Smart Vehicular Traffic Management System using RFID Technology

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***Abstract*—Public places are often characterized with incessant traffic congestion, especially during special occasions and events, as large number of automobiles attempt to use the same parking lot concurrently. This usually result in confusion and dispute, auto crashes, waste of time and resources, and release of more carbon into the ecosystem. Radio Frequency Identification (RFID) technology offers effective solution for distant object identification without requiring a line of sight. In this paper, the authors developed an intelligent, cost-effective, and eco-friendly park management system for scalable traffic control using RFID and Solar photovoltaic (SPV) technologies. Pre-registered and visiting vehicles are assigned tags to access designated parking lots. However, large-scale implementation of the technology for intelligent park management requires a stable power supply with no threat to our ecosystem. SPV-powered UHF RFID readers transmit vehicle information via wireless data links to a host system application at the SPV-powered central database management system for further processing. This system will ensure effective traffic control during peak periods in order to avoid crashes, save time and resources, and as well save our planet.**

***Index Terms*— RFID, park management, renewable energy, smart and connected communities**

I. Introduction

PUBLIC places are often characterized with incessant traffic congestion, especially during special occasions and events, as large number of automobiles attempt to use the same parking lot concurrently. This usually result in confusion and dispute, auto crashes, waste of time and resources, and release of more carbon into the ecosystem.

RFID technology offers a more convenient and flexible technology which is well suited for fully automated systems, directing human lifestyle towards automation and reality [1]. This technology have been widely deployed for tracking and localization solutions in wide range of industrial and commercial systems in manufacturing, supply chains, agriculture, transportation, library, managing toxic and hazardous chemicals, and healthcare services [2-4]. Data can be stored and read from RFID tags embedded or attached to an object. Modern advances in the technology enables direct printing of tags on objects [5]. Hence, information stored in the tag can be wirelessly transmitted to the RFID reader via reader antenna [6, 7]. Proper networking of readers at various smart parks to a central database management system facilitates object and human identification, monitoring, authentication and alerting [8-10]. Interestingly, the operation of this technology accommodates Non-Line of Sight (NLOS) communication between the tag and the reader; it also offers concurrent scanning of multiple objects.

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Low-power wide area networks (LPWAN) technologies offer low power consumption, low transceiver chip cost, and large coverage area. While wireless personal area network (WPAN) technologies (e.g., ZigBee, Bluetooth Low Energy) provide wireless communication for things at short range (i.e., tens of meters), LPWAN technologies (e.g., SigFox, LoRA) focus on long range communications of a large number of battery-powered smart things in an energy-efficient manner [11]. For this application, LoRa LPWAN is deployed as an Internet of Things (IoT) monitoring platform, where a large number of RFID readers located at different access points upload vehicular data readings obtained from RFID tags at various intervals.

Unlike automatic license plate recognition (ALPR) technology [12], the operation of automobile recognition system using RFID technology is more efficient as it does not require complex processes of segmentation. Although several work have been done on vehicle identification and localization using RFID technology [13-20], large-scale implementation of RFID-based vehicular access control in a smart-green city requires a stable power supply that poses no threat to our ecosystem. Unfortunately, the power grid in most developing countries today are majorly fossil-fuel dependent and highly unreliable. Therefore, this paper integrated SPV technology into RFID-based automobile recognition system for efficient, eco-friendly, intelligent parking solution for smart and connected communities in developing countries.

II. Materials and Method

The proposed system depicted by Figure 1 was designed in conjunction with the Directorate of Physical Planning and Development at Canaanland city, Ota, Nigeria. Parking lots are allocated to vehicles based on availability.

Canaanland city houses the headquarter secretariat of Living Faith Ministries Worldwide (aka Winners' Chapel), Faith Tabernacle church building, Covenant University, Faith Academy Secondary School, and Kingdom Heritage Nursery/Primary School. Several business ventures operated by the church including Dominion Publishing House, Hebron Bottled Water Processing Plant, a bakery, various restaurants and stores, four banks, and several residential estates that accommodates over 5,000 church employees and more than 15,000 students are all located within the city. The 50,000-capacity Faith Tabernacle is the largest church auditorium in the world. The five Sunday services usually see a flood of members arriving at Canaanland, and the ministry maintains more than 350 shuttle buses that bring congregants to the church from different locations of Ota and Lagos metropolis [21]. The city maintains a single opening for entry and exit.

At the city main entrance, pre-programmed RFID tags are assigned to each of these vehicles. On getting to any of the parks, the tag is scanned by the RFID reader to ensure the eligibility of entry. For better efficiency, the UHF RFID reader is re-engineered to accommodate LPWAN wireless communication network, and powered by SPV system. Unauthorized vehicles are denied access. Automated barriers are installed at the parks, and alternative exit routes are provided for unauthorized vehicles in order to reduce traffic congestion. Vehicle information are transmitted via wireless data links using LoRa LPWAN to a host system application at the SPV-powered central database management system for further processing and access control.

