Design and Simulation of the Internet of Things for Accra Smart City

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Abstract
The Internet of Things (IoT) concept of connecting objects with IP address to a network has many significant applications such as smart health, smart cities, and smart energy. This study focuses on the use of Internet of Things for smart cities and its advantages. In this paper our main goal is to model and simulate an IoT system for Accra smart city that uses smart webcams with IP address that are addressable to allow these smart webcam transmit valuable information to users. The designed smart city will address a challenge by giving live feeds on traffic situations and flooding on major routes to people. We used cisco packet tracer to model and simulate the IoT network where smart webcams can remotely transmit data packets. The results of the simulation indicates that when the smart webcam are connected in a wireless medium, they can send and receive data packets via a 6LowPAN gateway which can be access by users in the Internet.
Keywords:Internet of Things, Smart City, Smart Webcam

1. Introduction

The Internet of Things (IoT) has been describe as a worldwide network, which interconnects seemly unique objects that are addressable, based on standard protocols for communication. [1] The Internet of Things is aimed at connecting smart objects to a network which can be access from anywhere and at anytime in the Internet. The concept of Internet of Things (IoT) will allow unique objects to be connected to a network that will remotely share data generated by these objects and interact with each other. The IoT seeks to present many benefits that will improve upon all aspects of our everyday living. This perhaps will allow people live a smart life in an IoT system. The key objective of IoT is to allow for the creation of a smart environment and the presents of things that are self-aware which formed the vision of IERC. [2] The smart objects present in the IoT space are self-aware and are able to remotely send data packets generated to each other via a communication network. The conceptualization of IoT is to make the Internet more pervasive for smart things, by allowing for heterogeneous devices such as sensors/actuators, RFIDs, ZigBee, 6LowPAN etc to connect and interact with each other. There are a number of applications of IoT that have significant benefits for people. Some applications of IoT include smart cities, smart health to improve the health of people, smart transport system that will help in the movement of people from one location to another and smart energy to ensure energy efficiency. A detail description of some useful application of IoT is below;

Smart Energy: Energy plays a key role in achieving the desired economic growth of a country. The entire fabric of developmental goals is webbed around a successful energy strategy. Energy is vital for the creation of wealth and improvement of social welfare. Smart Energy Monitors (SEM) is a technology introduced to help people to conserve energy and to use electricity efficiently when needed. Smart energy monitor helps individuals to identify their home's energy-hungry habits, where they can have an automated IoT monitor device that allows users to see how much energy they are consuming whenever an appliance is switch on and cost of power consumption.

Smart Health: An important application of IoT is smart health where special monitors are used to observe patients in a hospital and take care of them. These devices are used to monitor and evaluate the health condition of patients. Sportsmen can also use sensor devices to monitor their blood pressure, heartbeat and temperature when they are engaged in sporting activities. A patient monitor system can also be used to take care of patients at homes with chronic health conditions or special needs.

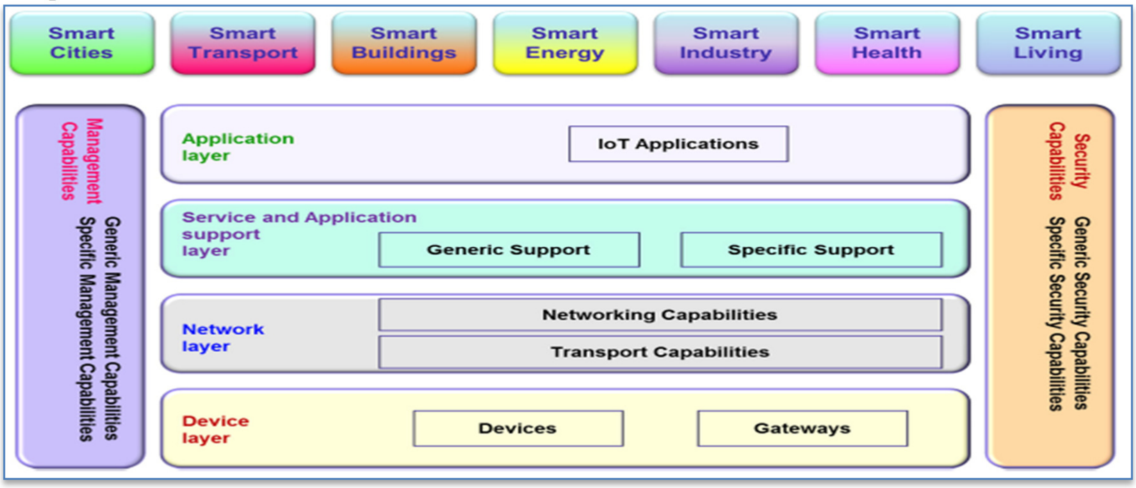
Smart Manufacturing: The application of IoT for manufacturing has some significance where an automated system can be use to restock raw materials in a manufacturing warehouse. A special control system is used to alert when raw materials are running out at a warehouse and trigger the process of replacing the raw materials to continue the production cycle. This is important to ensure raw materials are always available for production at a warehouse.

Smart living: Another important application of IoT is to help people to life a smart live within their vicinity. People at a shopping mall can get tips of their favorite groceries at the mall, where a sensor monitors can alert shoppers when a particular grocery is due to expire and also warn them of allergy components in some food. The use of sensors in some products will allow users to scan the barcode components to see when the products are due for expiring, some components in product that may pose as an allergy to users and information about the manufacturers of the product.

These are the few applications of IoT that have significant advantages. In this paper our main focus is on the application of IoT for developing modern smart cities. With the Internet of things, we are gradually moving towards a paradigm where smart objects in an IoT environment are assign the needed protocols to allow these objects to communicate with each other and its users. These smart objects in the IoT space once they are assigned IPs are uniquely addressable and can remotely send data to a user. The IoT continuous to grow according to the OECD and it has seen that the growth engine of IoT will enhance the modernization of communication and information, which will bring the added new value for other sectors. [3] However there are some challenges to the growth and use of IoT. One of the main challenges of IoT has to do with the interoperability of the heterogeneous platforms and the issue about managing the data generated by the smart objects. It is quite difficult to a have a database system that manages the data generated by heterogeneous platforms, which is unlike other traditional database that can easily be managed. There is still a lot of work to be done to address some of the challenges in the IoT with some studies done in that area. A successful IoT platform strategy will be determined by the connection of several objects that allows for the data flow and its activeness for users. [4]

1.1 The Architecture of IoT

IoT system architecture consists of the interconnection of physical objects and a network connectivity platform that allows the exchange of data generated by the objects where an application layer support the access of data from the objects. The main layers for the IoT architecture are divided into four layers. These are the application layer, service support layer, the network layer and the device layer. At the bottom of the IoT architecture consists of the device layer, which is made up of the physical objects such as sensors/actuators, RFIDs, 6LowPAN and ZigBee. The second layer is the network layer, which provides the network platform to connect the smart objects or "things" to the application layer. The third layer is the service support layer that provides the generic and specific service support and the fourth layer provides the platform for the IoT application service to run. A detail description of each phase of the IoT architecture is discussed below;



