The Impact of Network Topologies on OSPF Networks and Router's CPU Utilization

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Abstract

The study explores the influence of network topologies, (Star, Ring, and Point-to-Point Topology) on OSPF networks using Opnet simulator. The results show that the network topology is very important factor and it affects directly the performance of the network and it's reliability, one of the major results of this paper that the loop topology makes balance through network performance, network redundancy and router's CPU utilization.

Keywords: OSPF, Routing Protocols, Networks Topologies, CPU Utilization.

1. INTRODUCTION

Routing is a crucial process in data communication networks, transferring data between networks and determining the flow of network communications (G. Obunadike et al., 2018) (M. Raga, & A. B. Primawan, 2023). Routing Protocols communicate link information like bandwidth, link failure, and error rate between routers, selecting the best network route based on various routing metrics (G. Obunadike et al., 2018). The metrics include link reliability, path length, bandwidth availability, network delays, system load, and communication cost (G. Obunadike et al., 2018).

It works with different algorithms and is usually classified into two groups:

- Static routing protocols
- Dynamic routing protocols

Routing protocols can also be classified into two based on algorithms:

- Distance vector
- Link state.

1.1 Static Routing Protocols

Static routing is a manual routing process.

1.2 Dynamic routing protocols

Dynamic protocols are categorized based on their operation within or outside an autonomous system, whether they use distance-vector or link-state protocols (C. Wijaya, 2011).

1.3 Distance Vector
The Bellman-Ford algorithm and Ford-Fulkerson algorithm are utilized in distance vector protocols for path calculation (G. Obunadike et al., 2018).

1.4 Link State
Link-state routing protocol, also known as shortest path routing, computes the finest path in a network using the Dijkstra algorithm, requiring more system resources (G. Obunadike et al., 2018). Link-state advertisement (LSA) facilitates routing information exchange between routers, enabling neighbor router information to be known. Routers flood their LSA to the network, processing it as network topology changes occur (C. Wijaya, 2011).

2. OPEN SHORTEST PATH FIRST (OSPF) ROUTING PROTOCOL
The open Short Path First Protocol (OSPF) is one of the most widespread routing protocols in communications (M. Navarro et al, 2018). OSPF is an efficient interior gateway routing protocol that maintains a topological database oflocal network connections. It belongs to the connection status routing protocol family and uses link state advertisements, such as hello, to form neighbor relationships and keep alive functions (T. Diansyah et al, 2019) (S. Thorenoor, 2010) (G. Tsochev et al, 2022) (Y. Krishnan & G. Shobha, 2013). OSPF, or Autonomous System (AS), is a combination of routing networks with shared methods and policy settings, used for managing large-scale networks to facilitate routing information addition and minimize errors (M. Taruk et al, 2019). This protocol is widely utilized in various network types, including wired and wireless networks. M. E. Mustafa (2017) states that a router sends Hello packets to neighbors, receives them back, and establishes routing connections by synchronizing databases with adjacent routers that agree to synchronize (S. Thorenoor, 2010).Regularly, routers send "link state" updates to other routers, ensuring consistent network topology. They calculate a "shortest path tree" to determine the closest router for each communication (S. Thorenoor, 2010).OSPF uses areas to group routers together, supporting twolayers' hierarchy with the default area being area0. Between area routing is done by the backbone router using route summarization. OSPF supports load balancing up to 16 equal paths and undergoes 3 processes during configuration (Y. Krishnan & G. Shobha, 2013).

- Finding neighbors
- Creating Adjacency
- Sharing routing information

2.1 Finding Neighbors
The router uses link state advertisements to locate neighbors, with OSPF generating LSA hello messages every 10 seconds. Adjacencies form when neighbors are discovered, with dead interval time if not seen within 40 seconds (Y. Krishnan & G. Shobha, 2013).

2.2 Creating Adjacency
OSPF creates adjacency when hello packets match with the router's configuration file. It implements a client server design on each broadcast segment, with designated routers (DR), backup designated routers (BDR), and other DROTHERs. The DR is chosen when routers boot up, with the highest router ID chosen as the Designated router. Other routers are considered DROTHERs. This process is only carried out once, ensuring no changes in DR after adding another router (Y. Krishnan & G. Shobha, 2013).

