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The Impact of Quality of Service (QoS) Parameters on IoT Application Performance

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Abstract - The Internet of Things (IoT) is a network of rapidly growing devices that is transforming many sectors. However, the heterogeneous nature of IoT networks and the wide range of applications that support them hinder the guarantee of coherent service quality. This can lead to performance problems, such as delays, fame, and loss of packages, affecting the user's experience and the reliability of IoT applications. This document analyzes the impact of the QoS on the performance of IoT applications. The document identifies the key to key important parameters for IoT applications; therefore, some quality parameters have been evaluated according to the simulation and analyzed using the NS-2 simulation tool known. The document concludes the discussion of the future of QOS in the IoT and the challenges that must be addressed to guarantee a coherent QoS for all IoT applications.

Keywords— Internet of Things, Quality and performance, Quality of Service, IoT Service, , NS-2 Simulation, Performance measurement, Model development.

1. Introduction

The IoT has a wide range of applications in different fields, which include medical care, agriculture, intelligent cities, intelligent houses, transport, communication, safety and surveillance, and entertainment. In medical care, IoT facilitates the remote monitoring of patients through wireless sensors, reducing the cost of care and improving the effectiveness of the treatments. This technology allows medical care providers to keep track of vital signs and receive notices in real-time, thus improving patients' results. By offering such different applications, IoT is revolutionizing how we live, work, and interact with the world around us. The IoT can be used to monitor the environment in the form of contamination and climatic parameters with the help of the sensors. Intelligent cities, where all citizens can administer and control the city's resources, can be possible by implementing IoT -based solutions. Intelligent houses can be possible with the help of ado -based solutions, in which devices can connect to the Internet and can be controlled by remote positions. The IoT is actually a revolutionary technology that will contribute to the growth of the economy by introducing more imaginative solutions to the growing population. Some challenges, such as security, privacy, scalability, interoperability and reliability before the IoT can be widely accepted.

The Internet of Everything (IOE), coined by Cisco in 2009, refers to intelligent connectivity between devices and networks. IOE is a vital component of the Etheror of Things, but several technological and social challenges must be identified before becoming a reality. These challenges include the development of standardized communication protocols and guaranteeing privacy and security in the transmission and in the data storage space. Tackling these challenges is essential to perform all the potential of IOE and the transformative impact that can have on society.

According to Gartner, "the internet base of the installed things will grow up to 26 billion units by 2020. IoT products and services suppliers will generate an incremental income greater than $ 300 billion, mainly in services, in 2020. It will involve $ 1, 9 billion in global economic -aging value through sales in various final markets ". [1]. The existence of a market for IoT and IoT assistance through services is inevitable. There are more IoT applications, each with different roles in our daily lives; Therefore, it is essential to understand which QO metrics should be used to define expectations for users.

We examine the literature on the Internet of Things and we discover that there is no document of the genre that lists and describes different quality metrics of the service (QOS) for the IoT to our best knowledge. The absence of this work hinders the active participation of IoT service providers and service users. That's why we pass through different IoT applications and literature to identify different QO metrics. The main contribution of this work is to ensure and define different QO metrics to help IoT service providers, customers, researchers, and professionals.

This work is structured in seven sections, starting from an overview of the related research. The second section offers a detailed description of IoT architecture, highlighting the different IoT components and providing an identification of the Qos metric for each of them. The fourth section is prepared in different Qos metrics, defining them in detail to support their application in IoT. The fifth section demonstrates how these Qos metrics can be useful by presenting an application of the real world to solve a problem or face a specific need. The sixth section describes the evaluation and analysis of the QOT parameters for IoT simulated in NS-2. Finally, in section Sette, the work ends summarizing the importance of Qos metrics for the success of the IoT and the challenges that have not yet been faced in this field. The sections are organized in a logical order to provide full understanding of the topic.

