IJECBE (2025), **3**, **4**, 755–769
Received (15 October 2025) / Revised (14 January 2026)
Accepted (21 January 2026) / Published (30 December 2025)
https://doi.org/10.62146/ijecbe.v3i4.183
https://ijecbe.ui.ac.id
ISSN 3026-5258

International Journal of Electrical, Computer and Biomedical Engineering

RESEARCH ARTICLE

Latency Performance Improvement Analysis for Internet Services with Utilizing Core Transport Re-engineering for Bekasi Region: Case of PT. Telkom Indonesia

Amirsyah Rayhan Mubarak and Gunawan Wibisono*

Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia
*Corresponding author. Email: gunawan.wibisono@ui.ac.id

Abstract
The research object is aiming to answer how to fix one of the problems of a region regarding global latency conditions. Telkom, as one of largest ISP in Indonesia, is having problem with the overall score regarding quality parameters, impact on their internet service products in the Bekasi area being below other operators. With this problem, an evaluation needs to be carried out to analyze in depth the current position and the possibility of network improvement. The core-to-core backbone initiation for the Batam - Bekasi area is the object of research, by optimizing efficient transport paths and designing an IP Backbone topology with a 1-hop router (bypass). The research began with brainstorming the topology of the transport system, IP system, finding gaps between these approaches, then initiating the implementation of integration and logic configuration, while maintaining the existing network conditions. As an addition, other parameters related to network traffic management are also considered. The results obtained from this study and its application to real networks are directly proportional to the objectives, marked by significant latency improvements for each PoP link from PoP Bekasi to PoP Batam by average 1 to 3 ms. Moreover, the results of the Bekasi based on network quality report have an impact, where there is improvement in latency with a delta of 2 to 4 ms in each subject area of Bekasi.

Keywords: Latency, Network Performance, Backbone Network, DWDM System, Core Router

1. Introduction

It is undeniable that technological developments and increasing demand for bandwidth will always grow over time. Various types of services, ranging from the internet, over the top applications, online games, real-time video and others are increasingly popular and require excellent networks. For quality parameter, one of these aspects to be concerned is the latency parameter [1], commonly known as a term for measuring how long a data package takes to travel from one place to another.

Telkom Indonesia is one of the largest ISPs in Indonesia [2] with number of customers served with various services, both for internet and non-internet contents. Customer Experience is an important parameter so that business engagement and reliability to customers remain good and optimal. All services provided by this company certainly have a role in how the telecommunications infrastructure is built. With all the existing complexities, the ISP needs to think hard to provide the maximum potential capability of its network in all aspects. There is currently an issue with reaching global latency performance experience at Bekasi city [3], where Bekasi has emerged to have optimizing improvements from current rankings. Based on the report, Indihome product has not won at all in the quality parameter sections, and is currently behind the other operator, MNC Play as the best provider in that region. One of these quality parameters to be objected is global latency.

Bekasi area is one of the Greater Jakarta areas in PT. Telkom Indonesia, categorized as a Primary Point of Presence (Primary PoP). This PoP has connectivity to the two locations of Main PoP in Greater Jakarta with different geographical distances. Each link between the Main PoPs also has connectivity connected using the submarine cable system (SKKL) from Greater Jakarta to Batam, as a connection route to carry upstream and downstream traffic of global content[4]. The Bekasi area itself has a large traffic density due to its extensive coverage area, as well as larger number of service subscribers. In terms of availability, Bekasi's connectivity can be said to be in a safe condition, because the capacity between the Main PoPs in Greater Jakarta is large enough to accommodate the total traffic occupancy of the region. However, the existing conditions still ignore the quality parameters for the region. So, this problem needs to be dealt with potential ways that can be done by utilizing the current conditions.

There are many techniques to seize the latency aspect. Using Content Distribution Network (CDN) locally or distributed in several areas which could be proposed for better experience [5], but it only reduce for domestical latency. Implementing traffic engineering around the backbone network is also a way to improve performance, with several services defined as a specific route inside the existing network. Another way to solve backbone network situations is by finding potential paths. It could be from the transport system along end-to-end connections [6] or bypassing the active processing equipment [7]. There are components of latency parameters which could improve the value, such as propagation, transmission, and processing delay [8]. With using this concept of latency, the author will try to observe and implement new potential ways in order to catch the problem into meaningful results from the approaches.

The structure of this paper is outlined as follows. Section 2 presents the idea and strategy to elaborate potential aspect of IP Backbone Network for Bekasi that would give positive impact through the latency problems. In section 3, the research analyzes and tests the proposed model and applied it in real network conditions to demonstrate the results. Finally, we summarize our findings and results in Section 4.

2. Method

Figure 1 shows the method of research implementation. This research begins with considering the transport layer and IP layer. In overlay networking architectures, the service (IP and MPLS) and transport (DWDM) layers are designed separately, this could be engineered properly to manage such efficient topology for Backbone network. Focusing on the Bekasi area, which is the object of interest in developing new ways of topological networks, the existing conditions are identified. With using several studies in [6], [7], an observational testing approach from several potential Batam – Bekasi area Transport segments that are available and already exist on the Telkom network are used. This research observed the transport layer by considering the length of the cable, the transport route path, and took a rough approach to the effect of distance on the round-time delay according to reference. Likewise, from the IP layer side, this research looks at the influence of the transit router from the Bekasi router to reach the Batam router.

