International Journal of Academy of Engineering Research and Theory (IJAERT), ISSN: 2545-5931
Adegbesan, A. S , Aderanti, A. T & Oni, O. O.
Open Access Vol. 2, Issue 1, February. 2022, Pp 7-11
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Design of Wireless Sensor Network-Based Smart Home Surveillance System

[1*] Adegbesan, A. S [1] Aderanti, A. T and [2] Oni, O. O.
[1] Department of Computer Engineering, Gateway (ICT) Polytechnic, Saapade, Ogun State, Nigeria.
[2] Department of Computer Science, Gateway (ICT) Polytechnic, Saapade, Ogun State, Nigeria.

Corresponding Author's Email: drwalex@yahoo.com

Abstract:
In this work, the design of a wireless sensor network-based smart home surveillance system is presented. Video surveillance systems have become widely acceptable but there are still limitations. The use of wireless sensor network (WSN) especially with Internet Protocol-based closed circuit television (CCTV) can enhance its performance. The work presented in this paper uses electronic gadgets such as Personal Computer (PC) system with monitor, Wireless CCTV, Digital Video Recorder (DVR), Video Motion detector (VMD) and an IP based network for efficient delivery of surveillance services in the smart home architecture. A simple experiment was designed to test the effectiveness of the proposed and the evaluated results showed that the system has high throughput and reliability values for different locations.

Keywords: *Video Surveillance System, Wireless Sensor Networks (WSNs), Monitor or Display Unit, CCTV, DVR, NVR.*

Introduction

Over the centuries there have been many techniques developed for the protection of lives and property from invaders, aggressors, or destroyers. Recently, the use of video surveillance systems has become widely acceptable (Zhang et al., 2015). It has enjoyed a high degree of patronage in smart home technology, where various services that provide information about the home status such as lights on/off, temperature, home/away mode are monitored to ensure that availability, confidentiality, and integrity of home activity are maintained (Zhang et al., 2016). The monitoring, detection, and tracking capabilities of video surveillance systems can be enhanced (Jadaa et al., 2019) using a wireless sensor network (WSN). A WSN has applications in numerous domains including industrial monitoring and control; home automation and smart cities, security and military sensing, traffic management, asset tracking, supply chain management, intelligent agriculture, environmental sensing, and health monitoring (Jadaa et al., 2019; Kandris et al., 2020). The growing applications of WSN in many domains are without pitfalls. For instance, users' security and privacy concerns have been most pressing issues in smart home (Nagarkar & Prasad, 2019). So, according to Kandris et al. (2020) there are still issues for indoor use, such as configurations setting for indoor, outdoor urban applications, and also the interoperation among various devices (Taj et al., 2019). All these challenges must be taken cognisance of in designing effective and highly performance system. An ideal WSN driven surveillance system with a camera sensor network for the purpose of surveillance could be helped in surveillance of areas that require security round the clock, observe and control traffic (human), prevents theft/ shoplifting, robbery and other crimes, raise alarms on approaching dangers or avoidable circumstances among others. Thus, presented in this work is an intelligent wireless sensor network enabled smart home surveillance using closed circuit television (CCTV) cameras that are arranged orderly so that intruders are quickly detected with notification. The aim of this study is to provide security for the premises of a smart home environment through the use of internet protocol integrated CCTV cameras on WSNs.

Background Study

Smart Home:

Zhang et al. (2016) opined that smart home system is supposed to improve the quality of life by offering various automated, interactive and comfortable services, such as sensing and communicating the family member's health information with their doctors, or remotely controlling the appliances via cellular phones, emails etc. A smart home system consists of application usually built on top of Internet of Things (IoT) infrastructure with main functions such as alert, monitoring, control and intelligence (Malche, 2017). Smart home is also enhanced with critical services like light switches using a smart phone or by voice command, thermostats that will adjust the indoor temperatures and generate reports about energy usage, or smart irrigation systems that will start at a specific time of a day, on a custom monthly schedule, and thus will control water wastage (Stolojescu-crisan et al., 2021). Wi-Fi enabled (Chowdhury et al., 2019; Murdan & Caremben, 2018), IP based (Shouran et al., 2019) and WSNs technologies (Zhang et al., 2016)are few of the internet connectivity available in smart homes. Meanwhile, WSNs have been used in almost all areas of smart home.