2. Related Work

In the Internet of Things (IoT), heterogeneous networks are established that are expected to provide services to various applications without compromising network quality. There are basically two kinds of applications running in an IoT environment: one that requires throughput and is delay tolerant, and another that requires bandwidth with different QoS requirements. Therefore, optimal approaches are required to serve these high-traffic accommodating various applications each with its own need for QoS. A few recent works that considered QoS are as follows:

The authors of the paper [5] proposed three-layer architecture for IoT, comprising the application layer, network layer, and perception layer. In [6], the authors discussed a similar architecture and proposed QoS-aware scheduling for service-oriented IoT. Additionally, [7] examined existing solutions to enforce QoS at the application level. Similarly, [8] analyzed possible integration techniques of Wireless Sensor Networks (WSNs) in IoT, taking into consideration the importance of QoS, and suggested best practices. Furthermore, [9] provided a comprehensive overview of IoT and explored various research challenges associated with it. The papers presented in these references demonstrate the significance of QoS in IoT and suggest solutions to ensure its effective implementation across different layers of the architecture. By examining these works, researchers can gain a deeper understanding of the various components of IoT and the challenges that must be overcome to maximize its potential.

While researchers have paid attention to various aspects of IoT, QoS in IoT has gained minimal attention. However, few works are available and they gave more attention to conventional QoS factors like bandwidth, jitter effect, packet loss, and network delay only. For proper management of IoT quality of services covering every aspect is required, then only optimal resource allocation could be possible [10]. Cloud computing also faced the same issue in its evolution; However, Carnegie Mellon University formed a group of professionals to list various QoS metrics of the cloud and named it as Service Measure Index (SMI). After the availability of SMI, various researchers contributed and helped identify new quality metrics with time [11][12]. From the above discussion, one can understand that identification of QoS metrics in IoT is a major challenge that needs attention from IoT researchers and professionals. This work is progressing in the same direction.

SN	Authors	Findings
1	*Kumar Shwetabhand, Asha Ambhaikar* *D., 2024[3]*	Development of a Low -Cost Livestock sorting Information Management system Leveraging Deep Learning, AI, and IOT Technologies.
2	Kumar Shwetabh, Asha Ambhaikar D., 2024 [3]	Smart Health Monitoring System of Agricultural Machines: Deep Learning-based Optimization with IoT and AI
3	*Hemlata Wamanrao Kohad, Sunil Kumar, Asha Ambhaikar* *D.P,2023[15]*	Design of a Novel Side Chaining Model for Improving the Performance of Security Aware E-Voting Applications
4	*Anjum Sheikh, Sunil Kumar, Asha Ambhaikar* *D., 2022*	Improvement of QOS Parameters of IOT Networks Using Artificial Intelligence.
5	*Waris, Z., Jaleel, A., Shoaib, M., Nigar, N., & Abalo, D., 2022[19]*	This study proposes a methodology for measuring the design quality of an IoT system during its design phase, using the ISO-9126 standard and considering proposed QoS factors.
6	*Singh, M., Baranwal, G., & Tripathi, A.K.,2020[13]*	Proposes a framework for selecting from an optimal IoT-based service by incorporating QoS parameters for its various components.

7	*Mashal, I., Alsaryrah, O., Chung, T.D., & Yuan, F., 2020[20]*	Recommends optimal Internet of things applications based on a user's preferences and the criteria provided by experts in the field.
8	*Contreras-Massé, R.A., Zezzatti, C.A., García, V., Dominguez, L.A., & Elizondo-Cortés, M.,2020[23]*	This study proposes a process for comparing Industrial IoT platforms to achieve accurate and repeatable results. The proposed process can aid in selecting the most suitable platform for specific industrial applications.
9	*Abosaif, A.N., & Hamza, H.S., 2020[24]*	This paper reviews the current state of machine learning approaches for solving the service selection problem. It provides an overview of the latest developments in this area, highlighting the strengths and limitations of each approach.
10	*Dongre, Y.V., & Ingle, R., 2020[25]*	Analyzes the three most common quality of service parameters - Response time, availability, and reliability.
11	*Zhang, X., Geng, J.C., Ma, J., Liu, H., & Niu, S.,2020 [26]*	Proposes an evolutionary algorithm to select optimal composite service to fulfill end-user QoS (Quality of Service) requirements.
12	*Baranwal, G., Singh, M., & Vidyarthi, D.P.,2019[14]*	This study proposes an MCGDM framework for ranking IoT services and evaluates its effectiveness in a healthcare application.
13	*Li, Y., Huang, Y., Zhang, M., & Rajabion, L., 2019 [15]*	This paper proposes a review of service selection mechanisms in IoT with a focus on establishing a framework for selecting services based on their performance. It also discusses the effectiveness of different selection mechanisms in various applications and distributed domains. By examining the different mechanisms for selecting services, researchers can gain a better understanding of how to optimize service selection in IoT and improve the overall performance of IoT systems.
14	*Vallois, V., Guenane, F.A., & Mehaoua, A.,2019[18]*	This study proposes a multi-criteria decision model for IoT security architecture, demonstrating its advantages in identifying the best architecture for different requirements. By providing a framework for IoT security, researchers can

