Effective Energy Consumption Routing Protocol in WSN for IoT Devices

ABSTRACT:

Our focus of research is mainly on the field of Internet of Things (IoT) devices. Poor IoT device management, insecure interfaces, insufficient data protection, and weak update methods are some of the key research challenges of IoT. We address the issue of energy wastage in wireless sensor networks (WSN). Wastage of energy cannot help the sensor nodes to work efficiently especially in large scale applications like IoT and can lead to division of network and can make WSN ineffective for the IoT application. To increase the lifespan of WSN, our goal is to decrease energy consumption in each node in WSN and find the shortest path between nodes in routing protocol. The available routing protocols use metrics such as number of hops for selecting a path from source to destination node. However, these metrics will result in frequent broken paths as and consumes more energy and thus decreasing the lifetime of IoT devices. One of the methods we can overcome the drawback is to implement cross-layering in WSN. The solution proposed in our paper is to use a cross layer variant of the AD Hoc On-demand Distance Vector (AODV) by using inputs like link quality index(LQI) and collision count(CC) known as energy efficient AODV (EEAODV) instead of using hop count metric.

Method proposed in our base paper is implemented in IEEE 802.15.4 in NS-2 platform. A detailed comparative analysis is done between the proposed method and the existing routing protocols as well as a graph is provided to indicate the result of the proposed routing protocol consuming lesser energy compared to the existing routing protocol.

Keywords — cross-layer, AODV, EEAODV, LQI, CC, WSN, IoT

1. Introduction:

Wireless sensor networks (WSN) have a wide range of applications in the modern world, even different intelligent Internet of Things (IoT) applications and are growing rapidly in academics. The advancement of communication and computing technology has made it possible to design sensor nodes that are more compact, less expensive, and resource-efficient (like battery, processing power and memory). These sensor nodes can build WSN as necessary using peer-to-peer topology.

Sensor nodes, which may be installed everywhere and are used to measure phenomena, are utilized in WSNs. But the resource constrained WSN nodes run on batteries with limited capacity. Replacing batteries is not an option as getting physical access of sensor node is difficult after deployment and applications must use methods that does not waste energy. Wasting energy results into partition of the network and makes WSN useless for the application, and therefore applications cannot reach it's full potential.

Researchers have provided various energy efficient solutions to solve this issue. One such method is to address each layer of protocol stack. However, the level of energy efficiency achieved using this method is restricted, and other solutions create hindrance for energy efficiency to a greater extent. By obliterating boundaries of the logical layers, information for one layer from other layers is being used to improve energy efficiency, also known as cross-layer design and without cross layering in wireless networks, loss of performance has been observed. During route discovery process, flooding of packets consumes lots of sensory energy while receiving and sending packets. Thus, the routing protocol being used for WSNs negatively impacts lifetime of the IoT applications.

Routing protocols of WSNs also uses shortest path like criteria for the selection of path from source node to a destination node. Shortest path routing metric and other of that sort selects unstable path having longer delay, depleted nodes' battery and more collisions. Depletion of energy on many nodes affects the topology and need route maintenance by exchanging more packets to re-establish the broken routes. Broken pathways initiate the route recovery process, which uses extra energy as a result.

For the WSNs, route recovery is an overhead. We should put off route recovery in order to improve energy efficiency or extend the life of the network. The topology is affected when multiple nodes lose energy, and the broken paths must be restored by exchanging more packets.

Broken pathways initiate the route recovery process, which uses extra energy as a result. For the WSNs, route recovery is a burden. We should put off route recovery in order to improve energy efficiency or extend network lifetime.

Routing protocol should select a path which is more stable and does not require selecting or re-establishing another path for the longer duration. After a path has been constructed, it is stable for a longer period of time, which lowers the overhead for the underlying routing protocol.

The method suggested in this study is a variation on the AODV protocol that takes collisions and energy into account while choosing a route. The method suggested in this research retrieves data from the physical and MAC levels, which are the bottom two layers, and is used by the network layer to choose the route.

The suggested solution retrieves collision count from MAC layer and connection quality information from PHY to create a path and assist network layer in making routing decisions. The suggested route metric selects an efficient and reliable routing path using these criteria.

The LQI values and collision detection at the PHY and MAC layers are likewise altered by the routing protocol. The method presented in this research is implemented in the well-known network simulator NS-2 by making the required modifications to the physical, MAC, and AODV protocols. The proposed solution provides LQI measurements to the MAC layer through the physical layer. LQI value is used by MAC layer to identify potential collisions. If a collision occurs, the collision count value is updated at the MAC layer. The proposed approach communicates collision count and LQI value to the network layer. The network layer intelligently chooses a stable short path using these variables.

2. Related Work

- In paper [1], the main objective is to present a new strategy for selecting an ideal way between the hubs for information transmission in portable network for improving communication between sensors. The algorithm brings changes to the AODV protocol such as reduced start to finish delay time and lower directing overhead. This research work can be extended further by considering various parameters like trust, remaining energy, transmission capacity, sign to commotion proportion in choosing the ideal way among various courses and another drawback is the security provided by sending information packets in various ways will make it difficult for malicious hubs to differentiate the true information being communicated by the source.

