Multi-Power Source and Cloud-Backup Enabled Security Framework for Surveillance in Nigeria

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Abstract. In Nigeria, power is one of the major problems and this deters the reliability and effectiveness of a video surveillance system as the case may be. Also, as criminal organizations tend to destroy every physical storage after an operation, providing a suitable backup to the cloud is a viable solution to serve as a failsafe plan in case of hardware eventualities. This work focuses on the design and construction of a real-time power and data backup surveillance system for security of lives and properties. Construction of a sufficient power bank backup system was developed in real time with average power outage duration in Nigeria considered. Lithium ion batteries with a cascade connection were used to provide alternate power to the system in a situation of power outage. An Arduino microcontroller controlling relay modules was used to ensure optimum battery life and efficiency and an IP camera was used for surveillance as well as cloud storage. This research was implemented and evaluated to measure the efficiency of the system. The results show that the entire system has the capacity to switch between the direct power source and the alternative power source; it could last for 100-156 hours after full charge in absence of power supply. The data backup was stored to a secured cloud and could only be accessed by authorized users when such is required.

Keywords: Security, Surveillance, Cloud Computing, Energy, Microcontroller

1 Background of the Study

Existing video surveillance research focused primarily on the impact of security and surveillance schemes on crime rates and public perception of municipal security systems. CCTV’s technological shift from analog to digital has created many opportunities for a wide range of stakeholders including business owners, councils, control room managers, security consultants and manufacturers. Keith Laidler proposed in an article “Surveillance Unlimited”, activities observation and investigation through video recording and evidences are as ancient
as advancement itself. In the past, surveillance is often referred to as spying. It often, occurred as a means of gathering information, overseeing other people’s actions and using this information to increase one’s knowledge of the party under consideration. High level technology glasses for spying purposes, optical instruments and radios are being developed, the way surveillance was carried out was continuously influenced. The first CCTV system was installed by Siemens AG at Test Stand VII in Peenemünde, Nazi Germany in 1942, for observing the launch of V-2 rockets [15]. A German engineer namely Walter Bruch was responsible for the technological design and construction of the system.

Surveillance is the monitoring of behavior, activities or other changing information for the purpose of influencing, managing, directing or protecting people [5]. This embodies observation within a range by means of electronic devices like surveillance cameras or interception of electronically transmitted data such as network traffic or phone calls. It also contains easy no- or comparatively low-technology strategies like human intelligence officer and communication interception. Surveillance is employed by governments for intelligence gathering, the securing of a method, person or object, or hindrance of crime. It’s conjointly utilized by criminal people to organize crimes like burgling, seizure of innocent individuals, etc. Video surveillance is employed for a spread of purposes and lots of users have completely different goals for their systems.

Design of a surveillance system is still challenging in Nigeria today. Many had underestimated the complexity of this problem as surveillance is done by just setting up cameras and reviewing recorded videos. However, for a surveillance system to be much more reliable, there are many challenges involved. One of the challenges faced in a surveillance system is a power outage which is addressed in this research work. Like any other electronic system, a power outage can be experienced, and the effect can be managed depending on the failsafe plans in place for such an occurrence. This constraint becomes a detriment in the surveillance process as security requires all-round monitoring. In a severe case where there’s an outage for a long period of time, criminal activities can occur and there’ll be no system in place for monitoring the activities.

In addition is data-backup. Data is the most valuable asset in a surveillance system as it is the whole output of the process. The images and video clips gathered by the surveillance system are stored in a drive or memory location. Data loss is a slip-up condition in data systems during which information is destroyed by failures or neglect in storage, transmission or process. Imagine having tons of data stored and all is lost due to virus, memory crash or the drive getting stolen. This diminishes the reliability of the surveillance system as the whole essence of the system is to provide video evidence when needed. Implementing a real-time backup system in a case of disaster hence recovery instrumentality and processes to stop information loss or restore lost data is a big challenge and needs to be addressed.

2.0 Theoretical Framework
Many researchers have proposed different techniques for carrying out surveillance. Most of these techniques proved efficient as impressive results were achieved. Many processes such as the use of specific microcontrollers, cloud computing, wireless transmission, storage optimization among others were used to serve as the building blocks of different surveillance systems [13]. Considering these techniques observed, laws and equations were used to actualize the feasibility of these processes hence we review these basic theories in the following sections.
2.1 Surveillance

Surveillance is the monitoring of activities, actions or others for the purpose of influencing, managing, controlling or protecting lives and properties. Surveillance is essential as it’s a step to ensuring security in homes and industries [6]. These systems have various components with a variety of functions, characteristics and specifications. A surveillance camera is an important element to several public and private establishments due to its efficiency in providing adequate and efficient security solutions that can protect these establishments. These cameras have unique properties and features which help in choosing the appropriate types for different problems. Design considerations including camera positioning, resolution, field of view, rotation ability, lighting, microcontroller, power amongst others determine the efficiency of a surveillance system as these parameters are necessary for deriving the reliability of the system.

