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RESEARCH ARTICLE

Enhancing Network Administration Through Raspberry Pi-Driven Wi-Fi Analytics

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ABSTRACT

In the era of rapid technological advancement, the demand for fast and efficient Internet connectivity is critical. Wi-Fi, a key access technology, often faces performance degradation due to increased traffic and user expectations. Effective management, maintenance, and monitoring are essential to ensure smooth access for users. Network administrators face challenges in monitoring and optimizing Wi-Fi traffic, often resulting in decreased performance and user dissatisfaction. The lack of timely notifications regarding Wi-Fi signal availability further complicates the management of network access points (APs). The objectives of the study include examining the feasibility of using Raspberry Pi for Wi-Fi coverage analysis, developing an analysis engine to monitor network performance, and evaluating its effectiveness in a real-world environment. The methodology involved configuring a Raspberry Pi with a custom Wi-Fi adapter and antenna and implementing the Weighted Scoring Method (WSM) to analyse network metrics such as latency, jitter, and packet loss. The system continuously monitors network performance and sends email alerts to administrators when performance is degraded below acceptable levels. The study concludes that Raspberry Pi is effective in capturing and analysing Wi-Fi traffic, providing timely alerts that allow administrators to address issues proactively. This research demonstrates the potential of using low-cost technology to improve network management and optimizing Wi-Fi traffic, ultimately improving user satisfaction and network performance.

INTRODUCTION

Today, the need for the development of the Internet is critical. With extremely fast progress in the development of technologies and novelties, the demand for fast and efficient flow of information is imposed as a vital factor in modern communication. Wireless Fidelity (Wi-Fi) is a point of access technology for the wireless internet that allows one to connect to the internet with smartphones, computers, and other gadgets, and the evolution of Wi-Fi technology has transformed communication by enabling seamless access through billions of devices, from smartphones to IoT gadgets [1]. Most of the time, net traffic is the likely reason for rapid performance decline due to increasing the number of users and their expectations of faster speeds [2], therefore an effective network management, maintenance and monitoring of the network are essential to ensure smooth access for users.

The main crucial processes to follow during Wi-Fi traffic monitoring and optimization include the detection, recording, and analysis of packet data that is transmitted over Wi-Fi networks [3]. Congestion leads to decreased performance due to excess traffic on the network, and moreover, according to Srivastava et al. (2020), congestion leads to packet loss, high energy consumption, and increased transmission delays, degrading network quality and reliability [4]. Addressing these congestion issues is critical to improve system performance, reliability, and overall efficiency [5].

Thus, it is a challenge to the Pusat Pengurusan Infostruktur & Rangkaian in monitoring the Access Point (AP) in the network. When an administrator does not receive timely notifications of the availability of the Wi-Fi signal offered by the AP, it literally means that the monitoring capabilities are not there. The relevance of the notification status reflects the level of signal and the satisfaction of the user in the efficient and smooth operation of the network. There is, therefore, the need to come up with a mechanism for the network administrators to monitor better and more appropriately for the purpose of ensuring optimal Wi-Fi access coverage, and hence users' satisfaction.

This study aims to provide an outline regarding the suitability of Raspberry Pi as a device that aims to analyse the coverage of Wi-Fi, especially regarding capacity in network administration. The purpose aims to achieve the following specific objectives, including examining the feasibility of using Raspberry Pi as a tool for analysing Wi-Fi access coverage, creating an analysis engine, implementing a mechanism for alerting the network administrator before any issues arise, and evaluating the effectiveness of Raspberry Pi as a Wi-Fi coverage analyser in a real-world environment.

The remainder of the paper is structured as follows. Section 1 presents a background study of this work. Section 2 discusses the general methodology developed for the proposed approach; Section 3 presents the methodology used in this research. Section 4 elaborates the experimental results and discussion on the proposed approach. Lastly Section 5 concludes the study with conclusion and future work.

RELATED WORKS

In an age where connectivity is paramount, Wi-Fi traffic monitoring and optimization emerge as critical components of network management that encapsulates a study that stands at the intersection of innovative low-cost technology and sophisticated analytical methods, specifically the growing need for efficient network traffic analysis, the role of Raspberry Pi as a cost-effective tool in such endeavours, and the application of multi-criteria analysis to optimize network performance [6]. By synthesizing existing research findings and identifying knowledge gaps, this review serves as a valuable resource for network administrators, researchers, and developers aiming to improve the performance and reliability in an increasingly interconnected world.

