

Analysis of QoS Parameters for IoT Networks

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Abstract—A large amount of data is transferred by the IoT devices over the network. The successful transmission of data from the source nodes to the destination nodes depends on the reliability of the network. In the absence of good networks the IoT technology will not be able to work properly as the failure in transfer of data would result in the malfunctioning of the applications. The Quality of Services (QoS) parameters of the network helps in knowing the capability of the networks in transferring data. These parameters would help the service providers to improve the shortcomings in the network and provide better service to its users. End to end delay, packet delivery ratio, energy consumption, jitter, routing over load and throughput are some of the parameters discussed in this paper. The parameters have been calculated by the different types of network and the variation of these parameters with the change in the size of network have been studied.

Index Terms— Quality of Services, Internet of Things, Throughput, Packet Delivery Ratio, End to End Delay.

I. INTRODUCTION

Internet of Things (IoT) has changed our lifestyle in a considerable way. It works on the concept of connecting and controlling anything from anywhere with the help of internet. The numbers of IoT devices are increasing rapidly and similarly its applications are also increasing. Some of the areas where IoT is being used commonly are for automation of home appliances, agriculture, health and smart cities. A number of devices are connected with each other and share data on the giant IoT networks. The researchers working in the field of IoT has proposed different types of architecture. The basic type of architecture is the three layered with device, network and application layer [1-3] followed by the four layer [4, 5] that used an additional management service layer. A few more kind of IoT architectures with five layers [6, 7], six layers [22] were developed to increase the viability of the technology. In all the kinds of architectures studied so far, all the layers have their own importance. These layers work in coordination for the successful implementation of the IoT applications.

The network layer of IoT uses routing algorithms to enable data transfer among the desired devices with the help of internet. As more and more amount of data is being transferred over the network due to the increasing number of devices, maintaining confidentiality and integrity of data is become a challenging task. The data being shared on the network should reach their destinations within the stipulated time without affecting its contents. Failure of data transfer and long delays can cause instability in the functioning of IoT applications and therefore it has become essential to monitor the performance metrics at the network level. The performance metrics or the Quality of Service (QoS) parameters as they are commonly known play a crucial role in determining the satisfaction of IoT users and ensuring secure data transfers without any losses. The QoS parameters at the network level are transmission as discussed in some of the research work are transmission delay [1,3], throughput [4], packet delivery ratio [9], jitter [10], and energy consumption of the networks [9]. The

popularity of IoT can be increased among its users if the QoS metrics are clearly defined. The users will be able to specify their requirements of IoT applications with the knowledge of QoS metrics. This paper tries to study the variation in the values of the QoS parameters with the change in the size of IoT networks. Section 2 gives a brief literature review of the researches for studying the importance of QoS parameters in the IoT networks. Section 3 includes information of the various QoS parameters studied in this paper, results of the experiments have been discussed in section 4 while section 5 gives the conclusion of the paper.

II. RELATED WORK

The advantages and the useful services provided by the IoT has attracted many organizations and users towards it. But as more and more people have started adopting the technology it has become equally important to look after the QoS of the IoT networks as the networks accomplish the task to data transfer for the connected devices. Any kind of malfunctioning at the network level can disrupt the whole application. In some of the IoT applications like health care or smart transportation inappropriate data transfer can be fatal. So it is very important to meet the QoS specifications of the IoT networks.

The IoT nodes are battery powered, placed at different places and sometimes at remote locations due to which it is essential to pay attention towards the energy consumption of the nodes. In order to meet the QoS requirements of the real time applications the routing algorithms have to be selected or designed to maximize the lifetime of IoT network [11]. The function of data transfer by the network makes it a very important part of the IoT system but if the nodes in the network fail to forward data on its routing path due to insufficient energy the application cannot work. The nodes in the IoT networks consume energy while processing and transferring data and the amount of energy consumed is proportional to the distance between the transmitter and the receiving nodes [12]. Similarly end to end delay depends on the distance among the source and sink. The routing algorithms determine suitable paths for sharing data among the nodes so that the data reaches its destination within the specified time limits. If the routing path is large, the time required for sending data will be more which will result in more energy consumption. Therefore routing algorithms play an important role in determining the values of end to end delay and energy consumption of a network.

