ISSN 2250-3153

Combat Resources Shortages by making Stub Areas and Route Summarization in OSPF

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Abstract- Open Shortest Path First (OSPF), an open standard link-state dynamic routing protocol, is the most commonly used Interior Gateway Protocol (IGP) in IP networking worldwide. Wide spread deployment and years of experience running the protocol have motivated continuous improvements to make it more manageable, scalable and cost effective by configuring Stub Areas, Totally-Stubby Areas and Route Summarization to accommodate routers having limited resources using OPNET Modeler®14.5.

Index Terms- OSPF, IGP, Link-state routing protocol, Scalable, Stub Area, Route Summarization.

I. Introduction

OPEN Shortest Path First (OSPF) [1] is a popular link-state, interior gateway (IG), dynamic routing protocol, which is commonly used word wide within a single autonomous system (AS). OSPF belongs to the category of link-state routing protocol. Link-state routing protocols have been in use now for more than 30 years. The first major deployment dates back to 1978 when a link-state routing protocol, called SPF, replaced a distance vector approach in ARPANET [2], [3]. The principle of link-state routing is that all the routers within an area maintain an identical copy of the network topology by sending the *link state advertisements* (LSAs) to their neighbouring devices using a special multicast address. Each router performs a series of calculations that determine the best routes. They maintain the *link-state database* (LSDB), where each record represents the links to a particular node in the network. In addition, they are quick to converge to their routing updates across the network in comparison to distance vector protocols [4]. However, link-state protocols also require more CPU power, storage memory and links bandwidth. There are some prime design goals for OSPF network like Functionality, Scalability, Adaptability, Manageability and Cost effectiveness [5]. The ultimate criterion for satisfying *Functionality* is, ``the network must work´´. Here, one must use service level agreements (SLAs) to meet the business requirement and if the network design is not designed to meet this business goal, the network design is flawed. However, for *Scalability* reasons, to keep pace with the organizations business needs and the capability to further expansion as organization grows, OSPF allows the routing domain to be split into multiple areas and a router needs to know the complete topology of only those area(s) to which its interfaces belong. Whereas, *Adaptability* refers to network's capability to respond to the changes in the large network design environments involving multiple media, multiple protocols, and interconnection to networks outside any single organization's dominion of control. To meet these changing demands of the routing infrastructure the size of the link-state database becomes very large. Consequently, some routers may be unable to keep the entire database due to resource shortages. *Manageability* provides proactive network management; the network must have the proper tools and design to make the operator aware of its operation and current status. *Cost effectiveness* is the true bottom line of a network design. A network is cost effective when all the available resources could be used under predefined budget.

To meet these goals, to make OSPF works hassle free even with not-so-powerful routers and to avoid routing meltdowns even in the frequent topology changing environments. Here we present some of the various possible ways of reducing the size of link-state database by configuring stub-areas, totally-stubby areas and proper route summarization, which allows us to accommodate routers having limited resources thereby significantly reduces the processing overhead of the protocol.

The rest of the paper is organized as follows. Section II provides an architectural overview of OSPF and its LSA types. Section III describes some methods of reducing LSA flooding and LSDB overhead. Section IV describes the implementation overview of different scenarios. Section V describes the simulation result and analysis followed by conclusion in Section VI.

II. OSPF Architecture and LSA Types Overview

OSPF is a link state routing protocol. Link-state routing protocols are distributed and replicated database that describes the routing topology. For scalability reasons, OSPF divides the routing domain it is serving, into multiple areas. Splitting a routing domain into multiple areas allows a router to require the complete topology information of only those area(s) to which its interfaces belong [5], [6]. As shown in Fig. 1, the OSPF areas in a routing domain are arranged in a *hub and spoke* fashion with a special area, called *area 0* or the *backbone area*, serving as the hub and other areas connected as spokes to the backbone area. All OSPF routes from a source in one area to a destination in another area need to pass through the backbone area. A router may have interfaces in multiple areas. Such routers are known as the *area border routers* (ABRs). Also, some routers, known as the *autonomous system boundary routers* (ASBRs), may have links to routers in other autonomous systems.

