American Journal of Biological Sciences
1(1):15-18,May-June 2019.

Research Paper

Modeling, Simulation and Performance Evaluation of Wired Smart Home Technology Controlled by Wireless Mobile Device.

Dileep Keshava Narayana

University of Greenwich, London, United Kingdom.

To cite this article: Dileep Keshava Narayana. Modeling, Simulation and Performance Evaluation of Wired Smart Home Technology Controlled by Wireless Mobile Device. American Journal of Basic Sciences, 1(1):15-20, May-June 2019.

Email: dileep007k@gmail.com

Received: 18th April 2019.| Revised: 24th May 2019.| Accepted: 17th June 2019.

Abstract: Currently smart home devices work on the mobile agent *(MA)* technology, Open Services Gateway initiative *(OSGi)* framework, and service oriented architecture *(SOA).* However, usually smart home devices are connected by the wired network in the home by providing the gateway and a server. This enables to directly manipulate and control the home devices by using the wireless mobile device. We will propose a model, simulate it and carry out performance analysis for it.

Keywords: smart home, simulation, universal monitor and control, wired-cum-wireless smart home.

1. Introduction

There are many smart home projects up to this time such as House Genie **[4],** Control, Microsoft smart home technology and the like. These smart home projects provide an interactive application to directly manipulate the smart home devices by portable or mobile devices such as smart phones, I Pad, Laptop and the like. These applications support wide range of simple home monitoring and control operations to replace the remote of smart home appliances. These smart home devices require basic network-ready devices and the supporting infrastructure. Smart home technology provides the centralized architecture management that connects to all of smart home devices in home to provide a user-friendly interface and unified network devices operation to acquire the device status.

In smart home technology often the home devices are wired and extended it to be controlled by the wireless mobile devices. In this paper, we will create a model to simulate wired smart home devices controlled by wireless mobile device using *OPNET* Modeler. We will discuss common challenges that might be faced during the design, available solutions, and how OSGi framework can help to us to overcome these challenges. Finally, we will simulate and analyze the results of it.

2. Related works

2.1. Open service gateway Initiative (*OSGi)*

2.1.1. Framework

Lee et al. states that the technology was lacking long-term evolutionary vision and interoperability with the variety of devices and services from the developers & manufacturers. To achieve the architecture openness and vendor independence Open service gateway Initiative *(OSGi)* was started in 1999 to deliver *WAN* services to home environments. *OSGi* provides manageable, extensive framework to obtain connection with wide range of devices including home, office, and automobile. *OSGi* provides a standard execution platform and services interfaces that enables dynamic discovery, collaborative operation of devices, services such as remote control, management, support and diagnosis of different devices from different sources without the need of restarting whole system. **[1]**

2.1.2. Control of home & office devices by smart phones

Nichols and Myers points out that all home and office appliances such as refrigerators, copiers and the like are providing the remote controls and features of these devices were increased due to computerization. Computerization made it difficult to provide the easier interfaces. Using and carrying smart phones with better Input, output abilities were easier than carrying devices such as high resolution screens and the like. As the smart phones always maintains the advantage than those devices and most of the times it is used by single user, this lead them to develop a framework that automatically generates high-quality device interfaces to provide full functionality to control devices for users. **[2]**

2.1.3. Smart home architecture using *OSGi* & mobile agent technology

In traditional smart homes, devices were implemented in the centralized architecture in which they were connected by the home networks and managed by the home gateway using service provider's platform *(SPs).* Wu & Fu say that the smart home devices must conform to some kind of standard and *OSGi* was one of the emerging standards for smart homes projects. They used service oriented architecture of client- server methodology which uses Open Services Gateway Initiative *(OSGi)* and Mobile Agent *(MA)* technology to implement it. *OSGi* platforms are called as bundles which performs installation, updating and removal operations to dynamically discover the services from the service directory or from other bundles **[3].**

2.2. Simulation model

We will discuss challenges, available solutions and then we will create a generic model, extended model for the simulation of the wired smart home devices controlled by wireless mobile devices such as smart phones, I Pad, laptop and the like.

2.2.1. Challenges

Universal control of the smart home devices requires network capability infrastructure and different configuration characteristic that does not have anything in common. Some of the challenges in designing and implementing the smart home technology are:

- Creation of the visual presentation of all smart home devices together for the mobile device
- Creating the interaction of the different devices in the networking infrastructure to provide direct manipulation and control for the mobile devices.
- Smart home technology must address the advanced management needs to provide all the operations configured by the appliance manufacturers.
- From the user perspective. It must meet the requirements such as user friendly interface, consuming less battery, and the like.

