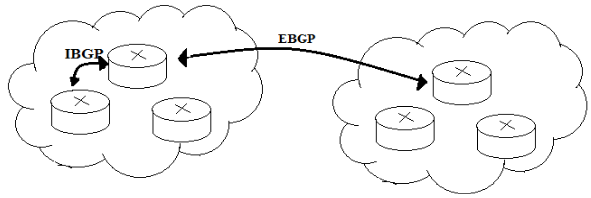

Fig 8: Bgp Neighbour Relation Architecture

BGP converges slowly. Keep alive are send every 60 seconds with hold down of 180 seconds. If updates are triggered every time a link goes down the internet would be filled with triggered updates. To avoid this the updates are slow.

3.6.3 Rule of synchronization:

Routes learned via BGP must be validated by the interior routing protocol before it is advertised to remote peer. This is to avoid black hole in a network.

3.6.4 Rule of split-horizon:

Routes learned via IBGP will never be send to another IBGP peer. This is to avoid loops in the network.

4. SUMMARIZATION OF ROUTING PROTOCOLS

Table 3: Comparison of Routing Protocols:

Name	Type	Proprietary	Function	Updates	Metric	Summarization
RIP V1	Distance Vector	No	Interior	30 seconds	Hops	Auto
RIP V2	Distance Vector	No	Interior	30 seconds	Hops	Auto
IGRP	Distance Vector	Yes	Interior	90 seconds	Composite	Auto
EIGRP	Advanced Distance Vector	Yes	Interior	Triggered	Composite	Both
OSPF	Link State	No	Interior	Triggered	Cost	Manual
IS-IS	Link State	No	Interior	Triggered	Cost	Auto
BGP	Path Vector	No	Exterior	Incremented	N/A	Auto

5. CONCLUSION

Thus we have studied different types of routing protocols. RIP is very simple to understand and configure. Also it is supported by most routers. Other advantage of RIP is it supports load balancing and is loop free. But there are vital drawbacks for using RIP, it is slow to converge. Slow convergence produces inconsistent routing. Also RIP learns about paths using 'Routing by Roomer' i.e. learning from routes to reach a network from neighbours. As a result the routes learned by RIP are not trustworthy. Another drawback of using RIP is that, it defines sixteen as maximum hop count hence networks which are genuinely sixteen hop counts away become unreachable. Due to these drawbacks RIP is not the best routing protocol to be used in network and hence its AD value is defined as 120. Another Routing protocol IGRP has advantage of easy configuration and unlike RIP uses composite metric thus an increased accuracy of the path. The disadvantage of IGRP is its slow convergence, slower than

RIP. Even though it has drawback the accuracy of it paths makes it more trustworthy and hence AD value of 100.ISIS has advantage that it is more secure as it works on layer 2. It has same convergence property as OSPF but less implemented on router platform. Its paths are not considered as trustworthy as that of OSPF and has AD value of 115.On the other hand Advantage of OSPF is it propagates the changes in the network very quickly. Another advantage is, it sends updates to other routers only when there are changes in the network. As OSPF uses the area concept the size of the routing table can be reduced. But the complexity of OSPF makes it difficult to understand. Less bandwidth is used by OSPF when there is no network change, but as soon as there is instability in the network, high bandwidth is used to send updates. Although OSPF has drawbacks it is still more sophisticated than ISIS and hence has an AD value 110. EIGRP being advance distance vector routing protocol gets best of the features. Main advantage is it plans ahead of time. So when a link goes down it knows which other route to use. EIGRP is not bound by areas like OSPF and hence is more scalable. Unlike OSPF which can do load balancing on only equal cost lines, EIGRP can balance load on unequal cost lines. And hence AD vale of 90, more sophisticated than above mentioned protocols. Thus we can choose any routing protocol depending on our requirement.

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