



## Comparison of Wi-Fi Roaming Performance between Software-Defined Networking-Based and Standalone Networks

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### Abstract

RSUD Bangil is transitioning toward the implementation of integrated Electronic Medical Records (EMR) connected to the Hospital Management Information System (SIMRS). The high mobility of medical personnel, particularly in the Emergency Department (ED), requires a stable Wi-Fi connection when users move between access points (roaming). This study aims to analyze and compare Wi-Fi roaming performance between a Software-Defined Networking (SDN)-based network and a standalone network at RSUD Bangil. Testing was conducted at two locations in the ED, with ten repetitions using Windows 11 and Android devices. The Quality of Service (QoS) parameters measured included throughput, delay, jitter, and packet loss using Iperf3 and Termux, complemented by an evaluation of user perceptions through questionnaires. In the SDN-based network, access points were centrally managed using Cloudnet, with max-power and channel settings configured accordingly. The results showed that the SDN-based network demonstrated better roaming performance than the standalone network, characterized by more stable throughput, lower delay and jitter, and no packet loss during the roaming process. The user evaluation results further confirmed improved connection stability following SDN implementation. Therefore, the SDN-based network architecture provides a more optimal solution for supporting the continuity of EMR services in hospital environments with high user mobility.

## Introduction

Digital transformation in the healthcare sector has encouraged hospitals to develop integrated, efficient, and quality-oriented service systems. One of the key implementations of this transformation is the adoption of Electronic Medical Records (EMR) integrated with the Hospital Management Information System (SIMRS). The implementation of EMR enables patient data to be recorded electronically, thereby improving the accuracy of medical documentation, accelerating access to clinical information, supporting continuity of care, and reducing the risk of recording errors commonly associated with paper-based systems. The Indonesian government has also encouraged all healthcare facilities to implement electronic medical records as part of the national healthcare system transformation (Ministry of Health of the Republic of Indonesia, 2022; Juliansyah et al., 2024; Vi'aqila El Tsana et al., 2025; Sugiarto et al., 2025; Nurmidin, 2025; Juliansyah et al., 2025).

RSUD Bangil is currently in the stage of full EMR implementation integrated with SIMRS. In practice, healthcare professionals access the system not only through computers available

in each room but also through mobile devices such as laptops and tablets when conducting patient visits and providing services in the Emergency Department (ED) (Wang et al., 2024; Eustache et al., et al., 2023; Marshall et al., 2023; Goldfine et al., 2022; Minervini et al., 2022). This condition has increased the importance of wireless network infrastructure, particularly Wireless Local Area Network (WLAN), as the network must be capable of providing stable connectivity even when users move between locations during healthcare delivery (Yuce, 2010).

WLAN technology has become a primary solution for providing flexible network access in various working environments, including hospitals, universities, and offices. The use of Wi-Fi technology enables users to access network resources without relying on wired connections, thereby enhancing user mobility and productivity (Shirvani Moghaddam, 2024; Konieczna et al., et al., 2026). However, the quality of WLAN services is strongly influenced by network design, access point placement, channel configuration, network management mechanisms, and the system's ability to maintain connection continuity when users move between the coverage areas of different access points (Hermawan & Rahmatia, 2025; Ardiansyah et al., 2024).

One of the main challenges in implementing WLAN in hospital environments is wireless roaming, which refers to the process by which a device switches its connection from one access point to another without interrupting an ongoing communication session (Islam et al., 2024; George, 2026; Ning et al., 2025; Ficara et al., 2023). An effective roaming mechanism is essential to ensure that real-time applications, such as SIMRS and EMR, remain accessible without disruption while healthcare professionals move between rooms. When roaming does not operate optimally, increased delay, jitter, and packet loss, as well as reduced throughput, may occur, ultimately resulting in slower application access or even network disconnection (Wibowo & Triloka, 2023; Siahaan & Suartana, 2023; Oleiwi et al., 2022; Li et al., 2024).

