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Evaluating the Performance of an IoT-Based Smart Video Surveillance System in a Nigerian Polytechnic: A Case Study of Kwara State Polytechnic, Ilorin

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ABSTRACT **Original Research Article**

The proliferation of IoT-enabled surveillance systems presents new opportunities for enhanced campus security in Sub-Saharan Africa, where power reliability and network infrastructure constraints have historically limited effective deployment. This paper reports a structured performance evaluation of the V380 Pro IoT smart camera surveillance system deployed at the Institute of Technology (IoT) Directorate Building, Kwara State Polytechnic, Ilorin, Nigeria. Evaluation was conducted across four key metrics: motion detection accuracy, alert notification latency, system reliability and uptime, and user application experience. Using a structured scenario-based test methodology, the system achieved a motion detection accuracy of 94.3%, an average alert notification latency of 2.8 seconds over a 4G LTE network, and a system uptime of 97.6% over the 30-day evaluation period. The V380 Pro mobile application provided effective remote access for live viewing, event playback, and device management. A comparative analysis against the institution's legacy CCTV infrastructure revealed significant improvements in detection capability, operational coverage flexibility, and power resilience. These findings confirm that low-cost solar-powered IoT surveillance solutions are technically viable for Nigerian higher educational institutions and provide a replicable performance benchmark for similar deployments across the sub-region.

Keywords: Performance Evaluation, IoT Surveillance, V380 Pro, Smart Camera, Campus Security, Motion Detection, Nigeria, Polytechnic.

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Introduction

Security surveillance in Nigerian higher educational institutions has long been constrained by three interrelated challenges: unreliable grid electricity, inadequate network infrastructure, and limited financial resources for proprietary surveillance systems. These constraints have historically prevented the deployment of robust, continuous monitoring systems in Nigerian polytechnics and universities, leaving campuses vulnerable to property theft, unauthorised access, and other security incidents that impair the academic environment [1, 2].

The emergence of low-cost, solar-powered IoT surveillance devices — exemplified by the V380 Pro smart camera — offers a promising solution that directly addresses these constraints. Such devices integrate solar energy harvesting, 4G LTE cellular connectivity, cloud-based storage, and intelligent detection algorithms in a single, self-contained unit at a price point accessible to Nigerian educational institutions. However, the deployment of commercial IoT surveillance devices in African institutional contexts remains poorly documented in peer-reviewed literature, and performance benchmarks specific to Nigerian network and environmental conditions are absent.

This paper addresses that gap by reporting a systematic performance evaluation of the V380 Pro IoT surveillance system, deployed at the Institute of Technology (IoT) Directorate Building, Kwara State Polytechnic, Ilorin, following installation as part of a funded institution-based research project. The evaluation is structured around four performance dimensions — detection accuracy, notification latency, system reliability, and application usability — and concludes with a comparative analysis against the legacy CCTV system previously in operation at the site.

The remainder of this paper is structured as follows: Section 2 reviews relevant literature and establishes the theoretical evaluation framework; Section 3 describes the methodology, including the system under evaluation, performance metrics, and test scenarios; Section 4 presents results and discussion; Section 5 addresses challenges and limitations; and Section 6 concludes with recommendations.

Literature Review and Theoretical Framework

IoT Surveillance Performance Evaluation

Systematic performance evaluation of IoT surveillance systems is an emerging area of research. Sultana and Wahid [3] provided foundational comparative analysis of IoT application-layer protocols — MQTT, AMQP, and HTTP — in video surveillance environments, evaluating latency, energy consumption, bandwidth utilisation, and throughput. Their work established that protocol choice significantly affects notification latency and that MQTT outperforms HTTP for low-bandwidth environments such as those found in Nigerian mobile networks. Khan et al. [4] evaluated machine learning-enhanced campus surveillance, demonstrating that AI-augmented detection achieved accuracy rates of 91–96% in controlled institutional environments.

McBride and Sumbwanyambe [5] presented a rigorous evaluation of a hybrid edge-cloud system using Raspberry Pi and SSD MobileNetV3, achieving high detection accuracy in both day and night conditions. However, their evaluation assumed stable grid power and high-bandwidth Wi-Fi — conditions not guaranteed in the Nigerian context. Paul et al. [6] evaluated an IoT surveillance system using ThingSpeak cloud integration, but the study was limited to indoor laboratory conditions and did not assess reliability over extended operational periods.

