A Performance Analysis of Multimedia Traffic over Zigbee Network

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DECLARATION

We declare that this thesis is based on the work results done by ourselves. Other's Materials and data which we used for research are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

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Signature of Author

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Tanzila Jamil

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WSN ………………………………………………………….. Wireless Sensor Network

MAE ……………………………………………………. Riverbed Modeler Academic Edition

MAC ……………………………………………………. Media Access Control

WMSN …………………………………………………. Wireless Multimedia Sensor Network

PHY ……………………………………………………….. Physical

LR-WPANs ………………………………………………... low-charge WPANs

RFDs ……………………………………………………….. Reduced Feature Devices

FFDs ………………………………………………………… Fully Functional Devices

JPEG ………………………………………………………… Joint Photographic Experts Group

FPS ………………………………………………………….. Frame per Second

Abstract

A Wireless Sensor Network (WSN) offers the advantages of low power consumption and low cost. For some applications e.g. distributed surveillance, emergency, and rescue etc., ZigBee technology is needed to support multimedia traffic e.g. image, video streaming. However, transferring multimedia traffic over a ZigBee network is a challenging task because of its low data rate i.e. 250 kbps at 2.4 GHz. This paper investigates the performance of image and video transmission for three topologies e.g. Mesh, Star and Tree topologies over Zigbee network using Riverbed Modeler Academic Edition (MAE). The result shows that Mesh topology outperforms over Star and Tree topologies in terms of traffic reception for both image and video transmission.

Chapter 1

1. Introduction

A Wireless Sensor Network (WSN) is a number of low cost battery-operated sensors deployed in an environment and can communicate with each other or to a gateway via radio-interface [1], [2]. Temperature, humidity, pressure, position, vibration, sound etc. can be monitored using WSN which is consist of some nodes. These nodes can be utilized as a part of different applications to perform different assignments like distinguishing and revelation of neighbor node, processing, collecting and storing data, tracking object, synchronizing and routing between the base station and nodes [3]. User can configure and deal with the WSN with the administration node, distribute observing missions furthermore, accumulation of the observed information. Because of technological advancements, the cost of WSN hardware has dropped significantly and their applications are amplifying towards the military territories, mechanical and business fields. In the meantime, WSN technology have been enriched and one of the example is Zigbee [4].

The ZigBee technology is suitable for home monitoring and automation, environmental monitoring, industry controls etc. Zigbee works to control and sensor arranges on IEEE 802.15.4 standard for remote individual territory systems. This ZigBee standard characterizes physical and Media Access Control (MAC) layers to deal with numerous devices at low-data rates. Zigbee systems are extendable with the utilization of switches and enable numerous nodes to interconnect with each other for building a more extensive network. Because of the upsides of Zigbee innovation like minimal effort and low power working modes and its topologies, this short range correspondence innovation is most appropriate for a few applications contrasted with other restrictive interchanges, for example, Bluetooth, Wi-Fi, and so forth [5].

In the recent years, the research community has emphasised on WSNs especially on communication protocols to make it more efficient and robust to wireless losses [2]. Wireless Multimedia Sensor Network (WMSN) can be applied to a wide range of applications like object detection, recognition, tracking and video surveillance, etc. [6]. Usually, a multimedia sensor device incorporates a detecting unit, preparing unit (CPU), correspondence module, storage unit, activation unit [7]. Wireless Multimedia Sensor Networks (WMSNs) have developed and moved the concentration from the run of the scalar remote sensor systems to systems with sight and sound gadgets that are able to recover video, sound, pictures, and in addition scalar sensor information. WMSNs can convey interactive media content because of the accessibility of reasonable CMOS cameras and mouthpieces combined with the huge advance in distributed signal processing and multimedia source coding techniques [8].However, multimedia applications produce a huge amount of real time data which is a big challenge for such networks.

ZigBee networks have limited bandwidth e.g. 250 kbps at 2.4 GHz [9]. Video traffic contains large size of information and needs high data rate which creates an issue for this network. Researchers have reduced the complexity and difficulty of video transmission by advanced video compression techniques e.g. MPEG4 and H.264, advanced content based video segmentation and rate control algorithms etc. for such low rate networks. Many research have been done for handling multimedia over ZigBee which are mainly focused on physical layer [6]. Again high-quality video e.g. HD cannot be sent through WMSN for surveillance and monitoring applications [10].

This report investigates the performance of multimedia traffic i.e. image and video via Zigbee network in terms of traffic received using Riverbed Modeler Academic Edition (MAE) simulator for Mesh, Star and Tree topologies. The remainder of the paper is organized as follows. The preliminaries and relevant research works are presented in chapter 2. Chapter 3 describes the simulation environment of this paper. Chapter 4 presents and analyses the results of multimedia traffic using Zigbee network. Finally, Chapter 5 draws some conclusions.

CHAPTER 2

2. Literature Review

2.1 Related Work

Data communication and multimedia streaming have different characteristics and requirements. As wireless networks suffer from packet delays and losses and multimedia streaming is time constrained, the quality can be low or cannot be assured [1]. Lots of research has already been done about performance analysis of multimedia traffic over Zigbee network.Paper [6] has proposed a multipath routing which is interference-ware based so that it can improve the video quality and also the throughput. It only considers one video stream and also fixed one hundred one fixed or stationary nodes. Paper [11] has developed a multi-hopping wireless network for image transmission over ZigBee networks. It has evaluated the performance by considering JPEG and JPEG-2000 images. JPEG is discrete cosine transform (DCT) based while JPEG-2000 is image compression standard. The result from [11] shows that JPEG-2000 images are more error resistant which minimises channel errors during image reconstruction and it maintains the high Peak Signal to Noise Ratio (PSNR). For low rate image sensor network application, JPEG-2000 is an acceptable format. Paper [12] introduces an image monitoring system which relies on WSN using ZigBee and General Packet Radio Service (GPRS) networks. The proposed work shows that it is suitable for remote monitoring where an end device sends images to the monitoring center. Paper [13] proposes an efficient and reliable image retransmission scheme at minimal packet loss rate. It reduces the number of data retransmission by adding two-byte counter in the packet header. Paper [14] has proposed a network which is capable of faster transmission of images compared to the system without multi-diverse scheme e.g. time, space, polarization etc. In [15], a comparison between various image compression techniques is investigated and it also points out that transmission delay can be reduced by using efficient routing protocols in transport and network layers. Most of the studies investigate the performance of image transmission over ZigBee network and limited research has focused on performances of topologies e.g. Mesh, Star and Tree while testing the network.