IoT layered architecture. [Source ITU-T]

1.2 Application and Transport layers

In the application and transport layers, a message is send via HTTP over a TCP in the Internet. The HTTP will normally depend on TCP to send and receive data packets in the Internet. However in the case of IoT due to the verbosity and the complex nature of the HTTP, it renders it not suitable to be deployed on constrain devices in an IoT network. [5] That is to say the complexity of HTTP header presents a challenge for messages to be sent across from one constrain device to another in an IoT network. This becomes a challenge since the HTTP is unable to efficiently relay messages by the IoT devices, which are self-aware of their environment. The IoT devices, which are constrain will only allow for a small amount of data to flow in a network. HTTP normally relies on TCP to transmit messages across in the Internet. It important to note that data packets may get truncated in the process of using TCP, which is a stateless protocol to transmit messages across in the Internet. The transmission control protocol can correct errors in the process of data packets getting truncated from source to destination. Due to the constrain of the smart objects in the IoT which will result in a small flow of data from device to device, there is the need to use a protocol which will overcome this challenge. The Constrained Application Protocol (CoAP) has been used in IoT networks to address this issue with constrain nodes. Therefore the CoAP [6] can be used to overcome this challenge of constrain devices by introducing binary format that will be carried over a UDP. The CoAP which is a web transfer protocol will allow constrain devices to be able to remotely send messages across in the Internet and it can also work with HTTP.

1.3 The Network layer

The network layer in the IoT architecture serves as the platform that it is responsible for connecting the smart objects in the IoT environment to transmit the data generated by the devices that are accessible at the application layer. In the IoT there are multitude of devices that are suppose to be uniquely addressable via their IPs. Basically the key protocols used in the Internet are IPv4 and IPv6. IPv4 has run out of space and thus the deployment of IPv6 which has a huge address space to cater for the billions of IoT devices. In the Internet TCP/IP is responsible for routing data packets from a source to its destination. The Internet works by using the Border Gateway Protocol (BGP), which is inter-domain protocol that makes use of path vector routing to send traffic across. [7] In the case of IoT networks the nodes are uniquely assign IPv6 address, which are compressed based on standardization of 6LowPAN where each nodes can be accessed by a means of IPv6/6LowPAN in the Internet. [5] Once the nodes are assigned the IPv6 address they are can be configured to connect to the Internet and also allow the nodes to interact with each other.

1.4 The Device layer

The device layer of the IoT architecture consists of many objects or devices in the IoT environment. The smart objects such sensors/actuators, ZigBee, 6LowPAN are responsible for generating valuable data to be transmitted. The sensor/actuator at the device layer collects the data in the IoT environment and remotely transmits to their neighbors. The smart devices in the IoT that are usually constrained have a challenge for the integration of data. Data integration in different platform are tough and can be supported by using components which are modular interoperable in the IoT. [8] There are some other studies carried out on the challenges of IoT devices such as the security of the devices and the low power of sensor nodes.

2. Problem Formulation

Accra the capital of Ghana is a fast developing city in West Africa. As the population of the capital continuous to increase and there is a need for traffic congestion management in the city. Also the city experience perennial flooding every year due to low land area the capital is situated and the lack of adequate drainage system. The study seeks to design and simulate an IoT network that can be deployed for Accra smart city to address the existing problem by giving people access to timely information. Information on traffic congestion and floods on certain routes can be access in real time by users.

2.1 Motivation

In this paper our main objective is to model and simulates an IoT network for Accra smart city. The aim is to design an IoT network that deploys smart webcams with unique IPs address to "dweets" that is to send constant valuable information that can be access on the Internet by people. The smart webcams will capture the images around its surroundings and "dweets" the information to users. The valuable information generated by the smart webcams will allow people to be able to view images in real time on traffic congestions along certain major routes in Accra during peak hours and also allow people to view flooding situations when its raining. The paper is organized into four main sections; Section one looks at other related works of IoT for smart city, section two describes the methodology for the study. Section three discusses the simulation results of the modeled IoT network and section four is the conclusion.

3. Related Works

The Concept of IoT For Smart Cities

In recent times smart cities are becoming very fashionable where governments are putting in policies to build smart cities with a main focus on ICT infrastructure. The idea behind smart city is for the application of technology that can be used to solve problems in an urban environment. The use of ICT to connect people and business is important for the economic growth of a city using innovative strategies. One application of IoT this paper is focus on is smart city and its importance. A smart city is therefore an intelligent city that employs hi-tech solutions to address challenges in a city such as transportation system, planning of urban infrastructure, access to health by people and a proper house addressing system. Therefore the major driving force for a smart city is the use of information communication and technology to solve problems within a city. The application of IoT for smart cities will aid urban planners to design and properly manage key challenges confronting towns. Another goal of IoT for smart cities is to afford people the ability to live in comfort in their environment. The market value of smart cities continues to grow with governments investing heavily to build modern intelligent cities. A study done by Pike [9] indicates that the market of smart city is projected to be hundred billion dollars by the year 2020, where an annual spending is expected to reach almost 16 billion. Developing countries therefore need to take advantage of the concept of IoT for smart city to help in planning their urban environment. Some significant applications of IoT for smart city this study is focused on are; determining the structure health of buildings, waste management and managing traffic congestions [5], which is very essential for our discussion.

Smart city services

Monitoring the Structure of Historic Buildings: One good example of the application of IoT for smart cities is to determine the structural health of buildings of historic importance. In every big city, there are important and historical buildings, which have to be preserved for future generation. There is a need to have constant monitoring of the current conditions of these historic buildings in urban cities and to properly maintain these buildings. The use of embedded sensors on buildings can be used to monitor building conditions such as humidity and temperature. A distributed database in an urban IoT will provide the measurement of the structural integrity of buildings where suitable sensors on buildings can be used to monitor the stress of buildings, monitor pollutions levels and other environmental conditions such as humidity and temperature. [10] The health of a building can be monitored to ensure its proper maintenance in a smart city. Special sensors in buildings can give early warning signals of earthquake or fire in a building to occupants. This is an important application of using IoT to manage and maintain buildings structure in a smart city.

***Management of Waste**:* Another significant application of IoT for smart cities is addressing the issue of waste management in modern cities. Due to the huge tones of waste that are generated each day there is the need for an efficient management of waste. This may pose as a problem for most developing cities where urban authorities are looking for automated ways to improve upon sanitation and to recycle the waste generated. Intelligent contains can be used to address the challenge of waste management. An example is by using intelligent waste bins that can determine the quantity of waste in the bins and then allows for the optimization of routes for the collecting trucks in order to decrease the cost involve in waste collection and boost recycling quality. [11] The intelligent waste bins when full will alert the truck collectors to move to a certain location to pick up the waste from the container. This is very significant, as it will allow for the efficient management of waste in an urban environment by emptying waste bins regularly and timely.

