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Solar Photovoltaic Automobile Recognition System for Smart-Green Access Control using RFID and LoRa LPWAN Technologies

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Abstract: Increasing upsurge in the use of vehicle ramming tactics targeted against public buildings and crowd of people by terrorists and insurgents accounts for the unprecedented terrorism-related death record and extensive destruction of invaluable properties witnessed in recent time. Tracking and localization challenges can be effectively handled using Radio Frequency Identification (RFID) technology. However, large-scale implementation of the technology for access control in a smart-green city requires a stable power supply with no threat to our ecosystem. Unfortunately, the power grid in most developing countries today are majorly fossil-fuel dependent and highly unreliable. In this study, we developed an intelligent, cost-effective and eco-friendly automobile recognition system for scalable access control using RFID and Solar Photovoltaic (SPV) technologies. Vehicles authorized to access sensitive areas are pre-assigned passive RFID tags. SPV-powered UHF RFID readers are available at such places to activate and vehicle information on tags. Based on LoRa wireless technology, vehicle information are transmitted to a server host application at the SPV-powered central control center for further processing. The implementation of this system in Canaanland City, Ota, Nigeria, ensures efficient access control to soft targets in order to guarantee safety of lives and properties and as well save our planet.

Key words: Internet of things, RFID, smart city, green computing, LoRa technology

INTRODUCTION

Public buildings and crowd of people have become the target points of terrorists and insurgents in the 21st century. In recent years, increasing use of bomb-laden vehicles have led to unprecedented terrorism-related death record and extensive destruction of invaluable properties. Over the last 15 years, >61,000 incidents of terrorism claimed over 140,000 lives (Alissa *et al*., 2016). Within a period of 1 year, Nigeria witnessed the largest increase in terrorist deaths ever recorded by any country, increasing by over 300%; 7,512 fatalities in 2004 (Anonymous, 2016). On the evening of 14 July 2016, a 19-tonne cargo truck was deliberately driven into crowd of people celebrating bastille day on the promenade des anglais in nice, france, resulting in the death of 86 people (Fan and Zhang, 2009) and injuring 307. This gruesome act calls for the development of intelligent vehicular access control in order to protect lives and properties, especially at places vulnerable to such attacks.

Serious attempts have been made to beef up security measures at soft targets. However, traditional human-operated access control techniques usually result in avoidable traffic congestion, wasting time and resources. Security agencies attached to most visited public places such as worship centers, resorts and popular nightclub often find it difficult to effectively and efficiently handle the frequently high vehicular and human traffic attempting to access such places at the same time. In this study, we designed a more efficient vehicle identification system for smart-green access control to sensitive areas in public places, especially during special events and festive periods.

RFID technology offers a more convenient and flexible technology which is well suited for fully automated systems, directing human lifestyle towards automation and reality (Younis *et al*., 2013). 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 (Chen *et al*., 2010; Hwa *et al*., 2011; Zhou *et al*., 2008). 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 (Preradovic and Karmakar, 2009). Hence, information stored in the tag can

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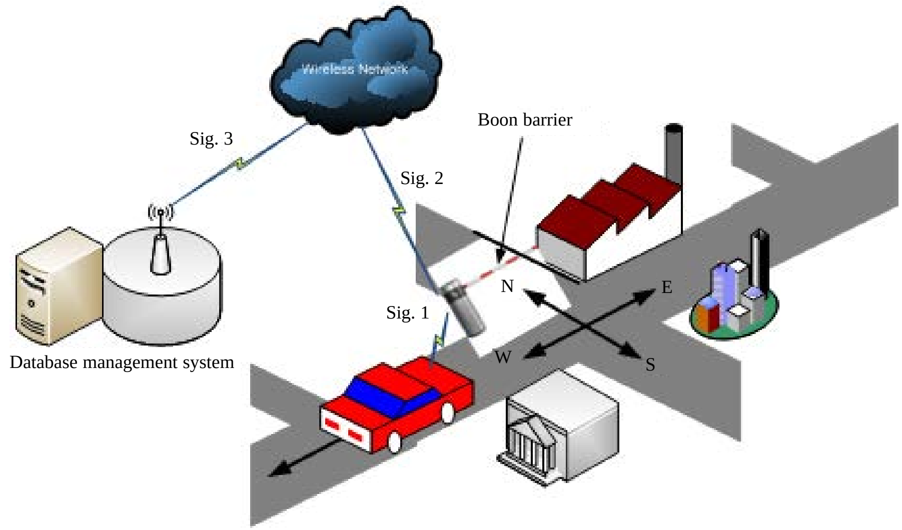

Fig. 1: Proposed intelligent automobile access control system

be wirelessly transmitted to the RFID reader via reader antenna (Balitanas and Kim, 2010; Meng *et al*., 2008). Proper networking of readers at various access points to a central database management system facilitates object and human identification, monitoring, authentication and alerting (Nambiar, 2009; Higgins and Cairney, 2006). 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.