The knowledge of energy consumption over a network helps in developing strategies that will increase the network lifetime. The optimization of delay time and energy consumption can be done by considering the load distribution over the nodes and avoiding congestion at the destination node. The author in [13] has used low duty cycle for the sensor networks to minimize the values of transmission delay. Similarly a research indicated in [14] has proposed a greedy resource allocation algorithm to achieve energy fairness for the LoRa networks. The algorithm considers transmission time and the probability of collision of data packets for better utilization of energy. Energy fairness is an important factor in the networks because if the load on the nodes is not properly distributed, it will cause rapid discharge of the nodes and the routing path will be broken leading to failure of data transfer. The large amount of data of the IoT devices may cause network congestion. Fulfilling QoS requirements of the IoT networks and providing appropriate routing paths at high bandwidth is very difficult. The application aware QoS routing algorithm in [15] improves the jitter, delay, and packet delivery ratio of the networks by using the maximum bandwidth and balances load for choosing good paths for transferring data.

Interconnection of numerous IoT devices over the networks has a great impact on the QoS of the networks due to the huge data being transferred. Some of the devices like cameras and alarm systems cause delay sensitive traffic due to their limitations of storage and processing abilities. Finite capacity queue has been used in [16] to predict the working of smart devices in different traffic conditions to fulfill the shortcomings of the QoS constrained IoT devices. The heterogeneous nature of the IoT network increases the complexity of looking after the QoS requirement for all the applications. A single network is not capable to many applications without compromising the QoS parameters. If a research intends to improve a QoS metric sometimes it has an adverse affects on other metrics. The process of making improvement in one of the parameters may have adverse affect on another parameter.

III. QoS PARAMETERS

The results in the paper are based on the simulations done using network simulator-2 and FEDORA7. The topology structure for the networks has been defined using the instructions of NS-2. Temperature and humidity sensors have been used for the formation of network. NS-2 can be used to implement many types of routing protocols for the IoT network. The network uses mobile nodes over a topology of 300 m length and 300 m wide. Packets of constant size are generated using the constant bit rate traffic and are transferred over the network. The

routing protocol used in this experiment is Adhoc on Demand Vector (AODV) routing. The nodes in the network are randomly located and keep on moving.

The QoS parameters studied in this paper include end to end delay, energy consumption, packet delivery ratio (PDR), throughput, energy fairness, jitter, normalized routing overhead and routing load. End to End Delay is the time required by the packets to travel from the source node to the destination nodes. The next parameter studied is energy consumption of the network during the data transfer from source to its destination. It is an important parameter as most of the IoT devices are battery operated and therefore energy efficient routing protocols are preferred to increase the life of IoT networks. Energy fairness is the ratio of the total energy consumed to the total energy present in the network. The packet delivery ratio is defined as the ratio of total packets received by the destination node to the number of packets that were actually transmitted by the source node. Another QoS parameter discussed in this paper is the normalized routing overhead which is calculated as the ratio of total requests served by the network by the total requests at the input. Another widely used metrics used for the studying the IoT networks is the value of throughput which is determined by the number of bytes transferred over the network from source towards the destination nodes in one second. The number of total load on the network called as the routing load is an important QoS metric that helps to provided good routing services for the applications that transfer large amount of data. Jitter in the network is a critical network QoS parameter which is variation in the timing of data arrival over the network dues to congestion and changes in the paths of data packets.

