International Journal
of Applied Information Technology

http://journals.telkomuniversity.ac.id/ijait

Performance Analysis of Frame Relay Network Using OSPF (Open Shortest Path First) and MPLS (Multi-Protocol Label Switching) based on GNS3

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ARTICLE INFO

Received June 7, 2017
Revised July 24, 2017
Accepted August 8, 2017
Available online August 14, 2017

Keywords
Frame Relay, OSPF, MPLS, Multi-Site Network

ABSTRACT

Communication today requires a secure, reliable and efficient network, especially on enterprise networks. This research focuses on combining advantages from Frame Relay, MPLS and OSPF into a modeled multi-site network. The combination is compared to the original OSPF network and analyzed for its throughput, packet loss, and delay. To meet the demand for efficient and resilient network, and to emphasize the advantages of MPLS-OSPF as well as to avoid traffic shifting, specific network topology models are applied: full mesh with virtual circuit in core network connected to OSPF nodes for the rest. From analysis and comparison of network quality values obtained at, this combination attests to be reliable and robust network architecture without trading off its efficiency. The average throughput value of the combination networks was 18.47 bps, which is better compared to the OSPF. The average delay and packet loss from combination network also show better results, which are 59.90ms and 2.01% respectively. The results shows that the combination of Frame Relay, OSPF and MPLS generates better performance as well as significant improvement in network security.

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https://doi.org/10.25124/ijait.v1i02.869
Paper registration number IJAIT000010201

1. Introduction

The configuration setup in network bandwidth utilization is vital that the network capacity can be used optimally. In corporate networks with different branch offices/topographic locations, data transmission over the network is emphasized through a particular route so that each packet sent is confirmed to the destination. This method results in slow data transfer speeds as it should pass through many nodes and processes on the network. This can be solved by implementing Frame Relay using Open Shortest Path First (OSPF) and Multi-Protocol Label Switching (MPLS) Routing Protocols.

Combined approach for MPLS and OSPF has been conducted by Stefan Köhler and Andreas Binzenhöfer. In their papers, a combination of default OSPF, weight optimized OSPF and pure MPLS has been defeated by OSPF Optimization and MPLS TE. They also stated if combined MPLS and OSPF has deliberately reduced state space and simplifies network for operators [1]. Another related research by Zhang et al (2009) stated hybrid routing uses both MPLS and OSPF could be avoided from network convergence and traffic shifting as well as full-mesh tunnels required by pure MPLS [2].

Frame Relay roles to divides information into frames and provides additional functionality and congestion control. The system is enhanced by OSPF protocol to find the best and distributed route, where all routers have network maps to transfer data faster. MPLS is used to forward packets with labels that can help speed up packet delivery by using both layer 2 and 3 simultaneously. This research focus on combining advantages from Frame Relay, MPLS and OSPF into a modeled multi-site network. This combination hopefully creates reliable and robust network architecture without trading off its efficiency.

2. Discussion

2.1. Frame Relay

Frame Relay is a high-performance WAN protocol that operates on the physical layer and the OSI reference data link layer model. Frame Relay is a packet-switched data communication that can connect multiple network devices with multipoint WAN. Frame Relay executes transmission of information by breaking the data into packets to be sent through a series of WAN switches before finally reaching the destination.

Each frame has an address used by the network to determine the destination. Frames will pass through the switches in the frame relay network and sent through the "virtual circuit" to the destination. The advantages of Frame Relay network is its high reliability level supported by fiber optic transmission system and its efficiency because it uses only one physical channel to connect to various destinations [3]. Frame relay can manage burst data traffic and use various communication protocols and application types.

2.1.1. Frame Relay Architecture

Frame Relay consists of endpoint (PC, Server, Host computer), Frame Relay access device (Bridge, router, host frame relay access device/FRAD) and network device (packet switch, router, Multiplexer T1/E1). The devices are divided into two categories:

1. DTE: Data Terminating Equipment; DTE is a code, usually belonging to end-users and internetworking devices. This DTE device includes "endpoints" and access devices on the Frame Relay network. DTE who initiated an information exchange.
2. DCE: Data Communication Equipment; DCE is an internetworking carrier control device. These also include an access device, a centralized type around a network device. DCE responds to information exchange initiated by DTE devices [4]. Figure 1 below is the model architecture of frame relay networks.

