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SMART INTERSECTION AND IOT: PRIORITY DRIVEN APPROACH TO UBRAN MOBILITY

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ABSTRACT

The recent growth in car use and population have been identified as potential drivers of municipal traffic congestion, particularly in emerging nations with inadequate road networks. In Nigeria, for example, traffic wardens and traffic lights are prominent traffic control measures used to ease traffic congestion at major road intersections. However, stress, public anger, and rash traffic signal judgements restrict the effectiveness of these tactics, resulting in delayed mobility, decreased transit times, and a climate disaster. Recent solutions have emphasized emerging technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and Artificial Neural Network (ANW). Consequently, an efficient use of these technologies can provide a sustainable future for city traffic management in Sub-Saharan African. This model seeks to develop a low cost internet-of-things traffic surveillance system to improve vehicles mobility on a Nigerian closed campus. The goal is to alleviate the academic community's problem of peak-hour traffic congestion by delivering real-time traffic updates.

I. INTRODUCTION

Smart mobility has long been regarded as a critical driver of a country's economic progress. Global traffic issues are growing as urbanization [1], population expansion [2], [3], and vehicle numbers increase [4], [5]. For a variety of reasons, countries have begun to focus on strategies such as smart traffic management (STM) and traffic efficiency (TE), with a special emphasis on African countries. The major purpose of these initiatives is to close the supply-demand imbalance in the transportation network, making cities more sustainable in terms of vehicle mobility. This includes projects like a smart transport system (STS), which minimizes traffic while also giving real-time traffic updates. For decades, a significant difficulty for Nigeria's transport sector has been a lack of smart transport infrastructure, with bad road networks, inefficient public transport, and primitive traffic control systems dominating most cities. Efforts to revitalize the transportation sector have failed due to economic, political, and policy challenges. Unfortunately, as shown in Figure.1, traffic congestion has been increasing across the country, despite efforts to relieve the situation by recruiting traffic wardens and utilizing the traditional traffic signal system. These efforts have not resulted in noticeable advances over time. Consequently, the number of automobiles on Nigerian roads has expanded dramatically, while traffic infrastructure has not kept up. As a result, traffic numbers have expanded dramatically, resulting in reduced mobility rates, shorter transit times, greater fuel prices, and higher carbon footprints. However, there is an increasing emphasis on using disruptive technology (IoT) to address this societal issue. Although IoT is not a new technology, its concept remains largely unexplored in several developing countries. The Internet of Things (IoT) is a revolutionary technology concept that has changed the way humans interact with devices and systems. It provides real-time internet connection between people and physical infrastructure in smart cities. This connection opens up new possibilities in a variety of applications, including, healthcare [6], smart energy meters [7], smart home automation [8], smart cities [9], smart libraries [10],

smart bins [11-13], smart parking [5], [14], [15], and smart vehicles [16].

Figure 1: (i) Congestion in Lagos's metropolitan area caused by a traditional traffic light control system *b)* The typical traffic pattern in a Nigerian city.
Source: [17].

In recent years, a number of traffic control schemes have been presented that use various communication and surveillance technologies to automate and manage municipal traffic congestion and provide solutions to the limitations of traditional traffic signal systems. Firdous et al. developed a fuzzy logic-based traffic controller to reduce queue length and wait time. Combines fog computing and IoT technology to reduce traffic congestion and detect accidents in real time. Hilmani employed a camera and an automated traffic system to measure traffic density and optimize traffic patterns by [18]. Presented an IoT-enabled vehicular traffic monitoring system for car sharing in smart cities [19]. Also features a real-time traffic detection algorithm based on IoT sensors for different road users [20]. The proposed strategy reduces vehicle density. Developed an online traffic controller based on Raspberry Pi and IoT to monitor the traffic density and present users with the optimum path for [21]. Presented an A-IoT-based traffic control scheme to improve vehicle mobility and emergency exits. The strategy employs several IoT devices to identify, monitor, control, and update traffic congestion as well as detect accidents in real time [22]. Employed a bylnk web server application, IoT, and AI to prioritize emergency vehicles including fire trucks, ambulances, and armed cars, as well as deal with life-threatening occurrences [23-26]. LachiReddy et al [27], used an IoT-enabled traffic controller to monitor vehicle congestion. Infrared sensors are also built into the design to detect vehicle movement. Talukder et al [28], used an Internet of Things-enabled traffic monitoring system to track traffic congestion at an intersection. The model includes an SMS notification system based on an Android mobile application to keep clients aware of traffic conditions and to aid drivers in selecting the best route.[29], presented sensor-based solution to air pollution at the traffic signal. The model uses smart sensors like gas and temperature sensors to sense and monitor toxic gasses including CO_2, CO, smoke and NH_3. [30], highlights the significant contribution smart mobility in in future transformation of road infrastructure and also provides smart technologies to enhance sustainable solution for a connected future.