Mohamed and Nassef (2020) has presented an algorithm grounded in fuzzy logic for managing session transfers in Wi-Fi/WiGig environments [7]. It has shown proficiency in its application but did not provide an extensive analysis of the context. researchers have developed a convolutional neural network algorithm to classify attacks on Wi-Fi networks, achieving significant results, although its scalability and utility in wider applications are not fully addressed [8]. Mbengue and Chang (2018) research has integrated marked Poisson point processes with Markov chains to examine Licensed Assisted Access (LAA) and Wi-Fi coexistence, but its performance in diverse network scenarios remains to be assessed [9]. The investigation mentioned in Sun et al. (2021) research has applied a graph-based temporal convolutional network to predict network traffic, achieving increased precision, yet its versatility across different contexts of mobile networks has not verified [10]. The work by Granato et al. (2022) has utilized graph-based methods to analyse network traffic, showing expertise, but not thoroughly evaluating in multiple traffic types [11]. Meanwhile, the research outlined by Sadiku et al. (2022) has leveraged semi-supervised clustering for real-time traffic surveillance, requiring further evaluation of its precision and dependability in various environmental settings [12].

Each work contributes uniquely but also highlights areas that need improvement, particularly scalability, adaptability, and comprehensive performance evaluation under diverse conditions. By bridging these highlights, the study addresses both the practical aspects of implementation and the theoretical frameworks that guide the optimization of Wi-Fi traffic monitoring.

METHODS

This study is structured into three phases, as illustrated in Figure 1, each phase explained in detail in the following sections.

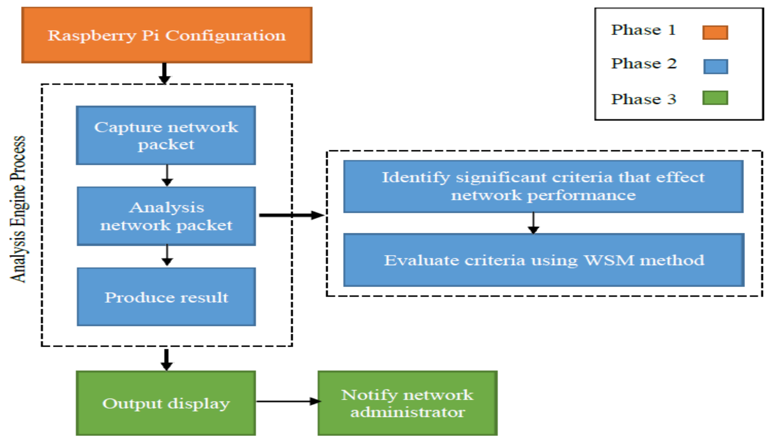


Figure 1. Enhancing network administration through a raspberry pi-driven wi-fi analytics framework.

Phase 1

Phase 1 involves the configuration of the Raspberry Pi Model B for use as a Wi-Fi traffic analyser in this study. The Raspberry Pi is a small, single-board computer that was first released in 2012 by the Raspberry Pi Foundation. Table 1 shows the specifications of the Raspberry Pi Model and their corresponding details as follows:

- **Processor**: This is the central processing unit that runs the operating system and software.
- **Memory**: This indicates the amount of random-access memory available to the device to use.
- **Storage**: This means that the device uses a microSD card to store its operating system, programs, and data.
- **Connectivity**: The connectivity options available on the device to connect to the network, peripheral devices, video and audio output, respectively.
- **Wi-Fi adapter:** The device uses the brand and model of the adapter to connect to wireless networks.
- **Wireless Standards**: these are Wi-Fi standards compatible with the device's wireless adapter, specifying the types of Wi-Fi networks it can connect to.
- **Antenna**: This details the type of external antenna used, which is likely to improve the

reception of Wi-Fi signals.

- **Customizations**: This would mean that the device is modified to include a Wi-Fi adapter and an antenna meant to analyze Wi-Fi traffic, a pretty good indicator of use in testing networks or for security analysis.

