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# Design and Implementation of a Self Adaptive Architecture for QoS (SAAQ) in IoT based Wireless Networks

**Durgesh Kumar Keshar[1], Dr. Guddi Singh[2], Devendra Kumar[3]**
[1]Research Scholar, Department of CSE, Kalinga University,
Kotni, Near Mantralaya, Naya Raipur, Chhattisgarh,Pin –492101 ,India
durgeshkeshar.prsu@gmail.com
[2]Professor, Department of CSE, Kalinga University,
Raipur, Chhattisgarh, Pin –492001,India
guddi.singh@kalingauniversity.ac.in
[3]M.Tech. Computer Science
Bilaspur, Chhattisgarh,Pin – 495220,India
devencaught@gmail.com

**Abstract**— The rapid growth of Internet of Things (IoT) applications has made ensuring quality of service (QoS) in wireless networks essential. This paper presents the design and implementation of a Self-Adaptive Architecture for QoS (SAAQ) in IoT-based wireless networks, using the NS-2 simulation tool as a foundation for analysis and evaluation. The SAAQ framework is carefully tailored to meet the dynamic demands of IoT applications, enabling real-time adjustment of QoS parameters such as packet delivery ratio, throughput, end-to-end delay, packet loss ratio, energy consumption and routing overhead. By integrating with NS-2, a simulation tool in network research, we conduct extensive simulations and experiments to evaluate the SAAQ's effectiveness in diverse IoT scenarios. This paper explores the adaptability and scalability of the SAAQ architecture and results of experiments reveal the practical benefits of the SAAQ in enhancing QoS in a simulated IoT application over other methods such as AODV, AOMDV, and LEACH.

**Keywords**- Self-Adaptive Architecture for QoS (SAAQ), IoT-based wireless networks, NS-2 simulation tool, QoS parameters, performance optimization .

## I. INTRODUCTION

In the contemporary digital landscape, wireless networks have evolved into a cornerstone of global communication systems. The ubiquity of wireless connectivity, driven by the proliferation of mobile devices, Internet of Things (IoT) applications, and the advent of 5G technology, has ushered in an era where wireless networks serve as the backbone for an array of services ranging from voice and data to multimedia streaming and mission-critical IoT applications. Amid this transformative connectivity paradigm, Quality of Service (QoS) emerges as a defining factor, intricately woven into the fabric of wireless networks, shaping their functionality and reliability.

QoS, in the context of wireless networks, encapsulates the mechanisms and strategies employed to guarantee the desired level of service quality in data transmission. It encompasses attributes such as low latency, high bandwidth, minimal packet loss, and efficient resource utilization. These factors are indispensable for ensuring the seamless operation of diverse applications that rely on wireless networks. Whether it be the uninterrupted streaming of high-definition video, the real-time responsiveness of autonomous vehicles, or the efficient collection of data from sensors embedded in smart cities, the success of these applications hinges on the network's ability to provide consistent and predictable QoS.

IoT-based wireless networks form the backbone of the IoT revolution, facilitating the exchange of data, the execution of commands, and the delivery of services across a wide spectrum of applications and industries. From smart cities and industrial automation to healthcare and agriculture, the influence of IoT-based wireless networks is pervasive, reshaping the way we interact with the world and harness data for informed decision-making.

Traditional wireless network architectures often struggle to meet the diverse and dynamic QoS requirements of IoT applications. These requirements encompass factors such as low latency, high reliability, energy efficiency, and scalability. The conventional, static network designs are ill-suited to adapt to the constantly changing demands of IoT devices and applications.

Hence, there is a pressing need for a Self-Adaptive Architecture for QoS (SAAQ) in IoT-based Wireless Networks. This research initiative is motivated by the desire to overcome the limitations of existing architectures and enable IoT networks to autonomously adapt to varying QoS needs. By achieving this goal, we aim to unlock the full potential of IoT by providing a network infrastructure that can guarantee QoS even in highly dynamic and heterogeneous environments. Implementing and evaluating the SAAQ routing protocol in NS-2 is a complex but crucial step in advancing the understanding and improvement of QoS in IoT networks. It will provide valuable insights into how self-adaptive routing can enhance the performance and reliability of IoT applications.

The rest of the paper will delve into a detailed discussion of the experimental methodology, simulation results, comparative analysis with existing routing protocols, and a comprehensive conclusion, providing a thorough understanding of the performance and implications of the SAAQ routing protocol in IoT-based wireless networks. Section 2 gives literature review, section 3 gives methodology adopted, section 4 gives simulation analysis, section 5 gives result analysis and finally section gives the conclusion and future directions of the research work.

## II. RELATED WORK

The papers considered in this research work collectively address some previously offered Quality of Service (QoS) improvements in IoT-based wireless networks focused by various researchers. Mahajan (2002) [1], proposes an adaptive end-system architecture that selects lower fidelity streams based on user preferences to improve QoS in wireless networks. Wang (2004) [2], presents a reservation-based QoS model for integrating cellular and WLAN networks, using an adaptation mechanism to improve resource utilization and reduce call blocking and handoff dropping probabilities. Gatouillat (2017) [3], introduces a QoS-driven self-adaptation framework for IoT-based systems, ensuring constant QoS despite changing physical environments. Wang (2005) [4], also proposes a reservation-based QoS model for integrated cellular and WLAN networks, demonstrating improved resource utilization and reduced call blocking and handoff dropping probabilities.