- In paper [2] the key objective is to increase throughput performance and improve overall lifetime of the cognitive radio based WSN. The proposed EAQ-AODV uses Q-learning based reward mechanism for cluster head selection and AODV enabled routing protocol based on different parameters such as Residual Energy, Common Channel and Trust Factor to establish the routing path. The routing protocol achieves an improved performance in terms of average end-to-end delay, average energy consumption and network lifetime when compared with the existing techniques. The drawback of the research is the research work only deals with static nodes and must be extended mobile nodes as well.

- In paper [3], the research work focuses on improving WSN security by developing an efficient algorithm which would detect security breaches and harmful nodes in sensors. A Trust-Aware Dynamic Routing algorithm based on Extended AODV protocol for secure communications in the WSN (TADR-EAODV) is developed considering factors such as trust, energy rate to measure the distributed safety among various section of nodes during routing. We use the AODV protocol for multi-route routing approach. A centralized ensemble clustering for node grouping is included in the proposed algorithm, to enable clustering-based routing to enhance

WSN performance. TADR-EAODV can detect anomalous behaviour of attackers and has improved the average packet transfer significantly in comparison to existing trust aware algorithms. However, this research work is not effective for multiple mobile links.

- In paper [4], this research work focuses on selects an effective route for the creating a structured multicast tree and selecting a unique group leader in the multicast group to share and exchange information among group members. ECA-MAODV performs better than other routing protocols with higher network lifetime, better throughput, lesser data packet loss ratio, average latency, and an average number of events processed.

- In paper [5], our goal is to enhance energy consumption in WSN and finds the shortest path between nodes in routing protocol. The method Implemented is the cross-layering variant of the AD Hoc On-demand Distance Vector (AODV) by using link quality index and collision count instead of using hop count metric parameter. The drawback is WSN complexity due to cross layering is not taken into consideration.

- In paper [6], the objective is to enhance FANET (flying Ad-hoc network) performance with regard to providing more connectivity and reliability to the network. An algorithm namely CLEA_AODV is developed, which reached much higher PSR (packet success ratio) rate when compared with other protocols like AODV, SOC-GSO, and EENFC.

Algorithm & Year of publication	Objective	Methodology	Input Metrics for making decision	Requirement /Assumption	Achieved enhancements	Simulator / Machine learning concept	Limitations
Q-learning based reward mechanism for cluster head selection and AODV enabled routing protocol Published in 2022	achieve an improved performance in terms of average end-to-end delay, average energy consumption and network lifetime.	the solution uses combined cognitive radio as well as sensor network method. Combined reinforcement learning and AODV protocol for cognitive radio sensor networks is also used.	Residual Energy, Common Channel, Number of Hops, Licensed Channel, Communication Range and Trust Factor to establish the routing path.	every sensor node knows its own location, residual energy, and it's neighbour's information such as its location, energy, and available channels.	achieves an improved performance regarding average end-to-end delay, average energy consumption and network lifetime	MATLAB tool and NS-2	The research only deals with static nodes and must be extended mobile nodes as well
Trust Aware dynamic routing algorithm, Published in 2022	To improve WSN security by developing an efficient algorithm which would detect security breaches and harmful nodes in sensors	a centralized ensemble clustering for node grouping	direct trust, recommended trust, connectivity strength, energy rate and worthiness score	In energy model assume size of control packets as 25 bits and initial energy (E0) of all nodes is assumed to be uniform and set to 0.5 J	Increases packet delivery rate and identifies malicious nodes, hence leading to more secure communication and reduces energy consumption.	MATLAB R2022a simulator	More research needs to be done on multiple mobile links

ECA-MODV (Event Condition Action) based Multicast Ad hoc On-demand Distance Vector Published in 2022	The ECA-MADOV protocol selects an effective route for creating a structured multicast tree and selecting a unique group leader in the multicast group to share and exchange information among group members using Computational Intelligence (CI) method	ECA-based path selection consists of blocks like routing metrics, logic, route rating, inference module, and optimal route to perform certain functions like creating a multicast routing control packet, enabling hello packet	Inputs such as hop count, energy level, processor speed, bandwidth, throughput, buffer occupancy, battery capacity	When the transmitted packet is not received by the member of the multicast group in a given time, we assume that packet is a lost packet.	ECA-MAODV performs better than other routing protocols with regards to lifespan of the network, better throughput, lesser data packet loss ratio, average latency, and an average number of events processed.	NS-3	
Cross-Layer and Energy-Aware Ad-hoc On-demand Distance Vector (CLEA-AODV) routing protocol Published in 2022	To improve FANET (flying Ad-hoc network) performance with regard to providing more connectivity and reliability to the network	Uses cross layering approach and the proposed protocol was constructed based on the combined CH selection and a cooperative MAC model.	Parameters which effects FANET routing process are threshold values, fitness calculation bandwidth, hop count, energy consumption , and delay	The source node is fixed, and the destination node is dynamic.	CLEA_AODV reached much higher PSR (packet success ratio) rate when compared with other protocols like AODV, SOC-GSO, and EENFC.	Mainly NS-2 tool, along with C++ and tcl scripts to execute energy aware FANET AWK language is used to analyze results of simulation	

