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OPTIMIZING TRAFFIC CONGESTION IN ROUTE PLANNING USING A SIMPLE PATH ALGORITHM

Brillian Adhiyaksa Kuswandi[1*], Faqih Hamami[2], Riska Yanu Fa'rifah[3]
Telkom University, Bandung, West Java, Indonesia[1,2,3]
Email: brillian.adhiyaksa@gmail.com[1*], faqihhamami@telkomuniversity.ac.id[2], riskayanu@telkomuniversity.ac.id[3]

Abstract

The increasing demand for a reliable internet network is very important to meet the needs of companies. However, currently the ranking of mobile internet and internet in Indonesia is still below global standards. Network congestion, which is a major contributor to low internet quality, causes various challenges such as service outages, communication failures, and decreased connection speeds. The study emphasizes the importance of implementing effective congestion management mechanisms. Focusing on the utilization of the simple path method and comparing its effectiveness with the Dijkstra algorithm in managing internet networks, this study aims to develop network traffic optimization methods and identify alternative routes to improve overall network performance, especially in complex traffic conditions, within the framework of a Decision Support System (DSS). The analysis showed that the use of Simple Path increased packet delivery rates threefold and reduced packet loss by half compared to the traditional Dijkstra method, with 58.54% of packets successfully delivered and a 41.46% reduction in packet loss. In addition, Simple Path facilitates the use of alternative routes for about 24% of total requests using alternative routes. Network graph exploration identifies solid points and analyzes the capacity on each network link. Twelve links show occupancy rates above 90%, indicating congestion, with NE2-4-KBL to NE3-KBL-HSI as the main cause of package delivery failures, accounting for about 70.6% of total failed requests. Simple Path analysis highlights about 46% of total failed requests, passing through this link. These findings emphasize the importance of congestion management strategies and the use of alternative routes to improve network performance and reduce packet loss, thereby contributing to business efficiency, user experience, and customer satisfaction.

Keywords: *congestion management, simple path, Alternative routing, Network Traffic Optimization*

Introduction

The development of internet network technology that continues to increase is a must to meet the demands of companies in getting a reliable network (Zhou, et al, 2021). Along with the times, the current internet network is not only expected to have high speed but also optimal stability and minimal latency (Ngafifi, 2014). This need is increasingly urgent along with the results of the Databoks report which records the number of internet users in Indonesia in 2022 to reach 204.7 million people, or equivalent to 73.7% of the total population. This figure reflects significant internet penetration in the community, showing how important the existence of a reliable internet network is in supporting the company's daily activities and operations.

Currently, Indonesia is in the 112th position for mobile internet and the 123rd for fixed internet (Simon Kemp, 2022). This ranking underlines the quality of internet networks in Indonesia which is still low compared to global standards. Low internet connection quality, which is generally caused by network congestion, has the potential to cause a variety of problems, including service outages, communication failures, low connection speeds, and increased

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response times (Salman, Ginting, & Wahyuningrum, 2021; Zulkifli, 2014; Siddik, Lubis, & Sahren, 2023).

The impact of this network congestion is very diverse, especially in the context of business and user experience (Firdausi, 2022). First, network congestion can cause service outages, especially in situations that require reliable connectivity, such as online financial transactions or critical data transmissions. Second, communication failures, such as virtual meetings, due to network congestion can hamper company operations and result in financial losses (Sina, Amsikan, & Salsinha, 2021).

In addition, low connection speeds have the potential to slow down business processes and reduce productivity. Delays in access to information or data processing can harm companies in making quick and effective decisions (Sina, Amsikan, & Salsinha, 2021). In the context of user experience, high response times due to network congestion can create frustration and dissatisfaction. According to a PricewaterhouseCoopers (PWC) report, the level of Internet customer satisfaction in Indonesia has decreased by 61%. This shows that the level of customer satisfaction with internet services in Indonesia is still low, indicating the need to improve internet quality with a focus on Quality of Service (QoS) (Ruth, 2015; Priyatna, Marsudi, & Rahadjeng, 2023).

Control over network congestion is the main key to achieving a superior Quality of Service (QoS) mechanism (Cardwell et al., 2019). Congestion management is an integral part of error management that plays a crucial role in helping administrators address problems that may arise on the network. With congestion control, administrators can avoid manual actions such as path switching and short path calculations in network topologies, ensuring higher operational efficiency.

However, in its implementation, often the ability to optimize network traffic and provide alternative routes to maintain smooth network operations is still not fully realized in modern network design. This creates its challenges for administrators who are often faced with similar problems. At present, the solution to these problems is still often done manually or based on personal experience.

A common method that administrators can use to optimize traffic is to apply the Dijkstra algorithm. This algorithm is effective in calculating the shortest and fastest routes, as reinforced by research findings stating that Dijkstra is very suitable for optimization (Lakutu et al., 2023). However, the use of Dijkstra has weaknesses in handling optimization on networks that experience congestion. The Dijkstra algorithm produces only one output path, and when that path is congested, Dijkstra cannot provide an alternative path.

Alternative routes are crucial for congestion management, as they play a pivotal role in reducing congestion, enhancing environmental performance, and fostering connectivity (Szele & Kisgyörgy, 2018). Recognizing these crucial aspects, it becomes imperative to explore alternative methods that address the shortcomings of the Dijkstra algorithm.

Research entitled "A Multi-Stage Metaheuristic Algorithm for Shortest Simple Path Problem with Must-Pass Nodes" has shown that simple path methods adeptly overcome these limitations by providing alternative routes (Su, Zhang, & Lü, 2019). This approach has proven to be more efficient in optimizing network conditions, offering an alternative path in case of congestion. Simple path implementation is emerging as a promising approach capable of improving network efficiency and resilience to potential congestion, thus providing advantages in optimizing network performance and overall service quality.

Based on these issues, this research aims to develop methods to optimize network traffic and provide alternative routes during congestion, using topology and network PT XYZ as a case study. It will adopt an optimization approach, f

ocusing on the simple path method, to identify solutions for enhancing network performance amidst complex traffic scenarios. This research holds significant importance due to the critical need for effective traffic optimization strategies, particularly given Indonesia's subpar internet quality compared to global standards.

Based on the formulation of the problem that has been described, the objectives of this study can be described as follows:

1) To assess and compare the results of the analysis conducted using the Dijkstra and Simple Path algorithms in optimizing the network topology of PT XYZ.
2) To investigate the impact of implementing the Simple Path algorithm on network routing within the network topology of PT XYZ.
3) To find out the topology condition after using the simple path method.

