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Data Loss Study in Zonal Systems and Servers in a Shopping Center Parking Lot

Estudio de Pérdida de Datos en Sistemas Zonal y Servidores de un Parqueadero en un Centro Comercial

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Packet loss, Radio link, PowerBeam 5AC Gen2, Wireshark, IT Infrastructure.

ABSTRACT
This study analyzes the packet loss in the radio link of PowerBeam 5AC Gen2 antennas connected to various Meypar equipment in the "red dot" area of the Guayaquil shopping center. The objective is to optimize communication and ensure a stable network environment for the equipment. A tester was used to measure the continuity of the cabling, and oxidation was observed in all eight strands. In addition, Wireshark software was used to analyze packet traffic on 14 devices, including 1 transmitter, 1 ticket validator, 6 perimeter cameras, 2 license plate cameras, 2 IP intercoms and 2 antennas. Four critical scenarios were identified: the license plate cameras (1600 packets), the transmitter (293 packets) and the ticket validator (280 packets), registering a total of 2173 packets lost in these devices. To solve this problem, an exhaustive analysis of the IT infrastructure was carried out, identifying critical failures and implementing backup solutions, data recovery and system security improvements, thus minimizing the risk of data loss and ensuring the operational continuity of the parking lot.

PALABRAS CLAVE
Pérdida de paquetes, Radioenlace, PowerBeam 5AC Gen2, Wireshark, Infraestructura de TI.

RESUMEN
El presente estudio analiza la pérdida de paquetes del radio enlace con las antenas PowerBeam 5AC Gen2 a diferentes equipos Meypar de la zona punto rojo del centro comercial de la ciudad de Guayaquil, se busca determinar la comunicación óptima para un entorno estable de la red en los equipos. Se utilizó un tester para medir la continuidad del cableado y se observa físicamente que las 8 hebras de todo el cableado esta con óxido. También se utilizó el software de Wireshark para examinar el comportamiento de los paquetes hacia los equipos Meypar que son 1 emisor, 1 validador de tickets, 6 cámaras de perimetrales, 2 cámaras de matrícula, 2 interfonias ip y 2 antenas, en total 14 escenarios, siendo 4 los más críticos, que son las 2 cámaras de matrículas 1600 paquetes, 1 emisor 293 paquetes y 1 validador de ticket 280 paquetes, en estos 4 equipos se registra niveles de pérdida totales de 2173 paquetes. Para abordar el problema, se llevó a cabo un análisis exhaustivo del sistema zonal, identificando fallos críticos en la infraestructura de TI. Se implementaron soluciones de respaldo y recuperación de datos, junto con mejoras en la seguridad del sistema, logrando así minimizar el riesgo de pérdida de datos y asegurando la continuidad operativa del parqueadero.

1. Introduction

Shopping malls [1], highly crowded and active places, have prioritized safety and efficient management of their operations. Improvements in zonal systems and servers have optimized parking monitoring and management [2]. Automation, vehicle control and real-time surveillance have significantly increased efficiency and safety. However, this technological dependence has introduced new vulnerabilities, such as data loss [3].

Beyond operational disruptions, the misuse of technology can compromise security and infrastructure [4]. Causes of data loss include hardware failures, human error, cyberattacks, and adverse weather conditions. Previous incidents have demonstrated the serious consequences of this loss, including chaos, financial losses.

In order to tackle this issue effectively, it becomes necessary to explore both the root causes and the possible impacts of data loss in zonal systems and parking servers [5]. Gaining insight into these factors will help identify practical solutions aimed at reducing such incidents and improving the overall reliability of the systems involved.

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The main objective is to assess the internal and external factors that contribute to data loss and analyze their impacts on daily operations [4], customer security, and corporate reputation.

Once the problems have been identified, the study proposes practical recommendations to reduce the frequency and severity of these incidents. The aim was to identify the enigma of the network [6], in the current parking system, evaluate the data recovery protocols and propose technological improvements. A framework was developed to implement backup and recovery strategies applicable to various operational situations of the shopping center.

The approach not only mitigated the challenges associated with data mitigation [7], but also improved the system's resilience to future incidents. To achieve these objectives, a quantitative methodology was used, which combines technical analysis and procedure reviews. The first phase consisted of an audit of the zonal systems and servers, identifying points of vulnerability [8], and evaluating their performance under normal and stressful conditions.

Hardware and software tests [9] were performed on the network to identify critical issues and analyze the probability of attenuation in the data. Historical failures will be monitored and data from past incidents will be collected to identify patterns. In addition, failure and crisis simulations were carried out to evaluate the resilience of the parking system.

The analysis of data loss in zonal systems and servers is a field of study that has become increasingly relevant, especially in the context of managing complex infrastructures such as parking lots in shopping malls [10]. These systems rely heavily on the integrity and continuous availability of data to ensure smooth and efficient operation.

The ability to prevent and mitigate data loss [11], not only improves operational efficiency, but also ensures user security and satisfaction. To address this problem, it is essential to delve into the underlying technical concepts, review the related work, and apply mathematical equations that allow modeling the risks associated with data loss and developing strategies to counteract them.