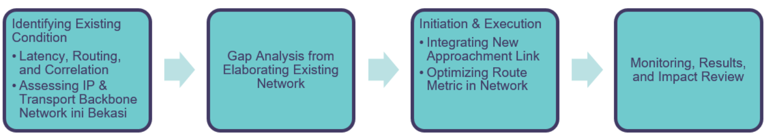

Figure 1. Research Method of Implementing Re-engineering IP Backbone Topology Batam – Bekasi

After finding the gap, the initiated new connectivity will be implemented in the network between the Batam and Bekasi by connecting from router to router, by using new transport path link scenario and router bypassing scenario. After each link is connected, real-time measurements are carried out in the form of ping testing as a benchmark for the previous calculation results.

The results of this test will be compared to the real network that is currently running. When the test results are better than the existing ones, network reconditioning will be carried out by prioritizing the latest link path as the main path for the traffic that is passed. This path reconditioning method considers the existing network, changing the OSPF cost metric on the IP Backbone network so that the new path is purely used effectively and optimally. After this is done, the impact of changes in the reference path traffic in terms of performance will be seen.

3. Analysis & Results

3.1 Latency, Routing, and its Correlation

Latency (or delay) is defined as the time required for a data packet to travel from the source to the destination [2], typically measured in milliseconds (ms). Latency is a critical metric for real-time applications such as video and gaming, as high latency can degrade the user experience. Total latency (End-to-End Delay) is the accumulation of four main components at each network device (hop) traversed by the packet, defined with the approach:

$$L_{backbone} = \sum (L_{Processing} + L_{queuing} + L_{transmission} + L_{propagation}) \quad (1)$$

- Processing Delay ($L_{processing}$): The time taken by a network device (such as a router or switch) to examine the packet header and determine the next path. In modern technology, this process is extremely fast, operating on a micro to nanosecond scale.
- Queuing Delay ($L_{L_q ueuing}$): The time a packet spends waiting in an output queue (buffer) before being transmitted, primarily occurring when the packet arrival rate exceeds the router's forwarding capacity, such as during network congestion.
- Transmission Delay ($L_{L_t ransmission}$): The time required to "push" or transmit all the bits of a packet into the transmission medium, influenced by the packet size and bandwidth. It is mathematically represented as:

$$L_{transmission} = \frac{L}{R} \quad (2)$$

- Propagation Delay ($L_{L_p ropagation}$): The time required for a signal (such as light in fiber optics) to travel across the physical medium from one point to another. It is determined by the physical distance and the speed of light in that medium:

$$L_{propagation} = \frac{d}{s} \quad (3)$$

(Where d is the physical distance and s is the propagation speed of the signal).

Among the four components, propagation delay has the most significant impact on latency parameters, especially within long-haul backbone networks. As a fundamental physical limit determined by distance and signal speed, it acts as the "floor" or inescapable baseline for network delay. There is a direct correlation between geographical distance and propagation delay; as the physical distance between nodes decreases, the latency improves proportionally.

For Internet Service Providers (ISPs), latency is a core pillar of Quality of Service and a primary driver of Customer Experience (CX). In a crowded market, customers use latency as a key metric to compare providers, particularly for sensitive applications. ISPs that consistently offer lower latency gain a significant edge in attracting and retaining users. A reputation for a "fast" and "responsive" network is a vital business asset, whereas being known for "lag" can be highly damaging to long-term success.

Routing is a critical process in networking responsible for directing data packets from a source to their final destination across one or more interconnected networks. Its primary function is to ensure that every packet discovers the most efficient path to its destination. Routing must maintain network stability while dynamically directing traffic through the most optimal paths available [7]. Effective routing is crucial because distance is a fundamental physical constraint; as the distance between points decreases, latency improves.[9, 10, 11, 12] By directing traffic through the most optimal paths, ISPs can minimize propagation delay. For major ISPs, maintaining low latency through superior routing is a key performance metric used by customers to compare services [13]. Table 1 can provide to see how optimal routing correlate to impacts performance, especially for the latency aspects. These approaches will be bringing to overcome the case that occurred for internet service at Bekasi area.

Table 1. Correlation about Routing with Latency Aspects

Routing Goal	Technical Action	Benefit
Stability	Consistent OSPF Cost Application	Predictable traffic flow and redundancy.
Efficiency	Shortest Path Selection	Reduced Propagation Delay ($L_{propagation}$).
Performance	Routing Management	Minimized Queuing Delay (L_{queue}), shorter distance transmission ($L_{transmission}$)

3.2 Identifying Exisitng IP Backbone & Transport Path Batam – Bekasi Condition

The IP network topologically and traffic are shown at Figure 2, where Batam area is the Main PoP as an International Gateway connectivity. In Jabodetabek area, there are Routers as Main PoP and also Domestical Gateway connectivity, namely Jatinegara and Cikupa as the central of distribution node. Bekasi area is categorized with Primary PoP, clearly having direct connection to each Main PoP Router in Jabodetabek. For Main PoP links, which is Bukit Dangas – Jatinegara and Batam Center – Cikupa, there are plenty of capacity over 4Tbps operating to accommodate traffic for Jabodetabek Gateway route, including Bekasi area. Primary PoP links, which is Jatinegara – Bekasi and Cikupa – Bekasi are also fulfil with 1,2Tbps capacity link to Regional Main PoP, with total occupied traffic of Bekasi is about 900Gbps at the peak is enough to accommodate its large amount of internet service traffic.

