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IoT and Edge Computing Technologies as Security Option for Train Service in Nigeria

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Abstract

The revival of rail transport service in Nigeria in recent years came at a critical moment of insecurity in Nigeria, it promised not only to serve as an alternative to overloaded vehicles on the roads but was also thought to be a safer means of transportation. Due to kidnapping on many roads, both high and low-class Nigerians patronized rail transport. However, train attacks and terrorism are major challenges that have impacted the sector negatively. Though the government has tried to improve surveillance along train routes, however, the result has not been impressive. The current level of insecurity in Nigeria is beyond the use of traditional surveillance and monitoring systems. It requires the adoption of technology to fight attacks and to monitor the health of train facilities. While the insecurity challenges that have overwhelmed the security forces will not permit the assignment of more personnel to the rail tracks that stretch several kilometres across the country, the incorporation of IoT and edge computing can be an optimal solution to the challenges of constant security problems. Among the trending technologies, IoT is a viable option that the country can adopt to improve security in the sector. It will increase the confidence of passengers and improve revenue and growth in rail transport.

Keywords: Train Security, IoT in Train Security, Train Security in Nigeria, edge-IoT

1 INTRODUCTION

The Nigerian rail sector was an efficient transport system during the colonial era and shortly after [1]. The train network spanned from north to south and was essentially the safest mode of transportation. However, abandonment of the sector later grounded the entire system, and subsequently the stoppage of the service. The restoration of train service in recent years came at a critical moment in Nigeria. The timing could not have been more appropriate, given the recent spate of kidnappings on several Nigerian roads in recent times. It was hoped that rail transport would serve as a safer means of transport in the country, and would reduce traffic congestion on roads. Regrettably, the insecurity in Nigeria seems to have a broader impact beyond road transport.

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Although the form and causes of rail transportation insecurity vary, the issue appears to be a global problem [2]; especially in India [3] and Europe [4]. In Nigeria, terrorist attacks on trains, explosions of tracks, and train derailment were recurring problems in the year 2022. In some instances, lives were lost. Solving these problems requires proper monitoring and surveillance of the rail facilities, track and their environment [5], especially in remote locations.

Several security techniques may be used, but the deployment of human agents to monitor the rail network cannot keep up with the elusive and gorilla-style terror attacks. Additionally, it might not be feasible to have enough personnel to secure the whole length of the train tracks. The technological solution remains a viable and sustainable long-term solution to terror attacks in Nigerian rails service.

Internet of Things (IoT) and edge computing technologies can be an optimal solution to insecurity issues in Nigerian rail transport. IoT makes use of sensors to collect data from the environment, whereas edge computing enables transmission and the analysis of enormous amounts of data in a fast and secure manner, even with a poor network connection. The integration of these two technologies is a powerful tool for solving the problem of insecurity in transport sector. This can monitor various rail facilities in real-time and will aid proper decision-making.

2. METHODOLOGY

Figure 2 represents the conceptual model of the methodology used in this research work.