Wireless Sensor Networks

Wireless sensor networks (WSNs) have several applications in many fields and particularly in surveillance systems (Kandris et al.,

2020). A real application system based on wireless sensor network (WSN) for fence surveillance which is implemented on our development platform for WSN, called ANTS (An evolvable Network of Tiny Sensors) was presented in Kim et al. (2011). This system was limited in that it used analog cameras which can be accessed physically. B.Patil et al. (2014) proposed a monitoring system for prisoner with geographical positioning system (GPS) using WSN. Again, the use of CCTV was not adopted in this work. For Nasser et al. (2021), an efficient time-sensitive data scheduling approach for wireless sensor networks in smart cities was proposed. The proposed work performs data processing and scheduling in two layers: infrastructure (i.e., sensors/device networks) and platform layer (i.e., cloud), hence, the authors wished to enhance the work using CCTV and other sensors for real-time data acquisition.

WSNs and CCTV technologies are essential for the smart home automation. These components are important IoT devices for the development of smart homes services that serve users effectively by communicating with various digital devices in the home (Alaa et al., 2017). Thus, automating smart home include but not limited to the use of adequate electronic gadgets such as Personal Computer (PC) system with monitor, Wireless CCTV, Digital Video Recorder (DVR), Video Motion detector (VMD) and an IP based network for efficient delivery of smart home services.

Surveillance Systems

Video surveillance systems have always been part of smart home security. Previously proposed are different kind and type of video surveillance system with which diverse researchers have performed many experiments. According to Murdan and Caremben (2018), video surveillance has undergone various technological developments with the latest being a total shift from analog CCTV surveillance to fully digital, network-based video surveillance systems, which are meant to be ON, 24-hours a day. In Jadaa et al. (2019), detection and tracking survey for smart home using wireless sensor network was presented. The work proposed a reliable smart system for detecting and tracking of moving objects. Stolojescu-crisan et al. (2021) presented an IoT-based smart home automation system. Their paper shows a system for interconnecting sensors, actuators, and other data sources with the purpose of multiple home automations. It should be noted that in surveillance applications, the sensor nodes have to be extremely small in order to be undercover (Kandris et al. 2020), and this is why IP-based CCTV cameras are essentially used (Shouran et al., 2019). A CCTV video surveillance system is an important part of smart home security for monitoring and detection of an intruder (Nagarkar and Prasad, 2019). A number of it has been used in various applications especially in smart home security.

Methodology

Typical Video Surveillance System for Smart Home Security

A typical video surveillance system is shown in Figure 1. It consists of video capture units, network transmission, and central control module. The video capture unit, compresses raw data and encodes it into a popular standard format (MPEG, Motion JPEG, H261, H263 or H264.). In the network transmission unit, the encoded video stream is delivered over an IP based network. This network could be a Local Area Network (LAN) or even the Internet. Meanwhile, the central control module displays the recorded videos through a visual display unit (VDU) or monitor. Traditional communication networks cannot meet up with the present day highly connected with IoT enabled communication systems (Zhang et al., 2016). To build a vibrant security system for smart home, video surveillance deployment on WSNs with IP-based CCTV cameras which is much easier and more cost-efficient than traditional hardwired closed-circuit television (CCTV) systems can be leveraged upon.