2.2 ZigBee Network

ZigBee technology is a low charge rate, low power consumption and low cost wireless networking. The ZigBee application profile includes home automation, commercial plant tracking, business constructing automation, computerized meter reading, telecom offerings, wireless sensor networks, non-public home and health facility care and so on [14]. More especially, ZigBee is built on top of the 802.15.4 specification which defines the physical (PHY) and Media Access Control (MAC) layers for low-charge WPANs (LR-WPANs). ZigBee provides layers on top of this to feature greater network and application intelligence. 802.15.4 is the idea for many other industrial Wi-Fi protocols as nicely so understanding it could be very useful to a security representative [16]. A ZigBee network permits devices to connect wirelessly via certainly one of several feasible topologies. Packets of data may be sent among nodes, and may be routed by means of intermediary devices to more remote nodes that might in any other case be out of range. Every device has each a MAC deal with and a ZigBee network address, and the network as a whole has its personal PAN id shared by using all devices. Packets can be included through encryption however for this to works all nodes will want a key and as we are able to see later there can be problems around how such keys are deployed to devices [16]. The simplified version of Zigbee stack is illustrated in Figure 1.

The MAC layer defines two sorts of nodes: Reduced Feature Devices (RFDs) and Fully Functional Devices (FFDs) and two operational modes, non-beacon-enabled mode and beacon-enabled mode. The ZigBee network layer defines how a network address is assigned to each participant ZigBee device and the way a packet is routed [6].

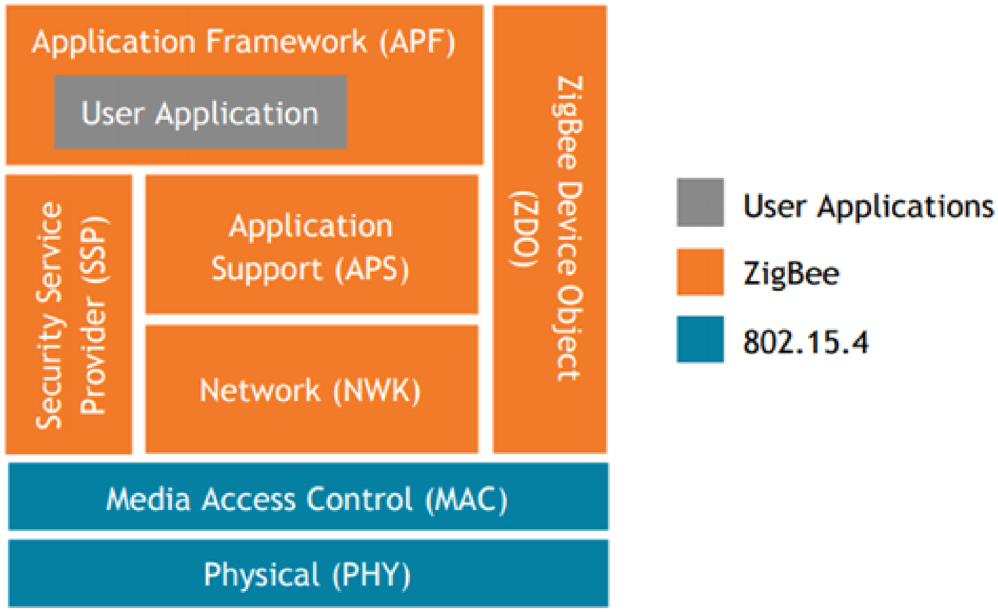


Figure 1: A simplified view of Zigbee stack

ZigBee networks have limited bandwidth e.g. 250 kbps at 2.4 GHz. The physical layer supports transfer of small sized packets confined to 127 bytes. Due to overhead on the network, MAC and physical layers, each packet may also incorporate no extra than 89 bytes for application data. This leads to fragmentation of bit streams larger than 89 bytes. The networking layer does not perform fragmentation. Consequently, the fragmentation and reassembly must be treated at the application layer. A go with the flow control mechanism is also needed to renowned and request retransmission of missing fragments above the network layer [11].

Within the ZigBee network it includes 3 kinds of network nodes, ZigBee Coordinator (Coordinator), ZigBee Router (Router) and ZigBee end-device (terminal) respectively. ZigBee network includes a Coordinator, multiple of the Routers and end-devices. ZigBee coordinator must set up a new network functions, and ZigBee routers and ZigBee end-devices need to offer support in a network [12].

2.3 ZigBee Topologies

To perform the analysis of multimedia traffic over ZigBee network, we use some topologies, which gives traffic reception for both image and video transmission. They are,

- Mesh Topology
- Star Topology
- Tree Topology

2.3.1 Mesh Topology

Mesh topology which is shown in the following figure provides a centralized structure wherein the coordinator acts as a central node. All of the nodes i.e. the end devices, routers, and the coordinator can connect with every other. Although it offers high flexibility, it reasons complexity among end to end connections [17]. The structure of Mesh topology is shown in Figure 2. This topology makes use of the energy very correctly and its battery utilization is also better than some other topologies e.g. star.

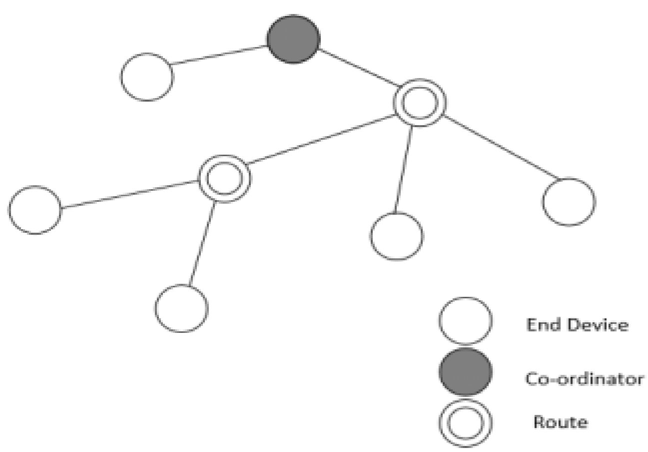


Figure 2: Mesh Topology

Mesh topology also referred to as a peer to peer network. It has several characteristics, which are [9],

- A mesh topology is a multihop community; packets skip through more than one hops to reach their destination.
- The range of a network may be accelerated through adding extra devices to the network.
- It can remove dead zone
- A mesh topology is self-recuperation, meaning at some stage in transmission, if a direction fails, the node will find an alternate direction to the destination
- Devices may be close to other devices in order to use less power
- Adding or deleting a device is easy
- Any source device can connect with any destination device in the network
- Programs such as industrial manage and tracking, Wi-Fi sensor networks, asset and stock tracking use this topology [18].

Every network connection has some advantages and disadvantages. For mesh topology the advantage and disadvantages are:

Advantages of Mesh topology

- Mesh Topology supports high traffic. Simultaneous data transferring from different nodes is possible in this network.
- Failure of one component does not affect the whole topology.
- Without disrupting the whole network new nodes can be connected or removed [19].

Disadvantages of Mesh topology

- Redundancy may occur in this system.
- Mesh Topology is expensive comparing with other network.
- Managing and maintenance of this network is tough [19].