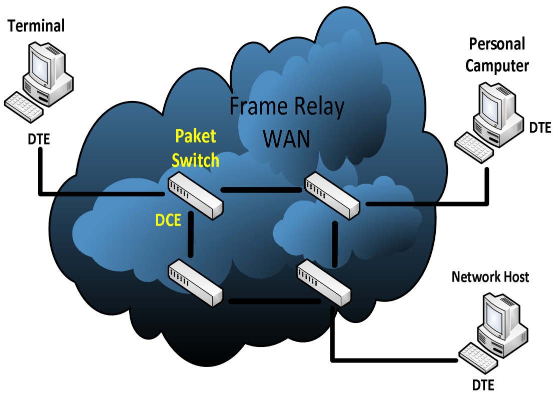


Figure 1 Frame Relay Architectures

2.1.2. Virtual Circuit (VC)

Frame relay networks are often described as cloud networks, because frame relays do not consist of one physical connection between endpoints with others, but rather logical paths that have been defined previously. This path is a Virtual Circuit (VC) in the form of two-way data path, which is software-defined between two ports that form a private channel for the exchange of information in the network.

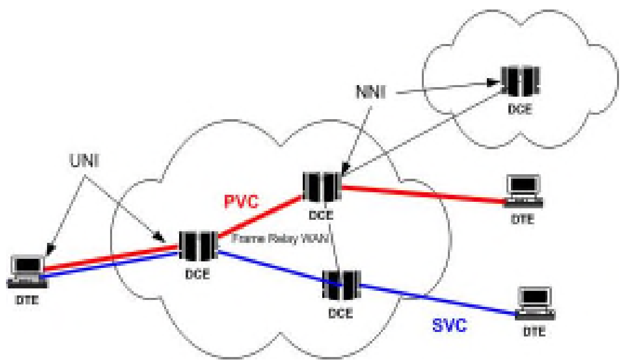


Figure 2 Virtual Circuit Process

There are two types of Virtual Circuit (VC) involved in the Figure 2:

- Switched Virtual Circuit (SVC), is a temporary connection which is used when data transfer between DTE devices passes through frame relay network.
- PVC is a fixed path, which is not made on request or based on call-by-call. Although the actual path through the network based on the variation of time to time (TDM) but the circuit from the beginning to the destination will not change. PVC is a continuous connection continuously identical to a dedicated point-to-point circuit [4].

2.2. Multi-Purpose Label Switching (MPLS)

Multi-Purpose Label Switching is a packet delivery technology on high-speed backbone networks. Its working principle combines the advantages of circuit-switched and packet-switched communication systems that generate a better system of both. Multiprotocol Label Switching is a network architecture defined by IETF (Internet Engineering Task Force) to integrate label swapping mechanisms in layer 2 with routing in layer 3 to speed up packet delivery.

2.2.1. MPLS Structure

MPLS works by labeling a package entering the core network managed by the MPLS node. MPLS node labeling based on priority routes and the package delivery. Labels also contain important information related to packet routing information, i.e. packet destination and packet delivery priority [5].

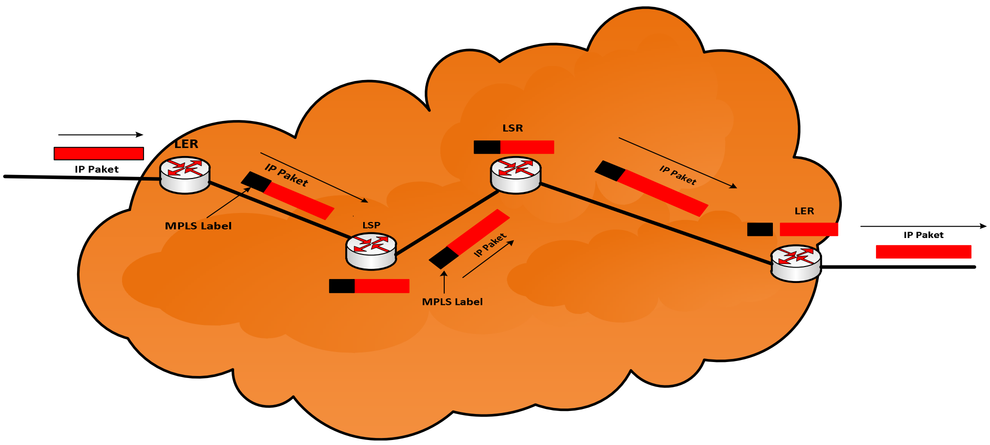


Figure 3 MPLS Working Mechanism

Here is the working process of MPLS in the core network area in handling data packets as illustrated in Figure 3.

