

Artificial Intelligence Network Construction Analysis in Rural Areas for FTTX Equal Distribution Model of Internet Access

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Abstract — Access to reliable and high-speed internet is a fundamental necessity in today's era of globalization, driving socioeconomic progress and global connectivity. The quality and reliability of internet networks are significantly influenced by the processes of construction and maintenance. This study introduces an AI-driven analysis for intelligent network construction to develop a Fiber-to-the-X (FTTX) distribution model that ensures equitable internet access in rural areas. The research focuses on the Ngabang region in West Kalimantan, detailing the construction of optical distribution cabinets (ODC) and optical distribution points (ODP) in November 2022, alongside performance testing conducted in December 2022. This paper leverages artificial intelligence (AI) techniques, to identify and optimize key factors affecting network deployment and scalability in rural regions. In addition, the network development process is evaluated using AI-Driven Algorithm (Time series forecasting) , Health, Safety, and Environment (HSE) compliance, and alignment with Sustainable Development Goals (SDGs). The results demonstrate that the construction quality and port attenuation test parameters meet ITU-T.G657 and ITU-T.G984 standards. This framework provides actionable insights for policymakers and stakeholders, facilitating the bridging of the digital divide in underserved areas while advancing sustainable development initiatives.

Keywords — Artificial Intelligence, FTTX distribution model, Network construction quality, Rural internet access, Sustainable Development Goals (SDGs)

I. INTRODUCTION

With a population of over 282 million in 2024, Indonesia has the fourth-highest internet usage ratio in the world. Indonesia has 221 million internet users, or 79.5 percent of the country's population, according to data from the 2023 Central Statistics Agency and the 2024 Indonesia Internet Profile report, which was released by the Association of Indonesian Internet Service Providers (APJII). This marks an increase from the previous period, which recorded 73.7 percent (196.71 million users), while in 2018, the internet penetration rate was only 64.8 percent (171.17 million users) [1]. Over 75% of all internet users in Indonesia are mobile users, making it one of the fastest-growing internet markets in the world [2]. The number of internet users in Indonesia has increased significantly in recent years and is expected to keep growing.

As of Q3 2023, global broadband subscription trends showed that fixed broadband connections reached 1.42 billion, reflecting a 1.6% growth compared to the previous quarter. East Asia dominates the market, accounting for approximately 49.96% of global broadband users, with China being the largest contributor. Africa recorded the fastest

growth rate at 2.6%, highlighting significant opportunities for future expansion in the region. Additionally, the adoption of FTTH (Fiber to the Home) or FTTB (Fiber to the Building) rose to 68.3%, while older technologies such as copper and cable continued to decline [3].

The Global Telecommunications Outlook for 2023-2027 highlights the evolving landscape of the telecommunications sector, driven by increasing consumer demand and rapid technological advancements. It is anticipated that there will be 25.1 billion IoT devices by 2027, up from 16.4 billion in 2022, offering telecom operators substantial growth prospects. Furthermore, video content is anticipated to play a major role in data consumption, with forecasts suggesting it will represent 79% of total data usage by 2027 [4]. In Indonesia, the telecommunications sector demonstrates a promising outlook, with a planned CAPEX allocation amounting to 22% of total revenue. This investment will prioritize the expansion of mobile services, fixed broadband, data centers, cloud computing, and infrastructure development, strategically positioning the industry for continued growth and enhanced performance [5].