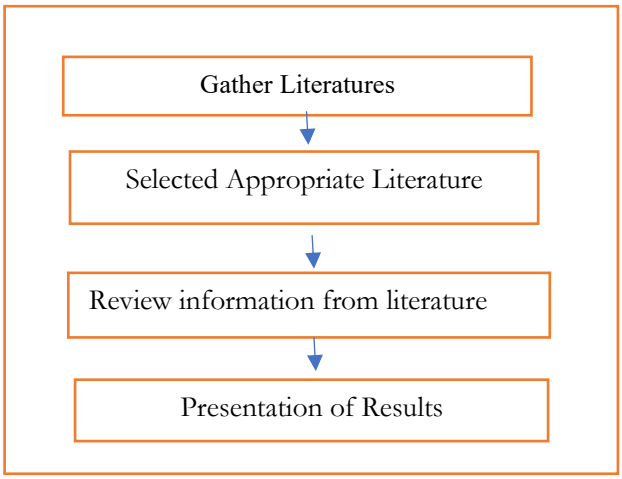

Figure 2: Research methodology

2.1 Materials Gathering

Being a paper that attempts to unravel the insecurity challenges of the rail sector in Nigeria and to proffer optimal technology solutions to it, this paper adopted a survey of extant pieces of literature on the subject matter to gather facts, establish a position, and understand the state of art in technology for security and surveillance. This method allows for data collection from the literature on variables of interest [6], with attention to the security of rails in Nigeria and the solutions.
A search was made on the problems of insecurity in Nigeria's rail in other to find the state of the problem and methods used by the government to tackle the problem. most number of the literature on this subject is the Nigeria newspapers that reported recent attacks and insecurity of rail lines and papers were also sourced from reputable databases like ScienceDirect, Google Scholar, Springer, etc.

2.2 Selected Appropriate Literature

The material gathered on insecurity in the rail sector in Nigeria was broad, however, only those whose information could be corroborated by several other papers or sources were used. The papers whose statistics were quoted in this research were checked on several other papers to ensure false information was not used. Where information cannot be corroborated by facts or other papers, such sources were discarded. Also, literature from reputable journals on trending technological solutions for surveillance, monitoring and security of rails was surveyed and used.

2.3 Review information from literature

The materials were surveyed with specific interest in attacks on trains, vandalization of tracks, insecurity of trains and government response. Also, papers on technology for security in rail transport were surveyed, especially IoT and edge computing.

2.4 Presentation of Results

The results of the findings are reported in narrative form which permits a presentation of facts in qualitative form, it also provide easy identification and comparisons of various features in the papers reviewed [7], [8]. The result is presented in the next section of this paper

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3. RESULTS AND DISCUSSION

3.1 Insecurity in Nigeria's Transport Sector

The major insecurity problem in Nigeria has been relatively confined to the problems of Boko Haram in the northeast; however, a new group, popularly called 'bandits' [9] emerged shortly after the 2015 general election. This is a disjointed group of terrorists who majorly kidnap citizens for ransom. the group uses roads as the best spot to capture travelers along Nigerian roads. From the year 2015, Nigerian roads have been so insecure that travelling along some routes would be like a suicide mission.

While insecurity problems bedevilled road transport in Nigeria in recent years, trains were relatively safe. The change in the dynamics of rail security came in 2022 when terrorists blew up the Abuja-Kaduna rail track [10]. The incident led to the derailment of a train and the stoppage of service for some weeks. The service was resumed a few weeks later, with the government reinforcing security in trains and along the rail networks. The second attack on the Abuja-Kaduna train later in March 2022 and another train attack at Edo state in January 2023 [11] are pointers to the vulnerability of rail transport to terrorist attacks. In the case of March 2022, the terrorists planted explosives that blew up the tracks, derailed the trains and killed many passengers onboard. The most recent warning of a possible train attack (published by many Nigeria dallies) was issued on 16 August 2023 by the State Security Service Department (DSS). The state security agency suggested an increase of security agents around the train facilities, surveillance, patrols, and raiding of the forests.

Bandits have used forest covers around the train lines to carry out attacks most of the time because rail routes pass through some bandits' inhabited forest zones. The nature of the terrain therefore increases the complexity of insecurity of rail services. Vandalization of the rail tracks is another critical part of rail insecurity. The lack of proper surveillance of rail tracks provides an opportunity for criminals to vandalize railroad rails [12]. The case of vandalism of tracks often increases train derailments. Insecurity in Nigeria has significant effects on the train service that often leads to loss of lives and disruptions of services. While several measures have been adopted for a short time, the long-term solution lies in real-time monitoring of the length of train tracks in Nigeria, this will monitor the movement and activities of terrorists for informed decision-making

3.2 Economic Impact of insecurity on rail transport

The economic impact of insecurity in rail transport became noticeable after the Abuja-Kaduna train attack in the second quarter of 2022. According to [13], the railway agency generated the sum of 734.473 million naira in the second quarter

of 2022, against 2.208 billion naira earlier recorded in the first quarter. The statistics suggest a decline of 66.73 per cent in revenue. The statistics of the revenue generation by railways between 2021 and 2022 can be seen in Figure 2. Based on [10], [14] reported a significant decline in patronage in the second quarter of 2022. From an estimated 953,099 persons who boarded the train in the first quarter, only about 422,393 passengers used the rail in the second quarter. The impact of frequent attacks on the rail line de-market the sector [9] with passengers turning to other ways of transportation. Several closures have led huge loss of revenue for the sector and several Nigerians who survive through pity business around the rails station.

