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Alternative Method for Calculating Service Level Agreements for Internet Access Services in Rural Areas

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Abstract

Indonesia faces significant challenges in providing equitable internet access, particularly in remote areas. To address these challenges, the government collaborates with private Internet Service Providers (ISPs) under Service Level Agreements (SLAs) that define key service metrics, such as uptime and response time. Network Management System A (NMS A), managed by the government, handles telecommunications infrastructure, while NMS B, operated by the private ISP, delivers the internet services. A critical challenge in assessing SLA performance is distinguishing between service disruptions caused by network issues and those caused by power outages. This study proposes an SLA calculation method that prioritizes uptime data from NMS A, reflecting the government's perspective. If NMS A's data is unavailable, UPS data is used as an alternative. NMS B's data is considered only if its correlation with NMS A is strong (≥0.6). Additionally, the study classifies downtime: link failures exceeding 300 seconds require compensation (restitution). Downtime less than or equal to 300 seconds is considered non-restitution, and no compensation is needed. Power outages are considered non-restitution events, as they stem from external factors beyond the service provider's control. This method has been tested in over 1,000 locations, proving its reliability and adaptability for fair, transparent SLA evaluations.

Keywords:

Rural Area;

Uptime;

Downtime;

Service Level Agreement;

UPS.

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1- Introduction

Indonesia, as an archipelagic country, faces significant challenges in providing equitable internet access, particularly in remote areas [1]. One of the government to bridge this gap involves offering free internet services through partnerships with private ISPs [2, 3]. In general, availability and reliability are the primary metrics used to evaluate the effectiveness of internet services provided by ISPs [4]. To facilitate efficient service distribution, the government appoints specific parties responsible for their implementation. Given the involvement of multiple stakeholders, a Service Level Agreement (SLA) is necessary to ensure that each party fulfills its responsibilities and that internet services meet the agreed-upon standards [5].

To facilitate the implementation of these services, the government has appointed NMS A as the entity responsible for service payments and telecommunications infrastructure development. NMS A collaborates with NMS B, the ISP tasked with delivering internet services and receiving payments from NMS A to extend internet access to rural areas [6]. The SLA between NMS A and NMS B defines critical aspects such as network uptime, minimum internet speed, response time to disruptions, and compensation mechanisms in case of non-compliance [7]. Additionally, NMS B must adhere to regulatory requirements, including business licensing and operational feasibility tests. The SLA aims to ensure reliable and stable services, supporting government initiatives to expand telecommunications access across Indonesia [8].

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However, reported discrepancies in SLA compliance have raised concerns regarding the accuracy of service payments. An interview with a government expert overseeing this service in 2016 revealed that payments for more than 100 locations were suspended. Each location incurred an operational cost of approximately Rp50,000,000 per month. At an exchange rate of 1 IDR = 0.0000603 USD, this equates to about $3,015 per month per location, or approximately $36,180 annually per location. These figures prompted questions regarding the validity of such payments. To ensure transparency and accuracy in billing, it is imperative to develop a robust SLA measurement methodology that can serve as a foundation for verifying and calculating restitution and non-restitution charges.

If the internet service provided by NMS B fails to meet SLA provisions, it indicates a disruption in internet connectivity. Consequently, the restitution mechanism is triggered, potentially affecting service payments. Therefore, the restitution decision-making requires swiftness, accuracy, and accountability to ensure fairness for all parties involved. In this context, SLA monitoring and evaluation are crucial in determining NMS B's compliance with the agreement [9]. SLA compliance is primarily measured using uptime, where the agreed uptime level determines the permissible downtime tolerance [10]. Additionally, SLA monitoring can be conducted using various network performance indicators such as ping, uptime, latency, and packet loss to assess network availability and power failures [11].

This study proposes both restitution and non-restitution methods to assess SLA compliance based on uptime data obtained from NMS A, NMS B, and UPS data to identify power failures. Under the restitution method, if the actual uptime (e.g., 98%) falls short of the promised level (e.g., 99.9%), compensation may be provided in the form of a billing reduction or additional service time [12]. Conversely, the non-restitution method does not impose direct financial penalties but requires the operator to restore service within a specified timeframe. Estimating the distribution of downtime over a service period is a prerequisite for accurately measuring service availability, which serves as the basis for determining compensation levels and necessary corrective actions [13]. Ultimately, uptime is not merely a technical parameter but a fundamental metric in SLA compliance, directly influencing the financial and operational aspects of service agreements. The restitution model ensures compensation for SLA breaches, while the non-restitution model prioritizes service restoration. Both approaches aim to balance NMS A's rights with NMS B's obligations in maintaining service performance, thereby fostering accountability and service quality in rural internet access programs.

Numerous studies have focused on calculating service levels based on availability, but the majority have been conducted for services in urban or well-developed regions, while numerous studies also describe service level calculations using the Ping method [14-16].