***Managing Traffic congestions**:* Traffic congestion is a huge problem for most developing cities. The use of IoT for managing traffic congestion is of high significance for smart cities. As the population in big cities continuously increases, traffic management becomes a problem. City planners are constantly looking for ways to manage and decongest urban space. There is therefore the need to develop models that can help manage urban space and reduce congestions on roads to ease the movement of people. It is possible in smart cities to employ services that will enable the monitoring and management of traffic congestions in cities using traffic monitors. GPS build in modern vehicles that have sensing capabilities can help in monitoring traffic. [12] This feature will help users in a smart city to monitor the traffic congestion situations on some routes and redirect which alternative routes to take to their destination.

Intelligent transport network: Another significant application of IoT for smart city is the use of Intelligent Transport Network (ITN). Every smart city needs to adopt the innovation of intelligent transport network to improve the movement of people within a city. An intelligent transport network gives service for different mode of transportation in a smart city by allowing users to be properly informed about the transportation networks and plan their journey adequately. This will help in the movement of people and goods from one location to another in a city using innovative transport system. People can use their smartphone with the help of an app to track the location of bus and its routes. People can also be informed on the arrival and departure of bus to their destination at a bus station. This is quite significant for users to have real time information on bus routes, the bus to take to a particular destination and the various stop points on a route. Intelligent buses with sensors inbuilt can also warn drivers of unfavorable weather conditions on a particular route and optimize which alternative routes should be taken to their destination. The intelligent bus can thus recalculate their routes after diversion so as to avoid severe weather conditions such as floods or heavy snow on a particular route.

3.1 Design of Ubiquitous Network Architecture

In this part of the paper, we consider at appropriate network architecture for the proposed Accra smart city. The network architecture we used in our design is a ubiquitous network approach architecture shown in figure A. In a ubiquitous architecture the objects connect to each other to form a network. By using a gateway, a user can access valuable information generated by smart objects in ubiquitous network architecture by directly retrieving data from the smart objects or from the IoT server. This design approach allows for the objects to form its own network that is connecting to the Internet. The users in a smart city can then either directly access the data from the smart objects or from the intermediate IoT server. In the designed network architecture the IoT server is a sink that receives data from the smart objects. Our design approach goal is to allow the smart webcams to connect directly to the 6LowPAN gateway and remotely transmit data packets. The smart webcams are data centric and thus constantly collecting data from its environment and transmitting data packets of images captured to users.

3.2 Implementation of IoT Architecture

In the architecture design of Accra smart city, we used seven smart webcams in an IoT environment that are connected via a wireless communication link to interact with the 6LowPAN gateway. These smart webcams in our design will be situated at the seven most congested routes leading to central Accra. The smart webcams with IPs address are able to generate valuable data that is transmitted to an IoT server at a centralized location. The smart webcams will then transmit images capture from the streets for users to access the valuable information. In the architecture design the smart webcams are assigned IPv6 address which are then connected to a 6LowPAN getaway and relayed across the Internet. The 6LowPAN gateway is suitable for constrains devices such as the sensor nodes in an IoT network and also allow users in the Internet to connect directly to it. The 6LowPAN gateway in the architecture design will also perform IPv4 translation to IPv6 for all devices connected to it in the IoT network. An architecture diagram of an IoT network for Accra smart city is indicated below. The detailed architecture and protocols used in the diagram is illustrated in figure A.

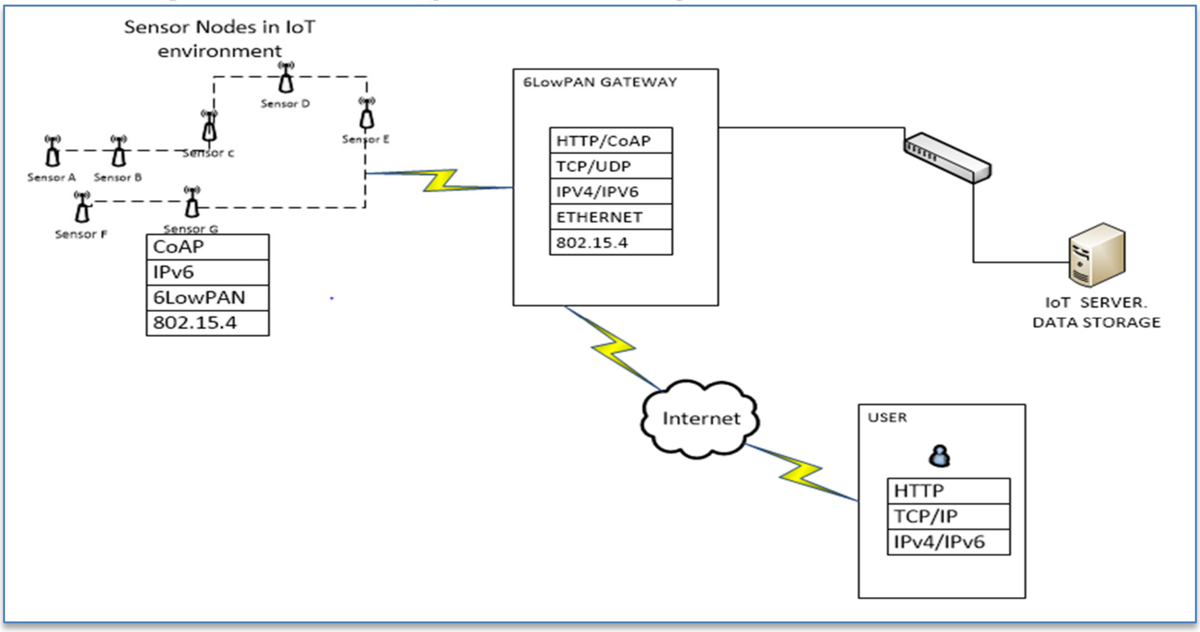


Figure A. IoT Architecture design for Accra Smart City.

Topology of the modeled IoT network: In a typical IoT network sensor nodes can connect to each other to form different topologies such as peer-to-peer, tree, star and mesh. The topology used for our model IoT network is a peer-to-peer topology where each smart webcam is directly linked to the 6LowPAN gateway to receive and send messages in the network. Depending on the type of topologies used in an IoT network, each topology has its advantages and disadvantages based on its connection to a sink. The mesh topology is quite predominant for IoT networks. With the mesh topology the sensor nodes are randomly distributed, where each sensor node can connect to its neighbor. The nodes within a particular location can connect and interact with its neighbors that are link to the sink. One key benefits of the mesh topology for sensor nodes in an IoT network is to allow the nodes to use different paths to transmit messages from source to its destination. Another benefit of mesh topology is that it is quite flexible and reliable compared to other topologies. The mesh topology makes the communication between the nodes very reliable as it ensures messages from the sources reaches its destination.

Data transmission: The role of the 6LowPAN gateway used in the smart city architecture is to serve as a network gateway that accepts data packets from the wireless smart webcams that can be routed to the IoT server in the network. The 6LowPAN gateway will also manage and control how the generated data from the smart webcams flows to the IoT server that stores the valuable data. The 6LowPAN will enable the communication between the smart webcam and users in the Internet. The 6LowPAN in the architecture design will forward request to access information from any particular smart webcam in the IoT environment.