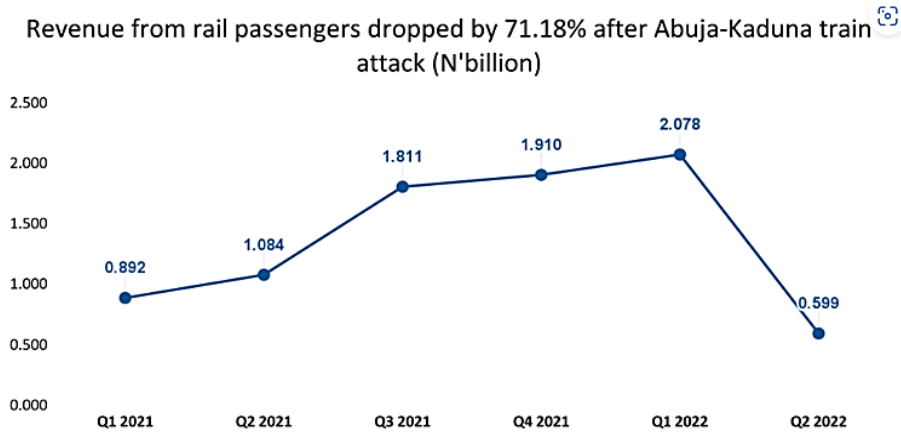

Figure 2. Railways revenue 2021 -2022 [13]

3.3 IoT technology and edge computing for rail monitoring

IoT are set of devices, actuator and sensors that generate large volume of data but with low computing and battery power [15]; it is a technology that let physical objects, with an IP address connect to the Internet. The phrase "Internet of Things" is now frequently used to describe situations where a range of objects, gadgets, sensors, and ordinary items have access to Internet connectivity and processing power[16]. IoT is an evolving technology for improved monitoring and surveillance of facilities remotely. It employs sensors to gather valuable data in dangerous and insecure environments and communicate the same to other computing entities which can either process the data or trigger an action [17]. The integration of sensors and communication technologies in IoT therefore provides a means to track the status and dynamics of an object in the real world [18][17].

Sensors can be used to collect data like sound, light, vibration, movements and a host of other variables. However, common sensors in the transport industry are loop detectors, magnetic sensors, cameras, infrared sensors, and Light Detection

and Ranging (LiDAR) sensors. It also includes acoustic sensors, Bluetooth, Wi-Fi, mobile phones, and probe vehicle sensors [5], [18]–[22]. These sensors can track traffic statutes, traffic accidents, the state of the road, and train tracks. They also collect congestion, collisions, and emissions data [23]. The use of sensors in rail service comes in various forms, it could be by planting sensors on the rail tracks to gather data or onboard sensors on trains (Figure 3). The sensors monitor the state of the facility and send data to a cloud or edge server. Figure 1 below shows a set of IoT devices that communicate with several trains but use edge computing as a data processing model.