One of the key concepts in this study is clearance attenuation, which refers to the amount of power of a signal [12], which is lost when it is transmitted through the air without physical obstacles in between. This attenuation clearance is primarily due to the dispersion of signal energy as it expands through space, with the final application being a drop in signal strength as it reaches the receiver. To calculate the percentage loss, the attenuation free space equation is applied, as shown in equation 1:

$$FSPL=20\log10(d)+20\log10(f)+20\log10(c4\pi) \quad (1)$$

Where:

d: is the distance between the transmitter and receiver in meters (m).

f: is the frequency of the signal in Hertz (Hz).

c: is the speed of light in a vacuum (m/s).

Simplifying the constant, the formula can also be written as equation 2:

$$FSPL=20\log10(d)+20\log10(f)-147.55 \quad (2)$$

If the distance d is in kilometers (km) and the frequency f is in Megahertz (MHz), the adapted formula would be equation 3:

$$FSPL=20\log10(d)+20\log10(f)+32.44 \quad (3)$$

In equation 1, it is the distance in meters between the transmitter and receiver, it is the frequency of the signal in Hertz, and it is the speed of light in a vacuum. The importance of understanding and calculating attenuation in free space lies in its direct impact on the planning of communication networks in open environments, such as parking lots, where distances can be significant and signals must be transmitted without interruptions to ensure proper operation of the system.

Another critical concept to consider is the Fresnel zone, an ellipsoidal region that details around the line directly between a transmitter and a receiver. The concept is fundamental as it can serve as a basis for understanding how obstructions in the Fresnel zone can lead to signal diffraction, resulting in signal loss, from there, data loss. The Fresnel zone is crucial when it comes to environments such as obstacle areas such as vehicles and buildings, which could hinder signal propagation, as shown in equation 4:

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}} \quad (4)$$

Where:

F_n: is the radius of the Fresnel zone at the point under consideration (meters).

n: is the number of the Fresnel zone (for the first zone, n=1).

λ: is the wavelength of the signal (meters).

d_1: is the distance from the transmitter to the point under consideration (meters).

d_2: is the distance from the point under consideration to the receiver (meters).

The wavelength (λ) can be calculated from the frequency (f) of the signal using equation 5.

$$\lambda = \frac{c}{f} \quad (5)$$

Where:

c: is the speed of light, meters/second.

f: is the frequency of the signal (Hertz).

Effective communication system design requires careful planning, particularly with respect to the Fresnel zone [13]. This region, which surrounds the direct line-of-sight between a transmitter and a receiver, has an elliptical shape and plays a crucial role in signal propagation. When objects intrude into this space, they can cause diffraction and weaken the signal. By accounting for the Fresnel zone during installation, engineers can better position antennas and related equipment to reduce interference and maintain consistent data transmission quality.

Network security and analytics are critical areas in data loss prevention [14], and tools such as Wireshark and Cisco Packet Tracer are indispensable for these purposes. Wireshark is a network protocol analysis tool that allows administrators to capture and analyze data packets in real-time [15]. Their ability to identify vulnerabilities in network infrastructure is crucial to prevent data loss and ensure the safe operation of systems [16].

Wireshark allows network traffic to be analyzed [17], at a very detailed level, which can help identify specific issues such as attacks or bad behavior and address them before they cause significant damage to the system. Cisco Packet Tracer also offers a simulation environment that can be used to model and analyze the operating behavior of complex networks under different operating conditions [18]. In this way, the software can be used as a tool to analyze the potential fallibility of the existing network and investigate its resilience with respect to different combinations of operating circumstances.

Simulations conducted using Cisco Packet Tracer help identify vulnerabilities in the network infrastructure [19], allowing engineers to develop strategies that reduce the risk of data loss. Additionally, the ability to test different network configurations enables the optimization of network designs, ultimately enhancing both performance and reliability.

A review of related studies shows that substantial research has been carried out on network management in similar environments [20]. These studies have explored various methods to tackle data loss, including simulations, empirical analysis, and the application of advanced technologies.

For example, some studies have used the simulation of the Fresnel zone and the configuration of equipment through tools such as the AirOS applications (shown in Figure 1) and UISP Design Center of Ubiquiti Networks, which has allowed the optimization of network infrastructure in high-density environments [21], such as shopping malls [16]. These approaches have proven to be effective in improving network coverage and reducing the incidence of data loss.

Figure 1

Monitoring via the AirOS web app.

Another key aspect in the management of parking in shopping centers is the implementation of advanced systems [22], such as Meypar equipment. This system is essential for the automation and optimization of access control and use of parking spaces. Meypar integrates with real-time monitoring and management systems, enabling more efficient and safer parking lot operation [23].

In addition, its configurability through applications such as the User Terminal allows administrators to fine-tune and control the system, minimizing the risks of operational failures and data loss [24]. The use of mathematical equations is another essential component in modeling data loss scenarios.

In addition to equation (1) of Loss of Clearance (FSPL), other equations related to information theory and the capacity of communication channels are used to calculate the maximum amount of data that can be reliably transmitted over a channel [25]. These calculations are critical for designing network systems that can withstand the required data load without significant loss.

Mathematical modeling is also applied to analyze how different environmental and operational conditions affect signal propagation and overall network performance [26]. These models provide valuable information for decision-making in the design and operation of parking lot communication systems, allowing engineers to anticipate potential problems and develop strategies to mitigate them before they occur.

The use of advanced tools such as Cisco Packet Tracer and Wireshark, along with the application of robust technical concepts and the integration of cutting-edge technologies, has enabled researchers to develop effective solutions to mitigate the risks of data loss in critical environments [27]. The strategies developed from these studies not only improve operational efficiency, but also strengthen the security and resilience of systems in the face of possible contingencies.

