Performance evaluation of wireless and wired network topologies

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***Abstract*—Network topology refers how devices are arranged in a communication network. There are various topologies associated with wired and wireless networks and this research paper will focus on the performance evaluation of star topology over tree in both wired and wireless networks. Besides that, other factors include the size of the network in different network types and topologies are discussed over here. NetSim simulation tool is used for evaluating the performance of wired and wireless topologies. As a result, the review claims are proven to be true, wireless networks outperformed wired networks and star topologies had displayed better performances compare to tree topologies.**

Keywords—Wired network, wireless network, network topology

I. INTRODUCTION

We have been in a computerized era for several decades right now. With the computer network technologies nowadays, no devices could be isolated, especially when internet has become the core communication and resource information media. There so many ways to connect computer and devices together to form a network and connecting networks into larger networks that form the internet to keep data transmission from one another. Hence, the physical layout that determines the arrangement and linkages of a network is known as network topology. Devices in a network includes routers, firewalls, switches, access points and peripheral devices [1]. A network topology is able to explain how data are transferred across a network with the help of any network models like the OSI Model to better understand the internet and troubleshoot issues when it arises.

Experts had explained that the few key factors of choosing a network topology that suits consist of consideration of future network expansion, reliability and performance expectation, size of network, level of implementation complexity, hardware resources and lastly budget of the project [2]. Each of the factors correlates and affects one another. Considering the fact that network topologies vary from Bus, Star, Ring, Hybrid to Mesh types [1], they bring unique advantages and disadvantages at different applications and geographical distributions. So as performance and reliability, hence the choice of network topologies in different circumstances would cause effect in all sorts of factors like costing, simplicity, scalability, difficulty in error troubleshooting and effectiveness of a network [3].

In this research, the performance and scalability of network topologies will be evaluated and compared at several circumstances. Circumstances covered in this research includes, the size of network and network type (wired and wireless) and topologies of two kinds (tree and star). Whereas performance measurements are based on throughput, delay, packet loss and jitter. Scalability of network will be measured by saturating the network with workstations until it reaches the bottleneck. In the following chapters, contents covered includes reviews on related works, methodology proposal to be implement, simulation and the results with discussion, lastly conclusion and future work proposal.

II. LITERATURE REVIEW

As mentioned, the logical layout or topologies of computer networks are classified into linear bus, star, ring, mesh, hybrid, tree, point-to-point and many other more. However, a few common topologies of wired and wireless network will be researched and discussed. The few of them includes, bus, star and tree topologies [1], [4]. Hence, related research works on network topology scopes on wired and wireless are discussed below.

A. Computer Network

The first wired network was dated back in 1876 where the telephone inventions sparked wired communication revolution until Ethernet was developed in 1980. Hence, the first standard, IEEE 802.3 was then published in 1983 and was latest revised in 2021[5]. Under the umbrella of network topology consist of physically topology and logical topology which defines how components of the network were arranged physically and the communication data flow respectively. So as the name says, wired networks connect a network of computer or network devices with a wire connection link called Cat 5 up to Cat 8 [6]. Although are now commonly called as LAN cables in layman terms. These connection cables give different performance at different application in terms of frequency and transmission speed requirement. For an example, Cat 8 cables could support larger transmission speed at of 25Gbps and bandwidth of 2000 MHz, comparing with Cat 3 cables that could only support 10Mbps speed and 16 MHz bandwidth [6].

Besides, the choice of network cables that are affected by expected speed and bandwidth required for a target network affects the suitability of topologies according to its properties. In wired networks, the most common topologies used are of bus, star and ring connection. For Ethernet network type where coaxial and Cat3 are used are recommended to use the linear bus and star topologies. Whereas for fast Ethernet, star topology is advised and lastly for gigabit Ethernet that uses Cat5 and above cables are also advised to designed with star topology [7]. A research had found that by implementing star topology in small networks range from 10 to 30 workstations, would cause an increase in delay when workstation increases

in early stages but however averagely have a constant delay [8].