These problems are still observed in the implementation of the Wi-Fi network at RSUD Bangil. Most access points still employ a standalone architecture, such as the TP-Link Archer C80, which operates independently without centralized control. Consequently, the connection handover mechanism between access points has not functioned optimally. Based on initial observations, in several areas, particularly in the Emergency Department (ED), user devices remain connected to an access point with a weak signal even when they have moved closer to another access point providing a stronger signal. This phenomenon is known as a *sticky client*, referring to a condition in which a device delays switching to a more appropriate access point, resulting in degraded communication quality.

This condition affects network performance, as indicated by throughput values of approximately 10 Mbps, delay reaching 100 ms, jitter of approximately 200 ms, and packet loss of approximately 2%. These conditions make access to SIMRS slower, particularly when medical personnel enter EMR data using mobile devices. In a healthcare environment, delays in accessing medical data may hinder patient care processes and increase the risk of delays in recording critical clinical information (Olakotan et al., 2025; Chen et al., 2024; Ghadi et al., 2024). Previous studies have demonstrated that the quality of handover processes between access points directly affects Quality of Service (QoS) parameters, including throughput, delay, jitter, and packet loss, which serve as key indicators of WLAN performance (Siahaan & Suartana, 2023). In addition, roaming performance is influenced by signal strength, measured through the Received Signal Strength Indicator (RSSI), channel interference, network configuration, and authentication mechanisms. Consequently, suboptimal handover processes may increase latency and packet loss during connection transitions (Hadiwinata et al., 2025; Elbatal et al., 2025; Gannapathy et al., 2023; Maiwada et al., 2025).

One approach that has emerged to address the limitations of traditional networks is the implementation of Software-Defined Networking (SDN). SDN is a networking paradigm that separates the control plane from the data plane, allowing network devices to be centrally managed through a controller. This approach enables administrators to configure, monitor, and optimize networks dynamically, thereby facilitating more efficient traffic and user mobility management compared with conventional network architectures (Ali et al., 2023). In wireless network implementations, this concept is known as Software-Defined Wireless Networking (SDWN), which enables roaming mechanisms to be managed in a more coordinated manner, allowing connection transitions between access points to occur more rapidly and seamlessly.

In contrast, standalone Wi-Fi networks rely on the independent configuration of each access point without a centralized decision-making mechanism (Ali & Almagrabi, 2026; Manzoor et al., 2024; Han et al., 2026). As a result, roaming decisions depend largely on the client device, which may cause connection switching to occur too late, particularly in environments characterized by high mobility and a large number of users. Therefore, analyzing roaming performance across these two network architectures is important for determining the effectiveness of each approach in providing network quality that meets hospital operational requirements (Ardiansyah et al., 2024; Mazhar et al., 2023; Raftopoulou et al., 2025; Chen et al., 2024; Yuvarani et al., 2025; Abujassar, 2025; Majumdar et al., 2024).

Several previous studies have reported that SDN-based networks can improve network management efficiency, traffic optimization, scalability, and user mobility compared with traditional networks (Ali et al., 2023). Other studies have also demonstrated that SDN enables the implementation of more adaptive network mobility mechanisms through centralized control, allowing handover processes to be performed with lower latency than conventional approaches (Purohith & Sivalingam, 2022). However, most of these studies have been conducted in laboratory or university network environments, and relatively few have examined SDN-based Wi-Fi roaming in hospital environments characterized by high user mobility, real-time access requirements, and critical demands for service continuity.

Based on the aforementioned considerations, a research gap remains regarding the comparison of Wi-Fi roaming performance between SDN-based and standalone networks in healthcare service environments, particularly in supporting the implementation of EMR integrated with SIMRS at RSUD Bangil. Therefore, this study aims to compare the performance of the two network architectures based on Quality of Service (QoS) parameters, including throughput, delay, jitter, and packet loss. The findings are expected to provide technical recommendations regarding the most optimal network architecture for supporting EMR implementation and to serve as a reference for other hospitals in developing stable, reliable WLAN infrastructure capable of ensuring the continuity of digital healthcare services.

## Methods

### Research Design

This study employed an experimental method with a quantitative approach to compare roaming performance between two wireless network architectures, namely a standalone Wi-Fi network and a Software-Defined Networking (SDN)-based network. The experimental method was selected because it allows testing to be conducted under the same environmental conditions, ensuring that the observed performance differences are attributable to the characteristics of each network architecture. The research object was the Wi-Fi network implementation in the Emergency Department (ED) of RSUD Bangil, with a focus on the roaming process as user devices moved from one access point to another. Network performance was evaluated using Quality of Service (QoS) parameters, including throughput, delay, jitter, and packet loss.

