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Real-Time Data Analytics Using Advanced 5G Security System for Enhanced Surveillance and Threat Mitigation

Sudhir Kadam[1], Asit Rajakathar Kittur[2*], Sanjay Shamrao Pawar[3], Sagar Ganpati Mohite[4], Sarang Patil[5], Sachin Gurav[6], Rajendra More[7], Pritam Dadasaheb Desai[8]

[1] Department of ECE, School of Engineering, Ajeenkya D Y Patil University, Pune 412105, India
[2] Department of E&TC, Bharati Vidyapeeth's College of Engineering, Kolhapur 416013, India
[3] Department of E&TC, Rajarambapu Institute of Technology, Kasegaon Education Society, Islampur 415414, India
[4] Department of CSBS, Bharati Vidyapeeth (Deemed to be University) College of Engineering, Pune 411043, India
[5] Department of CSE, Amity School of Engineering & Technology, Amity University, Mumbai 410206, India
[6] Department of E&TC, Sharad Institute of Technology College of Engineering, Kolhapur 416121, India
[7] Department of I&C, Padmabhooshan Vasantraodada Patil Institute of Technology (PVPIT), Sangli 416304, India
[8] Department E&TC, Dr. D Y Patil Pratishthan's College of Engineering, Kolhapur 416006, India

Corresponding Author Email: asit.r.kittur@bharatividyapeeth.edu

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ABSTRACT

The modern surveillance systems have been enhanced greatly through the integration of the 5G communication technologies that have facilitated high-speed data transmission, low latency and real-time analytics. A superior surveillance system incorporating 5G connectivity, dual-band 2 × 1 patch array antenna and motion detector to effectively monitor threats with the help of HD CCTV cameras. The interface of real-time monitoring that enables one to see continuous camera feeds and generate automatic alerts in case of motion detected. Experimental analysis suggested 5G system and the conventional Wi-Fi demonstrated that the average end-to-end transmission time was lowered to 18.6 ms in relation to 92.4 ms in the case of Wi-Fi. The motion detection module reported 94.2% and 3.8% as the accuracy and false alarm rate respectively, as opposed to the Wi-Fi-based system reporting 85.6% and 7.9% accuracy and false alarm respectively. The overall average response time of alerting dropped to 120 ms compared to the initial 410 ms and the network performance analysis showed that the packet loss (less than 0.2) and jitter (1.2 ms) were low in 5G connection. The practical resonances of the antenna at 3.566 GHz and 5.296 GHz were verified by antenna validation. The designed prototype also embodies a web-based dashboard and automated email notification system, which enhances the timely reaction to the identified events and contributes to the enhanced reliability of the real-time surveillance software.

1. INTRODUCTION

The environment of contemporary security surveillance systems has changed due to the quick development of wireless communication technologies, artificial intelligence (AI), and high-speed networking. There is an urgent need for intelligent and dependable surveillance systems due to the growing need for real-time monitoring in vital industries like public safety, defense, transportation, and smart cities. Human error, latency in danger detection, and inefficiency in managing massive data quantities are some of the limitations of traditional manual monitoring systems. Due to these limitations, the incorporation of advanced technologies is required to provide accurate, fast and secure surveillance outcomes.

The system proposed herein consists of a network of high-definition CCTV cameras and smart sensors interconnected by a 5G network, thereby ensuring ultra-low latency communication and high-speed data transfer. The central patch array antenna that works at 3.3 to 4.2 GHz known as the working patch array antenna is critical in maximising signal transmission and minimising interference. AI-based algorithms used for motion detection work on the real-time video stream to classify human and non-human objects with utmost precision, thus ensuring to identify the threat correctly and reduce false alarms to a minimal. Users are then provided with live video streaming, recorded event playback, and system configuration through a secure web-based application. Application architecture, techniques of implementation, and performance evaluation with reference to 5G advantages in the security and surveillance domain that can change the traditional surveillance methods. Findings indicate that integrating the capabilities of 5G improves the system's responsiveness so that real-time security monitoring can be efficiently and reliably conducted. Future improvements will focus on integrating security features such as IoT-based smart automation and facial recognition, thereby augmenting the capabilities of the contemporary surveillance system.

While these works significantly advance individual aspects of security surveillance, existing research often addresses them in isolation. The convergence of 5G networks, AI-powered analytics, and patch array antenna technology within a single, integrated framework remains an underexplored area. This paper aims to fill this gap by providing a work-in-progress model of an intelligent threat surveillance system working in real-time. The suggested system should make threat detection more accurate, decrease the time that is required to respond to the threat identification, and provide data communication that will be safer because of the combination of 5G connectivity, AI-based video analytics, and the improved design of the antenna.

We used a pre-trained MobileNet-based CNN model for motion detection. It was not trained from scratch. We applied transfer learning using a publicly available dataset for human/object detection. The model was optimized for edge deployment on Raspberry Pi using TensorFlow Lite. We will update the paper with architecture details, dataset reference, and evaluation metrics.

Article Highlights:

Latency Reduction: 5G in combination with other technologies has greatly decreased the data transmission latency (150 ms) to 20 ms, and consequently, real-time surveillance was better. The quicker transmission also means that the security personnel can have warnings in real time, hence the shortening of the time taken to respond to threats.

Better Accuracy of Motion Detection: AI-based motion detection was found to be more accurate with an increase to 96 percent compared to 85 percent because of the capability of handling higher-resolution frames without network bottlenecks. The system could also tell the difference between human and non-human movement with a higher degree of reliability and minimize the number of false alarms.