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., Zig bee, bluetooth low energy) provide wireless communication for things at short range (i.e., 10 of meters), LPWAN technologies (e.g., Sig Fox, LoRA) focus on long range communications of a large number of battery-powered smart things in an energy-efficient manner (Petajajarvi *et al*., 2015). 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 (Mohandes *et al*., 2016) 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 (Pandit *et al*., 2009; Hannan *et al*., 2012; Ying *et al*., 2010; Isasi *et al*., 2010; Makarov *et al*., 2012; Ojeda *et al*., 2006; Fan and Zhang, 2009; Foina *et al*., 2007) 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 study integrated SPV technology into RFID-based automobile recognition system for efficient, eco-friendly, intelligent access control suitable for a smart-green city in developing countries.

Proposed SPV automobile recognition system: This system is aimed at curbing the recently increasing terrorist attacks conducted by vehicle ramming into soft targets in Nigeria. Instability of power supply in most developing countries, especially in Africa and consideration of the adverse effects of fossil-fuel energy sources on our ecosystem will render available systems inefficient if deployed in this part of the world (Fig. 1).

Canaanland City, located in Ota, Nigeria, houses the headquarter secretariat of Living Faith Ministries Worldwide (aka Winner's 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, 4 banks and several residential estates that accommodates over 5,000 church employees and >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 >350 shuttle buses that bring congregants to the church from different locations of Ota and Lagos metropolis. The city maintains a single opening for entry and exit.

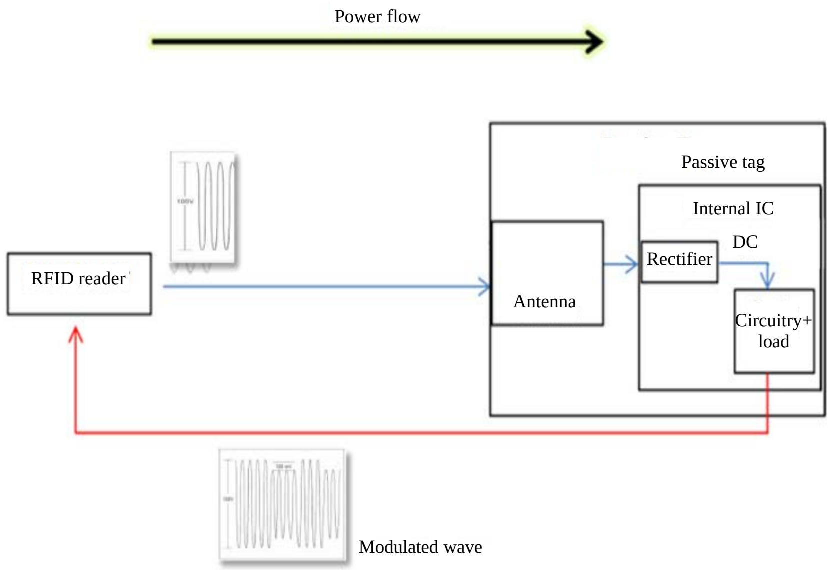

Fig. 2: Working principle of passive RFID tag (Makarov *et al*., 2012)

The proposed system is designed in conjunction with the Directorate of Physical Planning and Development at Canaanland City, Ota, Nigeria. Access to sensitive areas are restricted to limited vehicles within the city. Alternative routes are made for private and utility vehicles. At the city main entrance, pre-programmed RFID tags are assigned to each of these vehicles. On getting to any of the access points, the tag is scanned by the RFID reader to ensure the eligibility of entry into that particular area. 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 access points 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 (Fig. 2) (Ferdous *et al*., 2016).

MATERIALS AND METHODS

System design methodology: All vehicles are pre registered with the Directorate of Physical Planning and Development. Here, passive RFID tags are configured to contain driver's details, the vehicle registration data and particularly the areas accessible to the owner/driver. Each access point is equipped with the redesigned UHF RFID readers with LoRa LPWAN RF module for low-power wireless communication an embedded system, a SPV system and a barricade structure. In this arrangement, unauthorized users are strictly not allowed access, rather the barricade structure coerces such to take the exit route.