This study introduces a new approach for calculating the service level of internet access in rural areas by utilizing Uptime, ping, and UPS data. Key contributions of this work include a method for identifying failure causes, a technique for defining time tolerances, and a comprehensive framework for accurately calculating the service level.

2- Proposed Model

To improve internet access in rural areas of Indonesia, the government, through the Ministry of Digital Communication of the Republic of Indonesia, initiated a free internet access program. This program aims to provide internet services in remote areas through cooperation with the private sector, where internet service providers (ISPs) are responsible for providing infrastructure and the government acts as the party that finances the service.

Figure 1 illustrates the infrastructure for providing internet services in rural areas. This system integrates several main components that work in an integrated manner to provide internet access for people in remote areas. NMS Server A (the payer) processes payments to internet service providers. Meanwhile, NMS Server B is managed by the ISP to connect the internet network to the central infrastructure via IP HUB. Data from the ISP is then forwarded via a satellite network, functioning as the primary transmission medium to reach areas inaccessible via terrestrial networks.

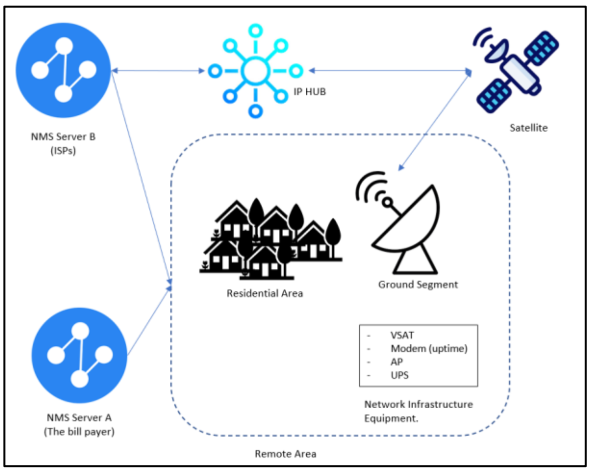

Figure 1. Network Infrastructure System

On the receiving side, the Ground Segment acts as a land communication terminal that receives signals from the satellite before being distributed to users in residential areas. This network infrastructure supports various network devices such as VSAT, modems (uptime), access points (AP), and UPS, ensuring service continuity during power outages. Thus, internet connections can reach various public service points such as schools, job training centers, health centers, village offices, and other locations in rural areas [17].

To calculate SLA, several key factors must be considered. Both NMS A and NMS B typically possess PING data, but they do not necessarily have uptime or UPS data. Our primary priority is to use uptime data from NMS A. If uptime data from NMS A is unavailable, we can use UPS data as an alternative. If neither uptime data from NMS A nor UPS data is available, we can compare the correlation between PING data from NMS A and NMS B. If the correlation is strong (between 0.6 and 1.0), then we can use uptime data from NMS B as a reference, as the strong correlation suggests NMS B's data is a reliable substitute.

Figure 2 illustrates the proposed methodology's decision-making process for determining uptime, downtime, and restitution eligibility based on available data from NMS A and NMS B. The process begins by checking whether NMS A has uptime data. If uptime data is available, downtime analysis is conducted to identify any link failures. If a link failure is detected, the system calculates the duration of failure using Formula 1 and determines whether the failure qualifies for restitution or non-restitution.