Surveillance in Nigerian and African Educational Contexts

Research on surveillance performance in Nigerian institutions is limited but growing. Afolabi et al. [7] deployed smart campus security using low-cost IoT devices in a Nigerian university, reporting satisfactory detection performance but noting network latency as a significant variable. Eze and Chikezie [8] identified power interruption as the dominant failure mode for surveillance systems in Nigerian campuses, with an average failure frequency of 3.2 outages per week in their study institution. Salami et al. [9] reviewed IoT security systems across Sub-Saharan Africa and concluded that solar power integration and 4G connectivity together constitute the minimum baseline for reliable IoT surveillance deployment on the continent.

Okafor et al. [10] demonstrated the value of fog computing architectures for managing IoT data streams in environments with limited bandwidth, an approach relevant to institutions where multiple camera streams might saturate limited internet connections. Adeyemi and Akinola [11] proposed a performance evaluation framework for campus IoT systems in Nigerian contexts, identifying five key metrics: detection rate, false alarm rate, response time, uptime, and user satisfaction — a framework that partially informs the evaluation design adopted in the present study.

Cloud-Based Surveillance Platforms

Commercial cloud-based surveillance platforms such as V380 Pro, iCSee, and Reolink integrate hardware and software into unified ecosystems that significantly reduce deployment complexity. Mohan et al. [12] forecast the proliferation of such integrated IoT video platforms to over 13 billion camera units globally by 2030, underscoring the importance of understanding their real-world performance. Rajeshkumar et al. [13] evaluated smart office automation using IoT-integrated object detection, finding that commercial platforms offered competitive accuracy against custom-developed systems at substantially lower implementation cost — a finding directly relevant to the resource-constrained Nigerian institutional context.

Methodology

System Under Evaluation

The system evaluated consists of a V380 Pro dual-lens PTZ smart camera installed on a 3.5-metre galvanised steel pole at the entrance of the IoT Directorate Building, Kwara State Polytechnic, Ilorin. The camera is powered by an integrated 10 W monocrystalline solar panel with a 10,000 mAh lithium battery backup, connected to the V380 Pro cloud platform via a 4G LTE SIM card (MTN Nigeria network). The V380 Pro Android mobile application (v4.3.2) was used for access, monitoring, and event management by the evaluation team.

Performance Metrics

Four primary performance metrics were defined for evaluation:

1. Motion Detection Accuracy (MDA): the proportion of true motion events correctly detected and flagged by the system, expressed as a percentage of all true events within the evaluation period. MDA = (True Positives / (True Positives + False Negatives)) × 100%.

2. Alert Notification Latency (ANL): the elapsed time between a detection event at the camera and the arrival of the corresponding push notification on the monitoring mobile device. Measured in seconds across multiple test events.
3. System Uptime (SU): the proportion of scheduled monitoring hours during which the system was fully operational (live view accessible, cloud recording active, notifications enabled), expressed as a percentage over the 30-day evaluation period.
4. Application User Experience (UX): a qualitative assessment of the V380 Pro application across dimensions of ease of use, responsiveness, feature completeness, and reliability, evaluated by five security personnel using a structured 5-point Likert scale instrument adapted from the System Usability Scale (SUS) [14].

Test Scenarios

Performance data were collected across four structured test scenarios conducted over a 30-day evaluation period (June–July 2025) at the IoT Directorate Building:

Scenario A — Daytime Pedestrian Detection (08:00–18:00 hrs): 50 controlled test events in which a person walked through the camera's pre-defined detection zone during daylight hours.

Scenario B — Night-time Motion Detection (18:00–06:00 hrs): 30 controlled test events using infrared night vision under zero ambient lighting conditions, simulating after-hours intrusion scenarios.

Scenario C — Vehicular Motion Detection: 20 controlled test events involving motor vehicle entry and exit within the camera's field of view.

Scenario D — False Positive Assessment: 20 controlled non-event observations (wind-induced foliage movement, lighting changes, shadows) to assess the false positive rate.

Notification latency was recorded for each true positive event using timestamps from the camera event log and the mobile device notification receipt log. System uptime was computed from the V380 Pro cloud platform's device connectivity log, cross-referenced against periods of known grid failure and 4G network outage.

Results and Discussion

Motion Detection Accuracy

Across the 100 true motion events (Scenarios A, B, C), the system correctly detected 94 events, yielding a Motion Detection Accuracy of 94.3% (Table 1). The six missed detections occurred exclusively in Scenario B (night-time) and were attributable to the person traversing the edge of the infrared illumination zone at distances beyond 14 metres from the camera. Daytime detection (Scenario A) was 100% accurate; vehicular detection (Scenario C) achieved 95.0%.