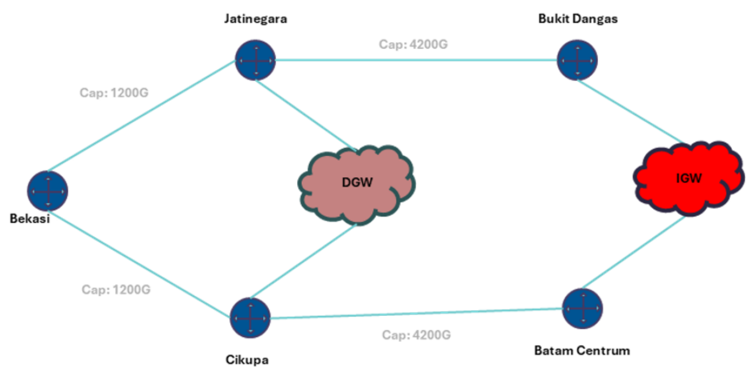

Figure 2. Existing IP Backbone Batam – Bekasi

Geographically, the transport structure layer between the connection of Batam and Bekasi is identified. Table 2 and Figure 3 show the path and the map of those Point of Presence. Each connection from Batam to Jakarta is using an independent DWDM System, in order to maintain redundancy in backbone network. Each link also has different latency values depending on its distance across the network. For Main PoP Bukit Dangas – Jatinegara link, the transport path has around 1561 km long, where 1443 km are the length of the JaSuKa cabling system from BMH Tanjung Pinggir (Batam) to BMH Tanjung Pakis (Bekasi) and the remaining path is the length of the cable in the region. Batam Center – Cikupa link is using B3JS cabling system from BMH Tanjung Bremban (Batam) to BMH Ancol (Jakarta) around 1091 km long, and the remaining path goes from Ancol to Cikupa by using DWDM region with transport route length of over 140 km end-to-end. For Primary PoP Jatinegara – Bekasi link has around 24 km long and Cikupa – Bekasi link has around 88 km long by using regional DWDM.

Table 2. Transport Path Structure between Backbone Network Batam – Bekasi

Link IPBB	Transport	Transport Path	Total Length Distance	Latency
Bukit Dangas- Jatinegara	DWDM JaSuKa	Bukit Dangas - (BMH Tanjung Pinggir - BMH Seikakap - BMH Tanjung Pandan - BMH Tanjung Pakis) - Cikarang - Bekasi - Jatinegara	1561 km	16 ms
Batam Center – Cikupa	DWDM B3JS	Batam Center - (BMH Tanjung Bremban - BMH Toboali - BMH Ancol) - Palmerah - Cikupa	1267 km	13 ms
Jatinegara - Bekasi	DWDM RMJ (Regional)	Jatinegara – Bekasi	24 km	0,3 ms
Cikupa – Bekasi	DWDM RMJ (Regional)	Cikupa – Jatinegara – Bekasi	88 km	1 ms

3.3 Gap Analysis from Transport & IP Layer of Batam - Bekasi

From the following Low-Level Design (LLD) on the transport path at Figure 4 and brainstorming results, it is recognized that the existing conditions that are running have important concerns, shown at Figure 4:

a) the transport conditions at the Jabodetabek location, especially from the BMH landing point location to the Bekasi location, have a back-and-forth transport path when heading to the Main PoP transit location, both Jatinegara and Cikupa, before finally continuing to Bekasi:

   i) On the link Bekasi to Bukit Dangas link via the Jatinegara hop, there is a contribution of a back-and-forth transportation route when BMH Tanjung Pakis heads to Jatinegara via the Bekasi site with the SKKL transportation route, then returns by continuing Jatinegara to Bekasi via Regional transportation. It contributes around 50km long distance, coming from the back-and-forth path between Bekasi – Jatinegara – Bekasi

   ii) ii. On the Bekasi to Batam Center link via the Cikupa hop, there is a contribution of a long transportation route circling the Jabodetabek area. From the