2.3 Sharing Router Information
Routing information exchange occurs between DR and BDR routers and OSPF routers in the segment. No two DROTHERs can directly communicate. OSPF routers use link state advertisements, like hello, to form neighbor relationships and keep alive functions (Y. Krishnan & G. Shobha, 2013).

2.4 How OSPF Works

- OSPF uses the Shortest Path Algorithm (SPF) to determine the shortest path to all known destinations, utilizing the Deakstra algorithm for optimal solution (G. Tsochev et al, 2022).
- Each router maintains a complete database of all network connections.
- Link State Advertisements (LSA) are generated by routers during network changes or initialization.
- LSAs are exchanged via "fill" between routers, with each storing identical connection status updates.
- The Dijkstra algorithm creates a tree with shortest paths to all destinations.
- Changes in the network are distributed throughout the network, ensuring all routers keep up-to-date information.
- The algorithm assigns each router to the root of a tree, calculating the shortest path to each destination based on cumulative costs.

2.5 Advantages and Disadvantages of using OSPF Routing Protocol

The following lines summarize the main advantages and disadvantages of the OSPF protocol.

2.5.1 Advantages of using OSPF routing protocol are: (G. Tsochev et al, 2022) (C. Wijaya, 2011)

- Open compared to Cisco's EIGRP.
- Determines loop-free routes.
- Updates quickly with network changes.
- Low bandwidth utilization.
- Supports multiple routes for a single destination.
- Cost-based on interface cost.
- Supports Variable Length Subnet Mask (VLSM).
- Disadvantages: Configuration difficulty, memory requirements.
- Not suitable for large-scale networks.
- No hop limit.
- Uses multicasting 224.0.0.5 for connection performance checks.
- Hierarchical protocol with Area 0 at top.
- Uses "value" as an indicator.

2.5.2 Disadvantages of using OSPF routing protocol are: (G. Tsochev et al, 2022)

- Complexity in implementing OSPF configuration and non-washes removal.
- Connection status scaling issues due to LSA flooding.
- High CPU usage required for SFP algorithm.
- Increased memory needed for neighborhood tables, routing, topology.
- Uneven load balance unachievable.

2.5.3 OSPF Packet Types Overview (D. Magnani et al, 2016)

- Hello packet
- Database description
- Link state request packet
- Link state update packet
- Link state acknowledgement packet

3. SIMULATION METHODOLOGY

OPNET® Modeler is a powerful simulation software tool that allows for the simulation of entire heterogeneous networks with various protocols. According to Mustafa (2017), the simulated network designed with four routers, 450 work station and three application servers (Data Base Server, HTTP server and video conference server).

4. SCENARIOS

The paper proposes three scenarios, first scenario is a loop topology as shown in Figure (1), the second scenario is a mesh topology as shown in Figure (2) and the last one is a star topology as shown in Figure (3).

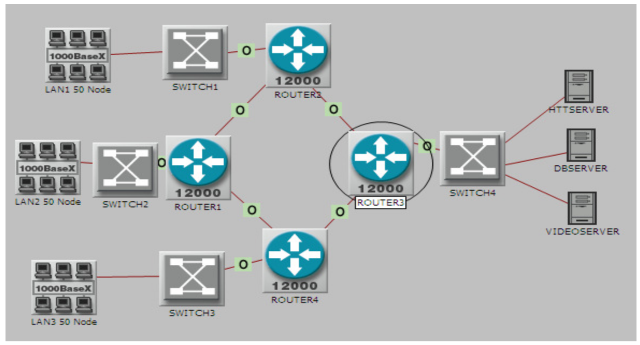

FIGURE 1: Loop Topology.