Multiple Metric based Twofold Route Selection AODV Routing protocol (MMBTRS_AODV) Published in 2020	presents a new strategy for selecting an ideal way between the hubs for information transmission in portable network for improving communication between sensors.	Two courses are found between the source and objective and afterward by considering the separation metric ideal course is chosen for information transmission between the hubs.	Depends on various parameters like separating space between the hubs, bounces check, trust esteems, leftover energy, delay signal quality	Any source node and destination node must be fixed	The algorithm brings changes to the AODV protocol such as reduced start to finish delay time and lower directing overhead.	NS-2 re-enactment apparatus is used. Re-enactment climate is when more than 1000 m * 1000 m network size is used along with 50 portable hubs.	This research work can be extended further by considering various parameters like trust, remaining energy, transmission capacity, sign to commotion proportion in choosing the ideal way among various courses.
EEAODV (Energy efficient AODV) Routing protocol Published in 2022	Enhance energy consumption in WSN and checks for the shortest path between nodes in routing protocol	cross layer variant of the AD Hoc On-demand Distance Vector (AODV) by using link quality index and collision count known as energy efficient AODV (EEAODV)	Uses Link quality Index (LQI) and collision count (CC) as routing metric inputs	Must receive minimum transmission power requirement from all neighbouring nodes	Energy consumption is reduced compared to other routing protocols	NS-2	WSN complexity due to cross layering is not considered

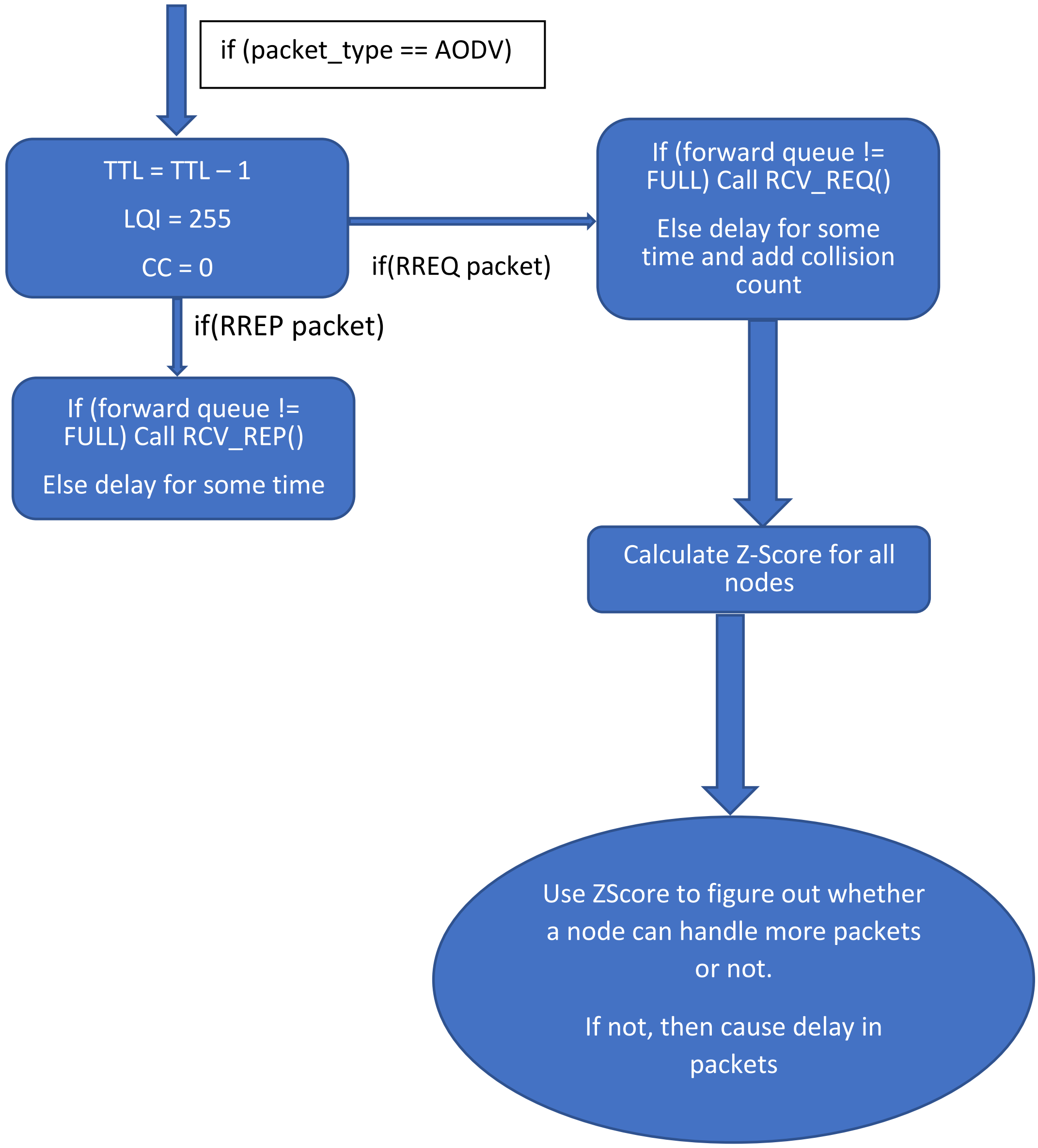
3. Proposed Methodology

In these algorithms, we implement queues to reduce collision and decrease the packets from dropping. When a packet is sent, it is stored in the queue and comes out in the order of First In First Out. Collisions cause a lot of energy wastage and decrease the throughput. With the implementation of queues, we attempt on getting better throughput and energy conservations.