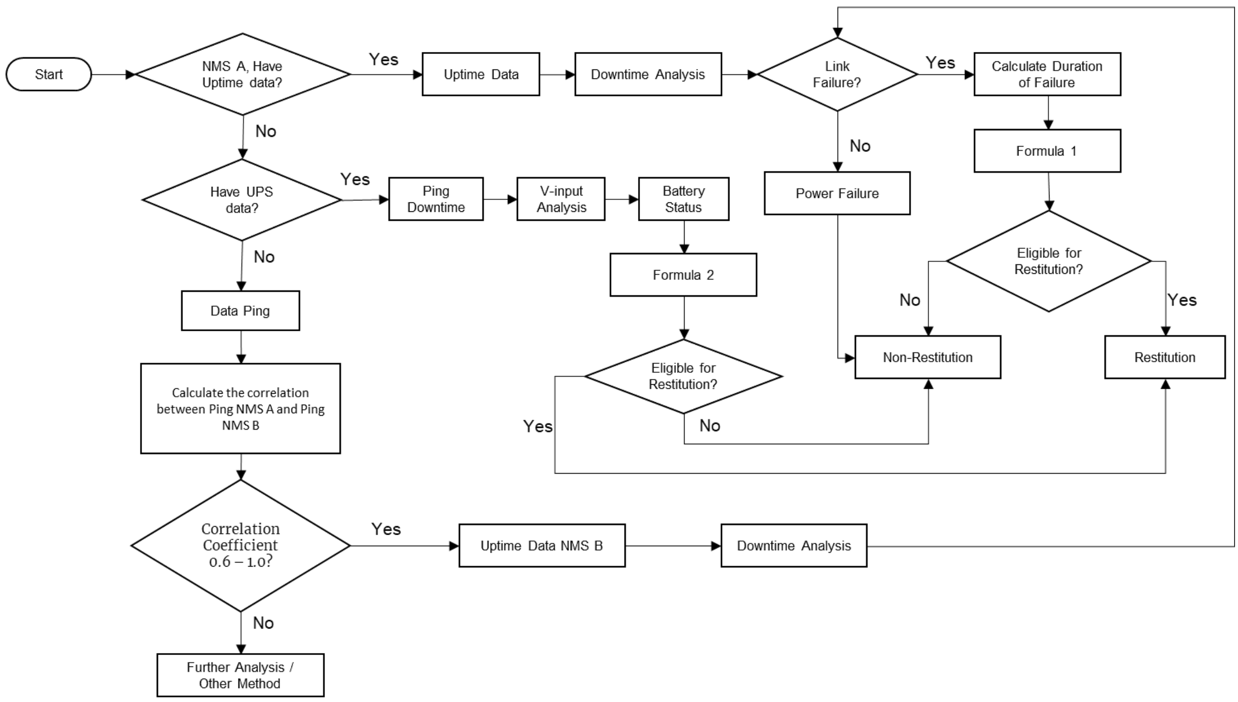

Figure 2. Proposed Methodology

If uptime data from NMS A is unavailable, the system checks for UPS data. If UPS data is present, an alternative analysis is performed using Ping Downtime, V-input analysis, and Battery Status. The failure duration is then calculated using Formula 2, and restitution eligibility is assessed. If neither uptime nor UPS data is available, the system relies on PING data from NMS A and NMS B. The correlation coefficient between the two is calculated. If the correlation is strong (between 0.6-0.79) and very strong (between 0.8-1.0) [18], uptime data from NMS B can be used for downtime analysis, following the same procedure as when uptime data from NMS A is available. However, if the correlation coefficient is below 0.6, further analysis is required, but this study does not cover that aspect.

Additionally, power failures are classified as non-restitution events because they result from external factors, such as electricity supply issues, rather than the service provider's fault. This structured methodology ensures that SLA compliance is accurately measured, distinguishing between failures caused by network disruptions and those due to external factors. By prioritizing uptime data from NMS A, followed by UPS data and correlated PING data, this approach ensures a fair and transparent evaluation of service availability.

3- Calculating Service Level Agreements

This calculation uses simulation data sourced from NMS A and NMS B. NMS A, designated by the government as the bill payer, serves as the facilitator and provider of telecommunications infrastructure. It collaborates with the

NMS B to enhance internet access in rural areas (remote, underdeveloped, and border areas). The simulation data is designed to reflect real conditions in rural areas, incorporating uptime, ping, and UPS data. This study introduces a novel approach to calculating the service level of internet access in these regions. Key contributions include a method for identifying failure causes, defining time tolerances, and a comprehensive framework for accurately determining the service level.

3-1- Alternative Method Using Uptime Data

In this method, the uptime data from NMS A is given the highest priority. This data is essential for calculating whether a service disruption qualifies for restitution or non-restitution. NMS A (the primary facilitator) collects and monitors uptime status to determine the availability and reliability of the network. By evaluating this data, it becomes possible to assess if the service level agreements (SLA) have been met or if any downtime necessitates restitution due to service failure. This ensures accurate accountability and maintains the integrity of the telecommunications service in underserved regions. Refer to Table 1 to see data uptime.

Table 1. Simulation Data Uptime NMS A (Link Failure)

Date	Time Start	Time End	Uptime
03/12/2024	00:00:00	00:05:00	
03/12/2024	00:05:00	00:10:00	300
03/12/2024	00:10:00	00:15:00	600
03/12/2024	00:15:00	00:20:00	900
03/12/2024	00:20:00	00:25:00	
03/12/2024	00:25:00	00:30:00	1500
03/12/2024	00:30:00	00:35:00	1800
03/12/2024	00:35:00	00:40:00	2100
03/12/2024	00:40:00	00:45:00	2400
03/12/2024	00:45:00	00:50:00	2700
03/12/2024	00:50:00	00:55:00	3000
03/12/2024	00:55:00	01:00:00	3300
03/12/2024	01:00:00	01:05:00	3600
03/12/2024	01:05:00	01:10:00	3900
03/12/2024	01:10:00	01:15:00	4200
03/12/2024	01:15:00	01:20:00	4500
03/12/2024	01:20:00	01:25:00	4800
03/12/2024	01:25:00	01:30:00	
03/12/2024	01:30:00	01:35:00	
03/12/2024	01:35:00	01:40:00	5700
03/12/2024	01:40:00	01:45:00	6000
03/12/2024	01:45:00	01:50:00	6300
03/12/2024	01:50:00	01:55:00	6600
03/12/2024	01:55:00	02:00:00	6900
03/12/2024	02:00:00	02:05:00	7200
03/12/2024	02:05:00	02:10:00	7500
03/12/2024	02:10:00	02:15:00	7800
03/12/2024	02:15:00	02:20:00	8100
03/12/2024	02:20:00	02:25:00	8400