The evolution of technology in the management of networks and communication systems continues to offer new opportunities to improve the management of complex infrastructures such as shopping mall parking lots.

The integration of new tools and techniques allows for more accurate and efficient management, reducing the risk of data loss and improving the overall experience for users [28].

Research in this field is essential to further advance in the protection and optimization of these systems, ensuring their robustness and reliability in the future [29]. It encompasses a wide range of key concepts, analytical tools, related works, and mathematical equations, providing a solid foundation for understanding and addressing the challenges associated with data loss in zonal systems and servers.

The combination of advanced techniques, careful planning, and the use of simulation tools allows network administrators to develop safer and more efficient systems, ensuring operational continuity in critical environments such as shopping mall parking lots [30], [31].

2. Method

The methodology used in this research is structured in a mixed approach that integrates quantitative and experimental methods, with the aim of achieving an exhaustive and detailed analysis of the zonal system and the parking servers in a shopping center. Quantitative methodology is critical as it allows for accurate and objective numerical data to be collected that is critical for evaluating network infrastructure performance.

Key variables measured include packet loss rate, cabling stability and quality, latency, network node performance, and data transmission rate across different segments of the system. Obtaining this data allows for early identification of any anomalies or inefficiencies that may be contributing to data loss, which is crucial for corrective interventions before problems are amplified.

In parallel, the experimental methodology focuses on the simulation of the system using advanced tools such as Cisco Packet Tracer, Wireshark, and other web applications specialized in network analysis. The simulation is a critical stage of the methodology, since it allows to virtually model the parking environment and test various network configurations in a controlled environment.

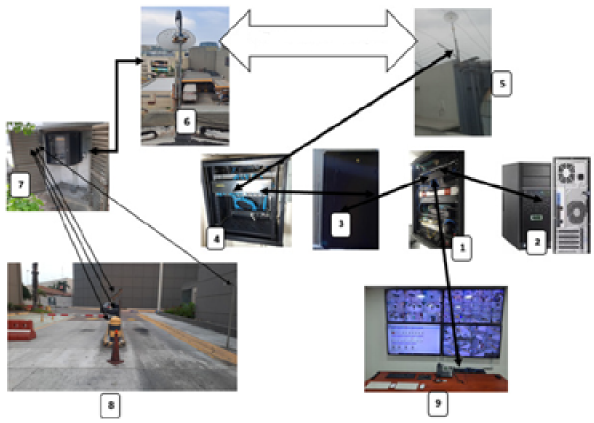
This phase is essential to predict how the network will behave under different operational scenarios, such as variation in data traffic density, interference in the radio frequency signal, and possible failure of key equipment such as routers and switches. Through simulation, it is possible to experiment with different network configuration and optimization strategies, making it easier to identify the most robust and efficient solution to minimize data loss and ensure optimal system performance.

The development of the prototype is based on a detailed model of the existing infrastructure of the shopping center's parking lot, which is used as a basis for simulation and analysis. This prototype includes all the critical components of the system, such as ticket dispensers, ticket validators, license plate cameras, perimeter cameras, and the main server, which are interconnected through a radio link.

This part of the system, often marked as the "red dot," is labeled a critical zone because it plays a central role in maintaining wireless communication between key components. Its functionality depends heavily on uninterrupted data exchange to keep operations synchronized. Any disruption in this area can compromise system performance, potentially causing data loss or service interruptions. For this reason, a detailed assessment is essential, along with preventive actions to strengthen the reliability of the communication link.

Figure 2.

Network diagram of the parking lot equipment.



As can be seen in Figure 2, the detail of the intercommunication of the local network of the parking lot is found.

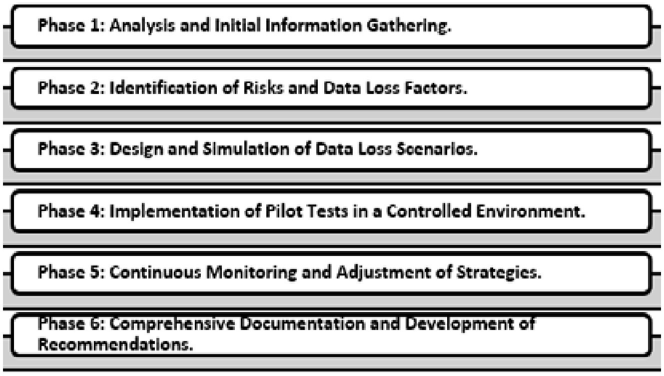
1. Main node.
2. Server.
3. Warehouse node.
4. Iron node.
5. PowerBeam 5 AC Gen 2 transmitter antenna.
6. PowerBeam 5 AC Gen 2 Receptor Antenna.
7. Red dot node.
8. Meypar Equipment.
9. Monitoring center.

Also, as these equipment, they communicate to the server, specifically the red dot area, because they have communication through a radio link. Before detailing the specific phases of the methodology, it is critical to understand that this comprehensive approach is designed to address both the identification and resolution of problems in the parking network infrastructure.

The methodology not only focuses on data collection and simulation, but also includes practical implementation and continuous monitoring to ensure the sustainability of the improvements made. This structured process allows for a thorough evaluation of the system, making it easier to identify critical points and implement effective solutions to minimize data loss and optimize overall performance. Below, we can see Figure 3 with the 6 main phases in this methodology:

Figure 3.