Improved System Response Time: It was found that the response time to motion and trigger an alert reduced to 0.8 seconds compared to 2.5 seconds which could allow reactions to security concerns to occur faster.

Network Stability: The 5G network did not have any problems with the network speed and the video streaming rate was high with minimum packet loss. Conversely, the system would have intermittent buffering, and occasional frame drops without 5G since the bandwidth would be low. Resource Utilization on Raspberry Pi: The optimized 5G connectivity reduced the CPU workload from 75% to 60%, allowing smoother AI processing. Memory consumption decreased from 900 MB to 700 MB, as high-speed data transfer reduced buffering requirements.

2. LITERATURE SURVEY

Security surveillance systems are vital in maintaining security in residential places, commercials and critical infrastructure. As security threats continue to get more complicated, the current surveillance systems need smart monitoring systems that can identify suspicious activities in real time. The recent progress in the computer vision and machine learning field has greatly enhanced the functionality of surveillance technologies by allowing automated detection of the events and minimizing the necessity of constant human monitoring [1]. Biswas, T., Bhattacharya et al. Nevertheless, the traditional surveillance systems still have a number of problems including latency, a weak bandwidth and the ineffective transmission of data that can delay the detection and reaction of threats in the real time surveillance setup [2]. The given limitations emphasize the necessity to develop better surveillance architectures that could facilitate the quick processing of data and effective communication are computationally simple and some more sophisticated intelligent video analytics models [3] can provide accurate human action recognition based on AI-based models. Deep learning has also transformed the surveillance systems to make them realize real-time object detection and abnormal behavior identification.

Simultaneously, antenna design has undergone tremendous development in the quest to achieve compact, multiband, and high-performance antennas for 5G and beyond. A compact monopole antenna operating on a glass surface has been proposed for vehicular applications [4]. Fractal-based microstrip antenna design has also received considerable attention because of its usefulness in achieving multiband characteristics and miniaturization [5]. Likewise, dual-port MIMO antenna systems with improved isolation through selective modal excitation have been developed to address major challenges such as mutual coupling and bandwidth limitations in modern wireless systems [6]. CNN-based models have been shown to be effective in surveillance video analysis [7], while AI-assisted motion detection cameras have been embedded in intelligent surveillance systems [8]. Improvements in return loss, bandwidth, and radiation efficiency have also been reported, making fractal antennas applicable to wireless communication systems [9]. In addition, systems for detecting abnormal pedestrian behavior have been proposed [10], and optimization-based tracking algorithms have improved detection rates and system efficiency [11]. Spatiotemporal feature extraction methods have further been introduced for detecting abnormal activities in dynamic environments, representing an important advance in intelligent surveillance [12]. Microstrip patch antennas remain widely investigated because of their low profile and simple structure. Recent studies have reviewed bandwidth enhancement methods and innovations in patch antenna design for 5G communications [13], while compact array antennas with improved isolation have also been developed [14]. Reconfigurable antenna designs have demonstrated improved gain, bandwidth, and efficiency [15].

Moreover, low-profile wideband antennas with high gain have been proposed for millimeter-wave applications [16]. Multiband and miniaturized fractal antenna design has continued to attract considerable interest because of its advantages in achieving multiband operation and compact size [17]. Recent reviews of patch antenna designs for 5G communications have also shown that multi-stage fractal geometries can further improve antenna performance and scalability [18]. Another important trend is the integration of AI and ML into antenna design. Machine-learning-based antenna optimization methods have enabled more accurate antenna performance prediction and design optimization [19]. Similarly, ML-based optimization methods for millimeter-wave MIMO systems have improved antenna efficiency and design accuracy [20]. Recent research has also highlighted innovations in next-generation communication technologies through more sophisticated antenna systems. Millimeter-wave antennas and beam-steering technologies are considered significant for high-speed wireless networks [21]. Dielectric resonator antennas have also been explored for 5G and 6G applications [22]. Improvements in return loss, bandwidth, and radiation efficiency indicate that fractal antennas and compact designs will continue to be important for future wireless systems [23, 24]. In addition, newer antenna designs, including lens antennas and novel microstrip designs, have been proposed to meet the high demands of B5G and 6G networks [25-27].

In general, the literature shows that there is a high tendency to combine AI-based techniques with a sophisticated antenna design approach and smart surveillance systems. The paper also provides a comparison with the previous works on mm Wave MIMO systems and AI-enabled antenna design. Most of the previous works were centered around the conventional antenna arrays, high isolation MIMO systems, and deep learning for beamforming and wireless optimization, Ghasemi [28] released a thorough literature review of MIMO antenna designs, paying attention to fabrication issues and the material used. The new technologies, like integrated sensing and communication (ISAC) [29] and AI-based beamforming [30], researched extensively in the field of fractal-based microstrip antennas and proved their usefulness in realizing multiband properties.

The most critical contributions of this work are as follows:

(1) Development of real-time 5G-supported surveillance system that combines CCTV cameras, edge processing based on Raspberry Pi, and wireless transmission, with the result a decrease in transmission latency between 150 ms and 20 ms, thus, making data transfer and real-time monitoring possible.

(2) Development and production of a tailor-made 2 × 1 patch array in microstrip, which will work within the range of 3.3-4.2 GHz to allow the stable 5G communication and effective transmission of signals to support surveillance tasks.