Wireless networks on the other hand, do not require wire cables to connect the end terminals. Wireless devices connect and transmits data through wireless signals like Wi-Fi, infrared and radio waves. Main network component of a wireless network is a wireless access point. However, Cisco had claimed that wireless network has evolved to be more secure and faster compared with wired networks [9]. With the development of wireless networks, standards have been improved from IEEE 802.11n to IEEE 802.11ac and now IEEE 802.11ax had just released this year [10] .

B. Bus Topology

In a bus topology, nodes of the network are connected to a backbone cable which also means that all devices are connected to single network segment. With such layout, all workstation might try to gain access or transfer data simultaneously. On the beneficiary leaf, a bus topology is easy to be installed because it believed to be the most cost effectiveness in terms of cable connection. Besides, such topology is of interests to network that are expected for expansion due to the simplicity of links to new devices. Hence, it is found to be best suit small or temporary systems. However, it could handle only a certain traffic until it reaches bottleneck which then slows the whole network and all data transmission would be halted when there's a fault in the bus [11].

C. Star Topology

After the bus topology, the star topology is now most common network layouts where all nodes centralize into a central hub, all data transmission go through and forth must pass the central hub. Hence, the central hub holds a grave responsibility in keeping up the network, if this hub fails, so as to the whole network. Computers would not able to transmit data to one another without the central hub [12]. On the optimism side, it would be simple for an IT technician to find the root of issues and conduct troubleshoots. More to that, star topologies are proven to give good network performances with reliability, high scalability and compatibility. When devices are disconnected or faulty, it doesn't cause any effect to the other nodes which describes the robustness of a star topology. Its easy to set up by just connecting all nodes to one centralized hub but the number of cables add ups when distances between nodes and hubs increases [11], [13]. Sensing and communication are the two major functions of the WSN and almost every one of us is connected through a wireless device and very much importance is given on the performance of the network we are on [14-15].

D. Tree Topology

Networks of tree topologies is a hybrid layout that combines bus topology and star topology in a hierarchical pattern. It's like a tree as how it was named, a tree trunk which resembles the back bone bus topology and branches are branched out from the trunk consist of star topologies branched out from a string of linear node links. Such topology is believed to best suit larger networks like the ones to be used in corporates and organizations. Tree topologies are great solution for high scalability networks due to its hierarchical nature, new expansion from the backbone could be added easily (Jahejo, 2019)Moreover, such property also ensure robustness of the network as failures of branches would not affect other branches but not the case of the backbone network fails. One main advantage of tree topology is its high compatibility for various devices from different vendors which makes it valuable for big application usage. On the other side, one huge problem about tree topologies is security as the more branches branch out from the main backbone, vulnerability possibly also increases as nodes are interconnected to one another. Hence without proper access control security management, exploits from a single node could easily compromised the whole network. (Roomi, 2021).

TABLE I. PROS AND CONS OF DIFFERENT NETWORK TOPOLOGY

Advantages	Network Topology	Disadvantages
• Simple connection/ layout • Easy to be expanded • Suit small networks	Bus	Network congestion during high traffic
• Ease troubleshoots • Reliable, high scalability and compatibility	Star	Central hub as point of failure
High product compatibility Robust Suit larger networks	Tree	Exist security vulnerabilities

III. METHODOLOGY

The first main study goals of this research are to evaluate the network performance and verify speculations of the advantages and disadvantages of both wired and wireless network at different topologies. Specifically, the star and tree topologies will be compared and studied.

Firstly, the star topology condition is made up by 10 personal computers of consistent distance interval of 50m, a level 2 switch and a router for a wired network simulation. On the other hand, the level 2 switch is replaced with a wireless access point in the wireless network simulation with the same router, personal computers along with the geographical arrangements. However, the network backbone which consist of switch or access point and router are placed at one end of the row of personal computers as illustrated in Figure 1 and 3. All 10 computers are centralized connecting the switch or access point in a wired or wireless network respectively. This is to mimic an actual arrangement in an office whereby routers and switches are normally placed near walls with electricity socket to serve computers nearby.

Furthermore, as for tree topology simulations, additional switches were added into network. Network devices in a wired tree topology consist of 10 personal computers, 6 switches and a router. From the router, two switches were branched out and later further branched out to another two more switches respectively. Among the two end switches, one is connected with 2 personal computers and another with 3 personal computers. Terminal nodes are arranged in the same manner with 50 meters apart. But the switches and access points were arranged in the middle of nodes connected with router placed at the middle of the two switches branched out from the router as displayed in Figure 5 and 7. Such arrangement is to mimic separation of rooms in an office, whereby each room have their own switches and access point.