Delivery of Data: In a sensor network based on the application, the model for data delivery on the sink can be grouped into event-driven, continuous, query-driven and hybrid. [13] In a wireless sensor network, sensor nodes can use any of the data delivery models to route data packets generated by the nodes to a centralized intermediate server. In the query and event driven models, data can be transmitted when there is a query or an occurrence of an event by the sink, [14] a continuous delivery model will have each sensor constantly sending data. The hybrid model is the combination of any of the models, which can be applied in certain sensor networks. These are the data delivery models for which the smart webcams in the IoT model will be able to deliver the needed data. The smart webcams will use a continuous delivery model to send data packets to the 6LowPAN gateway in the network.

Aggregation of data: In a sensor network, it is possible that sensor nodes may generate redundant data and packets which are the same from different nodes can be combined so as to reduce the number of transmission.[14] Therefore as the sensor nodes generated data constantly, they may be a duplication of the data by the sensors and it is possible for aggregation of packets which are similar. The smart webcams in the IoT network for Accra smart city may generate redundant data. It is therefore essential to have an aggregation of redundant data that might be generated by the smart webcams to reduce the transmission time to the IoT server. The use of an aggregation function like the suppression can eliminate the duplicate data packets from the sensor nodes. [15] The use of the aggregation function will perform the elimination of redundant data packets that are similar generated by the smart webcams in the IoT network. Two mechanisms for which data can be relay in a sensor network are flooding and gossiping [16] where there is no need for routing algorithms and maintenance of topology. With the flooding mechanism, each sensor node in a network that receives data packets transmits it to neighbors until the packet reaches the destination. In the design IoT network the smart webcam will route data packets to its neighbor and interact using the flooding mechanism. In the gossiping mechanism a receiving node will choose a neighbor at random and then transmit data packets to it. Therefore sensor nodes will be able to receive and send data packets to a randomly chosen neighbor by flooding mechanism.

Accessing data in the web: The information from the smart webcams in the IoT environment can be access by users on their smartphones in the web. The information in the web can be viewed by an IoT monitor application on a smartphone. The web services allows for the access of valuable information from the smart webcam in the IoT network. In the web service the use of standardization and open protocols such as XML, SOAP and WSDL enables communication in the web, where the XML is use to tag data, transfer of message is by the SOAP and the WSDL describes the service availability. [17] Therefore the combination of XML, SOAP and WSDL will make it possible for users to access and view web content data on their smartphones based on an application. The use of linked data browsers can enable the access of web of data just as how web documents can be access by the use of HTML browser. [18] Linked data browsers render the data content in the web for users.

Image capturing by Smart Webcams: The smart webcams in the IoT environment capture images that can be viewed by users in the smart city. Each smart webcams has a unique IP address that allows users to directly query to view images from a particular webcam at a particular street. The smart webcams have an inbuilt image sensor that captures images that can be converted into streams of digits. In the image capturing process, rays of light from the captured object enter the lens of the smart webcams. The image sensor of the smart webcams then splits the captured image of the object into millions of pixels. Thus the image sensor can divide the images of the capture object into millions of pixels. The image sensor then measures the brightness and colour of the pixels of the captured image. The colour and brightness are then measured for each pixel that is stored as binary digits that is in ones {1s} and zeros {0s}. The captured images which has been converted into binary digits that is transmitted in data packets to the 6LowPAN gateway. Users can view the capture images from the smart webcams in the smart city. Below is a diagram of the image processing of the smart webcams

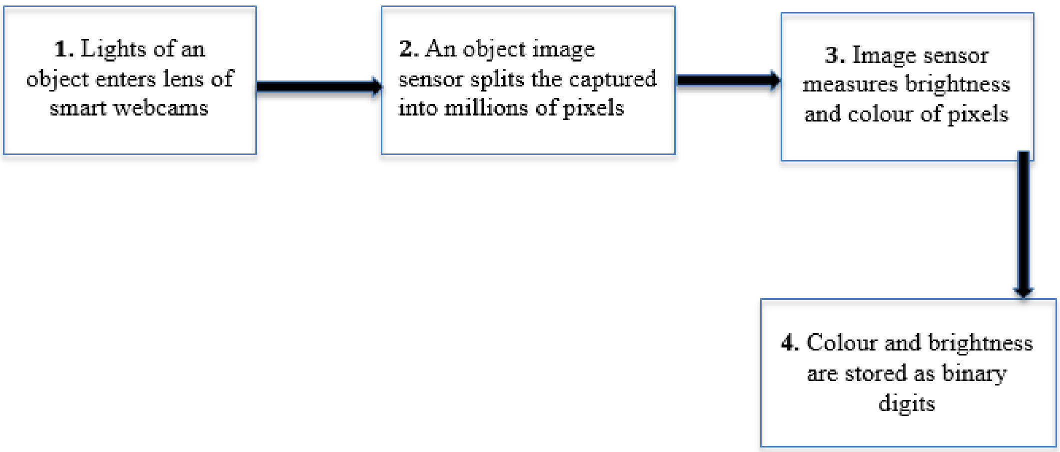


Figure B. Image capturing process by smart webcam

In the IoT environment, the smart webcams are placed on some major routes to capture and display images using the mechanism described. Vehicles moving in traffic on a particular street can be view on a smartphone of a user in smart city.

4. Methodology

The methodology for this study is in two main phases. Phase one is the network modelling approach using cisco packet tracer simulation package tool and the second phase is the discussion of the IoT network simulation results. We use cisco packet tracer version 7, that allows us to be able to view the flow of data packets and the analysis of the data packets transmitted in the design IoT network. Packet tracer will allow us to view the network metrics of data packets send and received by the IoT devices. The main concern of this simulation experiment is for users to access the valuable information generated by the wireless smart webcams in a smart city. The devices used for the simulation study are webcams, motion detector, 6LowPAN gateway, a switch, a smartphone and an IoT server. We used seven (7) webcam, which will be situated at the seven major routes in central Accra that are mostly traffic congested and flood prone areas.

4.1 Experimental Evaluation

In this section we describe the simulation environment of the proposed IoT network and the analysis of the network performance metric such as data packets within a network. Packet tracer used for the experiment enables us to see the packets flowing in the design IoT network and analyze what happens to the packet. Cisco packet tracer allows us to view the network metrics of data packet send and received from one device to another in the designed IoT network and read what happens when a packet is truncated. The evaluation of the network performance is to view the data packets send and received by the IoT devices.

Network Implementation Using Packet Tracer: Here we begin the modelling phase of the proposed IoT network using the packet tracer package which have the required IoT devices for the study. In the experiment setup, the smart webcams are randomly placed in the IoT environment with a motion detector are configured with dynamic IP addresses to connect via a wireless channel to the 6LowPAN gateway. The 6LowPAN gateway configured with a dynamic IPv6 address and connecting to the intermediary IoT server through a switch using a straight cable. A smartphone is configured to connect to the 6LowPAN gateway.

4.2 Smart city IoT network simulation

In the simulation process of the IoT network for Accra smart city, the webcams in the IoT environment are configured with IPv6 addresses to connect the motion detector and the 6LowPAN via a wireless medium. The role of the motion detector is to sense and detect the movement of objects in the street. The 6LowPAN gateway is also configured with IPv6 address that connects to the IoT server using a switch. The smartphone contains an IoT monitor application to view captured images from the smart webcams. The 6LowPAN gateway also does a convention of IPv4 to IPv6 of the devices connected to it. Users from any location in the smart city can access the smart webcams via the 6LowPAN gateway in the Internet using a smartphone.