To calculate the camera coverage, we consider a simplified two-dimensional (2D) example of camera coverage as shown in figure 1.0, where a number of important areas \( a_i \) are divided into cells \( C_{ij} \), assigned with importance value \( IV_i \) and a number of cameras \( K_x \) are placed for monitoring the desired areas. Hence, the weight of the important area \( a_i, W_{a_i} \)

\[
W_{a_i} = IV_i \sum_{j=1}^{n} C_{ij} \quad \ldots \ldots \ldots \ldots \ldots \ldots (i)
\]

The weighted covered cells in the area \( a_i, CC_{a_i} \)

\[
CC_{a_i} = IV_i \sum_{v=1}^{n} C_{iv} \quad \ldots \ldots \ldots \ldots \ldots \ldots (ii)
\]

Total coverage of camera, \( K_x \)

\[
K_x = \frac{\sum_{i=1}^{m} CC_{a_i}}{\sum_{i=1}^{m} W_{a_i}} \quad \ldots \ldots \ldots \ldots \ldots \ldots (iii)
\]

Hence, total coverage of all cameras is

\[
\sum_{x=1}^{Q} coverage \ of \ camera \ K_x \quad \ldots \ldots \ldots \ldots \ldots \ldots (iv)
\]
A concept to consider in surveillance cameras is the resolution. Resolution can be expressed as the level of detail with which an image is recorded and can be reproduced. The higher the resolution, the higher the surveillance storage requirements hence it prompts selecting the right resolution that highlights important features but also conserving space as it would be optimized[8]. For a surveillance system to be reliable, an adequate storage system must be provided and optimized to conserve storage space as the allocated space is usually large but not infinite[12]. Cloud computing can be defined as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction [13]. “It is a type of computing which provides simple, on-demand access to pools of highly elastic computing resources” [1]. These resources are provided as a service over a network which is usually the internet. The cloud technology offers effectively limitless, low-cost and reliable technology without the consumer being worried about how it operates, who runs it or where it is located. A branch under cloud computing is cloud storage which entails storing data on the internet. The term storage optimization which is associated with Information Lifecycle Management (IFM) is used to describe the management and implementation of storage solutions to obtain a low-cost per capacity data storage. The off-site storages are provided and managed by third parties over the internet which offers a large capacity of storage available for usage.

As the data gets recorded and stored, storage space needs to be considered and can be managed through different parameters such as Frame/Image size and Frames/Images per second.

### 2.2 Multi-power source concept

The idea of multiple power sources is long overdue; it is an effort to have one or more electrochemical cells coupled otherwise called battery to provide source of energy for most digital and electrical devices [6]. These devices include but not limited to personal computers,
hand held devices, sophisticated vehicles, home appliances among others. When electric power is supplied by battery, a redox reaction occurs which converts high-energy reactants to lower-energy products, and the free-energy difference is delivered as an output to the external circuit as electrical energy. Energy equation deduced based on Ohms law [9] is

\[ E = P \times t = V \times I \times t \]  

where \( P \) = power, \( t \) = time, \( V \) = voltage and \( I \) = current

Power is defined simply as work or energy divided by time. Therefore, power has the unit of joules/second which is also called the “watt”.

\[ P = \frac{W}{t} \]  

where \( P \) = power, \( W \) = work done, \( t \) = time

Power capacity is how much energy that’s stored in the battery. This power is often expressed as Watt-hour (Wh in symbol). A Watt-hour is the voltage a battery can provide multiplied by how much current the battery provides in the same amount of time usually in hours. The amount of energy charge in a battery is the capacity and is expressed in ampere-hour.

2.3 IP cameras
An IP camera is a networked digital video camera that transmits image data and receives control data over the internet. These cameras are IP accessible which implies that they can be controlled with the internet from anywhere in the globe, provided that the user has adequate network access and safety privileges for the camera [18]. Due to its wireless feature and IP data packets in use, an IP based surveillance system provides global access and wider flexibility compared to CCTV. In transmitting data, bandwidth is required as this determines the speed at which information is gotten. The main factors to consider are the video recording resolution, video compression/decompression used a number of cameras and the FPS (frame rate per second).

