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COMPARATIVE ANALYSIS OF ROUTING PROTOCOLS

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Abstract: In a computer network the transmission of data is based on the routing protocol which selects the best routes between any two nodes. Different types of routing protocols are applied to specific network environment. Three typical types of routing protocol are chosen as the simulation samples: RIP, OSPF and EIGRP. RIP (Routing Information Protocol) is one of the oldest routing protocols still in service. Hop count is the metric that RIP uses and the hop limit limits the network size that RIP can support. OSPF is the most widely used IGP large enterprise networks. OSPF is based on the Shortest Path First algorithm which is used to calculate the shortest path to each node. EIGRP (Enhanced Interior Gateway Routing Protocol) is Cisco's proprietary routing protocol based on Diffusing Update Algorithm. EIGRP has the fastest router convergence among the three protocols are testing. The main aim to analyze the performance of the three protocols such as their router convergence, duration and end-to-end delay. In this concept we are going to use OPNET to simulate RIP, OSPF and EIGRP in order to compare their attributes and performance. According to the convergence we want to find out which protocols are suitable for different sizes and types of network.

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

I. INTRODUCTION

A routing protocol is the language a router speaks with other routers in order to share information about the reach ability and status of network. It includes a procedure to select the best path based on the reach ability information it has and for recording this information in a route table. Regarding to select the best path, a routing metric will be applied and it is computed by a routing algorithm. Routing algorithms determine the specific choice of route. Each router has a priori knowledge only of networks attached to it directly. A routing protocol shares this information first immediate neighbors and then throughout the network. In this way routers gain knowledge of the topology of the network.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. Routing protocols are used to learn about networks and best path to reach the all networks and they also select the best path to reach the entire 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.

II. CLASSIFICATION OF ROUTING PROTOCOLS

2.1 Interior Gateway Protocol:

An interior gateway protocol (**IGP**) is a type of protocol used for exchanging routing information between gateways within an autonomous system. This routing information can then be used to route network layer like IP. Interior gateway protocols can be divided into two categories: distance vector routing protocols and link state routing protocols. It specifies the IGP protocols include Open Shortest path First, Routing Information Protocol (RIP) and Intermediate System to Intermediate System (IS-IS).

2.2 Exterior Gateway Protocol:

Exterior Gateway protocols (EGP) are used to exchange routing information between inter-autonomous systems and rely on IGPs to resolve routes within an autonomous system. When there are more than one internet service provider connected to a company. The EGP helps to find the redundancy. Example of EGP is BGP.

2.3 Classful Routing Protocol:

Classful routing protocols do not send subnet mask information with their routing updates. A router running a classful routing protocol will react in one of two ways when receiving a route:

- If the router has a directly connected to the interface belonging to the same major network, it will apply the same subnet mask as that interface.
- If the router does not have any interfaces belonging to the same major network, it will apply the classful subnet mask to the route.

2.4 Class less Routing Protocol:

Classless routing protocols do send the subnet mask with their updates. Thus the Variable Length Subnet Masks (VLSMs) are allowed when using classless routing protocols. Examples of classful routing protocols include RIPv1 and IGRP. Examples of classless routing protocols include RIPv2, EIGRP, OSPF, and IS-IS.

2.5 Static Routing:

Static routing is the process of manually entering routes into devices routing table via a configuration file is loaded when the routing device starts up. In static routing all the changes

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in the logical network layout need to be manually done by the system administrator.