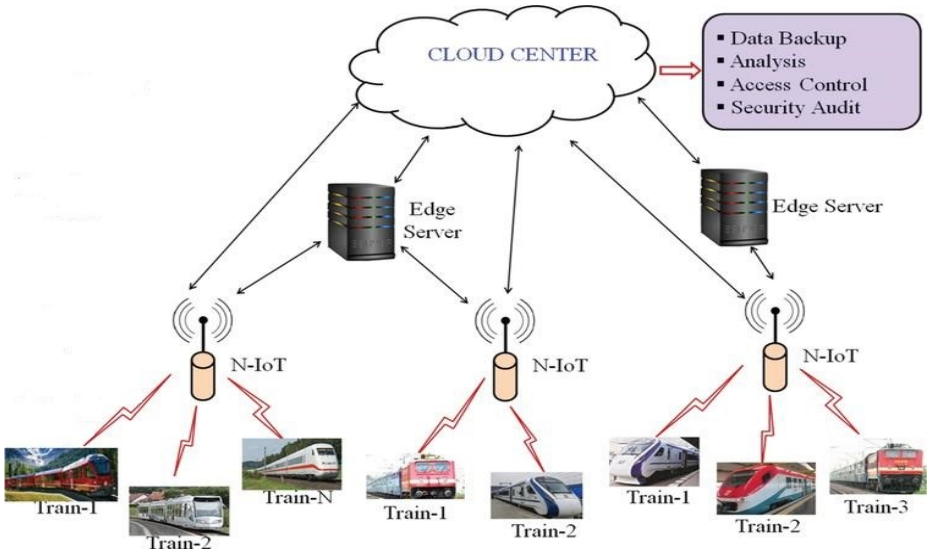

Figure 3. IoT edge architecture train service [24]

3.4 Edge Computing Paradigm and Transport Industry

The transport industry generates a large amount of data in the form of images, motion pictures, and control signals; the veracity and velocity of this data make for big data that require fast processing [25]. The priority of high-speed and time-sensitive processing therefore makes some systems perform poorly under cloud-based implementation. This problem is due to network traffic challenges, resulting in poor response time and quality of service[26]. Offloading tasks to the cloud in computationally intensive or latency-sensitive applications like automated driving and security systems [27] in an unstable network be challenging. The drawbacks of cloud computing necessitated the need for an edge computing model that is faster than cloud computing and can route tasks intelligently to meet quality of service. Edge computing has been a popular choice in recent times to reduce network transmission delays [28]–[30] since it is more tolerant of poor network connectivity [31], [32].

Edge computing is a distributed computing model that places processing entities or servers in proximity to the users[33]. The distributed nature of edge computing provides for intelligent task orchestration to have a good response time. With the priority of processing tasks close to the edge of the network, the challenges of network hitches, and cloud traffic are solved. The edge model (Fig. 4) operates a tier system where the user systems like vehicles, trains, and computers connect or request service from the nearest edge servers in the middle tier. The cloud servers are placed at the third tier and tasks are offloaded to the cloud only if the edge servers cannot provide processing within the desired time [26].Due to slow internet penetration in Nigeria, some parts of the country are still not covered by telecommunication nor have internet access [34]. Even the areas with internet access, not all are 4G or 5G which can aid fast processing. Therefore, Critical applications requiring real-time processing will underperform in Nigeria, especially in areas where internet access is limited or not installed at all.

To ensure the safety and stability of a moving train, real-time monitoring of the train and the tracks is of great importance. Therefore, the adoption of edge computing as a processing model is fitting for the Nigerian rail security system. The combination of IoT with high edge computing power is an optimal solution in this sense. Through edge computing, the status and state of the train or track can be analysed in real time. Another gain is the local processing of large security videos from the train without necessarily sending them to the cloud.

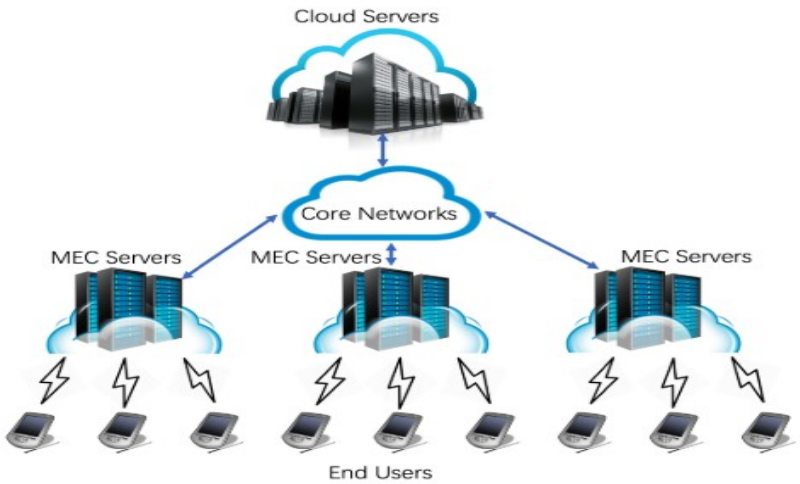

Figure 4. Architecture of edge computing [26]