## Research Framework

The research stages were systematically organized, beginning with the identification of roaming problems in the existing Wi-Fi network, which still employed a standalone architecture. This was followed by a literature review covering Wireless Local Area Network (WLAN), wireless roaming, Software-Defined Networking (SDN), and Quality of Service (QoS). The next stage involved designing the network topology using two scenarios: a standalone Wi-Fi network and an SDN-based network. After the topology was designed, network devices were implemented and each network architecture was configured accordingly. Roaming tests were then conducted using Windows and Android devices to obtain throughput, delay, jitter, and packet loss measurements. The resulting data were analyzed comparatively to determine which network architecture provided better roaming performance. As a complement to the technical evaluation, questionnaires were distributed to ED staff to assess users' perceptions of network connection quality while using both network architectures. The final stage involved drawing conclusions based on the results of the analysis.

## Research Equipment

The study utilized the hardware and software listed in Table 1.

Table 1. Research Equipment

| Category                | Device                                            |
|-------------------------|---------------------------------------------------|
| Firewall                | Sophos XGS3300                                    |
| Router                  | MikroTik CCR2116-12G-4S+                          |
| Switch                  | MikroTik CRS326-24G-2S+                           |
| Standalone Access Point | TP-Link Archer C80                                |
| SDN Access Point        | H3C WA6526                                        |
| Laptop                  | Lenovo IdeaPad Duet 3i                            |
| Smartphone              | Redmi Note 14                                     |
| Software                | Cloudnet, iPerf3, Command Prompt, Termux, NetSpot |

The specifications of the two access points used in the study are presented in Table 2.

Table 2. Comparison of Access Point Specifications

| Parameter                 | H3C WA6526              | TP-Link Archer C80      |
|---------------------------|-------------------------|-------------------------|
| Wi-Fi Standard            | IEEE 802.11ax (Wi-Fi 6) | IEEE 802.11ac (Wi-Fi 5) |
| Maximum Speed             | 5.375 Gbps              | 1.9 Gbps                |
| MU-MIMO                   | Yes                     | Yes                     |
| Beamforming               | Yes                     | Yes                     |
| IEEE 802.11r              | Yes                     | No                      |
| IEEE 802.11k              | Yes                     | No                      |
| IEEE 802.11v              | Yes                     | No                      |
| Radio Resource Management | Yes                     | No                      |
| Controller                | Cloudnet                | Not available           |

## Network Topology

This study compared two Wi-Fi network architectures. In the first scenario, the network employed TP-Link Archer C80 devices configured as standalone access points. Each device operated independently without centralized management; therefore, the roaming process depended entirely on decisions made by the client device. In the second scenario, H3C WA6526 access points managed through the Cloudnet Controller were used. All access points were placed within a single management domain, allowing SSID, channel, transmit power,

and roaming mechanisms to be configured centrally. This implementation supports IEEE 802.11r, 802.11k, and 802.11v features, which are designed to accelerate the handover process between access points.

## Research Procedure

The research procedures were conducted as follows: 1) Identifying roaming problems in the Wi-Fi network at RSUD Bangil; 2) Conducting a literature review on WLAN, roaming, SDN, and QoS; 3) Designing the standalone and SDN network topologies; 4) Configuring VLAN 20 on the MikroTik CCR2116-12G-4S+ router using the 192.168.17.0/24 subnet and connecting it via a trunk link to the CRS326-24G-2S+ switch; 5) Configuring two TP-Link Archer C80 access points as standalone devices with different SSIDs; 6) Configuring two H3C WA6526 access points using Cloudnet with a single SSID, together with channel and transmit-power settings to support roaming.

Determining two testing locations: Point 1: approximately 3 meters from the Nurse Station access point in the ED. Point 2: located within the overlapping coverage area, approximately 5 meters from the UHC room access point and 15 meters from the Nurse Station access point. a) Conducting QoS testing using iPerf3 and the ping command; b) Repeating the tests 10 times at each point for both network architectures; c) Collecting the test results; d) Analyzing the measurements and comparing the roaming performance of the two networks; e) Drawing the research conclusions.