Wired and wireless networks packets transmit with routing protocol OSPF in the application layer, TCP protocol in transport layer. Whereas for wireless networks in both

topologies implements IEEE802.11n wireless standards with high throughput (HT) transmission type of 100mW transmitter power, 1 meter antenna height and frequency band of 2.4GHz. Whereas wired networks implement the common Ethernet and ARP protocol. The network performance are then be simulated by transferring packets of 1460 bytes on TCP protocol.

All four networks of different network type and topology is then simulated with bigger network size by expanding computer end node to 24 with the same backbone devices. This is to investigate the impact of network size to the performances of different networks. Besides, the scalability of different network topologies could be evaluated based on performance after expansion of network.

IV. SIMULATION

In this chapter, simulation of above methodology is conducted using network simulator and emulator, NetSim Academic. The simulations consist of wired and wireless network each with star and tree topologies. Besides that, each topology will also be simulated

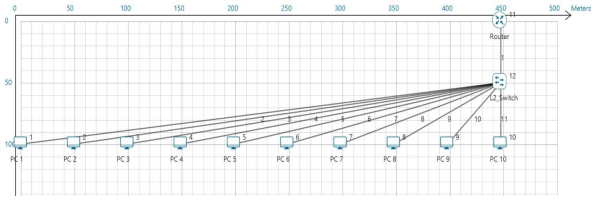

Fig. 1. Logical topology of small wired star topology network simulation

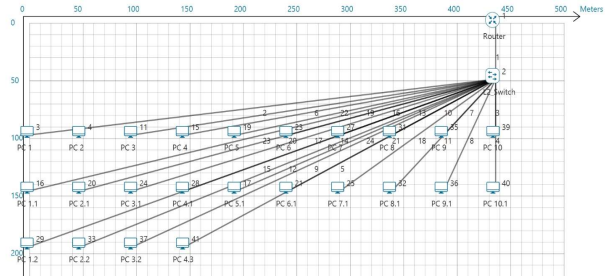

Fig. 2. Logical topology of big wired star topology network simulation

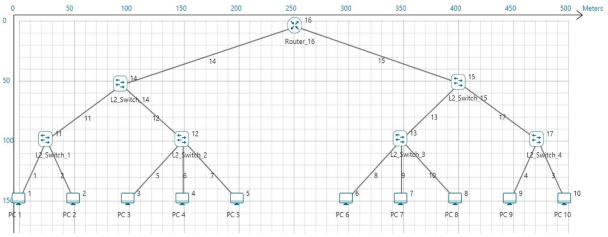

Fig. 3. Logical topology of small wired tree topology network simulation

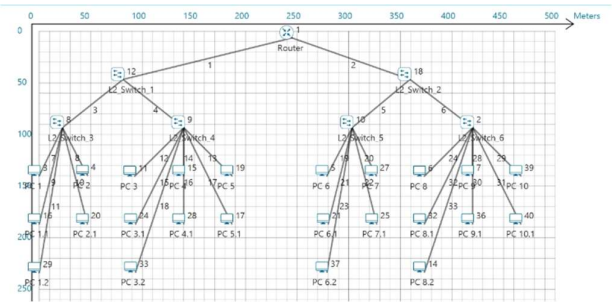

Fig. 4. Logical topology of big wired tree topology network simulation

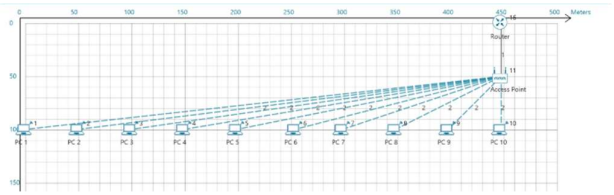

Fig. 5. Logical topology of small wireless star topology network simulation

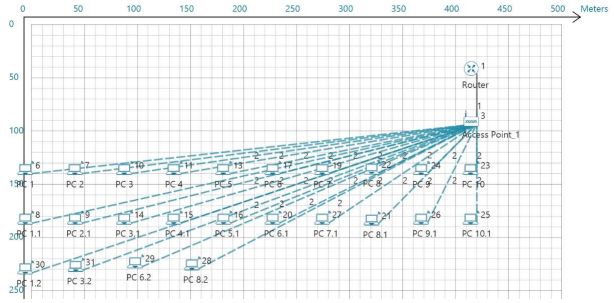

Fig. 6. Logical topology of big wireless star topology network simulation

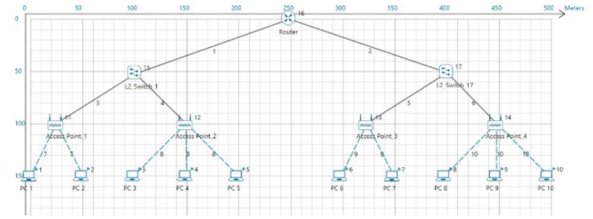

Fig. 7. Logical topology of small wireless tree topology network simulation

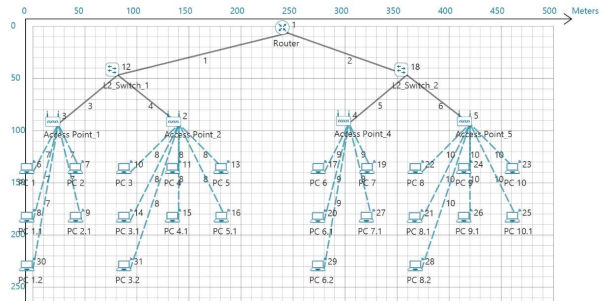

Fig. 8. Logical topology of big wireless tree topology network simulation

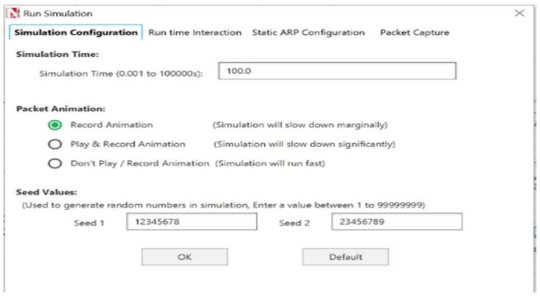

Fig. 9. Simulation configuration

V. RESULT AND DISCUSSIONS

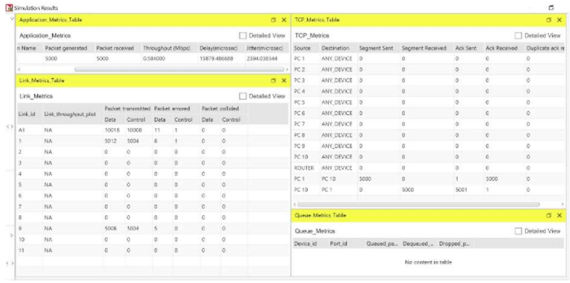

Fig. 10. Simulation results of small wired star topology network

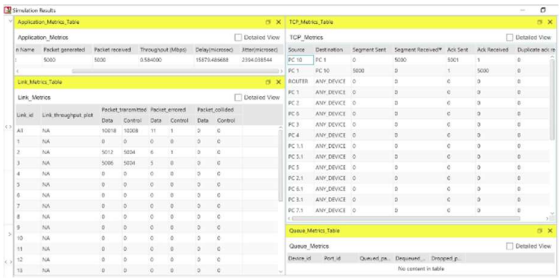