Figure 3 represents the uptime data of NMS A, which tracks the system's operational status over time. In this data, disruptions or interruptions in uptime are observed. A link failure occurs when there is a break or pause in the uptime, causing the system to stop temporarily. Once the uptime resumes and continues in a linear fashion, it signifies the restoration of the network. If the link failure duration exceeds 300 seconds (or 5 minutes), it is classified as a restitution case. This means that the service provider is obligated to compensate for the downtime. However, if the link failure duration is less than or equal to 300 seconds, the downtime is considered non-restitution, and no compensation is required. To determine whether the downtime qualifies for restitution or not.

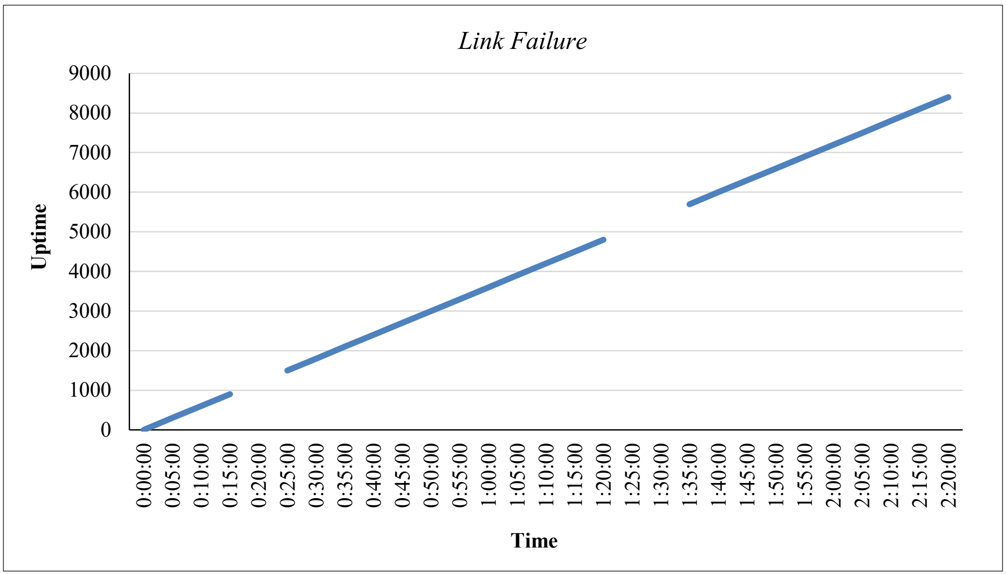

Figure 3. Link Failure

Let *T downtime* be the duration of the link failure in seconds, The condition for restitution;

$$T\ downtime > 300 = \text{restitution} \tag{1}$$

If the downtime lasts more than 300 seconds (5 minutes), it is classified as restitution.

$$T\ downtime \leq 300 = \text{non restitution} \tag{2}$$

If the downtime lasts for 300 seconds or less, then it is considered no restitution, and no compensation is required. This formula helps categorize downtime and establish clear criteria for whether or not service restitution is required. The 300-second threshold was chosen based on the default data collection interval of PRTG (Paessler Router Traffic Grapher), which is in line with previous research and ensures a balance between data accuracy, system efficiency, and smoothness of short-term fluctuations [19, 20].

The uptime data reveals multiple link failures within a short timeframe. This suggests potential instability within the network, possibly due to external factors such as environmental conditions, infrastructure limitations, or high network traffic. Even though some failures are categorized as non-restitution cases, frequent disruptions can still negatively impact user experience and service reliability. For critical applications such as financial transactions, remote healthcare, or emergency services, even minor downtimes can have significant consequences. While the current SLA classification ensures accountability in service provision, it does not fully address the impact of recurring short-term failures. To mitigate these disruptions, implementing redundancy measures such as backup links and predictive maintenance strategies can improve network stability. Additionally, real-time monitoring systems and AI-driven analytics can help anticipate and prevent failures before they occur, ensuring higher uptime and better service quality.

As part of the analysis of uptime data, it is essential to identify instances of power failure, which can disrupt the normal operation of the system. Table 2 shows data indicating power failures, where the uptime value resets to zero, signifying a complete loss of power. This table helps in distinguishing power failure events from other types of interruptions, such as link failures, and allows for a better understanding of the impact on network performance.