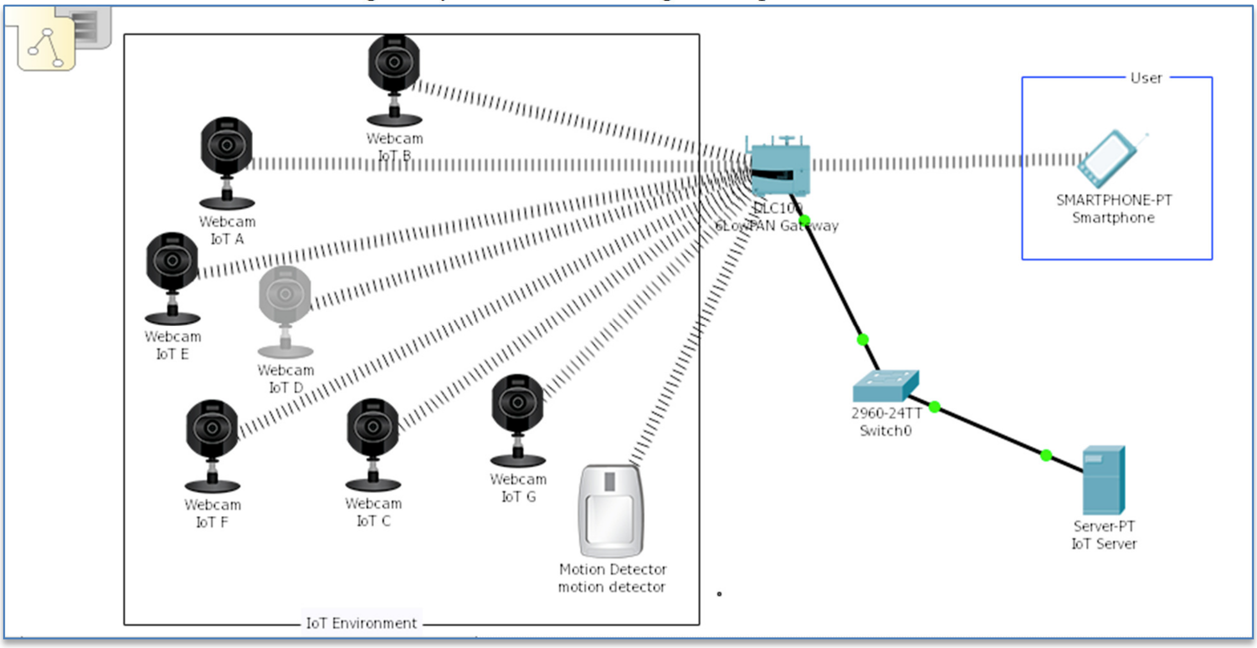


Figure 1. IoT model for Accra smart city

4.3 Protocols of IoT devices

The smart webcams use dynamic IPv6 addresses which are addressable in the IoT network. These smart webcams can dweets information by sending data packets to the 6LowPAN gateway. Below are the details of the protocols used for the simulation which is presented in tables.

Table 1: Dynamic IP address for smart webcams in the IoT network

IoT smart webcams	IP addresses
Device A	192.168.25.113/24
Device B	192.168.25.100/24
Device C	192.168.25.104/24
Device D	192.168.25.110/24
Device E	192.168.25.108/24
Device F	192.168.25.105/24
Device G	192.168.25.112/24

Table 2: Custom device model - Motion detector

Port	Wireless
Link	Up
IP address	192.168.25.105/24
Gateway	192.168.25.1
DNS server	10.10.10.2
MAC address	00D0.97B7.CA59
Wireless Best date rate	300 mps

Table 3: Custom device model -Webcam

Port	Wireless
Link	Up
IP address	192.168.25.115/24
Gateway	192.168.25.1
DNS server	10.10.10.2
MAC address	0001.64C2.6720
Wireless Best date rate	300 mps

Table 4: Custom device model - Smartphone

Port	Wireless, 3G/4G cell 1
Link	Up
IP address (wireless)	192.168.25.101/24
IP address (3G/4G cell 1)	169.254.160.125/16
DNS server	192.168.25.1
MAC address	0000.0CE4.51DC 0001.C903.A07D 00E0.0FE5.09ED
Wireless Best date rate	300 mps

Table 5: Custom device model - 6LowPAN gateway

Port	Link	IP address	MAC address
Internet	Down	192.168.25.2	00E0.A3A1.C801
LAN	UP	192.168.25.1/24	0006.2A60.A41D
Ethernet 1	UP	- -	00E0.A3A1.C802
Ethernet 2	Down	- -	00E0.A3A1.C803
Ethernet 3	Down	- -	00E0.A3A1.C804
Ethernet 4	Down	- -	00E0.A3A1.C805
Wireless	UP	- -	00E0.A3A1.C806

Table 6: Custom device model – IoT Server

Port	Fast Ethernet
Link	Up
IP address	1.1.1.1/8
Gateway	10.10.10.2
MAC address	00D0.D378.D504

5. Experimental Results and Analysis

In the simulation, when we mouse over the motion detector a red light signal appears on the smart webcams, the motion detector also detects the movement of an object by showing a red light that is indicated in **figure 2**. The motion detector and the smart webcams combine to capture the object in motion and its image. In the case of smart city whenever vehicles are moving in traffic on the road, the smart webcams captures the images of the vehicles in motion and dweets the valuable information.