We also use Collision Count in an advanced form in the implementation of the algorithms to give us better result. We use Z-Score in the algorithms.

$$ZScore = \frac{CCi - \mu}{\sigma}$$

Here, σ is the standard deviation and equals 5.567 and μ is the mean of all Collision Counts.



The ZScore was never implemented in the original paper. It was ideated and never used. We try to use the ZScore in the algorithms. By trial and error method we figured out that if ZScore is above 2.27 for a node, causing a delay while sending the ACK packet is better, otherwise there will be more chances of a collision occurring and a packet getting dropped.

The queue in the algorithm also betters the throughput as the threshold of packets is increased.

Extension of the Ad-hoc On-Demand Distance Vector (AODV) routing protocol is the method suggested in this study. Hop count is a routing measure used by AODV.

For WSNs with limited resources, using the shortest way results in issues including unstable paths, excessive energy usage, lower QoS, and shorter lifespans.

In the current paper, they've only played with concepts of Link Quality Indicator, Collision Count and Time To Live, but never delved deep in the concepts of ZScore and it's implications and benefits of using it in the algorithms.

The following is the path selection procedure from source node to destination node: The suggested solution employs a routing measure at the network layer that combines collision count and LQI. It is necessary to first normalise the values of link quality indicator and collision count before giving them equivalent weights in the calculation of the routing measure. The maximum link quality indicator value, 255, is used to normalise link quality indicator numbers, and the ZScore normalisation procedure is used to normalise collision count statistics.

The best path is chosen upon the final ZScore. And it is calculated multiple times. The aforementioned algorithm has been put into practise and integrated into the well-known and respected network simulator NS-2 in order to test and validate the suggested methodology. The first sub-part of this section contains a list of the simulation parameters. The findings for the proposed method's validation are derived from trace files produced following simulation runs.

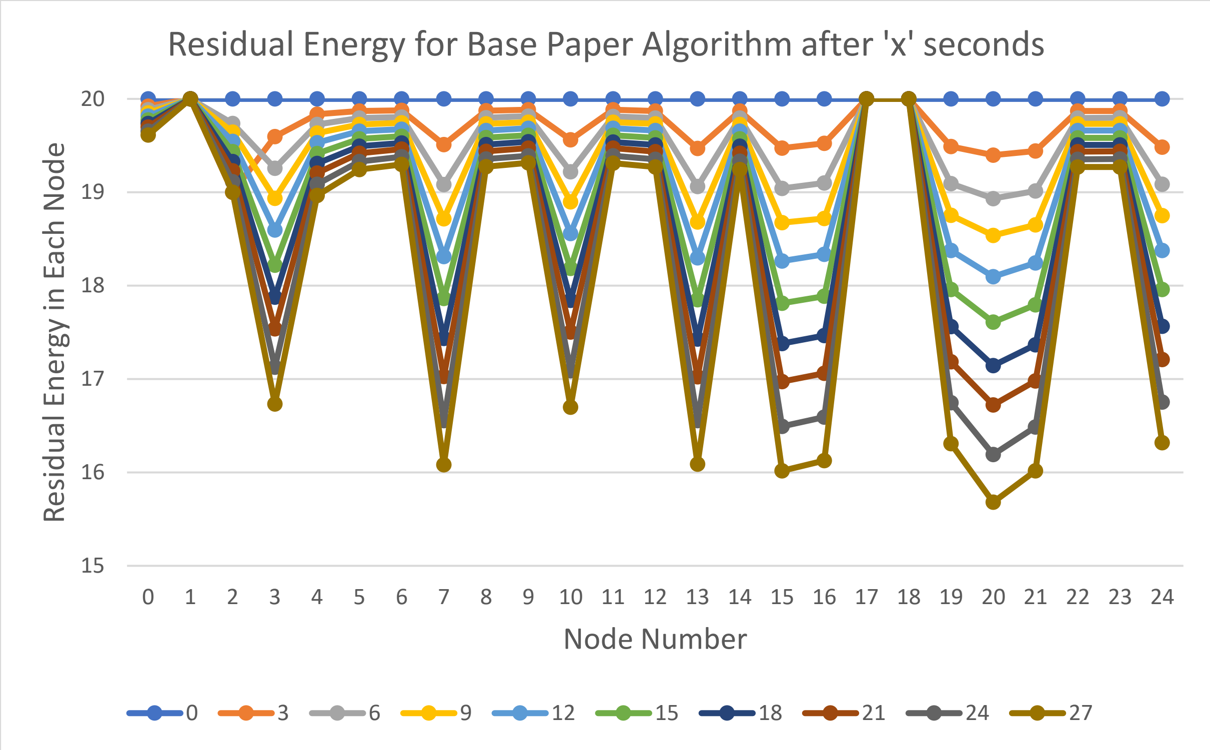
```
mu=0
for(int i=0;i<25;i++){
    mu+=cc[i]
}
mu=mu/25
zscore=0
for(int i=0;i<25;i++){
    zscore=(cc[pkt_id]-mu)/5.56
}
```