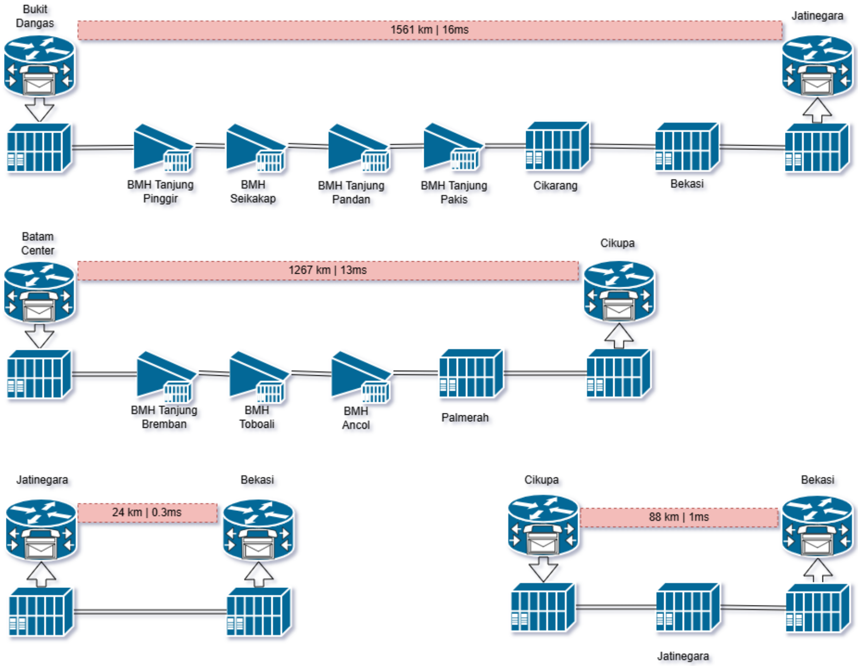

Figure 3. Transport Map between Backbone Network Batam – Bekasi

BMH Ancol landing point, the SKKL transportation to Cikupa passes through the Ancol - Palmerah area and ends in Cikupa. Then it continues back from the Cikupa site via Jatinegara and so on to the Bekasi site. It contributes around 250km long distance, coming from the sum of Ancol – Cikupa – Jatinegara – Bekasi

b) The existence of the Bekasi Primary PoP connected to the Jakarta Main PoP as a transit Router to the Gateway has an impact on the gap delay from the active Router device, due to the influence of the transmission, processing or queuing delay process. From the previous study [8] that it can estimated latency's contributing around 1ms.

3.4 Initiating & Execution of Batam - Bekasi Backbone Network

A proposal for reconfiguration of the backbone network to create a direct link between Bekasi and Batam (Bukit Dangas and Batam Center) is produced for each link, using separated method (i) providing new transport geographical path between Bekasi to Batam as the transport layer, and (ii) making 1-hop Router link from Bekasi to Batam from the service layer. Figure 5 shows the initiative backbone network topology between Batam and Bekasi. These initiative actions are using existing equipment that uses the existing and does not use a new lease link. Each link will use 2x100G transport layer capacity from existing to build a new direct link in IP layer.

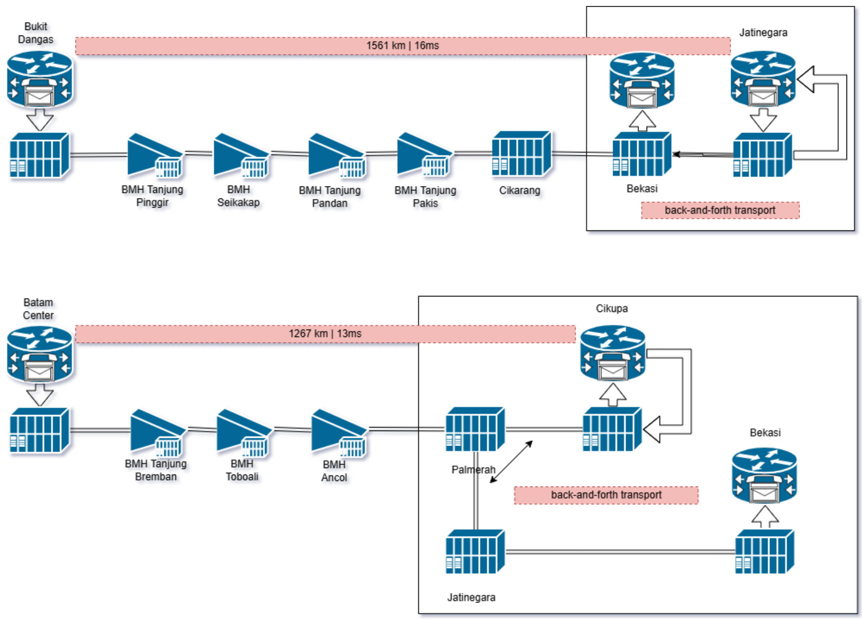

Figure 4. Connectivity Concern about end-to-end Batam – Bekasi IP Backbone

3.4.1 Integration 1-hop Batam – Bekasi Links

Firstly, those initial direct link conducted physical reconfiguration from the transport system, then providing reliability and BER testing on the selected DWDM link before finally connecting it to the Router. This activity is expected to test the link is in feasible and clean condition from internal and external interference[14].

The results of the IP Backbone's link Bukit Dangas – Bekasi providing a latency performance parameter of 14.95 ms. Another initiated link IP Backbone's link Batam Center – Bekasi is also having the round-trip delay of 10,56 ms. This result provides an approach with a similar end-to-end physical distance, for every 100km of distance will provide 1ms latency. After both links have been tested for reliability, the next stage is integration with the client router in Bekasi and Batam. As explained previously in the initiation section, this connection takes from the existing capacity that is already operating on the router, so this connection needs to be formed into a new bundle member. This implementation has the same impact on both links, namely the improvement of latency reduction.