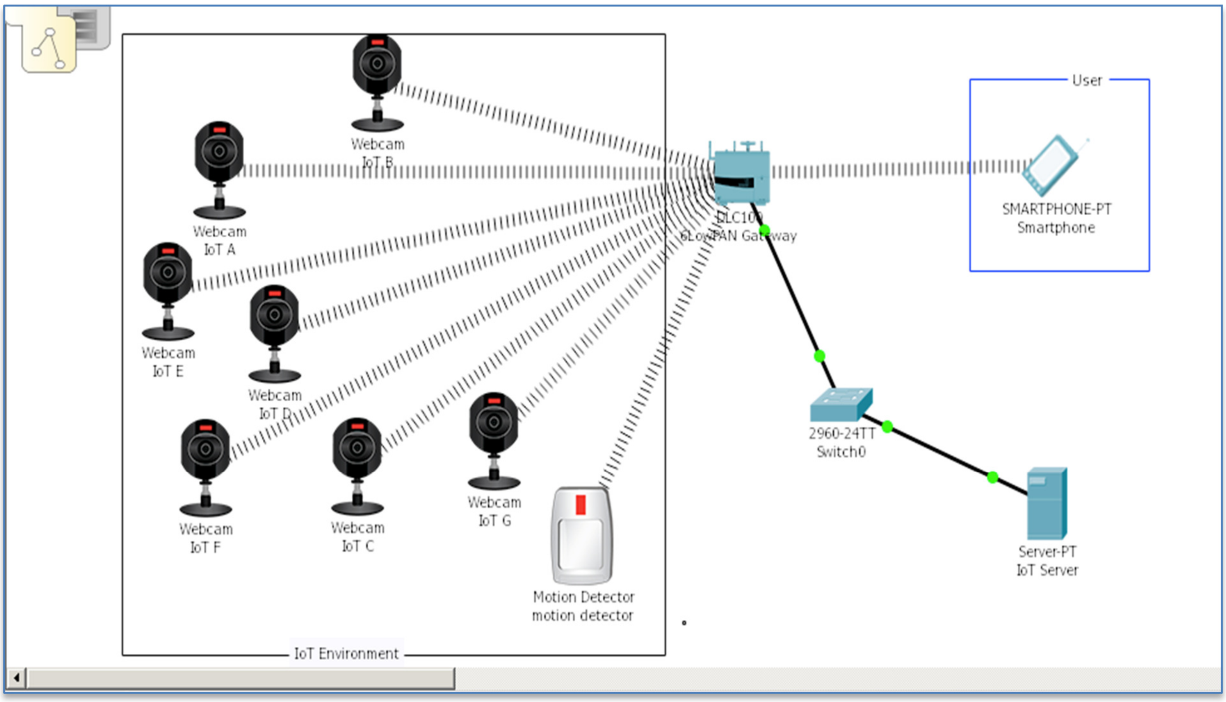


Figure 2. Smart webcams capture images from it surroundings

Figure 3 shows when images are captured by the smart webcam with a red light appearing on the smart webcams. In the IoT monitor application on the smartphone a green light appears when the webcams capture images. Once the images are captured by the smart webcam, they transmit the valuable information where users can have live feeds for example of traffic building up on a particular street. The IoT monitor application will display images from the various cameras at different streets and give users an option to view from a single smart webcam at a location. Hence users can view useful information such as traffic congestions or flooding when it is raining from the street where that particular smart webcam is situated. This will give users information on planning alternative routes they can use to arrive at their destination. **Figure 3** shows an image captured from a smart webcam displayed on a smartphone being access by a user.

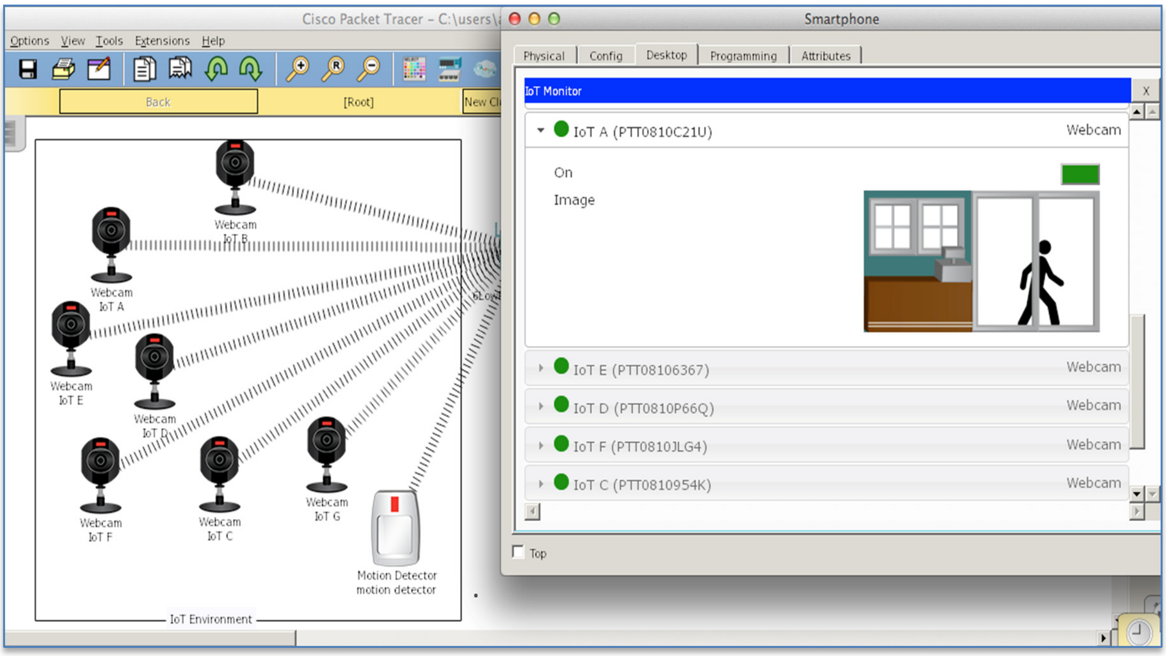


Figure 3. IoT monitor display images on a smartphone capture by the webcam

In **figure 4** below, the user sends a request by sending data packets to view capture images from the smart webcams in the IoT environment. The messages are broadcasted by the 6LowPAN and it arrives at the smart webcams. In **Figure 5** when the data packets arrive at its destination it turns blue. That is to indicate that the data packets in the simulated network arrived successfully without it being truncated.

