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Performance Analyze of Fog Computing Against Topology Using YAFS Fog Simulator

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Abstract: This research focuses on the analysis of fog computing performance on mesh, star, and ring topologies using the YAFS Fog Simulator. The reason YAFS (Yet Another Fog Simulator) was chosen was based on the consideration that this fog computing simulator, among other things, was designed to analyze topology and load balancing as well as include processing time for data transfer between devices into the fog layer. In addition, YAFS has a better level of time processing accuracy than other fog simulators. There are three test scenarios with additional load which includes 4, 8, and 12 fog nodes in each topology. Each scenario also has an additional load which includes 4, 8, and 12 devices in the form of sensors and actuators, respectively. The experimental results from the three scenarios show that the greater the load from the fog node and equipment, the longer the processing time will be. In addition, the results of the three scenarios also show that the mesh topology has the best time processing accuracy among the three tested topologies.

Keywords: Fog Computing; YAFS; Star Topology; Mesh Topology; Ring Topology

INTRODUCTION

Integration between cloud computing and IoT devices is limited by the resources to move data from IoT devices to the cloud. A centralized cloud system causes the topology to require reaching long distances between the cloud and IoT devices. Because the distance is so far, several problems may arise. The problem is in terms of latency, where several IoT device domains are included in URLLC (Ultra-Reliable Low-Latency Communications) (Fahimullah et al., 2023). Several IoT devices having bad data or signal transfer quality if used to send and receive very large amounts of data may cause data transmission to fail. Responding to these big problems, a computing solution is established between IoT devices and the cloud. This new computing is called fog computing.

Fog computing is a computing that becomes an intermediary to expand the spread of cloud computing in terms of computing and storage. In addition, fog computing is also tasked with executing applications to be closer to Internet-of-Things (IoT) devices as placement and allocating services from the Internet-of-Things itself (Margariti et al., 2020). Fog computing was first introduced by Cisco in 2012 and predicted that by 2020, approximately 50 billion devices worldwide would be connected to the internet and information from Internet-of-Things devices would amount to 500 zettabytes. In 2019, 45% of the data generated from the Internet-of-Things would be processed, analyzed, and stored on edge

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networking (Neware, 2019) (Rabay'a et al., 2019). This results in all nodes in fog computing tending to be closer to IoT devices using local services that are connected to one another. Structurally, fog computing consists of three layers, namely the edge layer, fog layer, and cloud layer.

Fog computing can optimize Quality of Service (QoS), especially in terms of latency, bandwidth, response time, processing time, privacy, and security (Singh et al., 2021). In addition, fog computing is also an alternative for storing data and local network capabilities (Dlamini, S. & Ventura, N., 2019). Fog computing itself consists of several nodes that are connected to one another through the topology used. These nodes are the start of the fog computing mechanism in which data transfers from Internet-of-Things devices will be received. The data transfer is then entered into a scheduling process to measure bandwidth, delay, latency, and privacy before entering the cloud.

The purpose of fog computing in the IoT device mechanism is to distribute and transfer data quickly into the central cloud (Dlamini, S. & Ventura, N., 2019). This is because the edge layer has limited data storage, and the nodes, whose job is to mobilize data, are also unreliable in terms of connectivity and causes a decrease in data transfer or even worse, the occurrence of interruptions and a lot of packet loss due to the large number of data queues entering in the edge layer.

Examining performance on fog computing in real terms requires a lot of resources and costs. For this reason, a simulator was created to make it easier for researchers to simulate fog computing as it exists in the real world. There are lots of fog computing simulators such as iFogSim, FogDirSim, and YAFS, each with its own advantages. However, the focus of this research is using YAFS as a simulator of fog computing.

YAFS (Yet Another Fog Simulator) is a fog computing simulator specifically designed to analyze and test the performance of fog computing which consists of IoT devices in the form of sensors and actuators, fog nodes, and related network resources. YAFS was first released in 2019 using python version 2.7 and in 2021, YAFS made several updates to support python version 3.6 and above as well as adding newer scenario examples (Lera et al., 2019). This simulator is designed to analyze a very complex fog computing architecture. YAFS provides simulations to model network topologies, manage resources on Internet-of-Things devices, and simulate data traffic flows in the computing process. Unlike other fog computing simulators, this simulator provides various features such as task scheduling, load balancing, performance analysis, and optimization of the fog computing system.

The load balancing feature on YAFS is a feature that distributes node loads evenly in a fog computing system with the aim of preventing overload to ensure optimal resource use and optimize system performance. This feature works seamlessly with the task scheduling feature, which manages data transfer routes between nodes. With the synergy between the load balancing feature and task scheduling, data transfer between device nodes and fog nodes can work optimally.

With simulators like YAFS, users can test and compare fog computing performance schemes as well as optimize resource use and improve overall efficiency. YAFS can simulate accurately and flexibly so that users can make good decisions in designing and managing fog computing systems.

LITERATURE REVIEW

Fog Computing

Fog computing is a platform that becomes an intermediary and completes the architecture between cloud computing and edge computing (Margariti et al., 2020). The most prominent feature of fog computing itself is in the decentralization section where cloud computing will transfer processed data to the edge where the data is then ready for use by Internet-of-Things devices (Sabireen & Neelanarayanan, 2021).