Research Methodology

Conceptual Model

This research employs the design science approach, a problem-solving paradigm aimed at constructing knowledge to achieve goals (Vom Brocke, Hevner, & Maedche, 2020). The primary objective of this study is to produce a research framework in the field of information systems that integrates environmental aspects and foundational knowledge from previous research. This framework aims to facilitate a better understanding of the research by defining the problems and illustrating their solutions. The problem-solving framework is depicted in Figure 1.

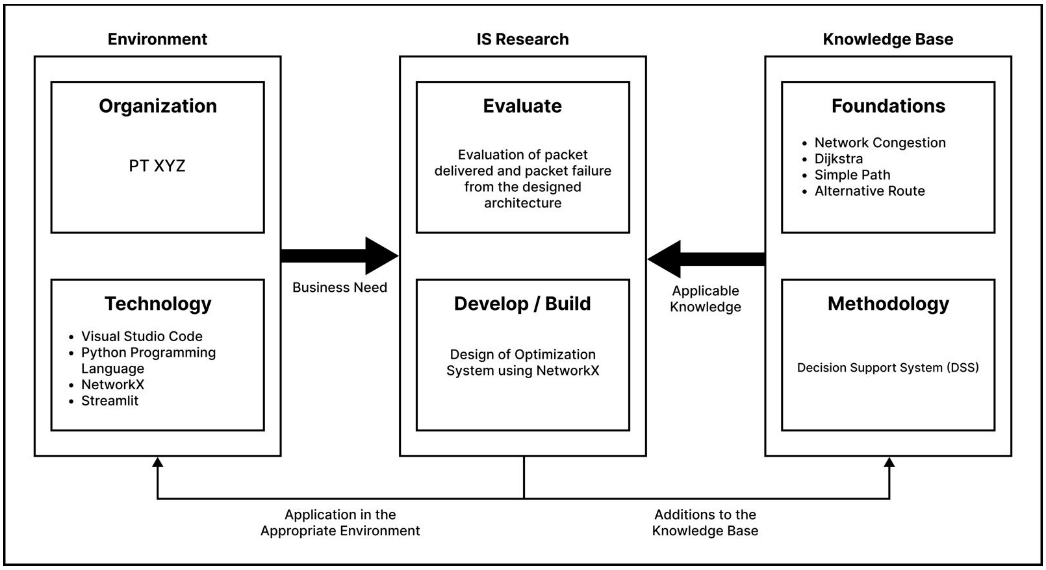

Figure 1. Conceptual model

This troubleshooting framework focuses on technology environments, where administrators currently perform network route mapping manually. Therefore, this research becomes important to create IT artifacts that can optimize traffic density in route planning. The output of this study will be evaluated by testing the packet delivery rate and packet loss of the traffic density optimization architecture on route planning developed by the authors. Basic concepts from previous studies, such as network congestion, the Dijkstra algorithm, simple paths, and alternative paths, were adopted in this study. The technologies used in this study include Visual Studio Code, Python programming languages, NetworkX, and Streamlit. This architecture development methodology uses a Decision Support System (DSS).

Systematics of Problem Solving

In conducting research, a clear and structured system is needed. Therefore, a systematic solution is needed to solve the research problem. The author uses the systematics of solving the Decision Support System (DSS). The DSS concept has five stages, namely initiation, data collection, preprocessing, system design, and measurement. The following stages of research systematics are described in Figure 2.

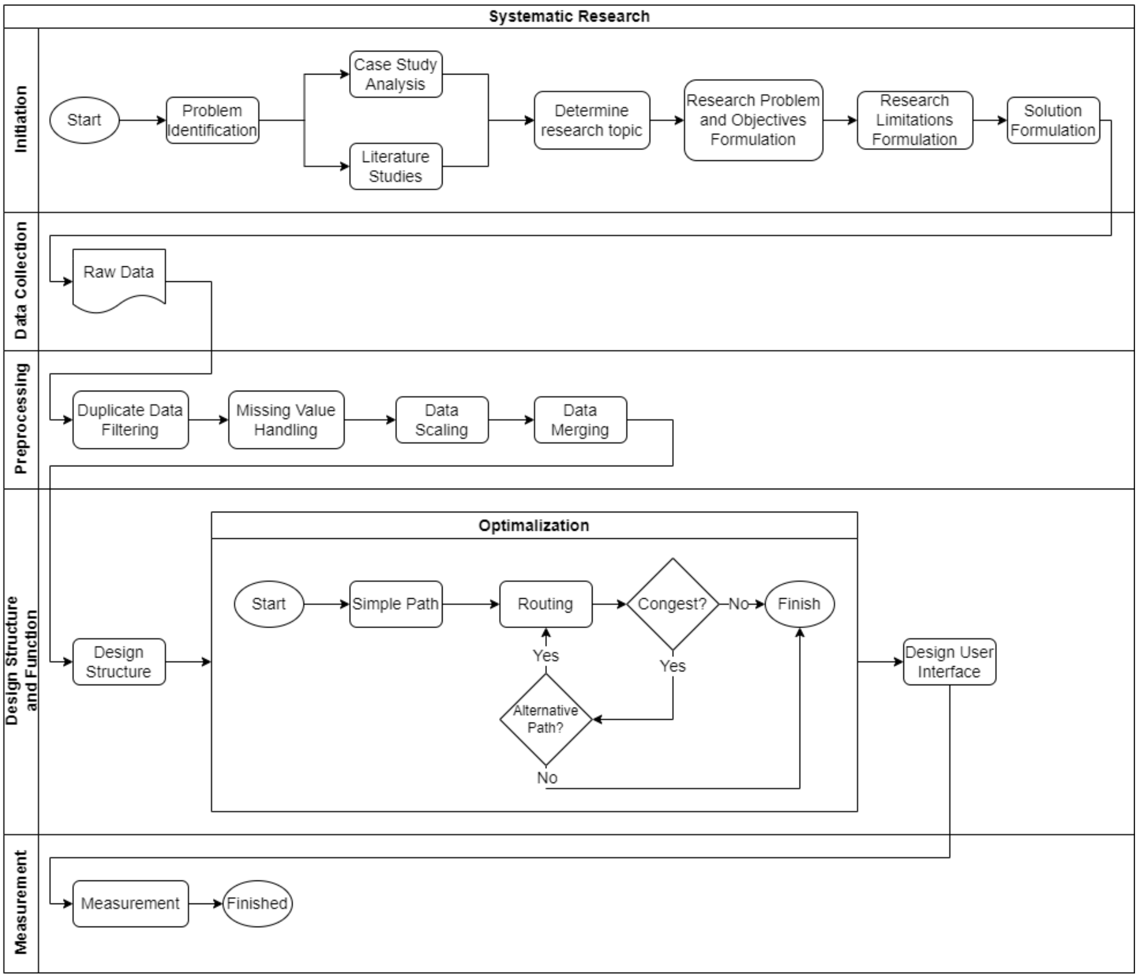

Figure 2. Research Systematics

Data Collection

At this stage, a data collection process was carried out sourced from PT XYZ, a company that was the focus of research. The data taken involves several tabular data that present detailed information about the network topology structure used by PT XYZ. In addition, the data collected also includes information related to requests in the network environment. This data collection process is carried out carefully to ensure the accuracy and completeness of the information that forms the basis of further analysis to understand and improve the efficiency and performance of PT XYZ's network.