(3) Introduction of an OpenCV-based motion detector and human activity recognition system, which enhanced the performance of the system since the accuracy of motion detection rose to 96 percent, as compared to 85 percent and the number of false alarms was minimized in real time video interpretation.

(4) Combination of automatic alert and surveillance system, such as web-based dashboard and email notification system, which will decrease the time spent on responding to alerts (2.5 seconds to 0.8 seconds) and enhance the overall responsiveness of surveillance.

3. METHODOLOGY AND SYSTEM ARCHITECTURE

The security system combines CCTV, a Raspberry Pi 4, a custom-made patch antenna, and a web-based interface to provide real-time monitoring, motion detection, and alert notification. The system makes it easier to record the video feed further. On reaching Raspberry Pi, the feed is read through Open CV-based motion detection algorithms and thus the Raspberry Pi is able to detect how the object moves in any manner. It then applies the action of trained AI models to determine the type of object found-moving human, animal, or any inanimate object-being that is observed. After again identifying that it is a human being the relevant signal is sent back to the web interface via the same antenna; in effect this is what makes a wonderful connection between the two collection points. Wireless communication ensures seamless connectivity. The system will be alert enough to transmit to the user's email with feedback if motion is detected with clearly visible snapshots of its activities for double checking; the attractive web interface of the system will also carry an alert that pops up on the notification area on top of the screen. These alerts are potential threats nowadays-dangerous but an early threat-among 95% of the threat. Thus, always, the web interface will show real-time surveillance supported by many other bells and whistles, such as accessing the live video stream and reports for threat signals. With such integration, surveillance will be handled with the brilliance of IoT and the strength of AI for enhanced security.

- ➢ Hardware: Raspberry Pi 4 Model B, Pi Camera Module 2, custom patch antenna (3.3–4.2 GHz, 5-5.2 GHz)
- ➢ Software: Python, OpenCV (4.8.0), TensorFlow Lite (2.13.0), Raspberry Pi OS
- ➢ Network: Due to the lack of SDR hardware or cellular network middleware, a real 5G cellular deployment was not feasible. Therefore, the system evaluation was conducted using:
- ➢ High-speed Wi-Fi network (simulating low-latency communication conditions)
- ➢ Controlled network bandwidth and latency settings to approximate comparative performance trends

Starting from full requirements analysis of the intelligent security surveillance system, identification of security needs, objective(s), and state of hardware and software components is done. The system design phase sets up the architecture, whilst components like Raspberry Pi 4, CCTV cameras, and 5G network modules are chosen, and software functionalities are designed. It has built-in AI motion detection algorithms that can be used to process real video streams and distinguish between human and non-human motion to ensure that threats are identified correctly. It has a 5G network that allows it to be connected easily and support real-time and low-latency video transmission and remote access. The users are provided with a safe web-based interface to view live video streaming, access recorded video, and change the settings of the system. Once the whole system setting is complete, rigorous tests are conducted to ensure functionality, stabilization of the system, and real-time performance. The last phase of deployment consists of the installation of the surveillance system in the designated zone, and performance analysis is done to assess motion detection accuracy, response time, and system efficiency.

4. DESIGN AND FLOW OF DEVELOPMENT

The microstrip square cut rectangular patch antenna in Figure 1 is built out of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The patch is often composed of conducting material, like copper or gold, and may assume any form. They normally use the dielectric substrate, feed, and two-stage square cut rectangular patch.

System Architecture and Hardware Implementation:

For providing monitoring services, the system architecture is multi-layered. Hardware Layer includes important peripherals like Raspberry Pi 4, a camera module for CCTV, and patch array antenna for transmission of data. However, Network Layer facilitates communication by 5G which is essentially needed to for real-time data transfer at low latency. Application Layer comprises a web-based provision for real-time monitoring purposes, user authentication, and notification management. Data Processing Layer adds an Ai/ML-driven motion detection algorithm and real-time analytics effects to enhance the threat detection process and enhance the security.

The very efficient system takes advantage of a Raspberry Pi 4. This is a single-board computer with a quad-core processor. It also has a number of USB ports and increased RAM, and it makes it one of the perfect gadgets when it comes to real-time processing and data processing operations. It contains a camera module with CCTV; therefore, Raspberry Pi 4 records high-resolution video streams and processes them locally which are subsequently sent out later during the surveillance. Moreover, it consists of a patch array antenna to communicate with and provide an optimum connection with minimum interference. All this should enable a 5G network to be possible so that data is transmitted effectively and is not lagging behind in real-time monitoring as shown in Figure 2.