Improvement from Bukit Dangas side with direct peering provides latency correction of 1 to 2 ms compared to existing conditions to Bekasi. As in Bukit Dangas, Batam Center also provides a correction of 2 to 3 ms to latency. Table 3 and Figure 6 show a comparison between the existing conditions of the IP Backbone link between the Batam - Bekasi link with transit (2-hop) to the Main PoP Jakarta with Batam - Bekasi with direct DWDM (1-hop). The contribution of this latency reduction is felt due to the bypass effect of the active Router device and the shortened DWDM transport route distance. Previously, Bekasi had an active path through Jatinegara

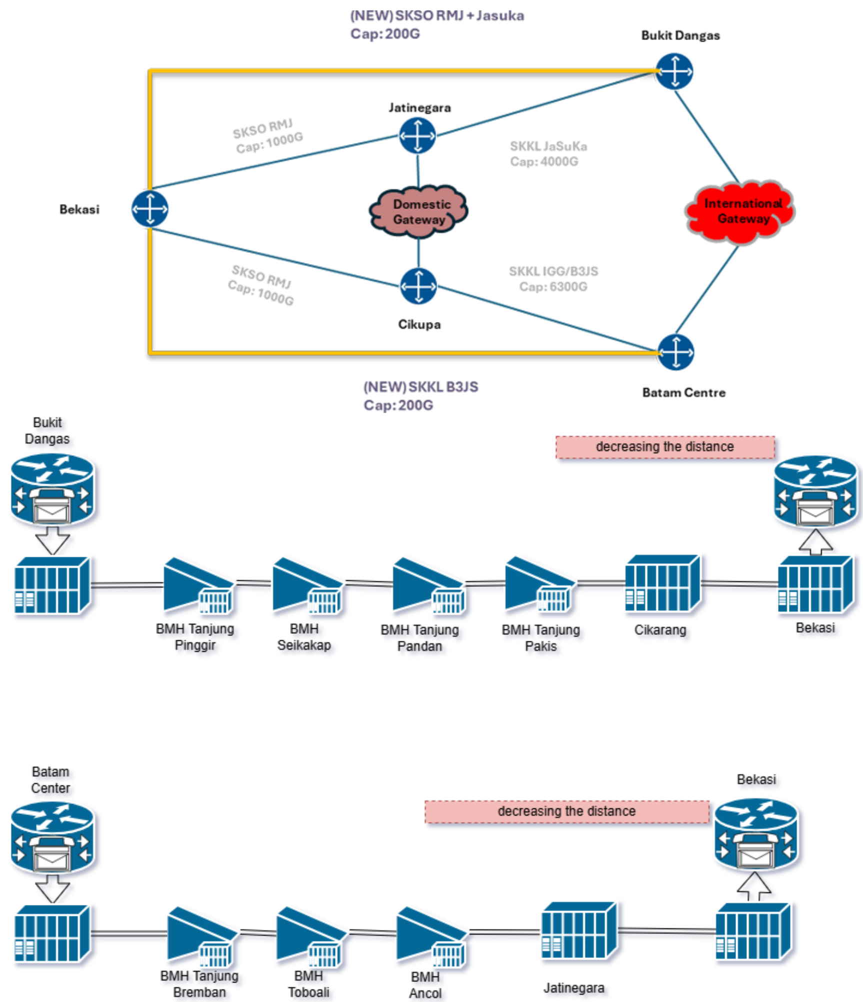

Figure 5. Initiative end-to-end IP Backbone Topology Batam – Bekasi

and Cikupa (2-hop) where there was the potential for a long back-and-forth path in terms of transport route. With a direct link, those formed IP Backbone link without going through both locations (1-hop) saves the length of the transport cable.

3.4.2 Route Optimizing Batam – Bekasi Links

After both links are activated, the final process to make the main route of Bekasi's connectivity traffic, moves from transit link into the direct link. This condition is done by recalculating the OSPF cost value of each IP Backbone link connection around its topology. The purpose of this activity is to make adjustment the direct route the selected route to be passed by traffic from the Bekasi uplink and downlink, also to

Table 3. Latency Comparation of IP Backbone Link Batam – Bekasi (2-hop vs 1-hop Router)

Link IP Backbone	Scheme	IP Hop Route	Latency (min/avg/max)
Bekasi – Bukit Dangas	Transit (2-hop router)	BDS-JT2-BKS	16/16/17
Bekasi – Bukit Dangas	Direct (1-hop router)	BDS-BKS	15/15/16
Bekasi – Batam Center	Transit (2-hop router)	BTC-CKA-BKS	13/14/15
Bekasi – Batam Center	Direct (1-hop router)	BTC-BKS	11/11/12

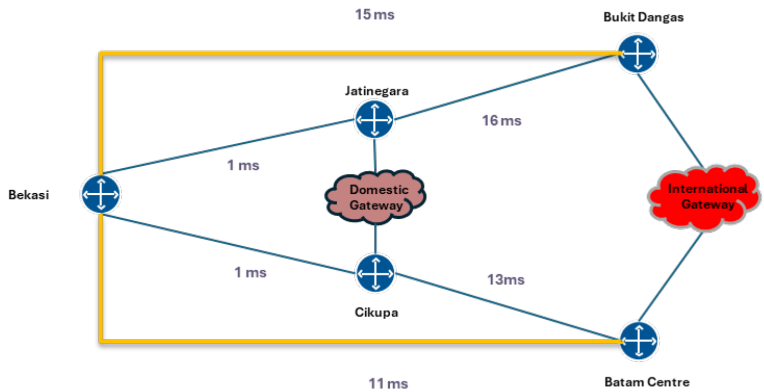

Figure 6. Latency Result in IP Backbone Batam – Bekasi Topology

make its routing's stability in the network. This cost metric configuration is two-way, so both sides of the Router need to be configured to be symmetrical.