Self-adaptive architecture for QoS (SAAQ) in IoT based wireless networks involves designing and implementing a managing system that can handle run-time uncertainties and provide guarantees on the Quality of Service (QoS) of the IoT system. Different architectural strategies can be evaluated for implementing the managing system, considering the impact on the QoS of both the managed system and the managing system [5]. Relay selection plays a significant role in improving network performance and increasing capacity efficiency in IoT communication. Adaptive priority-based relay selection decisions can be used to solve the imprecise nature of wireless networks and enhance throughput, packet delivery ratio, and end-to-end delay performance [6]. Software-Defined Networking (SDN) enables dynamic traffic control in IoT networks, but it may face scalability and single point of failure issues. EFQM++ is a self-adaptive framework that addresses these challenges by leveraging SDN controller topology discovery and distributed states management, resulting in reduced transmission delay in large-scale IoT networks [7]. There are many authors who have worked in such field and out which some relevant author findings and methods have been shown in following table 1.

Table 1: Literature Survey on some Author's Findings and their Methods

| SN | Author(s) | Findings | Methods Measured |
|---|---|---|---|
| 1. | Federico, Di, Menna., Henry, Muccini., Karthik, Vaidhyanathan [8] | The paper proposes a framework for designing and evaluating different architectural strategies for implementing the managing system of self-adaptive IoT systems. | -Proposed framework for designing and evaluating architectural strategies<br>-Evaluation results on a real-world IoT system |
| 2. | R., Prabha., Senthil, G., A., N., Naga, Saranya., A., M., K., Somasundaram., K., C. [9] | The paper discusses the design and implementation of an adaptive relay selection method for IoT communication in wireless networks. | - Adaptive priority-based relay selection decisions<br>- Investigation of various user options for relay selection parameters |
| 3. | Avewe, Bassene., Bamba, Gueye [10] | The paper proposes EFQM++, a self-adaptive framework for highly dynamic network topology changes in IoT networks, which improves flow end-to-end transmission delay. | - SDN-based architecture<br>- EFQM++ framework |
| 4. | Satyanarayana, Pamarthi., N., R. [11] | The paper introduces a security mechanism for wireless mobile adhoc networks in IoT applications, but does not specifically mention the design and implementation of a Self Adaptive Architecture for QoS (SAAQ) in IoT based Wireless Networks. | - Encoding and decoding packets using an arbitrary method selection scheme<br>- Authentication approach for security mechanism |
| 5. | Aurélien, Chambon., Abderrezak, Rachedi., Abderrahim, | The paper proposes a programmable multitier architecture and a continuity of service protocol for dynamic IoT | - Programmable multitier architecture<br>- Continuity of |

| | | | |
|---|---|---|---|
| | Sahli., Ahmed, Mebarki [12] | networks, focusing on end-to-end Quality of Service (QoS). | service protocol named ConSerN |
| 6. | Ahmad, Khalil., Nader, Mbarek., Olivier, Togni [13] | The paper proposes a QoS-based architecture for IoT environments, enabling the establishment of IoT Service Level Agreements (iSLAs) between IoT Service Providers and IoT Clients. | - QoS mechanisms implemented within each layer of the IoT architecture<br><br>- Adaptation of the IEEE 802.15.4 slotted CSMA/CA mechanism |
| 7. | Hongyu, Zhou., Xiaomin, Ren [14] | The given text does not provide any information about the design and implementation of a Self Adaptive Architecture for QoS (SAAQ) in IoT based Wireless Networks. | - Crosstalk suppression through beam angle reduction and power isolation<br><br>- Integration of transmitter and receiver on a single PCB |
| 8. | Cherifa, Boucetta., Boubakr, Nour., Alberic, Cusin., Hassine, Moungla [15] | The paper discusses the importance of link quality estimation in IoT networks for enhancing QoS and presents a classification of channels using machine learning techniques. | - Machine learning techniques (KNN and LSTM)<br><br>- Analysis of received signal strength (RSSI) and error rates |
| 9. | Nogaye, Lo., Ibrahima, Niang [16] | The paper proposes an analysis of QoS solutions and architectures for effective quality of service management in the IoT/Edge computing environment. | - Analysis of QoS solutions and architectures<br><br>- Classification of QoS mechanisms in IoT architecture |
| 10. | Jiaxin, Liang., He, Chen., Soung, Chang, Liew [17] | The given text does not provide any information about the design and implementation of a Self Adaptive Architecture for QoS (SAAQ) in IoT based Wireless Networks. | - Time synchronization mechanism for maintaining synchrony among nodes<br><br>- Just-in-time algorithm to reduce delays and delay jitters |
| 11. | Cmm Mansoor, G. Vishnupriya, A. Anand, S. Vijayakumar, G. Kumaran, V. Samuthira Pandi [18] | The need to access various parameters of QoS based on many perspectives is critical in IoT devices. | - Quality Of Service (QoS) |
| 12. | Zia, K., Chiumento, A., & Havinga, P.J [19] | AI and machine learning can address high-dimensional and dynamic problems in multi-RAT IoT networks. | -Throughput<br>-Reliability<br>-Latency (Quality Of Service) |
| 13. | Gatouillat, A., Badr, Y., & Massot, B. [20] | A quality-of-service driven self-adaptation framework can simultaneously handle changing adaptation strategies, monitoring infrastructure and physical environment while guaranteeing constant quality-of-service. | -Quality Of Service<br>-Adaptation Strategies<br>-Monitoring Infrastructure<br>-Physical Environment<br>-Safety Of Monitored Patients |
| 14. | Duan, R., Chen, X., & Xing, T. [21] | A QoS architecture based on IoT layered structure transmits QoS requirements. | -Qos Requirements<br>-Consistency<br>-Effective Use Of Existing Qos Mechanisms In Every Layer |
| 15. | Chu, Y., & Ganz, A. [22] | The proposed protocol assigns transmission parameters to nodes in the network based on the current traffic conditions to nodes in the network based on the current traffic conditions. | -Throughput<br>-Admission Ratio<br>-Energy Consumption<br>-Delay |