IV. RESULTS AND DISCUSSIONS

The values of the QoS parameters for the different types of network have been discussed in this section. The experiment has been performed by creating IoT networks with number of nodes as 30, 40, 50, 60, 70 and 80. The source node called as the UDP agent is fixed and the destination nodes for the data transmission are allotted as per the requirement. The values of all the QoS parameters have been calculated by changing the number of communications within the network. For each type of network, the values of the QoS parameters were calculated for communication like 3 ,7 10 and so on. The average values for the parameters for each network have been used to compare the functioning of networks and to study the impact of changing number of nodes on the network. We can see that the values of the QoS parameters show variations with the change in the number of nodes.

A. End to End Delay

The fig 1 given below indicates the variation in the values of the end to end delay with the change in the size of nodes. It can be seen that the end to end delay goes on decreasing with the increase in the number of nodes over the network For ex: the end to end delay value for the network with 30 nodes is the highest while the network with the 80 nodes has the least value. The size of the network is same but the number of nodes keeps on increasing from 30 to 80. Due to this more number of nodes are assigned to the same area and as the number of nodes increases the network becomes dense. Thus the distance between the nodes decreases with the increase in number of nodes for a network and therefore the time required for the communication decreases. It is therefore clear that less time is required for the transmission of data packets from source to destination is more for a network with more number of nodes as the distance between the nodes is less. The end to end delay values depends on the distance of nodes and hence as the network becomes dense, a decrease in its value can be observed.

B. Energy consumption of Networks

The IoT nodes are battery powered devices and therefore the energy consumption of the nodes in the routing path of the network play a significant role in transferring data over the network. The network lifetime which is known as the time for the nodes remain active is dependent on the energy consumption of the nodes while transferring data. Energy consumption is regarded as a very important factor as failure of any node in the routing path due to insufficient energy would not complete the data transmission thereby affecting the working of an IoT application. Energy is consumed in processing and transferring data. The energy required for data transfer over the network is inversely related to the distance between the transmitting and receiving ends. It is therefore necessary to develop routing algorithms that would be able to choose the shortest possible paths so that the energy required during data transfer will be less and the draining of batteries of the IoT nodes or devices can be reduces. As discussed earlier the experiment has been conducted with network with different number of nodes, the density of network increases with the increase in the number of nodes and therefore reduces the distance



Fig 1. Variation in end to end delay

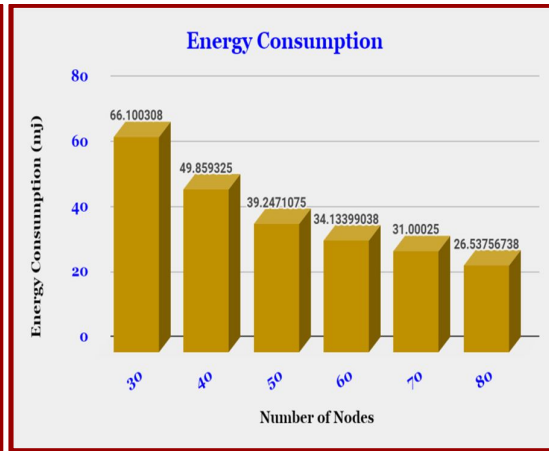


Fig 2. Change in Energy consumption

between the nodes. As the distance between the nodes with the increase in number of nodes over the network, the energy required for transmission of data in a network with more number of nodes will be less. A comparison of the energy consumption given in fig 2 indicates that the energy consumption of the network with 80 nodes is less as compared to the networks with lesser number of nodes like 70 , 60, 50 40, and 30.

TABLE I. COMPARISON OF QoS PARAMETERS (END TO END DELAY, ENERGY CONSUMPTION, ENERGY FAIRNESS AND JITTER)

Number of Nodes	End to End Delay (microseconds)	Energy Consumption (mj)	Energy Fairness	Jitter (microseconds)
30	755.875	66.100308	0.111447625	50.375
40	740.625	49.859325	0.12676525	105.5
50	687.875	39.2471075	0.1413215	208.875
60	634	34.13399038	0.153931375	153.125
70	620.75	31.00025	0.20586575	131.25
80	609.25	26.53756738	0.27957325	112