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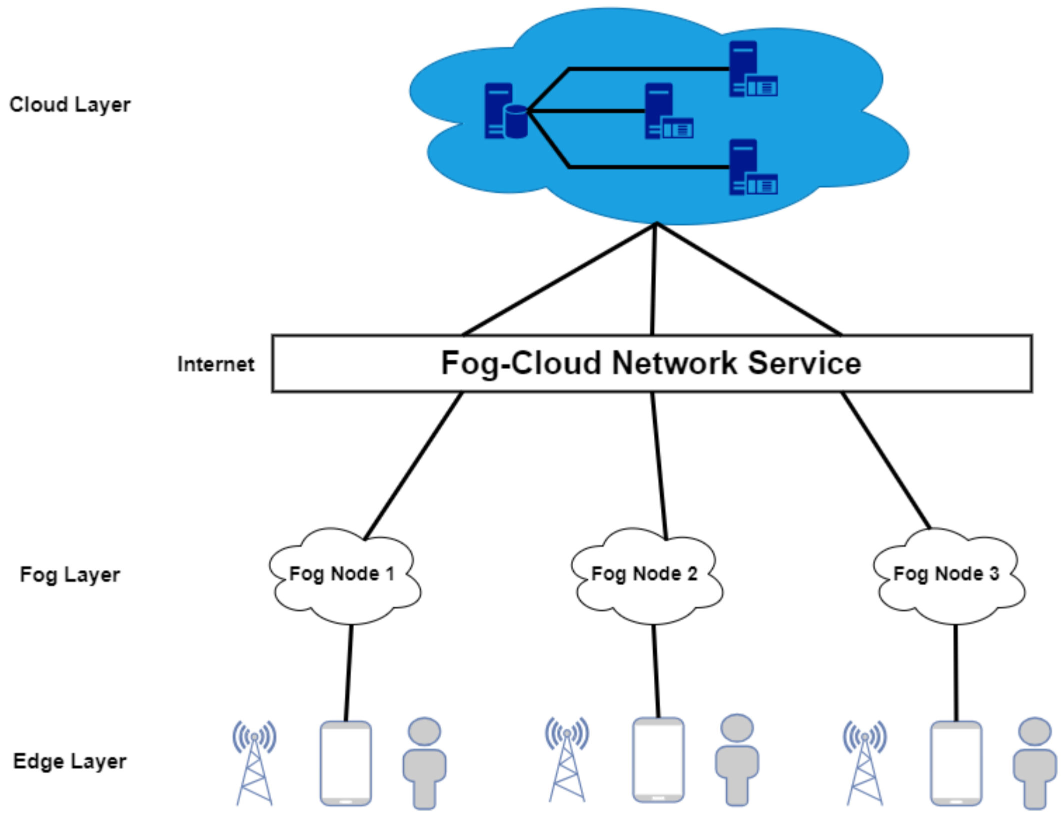

Fig. 1 Fog Computing Architecture (Neware, 2019)

The edge layer includes Internet-of-Things devices that capture all information actually and accurately and is able transfer, store and process data that has been processed on each device. Meanwhile, the fog layer has many nodes, such as switches, routers, access points, and fog server gateways (Neware, 2019). This fog layer facilitates connectivity that is linked between the cloud and the edge and has power in terms of data transfer, storage, time, and delay (Abdali et al., 2021). Each node in fog computing is connected to one another with the data centers in cloud storage to obtain larger storage and higher data transfer rates (Singh et al., 2021). The cloud layer itself consists of various servers which are responsible for storing the highest data and information stored on the server indefinitely.

YAFS

YAFS (Yet Another Fog Simulator) is a fog computing simulator that is designed to analyze scheduling and routing strategies. YAFS itself includes several functions such as response time, network delay, and waiting time. YAFS can support data transfer via JSON so that it can process dataset transfer scenarios. YAFS uses the simpy python library where this library supports the Discrete-Event Simulator (DES) process to execute in three modes, namely modes that can do it as fast as possible, real-time, and manually (Lera et al., 2019).

Star Topology

Star topology is a topology that is interconnected to form a star where there is one node as the center of connectivity (Permana et al., 2020). This topology is usually used to connect several devices to a central device or server. Star topology can be used on small or large networks, depending on the number of connected devices. In the star topology, each device is connected to a central device as a network controller and transmits data from one device to another. The star topology can improve network performance and security in fog computing architectures, as well as simplify network management and monitoring.

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Mesh Topology

Mesh topology is a topology that connects each node to one another. Mesh topology can be done wirelessly, and this makes mesh topology almost like Wireless Sensor Networks (WSNs) (Nurlan et al., 2021). The mesh topology is very well used to analyze the response time and the delay at each node in a stable manner. This topology allows each device to be directly connected to several other devices in the network, so that there is more than one connection path between the two devices. The mesh topology can be used on small or large networks, depending on the number of connected devices. The mesh topology can also improve network reliability and availability in fog computing architectures, as well as allow for more connection lines for data transmission.

Ring Topology

Ring topology is a type of network topology that is used to connect several devices in a computer network. In this topology, each device is connected to other devices to form a circle or ring (Rokhayah, R. & Syambas, N., 2020). Data is sent from one device to another in the same direction as the circle. Ring topology can also be used in fog computing architectures, where edge devices are connected to several other devices to form a circle. Ring topology can increase data transmission speed on fog computing architectures, as well as simplify network management and monitoring to be tested.

METHOD

In this research designed a simulation system on YAFS to simplify obtaining the fastest processing time results between the star, mesh, and ring topologies. The steps that must be carried out to obtain time processing results are namely determining the number of resources on the fog node and devices node. There are three scenarios tested with the addition of load balancing on fog nodes 4, 8, and 12 fog nodes.