2.2.2. Available Solutions

Almost all of the challenges discussed have been solved by adopting OSGi framework **[1], [3], [4],** MA technology and SOA **[3].** Zhong et al. states that *OSGi* can be used to provide user friendly interface, Unified network devices for the upper layer applications to acquire the device status and to activate the device operations by using the infrastructure of *OSGi* based Home Portal (*OHP*). *OHP* has been implemented by using *OSGi* framework. It provides dynamic, complete component model which is used for the remote services such as install, start, stop, update and uninstall without restarting or recompiling the whole system. The *OHGi* framework follows four layered architecture which makes it easy for the central management. *OHP* inherits these functionalities from *OHGi* framework to provide dynamic features and flexibility.

The four layers of *OHGi* frameworks comprise:

Adapter layer: Adapter layer addresses the devices which uses different protocols.
Device layer: The device status and the device profiles are managed for each device in this layer.
Service layer: This layer provides higher management functions to the upper layer of the device bundles consisting device manager and context services.
Interface layer: Interface layer consists of the application such as House Genie which provides unified multiple access that communicates with Smart home devices and the mobile device.

Wu et al. proposed architecture for smart home environments consists of Interface agent, device agent, components are distributed in multiple OSGi platforms in the smart home environment and they can communicate with each other in a service oriented approach. Those components are facilitated to provide cooperation by MA technology. **[3]**

2.3. Model

Nashiry et al. points out in his evaluation that wired networks have less delays, packet loss, and bit error rates when compared to wireless networks. The wireless networks have high bit error rates, temporary disconnections due to the factors such as channel fading and handoffs due to the mobility of the mobile device **[5].**So the wired networks provide the high bit rates when compared to the wireless networks and there are many advantages of using wired cum wireless networks.

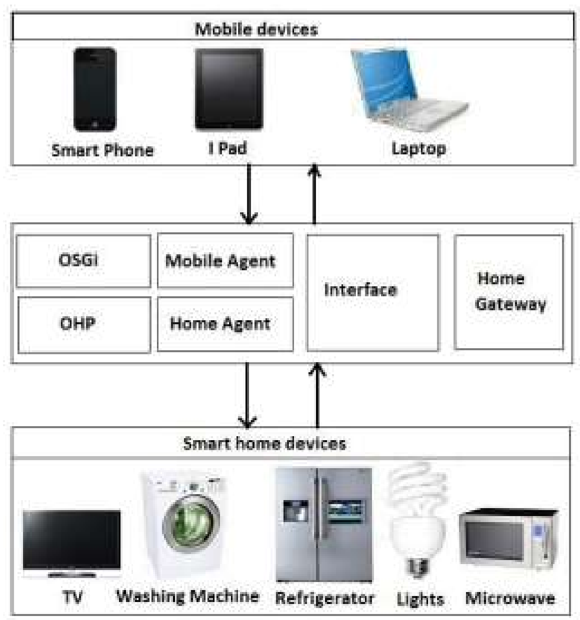

Figure 1: Generic Model

By using wired cum wireless network in the modeling for the simulation. The Figure 1 shows the General Model for the simulation. The home devices such as *TV*, microwave, washing machine, lights and the like will usually be wired in the home and will be connected to the Gateway. Hence it can communicate with the server. The gateway acts as the interface between the mobile device and the home devices. It is embedded with home agent, mobile agent, OHP which will be implemented by the use of *OSGi* framework to provide real time communication and system operation through the mobile devices. We have extended the generic model in Figure 2. Starting from the bottom up approach, Smart home devices and server is connected to the gateway. Gateway is connected to the Internet Backbone. Internet

Backbone is the Internet connection to the home from the Internet service provider *(ISP).*