Based on a literature survey, it is found that there are some common limitations and challenges associated with Quality of Service (QoS) in IoT-based Wireless Networks, such as, heterogeneous device ecosystem, resource constraints, scalability, dynamic network topologies, security concerns, interference, congestion, qos metric definitions, real time adaptation, energy efficiency, cross-layer coordination, network mobility, standardization, interpretability etc. Although, the research work in such a wide field of IoT is quite diverse, so it is better to analyse the research work through simulation. Hence the proposed research work for SAAQ, NS-2 simulator is used and its design & implementation is discussed in the next section 3.

## III. METHODOLOGY ADOPTED

SAAQ is a type of architecture that allows an IoT system to automatically adapt its behaviour in response to changes in its environment. This can include changes in the number of devices connected to the network, the type of data being transferred, or the network infrastructure. In this section 3, the proposed SAAQ algorithm and methodology is discussed which is implemented in network simulator 2. The SAAQ algorithm code is written in backend coding in C++ of the network simulator. There are many directories and core files which are modified which are difficult to discuss one by one, so only by methodology flowchart, it is tried to give the overview and working of proposed SAAQ method in this section.

The proposed algorithm utilizes the concept of Jellyfish Search Optimization (JSO) which is well known optimization algorithm to find the optimized route between source and destination nodes. The SAAQ method uses the concept of

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residual energy of nodes to start the communication among the nodes and sort the route in multipath manner using Jellyfish Search Optimization routing approach. This section explains the flowchart and algorithm of SAAQ method.

There are assumptions which are considered during the simulation of IoT network. They are discussed in following bullet points:

- Sensor nodes are randomly deployed in the sensor field. A homogeneous network is considered which means initial energy of sensor nodes is same.
- Sensor nodes are stationary.
- Sensor nodes are energy constrained and battery replacement or recharging is not possible after deployment.
- Random hierarchy is considered for sensor nodes. Sensor nodes send the data to the random receiver nodes.
- The set of experiment consists of static nodes which are further classified according to different number of nodes like 25, 50, 75, 100, 125, 150, 175 and 200 nodes. Therefore, there is eight scenarios are achieved using static topology of the network.
- As communication among nodes is to be chosen as random manner, so UDP protocol is involved during communication with constant bit rate at application interface.
- The nodes are allowed to communicate among each other continuously within the simulation time of 600 seconds, some of nodes are exhausted (dead) due to lower energy and considered as dead nodes. It is to be noted that at starting all sensor nodes are having equal amount of energy levels but as some nodes are act as router for communication, so they got exhausted earlier.

Nodes are setup with some initial parameters for wireless IoT applications. Here some default parameters are set like kind of wireless channel, type of routing protocol, number of nodes, simulation time etc. Particularly in any kind of wireless network, the nodes in a network share their information about location and other info using the beaconing of messages, which make any sender nodes easier to find the destination node. Since the SAAQ method code is implemented in the backend in C++ code of the simulation tool NS-2, so all the nodes are bound to follow the Saaq algorithm. Whenever any sender node starts the route discovery phase, the minimum distance is calculated among the nodes using dijkstra's algorithm Eq.(3).

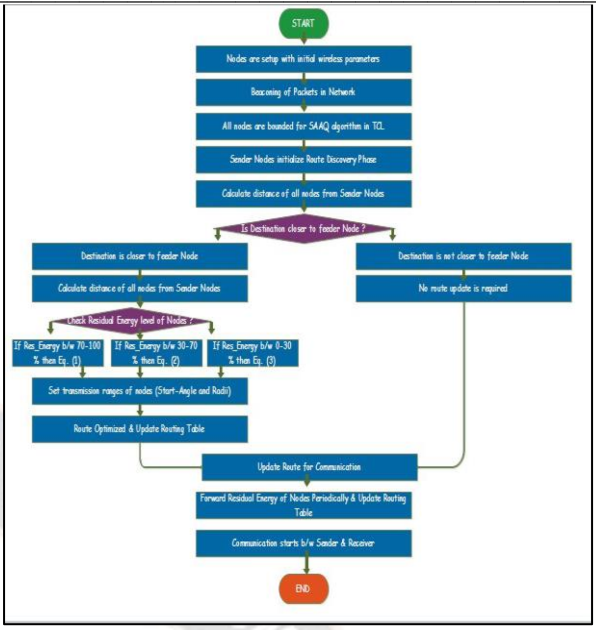

Figure 1: SAAQ Methodology Flowchart

$$n\_hop\_X=abs\ [nX-loc\_X] \quad (1)$$
$$n\_hop\_y=abs[nY-\ loc\_Y] \quad (2)$$
$$Distance,\ D=\sqrt[2]{n_{hop}Y^2+n_{hop}X^2} \quad (3)$$

