Energy Efficient & Secure Design Concept for Wireless Sensor Network Using Internet of Things and Machine Learning

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***Abstract*—** In wireless networks, power is a very significant problem in all of its operations regardless of application. The batteries of wireless nodes have a restricted lifetime. Furthermore, the recharging of these batteries is not possible during the application. Also, the attempts made to elaborate the network lifetime through some hardware-based technology are not that much deserving. The maximum amount of energy of a wireless node is used up for broadcasting the data packets or retransmitting the packets of other sensor nodes within the network. With the help of energy-efficient routing and consistent communication between the wireless nodes, the power consumption in the network can be minimized at the network layer. In some applications, the wireless nodes are frequently concerned with transmitting the data packets. Due to this the maximum amount of energy will be depleted between those nodes and the nodes will die much before the other nodes. Hence, discontinuities will cause in the network. Hence, in the energy-constrained nature of nodes in WSNs, it is very essential to make efficient utilization of available power to elaborate the lifetime of the network. It is difficult to secure WSNs, because of the vulnerability of wireless links, limited physical protection of nodes, topology, dynamically changing, and lack of infrastructure. Providing secure communication and assure secure network services is a challenge. Hence, it is necessary to cultivate an energy-efficient and secured routing Protocol in WSNs to enhance security assurance and increase communication efficiency in a network with good QoS provisioning.

Index Terms—WSN, Network Lifetime, Internet of Things, Wireless Nodes, QoS, Machine Learning, Routing Protocol, and Energy Efficiency.

I. Introduction

Wireless sensor networks are encompassed of spatially spread independent detecting and sensing nodes normally called as WSNs. The wireless nodes in the system have a comprehensive expanse of presentations, which happens due to their sensing capability. These nodes are scattered within the wireless communication area. For maintaining and detecting the environmental and physical states, the nodes in the network are linked with each other to access and sense the neighboring data of the particular organized region. The sensing capability of the wireless nodes has a wide area of applications. These applications are industrial method sensing and environmental and physical condition observation.

1.1 Overview of Wireless Sensor Networks

Advancements in WSNs have empowered the improvement of a novel production of massive-scale WSNs. These networks are appropriate for a variety of commercial as well as military applications. The wireless technologies have the potential to renovate the community life to interact with the physical environment and work effortlessly. In the future very cheap, tiny wireless sensor nodes will be sprayed on all home appliances, household things, roads, walls, and industrial automation devices [1]. Furthermore, for monitoring a person, traffic of vehicular in the human-aware environment and intellectual transportation grids. For detecting jungle fire to aid rapid critical situation responses and follow job flow and last but not least to provide chains in elegant factories [2].

The main function of a WSN is to monitor and collect related information about the specific environment. The nodes in the network sense and discover nearby nodes to communicate with each other by forwarding packets hop by hop. As the nodes are battery-operated, it may not be feasible to replace the battery, so energy consumption is the foremost issue. Network security is a key aspect for protecting their data services for any industry, Trust mechanisms are introduced to enhance security and improve cooperation among nodes [3]. Numerous trust-based routing protocols are projected to secure routing, in which they contemplate different routing attacks. Securing the routing process against compromised nodes, the trust Establishment avoids untrustworthy nodes and chooses only dependable ones in the routing procedure [4].

Cluster-based data communication in wireless networks has been examined by researchers to attain scalability and management of the network. In this technique, an optimal route selection model for packet transmission is introduced by proposing the new hybrid algorithm. The security consideration in our proposed work deals with the security modes [5]. Unlike existing information services, WSN provides authenticity to pair endwise users directly. It also provides information that is accurately localized in time and space. Existing information services are available on the internet where information can simply get stale and may become useless. In contrast with a centralized structure, in WSNs the node is subjected to an exclusive set of source constraints [6]. Such as limited power supply and restricted bandwidth for system communication. In a distinguished wireless network, all sensor nodes with a microprocessor unit and small memory space were used for the task arrangement and information processing. Also, the wireless nodes were outfitted using diverse sensors like acoustic microphone arrays, and magnetic, infrared, and seismic sensing devices. These sensor nodes communicate wirelessly with other nodes within their radio communication range [7].