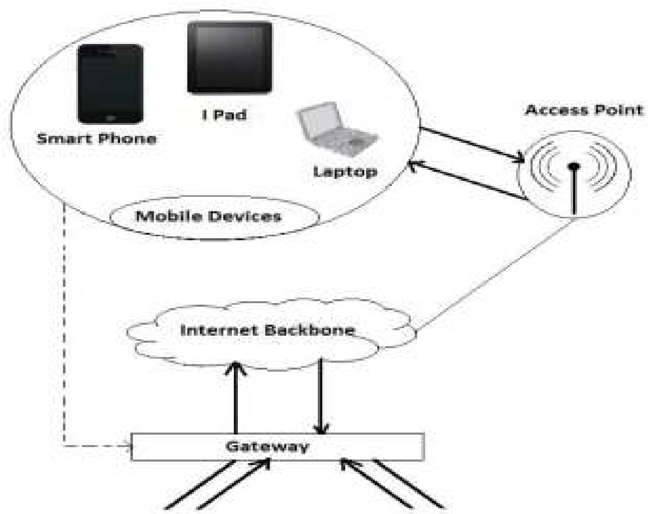

Figure 2: Extended model

Access point indeed is an extension from the Internet Backbone. Although wireless connection can exist without the wired connection. Here we consider access point is obtained from the wired network. Mobile devices are connected to this access point.

Let's look at communication of these components in the model. Mobile devices obtain the Internet communication through the access point. This sends the data requested by the mobile device in the form of packets to the destination by using the *ISP* servers and the packets are routed to the destination. Here our goal is to control the Smart home devices. So these packets will routed to the server at home through the gateway. Server responds to the query request made previously through the mobile device by sending the data to it.

- Some of the advantages of using server for these smart home devices are:
- We can create a single point of contact to perform the system operations such as start, stop, update and the like for smart home devices from a mobile device.
- Easy Information and device status retrieval of connected devices.
- Improves the security or authentication process for accessing smart home devices. As server communicates with the smart home devices just like in the computer networks internally.

For ex:

- By use of server, we can have a look at the vegetables available in the refrigerator. The inventory of the vegetables available will be stored as the database in the server. So we can access this information almost from anywhere, when we are away from home through mobile device.
- Considering *CCTV* cameras has been connected. The activities recorded, stored can be easily accessed from anywhere through the server through mobile device. However, Server must be turned on 24/7 to obtain these advantages. The dotted line in the figure 2 shows that virtually mobile devices are communicating directly with gateway

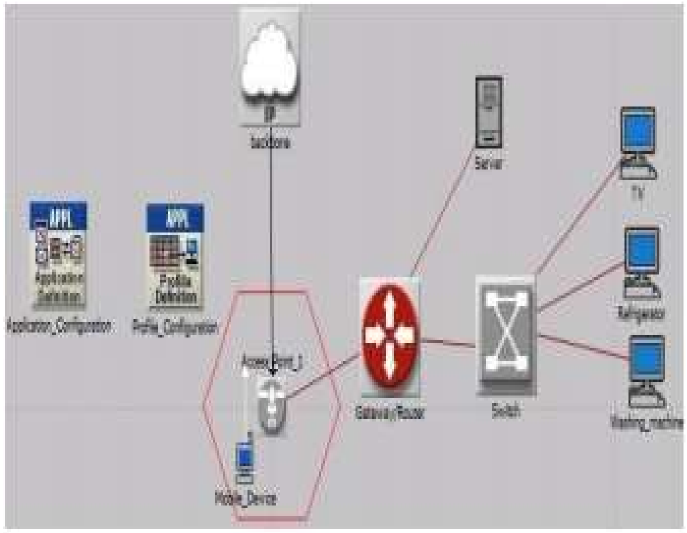

Figure 3: Simulation Model 1

Here the figure 3 shows the simulation model done using the *OPNET* modeler. We are taking the smart home devices such as *TV*, washing machine, Refrigerator and the like as the Ethernet workstations which are connected to a switch. Even though these can also be connected directly to the gateway/router. We have connected the switch to the Gateway/Router. The gateway provides the capability of connecting the smart home devices remotely. Gateway/Router is connected to the server and the access point. Some smart home service providers make use their own hosted servers instead of using a server in home to provide the remote services. However, it is better to host server in home. Access point is hence connected to IP backbone where the internet service provider provides the internet services. And we have created a mobile device which has the roaming capability through which the smart home devices are accessed.

In the Figure 4 we have extended the model shown in the figure 3 to observe the effects by adding 2 smart home devices namely Lights and Microwave. We have increased the speed from 12Mbps to 54 Mbps in 802.11g. We will discuss the analysis by showing the graph and parameters in the upcoming simulation analysis section.