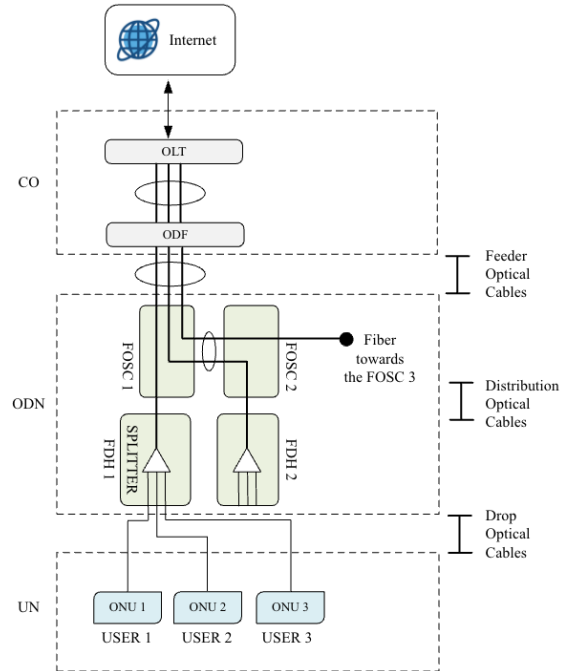


Fig. 1. System Deployment

One of the contributing factors to the rise in internet users is the Indonesian government's intensified efforts to advance the telecommunications sector over the past three years, particularly in 3T (frontier, remote, and underdeveloped) areas. To expedite the national digital transformation strategy, the government has delineated five major initiatives. These include accelerating the development of internet services and digital infrastructure, developing a roadmap for digital transformation for key industries, integrating national data centers more quickly, developing digital talent and skills, and putting in place financial and regulatory frameworks to support a strong digital ecosystem.[6]. Law Number 17 of 2007 (UU No. 17 Tahun 2007) regarding the 2005-2025 National Long-Term Development Plan (RPJPN) outlines four stages for implementing the National Medium-Term Development Plan (RPJMN) [7]. During the final phase of the RPJPN, which is the 2020-2024 RPJMN, Presidential Regulation Number 18 of 2020 (Perpres No. 18 of 2020) emphasizes accelerating progress across various sectors. One key area of focus is the development of digital infrastructure, aiming to establish a robust economic structure [8].

The contribution of this paper is to develop innovative solutions for internet network construction in rural areas through an artificial intelligence (AI)-driven approach. It introduces a Fiber-to-the-X (FTTX) distribution model designed to ensure equitable and reliable internet access, with a case study in Ngabang, West Kalimantan. AI techniques are employed to identify and optimize key factors affecting network development and scalability, providing efficient solutions to infrastructure challenges in underserved regions. The quality tests demonstrate that the network construction and port attenuation parameters comply with international standards ITU-T.G657 and ITU-T.G984, ensuring the reliability and compatibility of the deployed network.

Additionally, the study integrates principles of AI-Driven Algorithm, Health, Safety, and Environment (HSE) standards, and evaluating the network development process. This approach not only emphasizes technical aspects but also aligns with the SDGs, thereby delivering broader social and environmental impacts. By offering a practical framework for, the research helps bridge the digital divide in underserved regions while advancing global sustainability initiatives. With real-world implementation involving the construction of Optical Distribution Cabinets (ODC) and Optical Distribution Points (ODP), as well as measurable performance testing, this framework is positioned for broader application and scalability.

II. TELECOMMUNICATION SYSTEMS AND CONSTRUCTION INTERNET NETWORK

A. Telecommunications Network Construction

Telecommunication network construction involves several stages: planning, design, installation, testing, and operation. The process begins with planning, which includes analyzing network requirements and detailed planning, such as selecting technology, cable types, network devices, and cable routes. Following planning, the design phase involves creating a detailed blueprint of the network, including technical specifications, cable lines, and the devices to be used. Once the design is approved, the installation phase begins, where cables and network devices are installed and tested to ensure optimal quality and performance. The testing

phase includes testing cables, network devices, and overall network performance, as well as reliability and security checks. After successful testing, the network is ready for use and enters the operation phase, where it is continuously monitored to ensure optimal performance and reliability. Regular maintenance is also carried out to keep the network functioning properly. This structured approach ensures that telecommunication networks are built efficiently and effectively, meeting all necessary standards and requirements. [21].

B. ODC and ODP testing

FTTH network construction testing is conducted to ensure that the network meets predetermined technical specifications and functions correctly. The tests include fiber optic cable testing, fiber optic welding testing, acceptability testing, noise testing, network capacity testing, and performance testing. These tests aim to guarantee network quality and ensure that the network provides reliable and satisfactory services for users. Once all tests are completed and the network is confirmed to function properly, it is ready to connect customers to the FTTH network. ODC and ODP are crucial components in fiber optic networks. Their development must adhere to established standards to function correctly within the network. This paper follows FTTH standards, specifically ITU-T G.984 and ITU-T G.657. These standards define the technical specifications for network components such as OLT, ONU, ODN, and fiber optic cables [22].

This specification provides guidance for suppliers and developers to ensure that their products comply with standards and can operate interoperably with other products adhering to the same standards. By implementing the established FTTH standards, it can guarantee that its FTTH network is of high quality and meets international benchmarks. This enables customers to enjoy fast and stable internet services through FTTH network. Constructing ODC and ODP according to these standards will ensure optimal network performance and maximum security.