C. Energy Fairness

Energy fairness can be maintained by proper allocation of the network resources so that there is proper utilization of energy by the nodes. It is desirable to have energy efficient networks to ensure sustainability of the IoT networks due to the presence of battery powered nodes. The communication algorithms used over the network can be improved after knowing the energy consumption of the nodes for a data transmission. In this experiment it can be seen that the energy consumption of the networks required for communication among the nodes, decreases with the increase in number of nodes. Similarly the values of energy fairness as shown in fig 3, decrease with the increase in number of nodes. Energy fairness is the ratio of energy consumed by the total energy of the network. The energy consumption for the networks used in the experiment is less for the networks with more number of nodes. With the decrease in values of energy consumption over the networks we obtain better values of energy fairness.

D. Jitter

Jitter is an important metrics for judging the efficiency of data transmission over the network. Its value is determined by the difference in delay observed among the data packets travelling over the network. It is desirable to have fewer values for jitter to ensure better communication [17]. Increased values of jitter signify poor performance of networks and increased values of transmission delay which can cause change in the sequence of arrival of data packets. This results into receiving of data in an undesirable form. Fig 4 shows the comparison of the jitter values by changing number of nodes in the network. The values of jitter are dependent

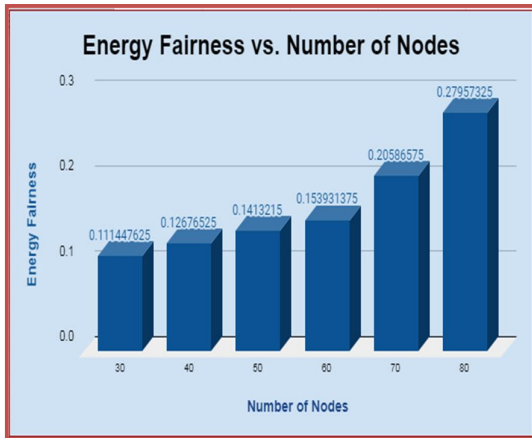


Fig 3. Energy Fairness of the network

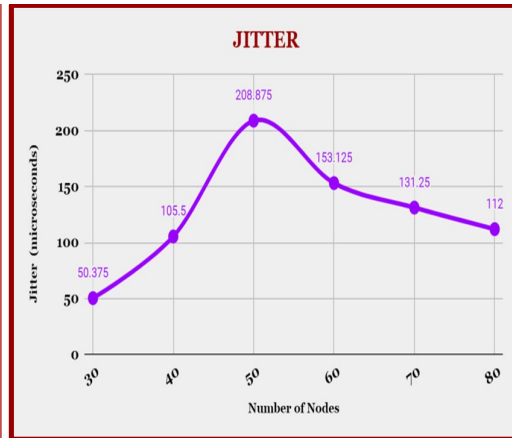


Fig 4. Variation in the values of jitter

on the traffic over the networks and queuing of data packets. The jitter is less number of nodes are less while the network with more number of nodes has higher values of jitter.

E. Normalised Routing Overhead

Fig. 5 given below illustrates performance of the network with the change in number of nodes. It can be seen that normalized routing overhead is insensitive to the change in network size. Normalized routing overhead is based on the total number of requests that have been served by the network. It can be seen that most of the requests out of the total actually sent on the network are being served and the variation in the number of nodes in the network does not have any significant affect on the value of normalized routing overhead. A low value of normalized routing overhead is possible due to the AODV routing protocol. The reactive routing protocols like the AODV do not required to exchange information about the network topology due to which the routing overhead is reduced.