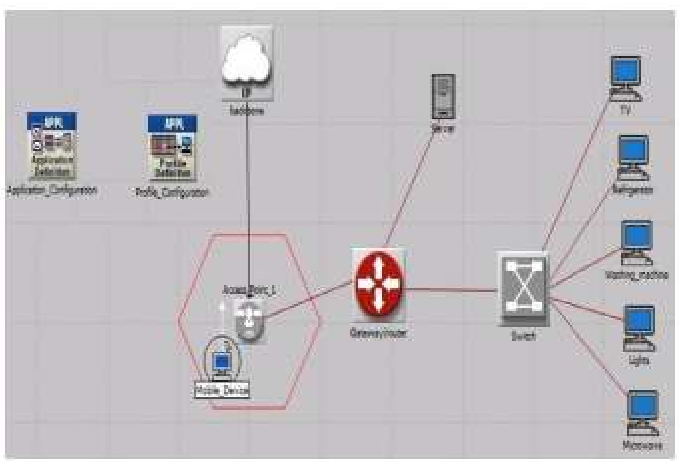

Figure 4: Extended Simulation model 2

3. Simulation Analysis

We simulated the models shown in the figure 3 and figure 4 for 1 hour

3.1. Simulation Model 1

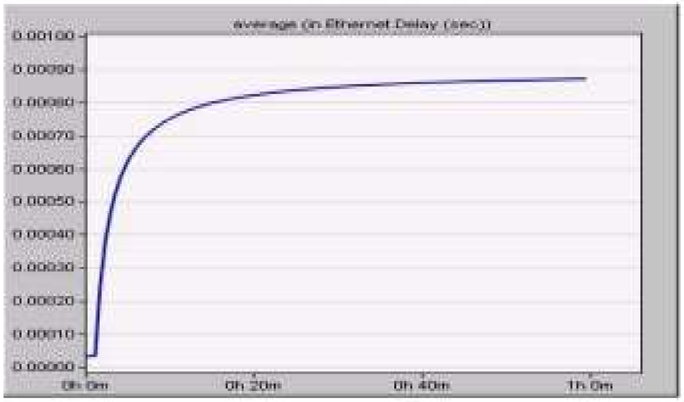

Figure 5: Ethernet delay (1) for Simulation model 1

Average Ethernet Delay: We have used the wired network to connect the smart home devices, so we will analyze the Ethernet delay from Figure 5 graph. It shows the average Ethernet delay for the simulation model 1 of the figure 3. By graph we can analyze that the Ethernet delay for the wired smart home devices at the start of the simulation it was very low like about 0.0005 seconds then gradually increased to about 0.00085 seconds and remains constant until the end of the simulation.

Wireless LAN: Mobile device connects through access point. Figure 6 shows the graph of average data dropped due to buffer overflow, delay, and throughput of the wireless *LAN.* We have used the 802.11g and speed of 12 Mbps.

Average Data drop: The data drop was low at the start of the simulation; it varied irregularly by decreasing and increasing the dropping rate up to max of 200 bits/sec at the end of the simulation.

Average Delay: The delay incurred by the wireless *LAN* was about 0.00018 seconds at the start of the simulation and increased irregularly up to max of 0.00058 seconds.

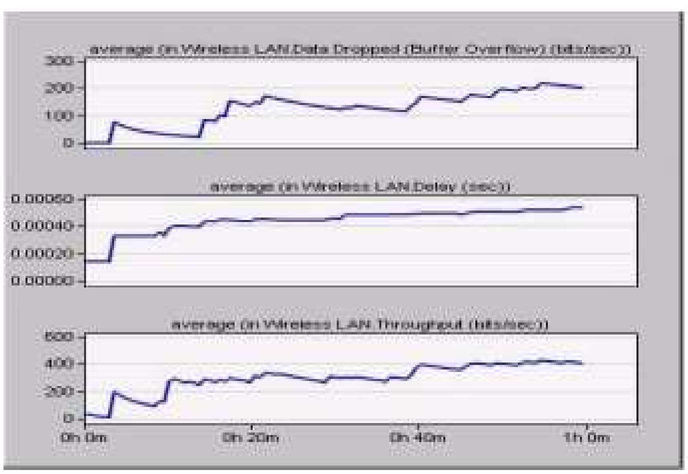

Figure 6: Wireless LAN (1) for simulation model 1

Average Throughput: Throughput of the wireless *LAN* started from 0 and it varied irregularly to 200 bits/sec and increased to max of about 400 bits/sec at the end of the simulation. Finally, for the simulation model 1 we can conclude that the Ethernet certain interval of time. However, for the wireless *LAN* the delay increased and decreased irregularly. The maximum delay of 58 milliseconds for the wireless *LAN* is pretty much acceptable and the max delay of 85 milliseconds is a bit high for the Ethernet.