System Specification

Table 1. System Specification

Resource	Fog	Sensor	Actuator
RAM	40 MB	10 MB	4 MB
Bandwidth	1 kbps	1 kbps	1 kbps
20 WATT	20 WATT	40 WATT	40 WATT

In the system specification, three resources are determined, namely RAM, bandwidth, and WATT in fog, sensors, and actuators as shown in table 1 below. The three specified resources greatly influence the results of the three scenarios applied.

Scenario With 4 Fog Nodes

In scenario 1, there are 4 fog nodes and several devices which include sensors and actuators. This scenario is also divided into 3 sub-scenarios including 4, 8, and 12 devices for each topology tested in YAFS.

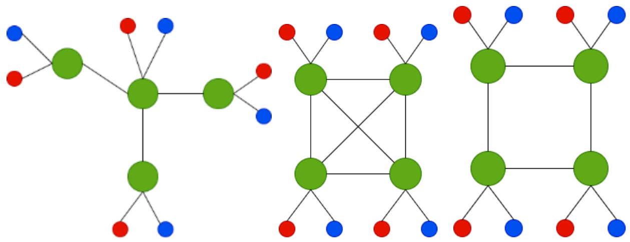

Fig. 2 Sub Scenario of 4 Fog Nodes with 4 Devices in Star, Mesh, and Ring Topology

Figure 2 above is a sub-scenario of 4 devices with 4 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

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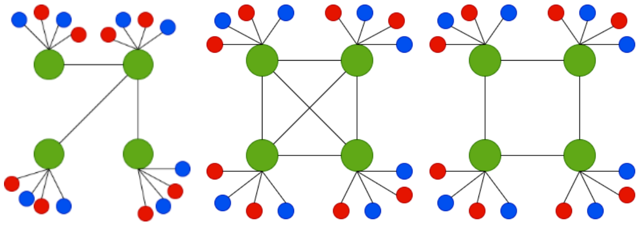

Fig. 3 Sub Scenario of 4 Fog Nodes with 8 Devices in Star, Mesh, and Ring Topology

Figure 3 above is a sub-scenario of 8 devices with 4 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

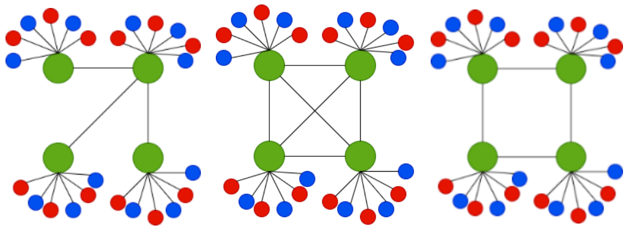

Fig. 4 Sub Scenario of 4 Fog Nodes with 12 Devices in Star, Mesh, and Ring Topology

Figure 4 above is a sub-scenario of 12 devices with 4 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

Scenario With 8 Fog Nodes

In scenario 2, there are 8 fog nodes and several devices which include sensors and actuators. This scenario is also divided into 3 sub-scenarios including 4, 8, and 12 devices for each topology tested in YAFS.

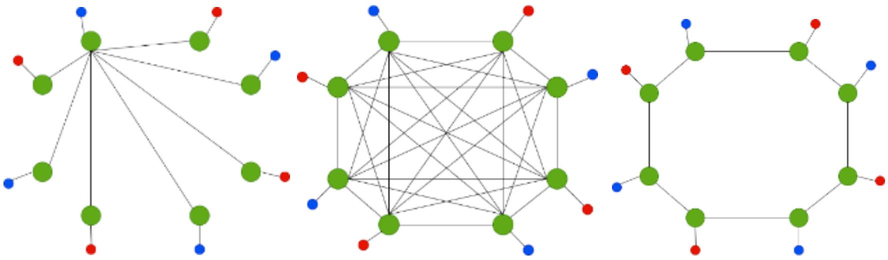

Fig. 5 Sub Scenario of 8 Fog Nodes with 4 Devices in Star, Mesh, and Ring Topology

Figure 5 above is a sub-scenario of 4 devices with 8 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

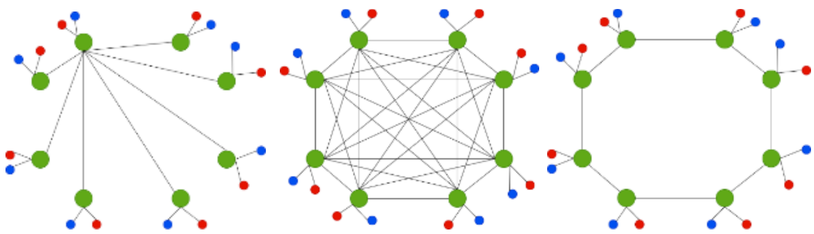

Fig. 6 Sub Scenario of 8 Fog Nodes with 8 Devices in Star, Mesh, and Ring Topology

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Figure 6 above is a sub-scenario of 8 devices with 8 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

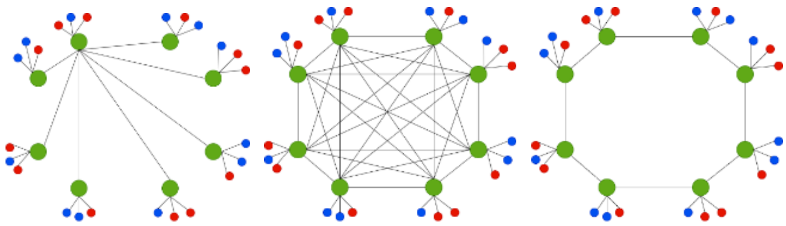

Fig. 7 Sub Scenario of 8 Fog Nodes with 12 Devices in Star, Mesh, and Ring Topology

Figure 7 above is a sub-scenario of 12 devices with 8 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

Scenario With 12 Fog Nodes

In scenario 3, there are 12 fog nodes and several devices which include sensors and actuators. This scenario is also divided into 3 sub-scenarios including 4, 8, and 12 devices for each topology tested in YAFS.