Table 1. The raspberry pi model B used in this study.

Specification	Detail
Processor	Broadcom BCM2835 SoC with 700 MHz ARM11 processor
Memory	512 MB of RAM
Storage	microSD card slot for storage
Connectivity	Ethernet port, 2 USB ports, HDMI port, 3.5mm audio jack
Wi-Fi Adapter	Alfa AWUS036NH
Wireless Standards	IEEE 802.11b/g/n
Antenna	External 5dBi antenna
Customizations	Modified with Wi-Fi adapter and antenna for Wi-Fi traffic analysis

Phase 2

Phase 2 captures and analyses network packets within the coverage performance of the network by any Access Point (AP). On the Raspberry Pi, the 'ping' command is executed using Python's subprocess module. The output of the command 'ping' is parsed to get some metrics such as latency, jitter and the percentage of packet loss. This was followed by extracting the value of rtt (round trip time) and using the percentage value in the loss field to gauge the value of the packet loss [9-10]. To improve the strength of the data, the command 'ping' is executed several times, and finally, the average values of latency, jitter, and packet loss are calculated, which would help better determining the Weighted Scoring Method (WSM) score. Data collection happens over time to monitor the variability of the network performance in all 24-hour periods.

The design of the WSM score is such that it calculates the network quality score following a weighted sum model [13-15], where the weight corresponding to latency, jitter, and loss is 0.3, 0.35, and 0.35, respectively. The output score is the sum of the products of these weighted values. WSM has an important theoretical advantage in the following sense: it allows one to simultaneously consider several criteria, each of which has a weight that indicates its relative importance. These weights help in determining a composite score that yields aggregate value results and offer a benchmark for the solution or alternative comparison. WSM can gauge the quality of the network, giving the values of latency, jitter, and packet loss that have been measured. This tool sends an alert via email to the network administrator immediately after the score has fallen below a preset threshold.

Phase 3

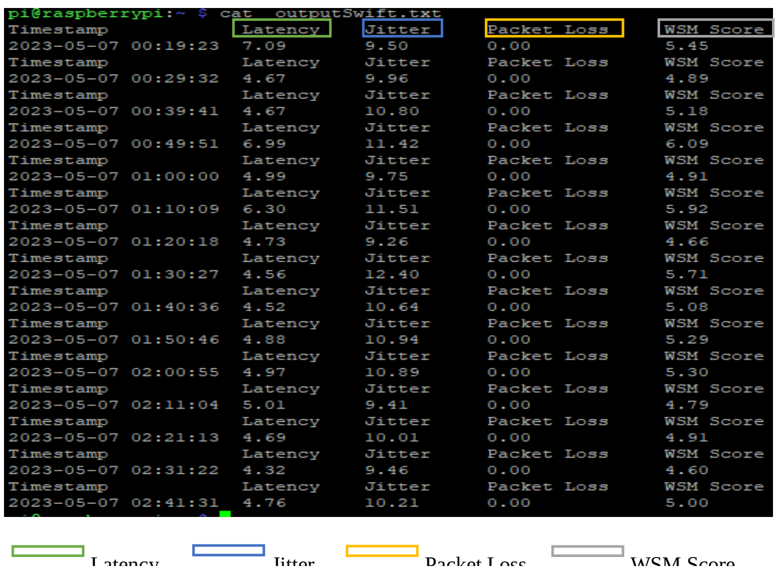
At this phase 3, the system administrator should be able to alert the network administrator of the outcome of the analysis. In this case, where the calculated score is less than the specified threshold, the system sends an email to the network administrator using the Simple Mail Transfer Protocol (SMTP). This sends an alert message with the Network Quality Score update to the administrator to investigate the matter. At the same time, this system does keep track of the output of each execution of the ping in tabulated form, recording the timestamp and latency, jitter, packet loss, and score of WSM. The output is not just displayed on the console but acts as a tool that gives one a view of network quality over long periods, enabling the identification of trends or patterns in network performance.