3.2. Simulation Model 2

In the simulation model 2 we have extended the simulation model 1 by adding other two smart home devices namely Microwave and lights. We have also increased the speed to 54 Mbps for 802.11g wireless connection.

3.2.1. Average Ethernet Delay

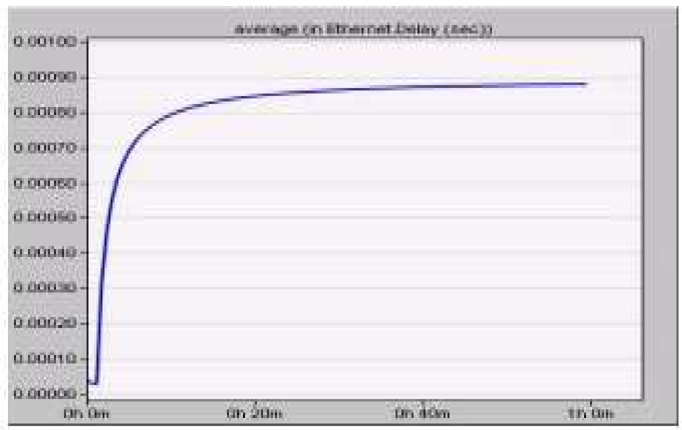

Figure 7: Ethernet delay (2) Simulation model 2

As shown in the figure 7, the average Ethernet delay is almost same as the Ethernet delay of the simulation model 1 as shown in the figure 5.

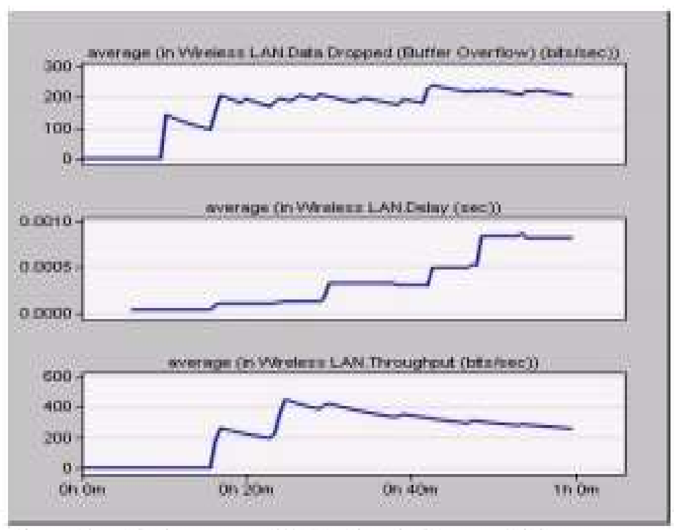

Figure 8: Wireless LAN (2) for simulation model 2

Wireless *LAN*: In the simulation model 2, we will now analyze the average data drop, Delay and throughput for the simulation model 2 from figure 8.

Average Data Drop: The data drop due to buffer overflow was 0 at the start of the simulation and it irregularly increased over time to maximum of 225 bits/sec.

Average Delay: The average delay was 0.0001 seconds at the start of the simulation and it has been irregularly increased to the maximum of 0.008 seconds.

Average Throughput: The average throughput starting from 0 at the start of the simulation has been irregularly increased to maximum throughput of 420 bits/seconds.

Finally, we can conclude that the average Ethernet delay is higher than wireless *LAN* Delay. The data drop rate, Delay, and Throughput has been slightly increased.

3.2.2. Simulation set up

For simulating the smart home devices we have taken 3 Ethernet workstations in the simulation model 1 and is connected to a switch through a 100 base T link. Switch is then connected to gateway/router through 100 base T link. Server has been connected to gateway/router. Gateway/router is connected to the access point wireless router. Mobile device uses this access point to communicate with the smart home devices. Access point is connected to the *ip* backbone.