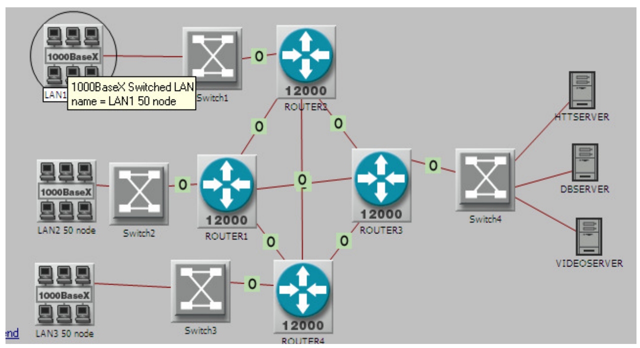

FIGURE 2: Mesh Topology.

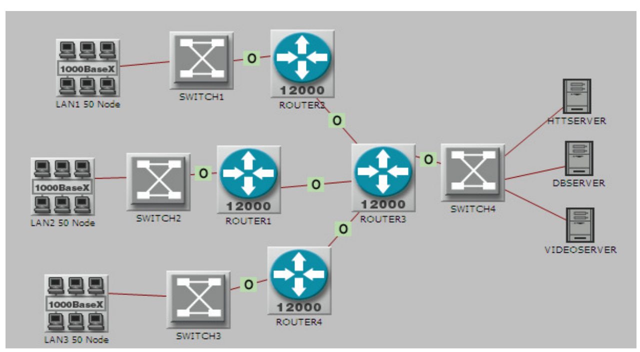

FIGURE 3: Star Topology.

5. RESULTS

Figures (4,5,7) show maximum CPU utilization for Router1, Router2, Router4 using Mesh Topology, lowest load using Star Topology, average utilization for Router1, Router2, Router4 loop Topology, while in Router3 in figure (6) shown that it is CPU utilization is high, when using Star topology and Mesh Topology because it is the central point of the star.

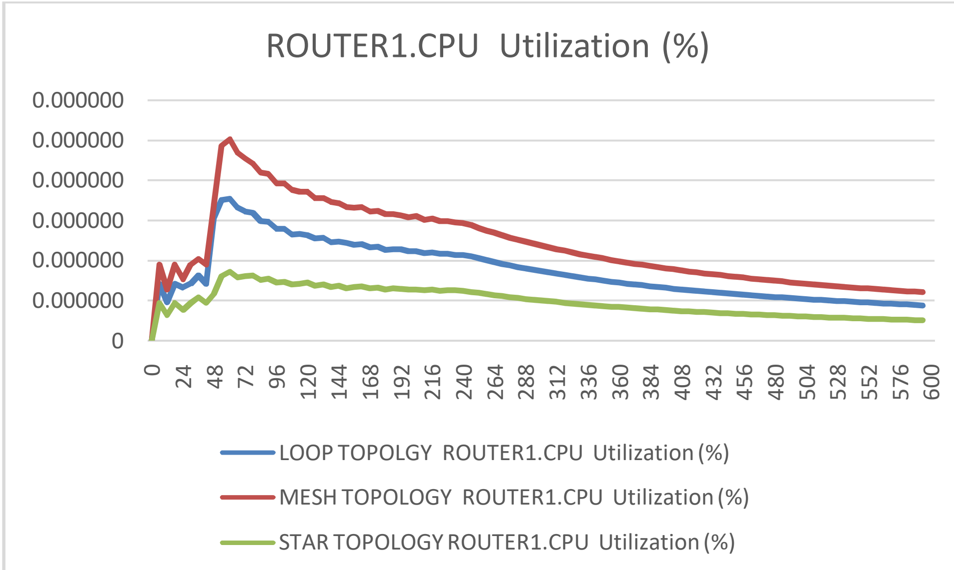

FIGURE 4: ROUTER1 CPU Utilization (%).