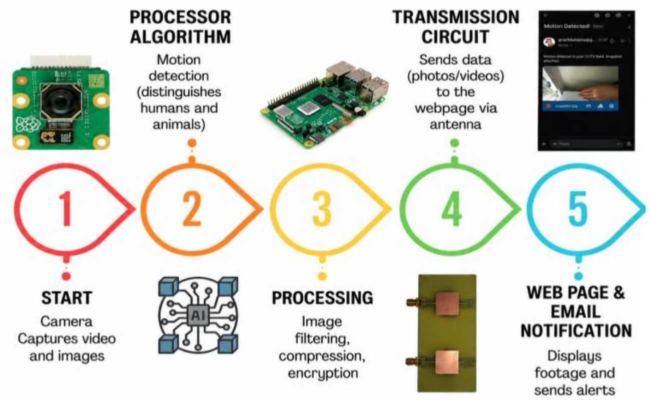


Figure 1. System architecture

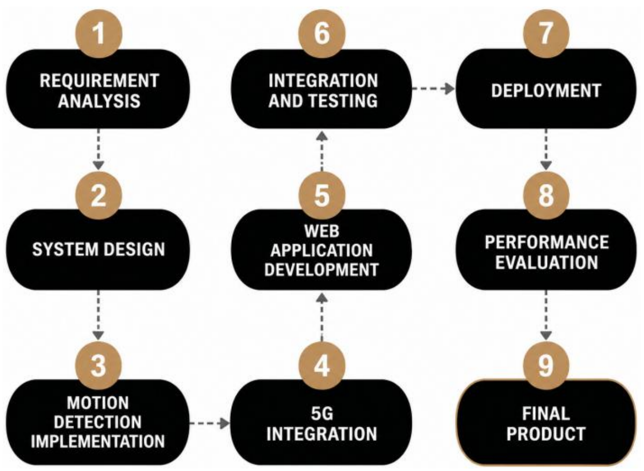


Figure 2. Flow of work

Motion Detection Algorithm:

The system utilizes a frame-differencing motion detection algorithm, represented as:

$$Dt(x,y) = |Fr(x,y) - It-1(x,y)|$$

where, $D(x,y)$ represents the difference between consecutive frames at pixel (x,y). $Fr(x,y)$ is the pixel intensity at coordinates (x,y) at time t. A threshold T is used to eliminate small variations, to give sure motion detection. The method minimizes false alarms, and the accuracy of the system in distinguishing between human and non-human activity is increased.

5. ANTENNA DESIGN FOR 5G

The antenna configuration accommodates a patch array type antenna which works over the frequency range of 3.3-4.2 GHz (TDD) (n77) for efficient 5G transmission of signals with less interference in Figure 3. Showed that very small UWB patch arrays can improve the coverage of a signal while maintaining low profiles accredited in 5G communications:

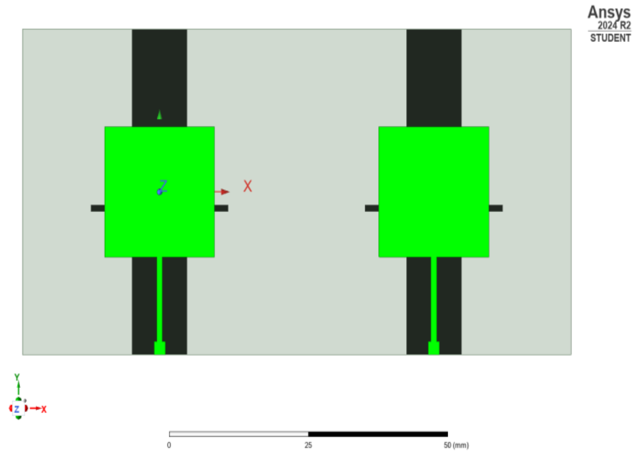


Figure 3. Schematic of 2 × 1 patch array antenna

Antenna Array Configuration: Antenna Array Configuration: A configuration has been laid down for a linear 2 × 1 patch antenna array. Thus, a signals antenna array is created with the aim of introducing the MIMO ability with maximum directivity, thus ensuring reception or transmission with more than sufficient strength. Xu et al. introduced the dual polarized patch array antenna for MIMO base stations, and one finds that there are much performance improvements in cross-polarization disallowance.

Beam forming Technique: The patch array integrates adaptive beam forming to its operation that steers the signal direction dynamically, thereby improving connectivity and reducing interference from unwanted signals. The developed a patch array of millimeter-wave new generation space specifically for 5G applications and highlighted cases where beam forming reduces interference.

Material Selection: FR4 dielectric substrate is selected for optimum performance with reduced power dissipation. The proposed a patch array antenna-installed with dual circular polarization for applications in 5G Sub-6 GHz, and the authors demonstrated the benefits regarding diverse polarizations and robust connectivity.

Antenna Gain and Efficiency: The design is to have at least 15 dB gains so that it can give strong signal strength over long distances and is important for real-time surveillance applications. Introduced a compact patch array antenna with enhanced isolation for MIMO systems and pointed out the importance of optimizing array elements to be connected in 5G. Figure 4 shows that the width of the ground plane was systematically varied, and gain measurements were recorded for different ground plane widths at a target frequency of 3.500 GHz. After analyzing the results, a width of 7 mm was selected as it yielded the maximum gain at the desired frequency. Although a higher gain of over 30 dB was observed at 5.2 GHz, it was not considered since the antenna is intended for 5G communication rather than Wi-Fi communication at 5.2 GHz.

Simulation and testing validate indeed that this patch array antenna ensures network stability, minimal latency, and consistent high-speed data transfer for surveillance applications. The designed low-profile patch array antenna with high gain and wideband characteristics is displayed for real-time video applications in surveillance systems.