Table 2. Simulation Data Uptime NMS A (Power Failure)

Date	Time Start	Time End	Uptime
03/12/2024	01:55:00	02:00:00	6900
03/12/2024	02:00:00	02:05:00	7200
03/12/2024	02:05:00	02:10:00	7500
03/12/2024	02:10:00	02:15:00	7800
03/12/2024	02:15:00	02:20:00	8100
03/12/2024	02:20:00	02:25:00	8400
03/12/2024	02:25:00	02:30:00	8700
03/12/2024	02:30:00	02:35:00	9000
03/12/2024	02:35:00	02:40:00	9300
03/12/2024	02:40:00	02:45:00	9600
03/12/2024	02:45:00	02:50:00	9900
03/12/2024	02:50:00	02:55:00	10200
03/12/2024	02:55:00	03:00:00	
03/12/2024	03:00:00	03:05:00	
03/12/2024	03:05:00	03:10:00	300
03/12/2024	03:10:00	03:15:00	600
03/12/2024	03:15:00	03:20:00	900
03/12/2024	03:20:00	03:25:00	1200
03/12/2024	03:25:00	03:30:00	1500
03/12/2024	03:30:00	03:35:00	1800
03/12/2024	03:35:00	03:40:00	2100
03/12/2024	03:40:00	03:45:00	2400

Figure 4 illustrates a power failure, defined as an unexpected loss of electrical supply, causing the system to shut down or reset. In the context of uptime data, a power failure is identified when the uptime value resets to zero, signifying that the system experienced a complete loss of power. This interruption leads to a fresh start in the data collection process, disregarding any prior uptime values. The power failure typically indicates a hardware or power supply issue that disrupts the normal operation of network infrastructure, causing an abrupt reset in the system's uptime tracking. Power failures can have significant effects on service continuity, especially in critical network systems, as they result in temporary unavailability of services until the power is restored and the system resumes normal operations. However, in the context of uptime measurement, power failures are considered non-restitution events because they are external and not attributable to the service provider.

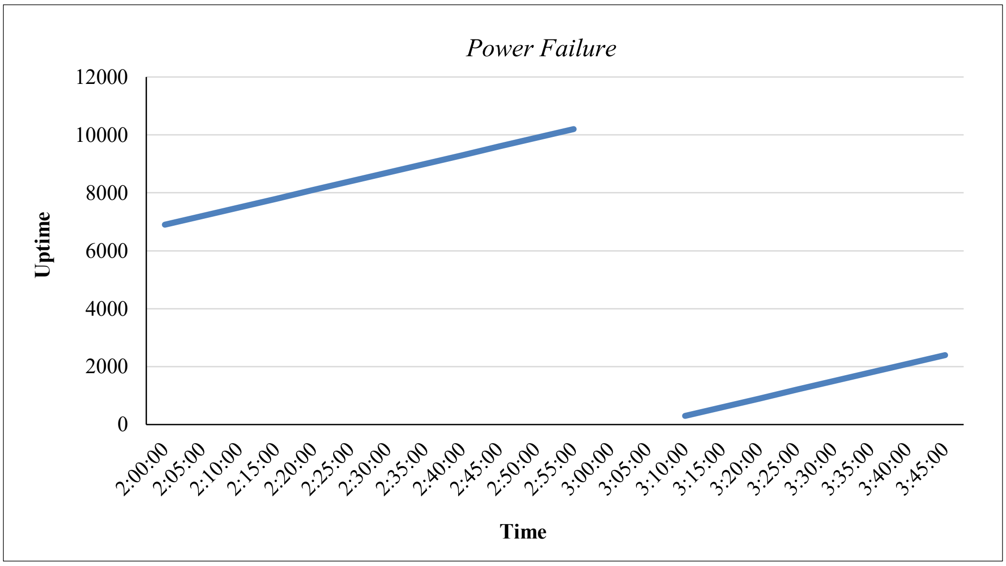

Figure 4. Power Failure

3-2- Alternative Method Using UPS Data

UPS data is used to analyze the stability of the power supply and its relationship to network disruptions. One of the factors affecting the Service Level Agreement (SLA) is service downtime, which can occur due to various causes, including power outages or network failures. In SLA calculations, restitution is granted if the customer experiences service disruptions not caused by power outages but due to other factors such as network issues or system failures. Therefore, the restitution calculation considers Ping Downtime and the condition of the power supply, including V-Input and Battery Status. Restitution is determined when the power supply remains stable, indicated by a non-zero V-Input and Battery Status being OFF. If the accumulated Ping Downtime under these conditions exceeds 300 seconds, the period is classified as restitution.

Based on Table 3, the calculation of restitution considers the stability of the power supply and network availability. Restitution is granted if the accumulated Ping Downtime occurs while the power supply remains stable (V-Input ≠ 0V and Battery Status = OFF).

- T Downtime: The total duration of downtime, which sums all periods of Ping Downtime under stable power conditions.
- T Ping Downtime: The duration when the network is down, meaning no response from the monitored service.
- V-Input: The input voltage to the UPS, indicating whether the power supply is stable. If V-Input ≠ 0V, the power is stable; otherwise, it indicates an outage.