Figure 1.1, gives the simple communication design of the WSN. These nodes are spread out randomly over an area within the given sensor network field. They coordinate with each other to produce information concerning the physical environment. These wireless nodes receive process and transmit accessible and high-quality information data packets. Each wireless node operates independently without any central point for controlling the network. Moreover, they communicate with each other by using infrared devices [8].

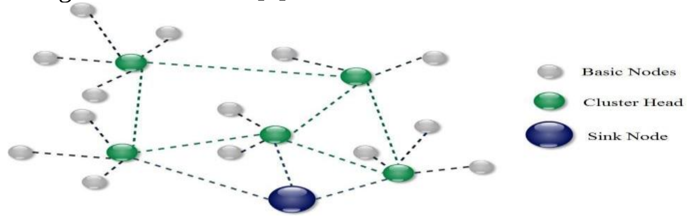

Figure 1.1: Simple Communication Design of WSNs

1.2 Advantages of Wireless Networks

Various Wireless Sensor Network technologies have

numerous advantages that can be given by a lavender grade. These advantages are, lesser performance cost and remote communication it supports. WSN can make use of innovative data sources in a very simple way with improved performance and accuracy. Furthermore, WSNs are time-driven and event-driven, to overcome the usual issue of the disorganized move towards monitoring [9]. The localization can be done efficiently; it means data information through the sensor nodes can be rapidly gathered with additional information from supplementary nodes. In WSN some possibilities are there to have the data functions which can provide preventative and proactive approaches. Furthermore, due to its autonomous nature, the wireless nodules were used in the fields wherever human presence is not feasible [10].
Some other qualities which are possible with wireless sensor technologies are the quick response for installation and reconfiguration. The qualitative novel characteristic of sensor systems and wireless networks is mobility. The additional extremely immense driver contained by industrialized as well as commercial organizations is its cost. Even though, the installation cost, maintaining, and reconfiguring in scenarios, like nuclear reactors, are incredibly economical [11].

1.3 Routing in Wireless Network's

In wireless network routing i.e., rout-finding is an extremely demanding but challenging process. Due to the individuality of the wireless network, they will differentiate from further accessible wireless ad-hoc and communication systems like MANETs. Those information packets are transmitted through various source nodes to a particular sink node that may be stationary or mobile as shown in figure 1.2. Third, the generated data packet interchange has considerable idleness because numerous wireless sensor nodes may produce similar data packets within the neighborhood of an occurrence.

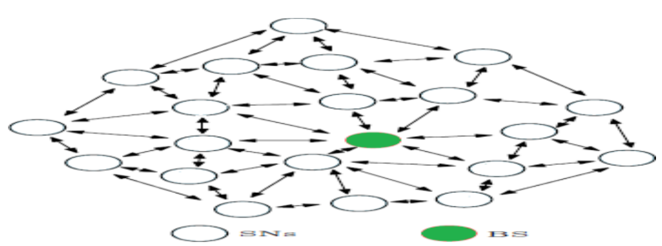

Figure 1.2: Wireless Networks Routing Strategy

1.4 Routing Challenges in WSN

Despite enough applications of WSNs, these networks face numerous limitations. Those were limitation in power supply, restricted computing energy as well as inadequate bandwidth of the links which connects the sensor nodes wirelessly. The major goals behind designing of WSNs are to spread data packets between the transmitting nodes. It elaborates the network's lifetime and also prevents network humiliation by using different power management techniques [12]. For designing a well-organized direction-finding protocol employing energy and network lifetime, numerous demanding factors are supposed to be addressed carefully. Those different factors were discussed below [13].

1.4.1 Deployment of Nodes

Deployment of Nodes in wireless networks depends on various applications. Furthermore, it upsets the enactment of the routing procedure. The positioning may be deterministic or randomized, in the random type of deployment, the wireless nodes are spread randomly to create the structure as per the requirement in an ad-hoc manner. This type of exploitation technique elevates numerous problems that need to be dealt with adequately, such as coverage issues, and optimal clustering issues [14]. On the other hand, in deterministic deployment, nodes were deployed physically and information data packets were routed through the preselected paths.