Data Processing

The data that has been successfully collected comes in the form of tabular data stored in CSV format. Ensuring the quality and relevance of the data is the initial step in data processing, which involves thorough handling of data duplication to eliminate redundancy and ensure data integrity and accuracy. The subsequent step involves handling missing data, aimed at addressing any absent data points. Following this, data scaling is performed to standardize the units used in the data. Finally, the last step involves data merging, integrating two initially separate data sources into one comprehensive and cohesive dataset.

Design Structures and Functions

Once the data preprocessing phase is complete, the next steps involve creating a graph structure, optimization, and designing the user interface. These components are crucial in designing the foundation for effective and effective data analysis.

Measurement Method

This process is continued by measuring the packet delivery rate and packet loss rate. The purpose of this measurement is to assess the performance of the system that has been designed. Through this series of steps, it is expected to provide a solid basis for producing relevant findings, as well as make a significant contribution to the understanding and improvement of networks at PT XYZ.

Results and Discussion

Data Collection

In this research, analysis was conducted using two different data sets. The first dataset contains information about the network infrastructure, while the second dataset contains internet traffic data.

Network Data Infrastructure

The first dataset, referred to as the network infrastructure data, is contained in a file named “relationlink”. This dataset provides detailed information about the network topology, including the connections between various network nodes. The following is a sample of the network data infrastructure data in Table 1.

Table 1. Sample Relationlink Data

froma	tob	totalkap	cost
NE1-00-MGO-3	NE2--MGO	30	NULL
NE2--MGO	NE2-9-KBL	100	60000
NE2-9-KBL	NE2-9-RKT	500	10
NE2-9-KBL	NE34-KBL-TRANSIT	120	NULL
NE2-9-KBL	NE32-KBL-VPN	110	NULL
NE2-9-RKT	NE32-RKT-VPN	82	NULL
NE32-RKT-VPN	P-RKT	20	NULL
P-RKT	NE34-KBL-TRANSIT	10	65535
NE34-KBL-TRANSIT	NE2-9-KBL	66	NULL
NE34-KBL-TRANSIT	NE2-8-KBL	40	NULL
NE2-8-KBL	NE32-KBL-VPN	11	NULL
NE32-KBL-VPN	CN_Iptv	110	NULL

Following the description of network infrastructure data in Table IV.1, it is important to outline the key attributes that play an important role in understanding and optimizing network topology. The node identifier, denoted as the "froma" and "tob" columns, serves as an important indicator of the start and end points of a network link. These identifiers form the backbone of the network structure, providing insight into connectivity and relationships between various network nodes.

In addition, the "totalkap" column in the dataset is very important, as it shows the overall capacity of each link in the network. These capacity metrics play an important role in assessing the efficiency and feasibility of the network to accommodate data flows. Understanding the total capacity of network links is critical to making informed decisions regarding data routing and resource allocation in the network infrastructure.

In addition, the "cost" column reflects the charges charged for traversing a particular connection within the network. This cost factor is integral in the decision-making process, influencing the selection of optimal routes and resource utilization strategies. A thorough analysis of these key attributes contributes to a comprehensive understanding of network capabilities, enabling informed decision-making to improve the performance and reliability of the overall network infrastructure. The following is an explanation of the columns in relationlink data, which are found in Table 2.

Table 2. Relation link Column Explanation

Column Name	Data Type	Description
froma	string	This column represents the initial identification or starting point of a connection or link in the network.
tob	string	This column reflects the identification of the connected points from the froma column.
totalkap	integer	This column contains the total capacity of each path or connection in the network.
cost	float	This column reflects the charges charged for traversing a particular connection within the network.

Data Usage

The second dataset, titled "Uplink" and "Downlink," furnishes information on network requests. This dataset encapsulates details regarding bandwidth and the types of services operational in diverse network segments. It stands as a pivotal source for comprehending the utilization of network resources and the distribution of traffic load by various service types across network segments. Analyzing the "Usage Data" offers profound insights into network usage, aids in capacity planning, and supports decision-making concerning resource optimization and overall network performance enhancement. The distinction between uplink and downlink lies in the direction and destination of requests, with uplink involving requests from lower to higher levels, and downlink operating in the opposite direction. Furthermore, an elucidation of the column descriptions for both Uplink and Downlink data is provided in Table 3.

Table 3. Uplink and Downlink Column Explanation

Column Name	Data Type	Description
froma	string	This column represents the starting point of network traffic, providing information about the source of data movement within the system
tob	string	This column represents the endpoint of the network traffic, giving an idea of the destination or destination of the data in the network
service	categorical	This describes the type of service using the network link, such as retail, mobile, wholesale, and ebis services.
bandwidth	integer	This quantifies the amount of bandwidth used in each link, which is essential for assessing the load and capacity utilization of the network.

Uplink

The Uplink dataset encompasses requests from lower to higher levels, specifically focusing on those originating from lower-level nodes and directed towards higher-level nodes in the network hierarchy. A sample of the Uplink data is presented in Table 4.

Table 4. Sample Uplink Data

froma	tob	service	bandwidth
NE1-00-MGO-3	CN_Iptv	RETAIL	82
NE1-00-ABU-2DSU	CN_Netflix	EBIS	12
NE1-00-ABT-3	CGW-.BDS	WHOLESALE	35
NE1-00-SAR-5	CN_Google	MOBILE	16
NE1-02-KNN-3	CGW-.MDO	MOBILE	162

Downlink

The Downlink dataset encompasses requests from higher to lower levels, specifically focusing on those originating from higher-level nodes and directed towards lower-level nodes in the network hierarchy. A sample of the Downlink data is presented in Table 5.

Table 5. Sample Downlink Data

froma	tob	service	bandwidth
CGW2-.BTC	NE1-00-ABT-3	RETAIL	82
CN_Netflix	NE1-00-ABU-2DSU	EBIS	35
CGW-.BDS	NE1-00-ABT-3	WHOLESALE	105
CN_Google	NE1-00-SAR-5	MOBILE	48
CGW-.MDO	NE1-02-KNN-3	MOBILE	487

Data Preprocessing

Data preprocessing is a critical step in the analysis process, particularly in network optimization studies. This chapter details the procedures undertaken to prepare the Network Infrastructure Data and the Usage Data for effective utilization in the ant colony optimization algorithm for network topology and capacity management.