		better protect IoT systems and their users from security threats.
15	*Badawy, M.M., Ali, Z.H., & Ali, H.A., 2019[21]*	Proposes a QoPF to optimize the quality of services by proposing a framework that maximizes the composite quality of services.
16	*Contreras-Massé, R.A., Zezzatti, C.A., García, V., & Elizondo-Cortés, M., 2019[22]*	Proposes applying MCDA to compare IoT platforms with aspects like security, cost, performance, and bandwidth.
17	*Singh, M., & Baranwal, G., 2018[12]*	Defines QoS metrics for IoT, by taking into consideration that computing, communication, and things are three pillars of IoT.
18	*Tanganelli, G., Vallati, C., & Mingozzi, E.,2018[16]*	Explore the field of QoS for the internet of things, comparing and contrasting quality at different levels: network and application.
19	*Nuaimi, E.A., & Darmaki, N.A., 2017[17]*	This study suggests a new classification for QoS attributes of IoT based on the properties of resources, performance, and networks.

3. IoT Applications

The intelligent city, the manufacturing industry, electronic health, intelligent agriculture, intelligent retail trade, the supply chain, the manufacturing industry and transport are some applications that provide an idea of how IoT will transform the our life in the future. Smart Parking, one of the rapid growth applications in the IoT, provides Smart City solutions that allows customers easily, quickly and quickly and quickly. It will help us understand the relevance of the IoT in daily life. Under the parking sidewalks, the low -grade sensors are integrated in each place to collect real data on the number of spaces and positions available. The implementation of this model depends on the type of parking, on its position, costs, types of network, the nature of traffic, requires greater safety, greater accessibility, etc.

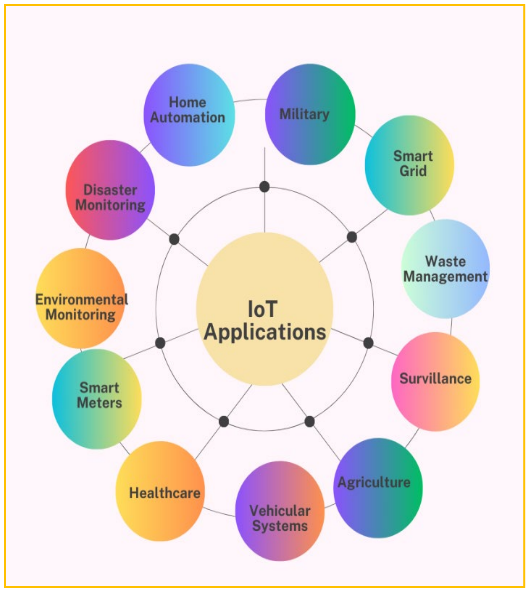

Figure 1: Different IoT Applications

When an application is practically implemented, to guarantee quality, it is essential to identify Qos in it. Customer satisfaction and expectations can only be satisfied by identifying Qos in any application. Given the intelligent parking application, before the market launch, the service provider focuses on the maximization of customer satisfaction. And to evaluate the services of the service provider, the QO attributes identified in section IV of this work will be useful for customers and service providers. The customer can take the network service after examining QO measures, such as the width of bandwidth, latency, availability, access control, platform support, interoperability and network efficiency. In addition, the network service provider can express its QO parameters to achieve user expectations. Computer suppliers can improve their quality by following customers' quality needs, such as their availability, reliability, scalability, dynamic prices, skills, etc. Likewise, the layer of the device will have the following necessary precision of the QO sensors, the drift speed, the support of mobility, sensitivity, error rate and stability are important. Cost, customer service, installation of free tests, monitoring, ease of use, energy consumption, safety and privacy, structures and audibility are other important Qos provided by the user application services.

4. QoS Parameters in IoT Communication

Qos (quality of service) is a set of metrics that measure the performance of a network or a communication system. In the IoT, Qos is important to ensure that the data transmitted between the devices are reliable and timely.