To calculate the bandwidth necessary [6],

\[ B_T = (B_m \times N) + (B_s \times M) \]  

where \( B_T \) = Bandwidth required in mbps  
\( B_m \) = Bitrate main stream in kbps  
\( B_s \) = Bitrate sub stream in kbps  
\( N = \text{no of cameras for main stream} \) & \( M = \text{no of cameras for sub stream} \)

2.4 Empirical review
Surveillance systems monitor the events that happen in an establishment/facility with the use of video cameras. The cameras can either rotate or remain stationary depending on the area of focus. Aditya et al, [3] proposed a system based on IOT to serve as smart surveillance and monitoring system using Arduino. Web of things (IoT) is a concept of the ongoing development of web, by which ordinary things have direct characteristics that enables them to transmit and receive information through remote or wired means creating an extraordinary trend to achieve a shared objective. Using an Arduino and a PIR sensor, a surveillance system
was designed in this paper. When there is motion in the area under monitoring, the Arduino sends a message like a push button to the Android smartphone using Firebase API. The Arduino is connected to the internet by means of Wi-Fi by modifying the existing code and adding the Wi-Fi connection command in it. The system’s performance level is okay although it lacks remote access meaning it can only be accessed physically hence causing this is a drawback of the system.

Han et al. [8] proposed a model to identify the security model for a video surveillance system and ensuring safety, reliability and privacy protection. As video surveillance is widely developed on open IP-based network, security functions such as privacy masking, user/device authentication, and access control amongst others were considered. The security model for the video surveillance system consists of four security modules namely RPM, CPM, MPM and SPM. The RPM (Resource Protection Module) protects system data from internal and external threats. This module protects the system resources. The CPM (Channel Protection Module) secures communication channels for secure video data transmission. It provides privacy masking and security tunnelling. The MPM (Misuse Prevention Module) prevents the misuse of any gathered video information. It provides access control and forgery prevention. Finally, The SPM (Service Protection Module) protects services such as authentication, prevention of intrusion and forgery intrusion. An IP camera and a video storage module were used in the implementation of the system.

Rajan et al. [20] presented a paper which introduced video surveillance system development and security. The system’s main objective is to enhance the video quality and safely store it on distinct servers. The research was split into two phases; the first phase entails the enhancement of the low light video to achieve a noise-free video with high-quality and the second phase entails the distributing video to trusted servers through secret sharing and safe storage. The secret shares do not disclose any information and by selecting any two shares, the original video can be obtained at any moment. The improved videos are clearer and better for analysis and observation although they are larger in size hence causing numerous space requirements. Sruthy et al. [21] proposed the design and implantation of real-time low cost, reliable, energy efficient, storage effective surveillance system using a Raspberry Pi, IOT module, GSM modem and Node MCU. The system was constructed as an integrated system which consists of two parts; Wi-Fi with active sensor nodes and surveillance management system. It is an active surveillance system which when intruders and fire is detected, the user gets a notification of the situation. Live video streaming is an additional feature as web servers were created which enables the user to view the sensors status and the live video. The system captures and sends the intruder’s picture via email to the user. The drawback of this system was the bulkiness of the circuit and it is not portable.

Murdan et al. [22] presented an autonomous solar-powered wireless surveillance system for several purposes. The system is based on a relatively cheap microcontroller coupled with online security camera. It consists of more than a block; the power block, camera system and the communication block. The main brain of the project is an Arduino Yun microcontroller powered using a solar PV panel. Other features of the system include motion triggered picture emails amongst others. A shortcoming of this system is its inability to optimize data and store only what’s necessary. This makes irrelevant data keep getting stored and wastage of storage space. Uysal et al. [23] presented an embedded homeland security surveillance system. The system utilizes a modular design to create regional clusters; a cluster head gathers related ambient information from surveillance modules which are connected to it. This is an
embedded wireless solar-powered system based on anatomical research of all the system-related parts and variables. With inclined surfaces to optimize the position of the solar panel and antenna beam alignment, microwave communication is achieved at the desired ISM band. Although efficient, the complexity and bulkiness of the circuit is a huge drawback of this system.