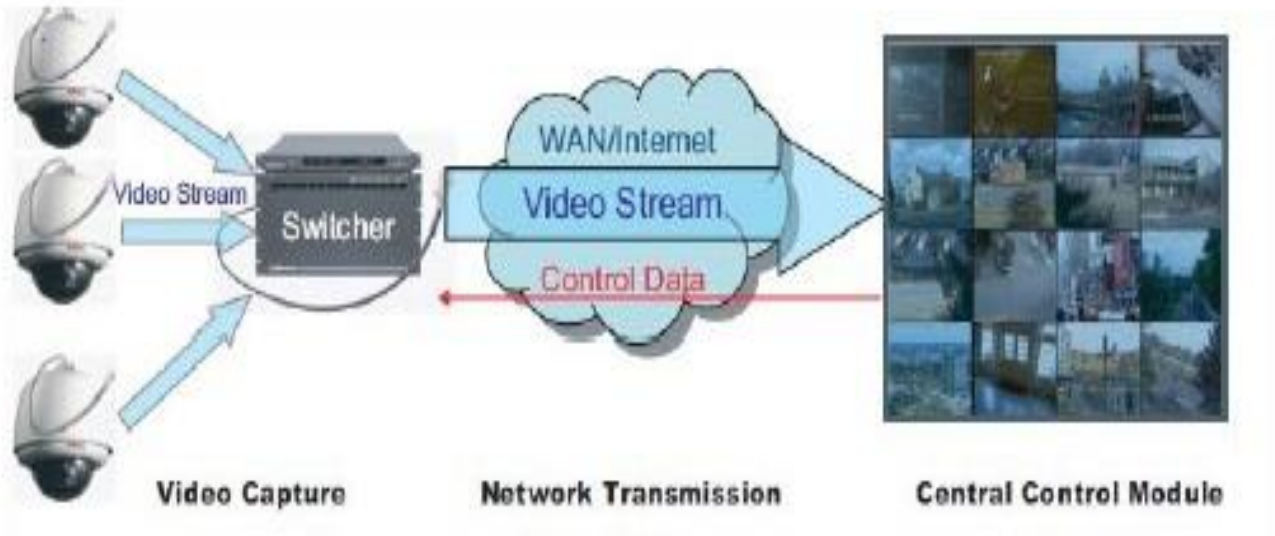

Figure 1: A typical video surveillance camera control system

Wireless Sensor Network-Based Smart Home Surveillance System

In the wireless sensor network-based smart home surveillance system proposed in this work, we employed the services of wireless IP-based CCTV cameras, a complete PC system, a DVR, VMD built on a LAN infrastructure for the transmission of data. The architecture of the proposed system is presented in Figure 1. The roles and applications of these major components are explained as follows:

(i) IP-based closed-circuit television (CCTV) cameras uses four arranged in parallel at different locations of the smart domain. The purpose of CCTV in this security plan is to provide remote eyes for a security operator in order to create live-action displays from a distance. This video surveillance system has a recording mean of a VCR and a DVR, with storage media such as 16GB flash drive for permanent records or data. They are expected to give the following solutions to the proposed system: 1. Recording of visual effects and observations of a scene or activity in the required remote location; 2. Covert observation of a scene by hiding a small camera and lens in a target location easily; 3. As an intrusion-detection of remote location of events in the area when they occur; 4. Simultaneous observation of events at different locations from different perspectives; 5. Tracing of a person, a vehicle or event from beginning to the end in case of intrusion, disaster or even robbery in a remote location is possible.

(ii) DVR (Digital Video Recorder) is a digital video recorder that records motion video in a digital format to a hard disk. A more superior form of CCTV, utilizing digital video recorders (DVRs), provides recording for possibly many years, with a performance options and variety of quality and extra features such as email alerts and motion-detection (B.Patil et al., 2014).DVRs are superior to VCRs in that they offer: - better images, superior search capability, simultaneous recording, live viewing and playback, remote access, easier integration with security systems.

(iii) NVRs (Network Video Recorder): This is an Internet Protocol (IP) based device embedded with software program that can be used on a network. They are used to record video in a digital format to a disk drive, USB flash drive, SD memory card or other type of storage device. An NVR contains no dedicated video capture hardware but are typically managed remotely via a LAN or over the internet.