It is important to consider the Qos requirements of each IoT application during the design and implementation of an IoT network. When you carefully select the correct network components and protocols, it is possible to ensure that IoT applications can meet their Qos requirements and provide a reliable and pleasant user experience.

Here are some additional details about each of the QoS parameters mentioned above:

- ***Packet loss:*** Packet loss occurs when a packet is not successfully delivered to its destination. This can happen for a number of reasons, such as congestion on the network, interference, or a device going offline. Packet loss can have a significant impact on the performance of IoT applications, especially those that require real-time data transfer.

- ***Delay***: Delay is the amount of time it takes for a packet to travel from one device to another. Delay can be caused by a number of factors, such as the distance between devices, the network bandwidth, and the traffic on the network. A high delay can make IoT applications unresponsive and unusable.

- ***Throughput:*** Throughput is the amount of data that can be transferred in a given amount of time. Throughput is important for IoT applications that require a lot of data transfer, such as video streaming. A high throughput is essential for these applications to function properly.

- **Packet delivery ratio:** It is the percentage of packets that are successfully delivered to their destination. It is a measure of the reliability of a network. A high packet delivery ratio indicates that most packets are successfully delivered, while a low packet delivery ratio indicates that many packets are lost.

- **Routing overhead**: It is the amount of data that is used to maintain routing information in a network. It includes the size of routing packets, the number of routing packets that are transmitted, and the frequency with which routing packets are transmitted. Routing overhead can have a significant impact on the performance of a network, especially in networks with a large number of nodes.

By carefully considering the QoS requirements of each IoT application, it is possible to design and deploy an IoT network that can meet the needs of the application and provide a reliable and enjoyable user experience.

In IoT networks, packet delivery ratio and routing overhead are important QoS parameters. A high packet delivery ratio is essential for IoT applications that require reliable data transmission, such as industrial automation and medical monitoring. A low routing overhead is important for IoT networks with a large number of nodes, such as smart city networks.

There are a number of factors that can affect IoT networks. These factors include:

- ***The network topology:*** The network topology can affect the number of hops that packets need to take to reach their destination. A network with a lot of hops will have a higher packet delivery ratio than a network with a few hops.
- ***The network bandwidth:*** The network bandwidth can affect the amount of data that can be transmitted in a given amount of time. A network with a high bandwidth will have a higher packet delivery ratio than a network with a low bandwidth.
- ***The number of nodes:*** The number of nodes in a network can affect the amount of routing overhead. A network with a large number of nodes will have a higher routing overhead than a network with a small number of nodes.
- ***The routing protocol:*** The routing protocol can affect the amount of routing overhead. Some routing protocols are more efficient than others and generate less routing overhead.

By understanding the factors that affect QoS parameters, it is possible to design and deploy IoT networks that meet the QoS requirements of IoT applications.

5. Analyzing QoS Parameters via Simulation tool NS-2

This section describes the simulation scenario conducted through experiment in NS-2. The figure 2 to figure 4 shows the snapshot for AOMDV method and figure 5 to figure 7 shows the snapshot for AODV method. In experiments, the simulation starts with 0^{th} second up to 150 seconds. Figure 2 shows the AOMDV scenario where the relay node depletion is seen as yellow color. The start time at which the relay node is seen as yellow is 70^{th} second.

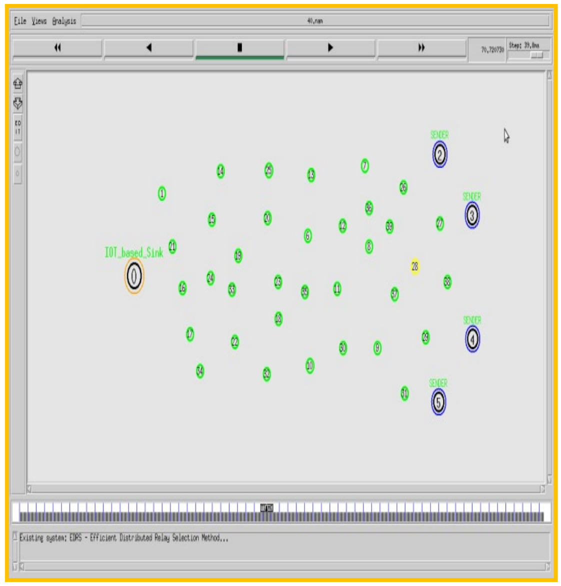

Figure 2: AOMDV Method Step 1

Figure 3 shows the AOMDV scenario where the relay node depletion is seen as red color. The start time at which the relay node is seen as red is 118th second.