## Testing Scenarios

Testing was conducted on two operating systems to represent actual usage conditions in the hospital environment. For Windows 11, a Lenovo IdeaPad Duet 3i was used as the client device, with iPerf3 operated through Command Prompt. For Android, a Redmi Note 14 was used as the client device, with Termux running iPerf3. The iPerf3 server was configured with a bandwidth of 50 Mbps, while delay was measured using the ping command by sending 20 packets to the server. Each testing scenario was repeated 10 times on both the standalone and SDN-based networks.

## Data Collection

Research data were obtained through two methods: a) Primary data, consisting of QoS measurement results obtained using iPerf3, Command Prompt, Termux, and NetSpot; b) Supporting data, consisting of questionnaire responses from ED staff regarding their experience using the Wi-Fi network during ERM implementation. RSSI values at each testing point were recorded using NetSpot to verify signal coverage conditions during the roaming process.

## Quality of Service Parameters

Network performance was evaluated using four Quality of Service (QoS) parameters.

Table 3. Quality of Service Parameters

| Parameter   | Unit | Description                                                          |
|-------------|------|----------------------------------------------------------------------|
| Throughput  | Mbps | Effective data transfer rate                                         |
| Delay       | ms   | Time required for a packet to travel from the sender to the receiver |
| Jitter      | ms   | Variation in packet arrival time                                     |
| Packet Loss | %    | Percentage of packets that fail to reach the destination             |

## Data Analysis

The test results were analyzed using a descriptive-comparative approach by comparing the average throughput, delay, jitter, and packet loss values obtained from the two network architectures. The measurement results were presented in tables and graphs to illustrate

differences in roaming performance between the standalone Wi-Fi network and the SDN-based network. Subsequently, the QoS measurement results were interpreted based on applicable service-quality categories to determine the network architecture that provides the most optimal performance for supporting the implementation of Electronic Medical Records (EMR) within the SIMRS environment at RSUD Bangil.

## Results and Discussion

### Network Implementation

The research implementation was conducted on the Wi-Fi network in the Emergency Department (ED) of RSUD Bangil by comparing two network architectures: a standalone Wi-Fi network using two TP-Link Archer C80 access points and a Software-Defined Networking (SDN)-based network using two H3C WA6526 access points managed through the Cloudnet Controller. Both networks utilized the same infrastructure, consisting of a Sophos XGS3300 firewall, a MikroTik CCR2116-12G-4S+ router, and a CRS326-24G-2S+ switch. The network configuration was implemented on VLAN 20 with the 192.168.17.0/24 subnet, ensuring that both testing scenarios were conducted under identical network conditions.

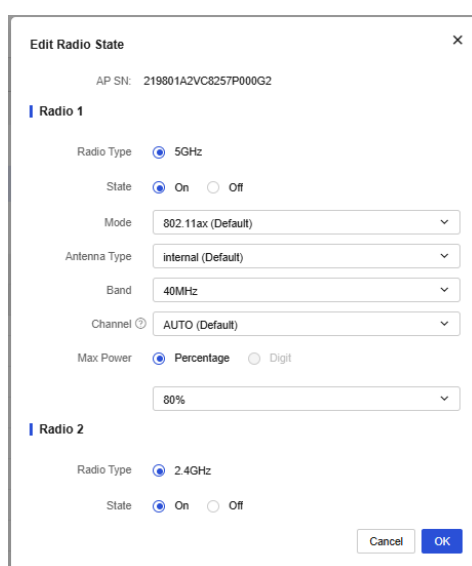


Figure 1. SDN Network Implementation Topology

Figure 1 illustrates the implementation of the two network architectures used in this study. In the standalone network, each access point operated independently, whereas in the SDN-based network, all access points were centrally controlled through the Cloudnet Controller, allowing network configuration and roaming processes to be centrally managed.

### RSSI Measurement Results

Prior to the Quality of Service (QoS) testing, Received Signal Strength Indicator (RSSI) measurements were conducted to determine the signal quality at the two testing locations.