2.6 Distance Vector Routing Protocol:

Distance vector routing protocol is based on Bellman-Ford & Ford-Fulkerson algorithm to calculate paths. A distance vector routing protocol uses a distance calculation and a vector direction of next hop router as reported by neighboring routers to choose the best path. It requires that a router informs its neighbors of topology changes periodically. This approach assigns a cost number to each links between each node in the network. Nodes send information from point A to B via the path that result in the lowest total cost. When a node first starts it only knows of its immediate neighbors and the direct cost involved in reaching them. Each node on a regular basis sends to each neighbor node its own current assessment of the total cost to get to all the destinations it knows. The neighboring nodes examine this information and compare it to what they already know and anything that represents an improvement on what already have they insert in their own routing tables. All the nodes in the network discover the best next hop for all destinations and the best total cost. When one network node goes down, any nodes that used it as their next hop discard the entry and create new routing-table information. These nodes convey the updated routing information to all adjacent nodes which in turn repeat the process. Especially all the nodes in the network receive the updates and discover new paths to all the destinations they can still reach.

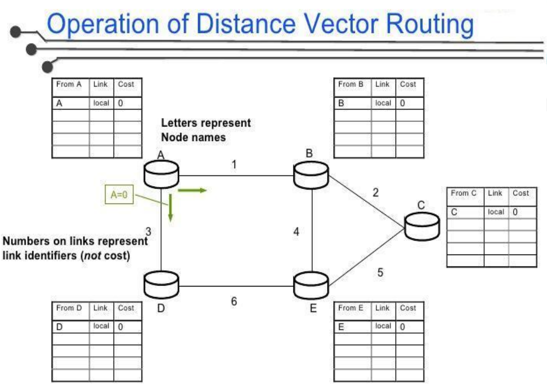

Figure 1: Architecture of Distance Vector Routing Protocol

2.7 Link State Routing Protocol:

Link state routing protocols build a complete topology of the entire network and then calculating the best path from this topology of all the interconnected networks. It requires more processing power and memory because it has a complete picture of the network. In each router possesses information about the complete network topology. Each router independently calculates the best next hop from it for every possible destination in the network using local information of the topology. The collection of best-next-hops forms the routing table. This contrasts with distance-vector routing protocols which work by having each node share its routing table with its neighbors. In a link-state protocol the only information passed between the nodes is information used to construct the connectivity maps

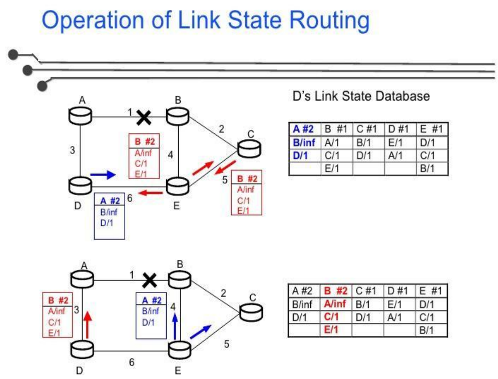

Figure 2: Architecture of Link State Routing Protocol

2.8 Anatomy of Gateway Protocol:

ROUTING PROTOCOL TYPE	CLASS	TYPE OF ROUTING PROTOCOL
RIP V2/ RIP V1	classless	Distance Vector Routing
IGRP	classful	Distance Vector Routing
EIGRP	classless	Advanced Distance Vector Routing
ISIS	classless	Link State
BGP	classless	Distance Vector Routing

Table 1: Illustrates anatomy of Gateway Protocol

2.9 Advance Distance Vector Routing Protocol:

Advanced Distance Vector Routing Protocols are derived from the 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

III. DIFFERENT ROUTING PROTOCOLS

3.1 RIP (Routing Information Protocol):

RIP is a standardized vector distance routing protocol and uses a form of distance as hop count metric. It is a distance vector. Through limiting the number of hop counts allowed in paths between sources and destinations RIP prevents routing loops. The maximum number of hops allowed for RIP is 15. To achieving this routing loop prevention, the size of supporting networks is sacrificed. Since the maximum number of hop counts allowed for RIP is 15, as long as the number goes beyond 15 the route will be considered as unreachable. When first developed RIP only transmitted full updates every 30 seconds. In the early distributions traffic was not important because the routing tables were small enough. As networks become larger massive traffic burst becomes more likely during the 30 seconds period even if the routers had been initialized at different times. Because of this random initialization it is commonly understood that the routing updates spread out in time but that is not in the real practice.

