Evaluation of OSPF and EIGRP Routing Protocols for IPv6

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Abstract—**IPv4 addressing space has almost been exhausted; many organisations will soon be required to perform the changeover to IPv6. Traditional IPv4 routing protocols must be replaced with new IPv6 compatible protocols to ensure systems continue to operate effectively; however these protocols have undergone significant changes in order to support IPv6. Understanding these changes is important when selecting a routing protocol for a system, in order to facilitate this, a study and comparison of two popular routing protocols; OSPF and EIGRP has been undertaken. The major changes between the IPv4 and IPv6 editions have been identified and discussed and the two protocols have been compared against a number of criteria.**

***Index Terms*—EIGRP, IPsec, IPv6, OSPF**

I. Introduction

Internet Protocol version 4 (IPv4) was developed in 1981; it provides a 32bit addressing space containing 4.3billion unique Internet Protocol (IP) addresses [1]. Each Internet enabled device requires a unique IP address from this address space; however the rapid growth of the Internet has resulted in these addresses being exhausted; with the last of the address space allocated in February 2012 [2].

Internet Protocol version 6 (IPv6) is designed to address the problem of limited address space by providing 128bits of addressing space, providing 2^{128} IP addresses; a practically limitless addressing space for new internet enabled devices to utilize [3].

IPv6 brings a number of improvements over IPv4 in addition to increased addressing space; IPv4 contains no security mechanisms: IPv4 relies upon higher level protocols to handle authentication and encryption of packets; this can lead to vulnerabilities when deploying IPv4 systems. This issue is addressed in IPv6 which increased security through the use of integrated Internet Protocol Security (IPsec) within the IPv6 protocol which provides authentication and encryption using cryptographic keys [4].

IPv4 includes no quality of service mechanisms: IPv6 adds support for Quality of Service (QoS) mechanisms through the use of flow control bits; these will enable routers to prioritise packets based upon QoS considerations and economise storage by aggregating routing tables [5].

IPv4 headers have limited extensibility due to only containing a single options field within the header: IPv6 uses a fixed length header of 40 octets, but utilises a separate extension header after the main protocol header which will enable the protocol to be extended with future developments [6].

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Differences between IP version 4 and 6 packet layout mean that routing IPv6 traffic is not supported by existing IPv4 routing protocols [7]. Given the importance placed upon reliability and scalability in many networks, development of IPv6 dynamic routing protocols are essential for their operation.

Dynamic routing protocols provide increased scalability over static alternatives and the ability to automatically adjust to network topological changes such as a failed components; rerouting traffic through alternative paths automatically with minimal disruption. This is very important because of the current trend of network growth rate hence the need for the use of an appropriate routing protocol that will adjust to scale with this increasing growth [8].

In this paper, we will critically review two popular interior routing protocols for IPv6; Open Shortest Path First version 3 (OSPFv3) and Enhanced Interior Gateway Routing Protocol version 6 (EIGRPv6) and compare the changes these protocols have undergone to support IPv6.

This paper is structured as follows; Section 2 investigates interior gateway routing protocols EIGRP and OSPF, section 3 compares the two routing protocols against a number of criteria to identify strengths and weaknesses and section 4 proposes a number of considerations for implementing these protocols based upon the identified strengths and weaknesses of each. Section 5 concludes the paper and proposes future work which could be performed.

II. Interior Routing Protocols

Interior routing protocols are classified into two categories: distance vectors and link state routing protocols.

Link state routing protocols maintain a complete map of the network and associate a cost value with links between routers; these costs are used to determine the best route for forwarding data, typically the lowest cost path to a destination. [9].

Distance vector routing uses distance to the destination as the key routing consideration, this distance is typically the number of intervening routers or hops necessary to reach the destination using a given interface. Distance vector routing protocols typically favour the shortest paths available causing routers to forward packets out of interfaces which have shorter hop counts to the destination [10].

Routers periodically share routing information by flooding to neighbouring routers; each recipient router uses this information to update their routing table before passing it on to other routers [11].

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A. Open Shortest Path First

The Open Shortest Path First (OSPF) is a link-state routing protocol and a popular interior gateway routing protocol used for routing within one autonomous system.

OSPF performs routing calculations based upon data stored within a Link State Database (LSDB); this database is a logical tree structure of the network topology [3]. The Dijkstra's algorithm is used to determine the shortest path from the source to the destination within the LSDB using the accumulating cost of links in the path [12].