By considering this, the OSPF cost optimization is approached in a value that is produced to be applied to the network. Table 4 and Figure 7 show the metric in each link, that will be carried out after the application is configured. The value from "Existing OSPF Cost" are changed to the "New OSPF Cost", there will have a new calculation of each type of route that is possible in the Bekasi IP Backbone area to Batam. In practical, the path will change into the direct (1-hop) link because of the lowest value across the IP network topology around Batam and Bekasi. Several changes are made, so the direct link will be the best route for end-to-end connection in every PoP, vice versa.

3.4.3 Results

The results can be seen from routing perspective and latency performance. The routing's point of view for Bekasi into Batam are displayed in Table 5 and Figure 8, where each Router has a new best path after optimizing the network's metric value between Batam, Jakarta, and Bekasi. The traffic stream originating from Bukit Dangas to Bekasi will pass through the direct link, so does the stream originate from Batam Center to Bekasi with the metric value is 4001. The remaining link with 2-hop router will be the alternative link, where the metric value of each links is 4002, below the direct link. Whenever the direct link is having problem, such as transport incident

Table 4. Cost OSPF Values in IP Backbone Topology Design

Link IP Backbone	Existing OSPF Cost	New OSPF Cost	Link IP Backbone	Existing OSPF Cost	New OSPF Cost
Bekasi - Bukit Dangas	65535	4000	Bukit Dangas - Bekasi	65535	4000
Bekasi - Batam Center	65535	4000	Batam Center - Bekasi	65535	4000
Bekasi - Jatinegara	3000	1000	Jatinegara - Bekasi	3000	1000
Bekasi - Cikupa	3000	1000	Cikupa - Bekasi	3000	1000
Bukit Dangas - Jatinegara	3000	3001	Jatinegara - Bukit Dangas	3000	3001
Batam Center - Cikupa	3000	3001	Cikupa - Batam Center	3000	3001
Jatinegara - Cikupa	100	100	Cikupa - Jatinegara	100	100
Bukit Dangas - Batam Center	100	100	Batam Center - Bukit Dangas	100	100

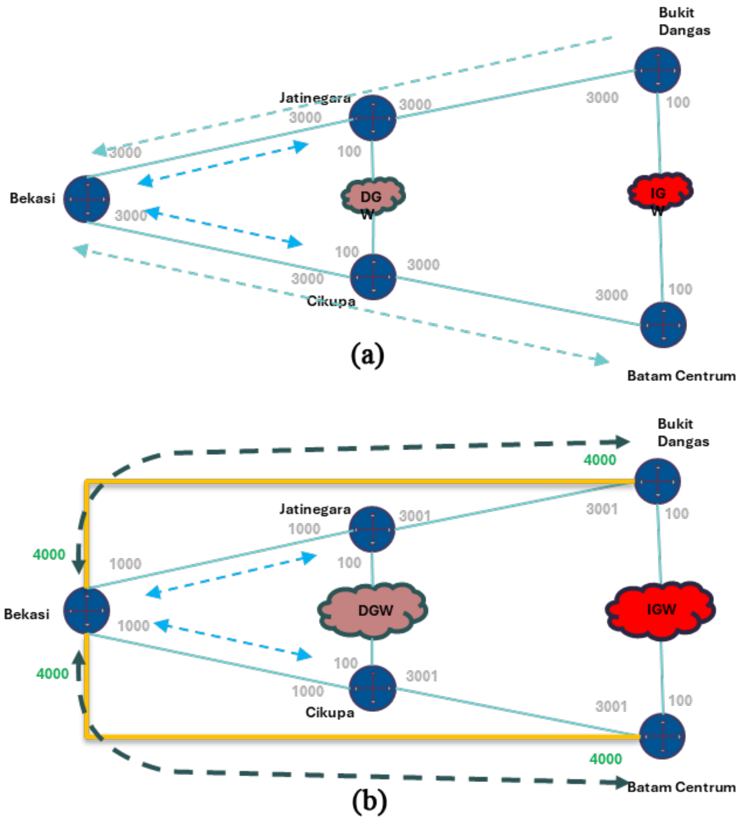

Figure 7. OSPF Cost Metric IP Backbone Batam – Bekasi: (a) existing, (b) proposed

or line module failure, the alternative link will be chosen by its routing network through Bekasi. This condition will keep the network safe in terms of routing.