Zhang et al. [24] reported on the design and implementation of Vigil, a real-time distributed wireless surveillance system that utilizes edge computing to manage surveillance and real-time monitoring in schools, retail enterprises and across smart cities. The paper determines the feasibility of setting up a wireless monitoring system for uploading instant camera feeds to the cloud over UHF whitespace and unlicensed Wi-fi spectrum bands. The real-time wireless video surveillance for many cameras and expand its coverage network in a crowded wireless spectrum. The surveillance system’s work flow is initialized by the user inputting a command into the system then it locally processes the camera video feeds using different parameters such as object and motion detection resulting in a sequence of analytic data comparing the collection of important frames in the raw video camera stream. The shortcoming of this system is it produced poor performance in cases where the scene changes are frequent.

3.0 Design Considerations
3.1 Power Backup System
The electric power mains supply is converted and stepped down to about 12v for this project with the help of an adapter. Mains supply can either be from PHCN or generator (as the case may be). The power backup system comprises of two power bank systems built using lithium batteries. Both systems alternately supply the surveillance system with power. A power backup source of about 20,000mAh per bank would be constructed to serve as the failsafe in a situation of a power outage. Each bank consists of lithium 18650 cells connected in parallel. The 18650 cell is a lithium-ion rechargeable battery that has a voltage of 3.7v and has between 1800mAh and 3500mAh. The average 18650 battery charge time is about 4 hours and can be recharged about a life span of 1000 to 2000 times. 18650 lithium batteries are used due to their efficiency and reliability. The system is configured in a way such that while bank1 charges, bank2 supplies power to the surveillance system and vice versa.

From the energy equation based on Ohm’s Law,
\[ E = P \times t = V \times I \times t \]
It can be deduced that each power bank has about 74,000mWh since the operating voltage is 3.7v. A microcontroller connected to one of the terminals controls the energy supply system and supplies each bank according to a programmed algorithm.

3.2 Auto-switching System
The auto-switching and monitoring system is to maximize the battery life and energy storage of the battery. This module consists of two selectors/switches. Switch 1 handles the selection of which bank charges while Switch 2 handles the selection of the bank supplying the surveillance system with power. The primary benefit of the dual surveillance system is that it enables both the capacity of the battery charging and the one being discharged to be continuously measured. This switching is only made possible with the help of an Arduino microcontroller.
3.3 Security Camera Module
This module consists mainly of the IP camera and the storage unit. The IP camera connected to a Wi-Fi internet is configured to store video feeds to a cloud account. The framework gets its input from mains power and it is then stepped down by the adapter to be used in powering the batteries. The system has two battery banks working alternately. The power supply plug serves as the charger for both bank1 and bank2. In charging the batteries, a monitor is designed in place to handle overcharging/undercharging. In a situation where bank1 is full, bank 2 gets charged while bank1 starts discharging i.e. supplying power and vice versa. For this phenomenon to happen, a switch is installed which changes the input power between the two banks. The selection between the supplying bank and the charging bank is made possible by an Arduino which sends commands to the switch. The Arduino measures the power in both banks and acts in accordance with the code configured in it. The switching system serves as the decision maker in monitoring and maintaining the batteries. Switch 2 serves as the decision maker between the power banks and the surveillance unit. This process is responsible for the selection of the battery bank best placed to supply the surveillance cameras. The IP camera is powered up and can be accessed and controlled remotely from anywhere in the world through an application or a web-based platform. Storage backup to the cloud is configured and Wi-Fi connectivity is provided.

4.0 Methods and Details of Construction

4.1 Materials required: The materials for this framework are:
Arduino ATmega328 Microcontroller: ATmega-328 is an Advanced Virtual RISC (AVR) microcontroller. It supports the data up to eight (8) bits. ATmega-328 has 32KB internal inbuilt memory. The microcontroller is programmable and contains the codes to run the constructed project.
18650 Lithium Batteries: The 18650 is a kind of lithium-ion rechargeable battery. They offer a lithium-ion cell’s efficiency, 1800mAh to about 3500mAh capability and a 3.7-volt output.
5V 2-Channel Relay Module: This relay module is a hardware device used for remote device switching. It can be used to control various appliances and equipment with large current. It has a standard interface that can be controlled directly by a microcontroller.
‘YCC365 Plus’ CloudCam: This is a smart indoor IP camera for the monitoring of lives and property with viewing and hearing features of live & recorded footage.
3S 3.7V Lithium battery Protection Board with Balanced Circuit for 3 string: This 3S 18650 Lithium Battery Protection Board is a high current board with Balanced Circuit for overload protection, over discharge, over current and short circuit feature.
DC 4.5-40V DC-DC Step-down Buck Converter Voltmeter Module: This step-down converter is a DC-to-DC power converter that steps down input voltage (energy supply) to the desired output (load) voltage (while increasing current).
Mi-Fi router with an internet connection: This is a wireless router that acts as a mobile Wi-Fi hotspot. It is responsible for the connectivity of the IP camera to the internet.