1. MPLS data packet entering the network via LER (Label Edge Router).
2. The data packets which have been classified into FEC passes Label Switch Path (LSP).
3. Labels in and label out and determine the exit interface that will be carried by data packet label switching router (LSR).
4. Labels on data packets will be omitted (Egress) and data forwarded outside the MPLS Network.

2.2.2. MPLS Functionality

Below are MPLS functionality in this research.

1. Connect between protocols with Resource Reservation Protocol (RSVP) and open Shortest Path First (OSPF).
2. Establish mechanisms to regulate traffic flow from various paths, such as the flow from different hardware, machines, or applications [6].

2.3. Open Shortest Path First (OSPF)

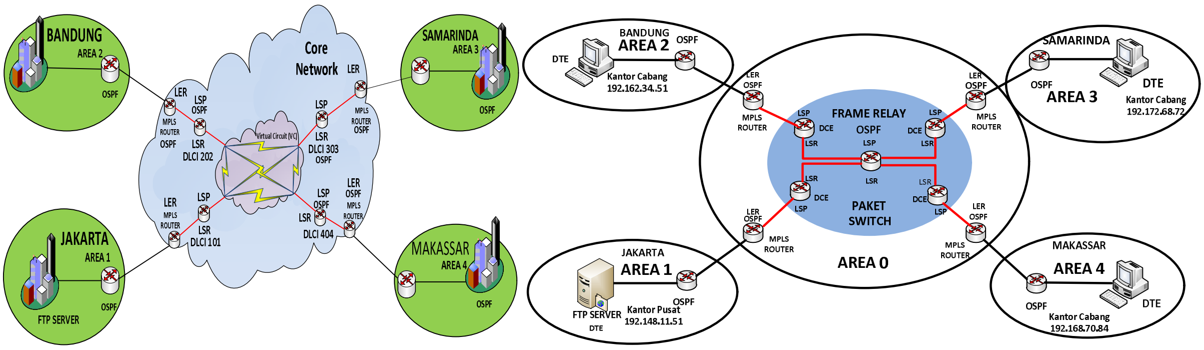
OSPF is a fully link-state IP routing protocol. Link-state protocols send updates containing the status of their own links to all other routers on the network. OSPF works on the internal network of an organization or Company to find the best and distributed route, where all routers have a network map so that the data transfer process will be faster. OSPF has the following characteristics [7].

1. OSPF using System Application and Product algorithm (SPF) to calculate the lowest cost available.
2. Routing updates are flooded when network topology changes.
3. OSPF uses a link-state method where it can maintain routes within dynamic network structures and can be constructed from several subnetwork sections.

3. Result

3.1. System Design

In this research, two network topology models are applied: full mesh with virtual circuit in core network and star for the rest of the network.



(a) (b)

Figure 4 Physical Topology vs GNS3 Schematic

In the figure above (Figure 4a and 4b), Headquarters and Branch Offices are connected to branch routers running OSPF. To be able to connect to the core network, the branch router should communicate with the MPLS router (LER), which will perform the insertion label (ingress). Inside the core network use frame relay for communication between LSP and LSR. Virtual Circuit established between LSP and LER to the egress LER.

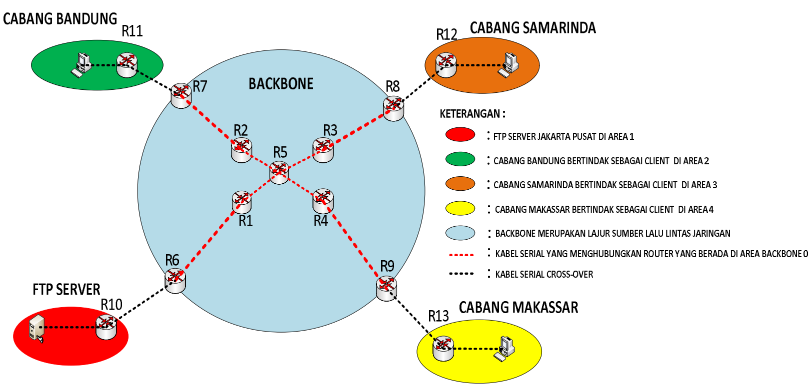


Figure 5 Network with OSPF Only

Figure 5 above is an alternative topology with OSPF only as a comparison with proposed system.