The jellyfish methodology can be used to improve the performance of the Saaq algorithm for the optimized path/route by using a jellyfish swarm to guide the PSO swarm towards better solutions. The jellyfish swarm is initialized in the same way as the PSO swarm. However, the jellyfish swarm is updated using the jellyfish algorithm, which is designed to move the jellyfish towards the best-known solution. Jellyfish move within their current location, and the position of each jellyfish is updated according to Eq.(4):

$$X_j\ (t+1) = X_j\ (t) + \alpha\ x\ (\ B_u - B_l)\ x\ rand\ (0,1) \quad (4)$$

*Where* $\alpha$ *is motion coefficient,* $B_u$ *and* $B_l$ *are upper bound and lower bound.*

In this case feeder nodes location are the best known solution; if the feeder nodes and source node are closer to each other then there is no need to optimized the path or we can say that there is no need to update the route. This procedure saves the time delay and residual energy of nodes which may be wasted during route discovery and setup phase. SAAQ algorithm in this phase certainly saves energy of the nodes during communications among sender and receiver nodes. If the feeder nodes and source node are not closer to each other then there is a much need for optimized path, so again the dijkstra algorithm is used to find the shortest path and based on residual energy of nodes, the transmission ranges are decreased accordingly.

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*If Nodes residual energy is between 70 to 100 percent set Tx=250 meters* (5)

*If Nodes residual energy is between 30 to 70 percent set Tx=200 meters* (6)

*If Nodes residual energy is between 30 to 70 percent set Tx=150 meters* (7)

*Where Tx is transmission range of nodes.*

The radiant path using start angle and transmission radius is calculated to find the advance solution which check again that optimized path lies within boundary circle of the nodes.

$$E_{TX}(M,D) = M.E_{elect} + M.\epsilon_{fs}.d^2 \text{ if } d \le d_0$$
$$M.E_{elect} + M.\epsilon_{mp}.d^4 \text{ if } d > d_0 \quad (8)$$

Where, $E_{elect}$ denotes residual energy, $\epsilon_{fs}$ and $\epsilon_{mp}$ denote energy consumption of free space and multipath fading channels respectively and d denotes the distance between sensor nodes of sender and receiver nodes. $d_0$ is a threshold distance between transmitter and receiver that can be measured using $d_0$ = square root of $\epsilon_{fs}/\epsilon_{mp}$ . The radio dissipation of receiving M bits data can be measured using $E_{R,X} = M.E_{elect}$.

Then subsequently the route is optimized and the routing table of source is updated during the communication. So, for all the RREP received, distance is calculated as given in equation 3. The node having minimum distance is then selected as the next hop and its location is also updated in the routing table as two entries n_hopX and n_hopY.

*Select node with and add n_hopX, n_hopY in routing table* (9)

The minimum distance (dmin) is the distance between the current node and the next hop node in the algorithm. The power threshold received by all nodes remains constant during the path detection phase. This path between source and destination is maintained for data transfer.

After the communication phase of source node, there is need to update the status of energy level of nodes in a network which is used to update via forwarding function. Then again the same steps are utilized for communication between sender and receiver. The figure 1 shows the methodology and figure 2 shows the pseudo code algorithm for SAAQ algorithm.

*Step 1: Initiate all sensor nodes for IoT based wireless Network.*
*Step 2: All node sends beaconing message in a wireless network.*
*Step 3: TCL script bounds all nodes for SAAQ method.*
*Step 4: Sender nodes establish route and calculate the distances among other nodes.*
*Step 5: Is destination node is closer to feeder node.*
*Step 6: If no;*
*>>> No route updating is required*
*>>> go to Step 9*
*Step 7 : If yes;*
*>>> Route updating is required*
*>>> Residual energy of nodes are determined.*
*>>> Set transmission range to 250m for nodes having residual energy between 70-100%.*
*>>> Set transmission range to 200m for nodes having residual energy between 30-70%.*
*>>> Set transmission range to 150m for nodes having residual energy between 00-30%.*
*Step 8: Probable location of feeder node is detected; WSN node which is node closer to region of interest is selected as forwarder/ intermediate node.*
*Step 9: Route is optimized and Routing Table is updated.*
*Step 10: Forward Residual Energy of nodes using forwarding function.*
*Step11: Data Transmission between sender and destination node would be completed.*
*>>> goto step 12.*
*Step 12: Stop.*

Figure 2: Pseudo Code for SAAQ Algorithm.

## IV. SIMULATION ANALYSIS

There are four routing methods namely AODV, AOMDV, LEACH and SAAQ have been considered in this experiment. The performance of AODV and AOMDV has been seen in previous experiments of Module I and Module II that AODV performs better than AOMDV. LEACH method is revolutionized for energy of wireless nodes so it is pertinent to consider such kind of method so that proper understanding could be made for evaluating QoS parameters. Hence, the proposed SAAQ method has been compared among these routing methods. There are six QoS parameters which are considered namely: packet delivery ratio, packet loss ratio, average end to end delay, throughput of the network, routing overhead and average energy consumption. Total eight scenarios are considered in which nodes are varied from 25 nodes to 200 nodes. There are random sender and destination node pairs which are increased as more the scenarios are discussed. From figure 3 to 10 shows the snapshots of the network scenarios obtained during simulation for the eight experiments in network simulator 2.