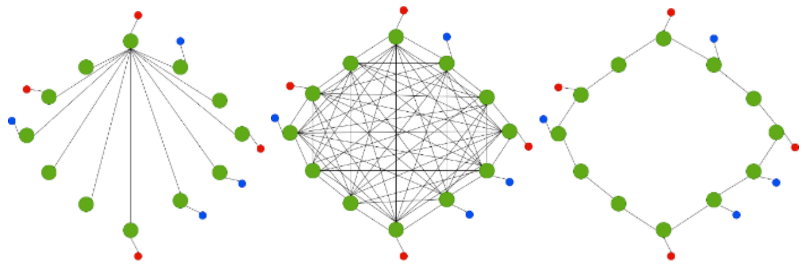

Fig. 8 Sub Scenario of 12 Fog Nodes with 4 Devices in Star, Mesh, and Ring Topology

Figure 8 above is a sub-scenario of 4 devices with 12 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

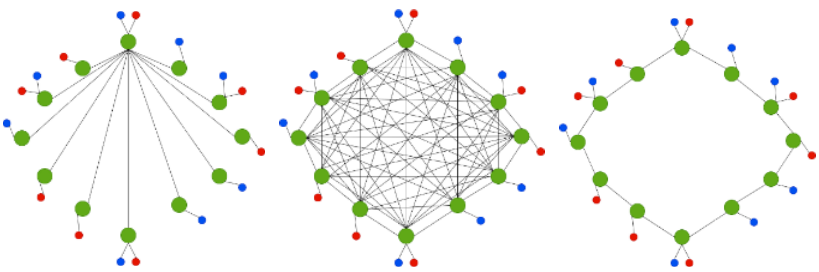

Fig. 9 Sub Scenario of 12 Fog Nodes with 8 Devices in Star, Mesh, and Ring Topology

Figure 9 above is a sub-scenario of 8 devices with 12 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

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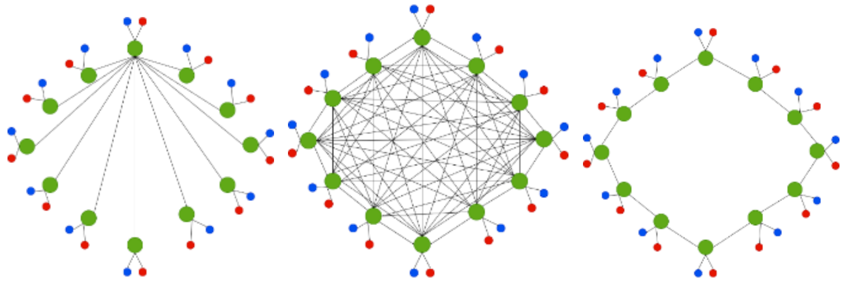

Fig. 10 Sub Scenario of 12 Fog Nodes with 12 Devices in Star, Mesh, and Ring Topology

Figure 10 above is a sub-scenario of 12 devices with 12 fog nodes in testing using the star, mesh, and ring topology in which the green color in the image indicates the fog nodes while the red color indicates the sensors, and the blue color indicates the actuators.

Time Efficiency Scenario

In this scenario, the time efficiency of the three topologies compared. Time efficiency obtained from the percentage of the three additional fog node load scenarios and the devices for each topology. This scenario needed to see which topology has the least time efficiency with the added load on each topology.