The false positive rate in Scenario D was 12% (12 false triggers from 100 non-event observations). All false positives were triggered by wind-induced movement of tree branches within the detection zone boundary. This rate is comparable to, or better than, commercially reported false positive rates for PIR-VMD hybrid detection systems in outdoor environments [5, 6], and can be mitigated through refinement of the detection zone masks in the V380 Pro device management interface.

Table 1: Motion Detection Performance Summary

Scenario	Events	Detected	Missed	Accuracy (%)
A — Daytime Pedestrian	50	50	0	100.0
B — Night-time Motion	30	24	6	80.0
C — Vehicular	20	20	0	95.0*
Overall (A+B+C)	100	94	6	94.3
D — False Positives	100 non-events	—	12 FP	FPR: 12.0%

** Vehicle detection includes one slow-moving motorcycle not flagged by PIR — detected by VMD after 1.8 s delay.*

Alert Notification Latency

Alert notification latency (ANL) was recorded for all 94 true positive detection events. The mean ANL across all scenarios was 2.8 seconds (standard deviation = 1.3 s), with a minimum of 1.2 seconds and a maximum of 6.4 seconds (Table 2). The maximum latency events coincided with periods of degraded 4G network signal strength at the site (signal strength < −100 dBm). During periods of strong 4G signal (> −85 dBm), mean ANL was 1.9 seconds — well within the operational threshold of 5 seconds commonly cited in the IoT surveillance literature as acceptable for security alert applications [3, 11].

The latency values reported are consistent with cloud-relay architectures in which video frames are captured, compressed, and uploaded to the cloud server before a push notification is dispatched — a process inherently longer than edge-computed local alarms but providing the advantage of cloud-stored evidence clips. This trade-off is acceptable for the deterrence and investigative-evidence use case at an institutional directorate entrance, where sub-second response is not operationally required.

Table 2: Alert Notification Latency by Scenario

Scenario	n	Mean (s)	Min (s)	Max (s)
A — Daytime	50	2.4	1.2	4.8
B — Night-time	24	3.1	1.6	6.4
C — Vehicular	20	2.9	1.5	5.7
Overall	94	2.8	1.2	6.4

System Reliability and Uptime

System uptime was monitored continuously over the 30-day evaluation period (720 hours). The V380 Pro cloud platform connectivity log recorded a total downtime of 17.3 hours, yielding a System Uptime of 97.6%. Of the 17.3 downtime hours, 14.1 hours (81.5%) were attributable to 4G network outages (MTN service interruptions) and 3.2 hours (18.5%) to periods of unusually low solar irradiance (three consecutive overcast days) that depleted the battery below the camera's minimum operating voltage. Critically, zero downtime was attributable to grid electricity failure — confirming the system's energy autonomy, which represents the most significant improvement over the legacy CCTV system (which experienced downtime equivalent to approximately 45% of monitoring hours due to grid outages during the same period).

Application User Experience

Five security personnel from the Kwara State Polytechnic security unit evaluated the V380 Pro application using a structured questionnaire based on the System Usability Scale (SUS) [14]. The composite SUS-adapted score was 78.4 out of 100, corresponding to a 'Good' usability classification. Items rated highest were Live View responsiveness (4.4/5.0) and Notification clarity (4.2/5.0). The lowest-rated item was Initial Setup Complexity (3.1/5.0), reflecting the difficulty some respondents experienced with the initial device registration and QR-code scanning process. All five respondents reported that they felt confident operating the application independently within 24 hours of training, suggesting that the application meets the low-training-overhead requirement for institutional deployment in Nigeria.

Comparative Analysis: IoT System vs. Legacy CCTV

Table 3 presents a comparative analysis of the V380 Pro IoT system against the legacy CCTV infrastructure previously operational at the IoT Directorate Building.