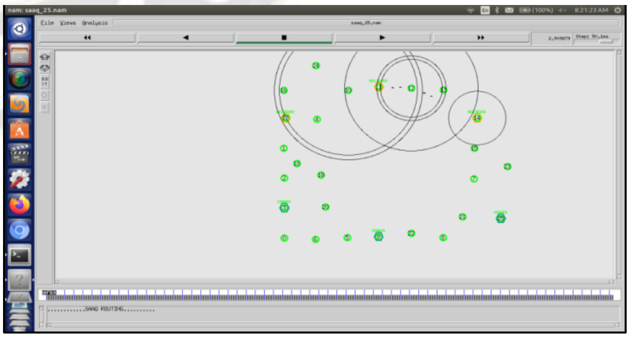

Figure 3: Scenario of 25 nodes

Figure 3 to 5 shows the simulation scenario snapshots for nodes 25 to 75. It can be seen that there are different zones of nodes which communicates with each other. Every zone is thought that there is a presence of some feeder node which is

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optimized for getting best possible route for sender node to receiver node.

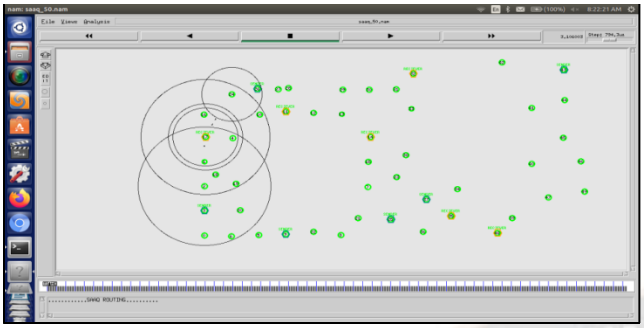

Figure 4: Scenario of 50 nodes

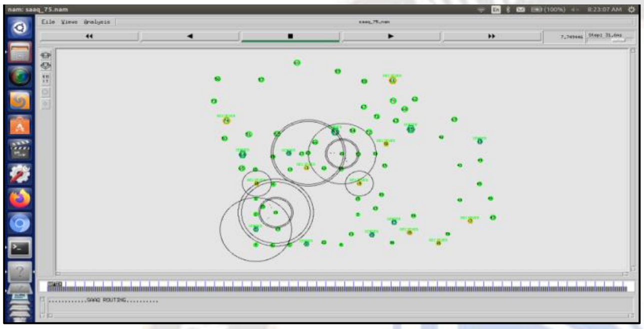

Figure 5: Scenario of 75 nodes

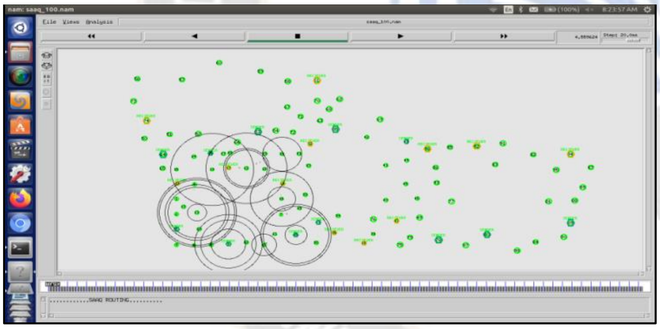

Figure 6: Scenario of 100 nodes

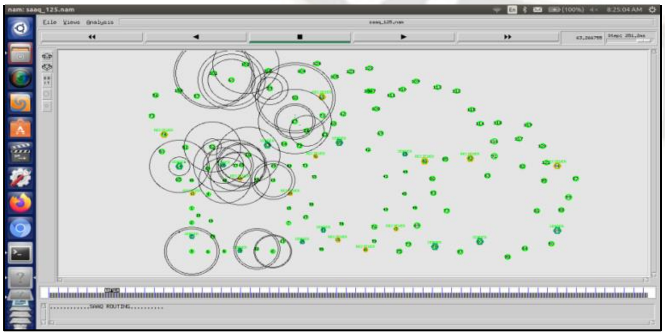

Figure 7: Scenario of 125 nodes

Figure 6 and 7 shows the simulation scenario for nodes 100 and 125 respectively. It can be seen that nodes are communicating in different zones of network. The boundary circles as transmission range of nodes can been in the entire scenarios.

Figure 8 and 9 shows the simulation scenario for nodes 150 and 175 respectively. When the route is optimized for communication between sender and receiver nodes, there is communication among nodes which can be in the entire scenarios.

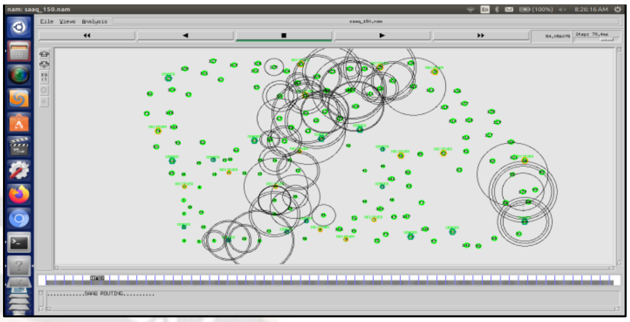

Figure 8: Module3- Scenario of 150 nodes

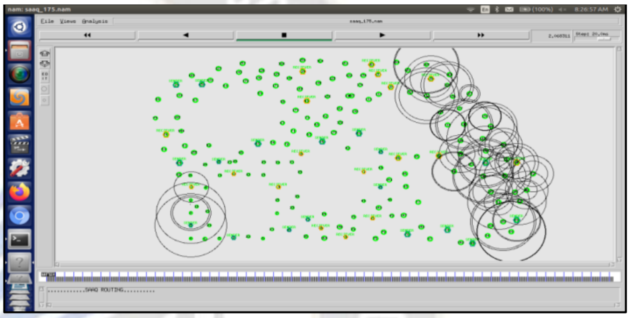

Figure 9: Module3- Scenario of 175 nodes

Figure 10 shows the simulation scenario snapshot for 200 nodes. This is the largest simulation scenario considered in Module III where 200 nodes are communicating with each other classified in five zones of wireless network.