2.3.2 Star Topology

Star topology is the best and most constrained topology in ZigBee. Devices all connect with a single coordinator node and all communication is going through this coordinator. It’s far interesting to be aware that this topology is certainly defined by using the underlying 802.15.4 specification which ZigBee builds on [16]. It has no router and consequently a star topology has an intensity of one [20]. The disadvantage of this topology is the operation of the topologies relies upon at the coordinator of the network, and because all packets among devices have to undergo coordinator, the coordinator may additionally end up bottle necked. Also, there's no alternative direction from the supply to the destination. The advantage of this topology is that it is straightforward and packets undergo at maximum two hops to attain their destination [9]. Zigbee coordinator defines and holds the PAN ID [9]. This topology can consume more power than other topologies. Figure 3 represents the structural diagram of Star topology.

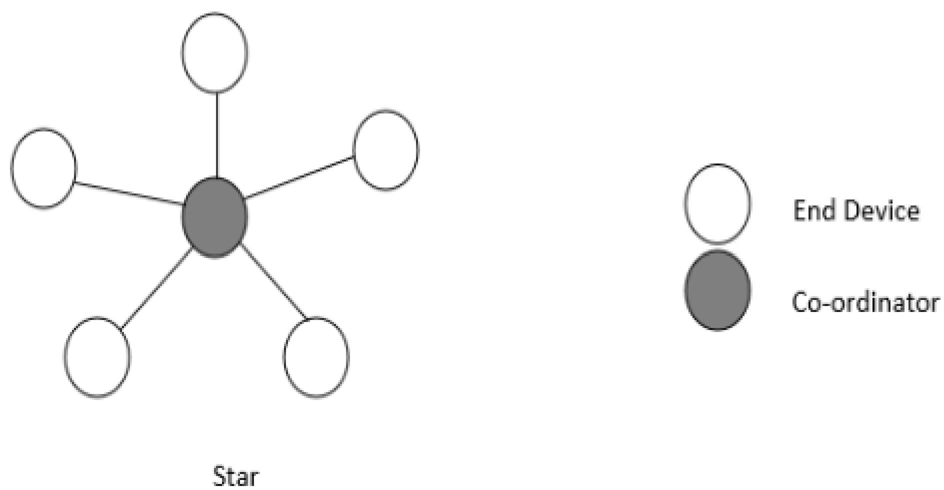


Figure 3: Star Topology

Star topology has some advantages and disadvantages in the network. They are:

Advantages of Star Topology

- Adding and removing new nodes is easy in case of star network as it does not affect other components of the network.
- This network is managed from the central device which makes the monitoring system easy.

- Troubleshooting of star network is easier and failure of one component does not affect others.
- Installation is easy.

Disadvantages of Star Topology

- As the whole network depends on the central device whole network goes down if the central one faces any problem.
- Using hub, router, switch etc. as central device makes the system costly.
- Length of cable is higher than linear bus topology [21].

2.3.3 Tree Topology

In this topology, the network consists of a central node (root tree), which is a coordinator, numerous routers, and end devices. The feature of the router is to increase the network coverage. The end nodes which can be connected to the coordinator or the routers are known as child. Only routers and the coordinator could have child. Every end device is simplest capable of connect with its parent (router or coordinator). The coordinator and routers may have child and, consequently, are the most effective devices that can be parents. Tree topology is illustrated in Figure 4. An end device cannot have child and, therefore, may not be a parent. A unique case of tree topology is known as a cluster tree topology [9].

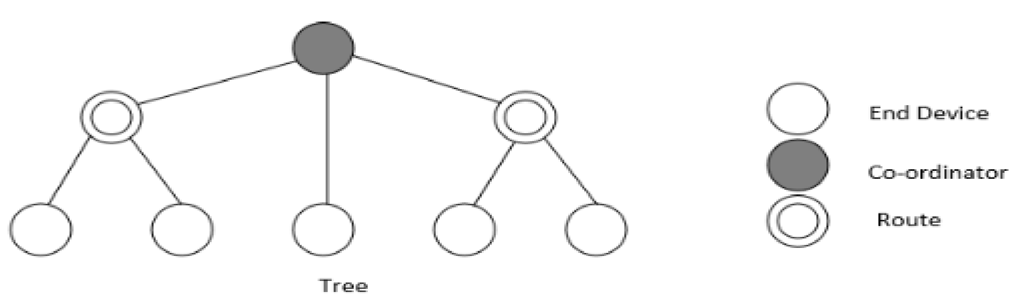


Figure 4: Tree Topology

Advantages of Tree Topology

- Tree Topology is an expansion of Star and bus Topologies, so in systems where these topologies can't be executed separately for reasons identified with adaptability, tree topology is the best option.
- Connecting new device is possible in this network.
- Whole network is divided into segments which makes the maintenance system easy
- Detecting error and solving the problems are easy in this topology.
- Failure of one part of the system does not damage other part of the tree topology.

Disadvantages of Tree Topology

- Tree topology is build based on the bus cable so if it damaged whole network can be broken down.
- Because of connecting more nodes and segments maintenance become tough for the Tree Topology.
- Huge cabling is needed in this network which makes the system complicated [22].

2.4 Riverbed Modeler Academic Edition (MAE)

A careful study is executed on how ZigBee network works. A simulation device became essential to research the performance of the proposed prioritized regions model. Several comparative research have been carried out amongst NS-2, NS-3, OMNET++, MATLAB, and Riverbed. Research show that Riverbed has right potential to perform precisely in simulating the ZigBee WSN; contrarily NS-2 has decrease actual world utility performance. Riverbed setup and configuration are less difficult than others. It is user friendly and has a wide range of acceptance. Intel Core i5 processor and 4GB RAM based workstation was used for Riverbed installation and configuration, for efficient analysis of ZigBee different layers [23].

Riverbed MAE [24] is considered as one of the most leading simulators for network architectures and protocols. This simulator is hugely used in each academia and enterprise. It is a discrete event simulator which runs the simulations with the aid of modeling the activities going on inside the network. Riverbed MAE has been chosen for this paper because it contains a big quantity of models, it has a real life configuration competencies offers graphical result, GUI interface, substantial amount of network protocols library and so on [25].

Chapter 3

3. System Implementation

In this report, I consider a smart home scenario. In this scenario, there are five rooms in this house. Each room has one camera. From these cameras, I get the image data and also video data, send it through the Zigbee coordinator. Here, I also consider three topology e.g. mesh, tree and star topology. By using these topologies, I collect the results and compare them with each other. The steps and topologies scenarios are discussed below.