Fig. 11. Simulation results of big wired star topology network

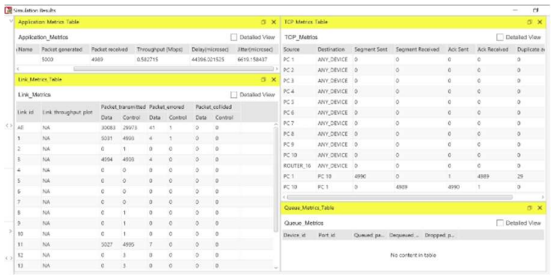

Fig. 12. Simulation results of small wired tree topology network

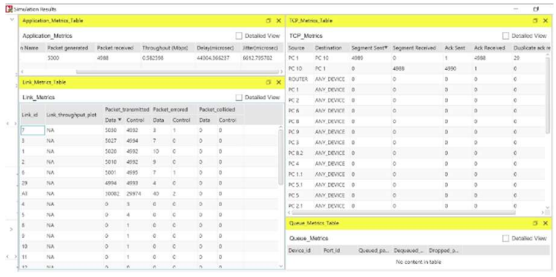

Fig. 13. Simulation results of big wired tree topology network

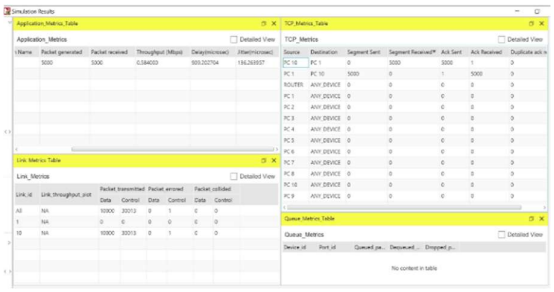

Fig. 14. Simulation results of big wired tree topology network

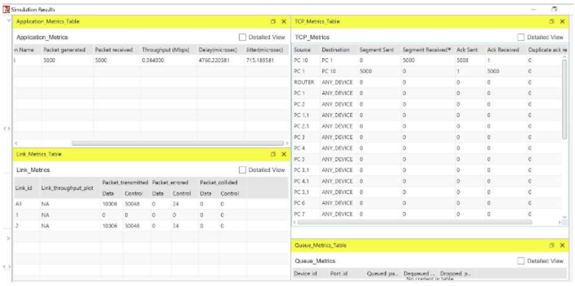

Fig. 15. Simulation results of big wireless star topology network

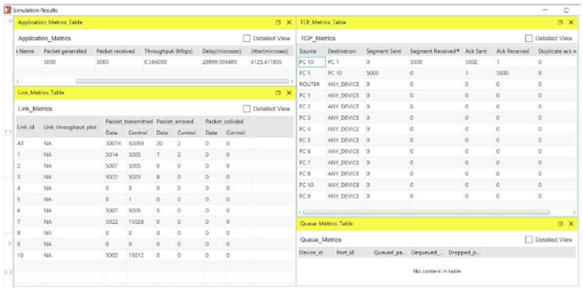

Fig. 16. Simulation results of small wireless tree topology network

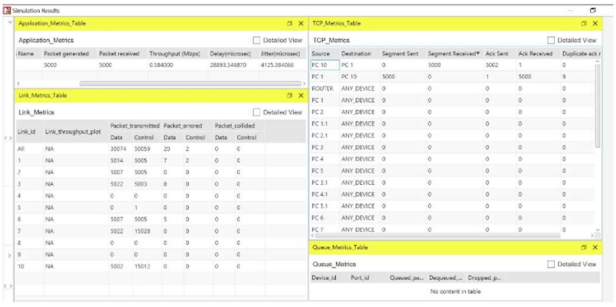

Fig. 17. Simulation results of big wireless tree topology network

TABLE II. NETWORK PERFORMANCES OF SIMULATIONS

Network			Performance			
Type	Size	Topology	Throughput (Mbps)	Delay (microsec)	Jitter (microsec)	Loss (qty)
Wired	Small	Star	0.58400	15879.48669	2394.038544	0
		Tree	0.58272	44396.02153	6619.158437	11
	Big	Star	0.58400	15879.48669	2394.038544	11
		Tree	0.58260	44304.36624	6612.795702	12
Wireless	Small	Star	0.58400	909.202704	137.263957	0
		Tree	0.58400	28899.00648	4125.471805	0
	Big	Star	0.58400	4760.220581	715.189581	0
		Tree	0.58400	28893.54687	4125.384066	0

