A Framework for Smart City Model Enabled by Internet of Things (IoT)

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ABSTRACT
The advancement in wireless telecommunication network has increase the accessibility of more users to wireless connectivity. With the advent of the fifth-generation (5G) wireless network, a seamless connectivity is available for internet users globally. A smart city is a metropolis that utilizes information and communication technologies (ICT) to grow its functionality effectively to disseminate information among the public and to develop the quality of government facilities and the welfare of the citizen. The Internet of Things (IoT) refer to the interconnection of several systems, devices or physical objects/things which are driven by sensors, software, and other equipment in order to interconnect and interchange data with other devices and systems through the internet. The Internet of things (IoT), is a revolutionary method that allows a diverse number of applications to be interconnected in order to create a single communication architecture. Urbanization has resulted in the increase in population, hence there is need to develop a smart traffic light system to help in managing the problem of urbanization; traffic congestion. The Internet of Things (IoT) a key features necessary for employing a large-scale in IoTS are low-cost sensors, high-speed and error-tolerant data communications, smart computations, and numerous applications which helps in solving these challenges associated with traffic congestion. It enables a smart environment, smart energy, smart transportation system. In this paper, we shall discuss IoT technology, review some literatures on application area of Internet of Things (IoT), and challenges of IoT. And also discuss the applications of IoT, in smart city development, and traffic congestion management in smart city design, and how it proffers solution to urbanization problem.

Keywords
Internet of Things, Smart City Model

1. INTRODUCTION
Nam and Pardo, (2011), they define a smart city as an investment that involves a human and public centre and an up-to-date transport means, and infrastructure communication to create a viable commercial development and a better way of living, with a prudent organization of natural assets, employing participating governance.

Jung Hoon et al. (2013), define a smart city as distinct paths that are categorized into four technological areas, which are: Digital City, Smart City, Ubiquitous City, and Data City, and they interconnect through IoT.

Barbara et al. (2013), focused on the quality of life as an essential Smart City mainstay to guarantee the orientation towards a better lifestyle for citizens.

Zanella et al. (2014), viewed a smart city as a critical area, that helps to improve the usage of community assets, and the enhancement of valuable amenities accessible to residents, while decreasing operating overheads of community management.

Lee et al. (2014), define a smart city as an inventive, viable region that increases the value of life, produces pleasant surroundings, and the predictions of profitable growth for its resident.

Biyik et al. (2021), found out that IoT and intelligent transportation systems (ITSs) permit the establishment of smart requests and facilities management, it helps in private and public traffic control, dynamic traffic direction-finding, smart car parks, vehicle allocation and viable movement, associated driving, etc. Intelligent traffic solutions depend on the use of analytical models for prompt cautions against accidents.

Cepeliauskaite, et al. (2021), observed that numerous IoT devices enable smart city mechanisms. This help in improvement and sustainability of smart city societies. Smart mobility solutions are key to establishing near-zero-emissions, enhancing traffic flow, and improving the implementation of smart transport and IoT models.

Badii et al. (2020), identified that IoT applications are used to enable smart city platforms, they are developing across society and multitenancy IoT platforms and applications. It permits the increase in enormous structures that supports several establishments. It increases scalability and decreases infrastructural overheads as they are collectively shared between multiple operators.

Traffic congestion has become a major problem in most urban cities in the world. This is as a result of urbanization problem and the increase in the number of vehicles on the road and poor road infrastructure.

2. RELATED LITERATURE
In recent time, machine learning has led to industrial expansion in industries, it is widely used in transportation due to its artificial intelligence capacities. A key area in machine learning is artificial neural networks. This machine learning technique has exceptional analytical abilities, it could adapt to learning, associative and memory features and large-scale and dispersed processing features (Yang et al. 2016).

Artificial neural networks (ANN) comprises of backpropagation neural networks, radial basis function neural networks and fuzzy-neural network, these neural networks are capable of approximating non-linear functions and execute outstandingly depending on the type of datasets used for its training and testing and the field of applications, (Zhang et al.2011)

In the past, transportation researchers used Kalman Filter, Hidden Markov and ARIMA models in predicting the traffic volume, by means of conventional techniques through geographical positional sensors. But, due to high costs of installing sensors on roadside, its usage has been limited. The increase in inventive growth of mobile internet, artificial intelligence, movable devices are commonly useful and the ease in retrieving user data (Yin et al. 2016).

Convolutional Neural Networks (CNN) can be used to capture spatial features and Recursive Neural Networks (RNN) to capture sequential characteristics. Neural networks comprise of variations and hybrid models, which are used in traffic flow forecasts.

In recent times artificial intelligence has been successfully used in several areas of transportation, such as service computing methods, edge computing methods and social networks, (Deng et al. 2016).

Generally, there are manual traffic control systems, which require a high number of personnel to handle intersections. The manual systems have poor traffic rules and personnel strength, and the establishments cannot efficiently manage the traffic system in cities effectively, due to the large volume of vehicles and population with the manual system.