The cost of a link is calculated based upon the bandwidth of the link; with higher bandwidths being allocated a lower cost, this can be manually changed by a network administrator [9]. The LSDB is maintained by routers who regularly send hello packets out their interfaces to neighbour routers and wait for a reply. If a reply has not been received within the time limit, the link state will change to down and the LSDB will be updated [13]. OSPF routers inform the network of changes to the LSDB using Link State Advertisements (LSA), these are flooded to routers in the same area periodically or whenever there is a change in a network link. Network topology changes must be reflected in the LSDB to ensure consistent routing throughout the network; once a LSA is received the router updates their copy of the LSDB and recalculates route costs accordingly [3].

The OSPF protocol uses a hierarchical structure which is split into areas to ensure that the LSDB of an area does not grow too large; using excessive bandwidth, memory and processing power to remain accurate. The hierarchical structure also helps to ensure that network performance is not degraded in large OSPF domains by limiting routing traffic flooding and LSA to within the routers current area [13]. Each area in OPSF is labelled with a unique 32 bit area ID, which are dotted decimal format and not compatible with IPv4 addresses, Area 0 is the backbone area of an OSPF domain, all OSPF areas need to connect to this backbone area; which manages all inter-area routing [14]. OSPF has a number of advantages which make it a very popular routing protocol; it features rapid convergence when a topology changes and will support several routes to a destination with different costing associated with each route, this means that backup routes will be available if a route goes down. Another advantage is the hierarchical nature of the protocol; this allows OSPF networks to scale very well with negligible impact upon routing overhead [12]. However the memory requirements on routers to maintain the LSDB can become an issue especially in larger OSPF areas where large numbers of nodes need to be stored in the LSDB tree and shared using LSA which adds to routing overhead. Another problem with the OSPF protocol is the difficulty in configuring and managing areas which can be configured in a number of ways such as stubby or transit areas, this adds to the complexity of deploying the protocol [14].

The core operation mechanisms of both OSPFv2 (for IPv4) and OSPFv3 (specifically designed to support IPv6) are very similar, with few major modifications. OSPFv3 maintains the same packet types as used in OSPFv2 namely; Hello, Link State Request, Link State Update, Link State Acknowledgement and Database Description, however changes were made to some of the fields preventing backwards compatibility between the versions [12]. OSPFv3 retains the domain and flooding scope areas from OSPFv2; it also adds a link local flooding scope; which is a requirement to support IPv6; routing both IPv4 and IPv6 traffic on the same network requires both versions of OSPF to be running simultaneously using dual-stack backbones [3]. OSPFv3 drops packets whose instances IDs does not match by assigning an interface ID to the OSPF packets to differentiate between instances. OSPFv3 utilises IPv6 IPSec extension Headers to provide authentication and encryption [3].

B. Enhanced Interior Gateway Routing Protocol

The Enhanced Interior Gateway Routing Protocol (EIGRP) is a Cisco Proprietary distance vector routing protocol [15]. The EIGRP protocol operates by making routing decisions based upon a number of cost metrics associated with interfaces on a router, these are calculated using the Diffusing Update ALgorithm (DUAL) to decide the best path to a destination. The metrics which DUAL uses to make its decisions are bandwidth, load, reliability, delay and Maximum Transmission Unit (MTU) for each link connected to the router [16]. The DUAL system has the advantage of being faster than systems used by other routing protocols such as the Distributed Bellman-Ford path calculation method, whilst creating less CPU overhead than link state equivalents [17].

EIGRP maintains a number of tables used to perform routing; the Neighbour table stores information about directly connected neighbour routers, the Topology table stores loop free paths to destinations as well as route metrics, successor routes and feasible successors, the final table is the Routing table which contains the lowest cost path for each destination [15]. Information in the EIGRP tables is gained from hello messages which are sent by routers to their directly connected neighbours, when a hello message is received from a newly connected neighbour the two neighbours will exchange routing information and update their tables; each router will then start a countdown timer. This timer is reset each time a new hello message is received ensuring the neighbour is still connected, should the timer expire it will trigger DUAL to recalculate the tables, removing the neighbour in the process [16]. EIGRP does not use periodic updates common in many routing protocols; instead EIGRP sends partial updates, containing only information which has changed to its neighbours, this will enable them to update their EIGRP tables and ensure optimal routing [15]. The EIGRP routing protocol offers a number of advantages which make it an attractive choice; EIGRP is easy to configure and features very fast network convergence with low resource usage and low routing overhead, it also supports authentication and has backup routes prepared in the form of successors and feasible successors stored in the topology table, this increases reliability [12]. Unfortunately as a Cisco proprietary technology the EIGRP is only supported by Cisco hardware and cannot exchange routing information with other devices or protocols, this limited compatibility reduces the choice of hardware when seeking to deploy a network using the protocol.