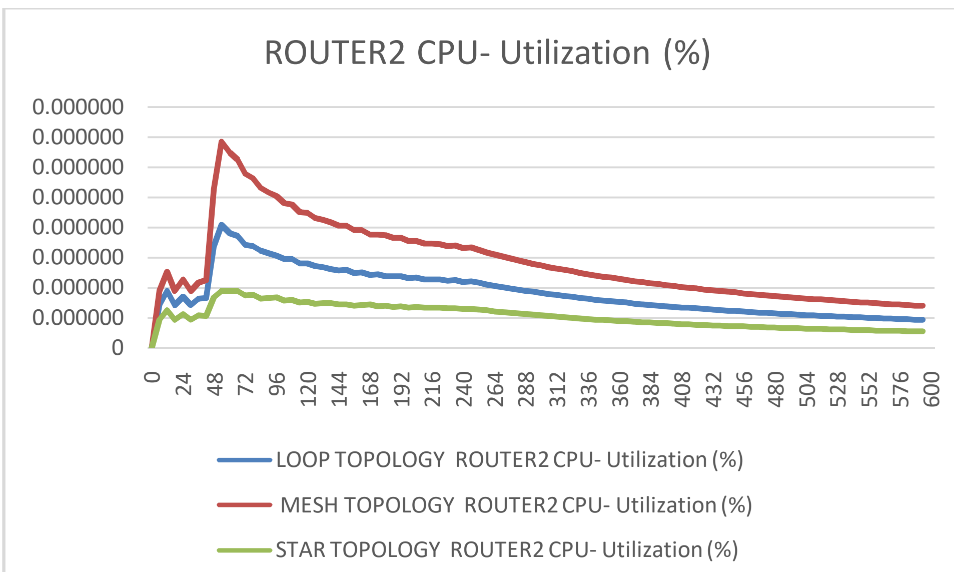

FIGURE 5: ROUTER2 CPU Utilization (%).

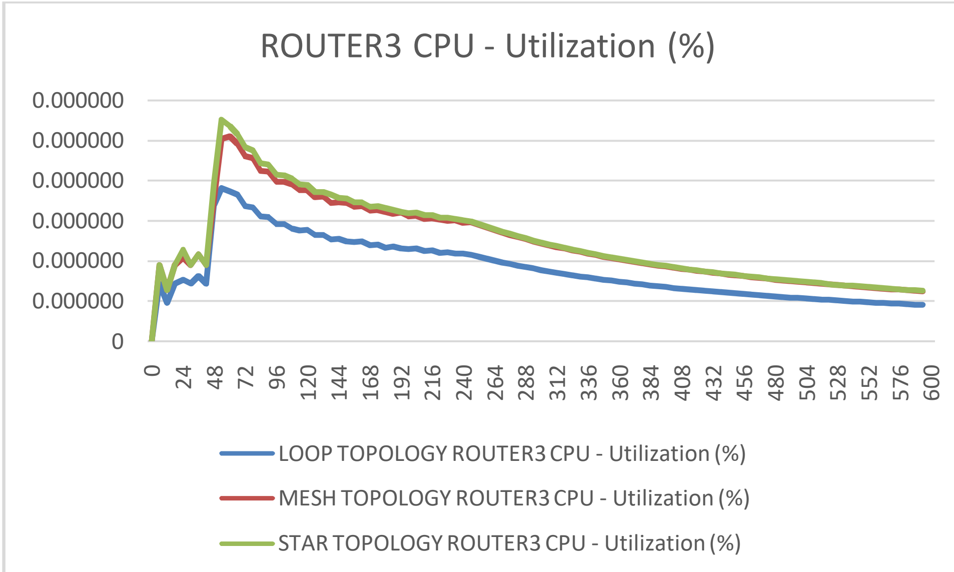

FIGURE 6: ROUTER3 CPU Utilization (%).