Phases to follow in this methodology



The main steps to be followed in this mixed methodology that integrates quantitative and experimental methods begin with phase 1 initial data collection. This process involves an exhaustive and meticulous evaluation of the existing system, where detailed measurements were made on the Meypar equipment of the parking lot of the shopping center in the red dot area.

These measurements include phase 2, verification of the condition of structured cabling, inspection of network equipment, and real-time monitoring of data traffic, this phase is crucial to establish a baseline against which the results of simulations and subsequent implementations can be compared. The data collected is used to build phase 3, a virtual model of the system in Cisco Packet Tracer, which simulates both normal operating conditions and failure scenarios.

Once the virtual model is complete, it moves on to simulation. During this phase, various configurations and optimization strategies are tested to determine which ones offer the best combination of performance and resiliency. This includes simulating situations such as network congestion, critical node drops, and radio link signal interference.

The simulation allows not only to identify possible points of failure, but also to evaluate the effectiveness of different mitigation measures, such as optimizing the network topology, improving packet routing, and implementing redundancies at critical points in the system. Each configuration is evaluated in terms of its impact on data loss, latency, and overall system availability.

The most promising configurations are then selected for phase 4 deployment in the controlled environment. During this phase, pilot tests are carried out in a section of the parking lot, which implements the selected configurations to verify the system that works in real conditions. During this period of time, various real-time monitoring tools are used to monitor and collect data about the system.

This allows configurations to be adjusted and refined as needed, ensuring that the system implemented throughout the facility performs optimally and meets the expected quality and efficiency standards. The process does not end with implementation, but extends to phase 5 of continuous monitoring and adjustment, where the system is monitored on a regular basis to ensure that the implemented configurations continue to work efficiently over time.

This phase includes post-implementation data collection and comparison with the initially established baseline, allowing the actual impact of improvements to be assessed and further adjustments made if new optimization opportunities are identified. This monitoring is critical to ensure the sustainability of the improvements implemented and to ensure that the system continues to operate without significant disruption or data loss.

Finally, phase 6 is carried out, the process of exhaustive documentation where all the steps followed, the configurations tested, the results obtained, and the lessons learned are recorded. This documentation is crucial not only to support decisions made during the project, but also to provide a valuable reference for future research and similar projects.

By documenting in detail each aspect of the process, a resource is created that can be used by other engineers and professionals in the area to replicate or adapt the solutions developed to different contexts, thus contributing to the advancement of knowledge in the management of zonal systems and servers in critical environments such as shopping centers.

3. Results and discussion

3.1. RESULTS

The results obtained in the study of data loss in the zonal system and servers of a parking lot in a shopping center are presented in detail through various tables and analyses that reflect the performance of the system and the problems detected. To quantify the signal attenuation in the wireless link, the equations of Loss of Free Space and Fresnel Zone were applied.

Equations (3), (4), and (5) were used to evaluate signal attenuation levels based on transmission distance and signal frequency, as well as to assess the influence of potential environmental obstructions on propagation performance. Once the corresponding data from the AirOS web application have been acquired, which are detailed in Figure 1, the calculation of the attenuation of the free space will be carried out using equation 3.

$FSPL=20\ \log_{10}(2.4\ km)+20\ \log_{10}(5225\ MHz)+32.44$

$FSPL=114.406\ dB$

The result of FSPL=114.406 dB represents the clearance between the PowerBean 5AC antennas. To obtain the Fresnel zone between the antennas, the values obtained from Figure 1 must be considered, for this I use equations 4 and 5.

$$\lambda = \frac{3 * 10^8}{5225 * 10^9}$$

$$\lambda = 0.057\ \text{m}$$

The result of λ=0.057 m represents the wavelength that was used to solve equation 4, which resulted in F_n=5.86 m of the Fresnel zone.

$$F_n = \sqrt{\frac{1 * 0.057 * 1200m_1 * 1200m_2}{1200_1 + 1200_2}}$$

$$F_n = \sqrt{\frac{1 * 0.057 * 1200m_1 * 1200m_2}{2400}}$$

$$F_n = \sqrt{\frac{1 * 0.057 * 1200m_1 * 1200m_2}{2400}}$$

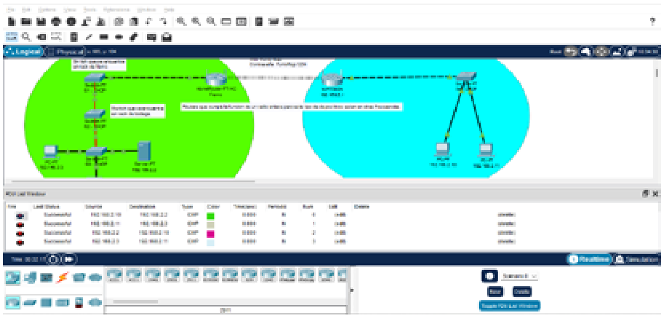
$$F_n = \sqrt{\frac{34.449}{2400}}$$

$$F_n = 5.86\ m$$

Therefore, as shown in Figure 4, a simulation was performed in the Cisco Packet Tracer software, where we were able to perform several tests such as; disconnection and connection of the wireless link, of the pc's, server and switches, sending and receivingpackets through ping between the pc's and server. Based on this simulation, it was possible to have a more referential idea of the possible problems in the attenuation of the network in the red dot sector in the parking lot of the shopping center.