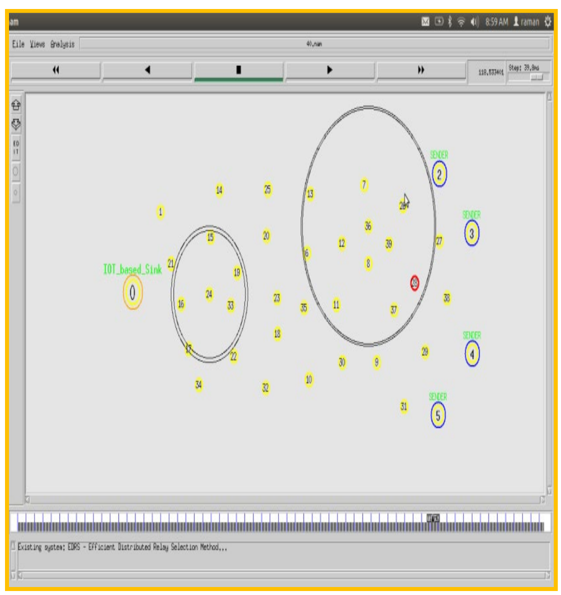

Figure 3: AOMDV Method Step 2

Figure 4 shows the AOMDV scenario where the relay node depletion is seen as red color at the end of simulation time of 150th seconds. At the end of simulation there are many nodes that depleted their energy completely seen as red color.

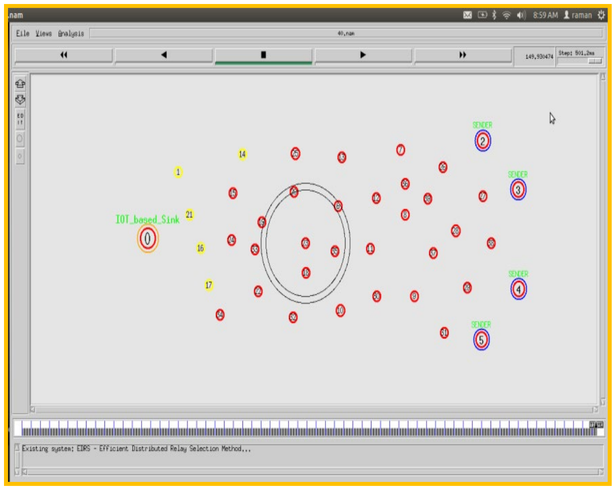

Figure 4: AOMDV Method Step 3

Figure 5 shows the AODV scenario where the relay node depletion is seen as yellow color. The start time at which the relay node is seen as yellow is 82th second while in the system is 70th second. Surely AODV method is better than AOMDV method, which is been visualized through simulation also.

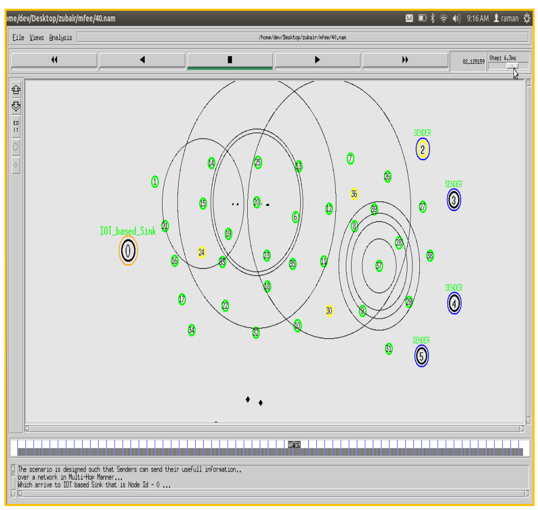

Figure 5: AODV Method Step 1

Figure 6 shows the AODV scenario where the relay node depletion is seen as red color. The start time at which the relay node is seen as red is 143th second while in the system is 118th second. Surely AODV method is better than AOMDV method, which is been visualized through simulation also.