RESULT

Adding Fog Nodes and Devices to The Topology

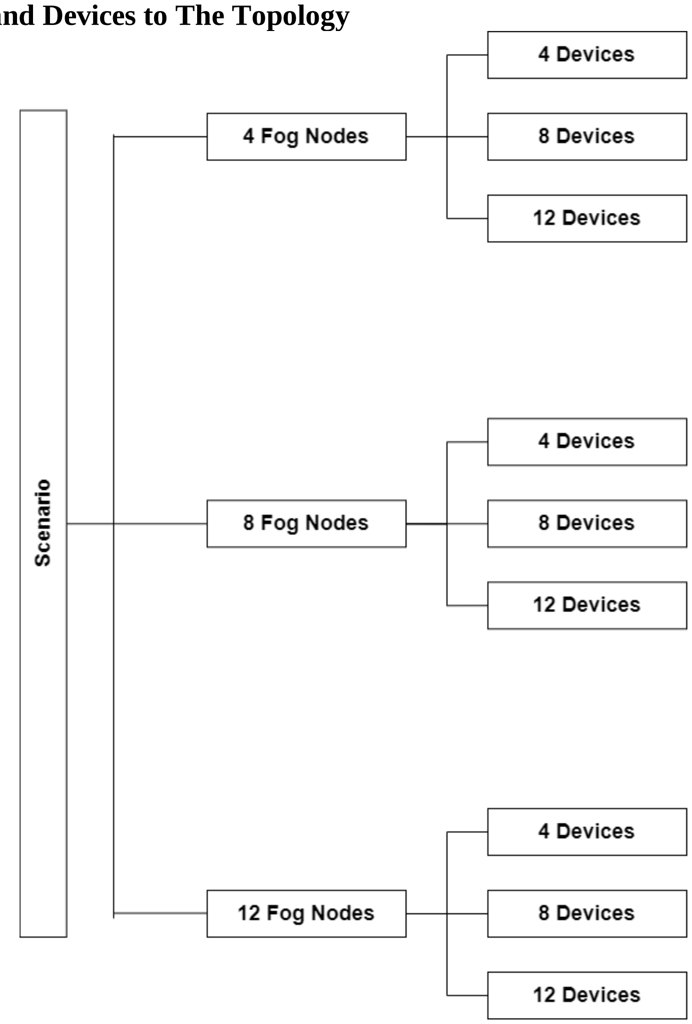

Fig. 11 Test Scenario Flow Diagram

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Figure 11 shows the scenario flow in added loads from star, mesh, and ring topologies. This test also compared the addition of fog nodes and devices from the three scenarios in star, mesh, and ring topologies. The test results with the addition of fog nodes and devices conducted to see the effect of adding load balancing on processing time on star, mesh, and ring topologies resulting in a graph with the average processing time of adding fog nodes and devices on star, mesh, and ring topologies.

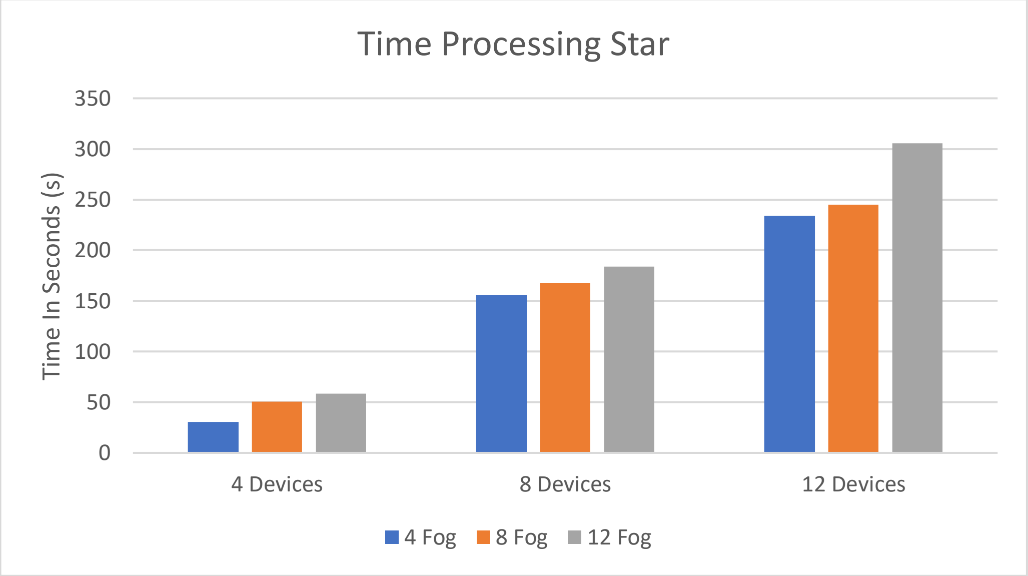

Fig. 12 Graph of Average Star Topology Time Processing

Figure 12 above is a graphical result of the increasing number of fog nodes relative to the increasing number of devices. Figure 12 shows the average output processing time for various numbers of devices in the star topology where there is an increased in processing time with an average of 159.072 seconds at each fog node.

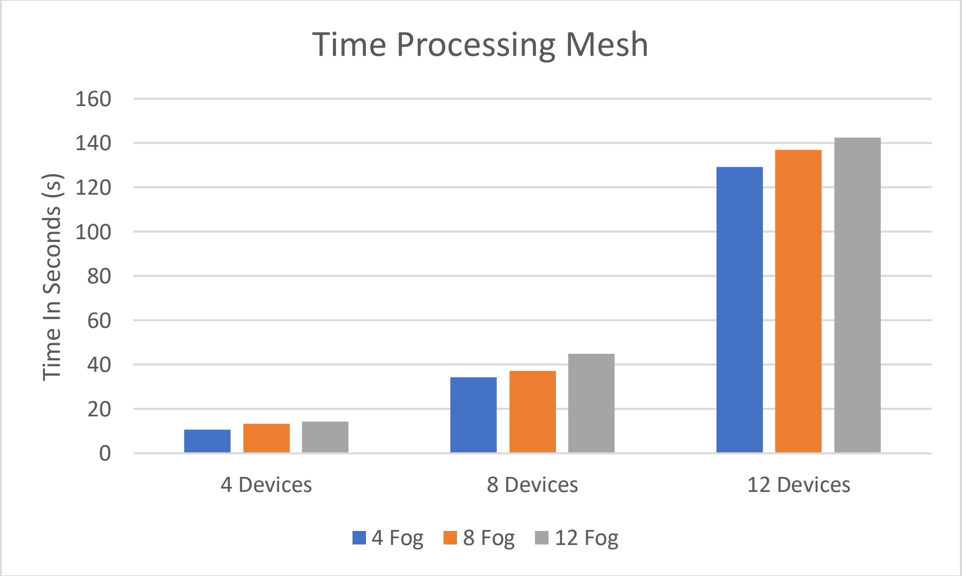

Fig. 13 Graph of Average Mesh Topology Time Processing

Figure 13 above is the graphical result from increasing the number of fog nodes against increasing number of devices. Figure 13 shows the average output processing time for various numbers of devices in the star topology where there is an increased in processing time with an average of 62.645 seconds at each fog node.