The main contributions of this study are summarized as follows.

- An IoT-based intelligent traffic surveillance system is proposed.

- Real-time monitoring of intersection traffic congestion is proposed.
- The proposed model uses web and mobile apps to inform drivers of regions with traffic congestion.
- The proposed model increases vehicle mobility and emergency response by giving real-time information.
- Real-time SMS alerts for traffic updates.

II. MATERIALS AND METHODS

The proposed methodology for the system is structured into two main parts namely; system hardware and system software as shown in Figure.2.
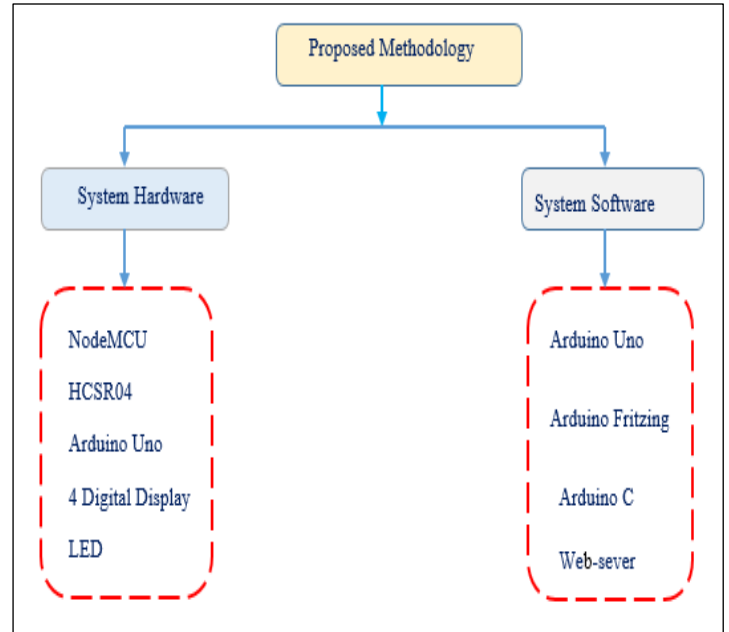

Figure 2: Proposed Design Methodology.
Source: Authors, (2024).

As illustrated in Figure.3, the system hardware incorporates sensors, an Arduino controller, a Wi-Fi module, and light-emitting diodes (LEDs) to detect, automate, and establish communication between different levels of IoT. The Arduino controller serves as the primary controller, controlling all data communication and transmissions throughout the system, while the NodeMCU (ESP 8266), a system-on-chip, establishes a communication link between the sensor module and web server. This module improves real-time traffic data updates and data mining. The ultrasonic sensor (HCSR04) detects motion and estimates the distance based on sound waves. It is primarily used in this study as motion identification measurement. Three ultrasonic sensors strategically placed at the T-intersection detect automobile activity. Hence, the Arduino controller establishes data communication between the sensors to monitor traffic congestion at each junction. In addition, three LEDs are included in this design to convey traffic status via a digital display. A vehicle is a mobile machine made up of different model, used to transport passengers or payload. Vehicles are of different types including wagons, bicycles, motor cars, motorcycles, trucks, ambulance, and buses. The sensors identify levels of traffic congestion in these vehicles and wirelessly upload the data to a cloud server for traffic analysis.
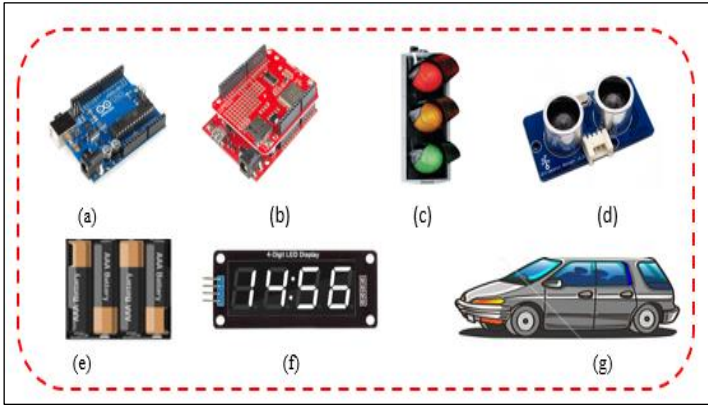
Figure 3: System hardware components (a) Arduino Uno, (b) NodeMCU, (c) Traffic light, (d) Ultrasonic sensor, (e) Battery, (f) 4 segment Display module, and (g) Vehicle.
Source: Authors, (2024).