Duplicate Data Filtering

This process is designed to filter the data under investigation or analysis, mitigating the risk of duplication within the dataset. Throughout this procedure, searches are conducted for comparable data entities within the dataset. If similar records are identified, one of them will be eliminated. The outcomes of filtering duplicate data in Table 6 are presented below.

Table 6. Filtering Data Result

Filtering Data Results	
Before	9900 rows
After	6138 rows

With reference to Table 6, before implementing the data screening process, there were a total of 9900 reviews in the dataset. However, after going through the filtering stage, the number of reviews was reduced to 6138, following the deletion of 3762 data.

Missing Value Handling

In the cost column, numerous entries were observed to be null or missing. Given the focus of the study on network topology and capacity rather than cost analysis, these null values were considered zero and hence not subject to cost imputation.

Table 7. Missing Value Handing Result

froma	tob	totalkap	cost
NE1-00-MGO-3	NE2--MGO	30	0
NE2--MGO	NE2-9-KBL	100	60000
NE2-9-KBL	NE2-9-RKT	500	10
NE2-9-KBL	NE34-KBL-TRANSIT	120	0
NE2-9-KBL	NE32-KBL-VPN	110	0
NE2-9-RKT	NE32-RKT-VPN	82	0
NE32-RKT-VPN	P-RKT	20	0
P-RKT	NE34-KBL-TRANSIT	10	65535
NE34-KBL-TRANSIT	NE2-9-KBL	66	0
NE34-KBL-TRANSIT	NE2-8-KBL	40	0
NE2-8-KBL	NE32-KBL-VPN	11	0
NE32-KBL-VPN	CN_Iptv	110	0

From Table IV.2.2.1, the paths from NE1-00-MGO-3 to NE2--MGO, NE2-9-KBL to NE34-KBL-TRANSIT, NE2-9-KBL to NE32-KBL-VPN, NE2-9-RKT to NE32-RKT-VPN, NE32-RKT-VPN to P-RKT, NE34-KBL-TRANSIT to NE2-9-KBL, NE34-KBL-TRANSIT to NE2-8-KBL, NE2-8-KBL to NE32-KBL-VPN, and NE32-KBL-VPN to CN_Iptv, the cost is NULL. Subsequently, the NULL values will be replaced with a value of 0.

Data Scaling

Data scaling within the "relationlink" dataset is indispensable owing to the inherent disparity in the units utilized for the "uplink" and "downlink" data. While the "relationlink" dataset employs Gbps (Gigabits per second) as its standard unit of measurement, the "uplink" and "downlink" data are denoted in Mbps (Megabits per second). Consequently, harmonizing these units becomes imperative to facilitate a cohesive and uniform interpretation of the dataset. By aligning the units to a common standard, such as converting Gbps to Mbps through a multiplication factor of 1000.

Table 8. Data Scaling Result

froma	tob	totalkap	cost
NE1-00-MGO-3	NE2--MGO	30000	0
NE2--MGO	NE2-9-KBL	100000	60000
NE2-9-KBL	NE2-9-RKT	500000	10
NE2-9-KBL	NE34-KBL-TRANSIT	120000	0
NE2-9-KBL	NE32-KBL-VPN	110000	0
NE2-9-RKT	NE32-RKT-VPN	82000	0
NE32-RKT-VPN	P-RKT	20000	0
P-RKT	NE34-KBL-TRANSIT	10000	65535
NE34-KBL-TRANSIT	NE2-9-KBL	66000	0
NE34-KBL-TRANSIT	NE2-8-KBL	40000	0
NE2-8-KBL	NE32-KBL-VPN	11000	0
NE32-KBL-VPN	CN_Iptv	110000	0

Data Merging

Merging data is a crucial step in the analysis process because the "Uplink" and "Downlink" datasets refer to the same request in the context of the network. Without merging, the risk of inappropriate prioritization may arise during the optimization process. This merger ensures that data from both sources is brought together coherently, allowing uniform handling of network requests. By aggregating data, we can avoid bias in the optimization process and ensure that all types of requests, both from uplinks and downlinks, are treated in a balanced manner.

Table 9. Data Merging Result

froma	tob	service	bandwidth
NE1-00-MGO-3	CN_Iptv	RETAIL	27
NE1-00-ABU-2DSU	CN_Netflix	EBIS	12
NE1-00-ABT-3	CGW-.BDS	RETAIL	35
NE1-00-SAR-5	CN_Google	MOBILE	16
CN_Iptv	NE1-00-MGO-3	RETAIL	82
CN_Netflix	NE1-00-ABU-2DSU	EBIS	35
CGW-.BDS	NE1-00-ABT-3	WHOLESALE	105
CN_Google	NE1-00-SAR-5	MOBILE	48

Graph Structure

Using the Network Infrastructure Data, a directed graph was constructed to represent the network topology. Each row in the dataset corresponds to a link in the graph, with attributes like capacity and cost.

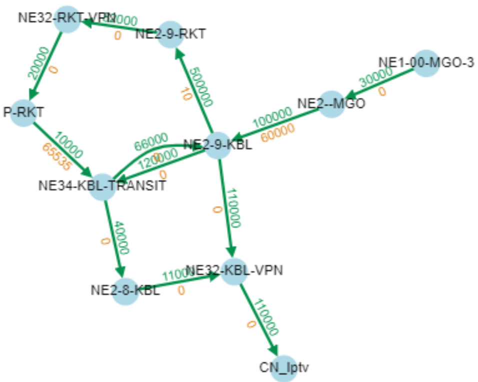

Figure 3. Graph structure of a topology subset

In Figure 3 you can see the graph structure of a topology subset. Each node has a unique name. Between the two nodes, there is a link that indicates the direction of movement of traffic. In addition to providing information about directions, the link also lists the total capacity marked in green if the capacity has never been used or has a usage of 0%. If the usage capacity reaches 90%, the link will be red. In addition to information about capacity, there is also cost information written in orange.

Optimization

Optimization refers to the process of improving or optimizing performance, efficiency, or resources in a network. The main goal of network optimization is to achieve better or optimal conditions to meet needs, minimize costs, or improve operational efficiency.

Get Available Path

The function to obtain available paths has a crucial role in the network optimization process. In this context, the use of certain algorithms, such as the Simple Path method, becomes crucial to determine the optimal path between the 'froma' (origin) node and the 'tob' (destination) node. Note that the Simple Path method takes into account certain constraints, where the resulting path should not be looped. For example, if it has passed a node on the path, it is not allowed to pass the same node again, because this is considered looping. To understand more, it is important to know the available paths from NE1-00-MGO-3 to CN_Iptv by paying attention to the restrictions imposed by the Simple Path method.