An interface of a router is considered an OSPF link and state of all the links are stored in link-state database. Each router in routing domain collects local routing topology and sends this

ISSN 2250-3153

information via link-state advertisements (LSAs). LSAs are flooded to all other routers in routing domain and each router generates link-state database (LSDB) from received LSAs [7]. The link-state protocol's flooding algorithm calculates routing table based on this link-state database. Table I provides a brief overview of different LSAs used in OSPF networks

TABLE I
OSPF LINK STATE ADVERTISEMENTS [6]

LSA Type	Originating Router	Information carried	Flooding Scope
Type 1 *Router LSA*	Any Router	Adjacency status on the router's interfaces in the area	Area wide
Type 2 *Network LSA*	Designated Router (DR)	Describes the set of routers on a broadcast/NBMA network	Area wide
Type 3 *Summary LSA (OSPFv2[1]/ Inter area prefix LSA(OSPFv3 [8])*	ABR	Describes the originating ABR's cost to destinations outside the area but inside the AS.	Area Wide
Type 4 Summary LSA (OSPFv2)/ Inter area router LSA(OSPFv3)	ABR	Describe an ASBR external to the area in which the LSA is flooded	Area Wide except stub areas[7]
Type 5 AS-external LSA	ASBR	Describes a destination external to the AS	AS wide except in stub areas and NSSA [9]
Type 6 Group Membership LSA	Any Router	Describes the originating router's directly attached networks that contain members of a particular multicast group	Area wide
Type 7 NSSA LSA	NSSA ASBR	Describes a destination external to the AS	Within the originating NSSA
Type 8 External Attributes LSA	Any Router	Used to internetwork OSPF and BGP	Area Wide
Opaque LSA	Any Router	Provides a general mechanism to distribute information via OSPF	Link local for type 9 opaque LSAs; Area wide for type 10 opaque LSAs; AS wide for type 11 opaque LSAs except in stub areas and NSSA

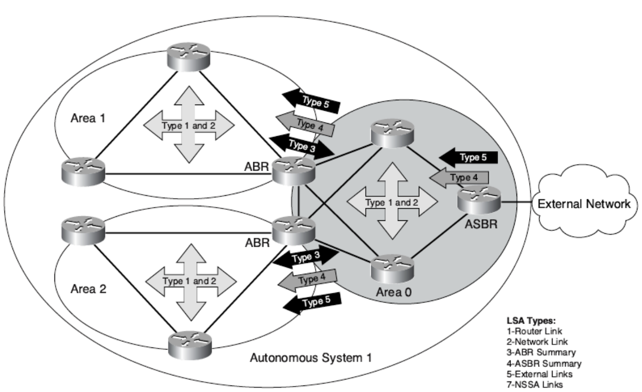


Fig. 1: OSPF Architectural overview and its LSA types

III. REDUCING LSA FLOODING AND LSDB OVERHEAD

A topology change within the area results in the generation of new instances of router/network LSAs by the affected routers. Similarly, the topology change events outside the area may result in generation of new summary/ASE LSAs. A new router, network or summary LSA is flooded throughout the area to which it belongs while a new ASE LSA may be flooded throughout the AS. Each router receiving the new LSA takes part in the flooding process by sending the new LSA across all interfaces within the flooding scope except the one on which the LSA has arrived, update their LSDB and perform recalculation of their routing tables to reflect the current topology [7]. An AS external LSA is 36 bytes long. Adding one third of a packet header (IP header plus OSPF Update packet) yields 52 bytes. Transmitting this amount of data every 30 minutes (LSRefrshTime) gives an average rate of 23/100 bits/second [10].

Scalability should always be taken into consideration when designing a network. All routers keep a copy of the LSDB. As network grows, the size of the link-state database becomes very large, resulting incapable to keep the entire database due to resource shortages; we term this ``database overflow´´. When database overflow is anticipated, the routers with limited resources can be accommodated by configuring OSPF stub areas and not-so-stubby areas (NSSA) [11], [12]. Subsequent subsections describe some proposals aimed at reducing LSAs flooding traffic and size of topological database [13].

A. Stub Area

External networks, such as those redistributed from other protocols into OSPF, are not allowed to be flooded into a stub area. Specifically, the ABR stops LSA Types 4 and 5. Therefore, no router inside a stub area has any external routes. Hence reduces LSA overhead on a router in a stub area.

B. Totally Stubby Area

A totally stubby area further reduces the number of routes in the routing table, by replacing external Type 5, summary Type 3 and 4 LSAs with a default route; results further reduce the number of routes in global routing table.

C. Not-So-Stubby Area (NSSA)

NSSAs are similar to the existing OSPF stub area configuration option but have the additional capability of importing AS external routes in a limited fashion. The NSSA feature allows an area to retain the other stub area features—the ABR sends a default route into the NSSA instead of external routes from other ASBRs—while also allowing an ASBR to be inside of this area. Redistribution into NSSA area creates a special type of LSA known as Type 7, which exists only in this area and an NSSA ABR translates it into a Type 5 LSA.

D. Route Summarization/Aggregation

Route summarization, another key for routing scalability in today's Internet, involves consolidating multiple routes into a single advertisement. CIDR as specified in [14] provides a mechanism to aggregate routes for efficiently utilizing IP address space as well as reducing the number of routes in the global routing table. Route aggregation would not only help global Internet scalability but would also contribute to scalability in local networks. The overall goal is to keep the routes in the backbone to a minimum [15].