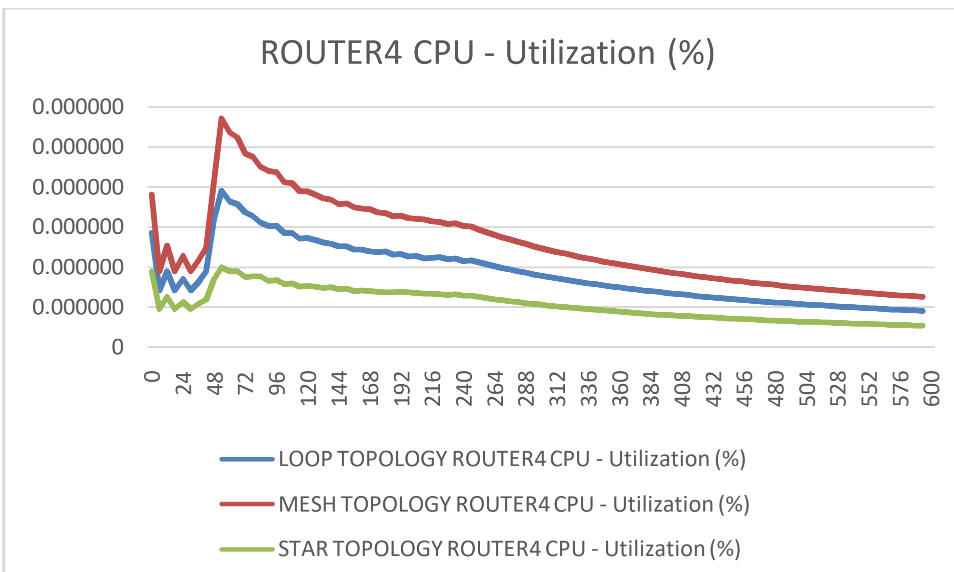

FIGURE 7: ROUTER4 CPU Utilization (%).

Figure (8) shows that the total traffic sent is higher when the topology is mesh, followed by loop traffic, and lower when the topology is star.

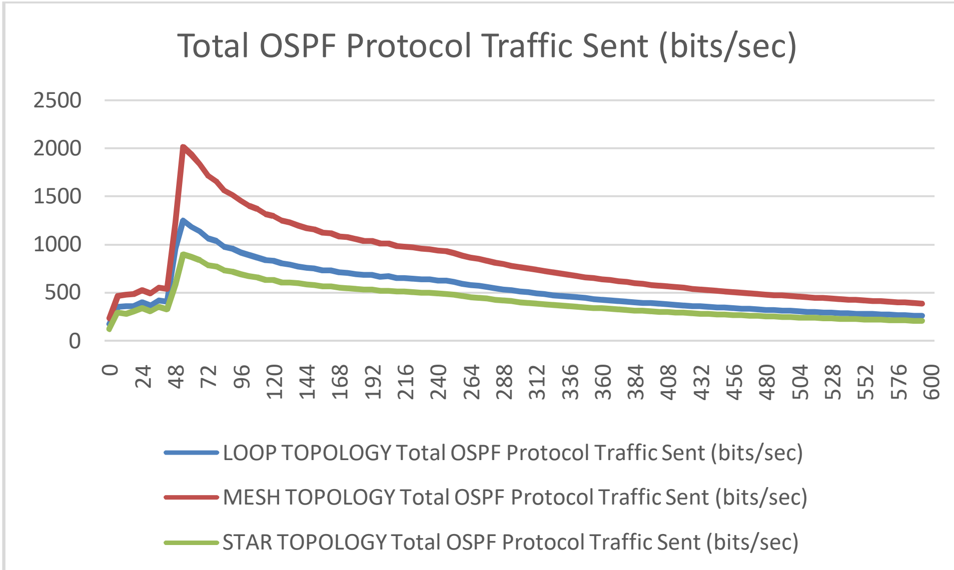

FIGURE 8: Total OSPF Protocol Traffic Sent (bits/sec).

The Database Description Traffic Sent is significantly higher with mesh topology, with slight differences at the starting point for loop and star topologies, which will eventually equalize, as seen in Figure (9).