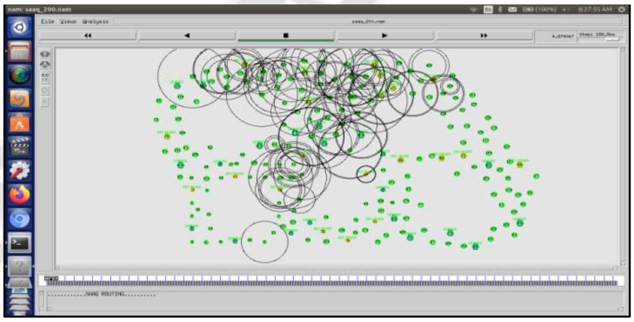

Figure 10: Module3- Scenario of 200 nodes

## V. RESULT ANALYSIS

As discussed earlier that this experiment is focused to improve the QoS parameter of lifetime of the network so the average energy consumption of nodes has been considered in the study. Also this is also the reason to include the LEACH routing method in the research work so that proposed SAAQ method can be enhanced in terms of energy consumption.

The graph in figure 11 shows the packet delivery ratio of four routing protocols (AODV, AOMDV, LEACH, and SAAQ) with respect to the number of nodes. The packet delivery ratio is the percentage of packets that are successfully delivered to their destination. The graph in figure 11 shows that the packet delivery ratio of all the routing protocols decreases as the number of nodes increases. This is because the network becomes more congested as the number of nodes increases, which makes it more difficult for the routing protocols to find efficient paths. The packet delivery ratio of LEACH is the lowest of all the routing protocols. This is because LEACH is a hierarchical routing protocol that divides the network into clusters. Each cluster has a cluster head that is responsible for routing packets within the cluster. This can lead to a higher packet loss ratio if the cluster head fails. The packet delivery ratio of SAAQ is higher between AODV and LEACH.

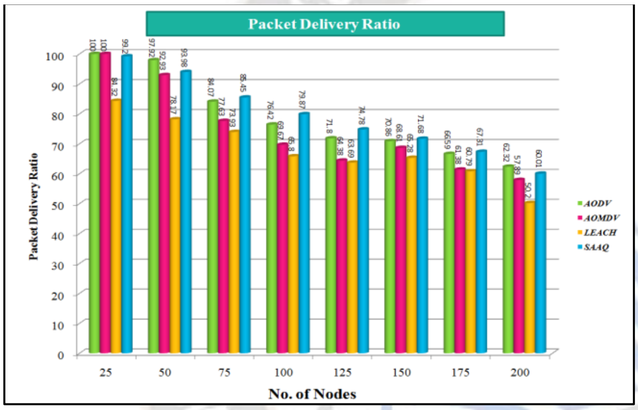


Figure 11: Packet Delivery Ratio

The graph in figure 12 shows the packet loss ratio of four routing protocols (AODV, AOMDV, LEACH, and SAAQ) with respect to the number of nodes. The packet loss ratio is the percentage of packets that are lost during transmission. The graph shows that the packet loss ratio of all the routing protocols increases as the number of nodes increases. This is because the network becomes more congested as the number of nodes increases, which makes it more likely for packets to be lost. The packet loss ratio of LEACH is the highest of all the routing protocols. This is because LEACH is a hierarchical routing protocol that divides the network into clusters. Each cluster has a cluster head that is responsible for routing packets within the cluster. This can lead to a higher packet loss ratio if the cluster head fails. The packet loss ratio of SAAQ is lower between AODV and LEACH.

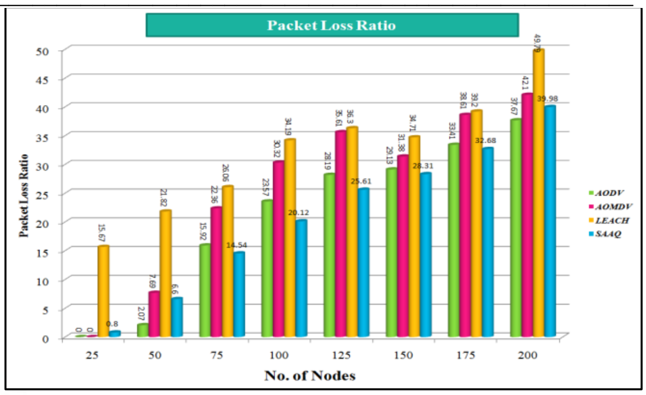


Figure 12: Packet Loss Ratio

The graph in figure 13 shows the end-to-end delay of four routing protocols (AODV, AOMDV, LEACH, and SAAQ) with respect to the number of nodes. The end-to-end delay is the time it takes for a packet to travel from its source to its destination. The graph shows that the end-to-end delay of all the routing protocols increases as the number of nodes increases. This is because the network becomes more congested as the number of nodes increases, which makes it more time-consuming for packets to travel from their source to their destination. The end-to-end delay of LEACH is the highest of all the routing protocols. This is because LEACH is a hierarchical routing protocol that divides the network into clusters. Each cluster has a cluster head that is responsible for routing packets within the cluster. This can lead to a higher end-to-end delay if the cluster head fails. The end-to-end delay of SAAQ is lower between AODV and LEACH.