1.4.2 Accuracy with Efficient Energy in WSN

The node in the network uses its restricted energy for performing computations. They utilize their power in receiving a data packet, processing and wirelessly broadcasting them, because, these conserving structures of energy for communication and computation are very necessary. The node's existence depends on the battery lifetime. In different multi-hop techniques, the node works as an information source as well as a data router also. In some cases, due to the idleness of the node in the network, some topological changes will occur. In that case, the network might need rerouting of the packets to reform the wireless network [15].

1.4.3 Quality of Service

In WSNs, some applications were time-dependent. The information must be delivered within the specified period only beginning the instant when it is sensed or else it will be ineffective. Consequently, waiting for the delivery of data is an additional factor for applications with time-controlled networks. Alternatively, in various applications, the saving of power which is directly connected to the lifespan of the system is considered the utmost important parameter than the quality of information sent [16].

1.4.4 The energy of the node

In WSNs, it is very essential to utilize the node energy properly to elaborate the network lifetime. Since the node energy gets depleted very quickly. Therefore, to confine this energy constraint, energy-aware routing protocols are very much essential [17].

II. Proposed Statement

Recently WSNs grow desirability for various applications, for example, environmental monitoring. (Jabbar et al. 2016), deployed a WSN on a farm to monitor the soil moisture profiles in different depths and tracking of the mobility of animals to reduce the farm management cost. Some of the applications of WSNs are been highly reactive and should be confined for example health care, military, and vehicular communication. For example, in information communication, a single incorrect communication can cause a lot of issues. We can say that it is directly associated with human beings and very harmful if a minor mistake is done.

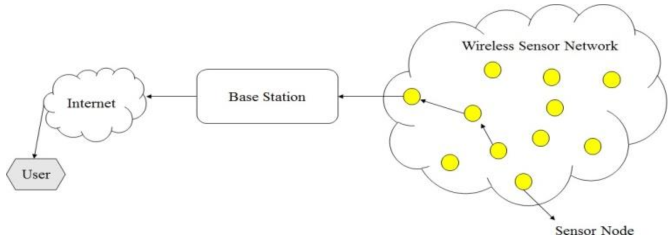

Figure 2.2: The basic structure of WSN

During the earlier period, wireless trade appreciated distinctive development and achievements. Wireless communication remains dominant in every position. Security is a foremost problem in identifying innumerable types of assaults in a WSN.

2.1 Contribution of The Work

2.1.1 Proposed Energy Efficient Routing Protocol Designing

Proposed Efficient Energy cost-based Routing Protocol in WSN (EECR) balances a load to the energy protection and maximizes the lifetime of the network. An important factor to be considered for extending the network performance is the buffer space of a node concerning packet delivery. The network can give better performance in the packet delivery if its energy is quite enough to process the packet [18].

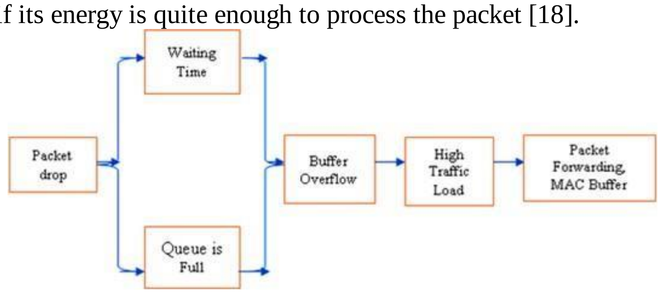

Figure 1.4: Security-Based Efficient Energy Routing Protocol

Furthermore, if a wireless node provides a free space for incoming packets when overhead is present, then it essential to drop packets from the node buffer. In together situations, node gears harm packet delivery which creates congestion in the network.

2.1.2 Optimization algorithm with Security

Security-aware routing using a hybrid optimization algorithm prolongs the lifetime of the network along with security by selecting the best route path. The existing routing protocol with energy efficiency in WSNs is briefly distributed into twofold parts.

1. Protocol to invent an efficient energy path
2. To discover the route with greater power nodules

Moderately, a lot of experiments are there in employed, usage, and manipulation of the node in the network. The figure below shows numerous wireless nodes which gather the data from the neighboring atmosphere and transmission the composed information to the object node (sink). It contributes a gateway between a user and the nodes and makes wireless connectivity between distributed wireless nodes and supported environments.