Figure 4.

Point-to-Point Wireless Link Simulation.



Next, he performed an exhaustive analysis of the data collected through the WireShark application, where the source and destination IPs were filtered to identify the equipment with significant packet loss which we observe in Figure 5. This analysis is summarized in Table 1, where it is observed that equipment such as license plate cameras and ticket vending machines presented the highest losses of packages.

Figure 5.

Packet filtering.

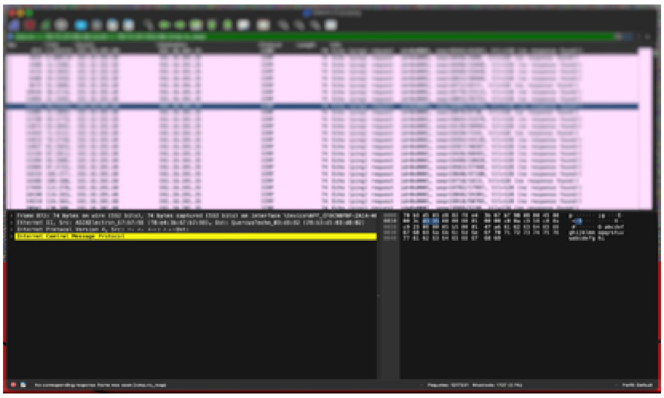


Table 1

Result of the analysis on each team

RED DOT ANALYSIS	20/2/24	12:43-15:26	02:43
TOTAL PACKETS ANALYZED		1217331	
EQUIPMENT	IP	PACKAGES	LOST
Ticket Dispenser	15	19078	220
Interphony	25	19076	220
Registration Chamber	35	3971	1507
Rear Perimeter Acts	145	19280	2
Acti Front Perimeter	185	19296	0
Acti Perimetral Facial	215	19296	0
Ticket validator	55	19262	4
Interphony	75	19296	0
Registration Chamber	95	15540	440
Rear Perimeter Acts	135	19296	0
Acti Front Perimeter	165	19296	0
Acti Perimetral Facial	225	19298	0
Antenna Transmitter	103	9648	0
Antenna Receptor	104	9648	0
Total Lost Packages			2393
Bytes per packet	74		
Bits per packet	592		

The results show that these devices are essential for parking access control, pointing to the need for enhancements in the existing infrastructure. Table 1 provides a summary of the outcomes from the different scenarios analyzed, detailing the total number of captured packets, lost packets, and the packet loss rate.

Once the problem areas were identified, corrective maintenance was performed, which involved replacing the damaged UTP cabling with new cables that meet the IEEE 802.3an standards. Post-replacement results show a significant improvement in data transmission, as shown in Table 2.

Table 2.

Result of the analysis in each team.

RED DOT ANALYSIS	27/6/24	02:59-10:59	08:00
TOTAL PACKETS ANALYZED		927215	
EQUIPMENT	IP	PACKAGES	LOST
Ticket Dispenser	15	24405	2
Interphony	25	24404	2
Registration Chamber	35	24413	0
Rear Perimeter Acts	145	24416	0
Acti Front Perimeter	185	24419	0
Acti Perimetral Facial	215	24417	0
Ticket validator	55	24425	0
Interphony	75		0
Registration Chamber	95	24424	1
Rear Perimeter Acts	135	24423	0
Acti Front Perimeter	165	24426	0
Acti Perimetral Facial	225	24427	0
Antenna Transmitter	103	24424	0
Antenna Receptor	104	24423	0
Total Packages Lost			5
Bytes per packet	74		
Bits per packet	592		

In Table 2, the number of lost packages was drastically reduced, especially in license plate camera and ticket dispensing devices. This loss reduction suggests that the wiring change was effective in mitigating previously detected data transmission issues.

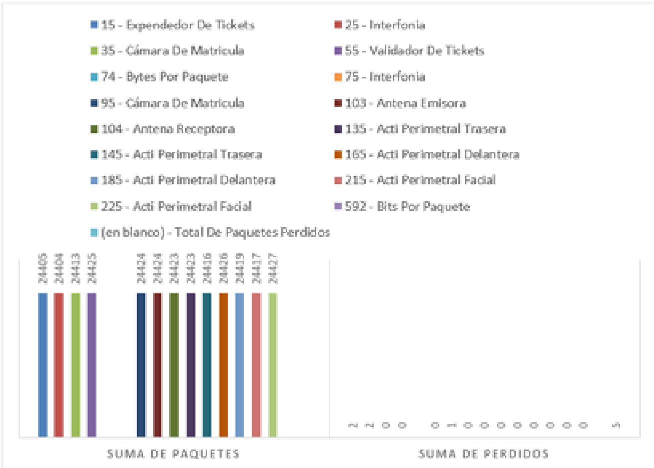
Comparing the data from before and after maintenance showed a significant drop in the number of lost packets. In particular, the camera of the IP 35 recorded a reduction from 1507 to 0, which means a 100% improvement. Therefore, the initial hypothesis that worn wiring was one of the key factors influencing data loss was proven.

The results obtained allow us to conclude that the maintenance actions carried out were effective in improving the quality of the network and the efficiency in the transmission of data in the parking lot. Early identification of critical points and the implementation of appropriate corrective solutions have proven to be essential to ensure the proper functioning of the zonal system and servers.