3.2. Performance Comparison

The test scenario is performed on combination of MPLS-OSPF-Frame Relay (Figure 4) and multisite network with original OSPF schemes (Figure 5). Network performance is measured by delay, throughput and jitter parameters. Network testing is performed with mandatory functional test first, i.e. by performing simple ICMP transmissions between sites. The result of ICMP test is displayed below in Table 1.

Table 1 ICMP Test

From \ To	Jakarta	Bandung	Samarinda	Makassar
Jakarta		1375 ms	1486 ms	1221 ms
Bandung	1423 ms			
Samarinda	1205 ms			
Makassar	1913 ms			

Network testing is accomplished with a test-node Jakarta-Bandung, Jakarta-Samarinda and Jakarta-Makassar consecutively. Second test were to check labelling process related to MPLS, which is related to effective virtual circuit path and relaying process. Figure 6 below is the test result, shown here an example from approximately 20 label in-out from LSR.

```
R6
R6#sh mpls ip binding
  1.1.1.1/32
        in label:     16
        out label:    imp-null  lsr: 1.1.1.1:0        inuse
  2.2.2.2/32
        in label:     26
        out label:    26        lsr: 1.1.1.1:0        inuse
  3.3.3.3/32
        in label:     27
        out label:    27        lsr: 1.1.1.1:0        inuse
  4.4.4.4/32
        in label:     28
        out label:    28        lsr: 1.1.1.1:0        inuse
```

Figure 6 MPLS Labelling Process

```
R8#traceroute 110.110.110.110

Type escape sequence to abort.
Tracing the route to 110.110.110.110

  1 140.125.30.2 [MPLS: Label 20 Exp 0] 204 msec 132 msec 184 msec
  2 11.11.11.1 [MPLS: Label 24 Exp 0] 100 msec 64 msec 156 msec
  3 110.117.10.1 [MPLS: Label 16 Exp 0] 160 msec 132 msec 60 msec
  4 180.154.17.11 228 msec 148 msec 104 msec
```

Figure 7 Traceroute at LER

From the Figure 7 above can be seen the MPLS label-checking process, "traceroute" command used to ensure MPLS works. Data transfer test commenced to check network QoS from headquarters (Jakarta) to branch offices (Bandung, Makassar, Samarinda). Throughput is calculated from the number of packets sent divided by the time taken, while delay is measured by packet size divided by transmission rate. Each test repeated for 5 times. Below are the results.

Table 2 Final Result

QoS	Mix Bandung	Mix Samarinda	Mix Makassar	OSPF Bandung	OSPF Samarinda	OSPF Makassar
Throughput (kbps)	18.47	18.40	19.22	17.45	4.44	18.66
Packet Loss (%)	2.01	1.99	1.97	2.45	3.37	2.01
Delay (ms)	59.90	60.04	46.37	777.32	585.83	37.02

Table 2 shows detailed result of network performance comparison between OSPF network and a combination of MPLS-Frame Relay-OSPF networks. From table above, the conclusion is certain, that combination network surpasses OSPF performance. For throughput, the highest values of OSPF performance obtained at 18.66 kbps in Makassar Branch. While for combination network, the lowest values are 18.4 kbps (Samarinda). Data from OSPF Samarinda branch shows anomaly in OSPF networks configuration.

The result from Figure 8 below shows that OSPF network perform slightly below compared to combination networks. While throughput is the amount of data passing the system / process, it relies on network resiliency to hold its value. Throughput from OSPF network also shows less steadiness than combination network.

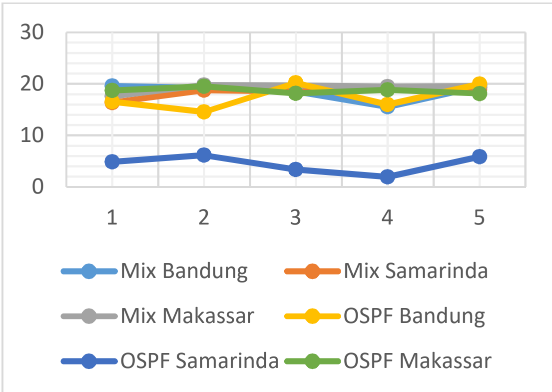


Figure 8 Throughput (kbps)

While for packet loss, steadiness still becomes an issue. From average QoS comparison in Table 2, the lowest value obtained at OSPF networks were 2.01% in Makassar Branch while for combination networks were 1.99%. This should not become in issue if the values were steady for certain time. Similar result was found in detailed Figure 9, that values from OSPF networks were less steady than combination networks.