RESULTS AND DISCUSSION

The weighted scoring method (WSM) score is recorded and compiled at 10-minute time intervals in a summary table that includes time of day, latency, jitter, packet loss, and WSM score. In real-time, data are accrued and stored in a text file on the Raspberry Pi, as indicated below in Figure 2:

- **Timestamp**: shows the date and time the ping command was executed.
- **Latency**: represents the time it takes for a data packet to travel from the source to the destination and back in milliseconds.
- **Jitter**: indicates the variability in the latency over time in milliseconds.
- **Packet loss:** represents the percentage of data packets that were lost during transmission.
- **WSM Score**: these scores are calculated using the Weighted Scoring Method based on the latency, jitter, and packet loss values.

These data are useful for analysing the stability and performance of a network at different times. The consistent pattern of zeros in the "Packet Loss" column suggests a stable connection during these times, while the "WSM Score" provides a quick reference to assess overall network quality. The output is neatly organized and appears to be intended to monitor network performance, with potential to troubleshoot or maintaining network reliability.



```
pi@raspberrypi:~ $ cat  outputSwift.txt
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 00:19:23   7.09       9.50      0.00           5.45
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 00:29:32   4.67       9.96      0.00           4.89
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 00:39:41   4.67       10.80     0.00           5.18
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 00:49:51   6.99       11.42     0.00           6.09
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 01:00:00   4.99       9.75      0.00           4.91
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 01:10:09   6.30       11.51     0.00           5.92
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 01:20:18   4.73       9.26      0.00           4.66
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 01:30:27   4.56       12.40     0.00           5.71
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 01:40:36   4.52       10.64     0.00           5.08
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 01:50:46   4.88       10.94     0.00           5.29
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 02:00:55   4.97       10.89     0.00           5.30
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 02:11:04   5.01       9.41      0.00           4.79
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 02:21:13   4.69       10.01     0.00           4.91
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 02:31:22   4.32       9.46      0.00           4.60
Timestamp             Latency    Jitter    Packet Loss    WSM Score
2023-05-07 02:41:31   4.76       10.21     0.00           5.00
```

Figure 2. Output of network latency, jitter, packet loss, and WSM score in terminal.

As illustrated in Figures 3 to Figure 6 , the data indicate that the network maintains a consistent performance level throughout the observation period, with no packet loss detected. The mean latency and jitter metrics fall within permissible bounds. Furthermore, the WSM score consistently remains below the threshold value of 75, suggesting robust network performance. Overall, the graphs reveal fluctuating network latency and jitter over time, with periods of higher values signifying potential network congestion. Packet loss remains at 0%, demonstrating consistent data delivery during the observed period. The WSM score, which exhibits overall network performance, shows variability correlating with changes in latency and jitter, suggesting that the network's quality fluctuates based on these metrics.

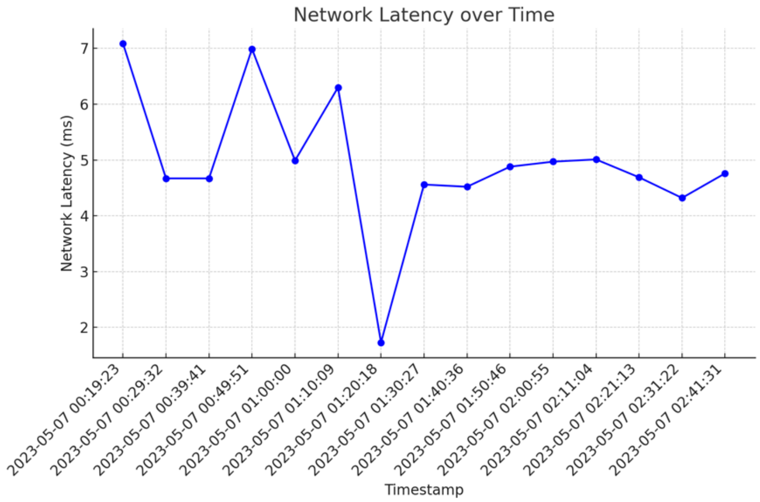


Figure 3. Graph of network latency over time.