UHF RFID readers operating at frequency range of 902-928 MHz were employed to ensure sufficient distance coverage. We redesigned the RFID reader system 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 (Fig. 3).

UHF RFID reader antenna: The passive RFID reader antenna has an adjustable wide range identification distance of 1-15 m 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 (Table 1).

Microcontroller: This acts as the central processing unit of the UHF reader system (Mohandes *et al*., 2016). It

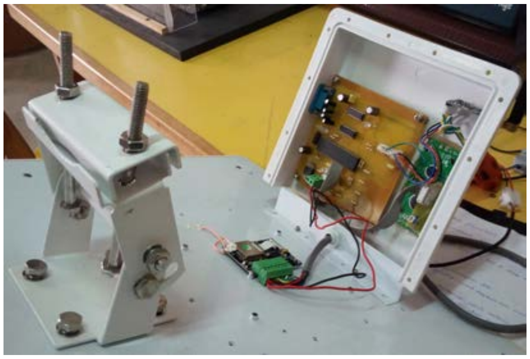

Fig. 3: Integrated design of UHF RFID reader with low power communication capability

Table 1: UHF RFID Reader antenna pin configuration

Pin	Identification	Description
1	+9 V	Connect to external power
2	GND	External power ground
3	RS-232 TXD	RS-232 data output
4	RS-232 RXD	RS-232 data Input
5	232-GND	RS-232 ground
6	Weigand DATA0	Weigand data 0
7	Weigand DATA1	Weigand data 1
8	Weigand GND	Weigand data ground

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.

RS-232 driver: 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 (Foina *et al*., 2007).

LCD display unit: 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 5×7 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 (Table 2 and Fig. 4).

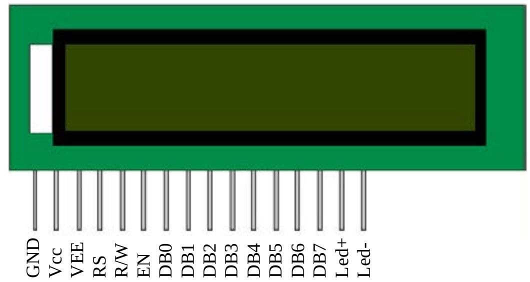

Fig. 4: Pin configuration of 16×2 LCD display unit

Table 2: Description of 16x2 LCD pin configuration

Pin	Identification	Description
1	GND	Ground (0 V)
2	V_{CC}	Supply voltage (4.7-5.3 V)
3	V_{EE}	Contrast adjustment
4	Register select	If LOW, select command register If HIGH, select data register
5	Read/write	Low (write); high (read)
6	Enable	Send data to data pins
7	DB0	8-bit data pins
8	DB1	
9	DB2	
10	DB3	
11	DB4	
12	DB5	
13	DB6	
14	DB7	
15	LED+	Backlight (V_{CC})
16	LED-	Backlight GND

RF module: 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 (Isasi *et al*., 2010).

RESULTS AND DISCUSSION

Solar Photovoltaic (SPV) System: 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.

System implementation

System hardware: RFID readers are installed at the entry points to all sensitive areas prone to terrorist attack. 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 5 V regulator (7805) which supplies 5 V 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. RFID technology uses system handshake and backscattering to transmit information to a reader (Rida *et al*., 2010). 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 research. 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 (-15 to -6 V for logic 1 while +6 to +15 V for logic 0). These voltages are clearly above normal digital levels, therefore a RS-232 level translator to logic 5 V 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 5 V 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 (Fig. 5 and 6).

Fig. 5: UHF RFID reader system

Fig. 6: System implementation

System software: 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.

CONCLUSION

Public buildings and crowd of people have become the target points of terrorists and insurgents in the

21st century. In recent years, increasing use of bomb-laden vehicles have led to unprecedented terrorism-related death record and extensive destruction of invaluable properties. Meanwhile, RFID technology offers a more convenient and flexible technology which is well suited for fully automated systems, directing human lifestyle towards automation and reality.

Although, several research have been done on vehicle identification and localization using RFID technology, 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. We, therefore, integrated SPV technology into RFID-based automobile recognition system for efficient, eco-friendly, intelligent access control suitable for a smart-green city in developing countries (Hannan *et al*., 2012).

The proposed system ensures effective access control to soft targets in order to guarantee safety of lives and properties and as well save our planet.

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