A. System Software

The proposed model's core software includes an IDE, Arduino Fritzing, and a web-server application, and the proposed traffic mode code is written in the Arduino C language and runs on the Arduino integrated development environment (IDE). Furthermore, the entire system schematic diagram is built and simulated in Arduino fritzing software, which allows users to edit, change, and upload code straight to the Arduino board. The Arduino code implements the following commands: (a) writing Arduino C code for the ultrasonic sensors; (b) Automating traffic light signals; (c) establishing a communication link between the web server and the Wi-Fi module; (d) establishing a communication link between the Wi-Fi module and the sensor module; (e) developing Arduino C code for SMS notification; and (f) developing Arduino C code for the Arduino controller. controller.

B. Method

The proposed IoT traffic system (IoTTS) serves as a sustainable solution to address the issues of traffic congestion often experience daily at T-intersection at OOU campus.
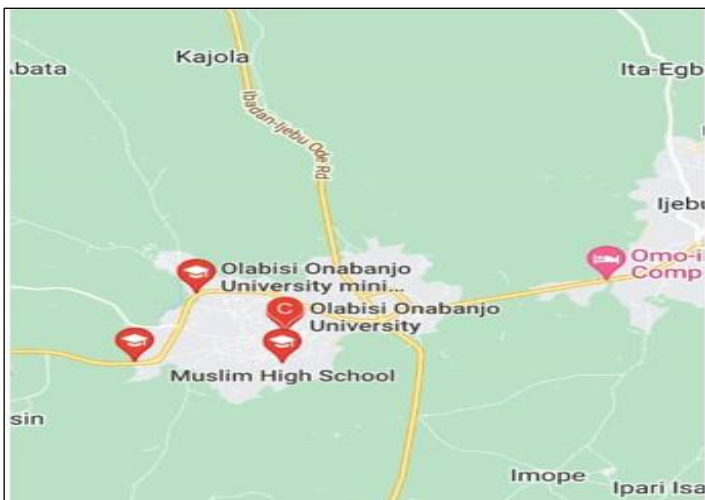

Figure 4: Location of Olabisi Onabanjo University.
Source: Google Map, (2023).

The system uses three ultrasonic sensors located at varied distances to determine traffic density at each junction. Each junction uses HCSR04 sensor to detect traffic levels. Furthermore,

when a vehicle enters the detection zone, the sensor detects the vehicle movement and calculates the traffic level at each junction based on the predefined distance at each junction. The first sensor node is held at 15 meters, the second at 55 meters, and the third at 100 meters. Hence, the sensors at each intersection assess the traffic density inside the detection zone to ensure accurate traffic level monitoring; once the traffic exceeds the sensor detection zone's threshold, the Arduino checks the traffic density level to allocate priority to the high-traffic intersection. The Arduino controller assigns low when the first sensor output is low, medium when the second and third sensors are high, and high if all sensor outputs are high. The Arduino controller adjusts signal timing based on traffic density. Low, medium, and high traffic intensities are given periods of 15, 30, and 45 seconds, respectively. Table 1 depicts the traffic density of the three sensors' conditions. Furthermore, the traffic management authority uses the web to obtain information and regulate traffic flow in real time, allowing road users, particularly drivers, to receive real-time updates. The traffic light and four-segment digital display show the traffic signal and timing. Figure 4 depicts the system schematic diagram.

Table 1: Sensor's Traffic Density.