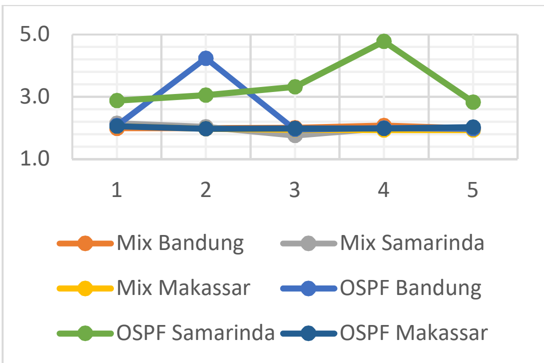


Figure 9 Packet Loss (%)

More volatile results found in the OSPF network delay measurements, both in Samarinda and Bandung branch. MPLS-Frame Relay-OSPF network delay was steady all the time, varies from 46 to 59 ms.

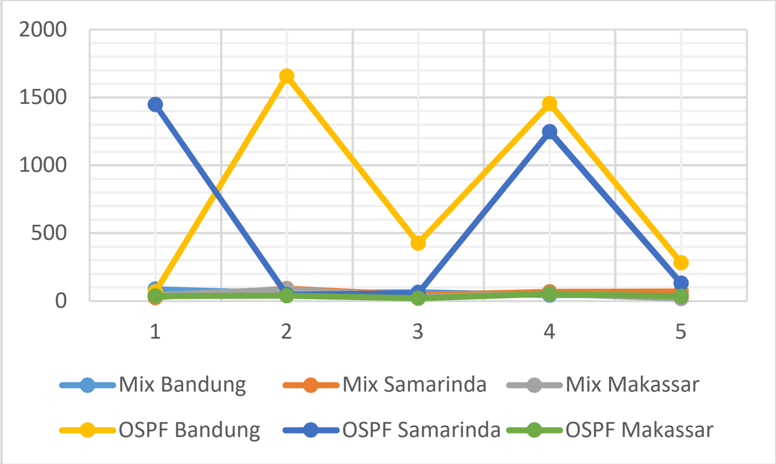


Figure 10 Delay (ms)

As shown in Figure 10, in multi-site data transfer testing, using the OSPF protocol has a larger average delay in comparison with Frame Relay, OSPF and MPLS. This is because when transferring data on the frame relay network, the switch at the service provider receives the frame from the DTE via LMI (Local Management Interface). When the switch analyzes the DLCI and send the frame to the port, thus increasing the checking time. OSPF networks do not necessarily exchange labels and authentication on data packets, so theoretically it will be faster. However, without authentication and labeling, the risk of damaged packets increases along with distance between sites.

3.3. Conclusion

This research has successfully implemented combination of Frame Relay-OSPF-MPLS on multi-site network. From analysis and comparison of network quality values obtained at, yield an average throughput of 18.47 kbps with Frame Relay, MPLS, and OSPF. While the test network with original OSPF generate 17.45 kbps. The average delay is 59.9 ms, which is smaller than 777.32 ms for original OSPF network. The average value of the packet loss is 2.01% and 2.56%. The resulting throughput between the Frame Relay network, OSPF and MPLS is superior in comparison with original OSPF networks. Frame Relay and MPLS use OSPF to establish relationships with neighboring routers. Thus, resulting in many pathways could be formed from main router to edge router and shorter packet queue.

Networks using Frame Relay, MPLS, and OSPF also superior to security because they provide authentication to the OSPF Protocol. Any path through which the packet will be authenticated by the previous router as evidence of network usage. Authentication process is also needed so that the authenticity of the package is certain to the recipient. Steadiness also become an issue in OSPF network as its QoS values harshly over combination network.

Results derived from this research shows that a combination of Frame Relay, OSPF and MPLS generate better performance than original OSPF network. Combination network also generate better result in packet security through its labelling and authentication nature.

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