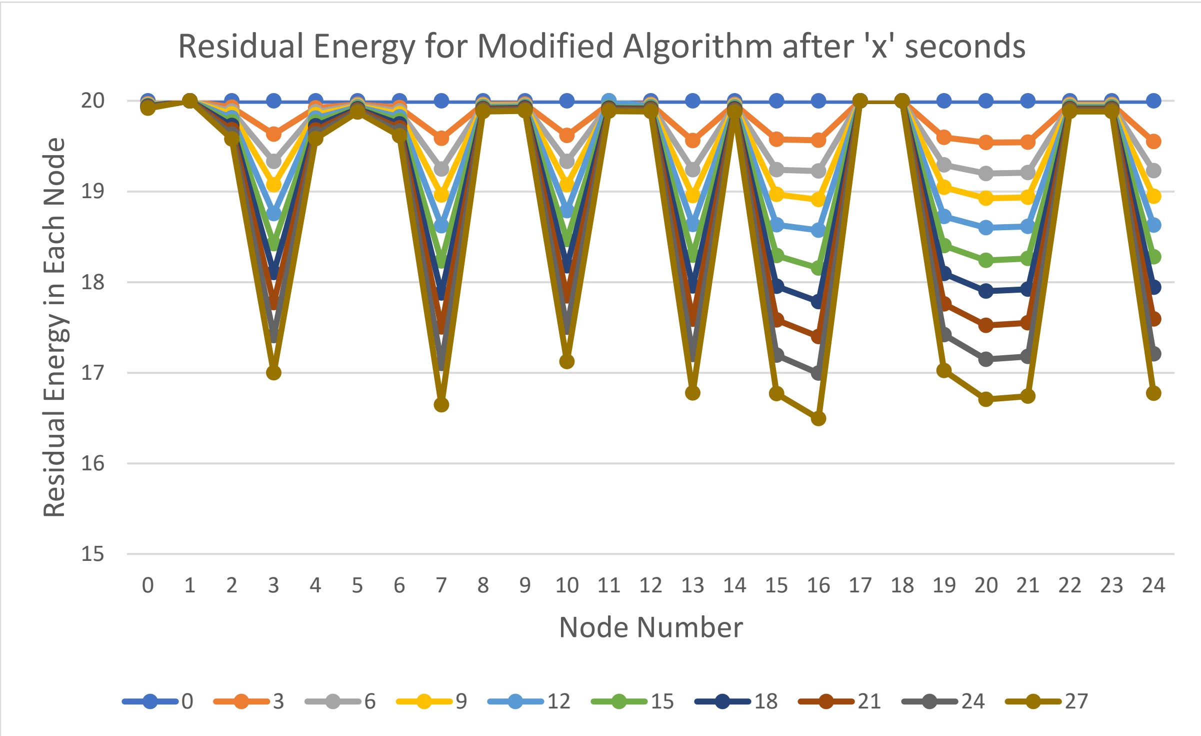
4. Simulation and Analysis

The aforementioned algorithm has been put into practise and integrated into the well-known and respected network simulator NS-2 in order to test and validate the suggested methodology. The first sub-part of this section contains a list of the simulation parameters. The findings for the proposed method's validation are derived from trace files produced following simulation runs.

We have calculated results of the first 10 intervals of 3 seconds each and compared the residual energy of the given algorithm with our improvements. Ultimately, we have also compared the final residual energy remaining.

The fundamental goal of the suggested strategy is energy efficiency. Network longevity is increased through energy efficiency. According to the literature, the period between the start of the simulation and the moment when any one of the nodes in the WSN reaches full energy depletion defines the network's lifetime.


Residual Energy for Base Paper Algorithm after 'x' seconds
Residual Energy in Each Node
20
19
18
17
16
15
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Node Number
0 3 6 9 12 15 18 21 24 27