The improvement or additional features on EIGRP for IPv6 are:

- Requires a route ID for the IPv6 configuration, similar to that of OSPFv3.
- The route ID is equivalent to the 32 bit IPv4 address.
- Route ID must be manually configured for IPv4 in an IPv6 environment only.
- Configuration of EIGRPv6 is done on a per interface basis, also similar to OSPFv3; no network command is used.
- Uses link-state address for establishing neighbour adjacencies, also similar to OSPFv3.
- Routers can become neighbours even if they do not have global unicast addresses assigned.
- Possesses a shutdown feature; starts in a shutdown state.
- Unlike in IPv4, route summarization is not automatic.

III. Protocol Comparison

The two routing protocols share several core features; both support Variable Length Subnet Masks (VLSM) and Classless Inter-Domain Routing (CIDR, both use 32 bit router ID's and record neighbouring routers information whilst managing their own routing tables. Both protocols favour sending partial routing updates over their entire routing table when topology changes occur, in order to reduce network traffic and both are optimised for fast convergence and backup routes [12].

However both routing protocols possess unique qualities, making it difficult to select the appropriate routing protocol. In order to compare the two protocols a criteria based comparison was employed, the criteria include desirable features as well as critical goals for administrators wishing to deploy networks [18];

A. Hardware Flexibility

System administrators may need to deploy networks using a wide range of network hardware; protocols which will only operate on specific hardware limit their available choices and may be less desirable. EIGRP is a Cisco proprietary routing protocol and is only supported on Cisco hardware, which can be very expensive. Comparatively OSPF is an industry standard open protocol and not bound to a particular hardware manufacturer, thereby increasing flexibility when deploying systems with limited budgets or administrative concerns such as interoperability with existing networks.

B. Range of Routing Metrics

Networks can be deployed for a wide variety of purposes; these networks may require traffic to be routed based upon very specific requirements; availability of a range of routing metrics may limit which routing protocols are appropriate. When performing routing decisions, EIGRP usually employs the combination of bandwidth and delay as primary metrics for the routing calculations; optionally the weighted load, reliability and MTU may also be added to the calculation. This range of metrics differs from OSPF which exclusively uses the cost criteria which is based upon link bandwidth to make routing decisions; this gives EIGRP the advantage of being able to control network traffic based upon a wider range of metrics than OSPF [16].

C. Rapid Network Convergence on Topology Changes

When a network topology changes the network will be unable to route traffic effectively until the routing protocol has converged and calculated new routes, minimising downtime is a key objective of most networks. OSPF and EIGRP convergence technologies remain the same from IPv4 to IPv6; both protocols only send partial routing updates containing changes to routes or links. EIGRP uses DUAL to provide fast convergence whilst OSPF detects topology changes using hello timers and interface changes, which trigger LSA to update neighbours, optimisations to convergence in OSPF are done by changing timer values. Numerous studies perform comparisons and analysis of the performance of EIGRP and OSPF for IPv4 with respect to convergence speeds [19] finds that EIGRP has faster convergence in a range of simulated networks. Simulations performed by [20] support these findings, comparing OSPF and EIGRP on a network featuring 6 subnet, the simulation revealed that EIGRP convergence times were around 6 seconds faster than OSPF in this network configuration.

D. Network Throughput

The available traffic throughput of a network is controlled by the routing protocol in operation, as well as the hardware of routers, this will be a key consideration for many network administrators. The advantage EIGRP has over OSPF is that it better utilizes the limited network bandwidth. Based on the evaluation of protocols performance by [21], it can be argued that EIGRP could function both as a distance vector and link state protocol. EIGRP exhibited better CPU utilization and bandwidth control compared to OSPF through the intelligent use of metrics within the DUAL algorithm. However the throughput of the protocols is comparable with simulation results from [20] finding OSPF providing greater network throughput than EIGRP, these results may differ due to the different network topology used in testing.

E. Scalability into Large Networks

With rapid growth of networks a possibility, protocols need to be able to scale to meet the increasing needs of a larger network should expansion occur. Protocols which are unable to scale to meet the traffic needs of the network may not be appropriate in these situations. The EIGRP protocol is designed for flat network topologies, however OSPFv3 requires high capacity routers to operate on large flat network topologies as the routing tables will contain every node and have high CPU and memory requirements. These requirements can be optimised and greatly reduced due to the hierarchical nature of the protocol. Careful planning and configuration of the OSPF areas can limit the size of routing tables and greatly increase the scalability of the protocol, however this adds to the configuration complexity [22].