3.1 Work Flow Diagram

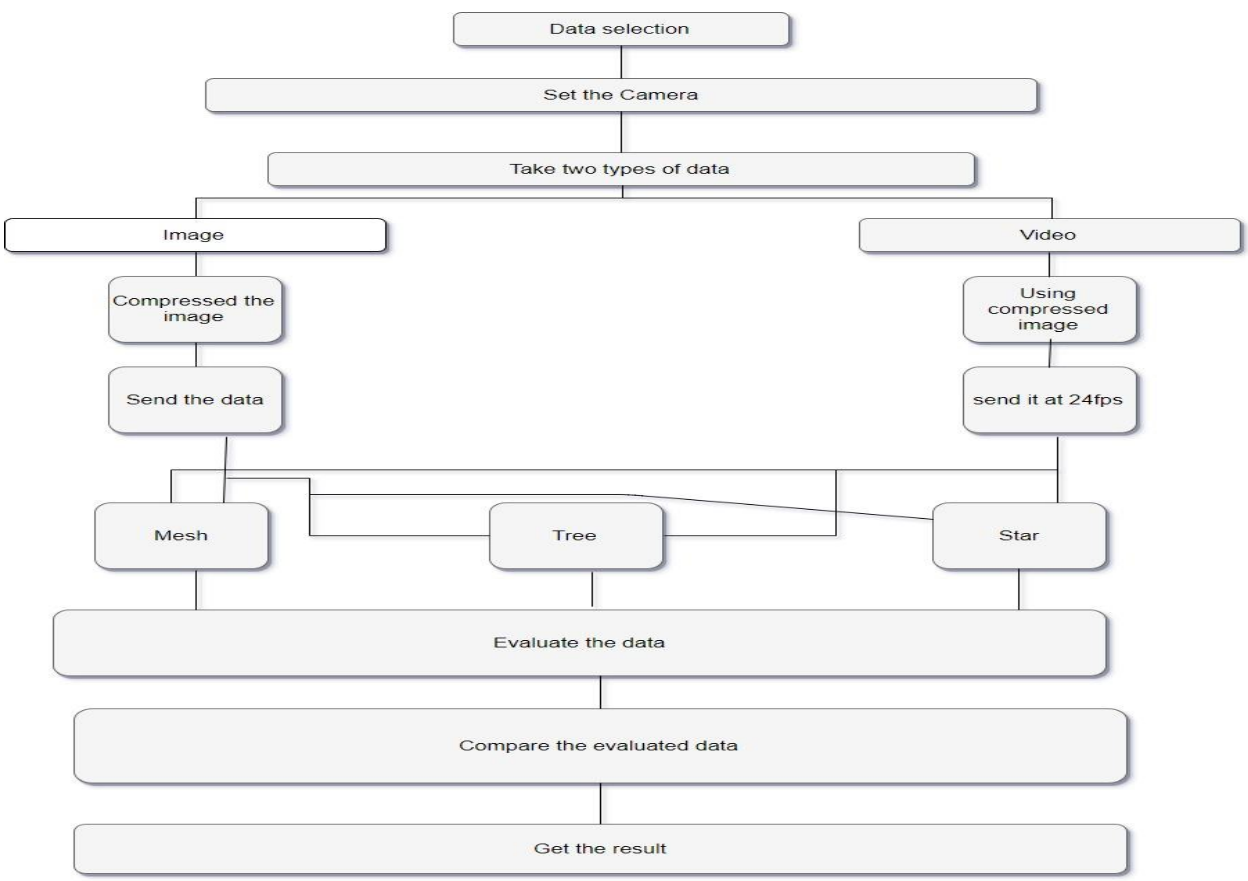


Figure 5: Work flow diagram

3.2 Implementation Details

The two types data used in these whole report are collected from the cameras.

3.2.1 Image

As image files can be significantly big, sometimes image compression methods are needed. There are different image formats like JPEG, PNG etc.

3.2.1(a) JPEG

Joint Photographic Experts Group (JPEG) plays a huge role in today's communicative and multimedia computing world [26]. JPEG is s standard way of compressing the photographic image. There are different types of file extensions like.JPEG, JPG, JFIF etc. Among all of them, JPG is the most common platform for storing images [27]. It is an algorithm that uses an image compression of 24 bits depth. JPEG image quality is denoted by its Q setting and the scaling rate is 0 to 100 [28]. This paper uses JPEG compression method of medium quality (Q=25) [29].

3.2.2 Video

When image is sent continuously at a fixed rate, it can be considered as a video. In this paper, the specification of Zigbee camera is considered based on [30]. The resolution for image is set (320 x 240) pixels. For video transmission, JPEG compression method is used varying 5 Frame per Second (FPS) to 20 FPS. 24 fps which is universally used in case of shooting video [31].

3.2.3 Network Model

The physical layer parameters used are data rate 250 kbps, transmission band 2.4GHz. The size of the data packet has been set to 1024 bits which is a Zigbee default packet size [32]. The simulation parameters are given in Table 1.

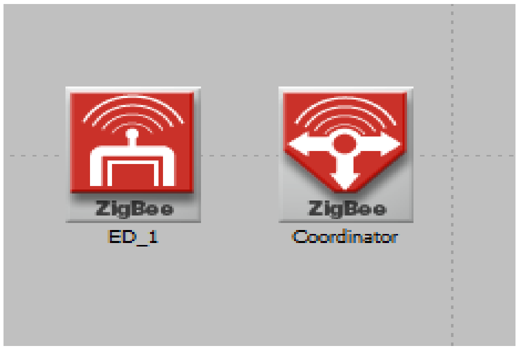
Table 1: Simulation of traffic parameter

Node	Packet Size	Start Time	End Time	Destination
Coordinator	Constant(1024)	Constant(0)	Infinity	N/A
Router	Constant(1024)	Constant(0)	Infinity	Coordinator
End Device	Constant(1024)	Constant(0)	Infinity	Coordinator

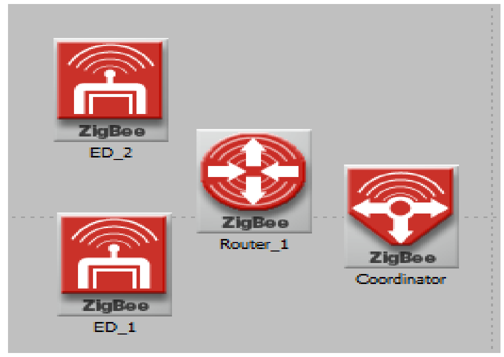
3.2.4 Topologies for this report

3.2.4(a) Mesh Topology

The topology considers a smart home scenario. There are five rooms in the house where up to five cameras are placed as shown in Figure 6(a) to Figure 6(e). Firstly, the result is taken from one end device then two end devices and so on. The end devices are considered as cameras.