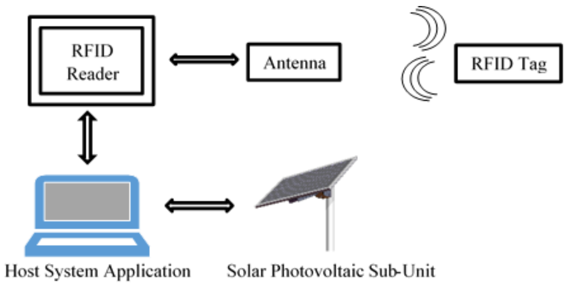

Figure 1: Block Diagram of Smart Park Management System

UHF RFID readers operating at frequency range of 902-928 MHz were employed to ensure sufficient distance coverage. We redesigned the RFID reader system, as shown in Figure 2, to avoid the need of personal computer at each access point. Instead, a wireless LoRa LPWAN transceiver module is embedded in each of the reader to enable seamless interconnection of all the readers within the city. The new system consist of UHF RFID antenna, a microcontroller (PIC18F4520), RS232 driver (MAX232), RF module (LoRA wireless module DT1276), and LCD display unit. Geographically dispersed RFID readers are interconnected wirelessly, producing a distributed RFID system or IoT grid with the aim to detect, identify, write process information and send data needed by the embedded system to control the barriers at the access points.

The passive RFID reader antenna has an adjustable wide range identification distance of 1-15 metres with a multi-tag identification ability of 1-50 tags. It is equipped with multiple interfaces for RS-232 and Weigand. It consumes extremely low power: no heat generation under full duty operation; maximum continuous current < 200 mA at 3.5 V (26 dBm output); maximum peak pulse current < 110 mA at 3.5 V (18 dBm output). The receiver sensitivity is -70 dBm.

A microcontroller acted as the central processing unit of the UHF reader system. It initiates and manages all the interactions between the system components. PIC18F4520 has four 8-bit ports, hardware UART, and an internal oscillator. It is considered suitable for this application because of its speed advantage, operating at a maximum oscillator frequency of 32 MHz. The microcontroller is designed with Flash technology, enabling the ability to alter the program run in the system as need arises. Since the programmable interface controller is soldered permanently on the circuit board, in-circuit serial programming method is employed.

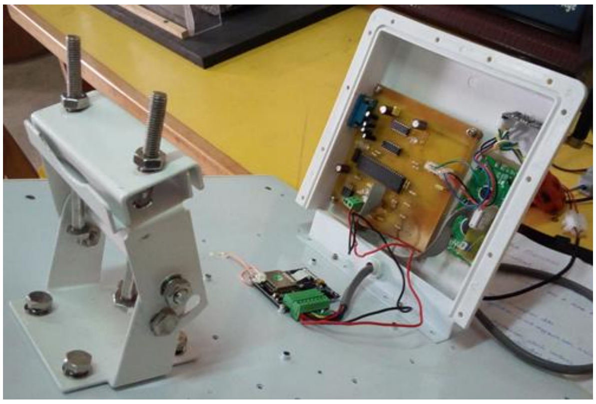
Figure 2: Re-engineered UHF RFID Reader

RS-232 is a standard for serial communication transmission of data. The RS-232 standard is commonly used in computer serial ports. RS-232 driver (MAX-232) was used for firmware debugging of the antenna. 16-by-2 Liquid Crystal Display (LCD) screen is a cost-effective, easily programmable electronic module that has the capability to display up to 16-character information on each of two lines. Here, each character is displayed in 5x7 pixel matrix. The display unit has two registers namely, command and data. The command register stores instructions to accomplish pre-defined tasks on the screen; while the data register stores the data to be displayed on the LCD. In this application, the LCD is used for alphanumeric display of vehicle information read from the RF tags placed within the automobile.

A low-power, wide-area networks (LPWANs) link was developed using LoRa technology to create the required wireless data links. This technology offers a very compelling mix of long range, low power consumption and secure data transmission. A network based on LoRa wireless technology can provide coverage that is greater in range compared to that of existing cellular networks. LoRa transceiver module, SX1276, was used for wireless communication between the UHF RFID reader antenna and the central host server. SX1276 modem provides ultra-long range spread spectrum communication and high interference immunity while minimizing current consumption. It exhibits a high sensitivity of -148 dBm combined with the integrated +20 dBm power amplifier.

Gradual decrease in the planet's fossil fuel reserves and the inevitable need to preserve our ecosystem promote the development of renewable energy harvesting as sustainable source of energy. Renewable energy harvesting system consists of the energy source (solar radiation), energy capture module (solar panels, and embedded system for control and regulation), storage module (battery/dry cell), and the load (end application). For this application, rechargeable batteries supplies primary power while renewable energy harvesting system charges the battery itself.