Table 4. RSSI Measurement Results

| Network    | Position | Frequency | Windows | Android | Category  |
|------------|----------|-----------|---------|---------|-----------|
| Standalone | 1        | 5 GHz     | -52 dBm | -60 dBm | Very Good |
| Standalone | 2        | 2.4 GHz   | -80 dBm | -78 dBm | Fair      |
| SDN        | 1        | 5 GHz     | -49 dBm | -58 dBm | Very Good |
| SDN        | 2        | 2.4 GHz   | -48 dBm | -57 dBm | Very Good |

At the first testing location, both networks demonstrated very good signal quality because the devices were still located close to the primary access point. In contrast, at the second testing

location, the standalone network experienced a significant decrease in RSSI to -80 dBm for Windows and -78 dBm for Android, whereas the SDN-based network maintained RSSI values within the very good category, at -48 dBm and -57 dBm, respectively. These results indicate that the roaming mechanism in the SDN-based network was more effective in maintaining connectivity by facilitating the transition to a more suitable access point.

## Quality of Service Testing Results

### Throughput

Throughput testing was conducted using the iPerf3 application with the server bandwidth configured at 50 Mbps. Testing was performed at two designated testing points and repeated ten times for each network architecture.

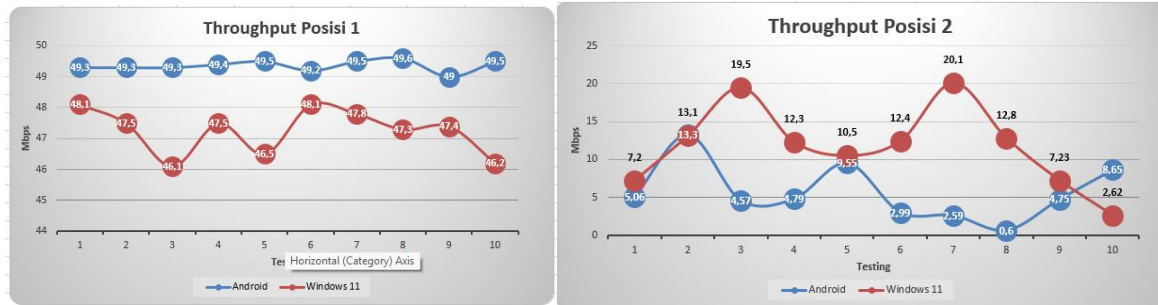


Figure 2. Throughput Comparison between Standalone and SDN Networks

The test results showed that throughput at the first testing point was relatively stable across both network architectures. However, a significant difference was observed at the second testing point. The standalone network experienced a substantial decrease in throughput, reaching as low as 0.6 Mbps on Android and 2.62 Mbps on Windows. In contrast, the SDN-based network maintained throughput at approximately 49 Mbps on Android and 26.6–48.7 Mbps on Windows. These findings indicate that the SDN architecture was more capable of maintaining connection quality during the roaming process.

### Delay

Delay was measured using the ping command by transmitting 20 packets at each testing point

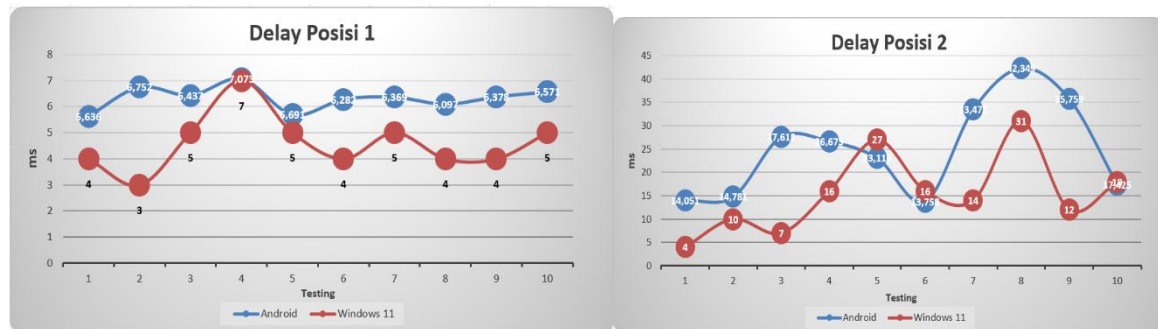


Figure 3. Delay Comparison between Standalone and SDN Networks

At the first testing point, the delay values of both network architectures were relatively low. However, when the devices moved into the access point overlap area, the standalone network experienced an increase in delay of up to 42.3 ms on Android, whereas the SDN-based network maintained delay values in the range of 6.2–11.7 ms. These results indicate that the SDN architecture was more effective in maintaining low communication latency during the roaming process.