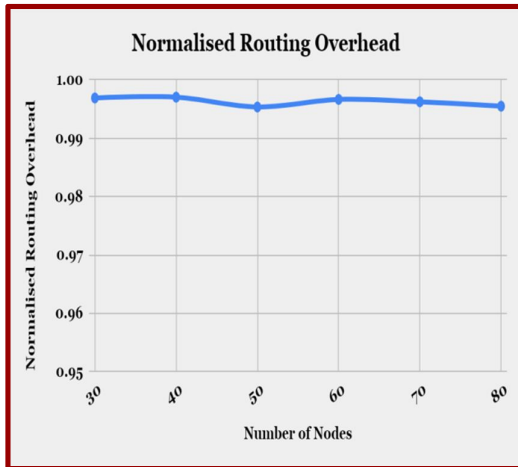


Fig 5. Normalised routing overhead

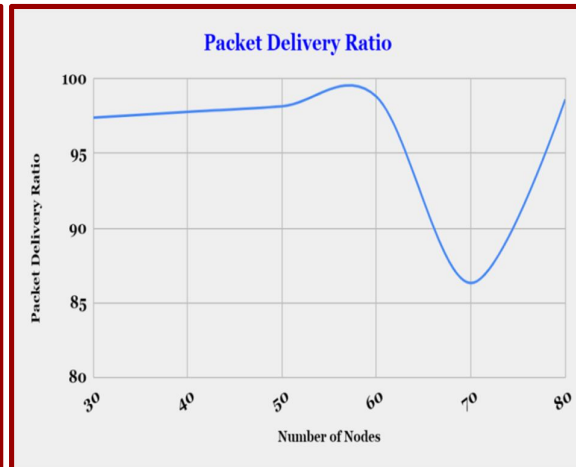


Fig 6. Variation in Packet Delivery Ratio

F. Packet Delivery Ratio

Packet delivery ratio (PDR) is an important performance parameter for the IoT networks as it determined the amount of information or data packets that have been sent successfully to the destination. Large values of PDR indicate that a large ratio of data packets out of the ones that had originated from the source node have reached the sink node. It also indicates that the network is able to transfer more amount of information without loss of data. At the same time, the networks with less value of PDR cannot be preferred as it will be able to forward less and incomplete data packets towards the destination which would lead to improper functioning of the applications. An IoT application depends solely on the capability of the network to transfer data packets in

TABLE II. COMPARISON OF QoS PARAMETERS (NORMALIZED ROUTING OVERHEAD, PDR, ROUTING LOAD, THROUGHPUT)

Number of Nodes	Normalized Routing Overhead	Packet Delivery Ratio	Routing Load	Throughput
30	0.996898625	97.4017425	6.4454975	197.1708825
40	0.997039	97.79348125	3.8928375	195.75055
50	0.995349875	98.1636375	2.43328575	192.1818825
60	0.9966485	98.8074185	2.1418905	194.6202926
70	0.996240625	86.31791888	1.778295513	192.4546826
80	0.995489375	98.6287815	1.590529938	191.8865954

correct sequence. It is therefore essential to maintain good values of PDR to increase the adaptability of the technology among its users and increase the satisfaction level regarding accepting the technology as an integral part of their life. Fig 6 gives the comparison of PDR values with the alterations in the number of nodes for the given network. It can be seen that the network achieves good values of PDR and changes in the number of nodes does not have any drastic affect in the values of PDR.

G. Routing Load

The variation in the values of routing load with change in the number of nodes is illustrated by fig 7. The value of routing load depends upon the traffic and congestion in the network. As seen in fig 1 the end to end delay is reduced as the distance between the nodes, there will be less chances of congestion in the network. This would result in reduction in load in the networks. Therefore the routing load reduces with the increase in number of nodes.