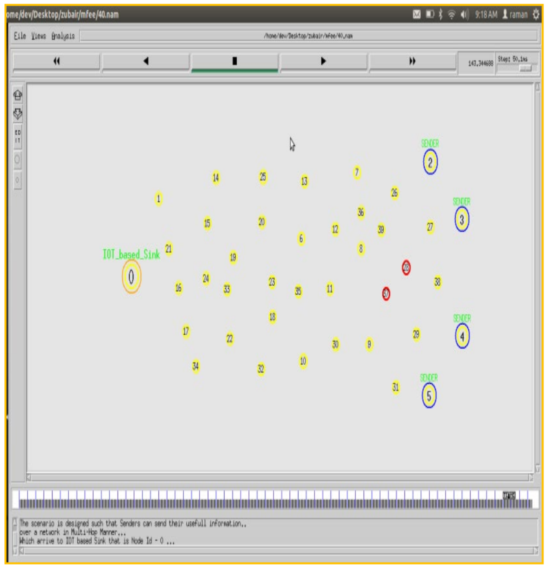

Figure 6: AODV Method Step 2

Figure 7 shows the AODV scenario where the relay node depletion is seen as red color at the end of simulation time of 150th seconds. At the end of simulation there are fewer nodes as compared to AOMDV method that depleted their energy completely seen as red color.

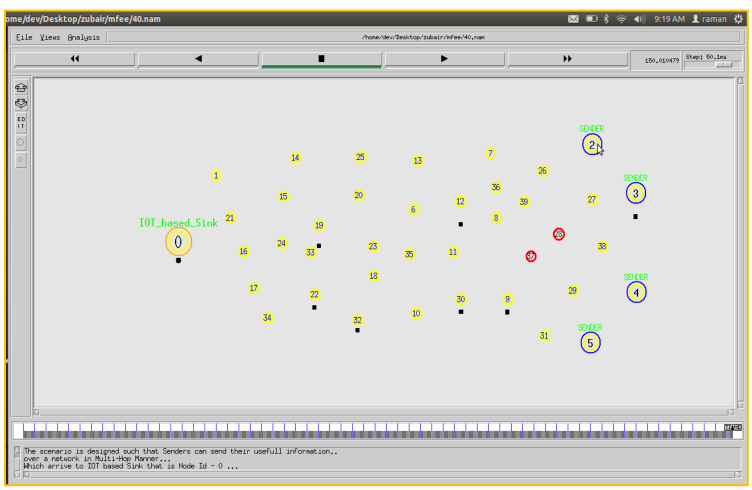

Figure 7: AODV Method Step 3

The visualization snapshots of both AOMDV method and AODV method are discussed which shows that the AODV method is enhanced successfully as compared to AOMDV method.

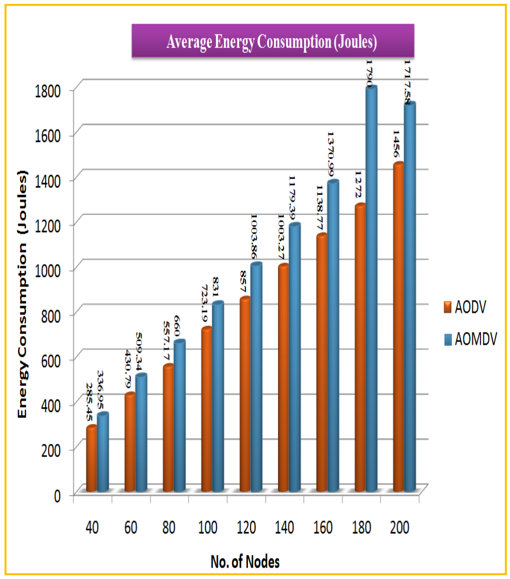

Figure 8: Total Energy Consumption

The graph preceding Figure 8 shows the total consumption of energy. It is seen that the average energy consumption of the AOMDV protocol is always superior to the average energy consumption of the AODV protocol. This difference is more pronounced for a greater number of knots. The reason for this difference is that the AOMDV protocol requires more messages between the nodes than the AODV protocol. This is because the AOMDV protocol uses an flooding algorithm to discover routes, while the AOOV protocol uses a more efficient algorithm. Further messages that are exchanged with the AOMDV protocol consume more energy, therefore the AOMDV protocol is less efficient in energy than the AOMDV protocol. The AODV method reaches an improvement of 17.83% of the total value of energy consumption compared to the AOMDV method.