## Jitter

Jitter was measured to assess the stability of packet arrival times during the data communication process.

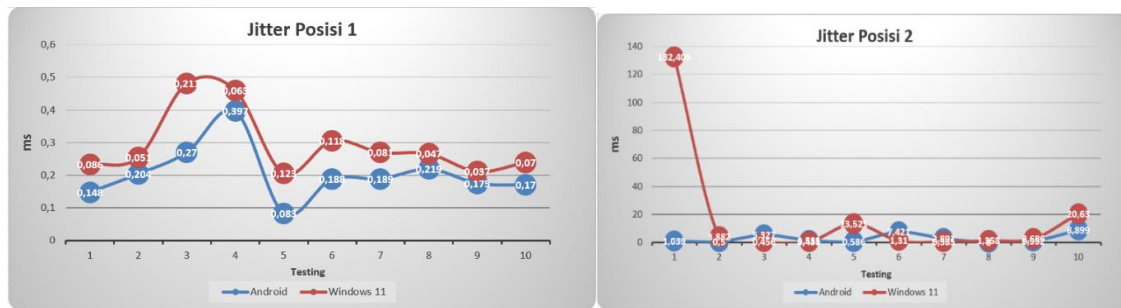


Figure 4. Jitter Comparison between Standalone and SDN Networks

The jitter values in the standalone network exhibited substantial fluctuations at the second testing point, with a maximum value of 132.4 ms on Windows. In contrast, the SDN-based network maintained jitter values below 0.5 ms throughout all tests. These findings indicate that the SDN-based network provided better data communication stability than the standalone network.

## Packet Loss

Packet loss was measured to determine the number of data packets that failed to reach the destination during the transmission process.

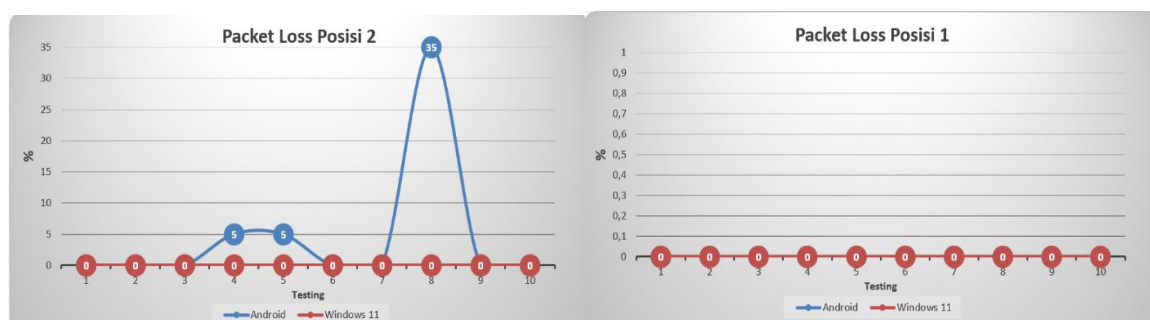


Figure 5. Packet Loss Comparison between Standalone and SDN Networks

The standalone network exhibited packet loss of up to 35% on the Android device during the roaming process in the access point overlap area. In contrast, all tests conducted on the SDN-based network resulted in 0% packet loss, indicating that the connection handover process occurred without any loss of data packets.

## Comparative Analysis of Roaming Performance

To determine the most optimal network architecture, all QoS parameters were compared at the location representing the roaming area.