In addition, as visualized in Figure 6, the reduction in packet attenuation ensures greater reliability in access control and monitoring systems, which is crucial for the operability of the shopping center. In summary, the analysis of the results reveals that, with proper maintenance and the updating of critical components, it is possible to significantly reduce failures in data transmission, thus guaranteeing a more efficient and reliable service for parking lot users.

Figure 6

Result bar diagram referring to table 2.



3.2. DISCUSSION

One of the main issues identified is the significant variability in packet loss across different devices. Specifically, the license plate cameras showed a high rate of data loss, with one camera (IP 35) losing 1,727 packets and another (IP 95) losing 440 packets. This packet loss can be attributed to various factors, such as network congestion, equipment malfunctions, or signal interference.

In an urban and commercial environment, radio signals are frequently affected by interference from other electronic devices, such as Wi-Fi routers, mobile phones, and other wireless systems; because of this, Rattle's reflected packet numbers are common to both systems, with consequent packet collisions and data loss. Radio frequency interference is one of the main forms of packet loss in a high-density environment [7].

The presence of physical structures, such as walls, vehicles, and other obstacles in the parking lot, can attenuate radio signals, resulting in packet loss. The effectiveness of radio links depends on direct line of sight. According to studies, physical barriers can significantly decrease signal quality on wireless links [8].

Incorrect configuration of antenna parameters, such as alignment, tilt angle, and transmit power, can significantly affect link quality. It highlights the importance of proper configuration to minimize packet loss [9]. Equipment performance can be affected by improper maintenance or lack of maintenance.

Dust, moisture, and general wear and tear can damage antennas and other components. The reliability of wireless systems depends on regular maintenance [11]. Detailed network infrastructure planning is critical to ensuring optimal performance. The antennas should be high and free of obstacles, ensuring a direct line of sight between the attachment points. Using RF planning tools can help identify optimal locations.

They emphasize the importance of strategic location in wireless network planning. Conduct field studies prior to implementation to identify potential sources of interference and physical obstacles. These studies allow antenna configuration to be adjusted and network planning more effectively. Field studies are essential for successful wireless network planning [12].

To reduce interference and maximize link quality, adjust technical parameters such as frequency, transmit power, and receiver sensitivity. They have shown that optimal equipment configuration can significantly reduce packet loss. Implement mitigation techniques, such as the use of band filters and the selection of less congested channels [13].

In addition, the use of antenna technology with dynamic tuning capabilities can help avoid interference. Interference mitigation is crucial to improving the stability of wireless networks. Create continuous monitoring to detect and resolve issues instantly. The use of network management software can provide early warnings about link degradation and allow for immediate corrective actions.

He notes that continuous monitoring can improve the operational efficiency of wireless networks [8]. To ensure that improvements to the network have had the desired effect, it is essential to reevaluate performance after making changes to the network. Field testing and performance data analysis are included in this. Post-implementation re-evaluation this is important for quality control.

Consider installing a fiber optic link as the primary connection, keeping radio links as a backup solution. This would ensure that the service would not be interrupted in the event of radio link failures. They suggest that a backup infrastructure can improve the resilience of networks. Implement a regular maintenance schedule for all network components, including cleaning, inspection, and replacement of worn parts.

Studies have shown that preventive maintenance can significantly reduce the incidence of failures and improve overall system performance [11]. Interference, physical obstacles, suboptimal configurations, and lack of maintenance are significant challenges that affect network stability and reliability.

However, by implementing mitigation strategies, continuous monitoring, periodic re-evaluation, and regular maintenance, it is possible to significantly improve network performance by 99.8%. These improvements will not only increase the efficiency and reliability of the network, but will also contribute to a better experience for parking users and the overall safety of the environment.

4. Conclusions

The operation of the radio links, which use PowerBeam 5AC Gen2 antennas, made it possible to determine that the data loss exceeded what is allowed by the IEEE 802.3an and 802.3af/at standards. Under critical conditions, the number of lost packets reached 2393, which meant a significant degradation of the transmitted packets and negatively affected the continuity of transmission to and from the most sensitive areas of the parking lot.

After the implementation of corrective measures, such as the replacement of the rusty UTP cabling with new one in accordance with IEEE standards and the optimization of the radio link configuration, a significant improvement in the quality of data transmission was achieved. Specifically, the number of lost packages was reduced by 99.8%, going from 2393 to only 5 packages in the areas assessed. This percentage improvement confirms that the degradation of the service was directly related to the conditions of the cabling and the suboptimal configuration of the links.

Another key factor contributing to the high failure rate in the network was the absence of a preventive and corrective maintenance program. Implementing regular equipment inspections and preventive maintenance every six months has been shown to reduce the likelihood of failure by 30% before maintenance is even required. This approach has proven to be a crucial strategy, significantly reducing data loss and improving the overall performance and reliability of the parking lot facility.

4.1. RECOMMENDATIONS

Perform a full audit of existing radio links, with a focus on optimizing configuration and replacing equipment that exhibits an unacceptable packet loss rate. Implement real-time monitoring tools to proactively detect and correct data loss.

Install equipment that operates on less congested frequencies and use technologies such as MIMO (Multiple Input Multiple Output) to improve resilience to interference. Additionally, replace UTP cabling with more rust-resistant versions, such as high-quality coated or outdoor-certified cables.