III. Proposed Work

The routing schemes used in WSN messages are classified into four categories i.e. Network structure scheme, Communication model scheme, Reliable routing schemes, and topology-based routing schemes.

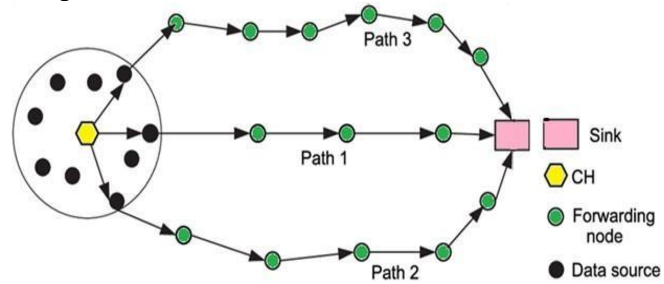

Figure 2.3: Different routing paths in WSN

The figure below shows different routing protocols with efficient energy related to WSN.
The proposed effort deals with the minimum consumption of energy in addition to elaborating the lifetime of Wireless Network with the consideration of the optimized ability to control packet fall concerning node energy and its buffer.
Likewise, its use in the agricultural field may advantage the farmers and can protect them from electric wiring in a difficult environment. Consequently, information communication can be scrutinized by wireless I/O sensors and strategies [19].
Instead, the delay and queuing issues are mostly universal features not just in our daily routine situations like at post office or bank services, in open transportation, or in traffic jams but also in additional technical surroundings, such as networking and telecommunications. It also represents different queuing systems that take place while practicing.Moreover, these models make it possible to find appropriate stability among the service cost and the amount of waiting. The period of the queuing system is used to specify a collection of one or more waiting lines all along with a server or group of servers that give service to these waiting lines [20].

Furthermore, to deal with the lifetime expansion, there should be some improvement in a load balancing scheme by applying sub-network management that will balance the consumption of energy in the wireless nodes to the minimum level and maximize the lifetime of the network. These schemes work on the balancing of a load for an individual wireless node for the elaboration of the NL. Hence, in larger areas with geographical routing, it is designed to enhance the network lifetime through the balancing of proper consumption of energy by each node [21].

IV. SECURITY MECHANISMS

The main motive behind the security mechanisms is to detect, prevent, and recover from security attacks. Security mechanisms are divided into two parts Low level and High level.

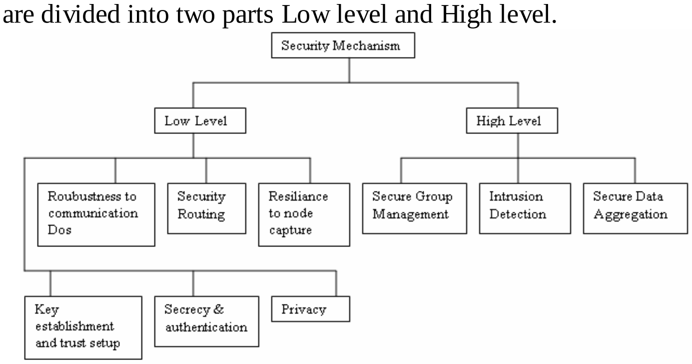

Figure 2.9: Security Mechanisms

4.1 Problem Formulation

The key experiments while designing based on an energy routing protocol for a network are the drain of battery as well as the constrained power. These metrics are discussed comprehensively. It will raise the effectiveness and improve the lifetime of the wireless network. Hence, spontaneously it will enhance the network's lifespan. Nowadays, mobile agent wireless networks are coming into the picture. These networks have some handsome applications in industrial as well as commercial applications. Additionally, the routing process is faultless, so, careful consideration should be taken to give security to the transmission of the data packets in the network. So, the appeal is made for the routing method will ensure proper information distribution. The interconnection between the sensor nodes and the improvement of the network's lifetime is described. Furthermore, the very essential thing about the proposed work is the data packets should reach properly in safe mode at the destination node [22].