Syed et al. (2021), identified a smart city to be made up of several components as shown in figure 1. The first aspect of smart city applications is data collection; the second is data transmission/reception; the third is data storage, and the fourth is data analysis. Data collection is application-dependent, and it has been driven majorly by sensor development in a variety of fields. The data transfer from the data gathering units is sent to the cloud for storage and the analysis is the second phase. Many smart city initiatives include city-wide Wi-Fi networks, and 4G and 5G technologies, they are employed in various forms of local networks that transmit data on a local or global basis.

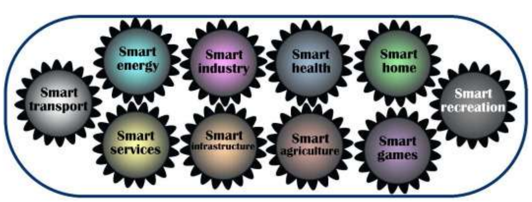

Fig. 1 The components of a smart city. (Ramson et al., 2020)

The internet of things (IoT) is core in smart city development, it is the enabling technology that enables ubiquitous digitization that gives rise to smart city development. The internet of things (IoT) refers to the ubiquitous connection of objects to the internet, which allows different devices to communicate data to the cloud and also obtain information for implementation activities. IoT involves the assembly of data and the use of data analytics to extract information which assist in decision-making and policy-making, Ramson et al. (2020).

Ramson et al. (2020), discovered that more than 75 billion gadgets would be connected to the internet by 2025, spurring even more application development. IoT allows sensors in smart cities to gather and communicate data on the status of the city to a central cloud, which is subsequently mined or processed for pattern extraction and decision-making.

Huang and Nazir (2021), shown that IoT and big data help in the management and analysis of a smart city. They compared the older city and the new smart city concept and the role of IoT devices in smart city development, as shown in Fig. 2.

Fig. 2. Old city versus smart city localities. (Huang and Nazir, 2021)

The figure above shows how a smart city is more organized when compared to an old city. The city is well planned with a better road network housing units and near zero vehicle emissions. The port, residential areas, and industrial areas are well planned.

3. SOME SMART CITY CHALLENGES ARE AS FOLLOWS:

3.1 Implementation Challenge

Ron and Friedemann (2015), reviewed some application challenges faced by the Internet of Things, these include the cost of implementation, with the expectation that the technology must be available at a low cost, irrespective of the number of devices implemented.

3.2 Scalability

Internet of Things has a vast concept than the conventional Internet of computers, Internet of things is in-cooperated within an open environment. Basic functionality such as communication and service delivery needs efficient functionality for both small-scale and large-scale environments. The IoT requires a new functional method for efficient operational scalability.

3.3 Data Volumes

Some application of the internet of things involves up-to-date communication and information gathering from sensor networks. logistics and large-scale networks collect a huge volume of data from central network nodes or servers. Big data is required to implement large operational technology and to store such information, process, and manage a large volume of data.

3.4 Interoperability

Each smart device in IoTs has different information, processing, and communication capabilities. These devices are subjected to different conditions, such as energy availability and communication bandwidth requirements. To facilitate this, communication and cooperation of these devices are required. These common standards help the objects to communicate properly.

3.5 Smart City Privacy

In any smart city development, security and privacy are of key importance. Any inconsistency in the operations of the city's services would be of great danger to the populaces and put human lives and property in great danger.

Smart cities require that key infrastructures must be online so that security difficulties will not be a major issue. In a technological era where cybercrime and warfare have become a major global issue, smart cities are increasingly becoming vulnerable to such hostile attacks. Data transmission over the network must be secured. Citizens' trust and involvement are required for smart city programs to succeed. The development of sensors in smart cities helps to collect data from user's activities continuously, this exposes residents' to daily attacks by third parties, (Ashraf et al. 2020).

3.6 SMART SENSORS EQUIPMENT

Ashraf and Ahmed, (2020), discovered that sensor equipment shares data, schedules responsibilities between them, and combines data to have an efficient smart city. Expansion and acceptance of open procedures and data layouts is a solution to this difficulty, it allows manufacturers to design equipment that can interact with one another, accelerating the implementation of IoT systems. Standard access point nodes for IoT systems interacts with devices using a variety of communication protocols and interpret the information received.

Ashraf and Ahmed, (2020), discovered that different manufacturers have designed their equipment to be interoperable with other protocols. An additional problem with smart sensors is their reliability and robustness. The reliability and accuracy of the IoT system are described as reliability and robustness.

The Internet of Things (IoT) is the strength of future smart city, this makes it significant to their working, IoT system must provide a seamless experience to its consumers. This demands a quick and accurate reply to service demands submitted by app users. Each individual in the smart city needs to have access to good services. Decentralized systems should be used to supply vital services like transportation and energy. The dispersed connection points improve the robustness and dependability of the system.