Residual Energy for Modified Algorithm after 'x' seconds
Residual Energy in Each Node
20
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16
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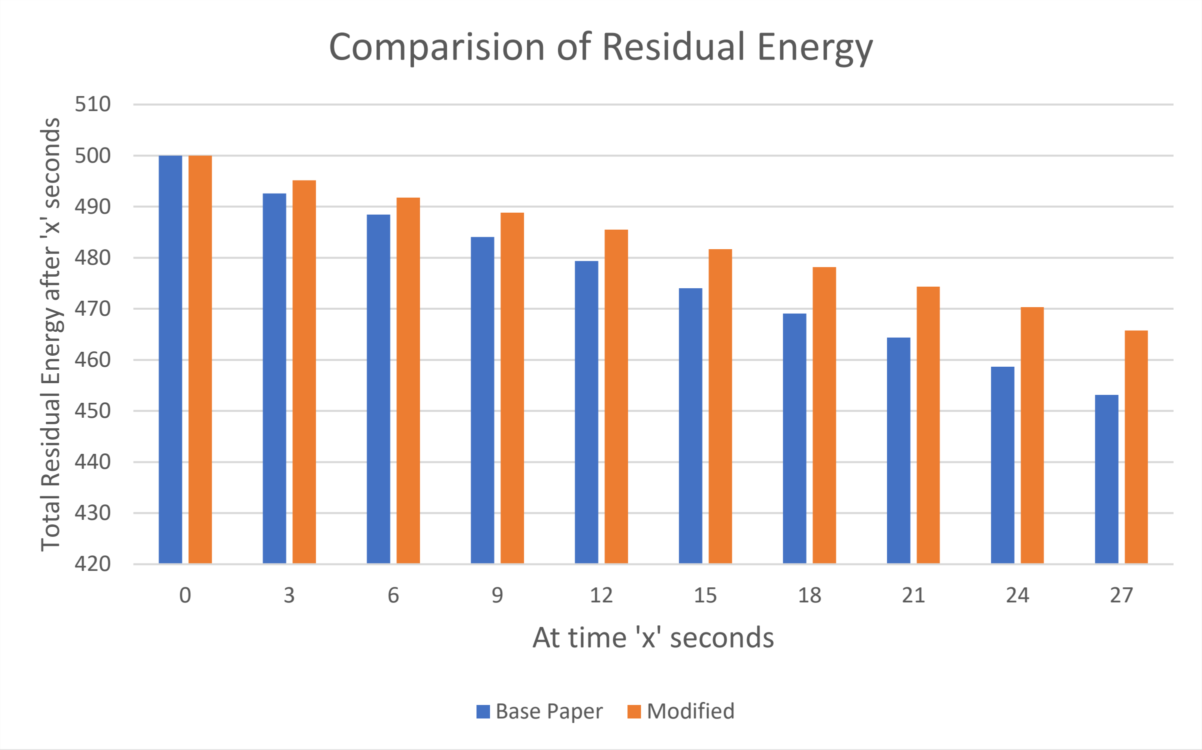
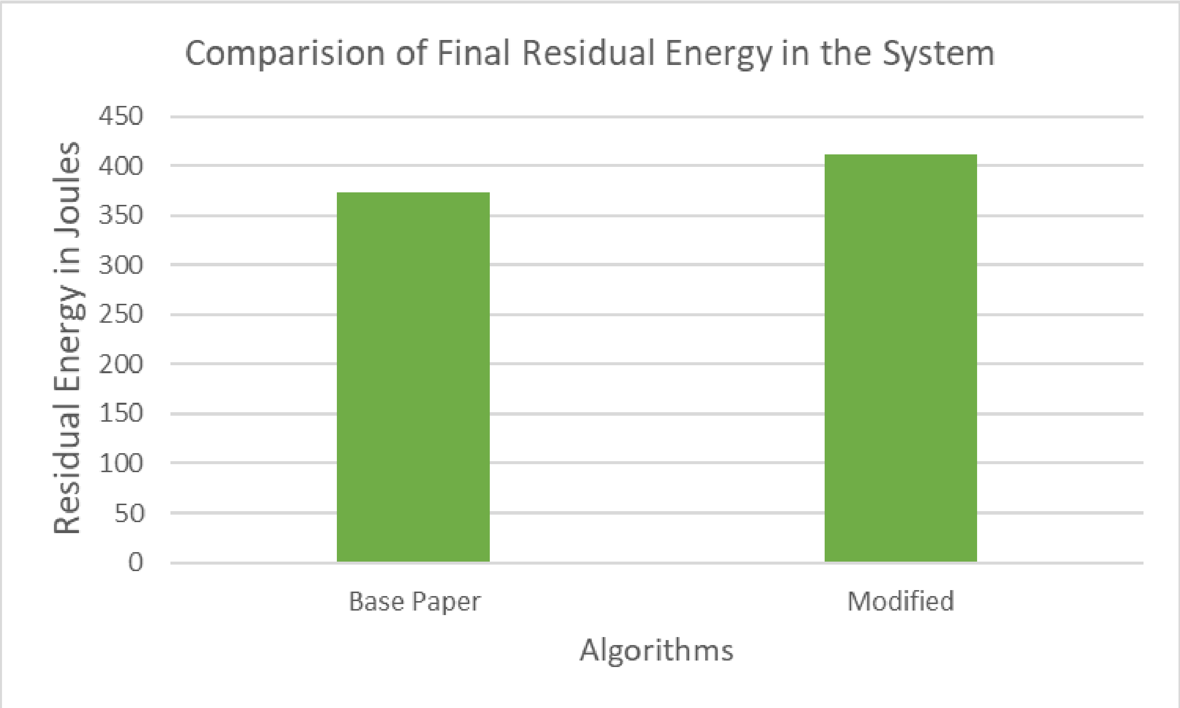
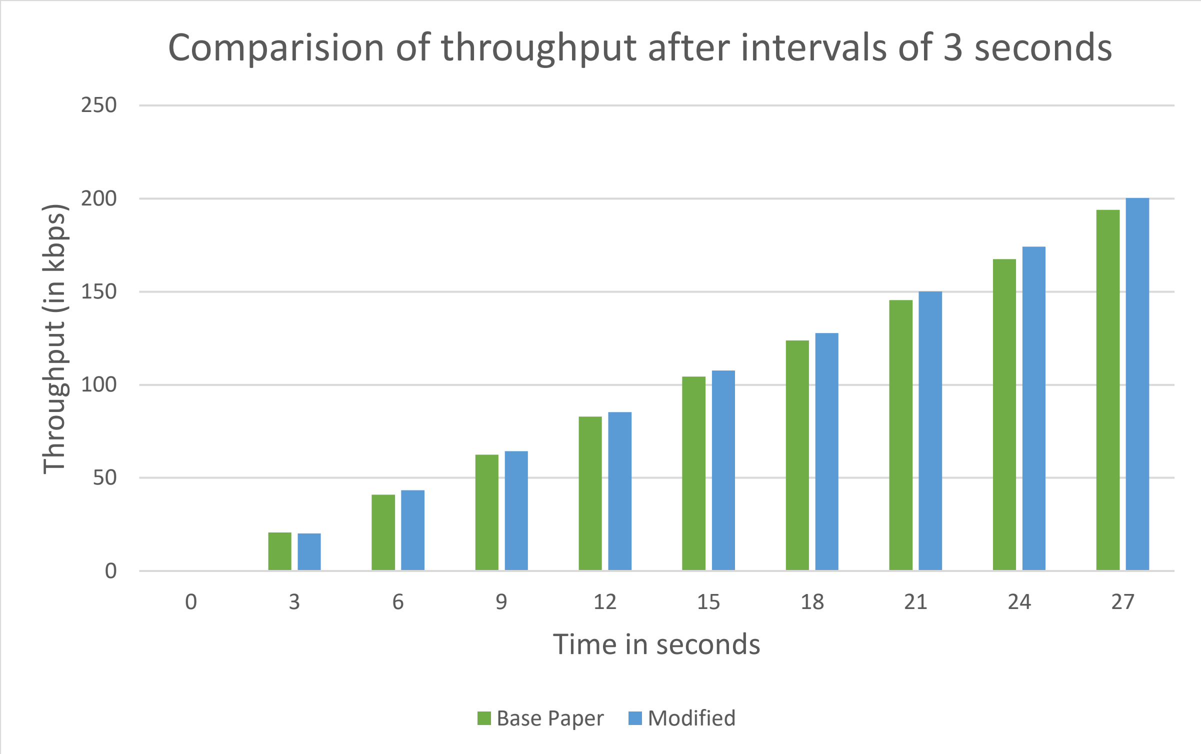
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Node Number
0 3 6 9 12 15 18 21 24 27