Establish and implement a preventive maintenance plan that includes periodic inspections of all network components, regular cleaning of connections, and performance testing of equipment. This plan must be documented and executed by trained personnel, with status reports after each intervention.

Design and execute an appropriate electric landing plan, ensuring that all critical equipment is connected to surge protection systems. In addition, review and restructure the physical distribution of equipment to minimize exposure to electromagnetic interference and electrical hazards.

Implementing a hybrid connectivity infrastructure that uses fiber optic links as the primary means of data transmission, complemented by radio links as a backup, will enhance stability and provide redundancy. This approach ensures service continuity, even in the event of a failure in one of the systems.

References

[1] E. Soacha, T. De Grado, R. Ruiz, Y. Alejandro, A. Sandoval, y D. Stefany, "Software to manage and manage the resources available in parking lots of small shopping centers – system parking," Nov. 2017. [En línea]. Disponible en: https://repositorio.ucundinamarca.edu.co/handle/20.500.12558/1207 [Accedido el 29 de mayo de 2024].

[2] J. Santiago y C. Pullopaxi, "Implementation of a system that guides the circulation of vehicles and the occupation of available spaces in the parking lots of the Medical Towers and Metropolitan Hospital," Enero 2014. [En línea]. Disponible en: http://bibdigital.epn.edu.ec/handle/15000/7122 [Accedido el 29 de mayo de 2024].

[3] Y. C. Lin y Z. S. Shih, "Design and simulation of a radio spectrum monitoring system with a software-defined network," *Computers & Electrical Engineering*, vol. 68, pp. 271–285, May 2018, https://doi.org/10.1016/J.COMPELECENG.2018.03.043

[4] W. Rehan, S. Fischer, O. Chughtai, M. Rehan, M. Hail, y S. Saleem, "A novel dynamic confidence interval based secure channel prediction approach for stream-based multichannel wireless sensor networks," *Ad Hoc Networks*, vol. 108, p. 102212, Nov. 2020, https://doi.org/10.1016/J.ADHOC.2020.102212

[5] W. Rehan, S. Fischer, M. Rehan, y M. H. Rehmani, "A comprehensive survey on multichannel routing in wireless sensor networks," *Journal of Network and Computer Applications*, vol. 95, pp. 1–25, Oct. 2017, https://doi.org/10.1016/J.JNCA.2017.07.006

[6] J. Mulder *et al.*, "26.3 An 800MS/S 10b/13b receiver for 10GBASE-T Ethernet in 28nm CMOS," in *2015 IEEE International Solid-State Circuits Conference - (ISSCC) Digest of Technical Papers*, 2015, pp. 1–3. doi: 10.1109/ISSCC.2015.7063126.

[7] M. Peng y F. Qin, "Clarification of basic concepts for electromagnetic interference shielding effectiveness," *J Appl Phys*, vol. 130, no. 22, p. 225108, Dec. 2021, https://doi.org/10.1063/5.0075019

[8] A. Colliander *et al.,* "Spatial Downscaling of SMAP Soil Moisture Using MODIS Land Surface Temperature and NDVI During SMAPVEX15," *IEEE Geoscience and Remote Sensing Letters*, vol. 14, no. 11, pp. 2107–2111, 2017, https://doi.org/10.1109/LGRS.2017.2753203

[9] B. Ojaghi, F. Adelantado, E. Kartsakli, A. Antonopoulos, y C. Verikoukis, "Sliced-RAN: Joint Slicing and Functional Split in Future 5G Radio Access Networks," in *ICC 2019 - 2019 IEEE International Conference on Communications (ICC),* 2019, pp. 1–6. https://doi.org/10.1109/ICC.2019.8761081

[10] D. H. Cuzco Torres y S. J. Pinos Carangui, "Design of a Smart Parking System for the Historic Center of the City of Cuenca, Applying an LPWAN Network," 2022. [En línea]. Disponible en: http://dspace.ups.edu.ec/handle/123456789/22405 [Accedido el 29 de mayo de 2024].

[11] S. ZOUGA, M. Benchagra, and A. Abdallah, "Backstepping Control Based on the PSO Algorithm for a Three-Phase PV System Connected to the Grid under Load Variation," in 2020 International Conference on Electrical and Information Technologies (ICEIT), 2020, pp. 1–6. https://doi.org/10.1109/ICEIT48248.2020.9113235

[12] F. Guo, H. Zhang, H. Ji, X. Li, y V. C. M. Leung, "An Efficient Computation Offloading Management Scheme in the Densely Deployed Small Cell Networks With Mobile Edge Computing," *IEEE/ACM Transactions on Networking*, vol. 26, no. 6, pp. 2651–2664, 2018, https://doi.org/10.1109/TNET.2018.2873002

[13] Z. Qian, Y. Zhao, X. Liu, L. Ge, y J. Mao, "A Novel Filter in Antenna (FiA) With Compact Size and High Performance," *IEEE Trans Antennas Propag*, vol. 72, no. 7, pp. 5550–5559, 2024, https://doi.org/10.1109/TAP.2024.3401477

[14] M. N. Al Rafi, M. A. J. Mojumder, S. S. Newaz, y R. Khan, "Study of Radio Link Losses in Different Mediums and Receiving Stations," in *2021 IEEE 19th Student Conference on Research and Development (SCOReD),* 2021, pp. 192–196. https://doi.org/10.1109/SCOReD53546.2021.9652725