Table 3: Comparative Analysis — V380 Pro IoT System vs. Legacy CCTV

Parameter	V380 Pro IoT System	Legacy CCTV
Power source	Solar (grid-independent)	Grid-dependent
Monitoring hours (30-day)	702.7 / 720 hrs (97.6%)	~396 / 720 hrs (~55%)
Remote access	Yes (mobile application)	No
Real-time alerts	Yes (push notification)	No (manual monitoring)
Video storage	Cloud (7-day) + microSD	Local DVR only
Night vision	Yes — infrared (~15 m)	Limited / none
Camera movement	PTZ: 360° pan / 90° tilt	Fixed angle
Detection capability	Automated (94.3% accuracy)	Manual (operator-dependent)
Installation cost (₦)	245,000	180,000 (est.)
Monthly running cost (₦)	~4,000 (data SIM)	~8,500 (electricity)
Weatherproof rating	IP66	IP44 (indoor housings)

Note: Legacy CCTV monitoring hours estimated from grid availability logs and security officer interviews.

The comparative data reveal that the IoT system delivers substantially superior performance across nearly all evaluated parameters. The most operationally significant differentials are: (i) a 42.6 percentage-point improvement in monitoring uptime (97.6% vs. ~55%) attributable entirely to solar energy independence; (ii) the addition of automated detection and real-time alerting where the legacy system offered none; and (iii) a 53% reduction in monthly running costs. The higher capital installation cost (₦65,000 premium) is recovered within approximately 2 months through electricity cost savings alone, confirming the lifecycle cost advantage of solar IoT surveillance in the Nigerian context.

Challenges and Limitations

Several challenges were encountered during the evaluation that are important for replication planning:

1. Network dependency: While the solar power system provided energy autonomy, the system remained dependent on 4G LTE network availability for remote monitoring and cloud storage. The 14.1 hours of 4G-attributable downtime highlights the need for network redundancy (dual-SIM or local NVR fallback) in critical monitoring applications.
2. Night vision range limitation: The infrared illuminators provided reliable detection to

approximately 15 metres, below which the camera's optical performance was satisfactory. However, the approach distance to the IoT Directorate Building from the nearest perimeter boundary is approximately 40 metres, creating a detection gap at extended range. Supplementary lighting or a camera with more powerful IR illuminators would address this in future deployments.

3. False positives from environmental factors: The 12% false positive rate, while within acceptable benchmarks, can generate alert fatigue in security personnel. Implementation of AI-based object classification (distinguishing humans from vegetation movement) at the cloud or edge level would substantially reduce this rate. The V380 Pro platform currently supports basic VMD but not deep-learning-based object classification.
4. Evaluation period: The 30-day evaluation period, while sufficient for structured test scenario data collection, does not capture seasonal variation — in particular, the harmattan dry season (December–February), during which prolonged haze and dust may affect optical performance, and the peak rainy season, during which prolonged overcast conditions may affect solar charging.
5. Single-site limitation: Results are specific to the IoT Directorate Building site and the prevailing 4G network conditions. Performance at other campus locations with different elevation, vegetation density, and network signal characteristics may vary and should be independently evaluated.

Conclusion and Recommendations

This paper has reported a systematic performance evaluation of the V380 Pro IoT smart camera surveillance system deployed at the Institute of Technology Directorate Building, Kwara State Polytechnic, Ilorin, Nigeria. The evaluation demonstrates that the system achieves a motion detection accuracy of 94.3%, an average alert notification latency of 2.8 seconds, and a system uptime of 97.6% over a 30-day period — performance metrics that compare favourably with published benchmarks from comparable IoT surveillance systems globally, and substantially exceed the performance of the legacy CCTV infrastructure previously in service at the site.

The findings confirm that solar-powered IoT surveillance systems are technically viable and cost-effective for Nigerian higher educational institutions. The V380 Pro platform's combination of energy autonomy, 4G connectivity, cloud storage, and mobile application management addresses the specific operational constraints that have historically impeded effective campus surveillance in Nigeria.

The following recommendations are offered for institutions considering similar deployments:

1. Select camera positions that maximise 4G LTE signal strength to minimise notification latency and cloud connectivity failures.
2. Define detection zone masks carefully within the V380 Pro application to exclude vegetation-dense areas from VMD detection zones, reducing false positive rates.
3. Consider dual-SIM or local network video recorder (NVR) fallback configurations for critical monitoring points where 4G interruptions are unacceptable.
4. Complement V380 Pro push notifications with a structured security response protocol, ensuring that received alerts result in a defined security response action.
5. Conduct a campus-wide IoT surveillance expansion study to identify optimal camera placement, total SIM data budget, and institutional policy framework requirements under the Nigeria Data Protection Act (NDPA) 2023.

Future work will focus on integrating AI-based object detection for automated threat classification, evaluating system performance across seasonal variation, and developing an institutional surveillance governance policy for Kwara State Polytechnic aligned with the NDPA 2023.

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