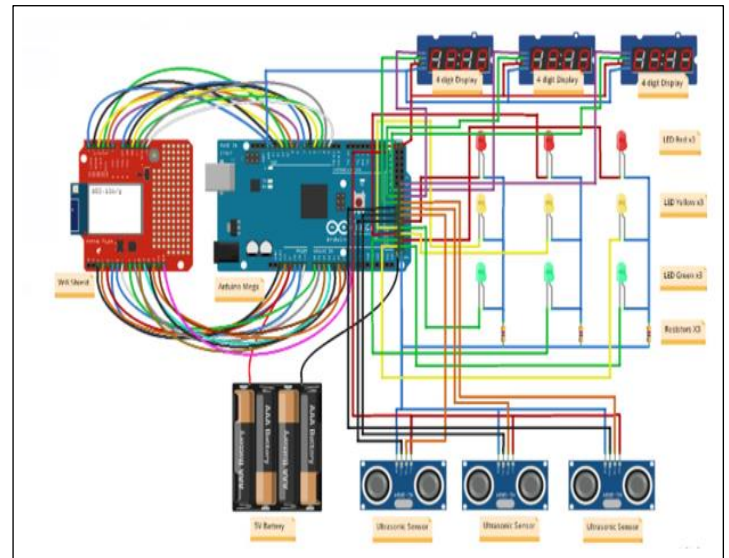| Scenairo	Sensors States at the junction			Traffic Level
	S_1	S_2	S_3	
	J_1	J_2	J_3	
A	1	0	0	L
B	1	1	0	M
C	1	1	1	H

L=Low, M= Medium, H= High
Source: Authors, (2024).

Figure 5: Proposed traffic surveillance system using IoT.
Source: Authors, (2024).

III. SYSTEM ARCHITETURE

Figure 5 displays the proposed system's three-tier Internet-of-Things infrastructure. The sensing layer detects and collects data via devices, sensors, and actuators. In this layer, the main controller communicates with the sensors and actuators to detect, collect, process, and transmit data via network connectivity. The network layer employs wireless technology to create a communication link between the sensing layer and the internet. The application layer handles data analysis and traffic congestion level processing. This layer is in charge of monitoring traffic congestion and updating traffic data.
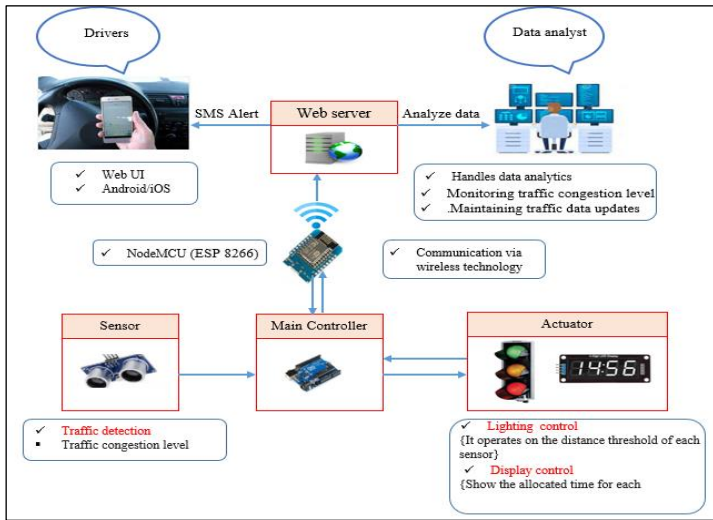
Figure 6: System Architecture.
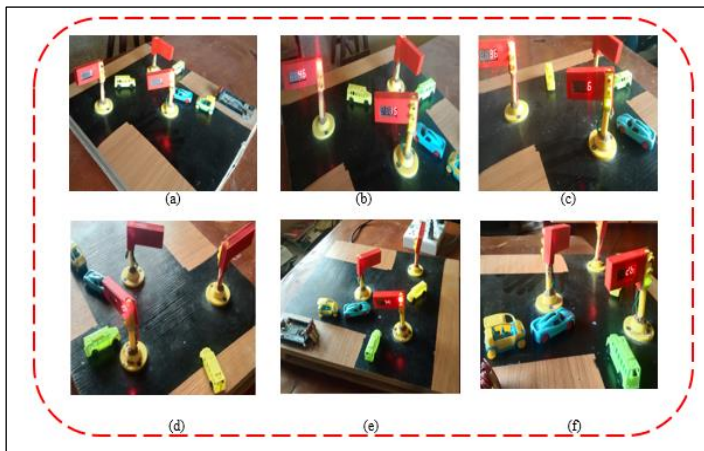Source: Authors, (2023).