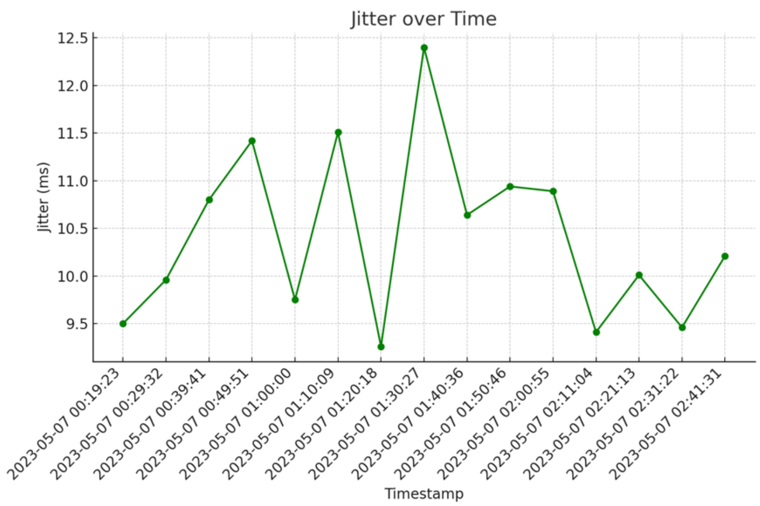


Figure 4. Graph of jitter over time.

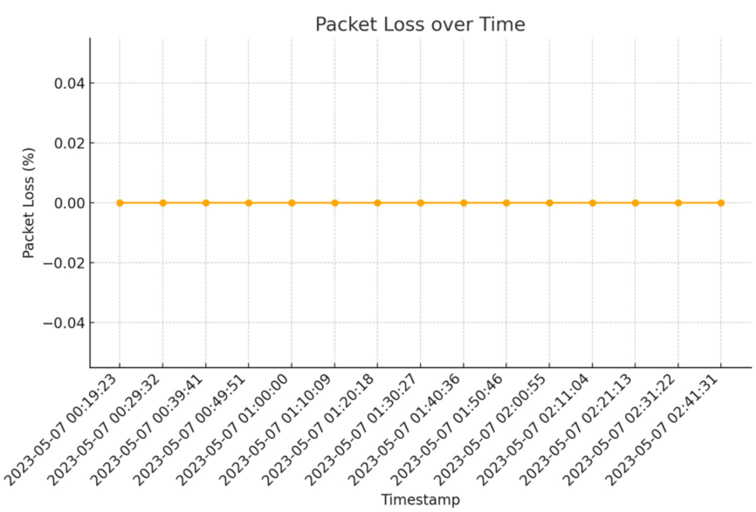


Figure 5. Graph of packet loss over time.

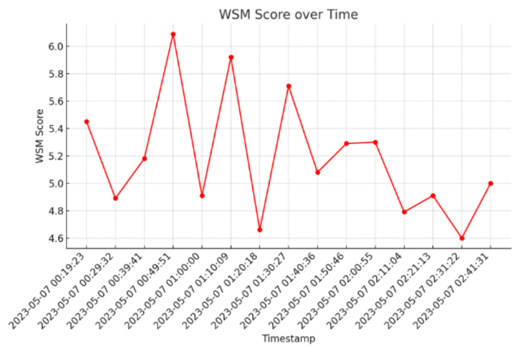


Figure 6. Graph of the WSM score over time.

Selecting an appropriate threshold value for the network quality score hinges on various determinants such as the network's nature, the sensitivity of the applications in operation, and the network administrator's criteria. However, given the customary range of outcomes derived from latency, jitter, and packet loss measures, a threshold value of 75 is considered judicious for alerting the network administrator to potential network complications. The WSM score offers a valuable aggregation of the overall health by integrating key metrics such as latency, jitter, and packet loss. However, the appropriateness of this value may necessitate adjustments based on the signified needs and criteria of the network under surveillance. For example, networks that facilitate time-critical applications such as live video conferencing might command a lower threshold to assure consistently acceptable network quality. Conversely, networks accommodating less imperative tasks, such as file transfers, may find a higher threshold adequate.

In instances where the network encounters an issue and the score surpasses the predefined threshold, the system sends an email to the network administrator via the Simple Mail Transfer Protocol (SMTP). This email features a subject line that signals a network quality alert and contains a message body detailing the current score, along with a request for the administrator to investigate, as illustrated in Figure 4 and Figure 5. It confirms that it works in the right way, whereby it proactively monitors the quality of the network and sends notifications to the network administrator only in cases where performance is reduced below the allowed threshold level.