(a)



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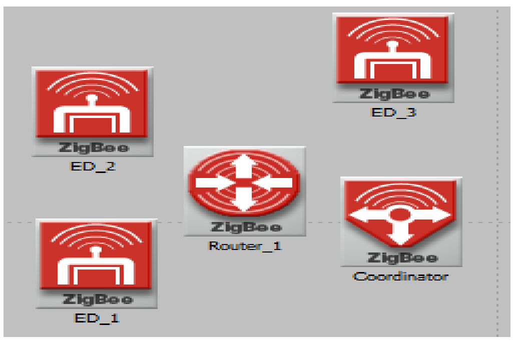
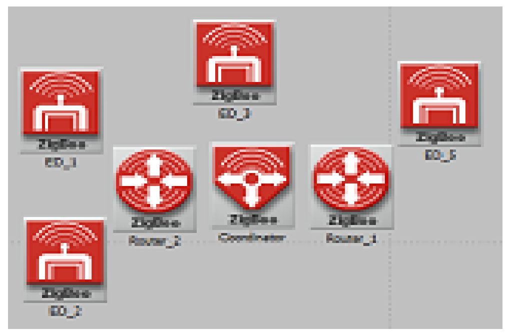
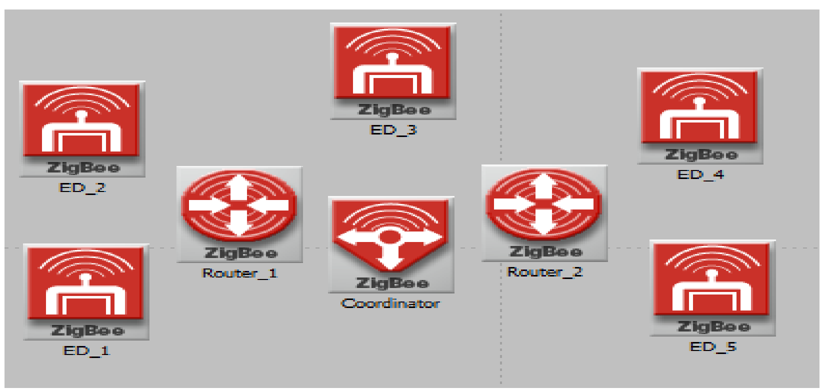


(c)



(d)



(e)

Figure 6: Mesh Topology for a) one end device b) two end devices c) three end devices d) four end devices e) five end devices

3.2.4(b) Star Topology

The Star topology is configured like Mesh topology. There are up to five end devices, one coordinator and two routers as shown in Figure 7(a) to Figure 7(e). For instance in Figure 7(d), Zigbee coordinator is connected with four end devices and one router.

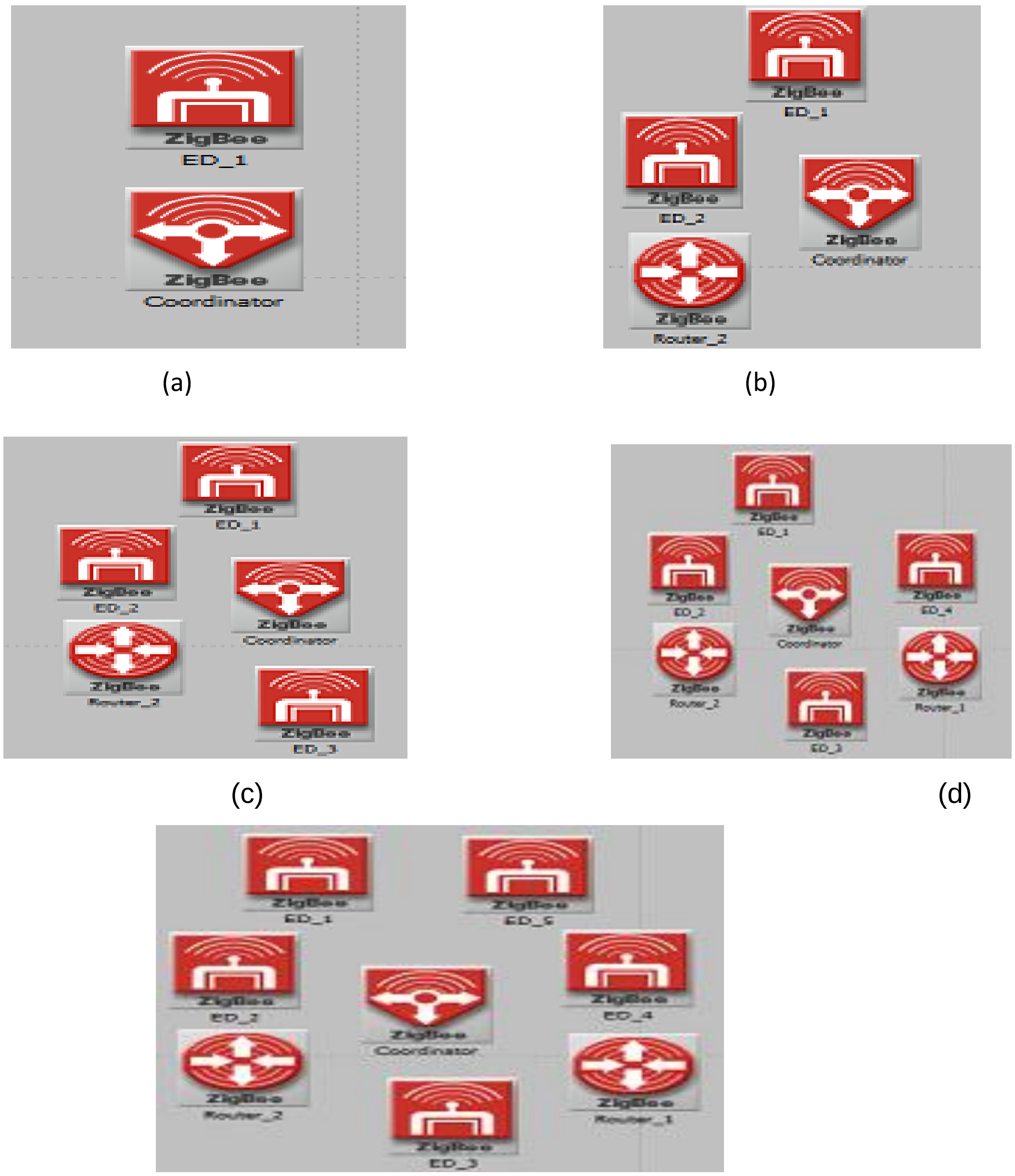
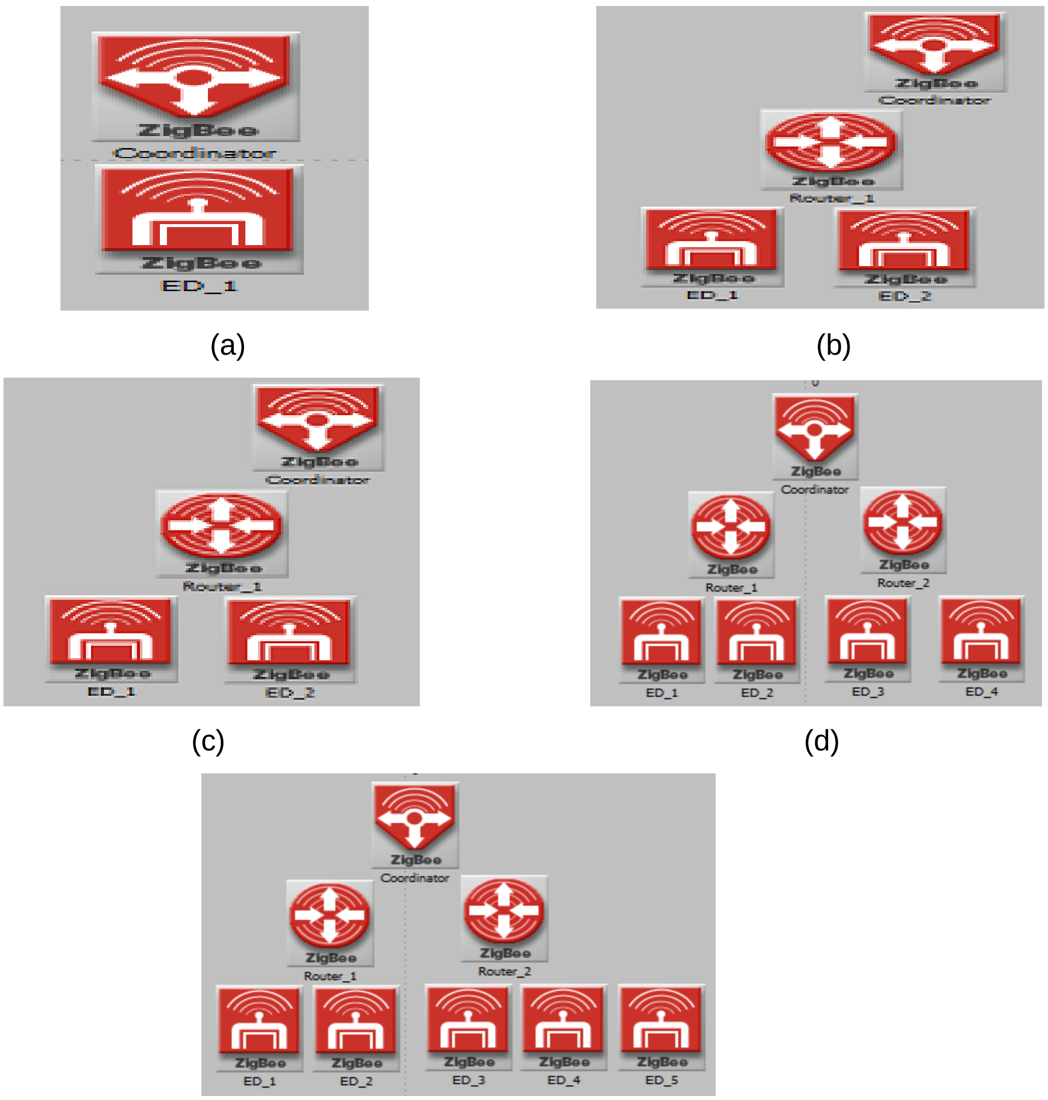