Figure 7: (a) Prototype set up test with sensor 1, (b) Prototype set up test with the sensor 2,(c) Prototype set up test with sensor 3,(d) Prototype set up test with sensor 3, (e) Prototype set up test with sensor 2, (f) Prototype set up test with sensor 1.
Source: Authors, (2024).

Figure 6 depicts the model's prototype, which integrates several hardware and software components. These components were assembled, programmed, and tested to ensure their functionality

IV. RESULTS AND DISCUSSIONS

A-Performance Analysis

Table 2: Traffic decision based on priority.

Case	J_1	J_2	J_3	Traffic Decision			Junction sequence
				1st$p$	2nd$P$	3rd$P$	
1	H	H	L	J_1	J_2	J_3	J_1 J_2 J_3
2	H	H	M	J_1	J_2	J_3	J_1 J_2 J_3
3	H	L	L	J_1	J_2	J_3	J_1 J_2 J_3
4	H	L	M	J_1	J_3	J_2	J_1 $J_3$$J_2$
5	H	M	H	J_1	J_3	J_2	J_1 $J_3$$J_2$
6	L	M	L	J_2	J_1	J_3	J_2 J_3 J_1
7	H	H	H	Normal			J_1 J_2 J_3
8	M	M	M	Normal			J_1 J_2 J_3
9	L	L	L	Normal			J_1 J_2 J_3

Source: Authors, (2024).

Six independent prototype snapshots were shown to demonstrate system functionality at various levels. In addition, data from ultrasonic sensors are used to calculate traffic density. This data is saved on the cloud, shown in real time, and used to offer real-time updates to road users via text message. Table 2 depicts various traffic density levels and junction sequences. The traffic density rating ranges from 1 to 3 to represent the priority of the intersection. However, intersections with high traffic density are prioritized over others, whereas junctions with equal traffic density are treated equally. Furthermore, the ultrasonic sensors transmit vehicle traffic density data to the main controller, allowing it to make traffic decisions based on junction priority.

time management and minimizes road congestion, as seen by the system's 3.7 user rating average. Table 6 compares the proposed system's performance to previous studies. n addition, in terms of cost, we application, SMS notification, and traffic density monitoring, the proposed system improve previous solutions. It also features a priority-based decision-making strategy.

Table 3: Traffic evaluation of the IoTTS and CTS.

Traffic Modes	J_1	J_2	J_3	Green light ON (sec)	Time savings(%)
Congestion	H	H	H	135	25
Normal	H	M	L	90	50
busy	M	M	M	90	50
Free	L	L	L	45	75
Standard	All Levels			180	None

The standard mode indicates fixed timing for operating the conventional traffic light system CTS
Source: Authors, (2024).

Table 3 compares the traffic performance of the proposed system to the current traffic system (CTS). Four traffic modes are compared to CTS's normal mode of operation. The CTS uses predetermined time for making traffic signal decisions. The integration of IoT with road intersection saves about 75% more time than the current traffic system. The time savings ranging from 25% to 75 %. According to the findings, using IOTTS could save time. A 4-point Likert scale questionnaire with a score range of 1 to 4 was used as an additional statistical check to measure how well the proposed system performed. As shown in table 4, the highest scale indicates the number of people who strongly agree that the proposed system performed satisfactorily, while the lowest scale signifies the number of people who strongly disagree with the proposed system's performance. The questionnaire evaluation and user distribution rank are shown in Table 5. According to the assessment results, around 90% of the users were satisfied with the proposed system's design, while 5% were unsatisfied. IOTTS improves

Table 4: 4-point likert scale.

Point	Scale range	Explanation
4	4.00 - 3.00	Strongly agree
3	2.99 – 2.00	Agree
2	1.99 – 1.00	Diagree
1	1.00 – 0.99	Strongly diasgree

Source: Authors, (2024).

Table 5: Design Assessment Data.