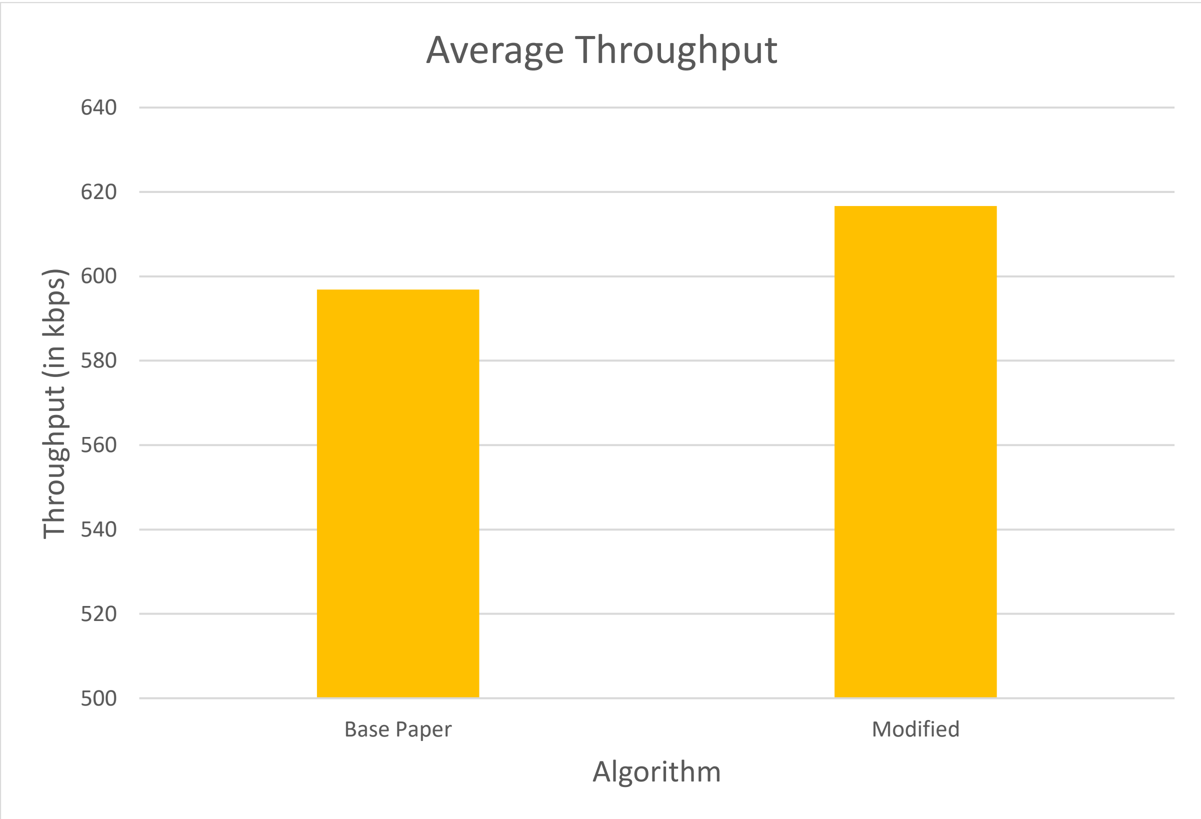




The graph above shows an end-to-end delay analysis using the suggested approach and EEAODV methodologies from the base paper for residual energy.