Server has been configured to provide the services such as system operations, web browsing, database access, email, voice and video conferencing to the smart home devices. Smart home devices are configured according to functionality of these devices. For ex: To check the inventory of the refrigerator for the available vegetables list, we need to have database storage either in device or in the server. Server provides this functionality. This enables the smart home devices user to control the system operations such as start, stop and the like to access the database through the mobile devices

The simulation model 1 is extended by adding additionally 2 smart home devices Microwave and Lights. We configured the simulation in the *OPNET* Modeler based on the following device functionalities or applications:

System operation: start, stop, update, install, and the like for all the smart home devices Lights, Refrigerator, Microwave, washing machine, *TV* using the remote login functionality.

Database access: for inventory information retrieval and control to the refrigerator such as the available vegetables in refrigerator using database functionality.

Web browsing: to access the web from *TV* using the web browsing functionality.

Voice conferencing: to speak to the individuals of the home inside or outside the home using *TV* using voice functionality.

Video conferencing: to speak to the individual of the home inside or outside the home with video using TV using video conferencing functionality.

In both the simulation models 1 & 2, we have used 802.11g technology. Speed of 12 Mbps and 54 Mbps for Simulation model 1 and 2 respectively.

3.2.3. Parameters

- Wireless technology – 802.11g 12Mbps and 54Mbps.
- Application & profile configuration – web browsing, database access, email, voice, and video conferencing & System operations.
- Mobile device vector trajectory & roaming capability.
- Access point & Mobile device *BSS ID* and Speed.
- Application support profiles & application supported services for server and smart home devices.
- Simulation time 1 hour.
- Ethernet Delay, Wireless *LAN* Data dropped due to buffer overflow, Wireless *LAN* Delay and throughput.
- 100 base T link

4. Conclusions & Future Work

We have modeled, simulated and evaluated the model for the wired smart home technology controlled by a mobile device such as Smart Phone, I Pad, Laptop and the like. From the graphs of the models, we can evaluate that the Ethernet delay was very low at the start of the simulation, after certain time it was increased and remained constant. However, the wireless delay constantly kept varying at many time intervals. This shows that the wireless *LAN* throughput varies very highly with time and Ethernet throughput will remain approximately constant at certain time intervals and provides a better throughput than the wireless *LAN*. This problem in wireless *LAN* is due to the channel fading; hand offs at certain time intervals and roaming capability of the mobile devices.

Now a days the virtualization technology has been used increasingly. We can further develop this smart home technology model to make use of the virtualization technology, wherever the information needs to be stored and retrieved. This might also further decrease the delay and improve the security for the smart home technology.

5. Acknowledgment

We Thank University of Greenwich staff for their valuable suggestions and comments. This work is supported by University of Greenwich as a part of the *MSc* Mobile technologies Coursework.

References

1. Lee, Choonhwa, Nordstedt, David, Helal and Sumi. Enabling smart spaces with OSGi. Pervasive Computing, IEEE, 2 (3):89-94, 2003.
2. J.Nichols, B.A.Myers. Controlling Home and Office Appliances with Smart Phones. Pervasive Computing, IEEE , 5 (3):60- 67, 2006.
3. Wu,Chao-Lin,Liao, Chun-Feng and FuLi-Chen. Service-Oriented Smart-Home Architecture Based on OSGi and Mobile-Agent Technology. Systems, Man, and Cybernetics, Part C; Applications and Reviews, IEEE Transactions, 37(2):193-205, 2007.
4. Zhong, Yu Suo, Yue Xu, Wenchang Yu, Chun Guo, Xinwei Zhao and Yuhang Shi Yuanchan. Smart Home on Smart Phone: UbiComp '11; Proceedings of the 13th international conference on Ubiquitous computing, 2011.
5. M.A.Nashiry, M.Abdullah-Al-Mahmud, M.M.Rahman and M.N.Anjum. Evaluation of TCP performance over mobile IP wiredcum-wireless network. Proceedings of 11th International Conference on Computer and Information Technology (ICCIT 2008), 24-27 Dec. 2008, 150-155, 2008.
6. Mitchell,Bradley.Gateway.Available[Online]: http://compnetworking.about.com/od/networkdesign/g/network-gateway.htm

About The Author

Mr. Dileep Keshava Narayana is a Post-Graduate of Master of Science in Network and computer systems security from University of Greenwich, London and Graduate of Bachelors of Engineering in Information sciences from Visvesvaraiah Technological University, India. He is a Microsoft Certified Professional with Microsoft Technology Associate Certifications in Networking fundamentals, security fundamentals and windows server administration fundamentals. He has worked in many job roles in many Multinational companies & Government Sectors including in India & United Kingdom.