Design Assessment Statement	4	3	2	1	Total	Sum	Average	Description
I found IOTTS more efficient and reliable in managing traffic congestion at the intersection than the existing traffic control system	40	10	0	0	50	190	3.8	Strongly agree
The developed system enhances the real time information update of traffic density	25	25	0	0	50	175	3.5	Strongly agree
The identification module is working perfectly within its detection zone	37	10	3	0	50	184	3.7	Strongly agree
Time management of the proposed system is optimal based on junction priority strategy	42	7	1	0	50	191	3.8	Strongly agree
Traffic data are easily accessible via webserver and sms notification	45	4	1	0	50	194	3.9	Strongly agree

Source: Authors, (2024).

Table 6: Performance evaluation of the proposed system with existing studies.

Performance metrics	Reference[29]	Reference[23]	Reference[16]	Reference[28]	Proposed System
System costs	Expensive	Cheap	Cheap	Cheap	Relatively Cheap
Technology	IoT	IoT	RFID	RFID	IoT
Web Application	No	No	No	No	Yes
SMS Nortification	No	No	No	No	Yes
Network Connectivity	Wi-Fi	GSM	No	No	Wi-Fi
Traffic Density Monitoring Application	No	No	No	No	Yes
Junction Priority	No	No	No	No	Yes
Automation	Smart	Smart	Smart	Smart	Smart

Source: Authors, (2024).

B-Economic Analysis

The proposed system costs are assessed to determine their economic viability and to provide a clear roadmap for mass production of the model. The total system costs are shown in Table 6. The proposed unit price is ($19.74), which translates to (N16, 576) in Nigerian currency. This suggests that the designed model is more cost-effective and budget-friendly than existing solutions.

Table 7: Table title.

System conponenets	Unit price ($)	Number of components	Amount ($)
Arduino Uno	7.91	1	7.91
NodeMCU module	2.46	1	2.46
LEDs	0.03	9	0.27
Ultrasonic sensors	1.36	3	4.08
Battery	3.58	1	3.58
Display module	0.48	3	1.44
Total			19.74

Source: Authors, (2024).

V. FUTURE OUTLOOK

Recent advancements in artificial intelligence (AI) and machine learning have the potential to improve real-time traffic patterns and prediction. Such an AI system can be implemented into the prototype to aid in future decision-making. In the future, the proposed system could be upgraded with the cameras, global positioning system (GPS), radars, and other modern sensors to collect traffic congestion data. Furthermore, integrating the suggested system with public transportation will improve the smooth and efficient transportation network, accurate prediction times of the transit system, and reduced waiting times. A highly interesting future path of this work may be found in the energy-efficient and sustainable techniques of minimising the energy consumption of traffic signals and signs. Using renewable energy sources such as solar or hybrid systems, on the other hand, would boost efficiency and provide a more sustainable traffic management system. Furthermore, big data and data mining are emerging technologies that can help transportation planners optimise traffic routes by improving infrastructure monitoring.

V. CONCLUSIONS

This study proposes a priority-based technique for minimizing traffic congestion at road intersections. The proposed model seeks to develop a low-cost Internet of Things-enabled traffic surveillance system in order to increase vehicle mobility. The system uses a three-tier Internet of Things architecture to detect, collect, process, and transmit data via network connectivity. An Arduino Uno was utilized as a core controller to assign priorities and make traffic decision at the intersection. In addition, the system was linked to a web server to give real-time traffic data and updates via smartphones and internet-enabled devices. The proposed strategy enables traffic management authorities to regulate traffic flow in real time while also providing road users with real-time updates, resulting in route optimization. Furthermore, economic and performance assessments highlight that the proposed system is superior to the current method in terms of mobility, efficiency, time management, and system costs. Therefore, shifting to intelligent, technologically driven traffic would help revolutionise the traffic management sector, especially in emerging nations.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Ayodeji A. Okubanjo.
Methodology: Ayodeji A. Okubanjo. Odufuwa Bashir, Akinloye, Akinloye Benjamin, Okakwu Ignatius
Investigation: Akinloye Benjamin, Okakwu Ignatius.
Discussion of results: Ayodeji A. Okubanjo.
Writing – Original Draft: Odufuwa Bashir, Akinloye, Akinloye Benjamin, Okakwu Ignatius.

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