RIP TIMERS:

1. **Update Timer (default 30 seconds):**
   It defines how often the router will send out a routing table update.
2. **Invalid Timer (default 180 seconds):**
   It indicates how long a route will remain in a routing table before being marked as invalid, if no new updates are heard about this route. The invalid timer will be reset if an update is received for that particular route before the timer expires. A route marked as invalid is not immediately removed from the routing table. Instead the route is marked with a metric of 16 which means the route is unreachable and will be placed in a hold-down state.
3. **Hold-down Timer (default 180 seconds):**
   It specifies how long RIP will keep a route from receiving updates when it is in a hold-down state. In a hold-down state, RIP will not receive any new updates for routes until the hold-down timer expires.
4. **Flush Timer (default 240 seconds):**
   When no new updates are received about this route, flush timer indicates how long a route can remain in a routing table before getting flushed out. The flush timers operates simultaneously with the invalid timer, so every 60 seconds, after it has been marked invalid, the route will get flushed out. When RIP timer is not in sync with all routers on the RIP network, system instability occurs. This timer must be set to a higher value than the invalid timer.

RIPv1	RIPv2
Classful routing protocol	Classless routing protocol
Uses broadcast to send periodic updates	Uses multicast to send periodic updates
No support for authentication	Supports authentication
No support for VLSM/CIDR	Support for VLSM/CIDR

Table 2: Difference between RIP VI and RIP V2

3.2 Open Shortest Path First (OSPF):

OSPF is defined in RFC 2328 which is an interior Gateway Protocol used to distribute routing information within an AS (Autonomous System). Among all the three chosen samples, OSPF is the most widely used routing protocol in large enterprise networks. OSPF is based on link-state technology by using SPF algorithm which calculates the shortest path.

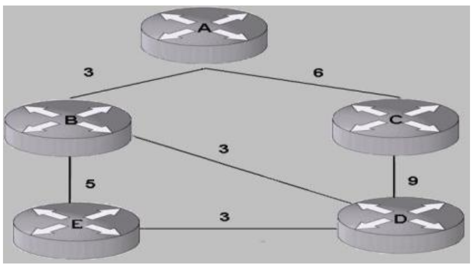

Figure 3: Simple structure of OSPF

Areas and Border Routers

In OSPF protocol, an Autonomous System can be divided into sections. A section and a nearby router can dorm an AREA. Since each section calculate the Shortest Path using the same algorithm as above, each section has its own database and path tree and the information are invisible outside this section. By doing this, the size of the database can be dramatically reduced.

Router ID concept:

Each OSPF router selects a router ID that has to be unique on your network. OSPF stores the topology of the network in its Link State Database and each router is identified with its unique router ID, if you have duplicate router IDs then you will run into reachability issues. Because of the two OSPF routers with the same router ID will not become neighbors but still have duplicated router IDs in the network with routers that are not directly connected to each other.
OSPF uses the following criteria to select the router ID:

1. Manual configuration of the router ID
2. Highest IP address on a loopback interface.
3. Highest IP address on a non-loopback interface.

Neighbourship:

OSPF routers need to establish a neighbor relationship before exchanging routing updates. OSPF neighbors are dynamically discovered by sending Hello packets out each OSPF enabled interface on a router. Hello packets are sent to the multicast IP address of 224.0.0.5.The process is explained in the following figure:

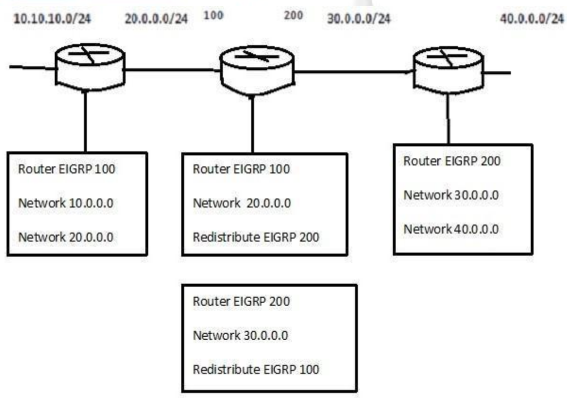

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Figure 4: Area

3.3 IGRP (Interior Gateway Routing Protocol):

Interior Gateway Routing Protocol is a Distance-vector interior routing protocol (IGP) developed by Cisco. It is used by routers to exchange routing data within a system. It is a protocol. It was created in part to overcome the limitations of RIP when used within large networks. IGRP supports multiple metrics for each route, including bandwidth, delay, load and reliability to compare two routes these metrics are combined together into a single metric, using a formula which can be adjusted through the use of pre-set constants. By default the IGRP composite metric is a sum of the segment delays and the lowest segment bandwidth. The maximum configurable hop count is 255 and routing updates are broadcast every 90 seconds.

3.4 EIGRP (Enhanced Interior Gateway Routing Protocol):

The Enhanced Interior Gateway Routing Protocol is a hybrid routing protocol which provides significant improvements on IGRP. EIGRP replaced IGRP in 1993 since Internet Protocol is designed to support IPv4 addresses that IGRP could not support. Hybrid routing protocol incorporates advantages of both Link-state and Distance-Vector routing protocols it was based on Distance-Vector protocol but contains more features of Link-State protocol. EIGRP saves all routes rather than the best route to ensure the faster convergence. It keeps neighboring routing tables and it only exchange information that it neighbor would not contain. EIGRP is commonly used in large networks, and it updates only when a topology changes but not periodically unlike old Distance-Vector protocols such as RIP. Metric is used to determine whether the chosen route is optimized. EIGRP metric is based on its bandwidth, delay, reliability, load and MTU. A default expression for EIGRP metricis $Metr\ c = BandW\ dt + Delay * 256$. There are four basic components to operate EIGRP which are,

1. Neighbor Discovery/Recovery
2. Reliable Transport Protocol
3. DUAL Finite State Machine
4. Protocol Dependent Module

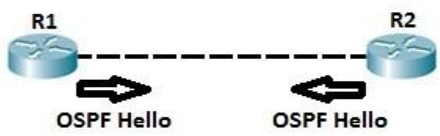

Figure 5: EIGRP Configuration

The EIGRP updates are triggered when there is a change it is important to have a process that routers dynamically. A router should discover once a neighbouring router is unreachable of inoperative. Neighbour Discovery and Recovery is accomplished by sending small Hello packets periodically at low cost. Once the hello packets are received whether this neighbour is alive can be determined. The neighbouring router will start exchanging information when routers are functioning.

3.4.1 Packet formats:

1. Hello/Acks
2. Updates
3. Queries
4. Replies
5. Request

ROUTERS TYPE:

OSPF defines the following overlapping categories of routers:

1. **Internal router (IR):** An internal router has all its interfaces belonging to the same area.
2. **Area border router (ABR):** An area border router is a router that connects one or more areas to the main backbone network. It is considered a member of all areas it is connected to. An ABR keeps multiple copies of the link-state database in memory, one for each area to which that router is connected.
3. **Backbone router (BR):** A backbone router has an interface to the backbone area. Backbone routers may be also area routers, but do not have to be.
4. **Autonomous system boundary router (ASBR):** An autonomous system boundary router is a router that is connected by using more than one routing protocol and that exchanges routing information with routers autonomous systems.

3.5 ISIS (Intermediate System Intermediate System):

Intermediate System to Intermediate System (IS-IS) is an interior gateway protocol designed for use within an administrative domain or network and move information efficiently within a computer network a group of physically connected computers or similar devices. It accomplishes this by determining the best for datagrams through a network. The protocol was defined in ISO/IEC 10589:2002 as an international standard within the Open System Interconnection (OSI) reference design. Though originally an ISO standard, the IETF republished the protocol in RPC 1142. It is called the "de facto" standard for large service provider network backbones. IS-IS uses Dijkstra's algorithm for computing the best path through the network. Packets are then forwarded, based on the computed ideal path, through the network to the destination.