Figure 7: Star Topology for a) one end device b) two end devices c) three end devices d) four end devices e) five end devices

3.2.4(c) Tree Topology

The scenarios shown in Figure 8(a) to Figure 8 (e) show the camera configurations for Tree topology. For example, Figure 8(d) shows that two end devices i.e. ED_1 and ED_2 are connected to one router i.e. Router_1 and other two end devices connected to the other router. And these routers are connected with coordinator.



(e)

Figure 8: Tree Topology for a) one end device b) two end devices c) three end devices d) four end devices e) five end devices

Chapter 4

4. Experimental Result

In this simulation, traffic is generated for image and video transmission. The performances of the topologies are explained in the following subsections.

4.1 Impact on Image Traffic

Figure 9 shows the performance for varying number of end or camera devices for Mesh topology. The traffic reception decreases as the number of end devices increases. This might be caused by the fact that when multiple sources send to the single sink i.e. the coordinator, the network experiences higher congestion and the sink struggles to receive all the traffic. For two end devices, the traffic reception slightly decreases to 68.78 kbps. However, for five end devices, the reception of traffic decreases linearly to 42.492 kbps.

Star and Tree topologies show a similar trend like Mesh topology for varying number of end devices as illustrated in Figure 9, respectively. However, it can be noted that Mesh topology performs better than Star and Tree topologies for varying the number of end devices. Mesh performs better because every node is connected with each other. If one node fails, the network can send the traffic through another node. Star topology performs worse than Mesh due to the fact that all traffic flow through the central node and exhibits traffic congestion. On the other hand, Tree topology performs better than Star because of the network partitioning using a fixed path for sending network traffic to the coordinator.

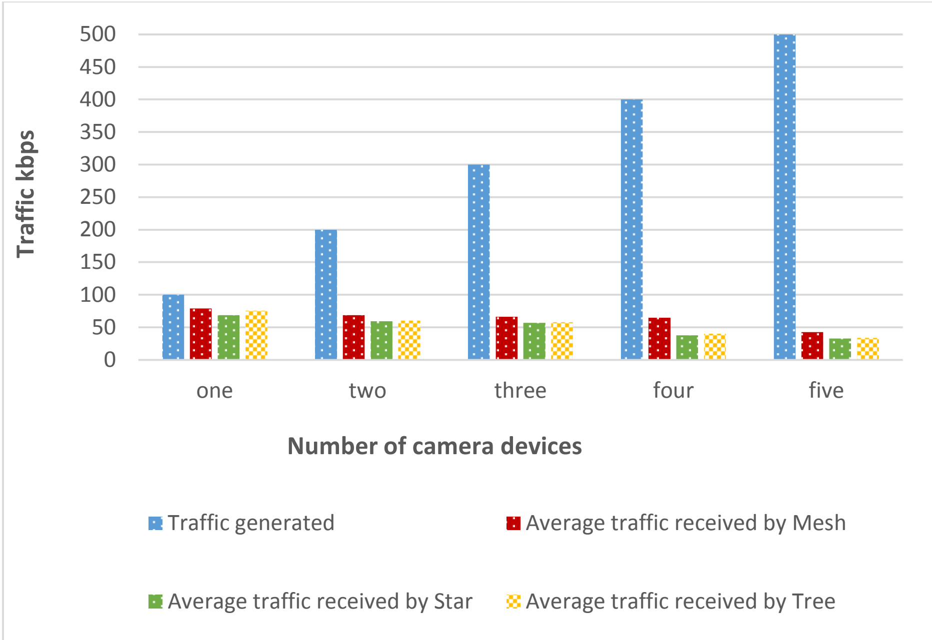


Figure 9: Image transmission for Mesh, Star and Tree topology

4.2 Impact on Video Traffic

Frame rate of 5, 10, 15 and 20 FPS are considered according to [6] in this paper and 24 fps is considered because it is globally used. So, these five fps are considered for the performance analysis of video transmission for three topologies. Video traffic generation for whole network is shown in Figure 10. For one end device, traffic generation is 200 kbps. Traffic generation is getting higher when the number of end devices are increasing.