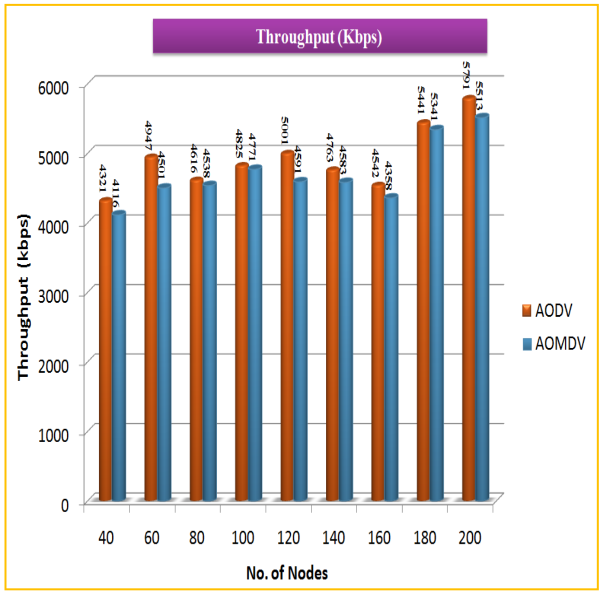

Figure 9: Throughput

The graph 9 shows the performance of routing protocols. It is seen that the performance of the AODV protocol are always superior to the performance of the AOMDV protocol. This difference is more pronounced for a greater number of knots. The reason for this difference is that the AODV protocol can maintain multiple paths among the nodes than the AOMDV protocol. This is because the AODV protocol uses an algorithm of discovery of the most aggressive path. The additional routes that maintain the AODV protocol allow you to transfer more data, so the AODV protocol has higher performance than the AOMDV protocol. In conclusion, the AODV routing protocol is more efficient than the AOMDV routing protocol for all nodes. This is because the AODV protocol can maintain multiple routes among the nodes, which allows you to transfer more data. The AODV method obtains an improvement of 4.57% in the value of the performance that the AOMDV protocol.

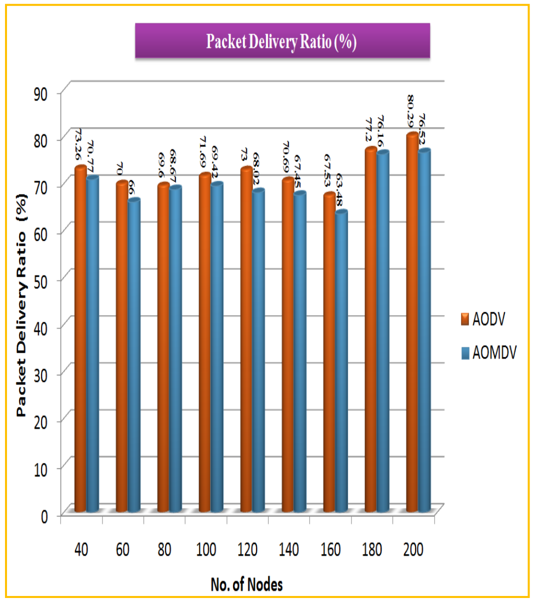

Figure 10: Packet Delivery Ratio

Figure 10 shows the graph of the delivery ratio of the package. You can see that the AOOV protocol PDR is increasingly higher than the AOMDV protocol PDR. This difference is more pronounced for a greater number of knots. The reason for this difference is that the AODV protocol can maintain multiple paths among the nodes than the AOMDV protocol. This is because the AODV protocol uses an algorithm of discovery of the most efficient path. The additional routes that maintain the AODV protocol make the packages less likely to be eliminated, therefore the AODV protocol has a higher PDR compared to the AOMDV protocol. In conclusion, the Aodv routing protocol is more reliable than the AOMDV routing protocol for all nodes. This is because the AODV protocol can maintain multiple routes among the nodes, which makes the packages less likely to be removed. The AODV method showed an improvement of 4.27% that the AOMDV method.