3.4. Technologies rail service security system

Damage to rail tracks and missing tracks are major challenges that can result from pressure, load, and the duration of usage or vandalization [24], hence the need for

proper monitoring. Rail track monitoring can use a variety of technologies to evaluate the track's condition, find flaws, and pinpoint locations that need maintenance or repair [35], [36]. A good number of technology has been applied in recent times to improve the security and health of the train sector [19], among them is fibre optics as an intelligent means of monitoring the state of critical infrastructures. It can detect damages and cracks in the tract and send signals to the necessary system. Fibre optics is a good option in high-temperature and corrosive environments [19]. Nigeria is a tropical nation with high temperatures during the dry seasons, hence the need for technology that is environmentally sensitive. Another consideration for this technology is the ability to be hidden from the terrorists and criminals who may vandalize the system.

IoT with sensor technology which in recent times has aroused interest for research and adoption in rail tract monitoring and train components inspection is another option. This technology extracts vital data from the rail or the track for detection of abnormality; allowing for early detection of potential problems. use of distributed sensors along the rail lines can continually take data on the health of the tracks [4]. As shown in Fig. 5, sensors (as a form of wireless sensor networks) collect data like vibration, cracks, sounds and other associated behaviour of the track and send data through a wireless channel to the nearest server for analysis or further action. Ultrasonic sensors and sonar sensors are good devices for obstacle and missing track detection [17], [37]. This technology can detect missing tracks or obstacles which could lead to train derailment. It increases safety by constant data collection which is not possible using human agents. The system provides a rich source of data that can be used with artificial intelligence and machines for other secondary benefits like predictive maintenance of trains and tracks.

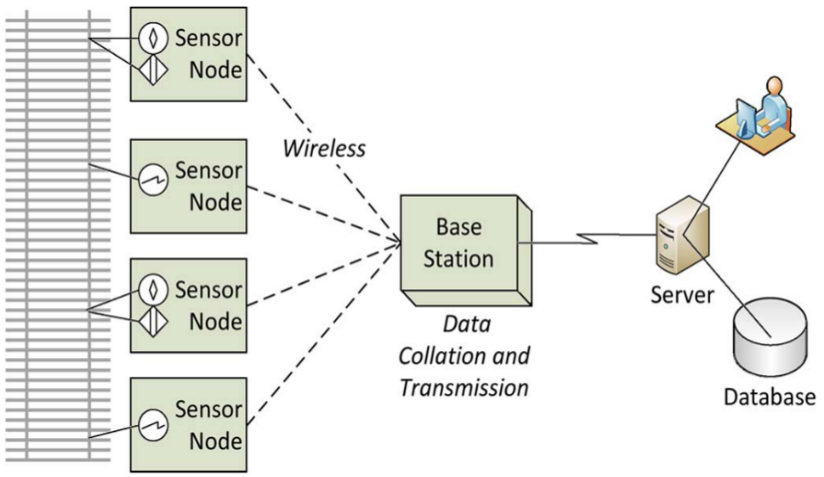

Figure 5. WSN rail monitoring [5]

Beyond the use of stationary IOT sensors and UAVs, an intelligent robot with a mobility system dedicated to detecting obstruction, objects and missing tracks is another viable option for Nigeria. This type of system is equipped with sensors to collect and track data and processing entities that analyze the data on the spot [3]. IoT sensors like IR sensors, and ultrasonic and acoustic sensors are used in this area to monitor tracks for possible obstacles [3], [17], [38]. A small robotic system using Raspberry Pi was implemented by [3] and [17] for real-time surveillance of Indian rail tracks. The robotic system travels ahead of the train to monitor the track, if the sensor notices an object, the data is sent to the Raspberry Pi and further communication is made to the train. other authors [38] used Sonar sensors for obstacle defection and microcontrollers to control train movement in the event of sudden obstacle detection. The adoption of robotic agents can be useful to detect explosives very fast and missing or track tracks in Nigerian rails,