Battery Status: The state of the UPS battery, showing whether it is actively supplying power. If Battery Status = ON, the UPS is running on battery due to an outage. If Battery Status = OFF, the UPS is inactive, meaning the main power supply is stable.

Table 3. **UPS Data**

Date	Time Start	Time End	Ping Downtime	Ping Uptime	UPS Downtime	V-Input (Volt)	Ping Downtime Duration (s)	Battery Status
03/12/2024	00:00:00	00:05:00	100%	0%	0%	220	300	OFF
03/12/2024	00:05:00	00:10:00	100%	0%	0%	220	300	OFF
03/12/2024	00:10:00	00:15:00	100%	0%	0%	220	300	OFF
03/12/2024	00:15:00	00:20:00	100%	0%	0%	220	300	OFF
03/12/2024	00:20:00	00:25:00	100%	0%	0%	0	300	ON
03/12/2024	00:25:00	00:30:00	75%	25%	0%	220	225	OFF
03/12/2024	00:30:00	00:35:00	85%	15%	0%	220	255	OFF
03/12/2024	00:35:00	00:40:00	0%	100%	0%	220	0	OFF
03/12/2024	00:40:00	00:45:00	0%	100%	0%	220	0	OFF
03/12/2024	00:45:00	00:50:00	0%	100%	0%	220	0	OFF
03/12/2024	00:50:00	00:55:00	0%	100%	0%	220	0	OFF
03/12/2024	00:55:00	01:00:00	0%	100%	0%	220	0	OFF
03/12/2024	01:00:00	01:05:00	0%	100%	0%	220	0	OFF
03/12/2024	01:05:00	01:10:00	100%	0%	0%	0	300	ON
03/12/2024	01:10:00	01:15:00	100%	0%	0%	0	300	ON
03/12/2024	01:15:00	01:20:00	100%	0%	0%	0	300	ON
03/12/2024	01:20:00	01:25:00	100%	0%	0%	0	300	ON

Restitution is determined using the following formula:

$$T\,Downtime = \sum T Ping\ Downtime\ ,\ if\ V\,Input\ \neq 0\ V\ and\ Battery\ Status\ =\ OFF \quad (3)$$

Based on Table 3, during the period 00:00:00 – 00:20:00, the total Ping Downtime while the power supply was stable is: 300+300+300+300=1200 seconds. Since 1200 seconds > 300 seconds, this period qualifies for restitution. However, during 00:20:00 – 00:25:00 and 01:05:00 – 01:25:00, the power supply was down (V-Input = 0V, Battery Status = ON). As these downtimes resulted from a power outage, they do not qualify for restitution.

3-3- Alternative Method Ping Correlation

Ping correlation analysis is employed when NMS A lacks uptime data, leaving only NMS B's data available for analysis. However, to ensure the reliability of NMS B's uptime data, it must be validated by calculating the correlation between Ping data from NMS A and NMS B. This correlation analysis is important to provide assurance to the government that the uptime data from NMS B is reliable. A strong correlation, in the range of 0.6 to 1.0, indicates that the uptime data from NMS B can be considered reliable for further analysis.

Figure 5 shows ping data from two network management systems (NMS), NMS A and NMS B, using a double axis. The ping of NMS A is shown as a blue line and plotted on the right vertical axis, while the ping of NMS B is shown as an orange line on the left vertical axis. Both NMSs have the same ping value, namely 1 and 0, but with different vertical axes, the scales appear different. The graph shows a pattern of periodic ping value drops to 0 before rising back to 1, indicating an outage or loss of connectivity at certain intervals.