F. Reduced Routing Overhead

All routing protocols create overhead when performing routing; often this is routing traffic overhead when exchanging information with other routers, this routing traffic is necessary for protocol operation. However in certain situations such as a rapidly changing network this traffic can come to consume large amounts of available bandwidth and be detrimental to the network throughput. Link state protocols such as OSPF are more complicated than distance vector protocols and create extra overhead in the form of bandwidth, memory and CPU usage in order to calculate and store the routing tables, in smaller networks this leads to EIGRP being more efficient. When used in larger networks OSPFs hierarchical nature gives an advantage over EIGRP when used with properly configured areas in order to limit routing overhead [13]. Simulations performed by [21] found that EIGRP has better bandwidth utilization and lower protocol traffic than OSPF in a 10 node network, which is a relatively small network, supporting claims that EIGRP performs better in smaller networks.

G. *Configuration Difficulty*

Routing protocols will need configuring by network administrators before they can be utilised in a network, the difficulty in configuring these protocols can be an important factor in selecting a routing protocol.

OSPF requires the configuration of OSPF areas and includes provisions for a number of different area types such as stubby areas and transit areas, amongst others. Understanding the differences between these area types and their purposes increases the difficulty of configuring the protocol. EIGRP is simpler to configure requiring only network addresses and interfaces to be configured; this is supported by [19] which conclude that EIGRP has the advantage over OSPF concerning configuration difficulty.

H. *Protocol Security*

Some networks may require technical measures to secure the information contained within routing protocol traffic to prevent reconnaissance and other threats to the network. OSPFv2 uses an authentication scheme built into the protocol, which features an authentication type field (AuType) within the packet header enabling multiple authentication options such as MD5 hashing [23]. This system is replaced in OSPFv3 with the IPsec Authentication Header (AH) and IPv6 Encapsulating Security Payload (ESP) found in the IPv6 protocol. These measures help to secure the routing infrastructure from unauthorised access and prevent many attacks which can cause denial of service by compromising routing protocol activity [2].

IV. Implementation Considerations

Operating multiple protocols on a network is possible but has numerous issues which must be considered;

- Protocol interoperability: protocols are not designed to interoperate with one another; the metrics used by the different protocols may result in different paths to a destination being selected or the creation of routing loops.
- System resources: additional CPU and memory will be required to maintain multiple routing tables and process updates.

Due to these issues it is often ideal to select a single routing protocol per autonomous system, although this is not always possible in every situation. Examples include networks which require both IPv4 and IPv6 routing or situations such as an organisation merger where multiple protocols are in use as different systems are brought together, alternatively departments with different network administrators may feature different protocols.

From the strengths and weaknesses identified in section 3 it can be argued that OSPFv3 will be most appropriate deployed in large networks which can make best use of its hierarchical nature and benefit from the scalability of the protocol, as well as networks which face budgetary constraints due to the flexibility of the hardware which the protocol can be deployed upon.

EIGRPv6 will be most appropriate deployed in networks with very specific routing metric requirements due to its wide range of available metrics; it will also be a good choice in flat network topologies or networks which require very fast convergence times, however the requirements of Cisco hardware and associated costs may be a problem.

V. Conclusion

This paper has compared the IPv4 and IPv6 versions of popular routing protocols OSPF and EIGRP and identified the changes made to these protocols to incorporate IPv6 Support. The new features and changes of these protocols have been highlighted and discussed; the strengths and weaknesses of each protocol have also been evaluated. Comparative analysis shows that EIGRP protocol has the advantage over OSPF in a number of key areas but is held back by its proprietary nature and costs. The OSPF protocol is one of the most popular available despite EIGRPs performance advantages and its complexity to configure; OSPF has advantages in large networks where its hierarchical nature increases scalability. Future work will involve collecting performance data such as network throughput, convergence speed or CPU and memory utilisation for networks operating the IPv6 routing protocols. This data will be collected using simulations and be used to construct accurate performance comparisons of the protocols in order to assist in selecting the most appropriate network routing protocol.

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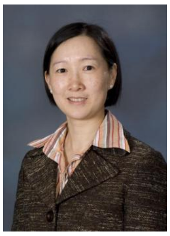

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