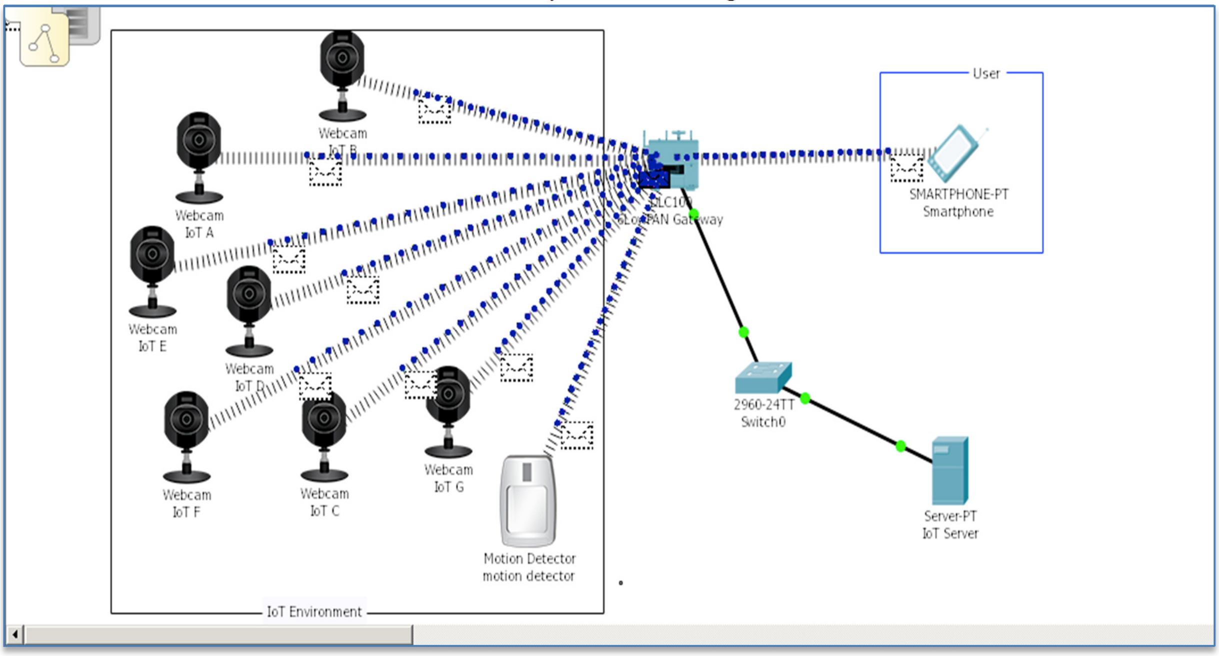


Figure 4. User sends data a request via a smartphone to the smart webcams

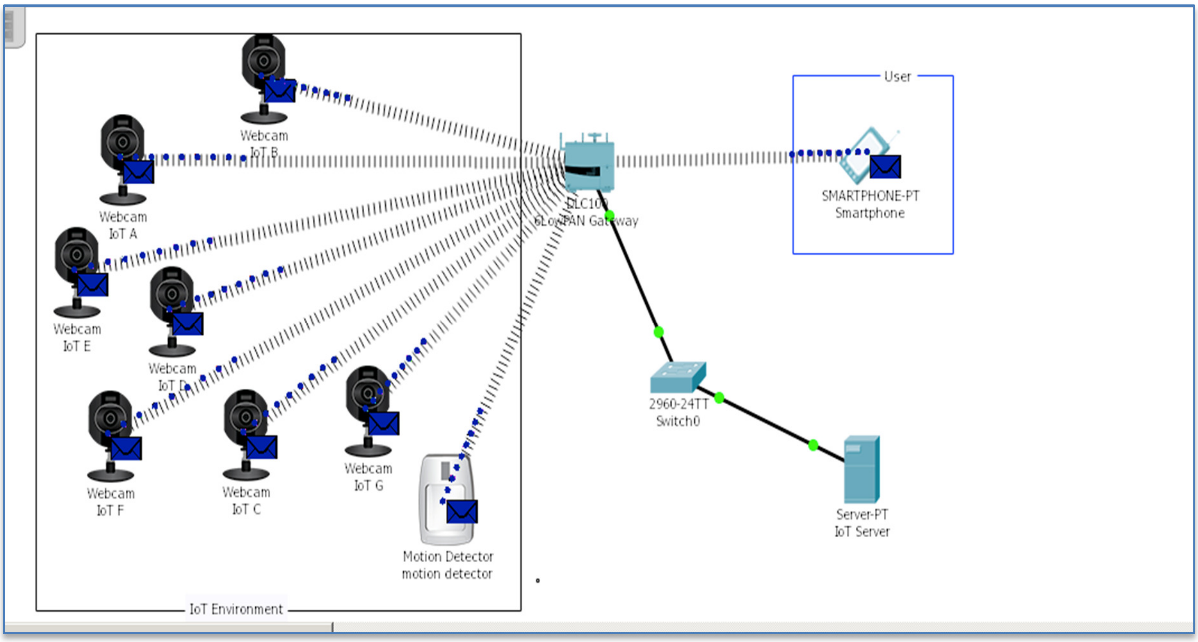


Figure 5. Data packets arrive at the smart webcams successfully

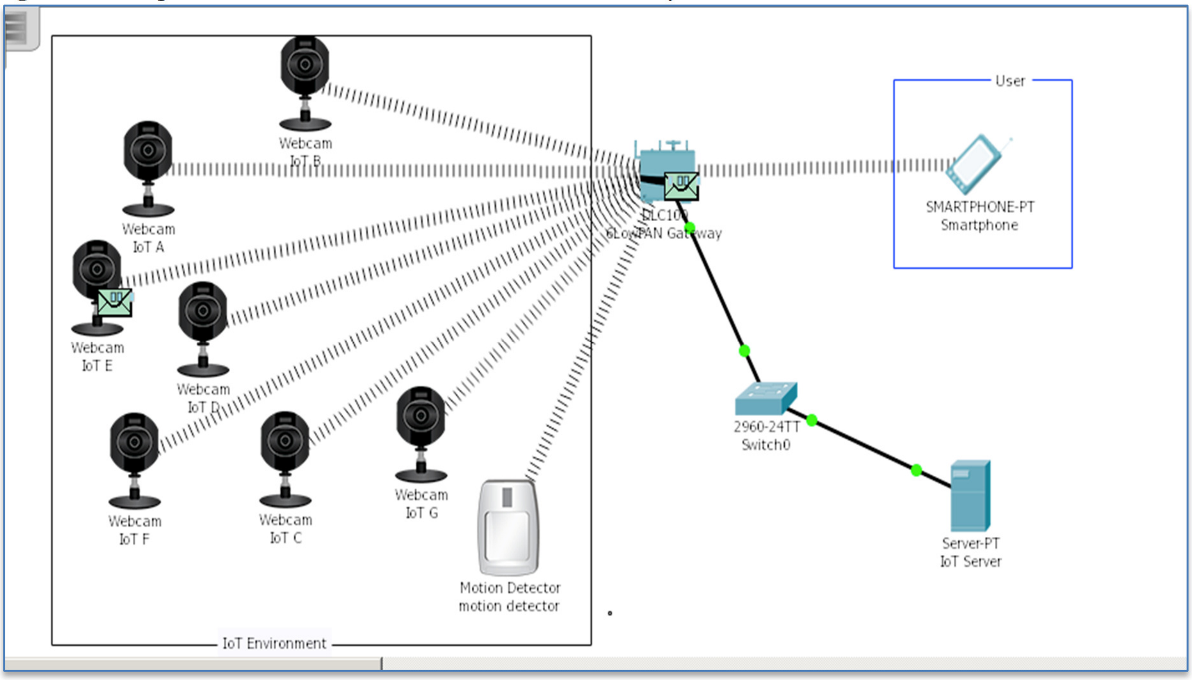


Figure 6. Smart webcam transmits data packets to the 6LowPAN

Each smart webcam in the IoT environment configured with a unique IP address can continuously dweets data packets of the images capture from its location to the 6LowPAN in the IoT network. In **figure 6**, the smart webcam IoT E device, transmits valuable data packets generated to the 6LowPAN gateway. All the other smart webcams can also transmit data packets to the 6LowPAN that will be routed to the IoT server. Users can also access information stored in the IoT server. **Figure 7** shows the IoT server receiving the data packets via the 6LowPAN from the smart webcams. The IoT server stores and manages the data generated from the smart webcams.