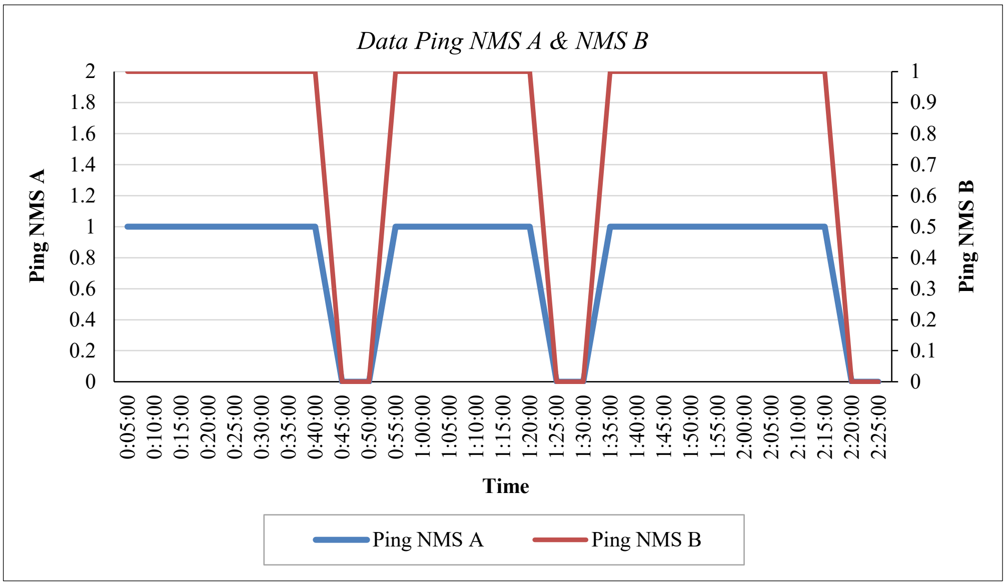

Figure 5. Data Ping NMS A & NMS B

In Table 4, The correlation between Ping NMS A and Ping NMS B can be measured using the Pearson correlation coefficient (r), which quantifies the strength and direction of the linear relationship between two variables. The formula for calculating this coefficient is:

$$r = \frac{n\sum XY-(\sum X)(\sum Y)}{\sqrt{(n\sum X^2-(\sum X)^2)(n\sum Y^2-(\sum Y)^2)}} \quad (3)$$

where n is number of observations, X is Ping NMS A values, Y is Ping NMS B values, ΣXY is sum of the product of X and Y, ΣX is sum of X values, ΣY is sum of Y values, ΣX^2 is sum of squared X values, ΣY^2 is sum of squared Y values.

This formula calculates how well the two variables move together. The result of r will be between -1 and 1:

$r = 1$ means perfect positive correlation (both values increase or decrease together).

$r = 0$ means no correlation (values do not affect each other).

$r = -1$ means perfect negative correlation (one value increases while the other decreases).

Based on Table 5, the results of the correlation calculation between Ping NMS A and Ping NMS B data show a value of 1.00, which indicates a very strong correlation between the two systems. In this study, the correlation is considered good if it is in the range of 0.6 to 1.0, so with a value of 1.0, it can be concluded that the data from NMS B is reliable. Therefore, SLA calculation can proceed using NMS B uptime data, given the demonstrated consistency, because Ping NMS A and Ping NMS B data show an identical relationship. However, if there is a difference in data that produces a correlation value below 0.6, then further analysis is needed to understand the cause of the discrepancy. Conditions where the correlation value falls below 0.6 are outside the scope of this study and represent an area for future research.

Table 4. Data Ping NMS A & NMS B

Date	Time Start	Time End	Ping NMS A	Ping NMS B
03/12/2024	00:00:00	00:05:00	1	1
03/12/2024	00:05:00	00:10:00	1	1
03/12/2024	00:10:00	00:15:00	1	1
03/12/2024	00:15:00	00:20:00	1	1
03/12/2024	00:20:00	00:25:00	1	1
03/12/2024	00:25:00	00:30:00	1	1
03/12/2024	00:30:00	00:35:00	1	1
03/12/2024	00:35:00	00:40:00	1	1
03/12/2024	00:40:00	00:45:00	0	0
03/12/2024	00:45:00	00:50:00	0	0
03/12/2024	00:50:00	00:55:00	1	1
03/12/2024	00:55:00	01:00:00	1	1
03/12/2024	01:00:00	01:05:00	1	1
03/12/2024	01:05:00	01:10:00	1	1
03/12/2024	01:10:00	01:15:00	1	1
03/12/2024	01:15:00	01:20:00	1	1
03/12/2024	01:20:00	01:25:00	0	0
03/12/2024	01:25:00	01:30:00	0	0
03/12/2024	01:30:00	01:35:00	1	1
03/12/2024	01:35:00	01:40:00	1	1
03/12/2024	01:40:00	01:45:00	1	1
03/12/2024	01:45:00	01:50:00	1	1
03/12/2024	01:50:00	01:55:00	1	1
03/12/2024	01:55:00	02:00:00	1	1
03/12/2024	02:00:00	02:05:00	1	1
03/12/2024	02:05:00	02:10:00	1	1
03/12/2024	02:10:00	02:15:00	1	1
03/12/2024	02:15:00	02:20:00	0	0
03/12/2024	02:20:00	02:25:00	0	0

Table 5. Range of Correlation Coefficient Values and The Corresponding Level of Correlation [18]

Range of Correlation Coefficient Values	Level of Correlation	Range of Correlation Coefficient Values	Level of Correlation
0.80 to 1.00	Very Strong Positive	-1.00 to -0.80	Very Strong Negative
0.60 to 0.79	Strong Positive	-0.79 to -0.60	Strong Negative
0.40 to 0.59	Moderate Positive	-0.59 to -0.40	Moderate Negative
0.20 to 0.39	Weak Positive	-0.39 to -0.20	Weak Negative
0.00 to 0.19	Very Weak Positive	-0.19 to -0.01	Very Weak Negative

After it is known that the correlation value between Ping NMS A and NMS B is 1.00 or in the range of 0.6 - 1.0, the next step is to calculate the SLA using the downtime analysis method. The downtime calculation process is carried out in the same way as when analyzing downtime on NMS A. If downtime occurs due to power failure, it will be categorized as non-restitution, while if it is caused by link failure, it will be included in the restitution category. Refer to section 4.1 Alternative Method Using Uptime Data for the SLA calculation details, where the formula used remains the same because both rely on uptime data. The difference lies in the data source used, in section 4.1, the uptime used comes from NMS A, while in this calculation, the uptime used comes from NMS B.