3.6 BGP (Border Gateway Protocol):

BGP is protocol for exchanging routing information between gateway hosts in a network of autonomous systems. BGP is used between gateway hosts on the Internet. The routing table contains a list of known routers the addresses they can reach and a cost metrics associated with the path to each router that the best available route is chosen. Hosts using BGP communicate using the TCP and send updated router table information only when one host has detected a change. Only the affected part of the routing table is sent. BGP-4, the latest version, administrators configure cost metrics based on policy statements. BGP communicates with autonomous i.e. local networks using Internal BGP (IBGP) since it doesn't work well with IGP. The routers inside the autonomous network thus maintain two routing tables:

1. One for the interior gateway protocol
2. One for IBGP.

3.6.1 Path vector routing:

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.

3.6.2 BGP neighbour relationship:

In BGP neighbors are manually configured. This is to prevent the network from attacks. Neighbours start in idle state.BGP routing protocols are available in two types:

1. IBGP
2. EBGP.

IBGP is used between routers in the same autonomous system.EBGP is used between routes in different autonomous system.

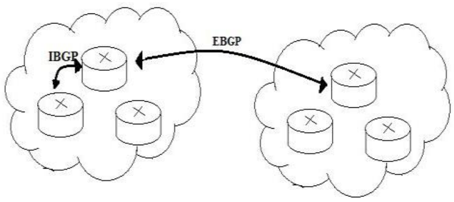

Figure 6: BGP Neighbor Relation Architecture

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 sends to another IBGP peer. This is to avoid loops in the network.

4. SUMMARIZATION 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	Advance Distance Vector	Yes	Interior	Triggered	Composite	Both
OSPF	Line State	No	Interior	Triggered	Cost	Manual
IS-IS	Line State	No	Interior	Triggered	Cost	Auto
BGP	Path Vector	No	Exterior	Incremented	N/A	Auto

Table: 3 Comparison of Routing Protocols

In the above table we are summarizing the routing protocols. We are having different type of routing protocols in the network. Some of these are RIPV1, RIPV2, IGRP, EIGRP, OSPF, IS-IS and BGP. The RIPV1, RIPV2, IGRP are distance vector protocol. These functions are based on the interior type and RIPV1, RIPV2 updates the data 30 seconds once but IGRP updates the data 90 seconds once automatically. EIGRP is advance distance vector protocol and it is a interior type and it updates the data trigger based. It performs the operation automatically and non-automatically. OSPF, IS-IS are Link state routing protocol, it function type is interior based and updates the data based on the trigger and it operation is manual and automatic.BGP is a path vector routing protocol, it is exterior protocol. It performs the operation automatically.

V. CONCLUSION

In this comparative analysis we have studied different types of routing protocols. RIP is very simple to understand, configure and also it is supported by most routers. The advantage of RIP is it supports load balancing and loop free. The drawback for using RIP is slow to converge. Slow convergence produces inconsistent routing. RIP is used to learn about paths using Routing by Roomer i.e. learning from routes to reach a network from neighbours.

The RIP is not trustworthy and 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. Another Routing protocol IGRP has advantage of easy configuration and unlike RIP uses composite metric that can be increased accuracy of the path. The disadvantage of IGRP is its slow convergence it is slower than RIP.

Even though it has drawback the accuracy of it path makes it more trustworthy. ISIS is more secure as it works on layer 2. It has same convergence property as OSPF but less implemented on router platform. The other Advantage of OSPF is it propagates the changes in the network very quickly and 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 it is difficult to understand. 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 it is more scalable. Unlike OSPF which can do load balancing on only equal cost lines, EIGRP can balance load on unequal cost lines. Every routing protocol having more merits and demerits. Depending on our requirements user can choose the routing protocols.

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