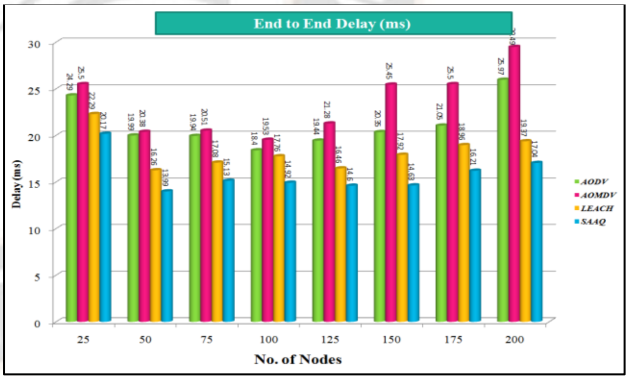


Figure 13: End to End Delay

The graph in figure 14 shows the throughput of four routing protocols (AODV, AOMDV, LEACH, and SAAQ) with respect to the number of nodes. The throughput is the amount of data that is successfully transmitted over a network in a unit of time. The graph shows that the throughput of all the routing protocols increases as the number of nodes increases. This is because the network becomes more interconnected as the number of nodes increases, which makes it possible for more packets to be transmitted simultaneously. The throughput of LEACH is the lowest of all the routing protocols. This is

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because LEACH is a hierarchical routing protocol that divides the network into clusters. Each cluster has a cluster head that is responsible for routing packets within the cluster. This can lead to a lower throughput if the cluster head fails. Overall, the choice of the best routing protocol depends on the specific application and the QoS requirements. If the most important QoS requirement is throughput, then SAAQ is a good choice.

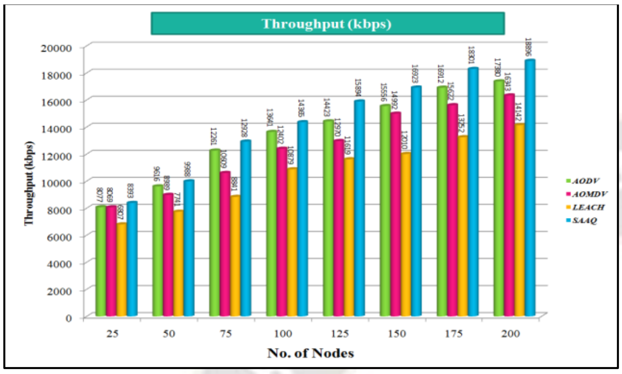


Figure 14: Throughput

The graph 15 shows the routing overhead of four routing protocols (AODV, AOMDV, LEACH, and SAAQ) with respect to the number of nodes. The routing overhead is the amount of data that is used for routing purposes. The graph shows that the routing overhead of all the routing protocols increases as the number of nodes increases. This is because the network becomes more congested as the number of nodes increases, which makes it necessary to send more routing messages. The routing overhead of LEACH is the highest of all the routing protocols. This is because LEACH is a hierarchical routing protocol that divides the network into clusters. Each cluster has a cluster head that is responsible for routing packets within the cluster. This can lead to a higher routing overhead if the cluster head fails. The routing overhead of SAAQ is lower between AODV and LEACH.

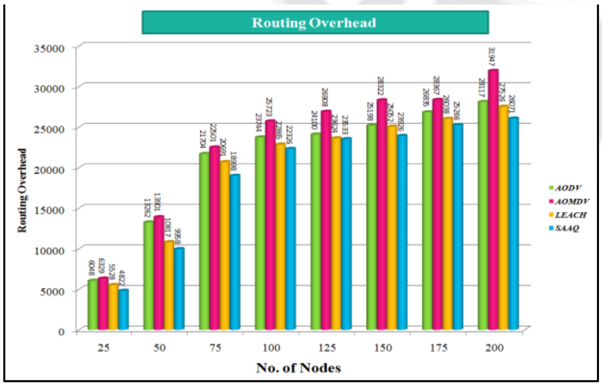


Figure 15: Routing Overhead

The graph 16 shows the average energy consumption of four routing protocols (AODV, AOMDV, LEACH, and SAAQ) with respect to the number of nodes. The average energy consumption is the amount of energy used by a node to transmit and receive packets. The graph shows that the average energy consumption of all the routing protocols increases as the number of nodes increases. This is because the network becomes more congested as the number of nodes increases, which makes it necessary for the nodes to transmit and receive more packets. The average energy consumption of AOMDV is the highest of all the routing protocols. This is because AOMDV is a proactive routing protocol that maintains a routing table for each node in the network. This allows AOMDV to quickly find a route to the destination, even in a congested network. However, this also requires the nodes to transmit and receive more routing messages, which can lead to higher energy consumption. The average energy consumption of SAAQ lower is between AODV and AOMDV.