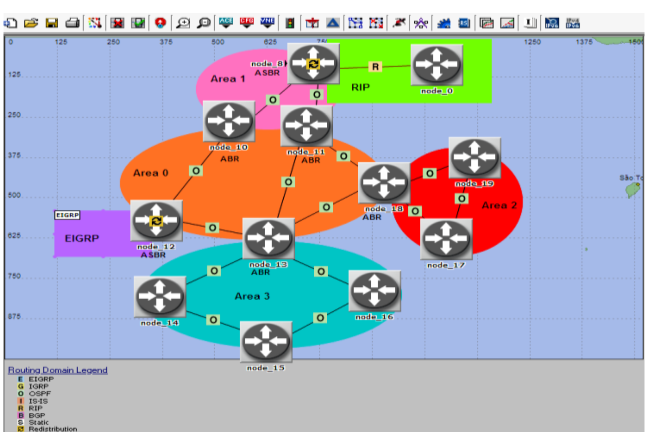


Fig. 2: OSPF Multi-area topology

IV. IMPLEMENTATION

Implementation is done in OPNET Modeler®14.5. In this paper, four scenarios- OSPF Multi areas, OSPF Stub area3, OSPF Totally Stubby area3 and Multi areas ABR Route summarization, are created each consists of twelve interconnected ethernet4 slip8 gtwy with PPP DS1 (1.544 Mbps) links, the topology is configured mainly with OSPF having area 1, 2 and 3 connected to the backbone area 0. In these scenarios node 8 and node 12 are acting as ASBR whereas node 10, 11, 13 and 18 are acting as ABR. We configured various loopbacks on node 0, 12 and 19 for generating the external and inter-area traffic respectively as shown in Fig. 2.

V. SIMULATION RESULTS AND ANALYSIS

In this section, we present a comparative analysis by simulating these four scenarios in OPNET Modeler®14.5 for 1200 seconds for a particular node 15. There are four network models, which are configured and run as 1st scenario is OSPF with multi-areas, 2nd one is OSPF with Area 3 as stub-area, and 3rd one is OSPF with area 3 as totally-stubby and 4th one is OSPF configured with ABR based route summarization.

A. Route Table Size Analysis

This statistic collects the average number of routing entries within a given bucket size of the node 15's routing table as shown in Fig. 3. We can see that the size of routing table decreases on reducing the LSDB overhead by configuring the area 3 as stub, totally-stubby and ABR based route summarization as compared to the simple multi-area scenario, found minimum in totally-stubby case.

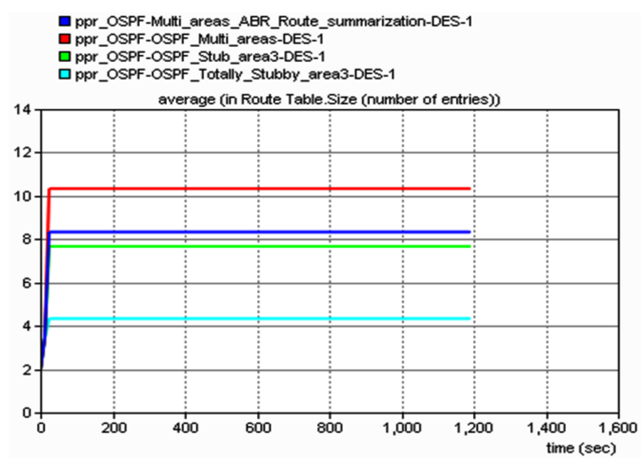


Fig. 3: Average route table size

ISSN 2250-3153

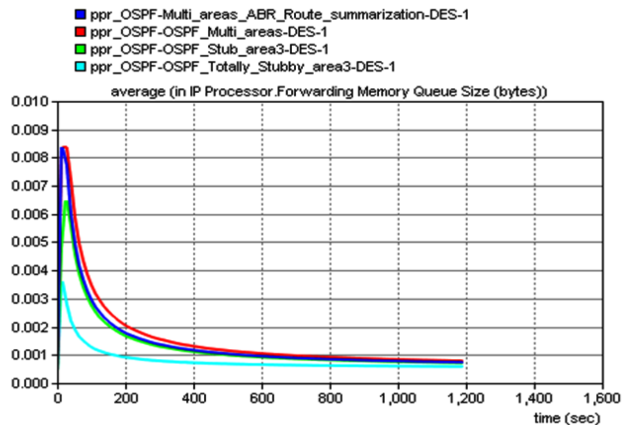


Fig. 4: IP processor forwarding memory queue size (bytes) of node 15

B. IP Processor Forwarding Memory Queue Size Analysis

This statistic represents the IP router processor's current amount of forwarding memory used by packets, expressed in bytes. As shown in Fig. 4, the size of IP processor's forwarding memory of node 15 is found to be decreases as decreases the LSDB overhead and found minimum in totally-stubby case.