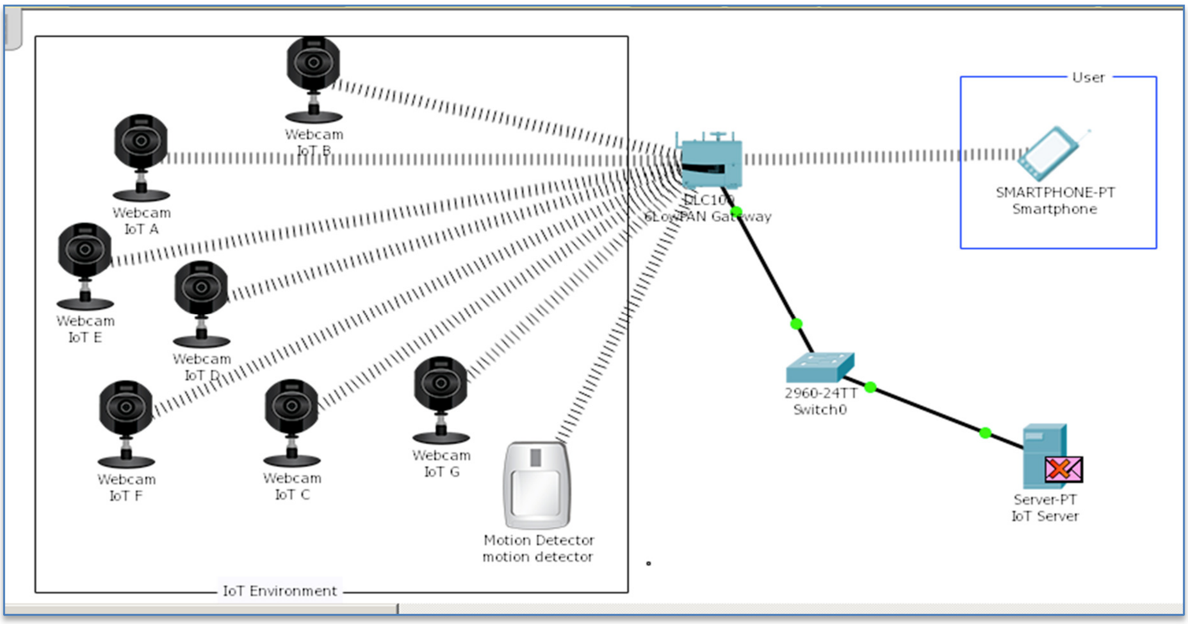


Figure 7. The IoT server receives and stores data packet

In the process of simulation, we test the modeled IoT network by pinging the smart webcams IoT device A and B using their IPs address from the smartphone to view the data packets sent and received. **Figure 8** show the connection is successful and the number of data packets sent and received is 4. There is no loss of data packets in the transmission. The approximate round trips average is 20ms that illustrates a fast transmission and retrieval of data packets on a user smartphone.

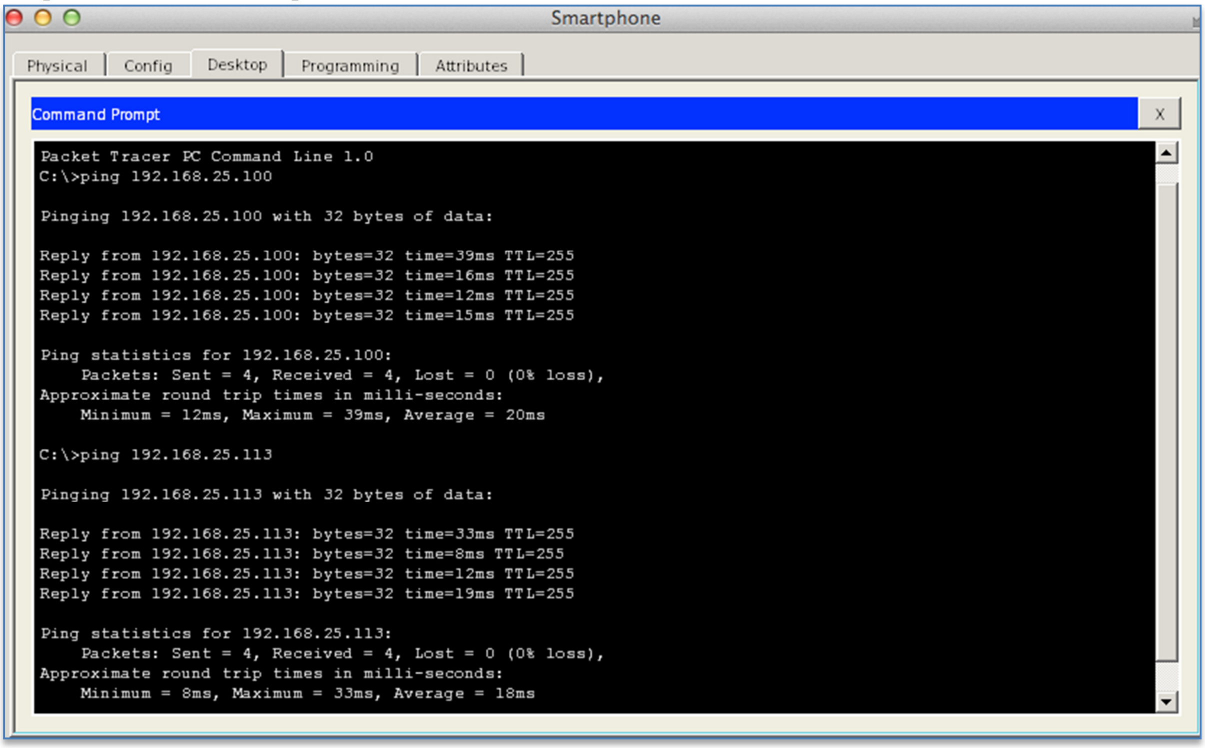


Figure 8. Pinging the smart webcams from a user's smartphone

Figure 8 shows a successful IoT network model that allows users to send and receive data packets in a smart city to view valuable information. The data packets received from the smartphone will display images on the various streets captured by the smart webcams for users to have live feeds.

6. Conclusion

In this paper we successfully model an IoT network for Accra smart city. The main aim of the study is to design and simulate an IoT network that allows users to view valuable information of images captured from smart webcams on a smartphone. In this paper, we discuss the concept of IoT network, some key applications of IoT and its architecture. We then focus on the applications of IoT for smart city and some examples of IoT for smart city are discussed. We describe the IoT architecture for Accra smart city, the protocols available in the web services and how data from smart devices are generated and transmitted. In the second part of the paper we simulated the designed IoT network for Accra smart city that deploys smart webcams, a motion detector, a 6LowPAN gateway and a smartphone using packet tracer simulation tool. The results from the simulation shows that when a smart webcam captures the image of an object, a red light is indicated and the motion detector also shows red light to indicate object movement. The findings from the study are very significant because from simulation results, users can directly interact with the smart webcams to view capture images via a 6LowPAN gateway in the IoT network. Users can also directly send and receive data packets to view images captured from any particular smart webcam in the IoT network. From the simulation results, the webcams can also dweets information by transmitting valuable data to the 6LowPAN gateway that can be routed to the IoT server in the network. Again the simulation results also indicate the 6LowPAN gateway can route data packets to the IoT server which stores the valuable data that can be access by users. Therefore the main objective of this paper is achieved from this simulation experiment for Accra smart city.

Our designed network model for Accra smart city is significant because it will address a key challenge by giving users access to information on live feeds of traffic congestions and flooding. A successful implementation of the model will allow people to view images on some streets and properly plan their routes via an application on their smartphone. This is very important because it gives users an opportunity to plan which routes to use in order to avoid traffic and flooded streets when it is raining. The designed model will thus improve Accra to become a modern intelligent city.

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