Ashraf et al., (2020), identified different areas of challenges of smart city operations, the operating mechanism involved in the digitalization process necessitates the growth of sensing nodes. With such a large application scope, developing and deploying IoT systems in smart cities presents great difficulties that must be considered. The problems that IoT system designers encounter while making deployments in smart city applications are discussed below. It majorly focusses on the technological problems associated with IoT deployment in smart cities as shown in the figure below. The numerous obstacles that Smart City IoT system implementation faces, include: Security and Privacy, smart sensors, Networking, and big data analytical.

Fig. 3 smart city challenges. (Ashraf et al., 2020).

Due to growth in road infrastructure and vehicles, handling a traffic and conveyance network has become difficult. The conventional traffic framework has a problem of not detecting the incidence of vehicles transversely on the separate road, and if a road is free, the traffic indicator waste time. The conventional vehicle controlling structure cannot manage traffic congestions efficiently when there is high density of vehicles on the road.

Traffic congestion has become a major problem in urban cities, most especially at peak periods (morning and closing hour) at intersections, due to an increase in the number of cars on the road. A lot of time is spent in traffic gridlock and accident do occur at this time, emergency vehicles like ambulances are not given priority to pass, and commuters spent time in traffic gridlock.

To solve this problem of traffic congestion problem, we propose a smart traffic light management system (STLMS), to handle these challenges associated with congestion at intersections during peak hours.

In this paper, we designed and implement a Smart Traffic Light Congestion Management System (STLCMS), enabled by IoT and machine learning technique.

4. METHODOLOGY

The proposed (STLCM) System Design

The system was developed using modular approach,

The various devices used are as follow; sensors, GPS, RFID tags, cameras, and actuators, and enabled by IoT.

The IoT make used of the available cloud resources, in establishing processes that integrate the traffic congestion management system. The STLMS utilizes the essential features of IoT, cloud computing, and big data. It enables different devices to communicate using M2M (Machine to Machine). IoT creates a platform for managing traffic-related difficulties (Sodhro, 2019).

The system architecture

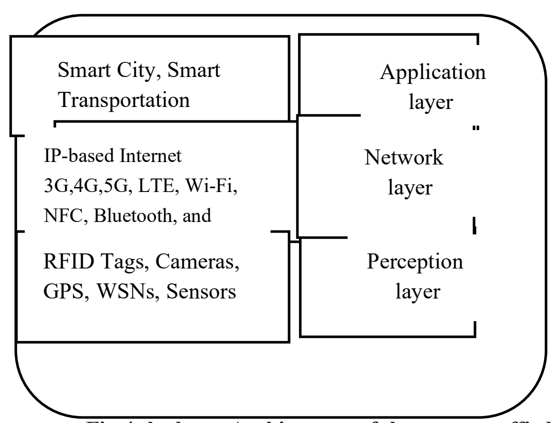

Fig.4 the layer Architecture of the smart traffic light

Figure 4. above is made up of three layers; the first layer is the application layer, which comprises the smart city application, and the smart transportation application (smart traffic light system). The second layer is the network layer, it helps to establish communication, using the various services, which include; IP-based internet, 3G, 4G, LTE, WiFi, etc. The third layer, which is the perception layer, which is use in capturing road traffic data at intersections through the following devices, such as the RFID Tags, cameras, GPS, WSN, and sensors.

The System workings

The architecture of the Smart Traffic Light System Congestion Management System

From the figure above, uses any of the following means to obtain the traffic light data, vehicle data, and the road data and it is then preprocessed. The traffic datasets collected using both inductive loop sensors and video cameras as acquisition systems and some selected parameters, which includes vehicle speed, time of day, traffic volume and number of vehicles on the road to detect congestions at intersections, is then use to monitor the road density for better traffic congestion management model, to de-congest vehicles at intersections and also give priority to emergency vehicles.

From figure 4 above, the IoT application uses the cloud Node facility to communicate with the IoT devices, and actuators, to send data to the data collection center for pre-processing. It is then stored in the database, and the traffic dataset is used for better traffic congestion management through the IoT application for smart traffic management system.

5. CONCLUSION

In other to improve the traffic situation, thereby controlling traffic congestions at intersections. The model will regularly update traffic sign programs subject to traffic capacity and projected schedules from neighbouring intersections. It will considerably reduce the waiting time by steadily moving vehicles across green signs and reduce traffic congestion by creating an improved switching time. A case study of Benin City, Edo State is considered, using a Smart Traffic Management System based on reinforced learning and IoT technology is considered in this paper. The system will solve the problems associated with traffic congestion at intersections during peak hours, in areas with high vehicle density, by directing them to alternative routes to eliminate traffic gridlock.

A smart traffic light system will positively impact the smart cities' decision-making process. Intelligent decision-making systems in smart mobility offer many advantages such as saving energy, relaying city traffic, and more efficiently, reducing traffic gridlock and air pollution by offering real-time useful information and imperative knowledge. As the system will be self-learning to adjust to the traffic situation, thereby reducing traffic gridlock by prompting commuters of possible congestion ahead at the intersection, so that it can be avoided.

Traffic Data

Fig. 5. Traffic data

Fig. 6. Traffic data

Fig 7. Traffic dataset obtained at road intersection

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