C. CPU utilization Analysis

This statistic reports the utilization, in percentage (%), of the central CPU and we found that as the size of the routing table decreases, the overhead on router's CPU decreases as shown in Fig. 5.

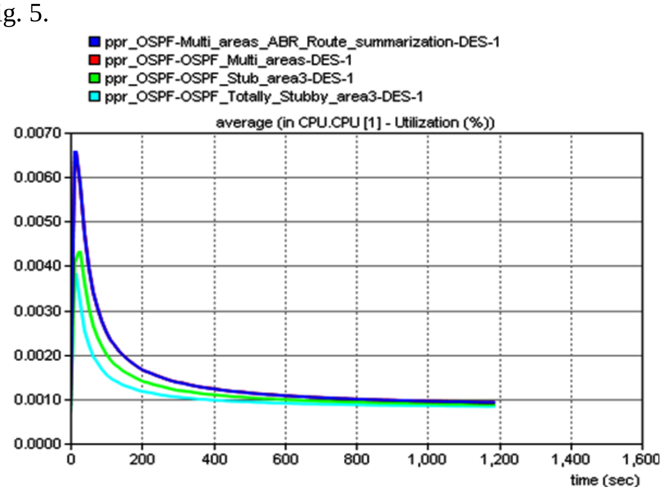
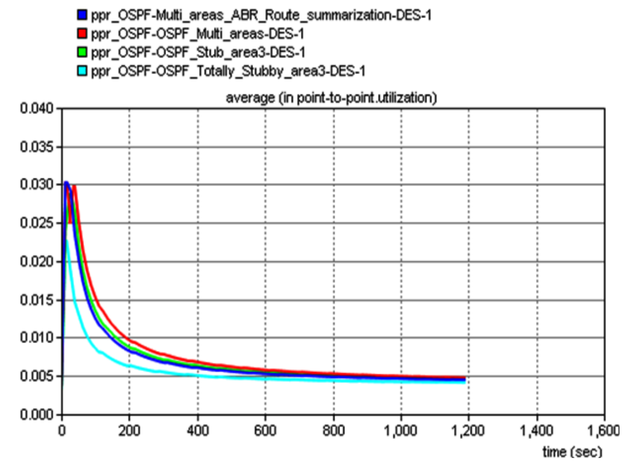


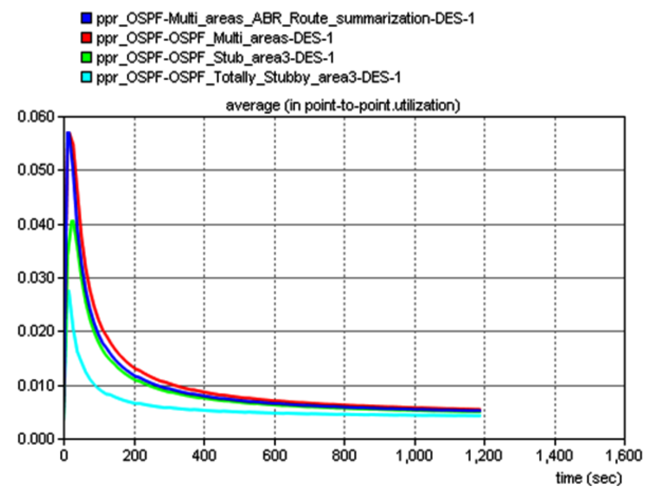
Fig. 5: Average CPU utilization of node 15

D. Link Utilization Analysis

This statistic represents the percentage of the consumption of an available channel bandwidth. In Fig. 6 (a) and Fig. 6 (b), we can see that the average point-to-point link utilization is decreases as the traffic on the links is reduced and is found minimum in case of totally stubby area.



(a) Average point-to-point link utilization between node 15<—>node 14



(b) Average point-to-point link utilization between node 15<—>node 16

Fig. 6: Link utilization analysis

VI. CONCLUSION

For the proper operation of OSPF protocol in the frequently changing environment requires that all the OSPF routers maintain an identical copy of the OSPF link-state database. However, some of the routers may be unable to keep the entire database due to resources shortages because of increasing link-state database with vastly growing demands of the routing infrastructure. In this paper, we presented some techniques to combat increasing link-state database and processing overhead of the protocol by configuring stub-areas, totally-stubby areas and proper route summarization that allow large OSPF networks to exist even with not-so-powerful routers and to avoid routing meltdowns even in face of multiple and frequent topology changes.

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