TABLE III. NETWORK PERFORMANCE RANKING

Ranking	Network			Performance	
	Type	Size	Topology	Throughput (Mbps)	Delay (microsec)
1st	Wireless	Small	Star	0.584000	909.202704
2nd	Wireless	Big	Star	0.584000	4760.220581
3rd	Wired	Small	Star	0.584000	15879.48669
4th	Wired	Big	Star	0.584000	15879.48669
5th	Wireless	Big	Tree	0.584000	28893.54687
6th	Wireless	Small	Tree	0.584000	28899.00648
7th	Wired	Big	Tree	0.582600	44304.36624
8th	Wired	Small	Tree	0.582720	44396.02153

Network performances in the simulation conducted were based on parameters, throughput, delay and jitter. The amount of data transmitted from a source at a given period of time in unit megabits per second (Mbps) are called as throughput. Whereas delay in microseconds unit is represents latency of data transmission from one point to another. Besides that, data packets can be delayed during transmission due to network congestion and such condition could drag down quality of audio and video in travelling data packets. Hence, well performing networks would display traits of high throughput, small delays and jitters because it represents more data are travelled by taking lesser time of communication and vice versa.

Based on the result obtained from the simulation conducted, network with highest throughput were shown in system arranged in star topologies for wired networks along with wireless networks that were arranged in star and tree topologies. This shows that network throughputs are mainly affected in wired networks of different topologies, which in this case star topology did performed slightly higher throughput comparing with tree topology. But not in the case for wireless network, the throughput do not change no matter the network size and arrangement. Besides that, among the wired tree topology networks, the size of the network did show slight difference in throughput whereby a smaller network (10 computers) have higher throughput than a bigger network (24 computers).

On the other side, longest delay was presented in the smaller sized wired tree topology with 44,396 microseconds leading among all other networks. Despite the fact that a smaller wired tree topology has higher delay than a bigger one, there wasn't any changes between the wired star topologies of difference size. Network delays were the lowest in wireless networks, especially the small star topology with 909 microseconds, which it was technically faster than by the same network but wired type by 17 times. However, as a star topology wireless network expands, so as data packet delay, although not for wireless tree topology. Data delay were almost the same between smaller and bigger tree topology.

Jitter performance trend were similar to network delay due to the close relation between them. Jitter was at the highest in small wired tree topology so as delay performances. The same goes to the similarity of jitter of wired star topologies of all size, lowest jitter in small star topology wireless network, similarity of jitter in wireless tree topology of any size and lastly it worsens when star arranged wireless network expands.

These character results differ from wired and wireless mainly due to the a few reasons. Firstly, the way data were transmitted in wired networks were through network cables as the name says and wireless network uses radio waves. Radio waves are able to travel longer distances with lesser travel resistance. On the other hand, network cables are main cause of communication resistance. The wrong type and longer cables will hinder and slow down movement of packets, not to mention the packets loss along the cables as shown in Table 2. Hence, no matter the size here, wireless network still wins. Secondly, the huge performance difference between star and tree topology is mainly due to the higher amount of "hierarchy level" that the packets have to climb up to get to find the common ground with the recipient to able to send out the packets to the right computer. Besides, OSPF routing protocol used in the application layer by the routers is assumed to worsen performance of tree topologies in this research. In every layer the data packet reaches, calculation to find the shortest path needs to be done, hence the more hierarchy it is the more calculation needs to be done.

The below Table 3 summarizes the best performing networks by ranking in descending order. Lastly by analyzing networks of the same network type and topology, the star topology definitely possesses high potential of scalability. This is because no matter whether it's wired or wirelessly connected, performances after expansion compare to the before decline are fairly acceptable. This research also did proved claims of related research that states star topologies better suits smaller networks and tree topologies perform better at bigger networks. Based on Table 3, all smaller sized star topology network out-performed bigger sized ones. Whereas in tree topologies, bigger networks definitely shown better performance than smaller networks.

VI. CONCLUSION

In a nutshell, performances, scalability and several claims of related researches on star and tree topology of wired and wireless network depending on network sized were completed in this research. By considering the network size limitation of 10 to 24 computers conducted in this research, wireless network had overall out-performed wired networks. In terms of topology, star-typed topology has defeated tree topology in terms of performance and scalability. Small networks like as simulated in this paper is best suit to use star topologies instead of tree topologies and vice versa on bigger networks. Therefore, while designing for a network, much consideration should be done on the estimated current and future network size to determine the best suitable topology and network type for an excellent network performance.

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