The mentioned routing technique has its features, but on the other hand, they are suffering from certain limitations also. Consequently, additional exploration has to be prepared for the development of the routing methodology that can improve the lifetime of the network with less power consumption. Furthermore, some more improvements can be done to increase the performance like Battery-less sensing. In this method, the concept of energy harvesting is kept into account.

4.2 Routing protocol with Energy Efficiency in WSN

The wireless networks are self-configure with the help of several small nodes. In this type of network, the nodes can interact with each other by using various communication channels like radio signals, etc. Moreover, the sensing and monitoring of the surrounding areas can be done by using these sensor nodes [23]. As an application, the physical well as environmental circumstances is sensed and monitored by spatial scattered sensors. The sensor nodes also ensure the data packet transmission in the network. They provide the optimum security to the network bi-directionality modern technology is applied to control the movement of the sensor nodes. The military applications developed wireless networks such as battlefield surveillance and were motivated by using in many applications for example consumer and industrial scenarios [24].

4.4 System model 3& assumptions made

In the proposed work the heterogeneous network is deliberated to execute the operations carried out in the network. Although, for the execution of the system operations, all these sensor network components consume energy that leads to additional energy consumption. It will affect directly or indirectly the lifetime of the network. Hence, it is very essential to reduce the consumption of energy during the processing of data packets. It will be done by designing an efficient energy model which will give optimal performances with prominent attention. A consideration is made in this chapter about a Heterogeneous network for WSN. For increasing the lifetime and performance of the network a mobile node is added which works as a sink node.

V. The Proposed Model

The proposed model categorizes into two different phases for this routing protocol. In the first phase, the clusters are made in the network, and cluster heads are designated. In the second phase of operation, the cross-layer routes and data collecting has been done with the mobile sink node.

5.1 The First Phase Cluster Formations

The first stage will give an idea about the formation of the clusters in the network. After that for each formed cluster, the cluster heads should be finalized in accordance with the level of energy of the nodes. Algorithm 1 below gives a clear idea about cluster formation.

Algorithm-1: Establishment of Cluster and Head Node Selection

Input: set of sensor nodes: $S_1, S_2, S_3, S_4, S_5 \dots\dots S_n$, clusters $C_1, C_2, C_3, \dots . C_n$., neighbour node list $n = \{NL_1\}, \{NL_2\}, \{NL_3\} \dots . \{NL_n\},\ and\ R$

Output: $C_1, C_2, C_3, \dots . C_n$.

Initialization of the network and setting of the nodes

Area of the System $N \leftarrow$

Set of nodules $S \leftarrow \emptyset$

2 Compute the neighbor node

$for\ i : 0\ to\ n-1$

$dis := \sum_{i=0}^{n-1} \sqrt{(X_{i+1} - X_i)^2 + (Y_{i+1} - Y_i)^2}$

Compare: $if: dis \leq R$

$NL_i \leftarrow x\ where\ x \in S_i$

$for: end$

3. Let $S = \{S_0, \quad S1, S2 \dots\dots, S_n\}$ are the node's operational states and $a\ and\ b$ are the two conditions of the node, (where $a\ b = 1, 2, 3, 4, \dots\dots$)

4. The conditions of the node are kept on changing during the data distribution process at timeT_i. Furthermore, in certain time period T_n, the probability of node state change is dignified as,

$P_{ab}^{n} = P\ \{S_n = b\ |S_0 = x\}$

5. P_{ab}^{n} is measured by the following equations:

$$P_{ab}^{n} = \sum_{c=0}^{n} P_{ac}^{i}\ P_{cb}^{(n-1)}$$

6. The succeeding duration of time during the dissipation of energy dissipation

7. $E_d = \sum_{y=1}^{4} (\sum_{t=1}^{T} P_{xy}^{n} * E_y)$

$$RE_i = E_{ini} - (E_{tx} + E_{rx} + E_{sp} + E_{idle})$$

Where E_{ini} = Initial energy of the node. E_{tx}, E_{rx}, $Esp, and\ E_{idle}$ is utilized energy at the time of reception as well as transmission of the data packets.