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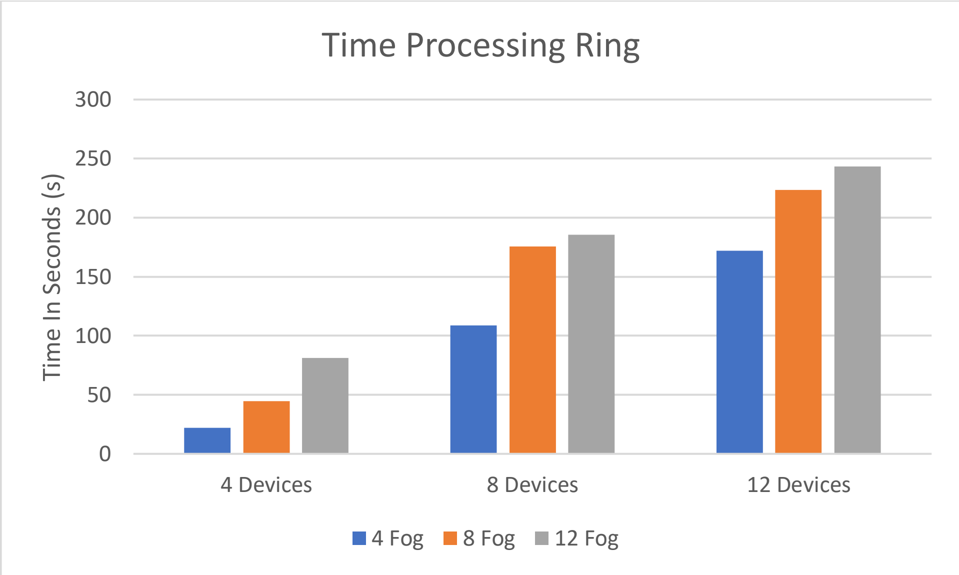

Fig. 14 Graph of Average Ring Topology Time Processing

Figure 14 above is the graphical result from increasing the number of fog nodes against increasing number of devices. Figure 14 shows the average output processing time for various numbers of devices in the star topology where there is an increased in processing time with an average of 139.628 seconds at each fog node.

Comparison of The Number of Fog Nodes and Devices Against Three Topologies

A comparison of the number of fog nodes was conducted to compare the effect of adding devices at 4, 8, and 12 fog nodes in the star, mesh, and ring topologies which will produce graphs with the average processing time of adding devices at 4, 8, and 12 fog nodes against the three topologies to be compared.

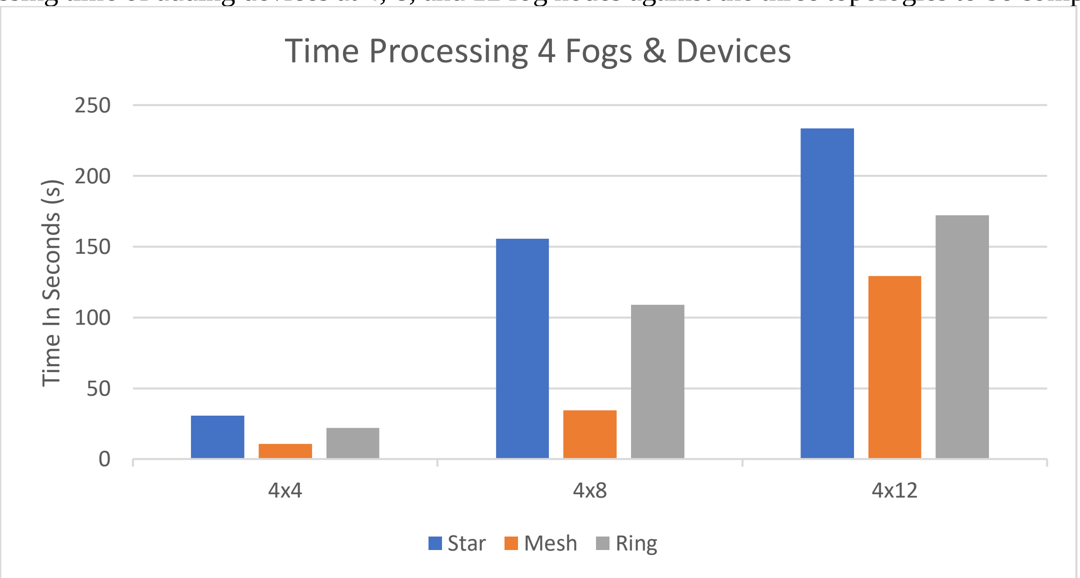

Fig. 15 Graph of Average Time Processing Comparison of 4 Fog Nodes

Figure 15 above is the result of a graphical analysis of the four fog nodes for the addition of devices to the three topologies. Figure 15 shows a comparison of the average output processing time of the four fog nodes in three topologies where the mesh topology has the smallest processing time with an average of 58.153 seconds compared to other topologies.