Table 5. Comparison of QoS Results in the Roaming Area

| Parameter             | Standalone     | SDN            |
|-----------------------|----------------|----------------|
| Throughput – Windows  | 2.62–20.1 Mbps | 26.6–48.7 Mbps |
| Throughput – Android  | 0.6–13.1 Mbps  | 49.4–49.7 Mbps |
| Delay – Windows       | 4–31 ms        | 6–23 ms        |
| Delay – Android       | 13.7–42.3 ms   | 6.2–11.7 ms    |
| Jitter – Windows      | 0.4–132.4 ms   | 0.1–0.4 ms     |
| Jitter – Android      | 0.5–8.8 ms     | 0.1–0.2 ms     |
| Packet Loss – Windows | 0%             | 0%             |

|                       |       |    |
|-----------------------|-------|----|
| Packet Loss – Android | 0–35% | 0% |
|-----------------------|-------|----|

Based on all QoS parameters, the SDN-based network demonstrated better roaming performance than the standalone network. The SDN architecture was able to maintain high throughput, reduce delay and jitter, and eliminate packet loss during the transition between access points. In contrast, the standalone network experienced a significant reduction in throughput accompanied by increased delay, jitter, and packet loss when devices entered the access point overlap area. These findings indicate that the controller-based roaming mechanism in the SDN architecture was more effective in maintaining connection continuity than the roaming mechanism employed by the standalone network.

### User Evaluation

To complement the Quality of Service (QoS) testing results, an evaluation was conducted among staff in the Emergency Department (ED) of RSUD Bangil who use the Wi-Fi network when entering Electronic Medical Records (EMR). The evaluation was conducted twice using the same questionnaire. The first data collection was carried out on June 7, 2026, when the network was still using a standalone Wi-Fi architecture. The second data collection was conducted on June 29, 2026, after the network had been implemented using a Software-Defined Networking (SDN) architecture. The use of the same questionnaire at both measurement times was intended to identify changes in users' perceptions of network service quality following the change in network architecture.

The user evaluation revealed differences in perceptions of network service quality between the standalone and SDN-based networks. When using the standalone network, most respondents reported that the network connection was less stable when devices were located in the overlap area between access points, resulting in slower EMR data entry. Following the implementation of the SDN-based network, most respondents reported that the transition between access points occurred more smoothly and that EMR data entry could be performed more reliably. These evaluation results are consistent with the QoS testing results, which demonstrated that the SDN-based network provided more stable throughput, lower delay and jitter, and no packet loss during the roaming process.

### Conclusion

This study demonstrates that the Software-Defined Networking (SDN)-based network architecture provides better roaming performance than the standalone Wi-Fi network in the RSUD Bangil environment. Based on the Quality of Service (QoS) test results, the SDN network was able to maintain more stable throughput as devices moved between access points, particularly in the overlap area where the roaming process occurred. In addition, the SDN network produced relatively lower delay and jitter values, with no packet loss observed throughout the testing process. These findings indicate that the roaming mechanism in the SDN-based network operated more effectively than that of the standalone network. The findings also demonstrate that the SDN-based Wi-Fi network is more suitable for supporting the implementation of Electronic Medical Records (EMR) integrated with the Hospital Management Information System (SIMRS). Centralized access point management through Cloudnet enables faster and more stable transitions between access points, allowing healthcare professionals to maintain continuous network access while moving between service locations. Therefore, the implementation of an SDN architecture can serve as a more appropriate solution for supporting digital healthcare services, particularly in environments with high user mobility such as the Emergency Department (ED).

Based on the findings of this study, future research is recommended to expand the scope of testing to obtain more comprehensive results. Testing should not be limited to QoS parameters but should also incorporate additional parameters, such as handover latency and access point

transition time, to enable a more detailed analysis of the roaming mechanism. Furthermore, future studies should consider using a larger number of access points, broader testing areas, and a greater variety of client devices and operating systems, including Windows, Android, macOS, and iOS. Testing under these diverse conditions is expected to provide a more representative picture of roaming performance in actual hospital environments. Further research is also recommended to evaluate SDN-based network implementations using access points and controllers from different vendors. Cross-vendor comparisons could provide insights into how device characteristics and controller mechanisms influence roaming quality and QoS performance. Such findings could serve as a technical basis for decision-making in the development and optimization of wireless network infrastructure in healthcare facilities.

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