(iv) Video Motion detector (VMD) is a component that produces an alarm signal based on a change in the video scene. The VMD can be built into the camera or be a separate component inserted between the camera and the monitor software in a computer. This work uses a digital VMD that stores the video frames, compare subsequent frames to the stored frames, then determine whether the scene has changed or not.

(v) Wireless Sensor Network (WSN) uses wireless links deployed with a large number of wireless sensors to communicate and collect data from the surrounding environment. Wireless sensor networks utilize the sensor nodes to sense the changes in surrounding environment and relay the information from various remote locations (Rashid and Rehmani, 2016). They can achieve greater flexibility and scalability in surveillance systems.

These components among others are arranged and set up as shown in Figure. 2. The DVR is connected to the router (192.168.0.1) using LAN cables. We use static IP address with the PC computer assigned (192.168.0.3), a DVR is setup via a user interface that is accessible via the LAN connection. The ADSL modem provides internet access to the system. Two cameras are used as shown and they are connected via a LAN port available at the DVR.

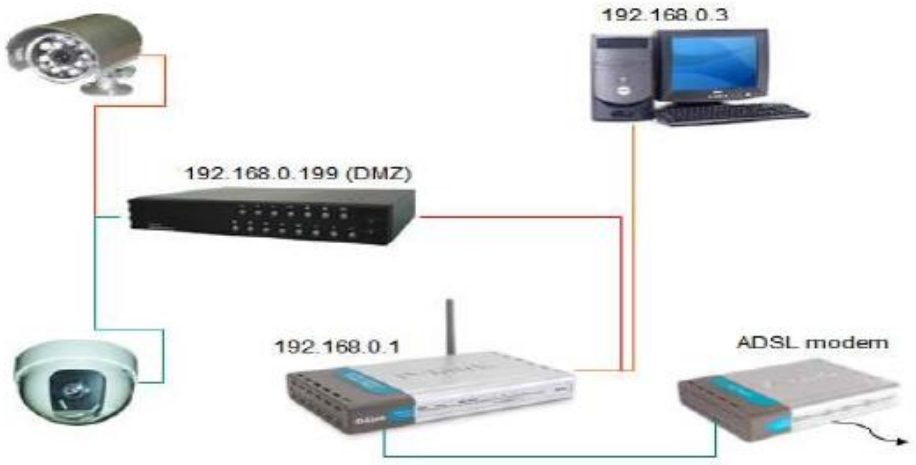

Figure 2: The proposed Video Surveillance System using IP-based CCTV cameras

After the setup was completed, the system was tested to ensure that it conform with all the functional requirements and specifications. For the evaluation of the system, a simple experiment was conducted while the efficiency and the percentage throughput of the system based on the following metrics were calculated:

$$(I) = (R) * (T) \quad (1)$$

Where: R = throughput rate, T is time taken and I is the number of units in the production

$$\text{Throughput Rate} = \text{Number of units/Time Taken} \quad (2)$$

Results and Discussion

Experiment conducted in this work follows a methodology reported in (Zhang et al., 2015) with little modifications. The components are setup and the video traces collected from the two cameras placed parallel with each. Time was taken when an intruder tries to gain entrance into the smart home by varying the distance of 50m, 100m and 150m for the recording monitor at different locations and the results were noted. We obtained 79%, 68% and 54% for 50m, 100m and 150m distance respectively. The throughput shows the percentage of units of output that are classified as appropriate. High throughput of the system indicates that the proposed surveillance model can perform better even with long distance environment. However, it should be noted that throughput degrades with increase in the number of nodes, which means that the more cameras are added the lower its performance.

Conclusion

This work presents a wireless sensor network-based smart home surveillance system using the closed-circuit television. The work uses adequate electronic gadgets such as Personal Computer (PC) system with monitor, Wireless CCTV, Digital Video Recorder (DVR), Video Motion detector (VMD) and an IP based network for efficient delivery of surveillance services in the smart home architecture. A simple experiment was designed to test the effectiveness of the proposed and the evaluated results showed that the system has high throughput and reliability values for different locations.

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