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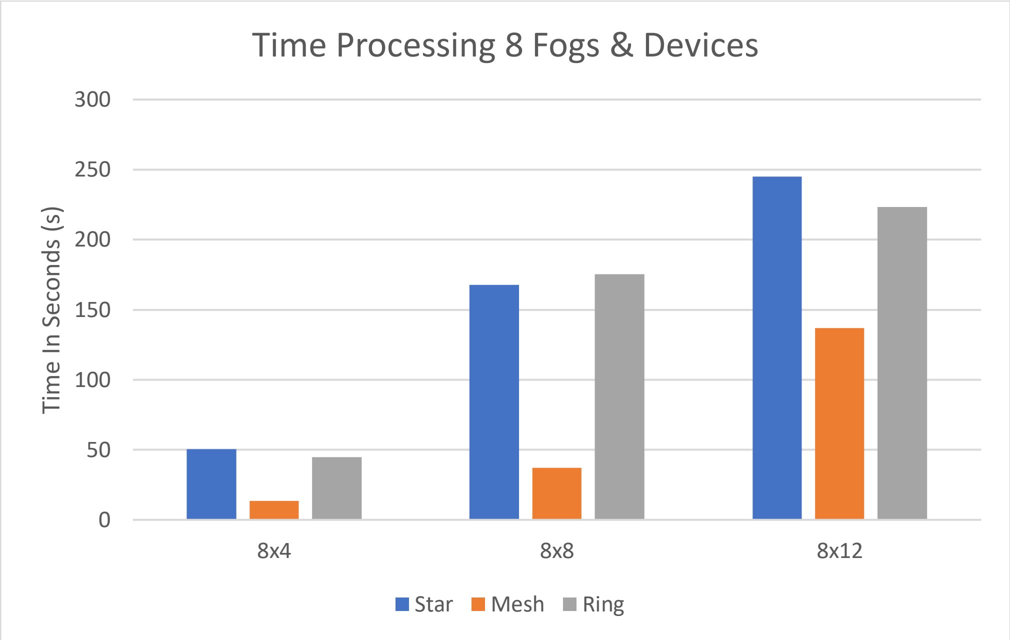

Fig. 16 Graph of Average Time Processing Comparison of 8 Fog Nodes

Figure 16 above is the result of a graphical analysis of eight fog nodes against the addition of devices in the three topologies. Figure 16 shows the output comparison of the average processing time of eight fog nodes in the three topologies where the mesh topology has the smallest processing time with an average of 62.517 seconds compared to other topologies.

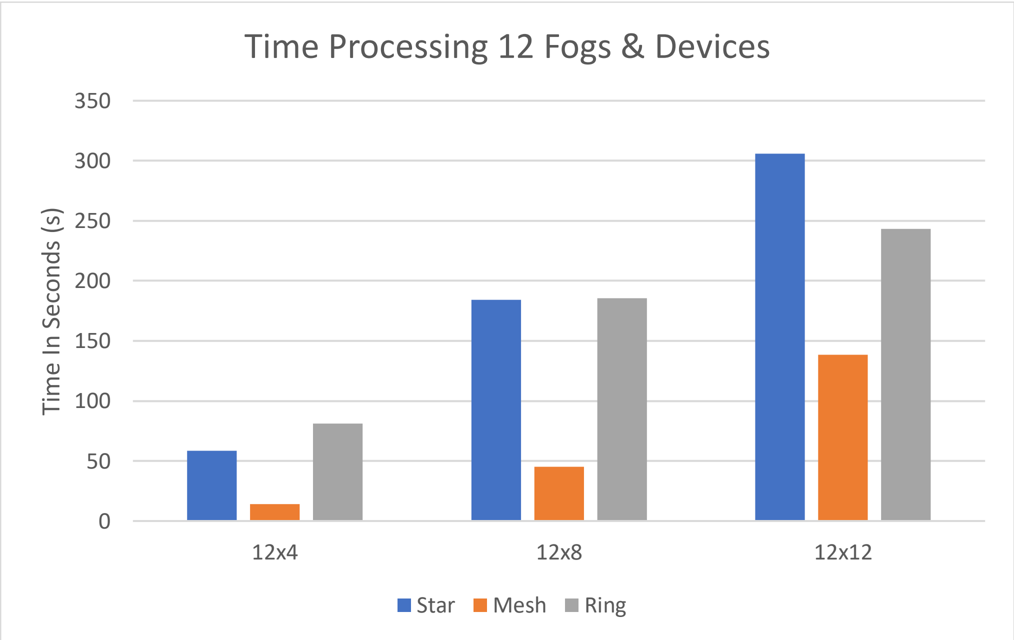

Fig. 17 Graph of Average Time Processing Comparison of 12 Fog Nodes

Figure 17 above is the result of a graphical analysis of twelve fog nodes against the addition of devices in the three topologies. Figure 17 shows the output comparison of the average processing time of twelve fog nodes in the three topologies where the mesh topology has the smallest processing time with an average of 67.267 seconds compared to other topologies.

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DISCUSSIONS

Analysis of Addition of Fog Nodes and Devices to Topology

Analysis related to the addition of fog nodes and devices in each of the topologies evaluated; processing time continues to increase along with the addition of the number of fog nodes, which means that the addition of load in each of the topologies evaluated influences processing time in fog computing. This can be seen from the graph of the average processing time for each topology, starting from a comparison of the addition of fog nodes from 4 devices, 8 devices, and 12 devices that experience an increase in processing time which causes an increase in load balancing in each topology, so processing time also increases.

Topology Comparison Analysis of Each Fog Node

Analysis related to the comparison of the three topologies against the addition of fog nodes; the mesh topology has the shortest processing time compared to the other topologies evaluated on each fog node. It is because the mesh topology has nodes that interconnected with each other so that data transfer from devices to fog is faster than other topologies.