The system was designed to continuously monitor the network's performance and then trigger the sending of an email alert once the threshold is exceeded. This kind of email alerting mechanism used in this study provides an effective way of notifying the network administrator in the event of possible issues on the network. Furthermore, the early notifications in the event of mediocre network performance give administrators a chance to intervene in time, hence pre-empting more problems and reducing potential harm to be caused to network users.

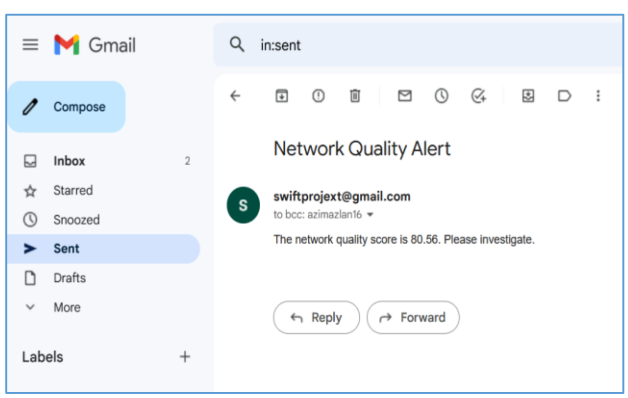


Figure 4. Email sent to Network Administrator using SMTP.

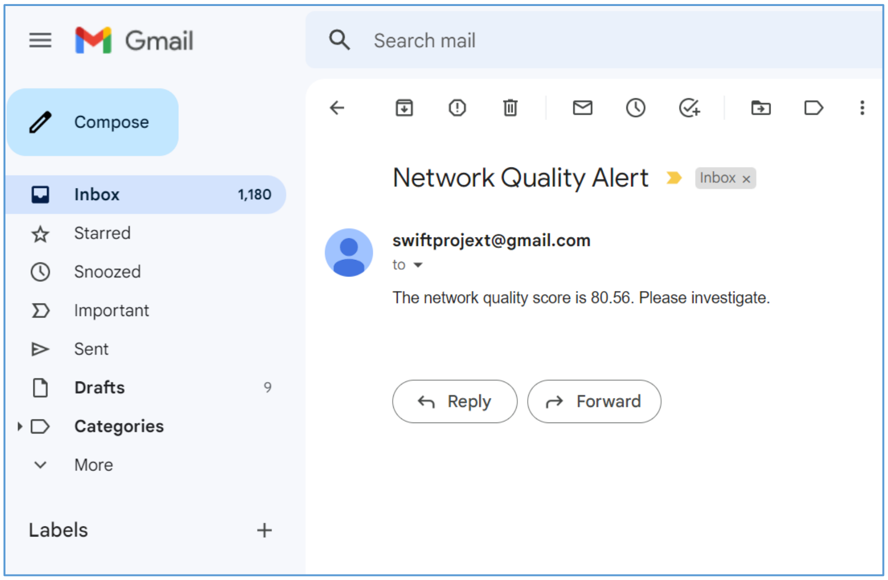


Figure 5. Email received by the Network Administrator.

CONCLUSIONS

In essence, this research was designed to confirm that the Wi-Fi coverage analysis is feasible with the deployment of the Raspberry Pi, especially in improving networks' management and Wi-Fi signal coverage. The findings corroborate the efficacy of the Raspberry Pi as a Wi-Fi coverage analyser within a real-world setting. Thus, the analysis engine using the Weighted Scoring Method for Wi-Fi traffic appraisal has been an efficient source to alert, on a timely and accurate basis, the network administrator regarding the problems that arose from time to time, so that the network operations continue effectually. This work strategically contributes to the surveillance of network administrators and extends their power to ensure the optimum coverage of access to the Wi-Fi and hence satisfy the users.

Moreover, the precursory identification of network anomalies, expeditious communication to the network administrator, and the capacity for continuous network quality monitoring are instrumental in avoiding operational disruptions and ensuring the network's peak performance. In terms of the specific indices utilized for the evaluation of network performance in this study, latency, jitter, and packet loss were the main metrics for WSM score computation. While these metrics are indicative of network performance, incorporation of additional metrics such as throughput, network utilization, and signal-to-noise ratio (SNR) could provide a more holistic perspective of network efficacy.

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