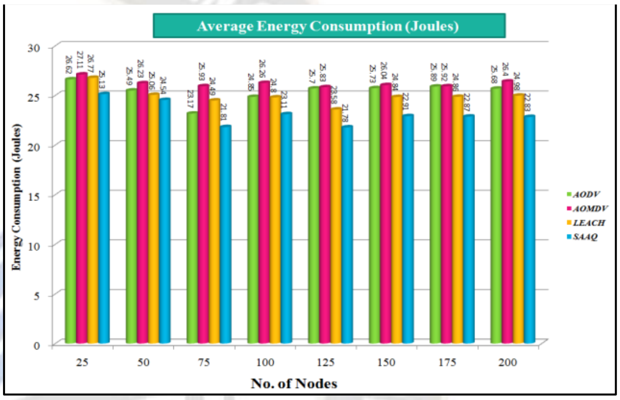


Figure 16: Average Energy Consumption

Here is a more detailed explanation of the performance of each routing protocol:

- AOMDV is a proactive routing protocol that maintains a routing table for each node in the network. AOMDV is known for its good performance in terms of packet delivery ratio and delay. However, it has a high routing overhead, which can be a problem in networks with a large number of nodes.
- AODV is a reactive routing protocol that only creates a route when a packet needs to be sent. AODV has a lower routing overhead than AOMDV, but it may have a higher packet loss ratio and delay.
- LEACH is a hierarchical routing protocol that divides the network into clusters. Each cluster has a cluster head that is responsible for routing packets within the cluster. LEACH can be energy efficient, but it may have a lower packet delivery ratio and delay than other routing protocols.
- SAAQ is a QoS-aware routing protocol that takes into account the QoS requirements of the traffic when routing packets. SAAQ can achieve good performance in terms of all the QoS parameters, but it may have a higher routing overhead than other routing protocols.

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Overall, the choice of the best routing protocol depends on the specific application and the QoS requirements. If the most important QoS requirements are all of the above, then SAAQ is a good choice.

## VI. CONCLUSION & FUTURE DIRECTIONS OF RESEARCH

In this research work, the SAAQ method has been designed to be lightweight and efficient. It is a good choice for use in IoT based wireless sensor networks where the nodes have limited resources. The SAAQ method has been evaluated in simulation and has been shown to be effective in providing reliable and efficient routing in IoT wireless networks. The SAAQ method is an improvement over AODV, LEACH, and AOMDV because it provides QoS guarantees, uses both proactive and reactive routing, and maintains multiple routes to each destination. This makes it a more robust and efficient routing protocol for wireless ad hoc networks.

### A. Conclusion

This research work has proposed SAAQ method which is improvised over AODV, LEACH and AOMDV methods. SAAQ uses a self-adaptive approach to routing, while AODV, LEACH, and AOMDV use a fixed approach. This means that SAAQ can dynamically adapt to changes in the network conditions, while AODV, LEACH, and AOMDV cannot. SAAQ uses a QoS-aware approach to routing, while AODV, LEACH, and AOMDV do not. This means that SAAQ can take into account the quality of service requirements of the traffic, while AODV, LEACH, and AOMDV cannot. SAAQ uses a distributed approach to routing, while AODV, LEACH, and AOMDV use a centralized approach. This means that SAAQ can be used in networks where there is no central controller, while AODV, LEACH, and AOMDV cannot. The following table 2 summarizes the comparison between the four routing protocols:

Table 2: Comparison of routing methods based on features

| Feature | SAAQ | AODV | LEACH | AOMDV |
|---|---|---|---|---|
| Approach | Self-Adaptive | Fixed | Fixed | Fixed |
| QoS Awareness | Yes | No | No | No |
| Distribution | Distributed | Centralized | Centralized | Centralized |

The following table 3 summarizes the advantages of SAAQ over AODV, LEACH, and AOMDV:

Table 3: Advantage of SAAQ method over other methods

| Feature | SAAQ | AODV | LEACH | AOMDV |
|---|---|---|---|---|
| QoS Guarantess | Yes | No | No | No |
| Proactive/Reactive | Both | Reactive | Hierarchical | Proactive |
| Multiple Routes | Yes | No | No | Yes |
| Energy Efficiency | Good | Good | Good | Good |
| Scalability | Good | Good | Good | Good |

Overall, the SAAQ method is a promising routing protocol for wireless ad hoc networks. It provides QoS guarantees, uses both proactive and reactive routing, and maintains multiple routes to each destination. This makes it a more robust and efficient routing protocol than AODV, LEACH, and AOMDV. The following table 4 summarizes the percentage of improvement of SAAQ over LEACH based on QoS parameters considered in the research work.

Table 4: Percentage of Improvement of SAAQ over LEACH

| QoS Parameter | LEACH (Avg. Aggregate) | SAAQ (Avg. Aggregate) | Percentage of Improvement |
|---|---|---|---|
| Packet Delivery Ratio | 67.7768 | 78.9631 | 16.5 % |
| Packet Loss Ratio | 32.2231 | 21.0369 | 34.71 % |
| End to End Delay | 18.2687 | 15.8415 | 13.28 % |
| Routing Overhead | 10661.38 | 14461.51 | 35.64 % |
| Energy Consumption | 19824.6 | 19362.5 | 2.33 % |

After analyzing the above table 4, it if found that SAAQ method is compared with LEACH method and improves the packet delivery ratio by 16.5%, packet loss ratio by 34.71%, end to end delay by 13.28%, throughput by 35.64%, routing overhead by 2.33% and average energy consumption by 7.23%.

### B. Future Scope

In addition to improving the performance of SAAQ, future work should also focus on evaluating its performance in real-world IoT networks. This can be done by conducting experiments with real IoT devices and applications. The results of these experiments will help to determine the effectiveness of SAAQ in real-world scenarios. This will help to make SAAQ a more practical and useful routing protocol for QoS-based IoT networks. These are just a few of the future directions for the thesis topic. The specific research directions that are pursued will depend on the specific goals of the research work and the expertise of the researcher.

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