1. Route 1 is NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv is the initial path that can be taken. This path does not loop, so it can be referred to as a simple path.

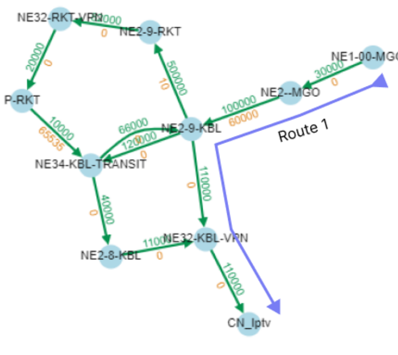

Figure 4. Route 1

2. Route 2, which consists of NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv, serves as the alternative path. This route maintains a non-looping trajectory, thus qualifying as a simple path. Route 2 is chosen when Route 1 experiences congestion, particularly on the link connecting NE2-9-KBL and NE32-KBL-VPN.

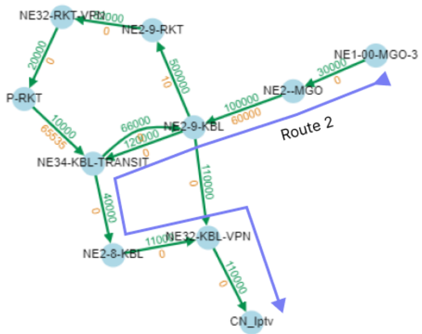

Figure 5. Route 2

3. Route 3, which consists of NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv, serves as the alternative path. This route maintains a non-looping trajectory, thus qualifying as a simple path. Route 3 is chosen when Route 2 experiences congestion, particularly on the link connecting NE2-9-KBL to NE32-KBL-VPN and NE2-9-KBL to NE34-KBL-TRANSIT.

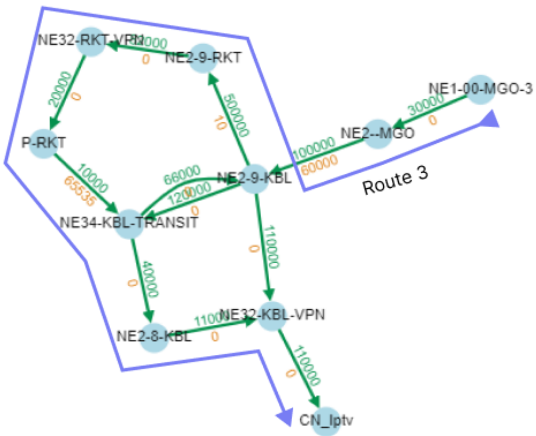

Figure 6. Route 3

4. Route 4, which consists of NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-CTR, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-9-KBL, NE32-KBL-VPN, and CN_Iptv. This route cannot be used because there is looping on the NE2-9-KBL node, so it is not included in the simple path because it violates the looping rules. So, this route cannot be said to be a simple path and alternative route. Therefore, this path will not be included in the available path.

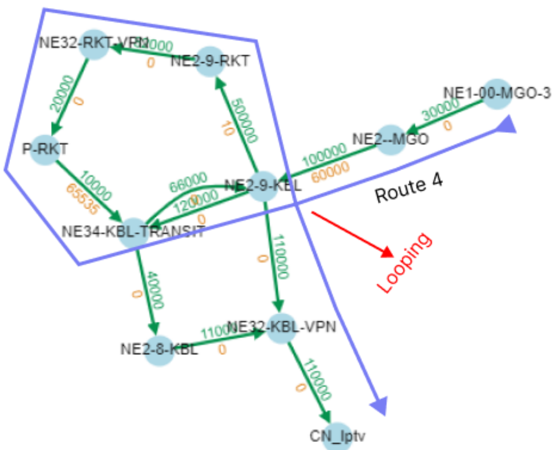

Figure 7. Route 4

Routing Optimization

After obtaining the available paths, routing optimization occurs, prioritizing services by type: mobile, wholesale, ebis, and retail. The paths obtained through the simple path method are then sorted based on length and total cost, followed by sorting based on total_path count, from smallest to largest.

1. Service Type

   Prioritizing based on service type is the main step to be taken because the order of services from mobile, wholesale, ebis, and retail is regulated as a policy by PT XYZ.

Table 10. Prioritize Service Types

Before				
froma	**tob**	**Service**	**path**	**total_path**
NE1-00-MGO-3	CN_Iptv	RETAIL	[[NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv]]	3
NE1-00-ABU-2DSU	CN_Netflix	EBIS	[['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix'], ['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-TRANSIT', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix']]	2
NE1-00-ABT-3	CGW-.BDS	RETAIL	[['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS'], ['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS']]	2
After				
froma	**tob**	**Service**	**path**	**total_path**
NE1-00-ABU-2DSU	CN_Netflix	EBIS	[['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix'], ['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-TRANSIT', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix']]	2
NE1-00-MGO-3	CN_Iptv	RETAIL	[[NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv]]	3
NE1-00-ABT-3	CGW-.BDS	RETAIL	[['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS'], ['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS']]	2

As observed in Table 10, There has been a change in data, by categorizing by service type. Priority is allocated to ebis services, reflecting the strategic emphasis on this category of services, followed by retail services. This categorization is in line with the protocol established at PT XYZ, where services are sorted systematically, starting with mobile services, followed by wholesale, ebis, and finally retail services.

2. Path
   Route planning by prioritizing the order from shortest to longest is an optimization strategy that provides advantages in the initial inspection of shorter routes, facilitating quicker decision-making and potentially reducing computational complexity. Additionally, arranging routes based on their length, complemented by sorting based on cost values from lowest to highest, constitutes a fundamental step aimed at optimizing resource allocation and minimizing cost usage. This meticulous process not only ensures the selection of routes that are short and direct but also economically viable, thereby enhancing the overall efficiency and robustness of the network infrastructure.

Table 11. Prioritize Path and Cost

froma	tob	Service	path	total_path
Before				
NE1-00-ABU-2DSU	CN_Netflix	EBIS	[['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix'], ['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-TRANSIT', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix']]	2
NE1-00-MGO-3	CN_Iptv	RETAIL	[[NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv]]	3
NE1-00-ABT-3	CGW-.BDS	RETAIL	[['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS'], ['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS']]	2
After				
froma	**tob**	**Service**	**path**	**total_path**
NE1-00-ABU-2DSU	CN_Netflix	EBIS	[['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix'], ['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-TRANSIT', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix']]	2
NE1-00-MGO-3	CN_Iptv	RETAIL	[[NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv]]	3
NE1-00-ABT-3	CGW-.BDS	RETAIL	[['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS'], ['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS']]	2

Noted in Table 11, there is a change in the line from NE1-00-MGO-3 to CN_Iptv because sorting is based on the length of the line and the total cost of each line. For lines through NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, and NE32-KBL-VPN have a path length of 6 with a total cost of 60000. Meanwhile, the line through NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, and CN_Iptv has a line length of 5 with a total cost of 60000. Finally, the path through NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv has a path length of 10 for a total cost of 125545. From the description, it can be concluded that a line with a length of 5 will take precedence, followed by a line with a length of 6 and the same total cost, and the last is a line with a length of 10 and a total cost of 125545.