3-4-SLA Calculate

Service Level Agreement (SLA) is a key metric used to evaluate the reliability of internet services. In rural areas, accurately assessing SLA is crucial to ensure fair agreements between Network Management System A (NMS A) and service providers. A key challenge in SLA calculation is distinguishing between service failures caused by network issues and those caused by power outages. If power-related downtime is not excluded, NMS A might incorrectly compensate for service unavailability that was beyond the provider's control. Therefore, a refined SLA calculation method is needed to ensure both parties NMS A and the service provider receive a fair evaluation.

To achieve accurate SLA measurement, a data hierarchy is established based on priority levels. The highest priority data is Uptime from NMS A, as it directly reflects service availability. If discrepancies arise, UPS status data is examined to determine if power failures caused the downtime. Next, Uptime from NMS B is considered, particularly if it strongly correlates (0.6-1.0) with NMS A's data, indicating consistent reporting between the systems. By structuring data in this manner, SLA calculations can be made more reliable and justifiable.

The SLA is computed using different approaches, depending on the available data:

T total = Total duration of the measurement period (e.g., 1 month, 1 year, etc.).

T downtime = Total downtime during that period

$$SLA = \frac{T_{\text{total}} - T_{\text{downtime}}}{T_{total}} \times 100 \quad (5)$$

The method's resilience has been demonstrated through testing across over 1,000 diverse locations with varying infrastructures, demonstrating its resilience across diverse conditions. Some locations operate without a UPS, while others are equipped with one. Additionally, certain sites only have Ping data, whereas others rely solely on NMS B data. Given these variations, this research presents multiple alternative approaches to ensure that the method remains applicable across different infrastructure setups. Furthermore, this method can be implemented in other developing countries aiming to expand internet access through government funding while involving private entities as service providers. The calculation of SLA plays a crucial role in this context, as the payer (government) and the service provider are distinct entities. Therefore, a clear and well-defined methodology for determining restitution and non-restitution is essential to establish fair and transparent service-level agreements.

4- Conclusion

The proposed SLA calculation method offers a systematic and fair approach to assessing internet service availability in remote areas. In this method, uptime data from NMS A (the government entity) is prioritized for SLA calculations since the government pays for the service and is responsible for evaluating the provider's performance. If NMS A's uptime data is unavailable, the system will analyze UPS data, which includes Ping Downtime, V-input, and battery status. If both data sources are unavailable, uptime data from NMS B (the private service provider) may be used, but only if its correlation with NMS A's data is strong (between 0.6 and 1.0). Therefore, NMS A's data remains the primary reference.

To ensure the reliability of uptime data from NMS B, a correlation calculation between Ping data from NMS A and NMS B is performed. Each NMS must have documented Ping data, allowing for statistical analysis of their relationship. Pearson correlation is used to validate the data's suitability. If the correlation is strong ($\geqslant$ 0.6), uptime data from NMS B can be used with the same calculation method as NMS A. If the correlation falls below 0.6, determining the appropriate approach requires further research beyond the scope of this study. Restitution is determined for network failures exceeding 300 seconds, while downtime due to power failures is considered non-restitution, as it is not the service provider's responsibility.

This method has been tested at over 1,000 locations with diverse infrastructures, proving its flexibility and reliability. It can serve as a reference for governments to determine SLAs fairly, transparently, and in accordance with each party's responsibilities, and it can be applied in other developing countries expanding internet access.

5- Declarations

5-1- Author Contributions

Conceptualization, I.J.M.E.; methodology, I.J.M.E.; software, N.F.; validation, I.J.M.E. and H.S.; formal analysis, H.S.; investigation, N.F.; resources, I.J.M.E.; data curation, I.J.M.E.; writing—original draft preparation, N.F., D.F.A., A.R., and J.N.M.; writing—review and editing, N.F.; visualization, N.F.; supervision, I.J.M.E.; project administration, N.F.; funding acquisition, I.J.M.E. All authors have read and agreed to the published version of the manuscript.

5-2- Data Availability Statement

The data presented in this study are available in the article.

5-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

5-4- Institutional Review Board Statement

Not applicable.

5-5- Informed Consent Statement

Not applicable.

5-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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