Time Efficiency Analysis

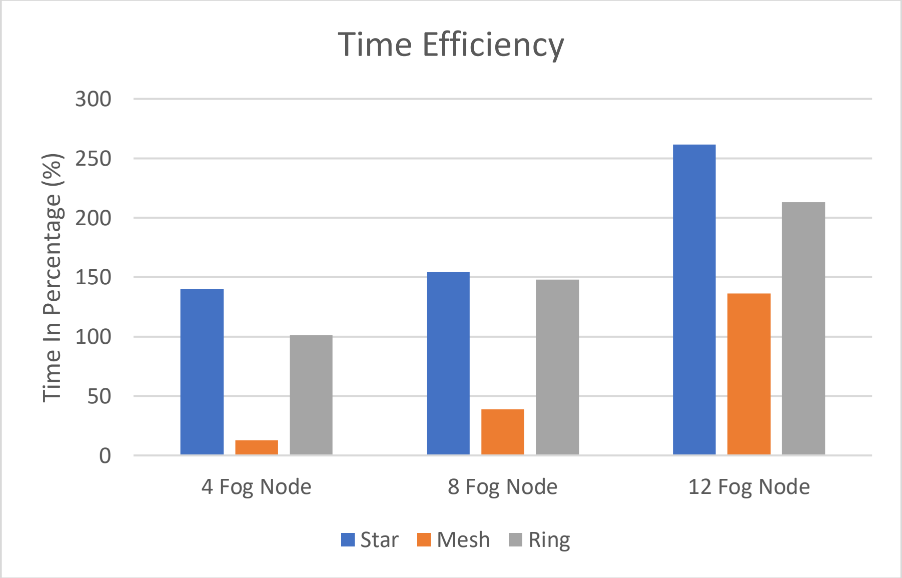

Fig. 18 Graph of Time Efficiency

Figure 18 shows the results of the three scenarios evaluated to get the Time Efficiency of the star, mesh, and ring topologies. In the scenario of four fog nodes, the smallest time efficiency is by mesh topology with a percentage of 5% and the highest time efficiency owned by the star topology with 55%. In the scenario of eight fog nodes, the smallest time efficiency is by mesh topology with a percentage of 11% and the highest time efficiency owned by the star topology with 45%. In the scenario of twelve fog nodes, the smallest time efficiency is by mesh topology with a percentage of 22% and the highest time efficiency owned by the star topology with 42%.

CONCLUSION

In this research analyzed the average processing time of the three topologies, namely the star, mesh, and ring topologies using the YAFS fog simulator. From the three scenarios that have evaluated, it can be concluded that the additional load affects the processing time of fog computing. This is due to the increase in performance in distributing the load from the devices to the fog nodes. The higher the number of nodes added in fog computing, the higher the average processing time. The mesh topology has the smallest average processing time because in the mesh topology each node connected to one another which results in the maximum transfer speed between data.

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REFERENCES

Margariti, S., Dimakopoulos, V. and Tsoumanis, G. (2020). Modeling and Simulation Tools for Fog Computing—A Comprehensive Survey from a Cost Perspective. Future Internet, 12(5), p.89. https://doi.org/10.3390/fi12050089

Neware, R. (2019). Fog Computing Architecture, Applications and Security Issues: A Survei. https://doi.org/10.20944/preprints201903.0145.v1

Singh, J., Singh, P. and Gill, S. (2021). Fog computing: A taxonomy, systematic review, current trends and research challenges. Journal of Parallel and Distributed Computing, 157, pp.56-85. https://doi.org/10.1016/j.jpdc.2021.06.005

Abdali, T., Hassan, R., Aman, A. and Nguyen, Q. (2021). Fog Computing Advancement: Concept, Architecture, Applications, Advantages, and Open Issues. IEEE Access, 9, pp.75961-75980.

H., S. and V., N. (2021). A Review on Fog Computing: Architecture, Fog with IoT, Algorithms and Research Challenges. ICT Express, 7(2), pp.162-176. https://doi.org/10.1016/j.icte.2021.05.004

Rabay'a, A., Schleicher, E. and Graff, K., 2019. Fog computing with P2P: enhancing fog computing bandwidth for IoT scenarios. 2019 International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) andIEEE Smart Data (SmartData), pp.82-89. https://doi.org/10.1109/iThings/GreenCom/CPSCom/SmartData.2019.00036

Shahzad, M., Panneerselvam, J., Liu, L. and Zhai, X. (2020). Data Aggregation Challenges in Fog Computing. 2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation, pp.1717-1721. https://doi.org/10.1109/SmartWorld-UIC-ATC-SCALCOM-IOP-SCI.2019.00306

Goudarzi, M., Wu, H., Palaniswami, M. and Buyya, R. (2021). An Application Placement Technique for Concurrent IoT Applications in Edge and Fog Computing Environments. IEEE Transactions on Mobile Computing, 20(4), pp.1298-1311.

Dlamini, S. and Ventura, N. (2019). Resource Management in Fog Computing: Review. IEEE.

Lera, I., Guerrero, C. and Juiz, C. (2019). YAFS: A Simulator for IoT Scenarios in Fog Computing. IEEE Access, 7, pp.91745-91758.

Nurlan, Z., Kokenovna, T., Othman, M. and Adamova, A. (2021). Resource Allocation Approach for Optimal Routing in IoT Wireless Mesh Networks. IEEE Access, 9, pp.153926-153942.

Brandao, A., Lima, M., Abbas, C. and Villalba, L. (2020). An Energy Balanced Flooding Algorithm for a BLE Mesh Network. IEEE Access, 8, 24 pp.97946-97958.

Permana, I., Abdurohman, M. and Putrada, A. (2020). Comparative Analysis of Mesh and Star Topologies in Improving Smart Fire Alarms. IEEE.

Rokhayah, R. and Syambas, N. (2020). A Heuristic Algorithm for Ring Topology Optimization Rokhayah School of Electrical Engineering and Informatics Institut Teknologi Bandung Bandung, Indonesia. IEEE.

Fahimullah, M., Phillippe, G., Ahvar, S. and Trocan, M., 2023. Simulation Tools for Fog Computing: A Comparative Analysis. Sensors, 23. https://doi.org/10.3390/s23073492

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