5.0 Implementation
This research implemented a prototype which was divided into different phases. These include the power system and the surveillance system. The power system circuitry comprises of two relay modules controlling the charging of the batteries and also the supply of power to the load. The Arduino measures the battery level of each battery using a connection to a
voltage divider circuit. The power circuitry comprises of buck converters which steps down the input voltage to about 6V which is appropriate for the load. The output voltage from either of the batteries or mains is higher than the required voltage for the load. The Surveillance system circuitry comprises of the IP camera itself. The camera powered by the battery or mains records footage and takes pictures of incidents. The camera has two types of storage; the physical storage location and the cloud. Video streaming of live footage was also accessible with this camera after major configurations to the system.

5.1 Results achieved
Different voltage levels were captured with respect to their battery capacity, drain rate data were also recorded from the power system per time, this gives a clear indication of how long the multipower system design can be sustained in case of power outage. Excerpt of this data is shown in Table 1.0 Figure 2.0 shows the graphs of system charge rate per time.

| S/N | Time (hrs) | Voltage level (v) | Battery level (%) |
|-----|------------|-------------------|-------------------|
| 1   | 02:00am    | 9.20              | 0%                |
| 2   | 03:00am    | 9.74              | 15.9%             |
| 3   | 04:00am    | 10.28             | 31.8%             |
| 4   | 05:00am    | 10.69             | 43.8%             |
| 5   | 06:00am    | 11.09             | 55.6%             |
| 6   | 07:00am    | 11.37             | 63.8%             |
| 7   | 09:00am    | 11.83             | 77.4%             |
| 8   | 10:00am    | 11.88             | 78.8%             |
| 9   | 11:00am    | 11.92             | 80%               |
| 10  | 12:30pm    | 11.97             | 81.5%             |
| 11  | 1:00pm     | 11.99             | 82.1%             |
| 12  | 2:00pm     | 12.03             | 83.2%             |
| 13  | 5:00pm     | 12.40             | 94.1%             |
| 14  | 7:00pm     | 12.60             | 100%              |
5.2 Results discussion

This work achieved its objectives stated earlier an extract of testing and performance evaluation shown in Table 2.0 and it can be deduced that power consumption and lasting duration of the system based on experimental data gotten, has a total capacity of about 50,000mAh. The battery banks take about 15 hours to charge fully from 0%. Each batteries last for about 100-156 hours on full load without interruption. The whole system can last for over 6 days 6 hours from full battery capacity without supply of electricity.

Table 2.0: Energy consumption of the system per time

| Apparatus    | Power/W | Energy (Wh) | Charge(Ah) |
|--------------|---------|-------------|------------|
|              |         | Min (6H)    | Max(24H)   | Min(6H)   | Max(24H)   |
| Arduino Uno  | 0.23    | 1.38        | 5.52       | 0.32      | 1.27       |
| Camera       | 1.5     | 9.0         | 36.0       | 1.8       | 7.2        |
| TOTAL        | 1.73    | 10.38       | 41.52      | 2.12      | 8.47       |

Arduino Uno microcontroller power consumption is calculated using an operating current and voltage of 45mA and 5V respectively, therefore a power of 0.23W was derived with an assumption that the system operates for a minimum of 6 hours and a maximum of 24 hours based on daily energy consumption. From the specifications of the camera, the operating voltage was taken as 5V and an operating current of 300mA. The total capacity of the whole system was calculated to be 50,000mAh. The switching system was developed to control the charging and supply of power to the circuit. This consists of a relay programmed by an Arduino to stop charging the batteries when they are above 90% and also stop supplying the system when it is below 5%. This feature was developed to obtain optimum battery life while also considering maximum performance evaluation of the system. The relay configured by the Arduino closes the contact necessary for the programmed situation.
6.0 Conclusion
A real-time cloud data bank and power enabled backup surveillance system has been designed. Series of literatures were reviewed from various surveillance systems, network technologies, microcontrollers and camera. Various sub-systems within the developed framework include calculation and provisions of different mechanisms and parts until the final prototype structure was coupled together. Tests and evaluation were carried out on the subsystems and also on the full system when integrated. This framework meets expectation as initially stated. The developed system was highly accessible, sovereign with remote access. It can serve various security purpose such as residential arrears (individual and general), business arenas market and academic areas. The implementation was not too high in terms hardware and software cost.

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