3. Total Path
   Similar to routing based on length and cost, this step involves structuring routes according to their total length. Routes with shorter total lengths are prioritized, ensuring efficient data packet delivery, while longer routes undergo handling at the final stage to address complexities and potential congestion points.

Table 12. Prioritize Total Path

After				
froma	**tob**	**Service**	**path**	**total_path**
NE1-00-ABU-2DSU	CN_Netflix	EBIS	[['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix'], ['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-TRANSIT', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix']]	2
NE1-00-MGO-3	CN_Iptv	RETAIL	[[NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv]]	3
NE1-00-ABT-3	CGW-.BDS	RETAIL	[['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS'], ['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS']]	2
After				
froma	**tob**	**Service**	**path**	**total_path**
NE1-00-ABU-2DSU	CN_Netflix	EBIS	[['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix'], ['NE1-00-ABU-2DSU', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-TRANSIT', 'P-KBL', 'NE3-KBL-VPN', 'NE2-4-KBL', 'NE3-KBL-HSI', 'CN_Netflix']]	2
NE1-00-ABT-3	CGW-.BDS	RETAIL	[['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE32-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS'], ['NE1-00-ABT-3', 'NE2--ABT', 'NE2-2-SMP', 'NE2-9-RKT', 'NE3-RKT-VPN', 'P-RKT', 'P-D1-BDS', 'CGW-.BDS']]	2

After				
NE1-00-MGO-3	CN_Iptv	RETAIL	[[NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE32-KBL-VPN, CN_Iptv], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN], [NE1-00-MGO-3, NE2--MGO, NE2-9-KBL, NE2-9-RKT, NE32-RKT-VPN, P-RKT, NE34-KBL-TRANSIT, NE2-8-KBL, NE32-KBL-VPN, and CN_Iptv]]	3

Noted in Table 12, the route from NE1-00-ABT-3 to CGW-. BDS is prioritized because it has 2 total_path, while the route from NE1-00-MGO-3 to CN_Iptv has 3 total_path.

Congest Scenario

The accumulated bandwidth from point NE2-9-KBL to point NE32-KBL-VPN reaches a total of 10972, so if there is a request, the path will be impassable because the request exceeds the total available bandwidth. This causes the path from NE2-9-KBL to NE32-KBL-VPN to become congested. For example, if a request from NE1-00-MGO-3 goes to CN_Iptv with bandwidth 82 it will go through the NE2-9-KBL line to NE32-KBL-VPN as the shortest path. However, the bandwidth required is 82 while the available is only 28. Therefore, it needs to be diverted to an alternative line because the main line is congested.

Rerouting

As described in the Congest Scenario, when congestion occurs, it is necessary to reroute using the available alternative paths, as shown in Figure 8. In this specific instance, congestion manifests along Route 1, particularly at the connection juncture between NE2-9-KBL and NE32-KBL-VPN. Hence, the implementation of rerouting becomes indispensable, necessitating the utilization of Route 2 as an alternative pathway to ensure uninterrupted data transmission and mitigate the effects of congestion.

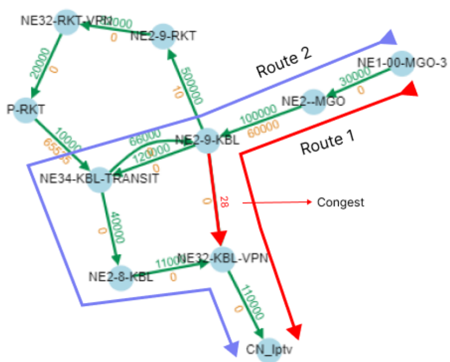

Figure 8. Rerouting if route 1 is congest

In flowchart optimization, the initiation uses a simple path algorithm to get all available paths with optimized available paths and with simple path constrain. After that, the path will be looping, the first iteration will check the path is available to use and the capacity is bigger than bandwidth. If yes, then the path is the first iteration. If no, it will check if is there any alternative route, if yes then it will check again the capacity. If no, then no path can used for the request. Here is a flowchart of the procedure to follow when congestion occurs in the network.

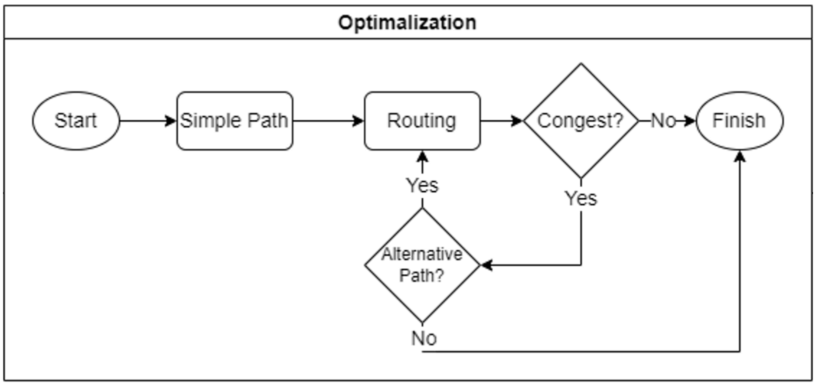

Figure 9. Flowchart optimization

Design User Interface

User interface design plays a crucial role in DSS methodology, where user interface design assists users in the decision-making process. This is in line with the function of the DSS which assists in decision making. The user interface design also serves as a report that can be utilized by users. In other words, user interface design is key to making it easier for users to understand, explore, and make decisions based on the information provided by the system.