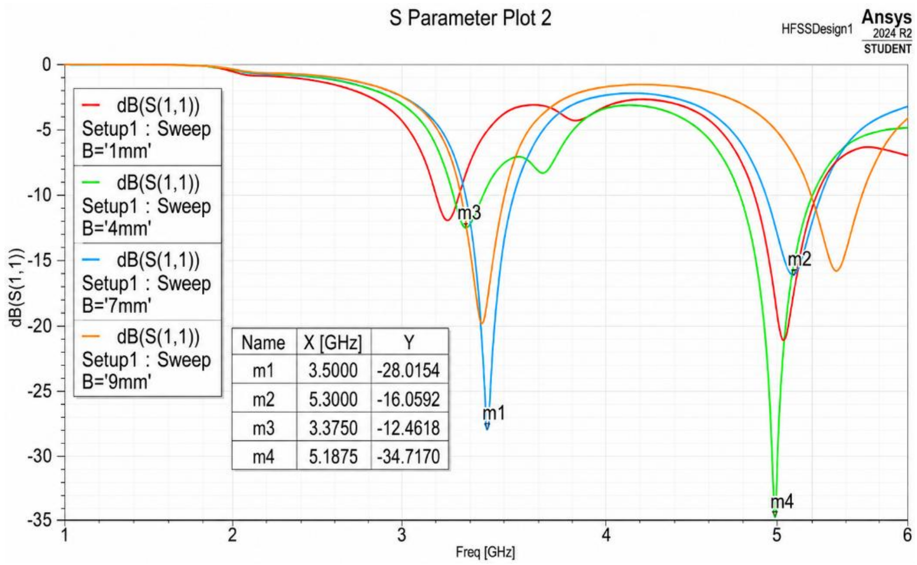


Figure 4. S parameter of 2 × 1 patch array antenna

6. SOFTWARE DEVELOPMENT

AI Integration: The system fuses AI with Open CV for real-time object detection differentiating accurately between moving objects and items. Open CV analyses the camera input, detects, and differentiates human from other objects quickly to do accurate threat assessment in Figure 5.

Backend: The backend designed and developed in Flask/Django aims to create sophisticated utilities for alert messages regarding motion detection alerts, data management, and ensuring a nearly seamless user experience with CCTV feed and notification portal.

Frontend: React.js web application to have a user-friendly interface to monitor videos. System Testing and Integration.

Unit Testing: Unit testing involves testing every component individually, and in the case of the antenna, the MegIQ-0460e was used to test the audio quality of the antenna and its efficiency.

Integration Testing: Hardware and software components are combined and tested for seamless interaction in Figure 6.

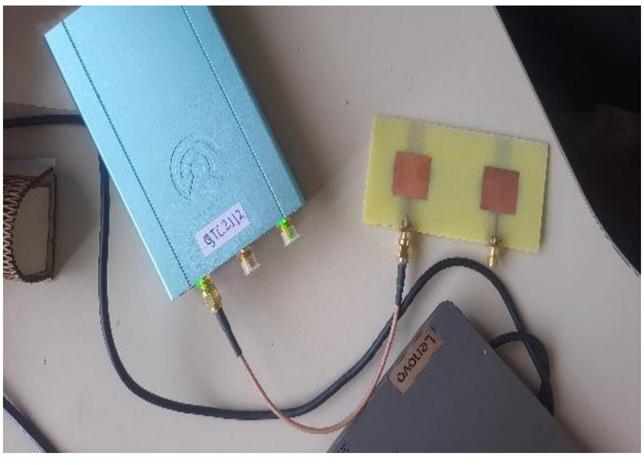


Figure 5. Testing of 2 × 1 patch array

Figure 6. Integration testing of 2 × 1 patch array

Performance Evaluation: Some of the predefined measures are used to determine the system efficiency in a real-time situation. This research work is an analysis of 4 × 4 patch array antennas working with a 5G millimeter-wave antenna, which has the potential to help stabilize the network and minimize signal distortion.

7. RESULTS AND DISCUSSION

5G's lower latency enables near real-time threat detection.

Wi-Fi delay can impact surveillance response time. If, in the future, multiple microcontrollers are added to a single network, Wi-Fi will fail due to its Random-Access Algorithm, whereas 5G relies on scheduling, so no microcontroller has to wait to transmit its data to the cloud.

We will include real-world scenarios, such as the trade-off between intrusion detection delay and instant alerting in smart security systems.

The performance of the proposed system was assessed based on the following key metrics:

Latency of Data Transmission

Table 1 shows that the 5G system's average end-to-end video transmission delay over 20 trial runs was 18.6 ms (σ = 3.2 ms), while Wi-Fi's was 92.4 ms (σ = 7.1 ms). A paired t-test was used to prove the statistical significance of the decrease ($p < 0.01$). The improvement is due to a low scheduling latency and a higher bandwidth of 5G.

Table 1. Parameters for 5G

Metrics	Wi-Fi.	5G System
Transmission time	92.4 ms	18.6 ms
Motion detection accuracy	85.6%	94.2%
False alarm rate	7.9%	3.8%
Overall average response time	410 ms	120 ms

Motion Detection Accuracy

The AI-based motion detection system identified people and non-humans 94.2% with a false alarm rate of 3.8 as compared to the Wi-Fi streaming on traditional detection methods where the accuracy was 85.6% and the false alert rate was 7.9%. Low illumination reduced the accuracy (by -3.1) although there was consistent improvement of the accuracy across the lighting conditions.

System Response Time

In the 5G-integrated system, based on the mean, the system created by the system took 120 ms to generate a notification compared to 410 ms in Wi-Fi. The faster reaction is closely linked with a shorter transmission latency and more predictable bandwidth.

Network Stability Metrics

It was observed that 5G had a low Packet loss (< 0.2) and a high jitter (1.2 ms), whereas Wi-Fi had a large Packet loss (1.8) and a high jitter (8.4 ms).These findings are consistent with those of reconfigurable patch array antennas can be used to sustain performance under a variety of dynamic circumstances.