Mesh topology's performance is shown in Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15 for different frame rates. The performance of traffic reception decreases when the number of end devices and video FPS increase. For 5, 10, 15 and 20 FPS, the traffic linearly decreases to 60.734 kbps which is for five cameras. But for 24 FPS, the traffic reception drastically decreases to 43.146 kbps when five cameras are applied.

In case of Star and Tree topologies, the traffic reception follows the same pattern as in mesh topology for varying number of end devices and frame rates as shown in Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15. Star topology performs worse than Mesh topology. Because in Star topology all traffic is going through one central node and create traffic congestion. Tree topology performs better than Star topology because all traffic follows a fixed path. Overall, Mesh topology outperforms over Star and Tree topologies.

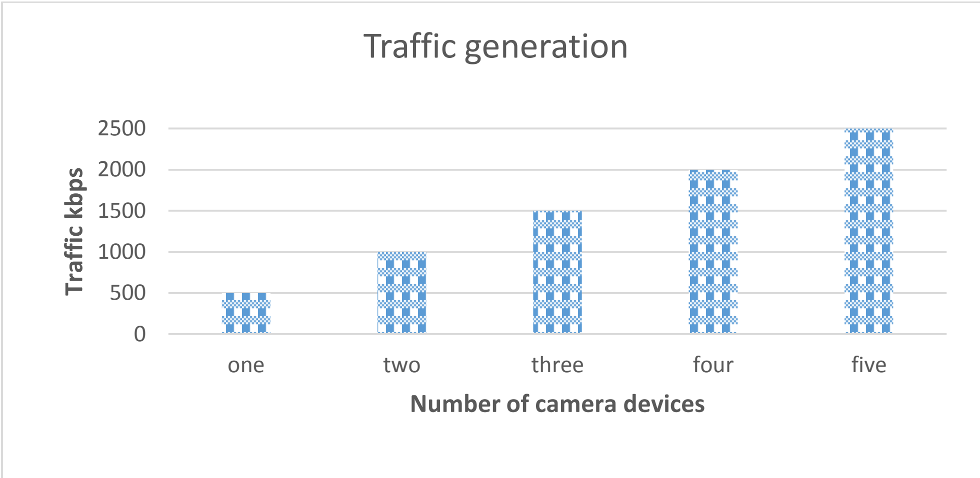


Figure 10: Video traffic generation for Mesh, Star and Tree topology

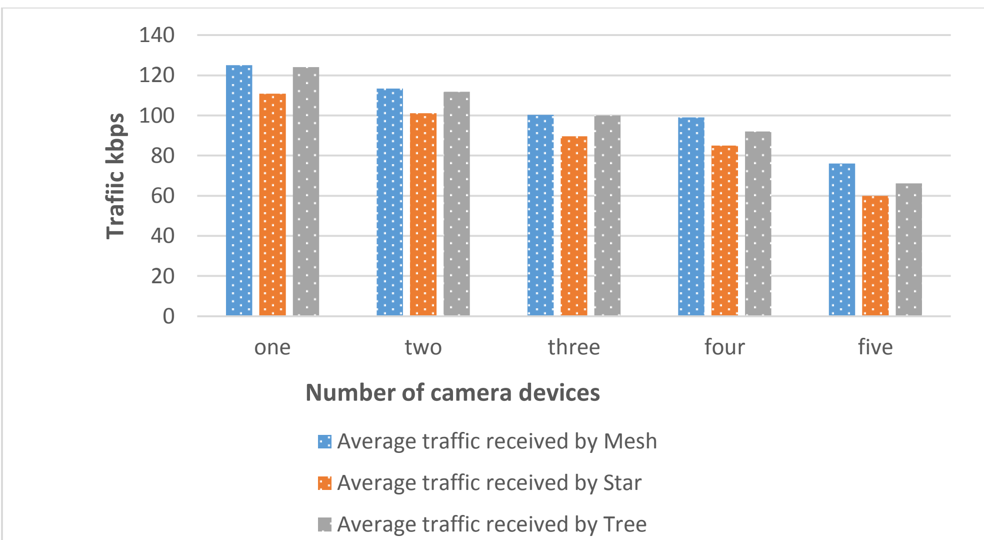


Figure 11: Video transmission for Mesh, Star and Tree topologies at 5fps

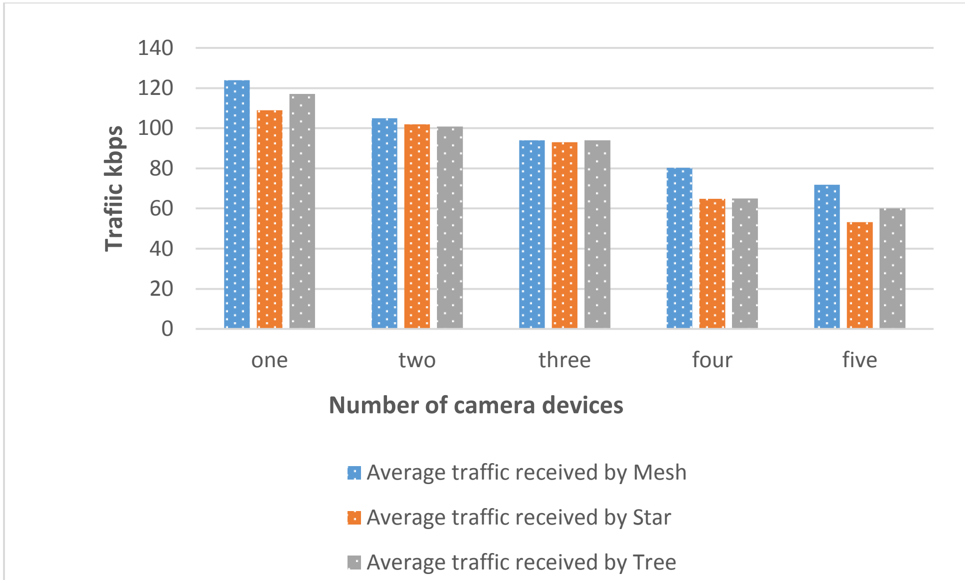


Figure 12: Video transmission for Mesh, Star and Tree topologies at 10fps

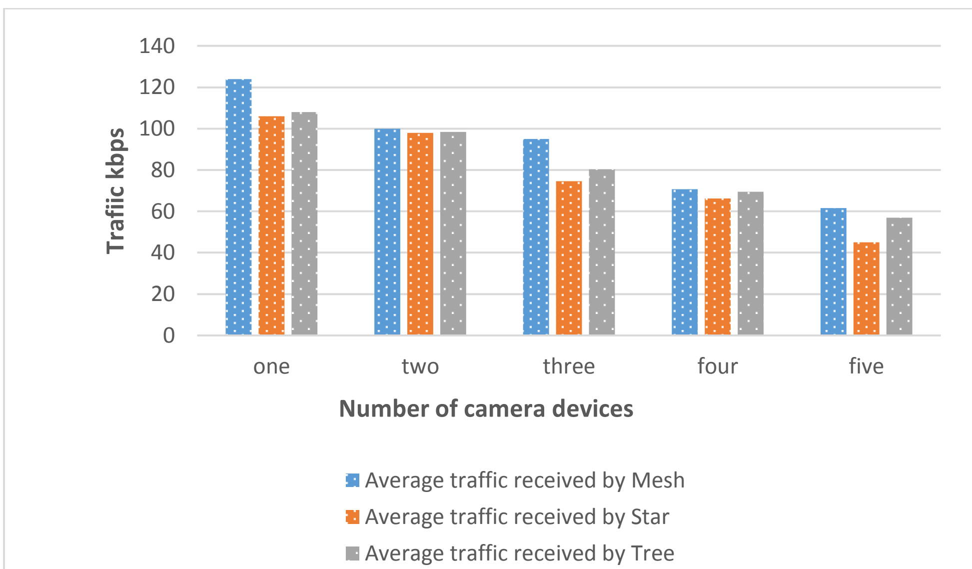


Figure 13: Video transmission for Mesh, Star and Tree topologies at 15fps

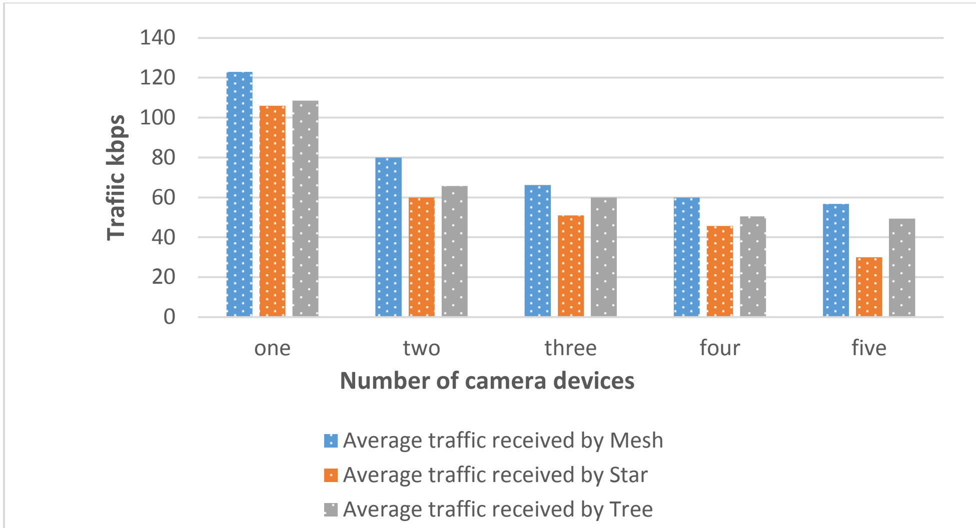


Figure 14: Video transmission for Mesh, Star and Tree topologies at 20fps

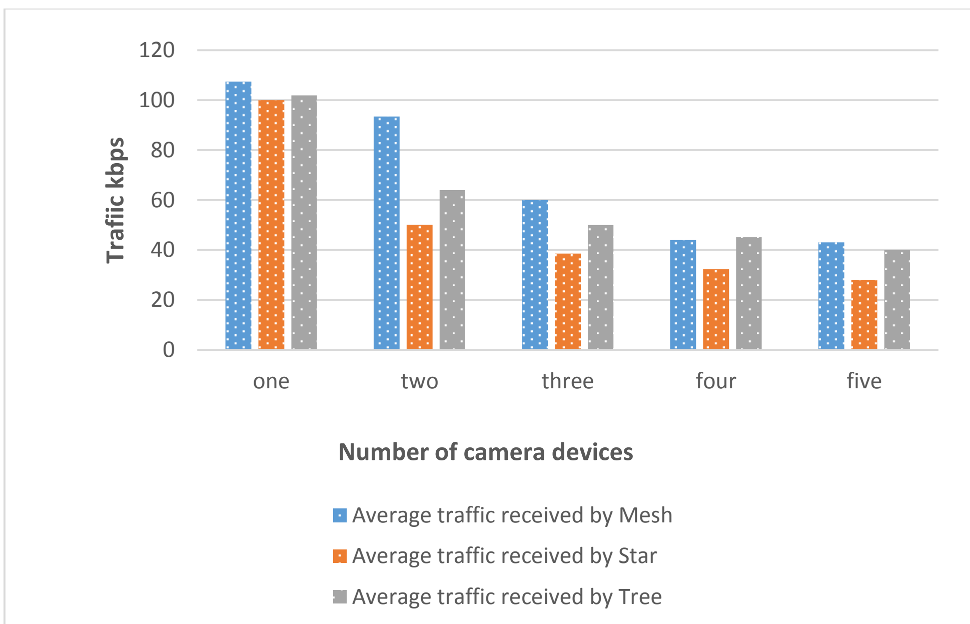


Figure 15: Video transmission for Mesh, Star and Tree topologies at 24fps

Chapter 5

5.1 Conclusion