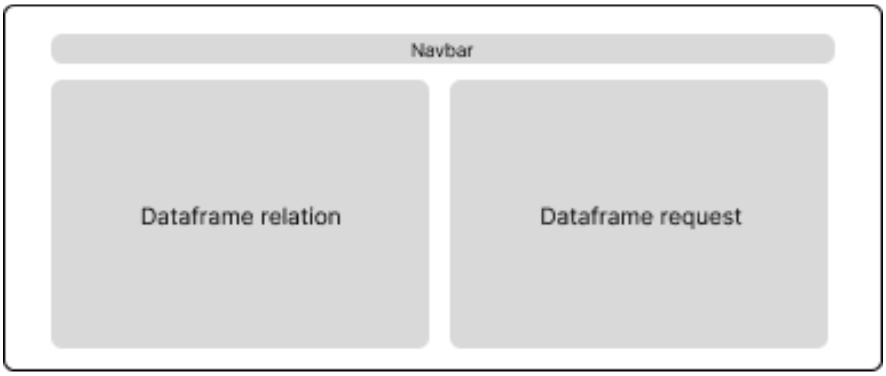

Figure 10. Database wireframe

The start page of the user interface is an interface that displays the databases available in the system. This page displays the datasets used, such as relationship data and data requests. At this stage, users can see directly information about data relationships and data requests that are the basis for decision making. It allows users to quickly explore relevant dataset content and understand the information structures that can be used to support decision processes.

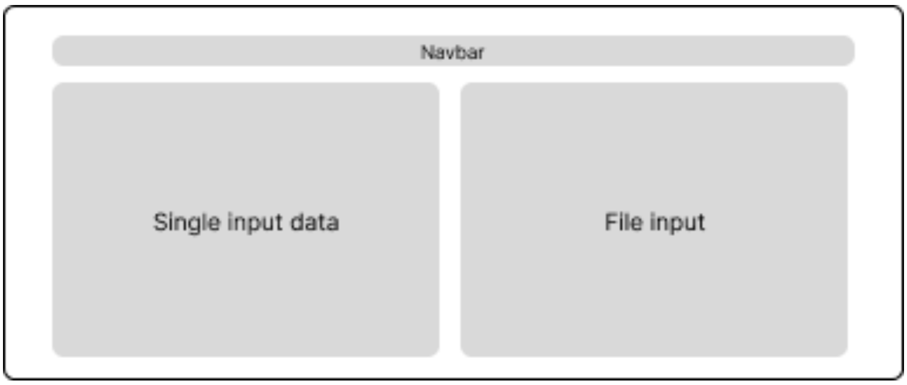

Figure 11. Action wireframe

Furthermore, on the action page, the user can decide or action. This page gives users the ability to add new requests, either individually or in bulk. When adding a new request, the user is given the option to carry out the process manually or automatically. If users choose the manual approach, they can choose an available and walkable path. Conversely, if the automatic option is selected, the decision will be executed automatically by the system. Thus, the action page becomes a focal point for users to take concrete steps in support of the decision-making process.

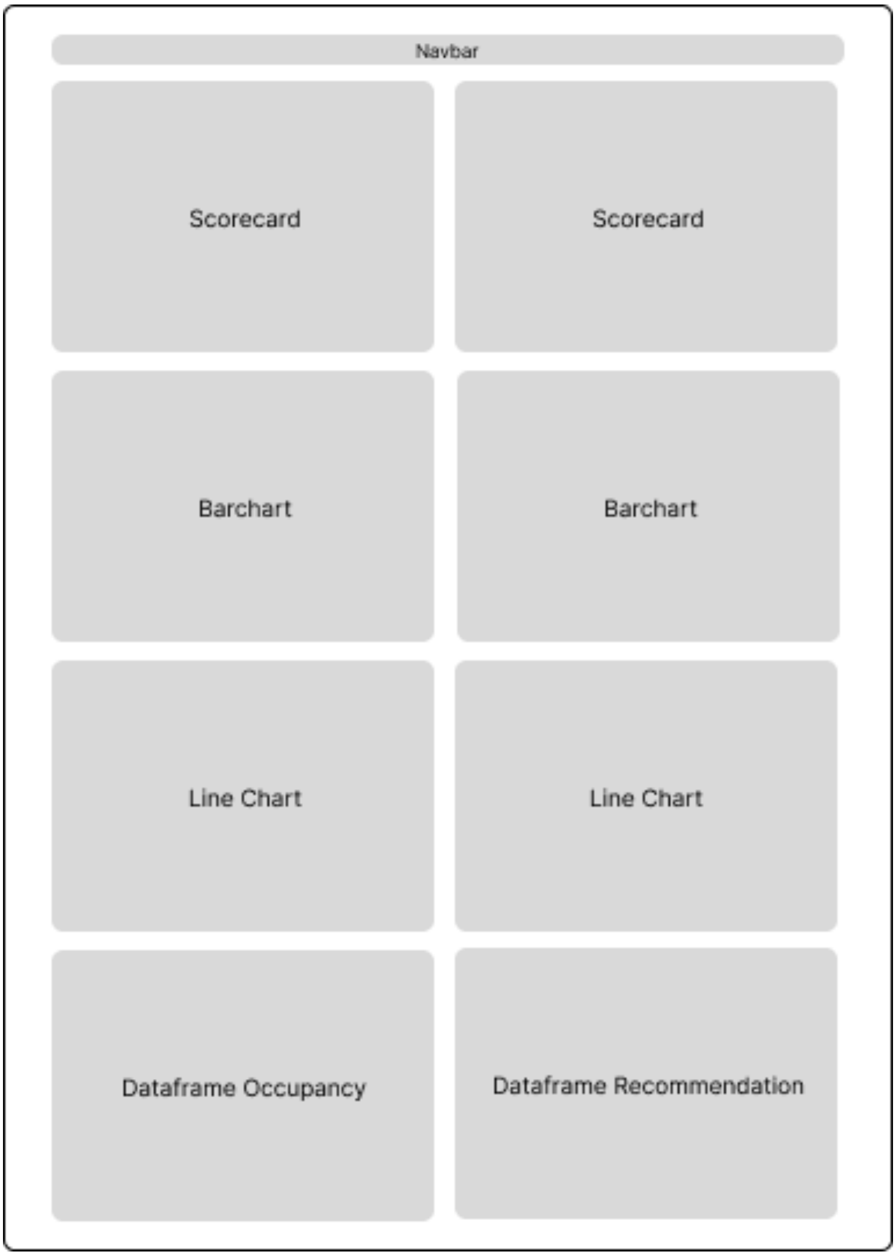

Figure 12. Dashboard wireframe

The Dashboard page is also important to provide a brief overview of the actual situation that are happening. In addition, the Dashboard also provides various graphs that visualize the data clearly. In this case, the included graphs include score cards, barcharts, linecharts, dataframe occupancy, and dataframe recommendations. With the Dashboard, users can quickly understand the overall information and make the right decisions based on the visualization of the data presented.

Measurement

Furthermore, calculations are made using packet delivery ratio and packet loss metrics. This process involves several stages, including calculating the percentage of delivery success and package failure for each request. An example calculation is performed for requests from NE1-00-MGO-3 to CN_Iptv, which will be routed according to the network conditions described in the congestion scenario, with a total of three routes available. The following is the result of calculating packet delivery rate and packet loss.