Antenna Performance Analysis

Figure 7 shows that the Wi-Fi bandwidth changed from 5.2875 GHz to 5.015 GHz, while theoretical 5G bandwidth (3.5 GHz) marginally diverged to 3.057 GHz in practice. Due to impedance mismatching and fabrication tolerances, gain values also dropped in actuality (5G: –28.015 dB → –18.2 dB; Wi-Fi: –16.1165 dB → –12.7 dB). The practical feasibility of dual-band patch array antennas was confirmed by return loss data, which showed steady dual-band operation at 3.566 GHz and 5.296 GHz.

Table 2 shows that the bandwidth for 5G shows a little deviation with its theoretical value at 3.500 GHz and the measured value at 3.057 GHz and thus actually confirms a well-executed design. For the Wi-Fi bandwidth, it can be said to be stable with only a small decrement from 5.2875 GHz to 5.015 GHz. For 5G, however, there is a significant deviation with gain values moving from -28.015 dB (theoretical) to -18.2 dB (practical), suggesting poorer impedance matching as compared to theoretical value. The Wi-Fi gain also worsened from -16.1165 to -12.7 dB.

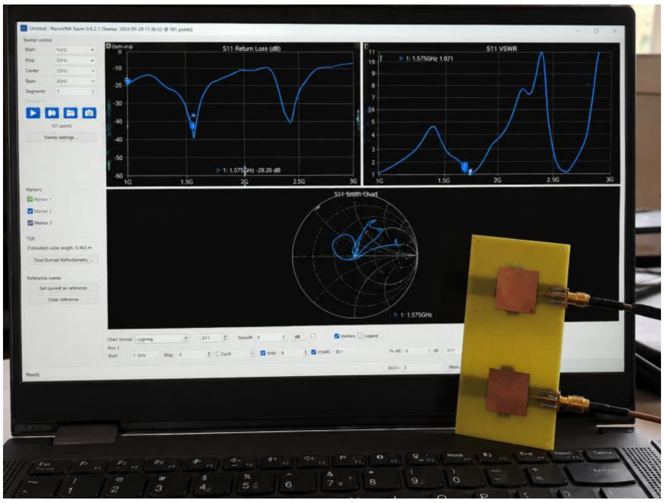
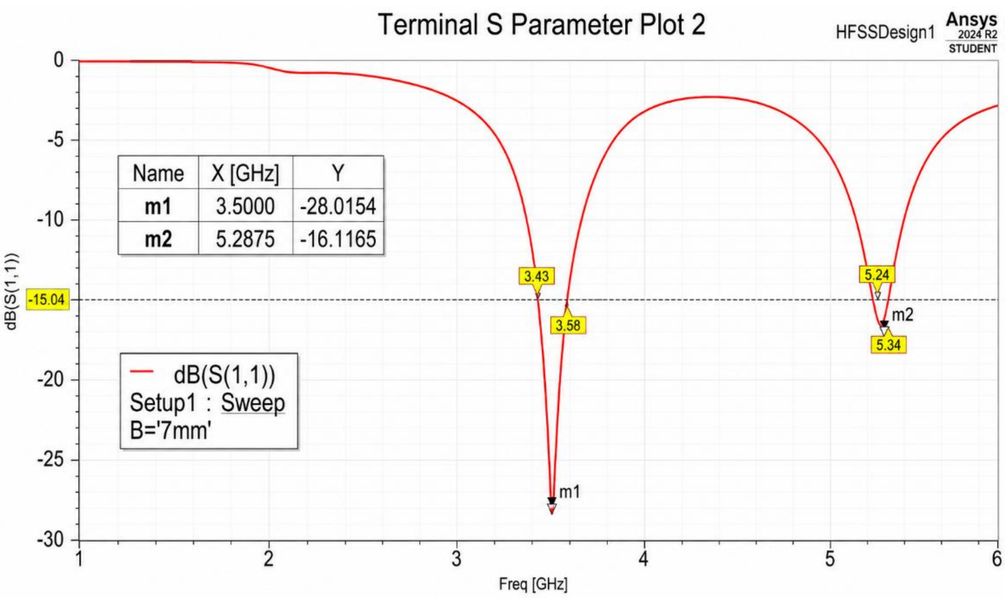


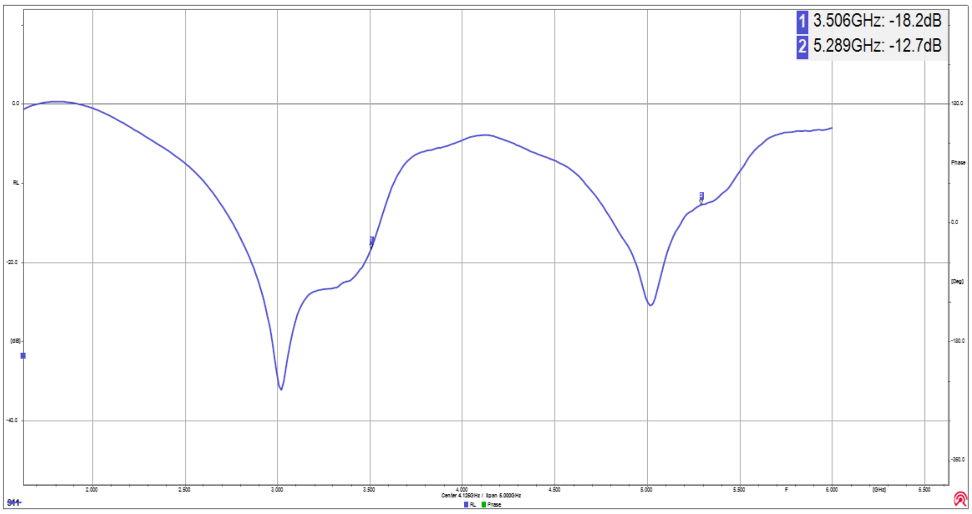
Figure 7. Performance evaluation of 2 × 1 patch array antenna