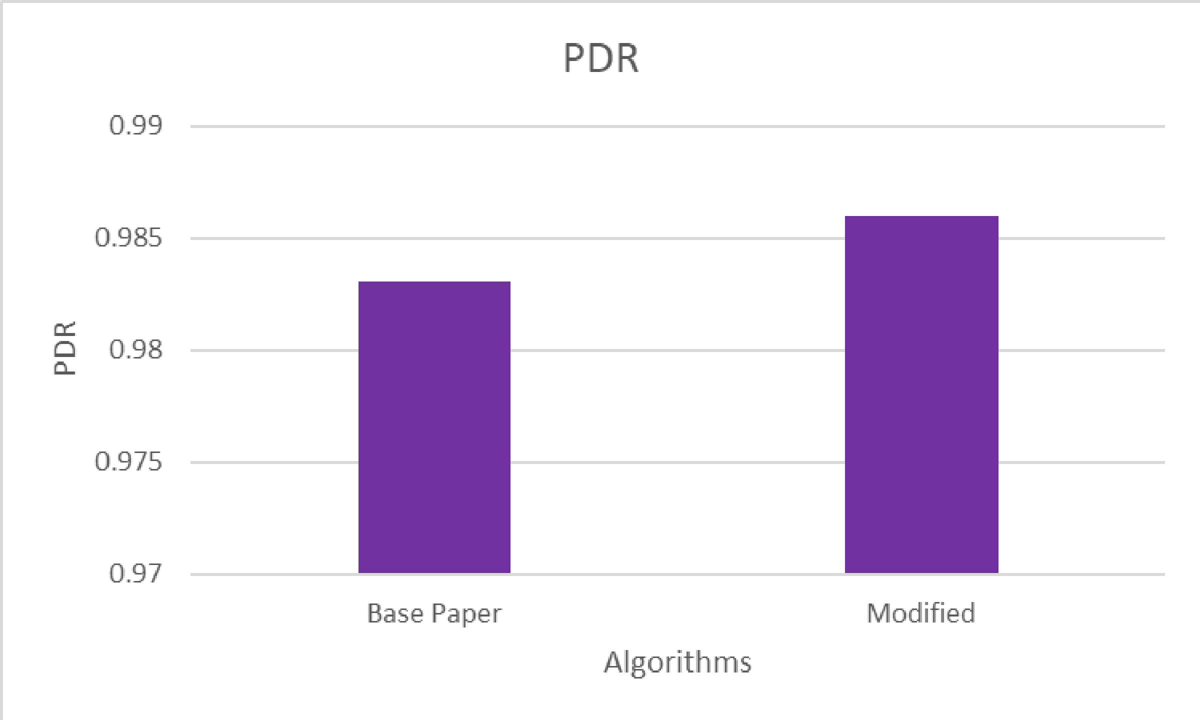
The final residual energy is increased by 9.16% after the entire simulation.





The graph above shows an end-to-end delay analysis using the suggested approach and EEAODV methodologies from the base paper for throughput.

The throughput is increased by 3.22% in the modified code.



The graph above shows an end-to-end delay analysis using the suggested approach and EEAODV methodologies from the base paper for PDR.

The throughput is increased by 3.22% in the modified algorithm.

5. Conclusion and Future Work:

Battery replacement for Internet of Things applications is challenging despite the fact that batteries are not always efficient. Energy consumption on each node and longevity of the total network is a genuine challenge for the uninterrupted and long-term operation of WSN and IoT applications, which has been solved by the solution presented in this research. The method described in the study decreases energy consumption per node, extending the lifespan of WSN.

Conventional routing techniques and non-cross-layer routing will frequently result in broken pathways, consuming more energy on each node and shortening the network lifetime. The suggested solution uses a mix of connection quality and collision count to replace traditional metrics like hop count.

Our approach, which is implemented in the Network Simulator NS-2, substitutes traditional metrics like hop count with a mix of connection quality and collision count. Future WSN complexity can be reduced by the suggested method since cross-layer design would use data from all levels while making judgments. One of our techniques (CLB) chooses less frequently used nodes when choosing a route. However, the CLB does not attain energy efficiency for each correctly sent bit using this kind of selection approach.

6. References:

[1] M. Anand, K. Thinakara , N. Kalyana Sundaram, M. Anbarasan, "Multiple metric based Twofold Route Selection AODV routing protocol for improved communications on MANET for industrial automation"

[2] Ranjita Joon, Parul Tomar, "Energy Aware Q-learning AODV (EAQ-AODV) routing for cognitive radio sensor networks"

[3] Zhe Yang, Lingzhi Li , Fei Gu , Xinghong Ling , Maryam Hajiee , "TADR-EAODV: A trust-aware dynamic routing algorithm based on extended AODV protocol for secure communications in wireless sensor networks"

[4] Chandrashekhar Pomu Chavan, Pallapa Venkataram, "Design and implementation of event-based multicast AODV routing protocol for ubiquitous network"

[5] Nilesh Kumar R. Patel , Shishir Kumar , and Sanjay Kumar Singh (Senior Member, IEEE) , "Energy and Collision Aware WSN Routing Protocol for Sustainable and Intelligent IoT Applications"

[6] Hassnen Shakir Mansour , Mohammed Hasan Mutar , Izzatdin Abdul Aziz , Salama A. Mostafa , Hairulnizam Mahdin , Ali Hashim Abbas , Mustafa Hamid Hassan , Nejood Faisal Abdulsattar and Mohammed Ahmed Jubair, "Cross-Layer and Energy-Aware AODV Routing Protocol for Flying Ad-Hoc Networks"