In line with routing optimization, the same thing is also corrected regarding with latency performance. As we can see with the latency comparation results in previous

Table 5. Metric Optimization Results in IP Backbone Batam - Bekasi

View	Destination	Route Path	Cost Calculation	Total Cost	Status
Bekasi	Bukit Dangas	Bekasi → Bukit Dangas	4000 (direct) + 1	4001	Best Path
		Bekasi & Jatinegara → Bukit Dangas	1000 + 3001 + 1	4002	Backup
	Batam Center	Bekasi → Batam Center	4000 (direct) + 1	4001	Best Path
		Bekasi → Cikupa → Batam Center	1000 + 3001 + 1	4002	Backup
View	Destination	Route Path	Cost Calculation	Total Cost	Status
Batam Center	Bekasi	Batam Center → Bekasi	4000 (direct) + 1	4001	Best Path
		Batam Center → Cikupa → Bekasi	1000 + 3001 + 1	4002	Backup
View	Destination	Route Path	Cost Calculation	Total Cost	Status
Bukit Dangas	Bekasi	Bukit Dangas → Bekasi	4000 (direct) + 1	4001	Best Path
		Bukit Dangas → Jatinegara → Bekasi	1000 + 3001 + 1	4002	Backup

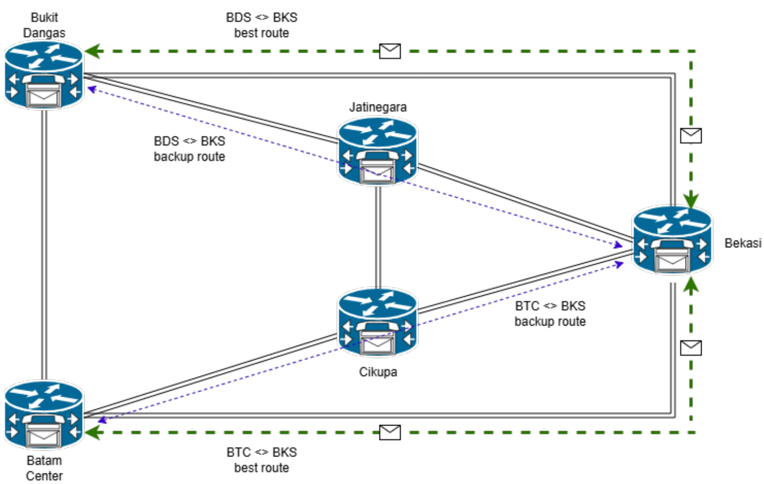

Figure 8. Traffic IP Backbone Batam – Bekasi after OSPF Cost Modification

discussion, we have observed and captured the average of latency over 24 hours through each link. Figure 9 shows the latency performance, where each observation result shows stable latency consistency. The direct link of Batam Center – Bekasi and Bukit Dangas – Bekasi have better latency compared to the existing link (2-hop links)[15]. The direct link of Bukit Dangas – Bekasi has 1ms better performance in average compared with Bukit Dangas – Jatinegara – Bekasi, and same as Batam Center – Bekasi having 2 to 3ms latency compared with Batam Center – Cikupa – Bekasi. This condition provides evidence of a significant impact related to latency improvements from creating an end-to-end direct link.

Seeing the impact of the implementation, the approach also confirmed how the implications of the route changes were made to the Network Quality team [16], especially for the Bekasi area. Figure 10 provides an overview of the performance of

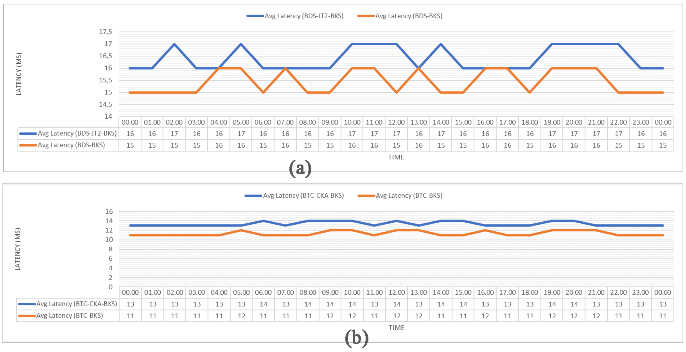

Figure 9. Latency Performance in each link: (a) Bukit Dangas <> Bekasi; (b) Batam Center - Bekasi

the Bekasi city area after approaching the re-engineering backbone network. The result shows that there is a significant improvement in almost all the Bekasi area coverage for global latency measurement in several districts. The global latency measurements in this area have an improvement of 2 to 4 ms delta from Week-25 through Week-28. This condition has justified with what the approaching initiation stands for, getting the good impact that the quality score for Bekasi City has increased significantly, providing good results for improving the Indihome service product in quality trends. These results reinforce that testing by identifying connections between core-to-core Routers by utilizing the shortest transport path distance and router bypass will provide benefits to overall latency for the test area.