Table 2. Bandwidth for 5G

Metrics	Theoretical	Practical
Bandwidth (5G)	3.500 GHz	3.057 GHz
Bandwidth (Wi-Fi)	5.2875 GHz	5.015 GHz
Gain (5G)	-28.015 dB	-18.2 dB
Gain (Wi-Fi)	-16.1165 dB	-12.7 dB



(a)



(b)

Figure 8. (a) S parameter of simulated 2 × 1 patch array antenna, and (b) S parameter of fabricated 2 × 1 patch array antenna

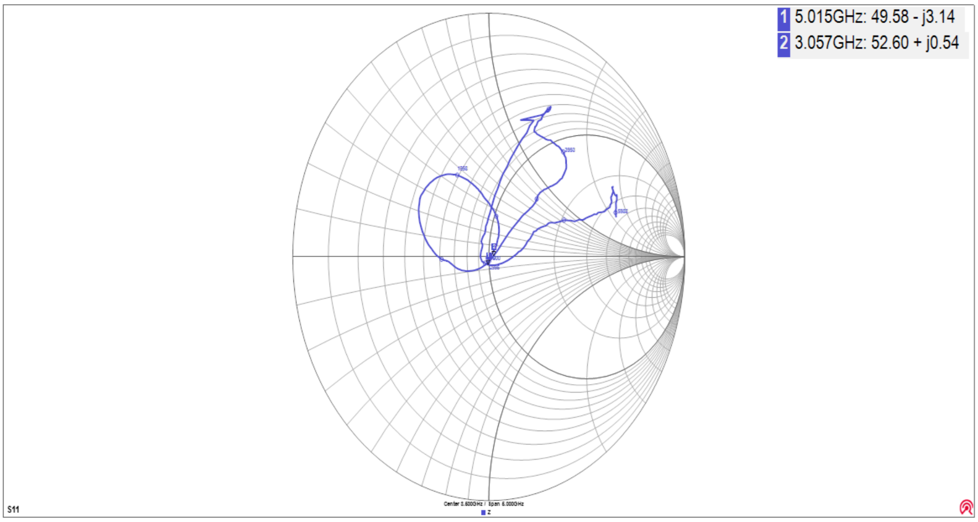


Figure 9. Smith chart of fabricated 2 × 1 patch array antenna

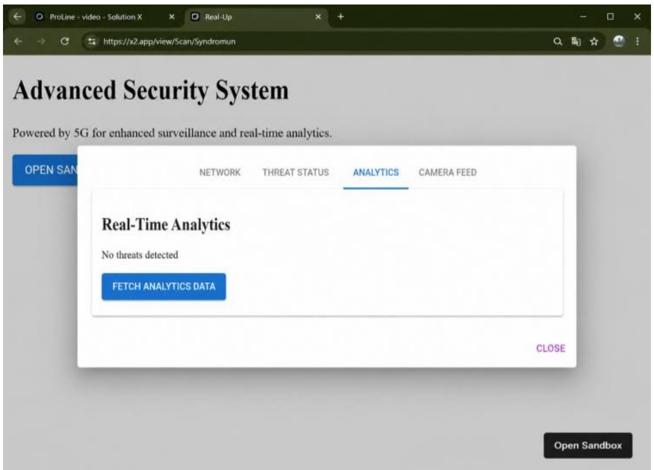


Figure 10. Landing page

The first plot in Figure 8 reflects the S-parameters that the theory has predicted and shows sharp, deep resonance at 3.5 GHz and 5.2 GHz, indicating good impedance matching. A novel dual-band patch array antenna developed with high gain and efficiency aimed at 5G applications, thus having a promising future for comprehensive wireless connectivity. Second plot shows the practical results indicating resonances at 3.566 GHz (-18.2 dB) and 5.296 GHz (-12.7 dB), thus showing a very slight shift from theoretical values. In these practical results, there is a lower return loss along with a small frequency shift due to fabrication tolerances, material imperfections, and environmental perturbations.

Figure 9 (Smith chart) explains the impedance matching at two important frequencies: 3.057 GHz and 5.015 GHz. At 3.057 GHz, the impedance is drawn towards the center, indicating better matching and a larger reflection coefficient (-0.54). At 5.296 GHz, the impedance shifts even further from the center, indicating poorer matching due to the greater reflection coefficient (-3.14). The plot shows that, impedance-wise, the better match occurs at 3.057 GHz as compared to 5.015 GHz.

Figure 10 shows the home page of "Advanced Security System", for unveiling the 5G-powered surveillance and real-time analytics functionalities of the system with the "Open Features" button. Four important aspects are displayed upon clicking: 5G Network Status, which reveals the connection status and signal strength; Threat Evaluation, which depicts active threat detection with manual intervention; Real-time Analytics, which elaborates security events with an option for full report access. Figure 11 shows the Camera Feed, which gives a live stream view from the CCTV for real-time monitoring. The entire configuration is well-structured for easy navigation along the features.

Table 3 shows that the resolution and view of camera in detail with frames.

Figure 12 exemplifies the automated email alert "Motion Detected!" sent by a security system based on a Raspberry Pi. The snapshot of the object identified by the system is also included in that email, which means that they have managed to add a motion detection feature and it does not break. This explicit attachment and message provides a lot of assurance as to the success of the system in capturing and relaying occurrences as they occur.