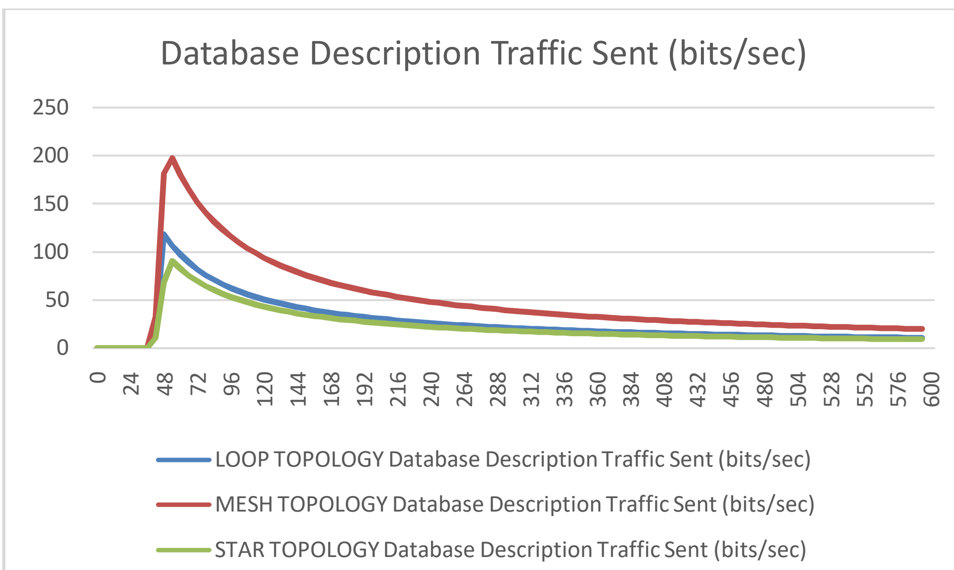

FIGURE 9: Database Description Traffic Sent (bits/sec).

The OSPF Hello Traffic Sent is directly proportional to the number of neighbors, with mesh topology having more neighbors than loop topology and star topology, as figure (10) explained.

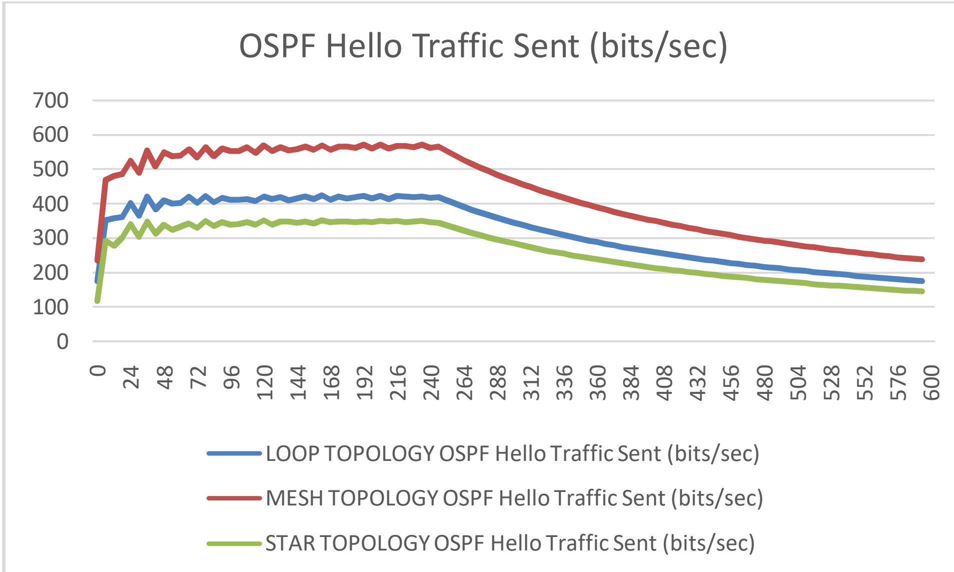

FIGURE 10: OSPF Hello Traffic Sent (bits/sec).

Figure (11) demonstrates OSPF Link State Acknowledgement Traffic Sent (bits/sec) as a Multicast, defer at the starting time, mesh topology, loop topology and star topology, higher traffic, average and lower traffic respectively. After that Link State Acknowledgement Traffic Sent is going to be equal.