[15] J. Allison, "Simulation-Based Learning via Cisco Packet Tracer to Enhance the Teaching of Computer Networks," in *Proceedings of the 27th ACM Conference on on Innovation and Technology in Computer Science Education* Vol. 1, in ITiCSE '22. New York, NY, USA: Association for Computing Machinery, 2022, pp. 68–74. https://doi.org/10.1145/3502718.3524739

[16] S. Unni, D. Raj, K. Sasidhar, y S. Rao, "Performance measurement and analysis of long range Wi-Fi network for

over-the-sea communication," in *2015 13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt),* 2015, pp. 36–41. https://doi.org/10.1109/WIOPT.2015.7151030

[17] S. N. R. Shah, N. H. Ramli Sulong, R. Khan, M. Z. Jumaat, y M. Shariati, "Behavior of Industrial Steel Rack Connections," *Mech Syst Signal Process*, vol. 70–71, pp. 725–740, 2016, doi: https://doi.org/10.1016/j.ymssp.2015.08.026

[18] L. Khichadi y K. Nagamani, "Performance Evaluation of Power over Ethernet in an Ethernet Switch," in *2019 International Conference on Communication and Electronics Systems (ICCES),* 2019, pp. 1091–1095. https://doi.org/10.1109/ICCES45898.2019.9002072

[19] M. A. Islam, R. Irishika, K. Iokibe, y Y. Toyota, "Suppression of Mode Conversion by Improved Shielding Effect of Ethernet Cable Connector Based on Imbalance Factor Matching," in *2019 International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering (IC4ME2),* 2019, pp. 1–4. https://doi.org/10.1109/IC4ME247184.2019.9036533

[20] H. J. Santillan Carranza, J. O. Enriquez Sandoval, y J. F. Bonilla Castro, "Development of a Raspberry Pi-based Wireless Educational Tool," Rev. Ingenio, vol. 7, no. 7, pp. 12–22, 2024. doi: 10.29166/ingenio.v7i1.5630.

[21] S. Caniggia y F. Maradei, "Filter and Grounding Solutions for Limiting Radiated Emission of a PCB with an Attached UTP Cable," IEEE Electromagn. Compat. Mag., vol. 10, no. 1, pp. 33–40, 2021. doi: 10.1109/MEMC.2021.9400990.

[22] J. B. Eom, D. S. Moon, U. C. Paek, B. H. Lee, y G. H. Yang, "Fabrication and transmission characteristics of couplers using photonic crystal fibers," en Optical Fiber Communication Conference and Exhibit, 2002, 2002, pp. 465–466. doi: 10.1109/OFC.2002.1036488.

[23] A. E. Ibhaze, A. O. Gbadebo, A. A. Amusan, y S. N. John, "Performance Analysis of Fiber Attenuation in Passive Optical Networks," Indones. J. Electr. Eng. Informatics, vol. 11, no. 3, pp. 700–712, 2023. doi: 10.52549/ijeei.v11i3.4919.

[24] S. Buhr, X. Xu, M. Kreißig, y F. Ellinger, "A Low Power Fast Ethernet Physical Layer Transceiver," in *2019 26th IEEE International Conference on Electronics, Circuits and Systems (ICECS),* 2019, pp. 478–481. https://doi.org/10.1109/ICECS46596.2019.8964920

[25] M. A. Ebrahimzadeh, M. Dabbaqi, y N. Nakhaie, "Investigating the reduction of the error caused by the counting of vehicle traffic in city license plate reader cameras by mathematical models (case study: Mashhad city)," *Road*, p., 2024, https://doi.org/10.22034/road.2024.416435.2199

[26] A. U. Jibia y N. D. Robinson, "A PC-Based Multifunctional Virtual Oscilloscope," in *2019 2nd International Conference of the IEEE Nigeria Computer Chapter (NigeriaComputConf),* 2019, pp. 1–9. https://doi.org/10.1109/NigeriaComputConf45974.2019.8949640

[27] S. Kakuru, "Behavior based network traffic analysis tool," in *2011 IEEE 3rd International Conference on Communication Software and Networks,* 2011, pp. 649–652. https://doi.org/10.1109/ICCSN.2011.6014810

[28] R. Gooty, G. Modi, S. Williams, K. Kruckmeyer, V. Salomon, y D. Boldrin, "Radiation Evaluation of the DP83561-SP Radiation Hardened 10/100/1000 Ethernet PHY Transceiver with SEFI Handling Sub-System.," in *IEEE Radiation Effects Data Workshop,* 2022. https://doi.org/10.1109/REDW56037.2022.9921702

[29] M. Elhamdadi y E. K. M. Moutuou, "Finitely stable racks and rack representations," *Commun Algebra*, vol. 46, no. 11, pp. 4787–4802, 2018, https://doi.org/10.1080/00927872.2018.1455102

[30] F. Ullah *et al.,* "Barrier Access Control Using Sensors Platform and Vehicle License Plate Characters Recognition," *Sensors*, vol. 19, no. 13, 2019, https://doi.org/10.3390/s19133015

[31] H. J. Santillan Carranza, M. A. Suarez Carvajal, y D. H. Cardenas Villacres, "Development of an IoT Tool for Optimizing Humidity Control in Cocoa Cultivation," Memoria Investigaciones en Ingeniería, vol. 2023, no. 2023, pp. 246–265, 2023. doi: 10.36561/ING.25.14.