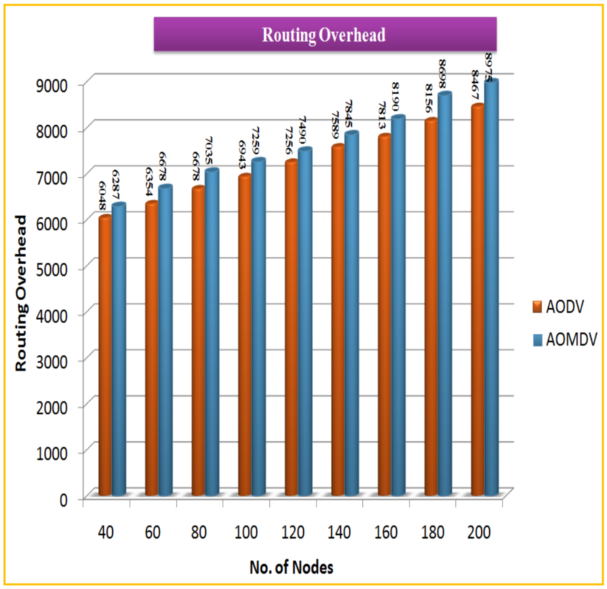

Figure 11: Routing Overhead

Figure 11 shows the routing chart on the head. You can see that the routine overload of the AOMDV protocol is increasingly higher than the routing of the AODV protocol. This difference is more pronounced for a greater number of knots. The reason for this difference is that the AOMDV protocol uses a more based on flood approach for the discovery of the path, which translates into multiple routing messages. Further routing messages that exchange the AOMDV protocol consume a broader band and resources, therefore the AOMDV protocol has a higher routing overload than the AODV protocol. In conclusion, the AODV routing protocol is more efficient in terms of routing overload compared to the AOMDV routing protocol. This is because the AODV protocol uses an algorithm of discovery of the most efficient path that translates into less routing messages. The AODV method showed an improvement of 4.60 % that the AOMDV method.

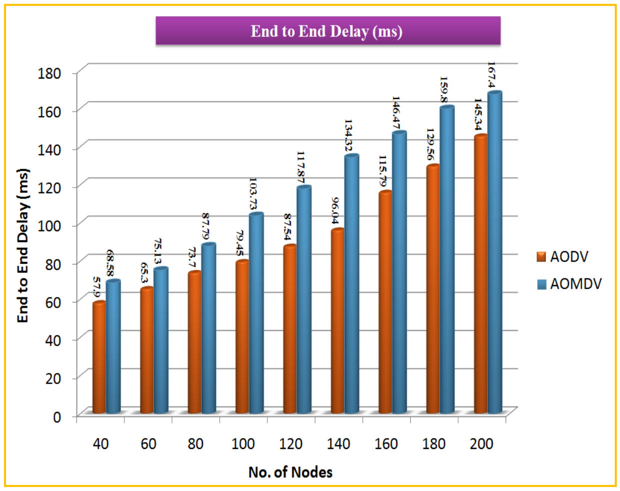

Figure 12: End to End Delay

Figure 12 shows the late end -end delay graph. As you can see, End's delay of the AOMDV protocol is always higher than End's delay -End of the AMDV protocol. This difference is more pronounced for a greater number of knots. The reason for this difference is that the AOMDV protocol uses a more based on flood approach for the discovery of the path, which translates into multiple routing messages. This can cause the congestion of the network, which can increase the end delay -End. The AODV protocol, on the other hand, uses a more efficient algorithm of discovering route that translates into less routing messages. This helps to reduce congestion in the network and improve the final delay. In conclusion, the Aodv routing protocol has a final delay compared to the AOMDV routing protocol. This is because the AODV protocol can maintain multiple routes among the nodes, which makes it faster than the packages traveled by the node of origin to the destination node. The AODV method showed an improvement of 19.83 % of the AOMDV method.

7. Conclusion

IoT services are able to connect several smart things together with the Internet, making life safer and more comfortable by reducing costs and risks. Taking into account the importance of the IoT on a one -day base, the metrics of the Qos in the IoT ecosystem must be defined and placed in one place. Since things, calculation and communication are three components of the IoT, this work identifies different qos relating to each component. The main contribution of this document is the identification of the Qos in diversity and provides their description. This work helps IoT service providers to describe their services in a better full way, which also helps to create healthy competition among IoT service providers. This work helps IoT customers understand their need for IoT services. In addition, researchers and professionals should consider the Qos factors in the development of models for different challenges. To evaluate and consider the Qos for the research factor, this document has also conducted the experiment in the simulation tool NS-2. This work will also help them to consider relevant and important Qos metrics.

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