3.5 UAV for surveillance of track and train attack

Air surveillance systems in the form of Unmanned Aerial Vehicles (UAVs) are other options that can salvage the problem of bandit attacks and detection of explosives on the track. This option provides air surveillance of the train and track environment against attack. Constant physical human monitoring of the length of train tracks in Nigeria is almost impossible and may not be cost-effective in the long run. The time taken to physically monitor tracks for possible damages or any foreign objects like explosives and other dangerous elements also reduces the safety of the rails system [38]. Though several sensor-based technologies are being used to monitor the health condition of the tracks, a lot requires that the train be in motion; while others are attached to tracks. The sensors can therefore be affected by the environmental conditions, be vandalised or be unable to function due to train immobility [35]. One easily implementable and cheap technological solution is the use of an Unmanned Aerial Vehicle (UAV).

UAV is a cheap technology for air surveillance of rail tracks [35], [39]. The system surveys the rail track to record video and take pictures of the environment; the data from the survey is further analysed for faults and foreign objects. This technology is very efficient for fighting terrorist attacks along rail routes. Rail time analysis of data from UAVs can detect movement, objects and people along the network of tracks, providing real-time data on the state of the road. Though the UAV is a good and easy technology, the challenge of data transfer from UAV to the server is a major issue if the communication infrastructure is poor [40], however, edge serves may reduce this problem by processing the data through edge servers instead of the cloud. Also, fewer UAVs are needed to cover the length of the tracks than human agents.

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3.6 Automatic crossing-gate control

The death of people at rail crossings has been heightening in Nigeria in recent times, with several lives being lost. The case of a train crushing a bus in Lagos on March 9, 2023; killing 6 persons and injuring 80 others and another case on June 7, 2023, in Lagos which killed an army sergeant [41] called for concern. Therefore, there is a need to provide an automatic control system that closes the gate if the train is some distance from the crossing line. IoT can function effectively here to control the opening and closing of the gage while the train is some distance away. Implementation of this type of control system requires the use of sensors that take data from the vibration of the tracks to know the distance of an approaching train [38]. The system then closes and opens the gate as necessary. This type of system is more efficient than human-control gates which have led to the death of many people.

3.7 Predictive track maintenance

IoT sensors can be used to monitor train components and predict when maintenance is required, allowing for proactive maintenance rather than reactive repairs [42]. Sensors can communicate track or carriage vibrations to an edge computer, and then using local processing of machine learning, you can send back to the cloud summary information if needed. The analyzed data can help detect when maintenance of trains or tracks is necessary. Being predictive, it helps to plan and schedule for maintenance before the system breaks down.

4. CONCLUSION

Rail transport is such large and capital-intensive that only the government runs it in Nigeria. It remains a viable and safe alternative transport in Nigeria. It was hoped that the revival of rails will boost the transport sector and also act as economic revival reduce the congestion on roads and increase the lifespan of Nigerian roads. However, train attacks and terrorism are major challenges that may impact the sector negatively, leading to loss of great revenue for the government and pity traders. The dynamic nature of insecurity in Nigeria and the evasive nature of the terrorists might be beyond the use of human agents to secure rail lines and facilities. Also, the length of the tracks across the country cannot be covered by security agents. It requires the adoption of technology to fight attacks and to monitor the health of train facilities. Among the trending technologies, IoT and edge computing stand as viable long-term sustainable solutions to the problems of attacks and vandalization of rail facilities. Few IoT devices can give daily coverage of the tracks, sending data for real-time monitoring of remote places and trains. It can send any form of signal, including video, to the edge servers for analysis and proper action can be initiated. The impact of this technology adoption will be increase in safety of the sector and confidence of passengers.

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