8 Compare $i : 0\ to\ n-1$

$if\ \sum_{i=0}^{n-1} RE_i < RE_{i-1}\ where\ N \forall C_i$

Select the Cluster Head

End if

Else

Replication the Step - 6

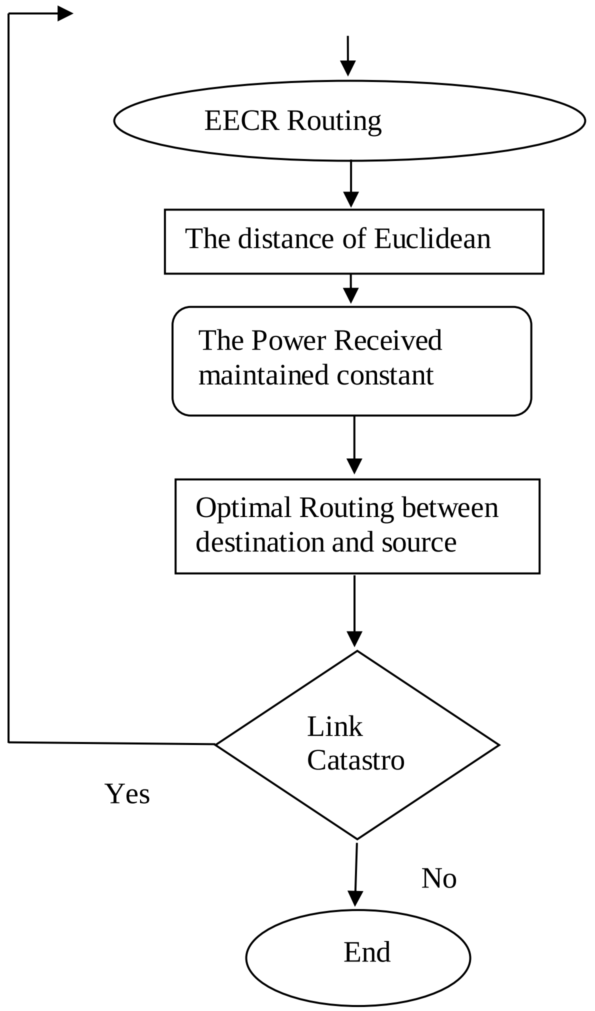

Figure 3.3: Optimal routing flow chart

VI. PERFORMANCE EVALUATIONS

The channel capacity of the mobile hosts is set as 2 mega bites per second. We use the DCF of IEEE 802.11 as the MAC layer protocol for wireless LANs. The IEEE 802.11 can inform the breakages of the links in the network to the network layer. The nodes move in an area of 1000 x 1000 meters for a time period of ten seconds as a simulation time. The transmission range in the network is allocated as 250 meters for the moving nodes. The Constant Bit Rate simulated traffic rate is maintained for the specific application. The below table demonstrates the imitation sceneries with their parameter values.

Table 3.1: The Imitation considerations

The overall amount of nodes	20, 30, 40, 60, and 100
Size of the Area	1000 Meters X 1000 Meters
Medium Access Control used	The MAC 802.11
The Range of Radio	250meters
The Time for Simulation	Hundred seconds
Foundation of the Traffic	CBR
The size of the Packet	512 Bytes
Power at Reception	0.395 W
Distribution power	0.660 W
The Idle Power	0.035 W
Preliminary Energy	10.3 Joules
Data Speed	2 MBs per second

6.1 Metrics used

The metrics used for performance evaluation,

The PDR Average value: The PDR is well-defined as a ratio of the number of packets received efficaciously per total number of transmitted packets.

Average Drop of Packets: The normal amount of the data packets dropped by the nodes in the network during the data processing.

The Delay: The time taken by the data packets in the network to reach the receiver node from the sender node.

The Energy Consumption: The total sum of consumed energy by the nodes in the network for data transmission.

The comparison is made between the proposed work; Efficient Energy Cost Based Routing Protocol with the existing work ELDC performance of Artificial Neural Network based Energy-Efficient and Robust Routing Scheme.

6.2 The Results of the Simulation Process

In the projected work the amount of nodes is varied from 20,30,40,60 and 100. The performance metrics are used to understand the routing approach as well as comparison with ELDC.