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III. Design Implementation

Large RFID readers are installed at the entry points to all the parking lots. The readers are strategically positioned beside the road leading to those areas. The SPV system powers the combined reader antenna and wireless data communication system. The power circuit is made up of a 5V regulator (7805) which supplies 5V to all circuit elements. The connected capacitors around the regulator (decoupling capacitors) eliminates any noise in the DC voltage supply line.

As soon as a vehicle enters the RF zone of the reader, the information preloaded on the RFID tag located on/within the automobile data is read by the reader antenna. Figure 3 shows a typical scenario of the system. RFID technology uses system handshake and backscattering to transmit information to a reader [22]. RFID reader emits a sinusoidal signal. The tag antenna is tuned to receive the signal from the reader. The internal IC of the passive tag contains a rectifier circuit that converts the power into DC, enabling the tag circuitry to work. The circuitry modulates the signal to an extent and then returns it to the reader. During this process, the tag does not create a separate signal; it merely modulates the signal received from the reader.

The microcontroller receives this data using RS-232 protocol. The RS-232 protocol defines only two lines for data transmission and reception but at RS-232 level (-15V to -6V for logic 1 while +6V to +15V for logic 0). These voltages are clearly above normal digital levels, therefore a RS-232 level translator to logic 5V level is needed (MAX232).

The tag data is converted to ASCII format and displayed on the LCD screen. Also, the ASCII-format data is sent to logger PC via the RF module. The communication with the RF module is based on UART which also defines two lines of data communication, Tx and Rx, like the RS-232. The difference is that UART communicates with Tx and Rx lines but at logic 5V level. This is suitable for direct microcontroller interfacing.

UART or RS-232 communication involves at least two elements: one will act as master (the initiator of the communication) while the other serves as slave (the receiver). In this application, the microcontroller plays the master role while RS-232 translator and the RF module are the slaves. Since communication can only take place between the master and one slave at any time, a multiplexer network is designed to facilitate communication from master to two slaves but one at a time.

RF signals transmitted from every access points are received at the central control centre for vehicle data matching and processing to determine vehicle identification, authorization, and authentication. A server host application was developed using Java programming language and it runs on Windows operating system. Vehicle information are logged using an open source database management software, MySQL. The server host application communicates with the MySQL database via MySQL.NET connector API. For sustainable power supply, a suitable SPV system was designed to power the logger PC.

IV. Conclusion

This work addressed the challenges of incessant traffic congestion in public places, especially during special occasions and events, where large number of automobiles attempt to use the same parking lot concurrently. Although several work have been done on vehicle identification and localization using RFID technology, large-scale implementation of RFID-based vehicular traffic management in smart and connected communities requires a stable power supply that poses no threat to our ecosystem. Unfortunately, the power grid in most developing countries today are majorly fossil-fuel dependent and highly unreliable. We, therefore, integrated SPV technology into RFID-based automobile recognition system for efficient, eco-friendly, intelligent traffic management system suitable for smart and connected communities in developing countries. This solution will minimize the incidences of auto crashes, waste of time and resources, and release of more carbon into the ecosystem.

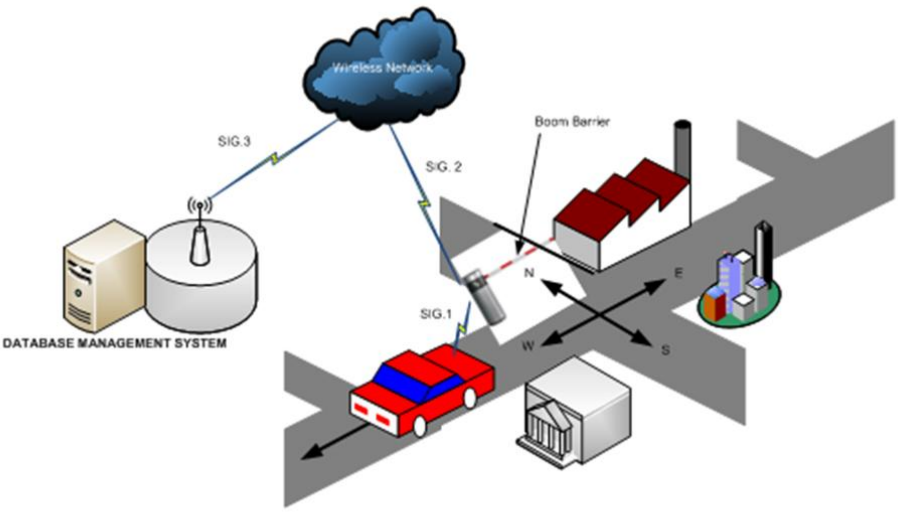

Figure 3: Use Case of Smart Traffic Management System

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