III. METHOD

In this paper, the method for developing telecommunications networks begins with planning the development area, followed by tagging the locations of development requests to ensure the process is effective and meets customer needs. The next step involves the *aanwijzing* process, which includes examining the existing cable lines to be used and observing the placement of new cable lines for the construction process. After the *aanwijzing* process is completed, the results are analyzed and the link budget is calculated. If the results are not satisfactory, the *aanwijzing* process is reviewed. If they are satisfactory, the network development proceeds. Once construction is finished, a Commissioning Test is conducted to ensure the work meets standards and engineering principles. If the test results are unsatisfactory, the development team makes repairs and rechecks. If the results meet the established standards, the project moves to the acceptance test stage. During this stage, all work done by partners is submitted to the company. Once the network development is completed and tested, the internet access network can be activated (*go live*) and made available to the residents of Ngabang, West Kalimantan.

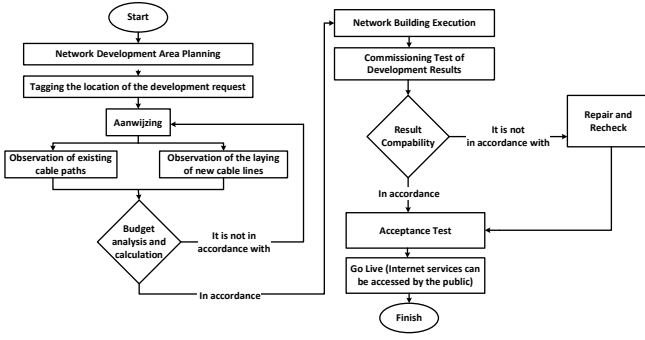


Fig. 2. Network development process flowchart

A. Design of ODC and ODP Development

The ODC and ODP development plan is a description of the location plan and configuration of ODC and ODP in a telecommunication network. In this paper, this map is made by network engineers or planners as a guide in building telecommunications networks. Some things that need to be considered in designing the ODC and ODP development maps include Locations, Types, Capacity, and Configurations. After designing the ODC and ODP development maps, engineers can start network construction and carry out tests to ensure network performance conforms to established specifications and standards. The development map that has been designed is as follow.

B. Aanwijzing Development of ODC and ODP

Aanwijzing ODC and ODP refer to technical instructions and guidelines that must be followed in building, installing and operating ODC and ODP in telecommunication networks. In this paper, the aanwijzing ODC and ODP are determined by the telecommunications service provider, to ensure that ODC and ODP are built and operated properly. Some of the things covered in the ODC and ODP aanwijzing include location requirements, physical specifications, cable installation, configuration and capacity, and testing and maintenance. The aanwijzing process is an essential step in the development of telecommunication networks because it guarantees that the equipment is constructed and run appropriately, taking into account the site and the company's criteria.

In the ODC aanwijzing process, a location survey was carried out at the ODC construction site which is located in the city of Ngabang. Laying the ODC and laying the position of the cable line from the OLT to the ODC is also taken into account so that it is in accordance with the standards and in accordance with HSSE rules so that it does not endanger both during pre-construction and post-construction. The aanwijzing process was also carried out for ODP development in the Buluh River area. In the aanwijzing process, planning and permits were carried out regarding the laying of 161 poles and 14 ODP for internet access to residents' homes, cable installation, and ODP capacity configuration was also calculated to suit the internet access needs needed by the community.

C. LSTM

The Long Short-Term Memory (LSTM) Neural Network was created with a special architecture to address the problem of long-term dependence. Unlike the traditional RNN, which

relies on a single hidden layer, LSTM incorporates a control unit that manages information flow separately from the main network, introducing a distinct state unit, C [25]. As illustrated in Fig. 10, LSTM divides the RNN's hidden state into two parts: memory cells (c_t) and working memory (h_t). The LSTM unit, depicted in Figure 3, acts as a memory cell that stores values. It is made up of an input gate, a forget gate, and an output gate that regulate the information that enters and leaves the cell.

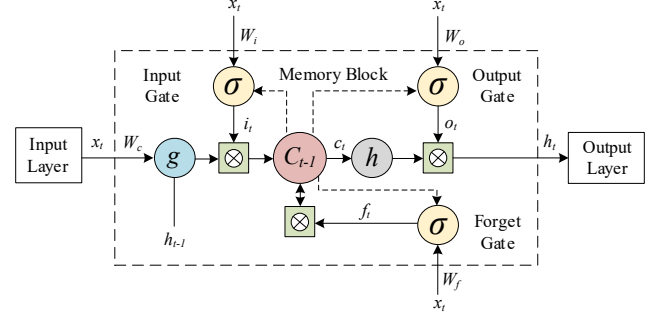


Fig. 3. LSTM Architecture

The hidden states of the memory cells are represented as $H = (h_1, h_2, \dots, h_t)$, the input time series as $X = (x_1, x_2, \dots, x_t)$, and the output time series as $Y = (y_1, y_2, \dots, y_t)$. T stands for the prediction period. In this context, X represents the historical flow data, and Y corresponds to the predicted flow. The primary goal of utilizing LSTM is to predict the flow at the next time step by leveraging prior sequence information. The information flow inside the hidden memory cell is controlled by the input gate (i_t), forget gate (f_t), and output gate (o_t).