The average throughput rate of EECR is varied concerning the number of nodes, where the throughput rate is estimated by varying nodes. Throughput of the EECR model obtains a higher value of 1.8Mbps than other existing ELDC 1.45Mbps for 100 nodes. The proposed model EECR improved the reliability which resulted in better throughput compared to ELDC shown in the figure below.

Algorithm 2: Selection algorithm for the node in the network

Advancing $(node\ p, data\ q, TTL\ t)$
1: Innovation of point q at nodule p;
2: if the q is not found then
3: $t = t + 1$;
4: if $t <= 0$ then
5: return;
6: end if
7: Distribute t consistently, deliberately three hops t_i and $t = \sum_{i=1}^{n} t_i$
8: Choose one node p_r from the neighbors of p;
9: Choose the min t_{min} from t_i;
10: Frontward (p_r, q, t_{min});
11: Elect the nodes $p1$; $p2$ from the intermediate node neighbor of p;
12: Frontward q to $p1$; $p2$ through the residual hops of t_i;
13: else
14: Direct acknowledged consequences to the motivator of q;
15: end if

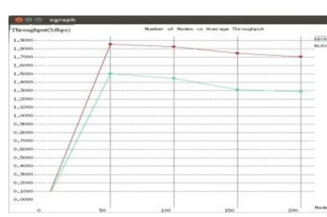

Figure 3.4: Throughput

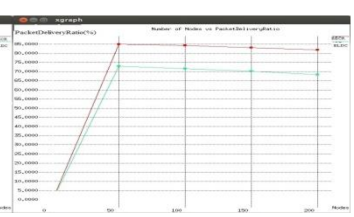

Figure 3.5: PDR Performance

The above figure shows the throughput comparison between EECR vs ELDC. The EECR has a better performance Iz comparison with ELDC.

The performance results show that EECR has better PDR than the ELDC on behalf of various system topologies. For 100 nodes packet delivery ratio is 72% of ELDC and 84% of EECR models. We observe that the delivery ratio of our proposed EECR is higher than the existing ELDC technique. The results clearly show the PDR rate is enriched concerning time intervals.

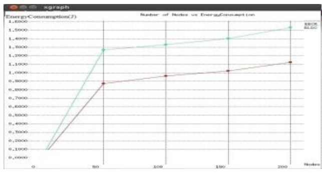
Figure 3.6: Energy Consumption

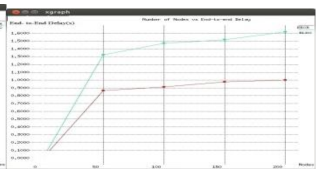
Figure 3.7: Delay Calculations

The figure shows the comparison results of ELDC, and EECR delay performance (end to end) where the ELDC shows good performance in comparison with EECR's delay upgraded in comparison with the ELDC process. In our experiment, we computed the total delay that occurred while receiving a packet from the source node. The Source node sends a packet to the destination with different transmission rates, the below figure 2 shows the nodes vs end to end delay for ELDC and EECR models, the delay rate is increased when the number of nodes is considered, based on this delay the drop rate is slightly increased. Compared to ELDC, there is 30% less delay in EECR.

Table 3.2: Evaluation parameters of ELDC vs EECR

Parameters	Existing (ELDC)	Contribution1(EECR)
Throughput(Mbps)	1.45	1.8
Packet Delivery Ratio (%)	72	84
Energy consumption(J)	1.32	0.95
End to End Delay(sec)	1.4	0.9

3.7 Conclusion:

The summary of the work says an efficient energy cross-layer routing protocol is premeditated for the wireless network to make improvements in energy efficiency for the system. The projected work unprotected the optimum value of the route based on the energy-efficient nodes. The energy consumption rate is 25% less than the conventional ELDC model as well as the results of the packet delivery ratio were almost10% higher when compared to ELDC. The delay of the proposed EECR model was constantly varied and the overall performance rate was almost 30% improved than the conventional scheme. Simulation results have shown that the proposed technique is more energy efficient. It is done by reducing the routing overheads by the data collector node (mobile sink). The performance outcomes show that the proposed work, the cross-layer approach, is operative in decreasing the needless maintenance for the routing. The operations raised by the ELDC protocol are within the transmission range of the interactive node.

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