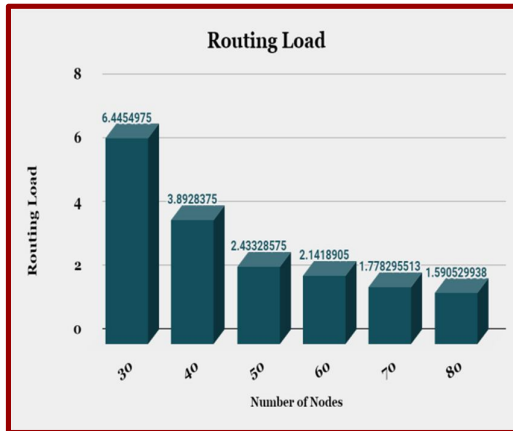


Fig 7. Routing load for the network

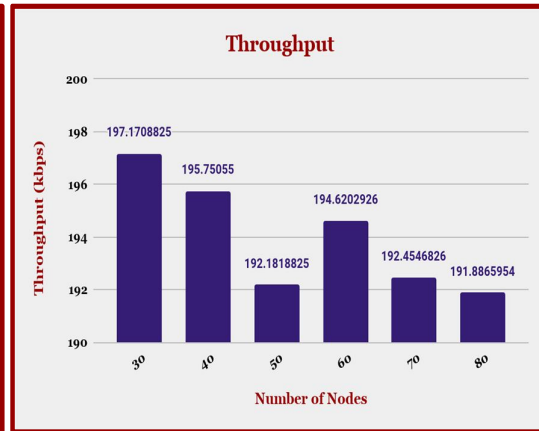


Fig 8. Throughput of network

H. Throughput

Throughput is a measure of the amount of information being transferred within a given time frame. It also helps to determine the speed of transfer of data packets from source to the receiver end. It is not desirable to have low values of throughput for a network. It indicates more packet loss and the network is considered to be slow or with poor performance. The fig 8 given below shows the variation in the values of throughput with the increase in number of nodes. The value of throughput is better for network with 30 and 40 nodes which later goes on decreasing. Though the transmission delay reduced with the increase in number of nodes but no significant improvement could be observed in the values of jitter and packet delivery ratio. The difference in packet delay or jitter is slightly increased for the networks with higher number of nodes therefore a decrease in values of throughput can be observed when the numbers of nodes are increased.

I. Discussion

The network studied in the experiment shows that some of the QoS parameters like end to end delay, energy consumption, energy fairness, and routing load and normalized routing overhead exhibit better values with the increase in the number of nodes. But the values of jitter slightly increase which has affected the values of throughput. Some of the key points observed in the experiment are as follows:

- i. The decrease in the distance among the nodes with the increase in number of nodes in the network has reduced the time required for the data packets to travel from source to destination.
- ii. The energy consumption of a network is directly related to the distance between the source and destination. Therefore as the distance reduces with the increase in number of nodes energy consumption decreases. These characteristics make it suitable to be used for the networks with IoT devices. It is because the IoT nodes or devices are battery operated and so it is essential to have routing algorithms that would consume less energy so that these devices could work for longer time to prevent loss of information due to failure of nodes.
- iii. The knowledge of energy consumption helps to plan for the strategies to be used for data transfer to increase the network lifetime and thus utilize the energy fairly.
- iv. The value of jitter is more for the network with more number of nodes. It is because increase in number of nodes means more devices are using the same network at the same time and the speed of the network is reduced.
- v. The increased values of jitter have resulted into lower values of throughput that indicates that there is more loss of data. The throughput values are getting reduced but its overall value is good which illustrates good performance of the network.
- vi. Though the values QoS parameters jitter and throughput show degrading performance but these values are satisfactory. But to improve the overall performance of the network both of these parameters should be improved.

V. CONCLUSION

This paper has presented comparative results for the QoS parameters for the networks with 30 , 40, 50, 60, 70 and 80 nodes. The QoS parameters studied in this paper are end to end delay, energy consumption, energy fairness, jitter, throughput, routing load, packet delivery ratio and normalized routing overhead. The good values of QoS parameters indicate the quality of performance for the given networks. In addition to this the QoS values of a network help in determining some useful factors like strength, authenticity and adaptability. The comparison of given networks indicates that with the increase in number of nodes the QoS parameters like end to end delay, energy consumption, energy fairness, routing load and normalized routing overhead show good performance. The packet delivery ratio is also satisfactory for the different sizes of the network. But the increase in the jitter for the networks with higher number of nodes results into lower values of throughput. Though the values of throughput are satisfactory but some steps need to be taken for decreasing jitter to improve the values of throughput.

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