The working memory (h_t) serves as the output, while the forget gate (f_t) controls how much of the prior sequence is retained. The portion of the current memory state (c_t) that is passed on is decided by the output gate (o_t). The input gate (i_t) regulates how much data is kept in the memory cells from the current input (x_t) and the prior hidden state (h_{t-1}). These gates function dynamically by combining the current input (x_t) and the prior state (h_{t-1}) via a linear transformation and a nonlinear activation function.

Implementing LSTM networks for intelligent network construction analysis in rural regions under a FTTH equal distribution model efficiently tackles the challenges of network deployment in underserved areas. By utilizing LSTM's strength in processing sequential data, this method enhances demand forecasting, resource allocation, and infrastructure planning.

IV. RESULT & DISCUSSION

In building a telecommunications network in the Ngabang area of West Kalimantan, several factors must be considered, including geographical location, population, internet needs, ethnicity, and culture. The region's challenging terrain, consisting of mountainous areas and forests, necessitates a well-designed network topology to ensure equal availability and quality of internet access. The diverse population density in the 3T area also requires an appropriate network topology. Additionally, the specific internet needs of the 3T area must be taken into account when selecting a telecommunication network topology, as different regions have varying requirements.

A. AI for Design and Planning FTTX

Rural FTTX network construction faces challenges such as uneven population density, limited infrastructure, and geographical barriers. These complexities necessitate advanced analytical models to ensure equal internet distribution. Data is a foundational element in this process, comprising historical network metrics (e.g., latency, bandwidth utilization), geographic and demographic details, and environmental factors such as weather conditions. Data preparation involves cleaning, normalization, and converting non-numerical data into a machine-readable format to create a robust dataset for LSTM input.

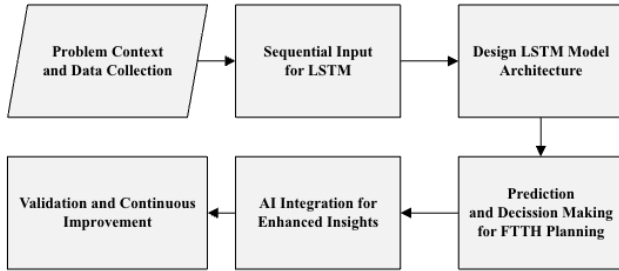


Fig. 4. AI Design for FTTX Planning

The LSTM network processes time-dependent data, making it ideal for analyzing network usage trends and forecasting future demands. Input sequences for the LSTM include temporal data such as bandwidth usage patterns, fiber installation progress, and spatial data like location-specific environmental influences. These sequential inputs enable the model to identify relationships between time, geography, and network performance, laying the groundwork for accurate predictions of network behavior.

B. Health and Safety and Environmental Protection

HSE is an important aspect that must be considered in the development of ODC and ODP in the Ngabang area, West Kalimantan. Some of the steps that need to be taken to ensure occupational safety and health as well as environmental protection during the construction process include ensuring that all workers involved in the construction process have been trained and have the necessary HSE certification. Then identify and analyze the hazards and risks associated with the construction process, such as fire hazards, electrical hazards, fall hazards, and others. Furthermore, establish safe work procedures and operating standards that apply during the development process.