The ZigBee standard is a wireless communication protocol in terms of low cost, power consumption and proficient battery usage. In this report, the whole scenario which is built here was established on Riverbed Modeler Academic Edition 17.5 simulator for analyzing and studying the performance of the multimedia traffic for Mesh, Star and Tree topologies in terms of traffic reception in the network with respect to number of end devices. With the help of Riverbed MAE the present network was analyzed. The simulation was started to study and analyze the image and video traffic for three topologies e.g. Mesh, Star and Tree by changing the number of end devices in terms of traffic reception. For theses topologies, five scenario was considered. Result is taken from first scenario then second scenario and so on. Mesh topology shows better performance for both image and video traffic than Star and Tree topologies. Tree topology maintains the fixed path and any how if one node stops in that path then that side of the tree network gets disrupted. In Star topology, one single node is responsible for the whole network and if that node fails, network will fall down. In general, as the number of camera devices increases or FPS increase for video, the traffic reception decreases. Although memory usage is increased by holding many alternative routes in the network, using Mesh topology is advantageous. Overall, Mesh topology is better than Star and tree topologies.

5.2 Future Work

This work can be used in home scenario. It will be really helpful for people in their life. This work has been experimented using software. In future, this experiment can be implemented in real life where they can work with actual Zigbee network, router and camera. Moreover, this report has shown a better performance for Mesh topology. I can work further to find a way of developing the performance of both star and tree topology.

Chapter 6

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