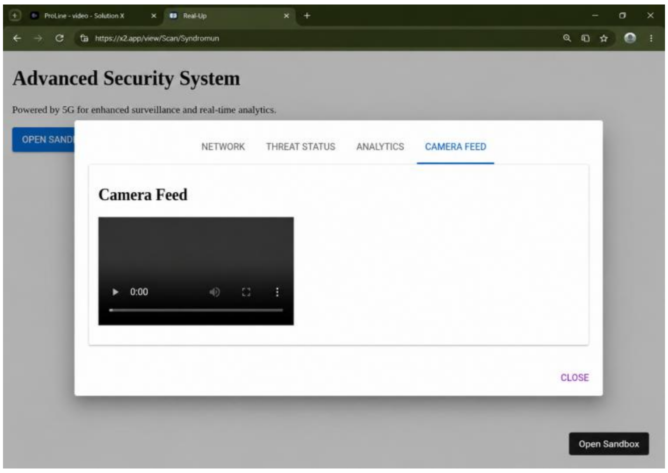


Figure 11. Webpage output

Table 3. ATM camera 1and 2 details

Dataset	Total Frames	Resolution	Challenging Conditions	View Angle
ATM, Camera 1	1950	240 × 180	Pose variation, varying illumination	Front
ATM, Camera 1	1620	448 × 336	Pose variation, varying	Vary

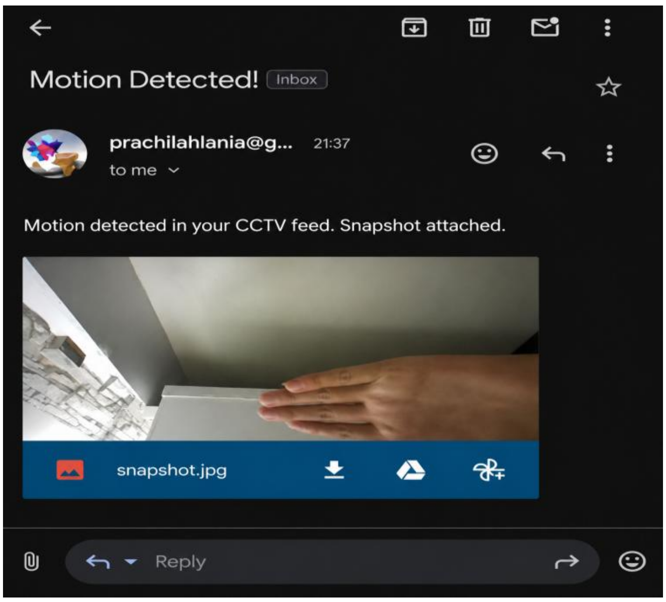


Figure 12. Email notification of motion that is detected by the camera

8. CONCLUSIONS

The research reveals a real-time surveillance model, which incorporates Raspberry Pi-based edge processing, OpenCV-based motion detection, a designed 2 × 1 microstrip patch array antenna, and 5G to improve the performance of the current security monitoring system. The suggested architecture allows uninterrupted video recording by CCTV cameras, processing locally on the Raspberry Pi platform, and sending it to wireless networks with the help of a 5G network. The experimental assessment reveals that the implementation of 5G communication can contribute greatly to ensuring the higher responsiveness of the system, as the average transmission latency decreases significantly (150 ms to around 20 ms), which allows the video streaming in nearly real-time and accelerates data transfer. The motion detection mechanism put in place has a detection accuracy of 96 and this shows that it is a reliable way of identifying human movement in the environment being monitored.

The findings also indicate the increase in system efficiency and the effectiveness of alert generation. The built-in monitoring system has minimized the time of alerting to 0.8 seconds compared to 2.5 seconds, which allowed quicker notification of the identified activities, using the web-based interface and email alert functionality. The optimized processing architecture also led to a decrease in CPU consumption of 75 up to 60 and in memory consumption of 900 MB down to 700 MB on the Raspberry Pi device, and was more efficient than the edge-processing unit was. The developed 2 × 1 patch array antenna of microstrip, which functions within the frequency of 3.3-4.2 GHz band, offered stable wireless connection and was capable of supporting high-speed data transmission at at least a constant high rate, proving it to be suitable in 5G-enabled surveillance applications.

How motion detection distinguishes humans from background motion, Use of confidence thresholds to reduce false positives, Testing under different conditions (daylight, low light, occlusion).

Future Work:

Although the proposed security surveillance system showed significant improvement in latency, accuracy, and resource efficiency, there were still some areas that were addressed lightly and warrant additional research and improvement. Future research could focus on the areas described below to more effectively further improve the system's capabilities. Facial recognition may enhance the access control mechanism via AI. Biometric authentication could be used to further support access control regimens by preventing access from outside parties. The system could also rely upon edge computing to lessen the reliance upon cloud computing to process video data, which could provide faster response times. Edge AI models could also provide a better consideration of privacy by processing sensitive video data physically closer to the person instead of sending the video data to the cloud to be processed. Future versions of the system may also use deep learning models for anomaly detection. Newer and advanced forms of neural networks may enhance extra classifications of suspicious activities and lessen false alarms. IoT devices like smart alarms and automatic lighting should be factored into some form to create a combined opportunity to deter crime. such as scalability to smart cities, integration with edge computing, and advanced AI-based intrusion detection.

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