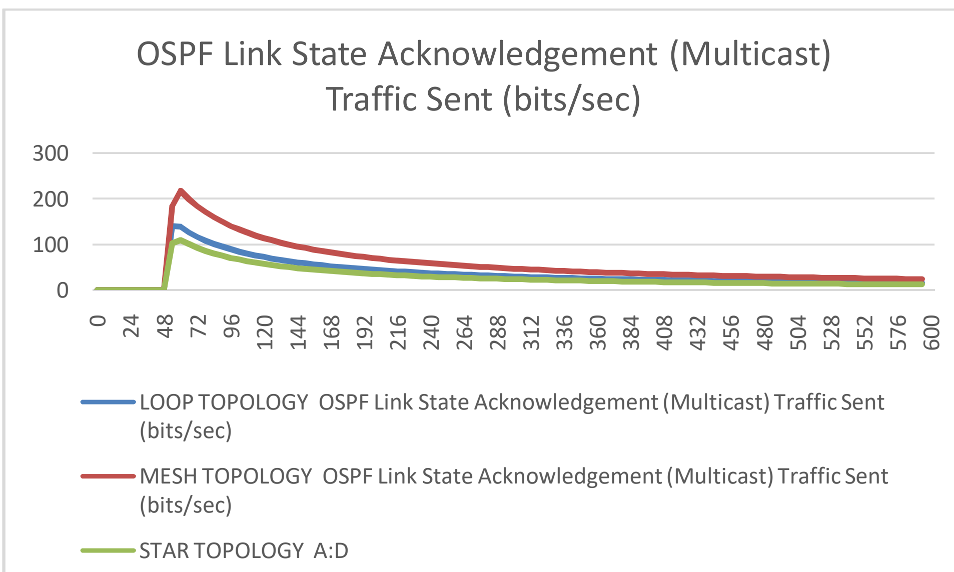

FIGURE 11: OSPF Link State Acknowledgement (Multicast) Traffic Sent (bits/sec).

Figure (12) demonstrates that the OSPF Link State Request Traffic Sent (bits/sec) is approximately equal when using mesh topology, loop topology, and star topology.

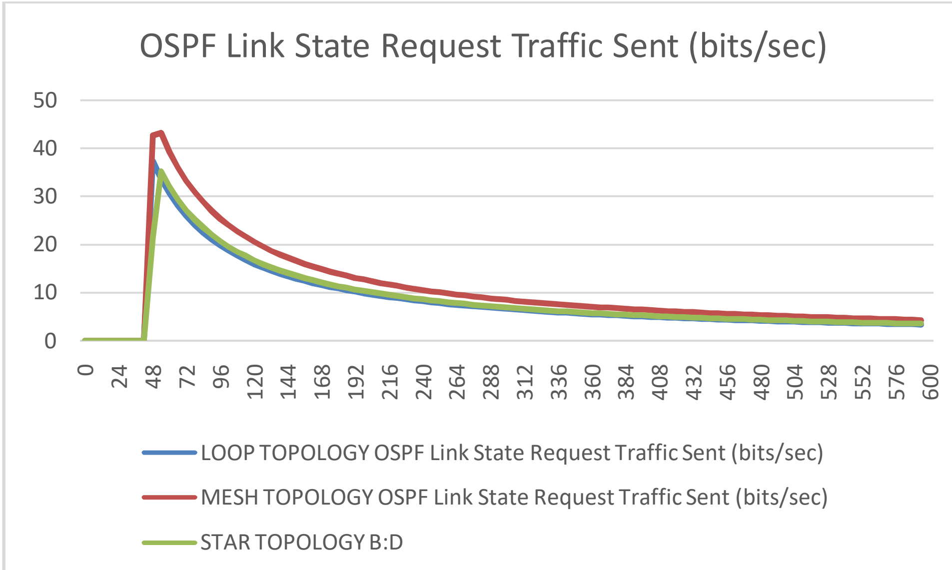

FIGURE 12: OSPF Link State Request Traffic Sent (bits/sec).

6. CONCLUSION

Network designers must consider that, the network topologies effect directly on the performance. As shown above, when mesh topology has been selected, regardless of its benefits (security, reliability and redundancy) the amount of the routing protocol (OSPF) data increased, and also CPU utilization increased and vice versa when star topology used regardless of its limitation (single point of failure and there is no redundancy). Loop topology between star topology and mesh topology and it is also offer redundancy.

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