1. Calculations on the first route

$$packet\ delivery\ ratio = \frac{0}{82} \times 100\% = 0\%$$

$$packet\ loss = \frac{82-0}{82} \times 100\% = 100\%$$

When the packet delivery ratio is 0% and the packet loss is 100%, it signifies a scenario where none of the data packets sent from the source successfully reach their intended destination. This indicates a complete failure in data transmission along the initial route. In practical terms, it means that no information or communication can be effectively conveyed between the source and destination nodes using the primary path due to congestion or network failure. In such circumstances, having alternative routes becomes crucial for maintaining connectivity and ensuring that data can still be transmitted despite the failure of the primary route. Alternative routes provide backup paths that bypass congested or malfunctioning segments of the network, allowing data packets to reach their destination even when the primary route encounters issues.

1. Calculation on the second route or alternative route

$$packet\ delivery\ ratio = \frac{82}{82} \times 100\% = 100\%$$

$$packet\ loss = \frac{82-82}{82} \times 100\% = 0\%$$

When nodes become impassable and congestion arises, the packet delivery rate drops to 0%, and packet loss surges to 100% due to congestion on some links in route 1. Specifically, the capacity between NE2-9-KBL and NE32-KBL-VPN is only 18, while the required bandwidth is 82. Such a scenario severely undermines network performance. Hence, rerouting becomes imperative. Following rerouting, the outcome is a significant improvement: the packet delivery rate increase to 100%, and packet loss decrease to 0%.

Test Scenario

Tests are carried out to measure the performance of the system that has been developed by ensuring that the inputs produce output according to needs. The purpose of this test is to measure and evaluate the performance of the system that has been implemented.

Table 13. Test Scenario

Scenario	Bandwidth	Total Link	Length Link	Cost
Scenario 1		Dijkstra		
Scenario 2	X	X	X	X
Scenario 3	Ascending	X	X	X
Scenario 4	Descending	X	X	X
Scenario 5	Ascending	Ascending	X	X
Scenario 6	Descending	Ascending	X	X
Scenario 7	Ascending	Ascending	Ascending	Ascending
Scenario 8	Descending	Ascending	Ascending	Ascending

Conclusion

Based on the results of the final project research that has been carried out, the following conclusion formulation is obtained; (1) the results of network optimization testing using the Dijkstra algorithm and Simple Path show that Simple Path consistently provides far superior performance than Dijkstra. Overall, Simple Path managed to increase packet delivery by 3 times and reduce packet loss by half compared to Dijkstra. Further analysis also revealed that Simple Path's advantages are not only limited to the overall level, but are also seen in every type of service, including mobile, wholesale, ebis, and retail. This shows that Simple Path has significant potential to improve overall network performance across multiple service contexts, (2) the implementation of Simple Path has a positive impact on overall network performance. Simple Path has consistently shown a significant increase in package delivery, with 58.54% of packages successfully delivered, as well as a 41.46% reduction in packet loss. In addition, the use of Simple Path also opens opportunities for the use of alternative routes, as evidenced by as many as 804 or about 24% of total requests using alternative routes. Thus, Simple Path not only improves the efficiency of packet delivery but also increases flexibility in network route management, which can ultimately optimize overall network performance, and (3) several challenges faced in network management, especially related to occupancy rates and package delivery failures. From testing, it was identified that as many as 12 links had an occupancy rate above 90%, indicating a congested state on these links. Furthermore, there is one main link that is the main cause of package delivery failure, namely NE2-4-KBL to NE3-KBL-HSI which causes as many as 2726 requests, or about 70.6% of the total requests that fail to be sent. Analysis using Simple Path also showed that 11093 routes, or about 46% of the total failed requests, went through this link.

BIBLIOGRAPHY

Cardwell, N., Jacobson, V., Cheng, Y., Yeganeh, S.H., Vasiliev, V., Swett, I., Jha, P., Seung, Y., & Wetherall, D. (2019). Model-based Network Congestion Control.

Databoks. Pusat Data Ekonomi dan Bisnis Indonesia. (2022, March 23). https://databoks.katadata.co.id/datapublish/2022/03/23/ada-2047-juta-pengguna-internet-di-indonesia-awal-2022

Firdausi, A. (2022). Pengoptimasian Traffic pada Jaringan Wide Area Network Menggunakan Application Aware Routing Berbasis SD-WAN. InComTech: Jurnal Telekomunikasi dan Komputer.

Lakutu, N.F., Mahmud, S.L., Katili, M.R., & Yahya, N.I. (2023). Algoritma Dijkstra dan Algoritma Greedy Untuk Optimasi Rute Pengiriman Barang Pada Kantor Pos Gorontalo.

Ngafifi, M. (2014). Kemajuan Teknologi Dan Pola Hidup Manusia Dalam Perspektif Sosial Budaya.

Priyatna, I.K., Marsudi, M., & Rahadjeng, E.R. (2023). The Effect of Service Quality and Price on Purchasing Decision of Telkomsel Internet Services in Indonesia.

Ruth, E. (2015). Deskripsi Kualitas Layanan Jasa Akses Internet di Indonesia dari Sudut Pandang Penyelenggara.

Salman, S., Ginting, J.G., & Wahyuningrum, R.D. (2021). Analisis Unjuk Kerja TCP Window Size 64k Menggunakan Algoritma TCP New Reno pada Jaringan Wired dan Wireless.

Siddik, M., Lubis, A.P., & Sahren, S. (2023). Optimalisasi Kecepatan Jaringan Internet Pada Mts Daarussalam Menggunakan Metode Simple Queue.

Simon Kemp. (2022). DATAREPORTAL

Sina, G.O., Amsikan, S., & Salsinha, C.N. (2021). Pengaruh Penggunaan Jaringan Internet Pada Pembelajaran Daring Dan Minat Belajar Terhadap Hasil Belajar Mahasiswa.

Su, Z., Zhang, J., & Lü, Z. (2019). A Multi-Stage Metaheuristic Algorithm for Shortest Simple Path Problem with Must-Pass Nodes. doi: 10.1109/ACCESS.2019.2908011.

Szele, A., & Kisgyörgy, L. (2018). Traffic operation on a road network with recurrent congestion. WIT Transactions on the Built Environment, 179, 233-244.
Zhou, W., Huang, H., Hua, Q., Yu, D., Jin, H., & Fu, X. (2021). Core decomposition and maintenance in weighted graph. World Wide Web, 1-21.
Zulkifli. (2014). Kecepatan Akses Layanan 3.5G Telkomsel Flash Yang Digunakan Untuk Koneksi Internet.