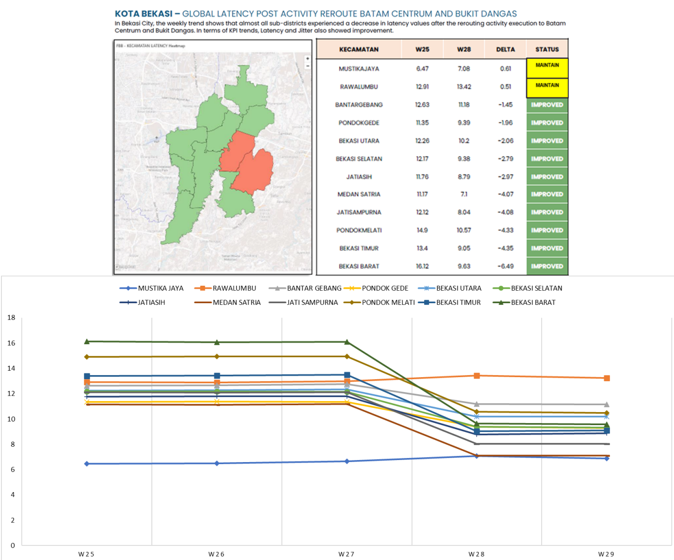

Figure 10. Global Latency Post-Activity in Bekasi for Indihome [16]

4. Conclusion

The research has presented the approaches of improving quality performance within stabilizing the network for Telkom's internet service, one of these parameters is about latency. To overcome better latency, there are several ways to be applied such as minimizing the initial distance between end-to-end link, simplifying the connectivity network by integrating directly to the destination while maintaining stable network conditions. The approach conducted to identify a more effective initiation Core to Core Backbone path for the Batam - Bekasi area, with optimizing the new transport path and router bypassing between Batam and Bekasi. The result shows a positive trend towards the experiments conducted for the Telkom network, where there is a latency improvement of 1 to 2 ms for Bukit Dangas – Bekasi link against the transit link. This also happens to the Batam Center – Bekasi link which gets a latency improvement of 2 to 3 ms. Shorter point-to-point distances provide direct latency results, so that the implication continue with the services passed through the transport route path. Global Latency measurements in several districts in the Bekasi area have been improved, providing a delta of 2 to 4 ms corrective Quality Performance for the internet service product of Indihome.

References

[1] PT Telkom Indonesia Tbk. *Laporan Tahunan PT Telkom Indonesia Tbk Tahun 2023*. Tech. rep. Bekasi: PT Telkom Indonesia Tbk, 2023.

[2] Cisco Systems. *Understanding Network Latency*. https://www.cisco.com. Accessed: 2025. 2022.

[3] Marco Iorio, Fulvio Risso, and Claudio Casetti. "When Latency Matters: Measurements and Lessons Learned". In: *ACM SIGCOMM Computer Communication Review* 51.4 (2021), pp. 2–13.

[4] Telkomsel. *FBB Optimization Focus 5 Cities Review W25*. Tech. rep. Network Quality Internal Report. Telkomsel, 2024.

[5] Bob Briscoe et al. "Reducing Internet Latency: A Survey of Techniques and Their Merits". In: *IEEE Communications Surveys & Tutorials* 18.3 (2016), pp. 2149–2196.

[6] Stefano Baroni et al. "Analysis and Design of Backbone Architecture Alternatives for IP Optical Networking". In: *IEEE Journal on Selected Areas in Communications* 18.10 (2000), pp. 1980–1994.

[7] Philip Smith. *IP Core Network and Backbone Dimensioning and Planning*. ITU Asia-Pacific Centre of Excellence Training. Traffic Engineering and Advanced Wireless Network Planning. 2018.

[8] X. Zuo et al. "Low-Latency Networking: Architecture, Techniques, and Opportunities". In: *IEEE Internet Computing* 22.5 (2018), pp. 56–63. DOI: 10.1109/MIC.2018.053681363.

[9] TeleGeography. *Submarine Cable Map*. https://www.submarinecablemap.com. Retrieved April 15, 2024. 2024.

[10] Riandra Alkausar. *DWDM: Teknologi Multiplexing untuk Jaringan*. https://www.hypernet.co.id/id/dwdm-teknologi-multiplexing-untuk-jaringan/. Accessed: 2025. 2025.

[11] Che-Nan Yang. *An Overview of the TWAREN Performance Measurement Project*. Tech. rep. Taiwan: National Center for High-Performance Computing, 2005.

[12] Ulrich Bauknecht and Thomas Enderle. "An Investigation on Core Network Latency". In: *2020 30th International Telecommunication Networks and Applications Conference (ITNAC)*. IEEE, 2020, pp. 1–6.

[13] Chuck Fraleigh, Fouad Tobagi, and Christophe Diot. "Provisioning IP Backbone Networks to Support Latency Sensitive Traffic". In: *IEEE INFOCOM 2003*. Vol. 1. IEEE, 2003, pp. 375–385.

[14] Teridion. *Backbone Network: The Backbone of Your Internet Infrastructure*. https://www.teridion.com/blog/networking-technology/backbone-network-the-backboneof-your-internet-infrastructure/. Accessed: 2025. 2024.

[15] Telkom Indonesia. *Overview PoP for Head of District*. Tech. rep. Internal Report. Telkom Indonesia, 2024.

[16] Telkomsel. *FBB Optimization Focus 5 Cities Review W28*. Tech. rep. Network Quality Internal Report. Telkomsel, 2024.