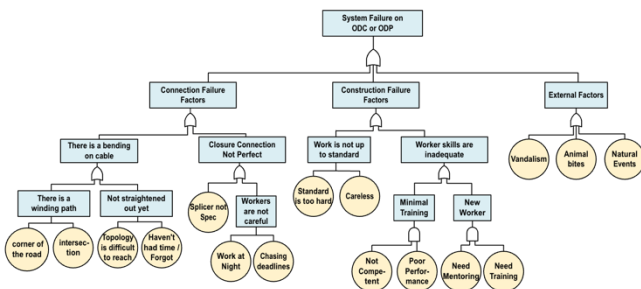


Fig. 5. FTA Network Development Process Flowchart

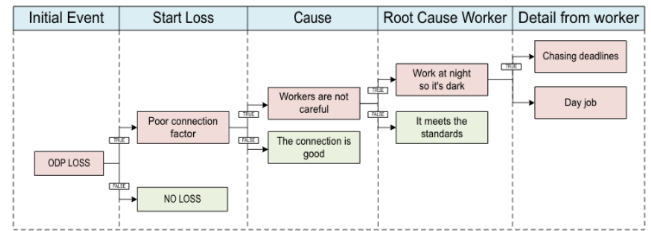


Fig. 6. Network Development Process ETA Flowchart

Fault Tree Analysis (FTA) is a failure analysis method used to identify and analyze possible failures of a system or process. FTA describes a cause-and-effect relationship between the failure of a system and the factors that influence that failure. In the construction of ODC and ODP, FTA can be used for K3L (Occupational Health and Safety and Environment) analysis by identifying the factors that cause accidents or disturbances to the environment that may occur during the construction and operational processes.

Event Tree Analysis (ETA) is a risk analysis technique used to identify, analyze, and evaluate possible events that may occur in a system. ETA is generally used to analyze risk on complex systems consisting of many elements, such as ODC and ODP construction systems. In ODC and ODP construction, ETA can be used to identify various possible events that may occur during construction.

C. Sustainable Development Goals

Linking the case study on network construction in 3T (frontier, remote, and underdeveloped) areas like Ngabang, West Kalimantan, with the Sustainable Development Goals (SDGs) is highly relevant, as internet access plays a crucial role in achieving various global goals. SDG 4: Quality Education, Internet access enables students in Ngabang to access information, online courses, and educational resources, helping to close the educational gap between 3T areas and urban regions. Teachers can access up-to-date teaching materials, and students can participate in online learning previously unavailable in the area.

SDG	Goal Description	Relevance to Network Construction in Rural Area
SDG 4: Quality Education	Ensure inclusive and equitable quality education.	Internet access enables students and teachers to access educational resources, online learning, and updated teaching materials, bridging educational gaps.
SDG 8: Decent Work and Economic Growth	Promote sustained economic growth, full employment, and decent work.	Internet connectivity empowers locals to enhance skills, start businesses, and connect to broader markets, fostering economic growth and job creation.
SDG 9: Industry, Innovation, and Infrastructure	Build resilient infrastructure and foster innovation.	Network construction strengthens technological infrastructure, drives digital transformation, and facilitates innovation in remote areas.
SDG 10: Reduced Inequalities	Reduce inequality within and among countries.	Internet access reduces disparities by improving access to healthcare, education, and social services, creating parity with urban areas.
SDG 17: Partnerships for the Goals	Strengthen global partnerships for sustainable development.	Collaboration among governments, telecom providers, and organizations supports network projects, aligning with the SDG partnership model.

SDG 8: Decent Work and Economic Growth, Internet access allows local residents to improve their skills, start digital-based businesses, and connect with wider markets. This can support the local economy by creating new job opportunities and business prospects in Ngabang, thus strengthening regional economic growth. SDG 9: Industry, Innovation, and Infrastructure, The internet network construction project in 3T areas supports technology infrastructure and strengthens innovation in remote areas. It facilitates digital transformation and collaboration with external partners that can drive locally-based innovation. SDG 10: Reduced Inequality, Internet access in 3T areas helps reduce disparities in access to information and services. With network connectivity, communities in Ngabang have increased access to healthcare, education, and social services, bringing them closer to equality with urban areas.

SDG 17: Partnerships for the Goals. Network construction projects in 3T areas often involve various stakeholders, such as government, telecommunications providers, and non-profit organizations. This collaboration aligns with the SDGs' goal of fostering multi-sector partnerships to achieve sustainable development. By building network infrastructure in regions like Ngabang, the government and partners can significantly contribute to improving local welfare and advancing the achievement of the SDGs.

V. CONCLUSION

This study on Intelligent Network Construction Analysis in Rural Areas for FTTH Equal Distribution Model of Internet Access demonstrates the potential of integrating advanced predictive models like LSTM with AI-driven methodologies to address the challenges of rural internet deployment. The method improves the precision of demand forecasting, route optimization, and resource allocation by examining both historical and current data, leading to the design of FTTH networks that are both economical and efficient. The findings align with industry standards such as ITU-T.G657 and ITU-T.G984, ensuring network reliability while supporting the goals of equitable internet access and sustainable development.

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