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Research Article

heTDR: Hierarchical Energy Based Clustering Head Selection with Trust Based Data Routing Protocol

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ABSTRACT

In wireless sensor networks (WSN), Energy consumption is a highly immersed area for the researcher. A sensor node is consisting the sensor, micro-controller, and battery. Wireless sensor network consists of the number of sensors node operated through battery for area monitoring and measurement. The sensors are also capable of data receiving, transmitting and processing. In the paper, proposed protocol is hierarchical clustering and residual energy-based CH selection trust-based routing protocol (HeTDR). This approach takes advantage of cluster formation using a hierarchical approach and CH selection based on the highest residual energy in every round. The life of network increase in HeTDR through trust-based data routing. Using feedback mechanism member node establishes the trust in the system and achieves system-level reliability. The simulation was carried out with specific parameters like network size, number of nodes, number of a cluster, packet size and many more. The simulation result of all proposed protocols compares with traditional protocols LEACH, HEED and EECRP in energy consumption, throughput, network lifetime, packet delivery ratio, end to end delay, bit error rate and jitter.

Keywords: HeTDR, WSN, Hierarchical clustering, LEACH and EECRP

I. INTRODUCTION

In wireless sensor network, small size sensor nodes are deployed in random distribution on the surface. The node distribution is random, so communication among the node is the main challenge [1]. Generally, cluster member nodes communicate directly to the other member node/cluster head or base station. Direct communication to the base station or CH leads to higher energy consumption and reduces efficiency and network life. The hierarchical way for cluster formation leads to the best grouping of the nodes. After the cluster form in each round to check the highest energy level node is become the cluster head respective cluster. Using trust mechanisms among the cluster member nodes to other nodes and CHs to reduce the network overhead like feedback or acknowledge mechanism takes significantly less power consumption.

Initially, all nodes are deployed in an environment in random order. Cluster formation, cluster head selection and data routing are the main criteria for design and development of any energy-efficient cluster-based routing protocols. Clustering is a technique for a divided group of sensors nodes. A group is a form of nodes depending on the residual energy or Euclidian distance [2]. Using clustering, it can maintain the bandwidth in the network and reduce the communication cost through intra and inter-cluster communication. So managing the whole network is complex instead of managing the cluster node. One sensor node representing the entire cluster is called cluster head—the selection process of cluster head in many ways. Using an energy-based, energy centroid position-based, or multi-criteria decision-making approach for CH node selection. There are various applications of WSN used in our lives in different aspects like healthcare, agriculture, security, military, and many more[3];[4].

The nodes are randomly deployed in the network; without forming structure node deployment and routing lead to higher energy consumption at network through direct data communication. Clustering is an approach for arranging the data in a grouped manner.

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II. RELATED WORK

Wendi B. first proposed the LEACH protocol [5], which addresses the crucial task of data transmission among sensors to the base station in WSNs. LEACH divides each transmission round into two phases: the setup and the run phase. In the setup phase, each node evaluates its probability of becoming a cluster head based on residual energy, with selection dependent on a random probability function between 0 and 1. Once a cluster head is chosen, it broadcasts its status to the cluster members. In the run phase, nodes send data to the cluster head based on a TDMA-assigned time slot, and the cluster head then transmits the data to the sink node. LEACH's main advantage is its random cluster head election, which results in low power consumption and an extended network lifespan.

Rejina et al. [6] proposed a swarm optimization-based clustering protocol to protect node residual energy. Unlike existing protocols, it includes all nodes in cluster formation and head election, enhancing network lifetime and reducing individual node energy consumption. Their E-OEERP protocol eliminates direct communication to the BS, instead using multi-hop transmission facilitated by a swarm optimizer and a gravitational search algorithm, which also helps in finding the best routing path. Comparisons with protocols like LEACH, DRINA, and BCDCP show improved energy consumption, throughput, PDR, and network lifetime.Yunquan et al. [8] introduced the DEARER protocol, based on distance and energy reservation and harvesting. This protocol aims to select the best cluster head with the highest residual energy and proximity to the BS, minimizing communication costs. Non-CH nodes conserve their residual energy for future use. Theoretical and numerical analyses indicate that DEARER outperforms traditional protocols.

Hassan al.[9] has been proposed Enhanced clustering hierarchical approach for WSN. This algorithm has improved the energy efficiency in a network through the hierarchical process. For the cluster formation, they used a hierarchical system and data transmission was done through the highest energy node in a network. This paper considers the redundant data collected from the adjacent node and overlapping each other. They used a sleeping and walking mechanism for the data collection from the network; with this approach, they can minimize the redundant data from the node and improve the network lifetime. The working mechanism of ECH and other traditional protocol can be differentiate based on routing approach.They consider all the node can collect and transmit the data but in ECH only waking nodes can do the process. Simulation results suggest that the ECH has been far better than LEACH,TEEN,SEP and DEECwith energy consumption, network load and packets received.

Jian et al. [10] presented a new clustering approach using centroid position for CH selection and efficient routing (EECRP) for IoT-supported WSNs. EECRP enhances sensor network efficiency through a three-level protocol: forming clusters with a distributed hybrid approach for self-healing capabilities, centroid position-based CH selection, and energy load-balanced routing. Simulation results demonstrate that EECRP performs better than traditional approaches across various network parameters.

III. PROPOSED SYSTEM

The HeTDR protocol improves network scalability, efficiency, and throughput by forming clusters. Once clusters are formed, member nodes elect a cluster head based on the highest residual energy level among them. The protocol is structured into three layers, as illustrated in Fig. 1, with each layer designed to extend the network's lifespan by reducing energy consumption during the data routing process.

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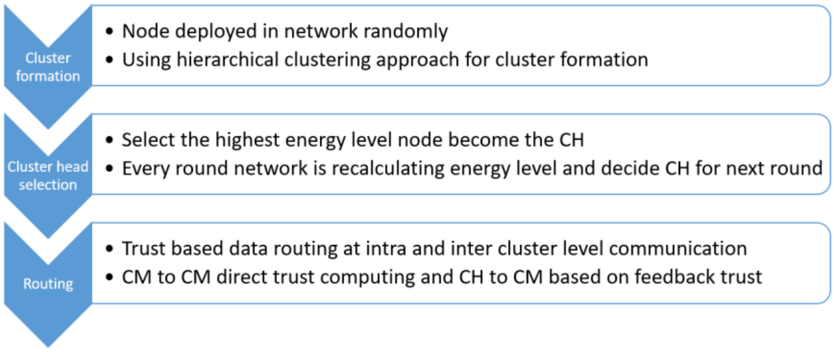

Fig. 1 Steps of HeTDR protocol

Figure 1 illustrates the three-level formation of the HeTDR protocol. The Cluster Head (CH) node broadcasts information to all member nodes, nearby CHs, and the base station. A trust-based decision-making system ensures smooth data routing from member nodes to the base station. In multi-hop clustering, if a cluster member node needs to communicate with another node, it first checks for an existing communication path. If one exists, it communicates directly; otherwise, it seeks permission from the CH. Upon CH approval, it sends or receives data from a neighboring node. Intra-cluster communication involves checking direct trust between member nodes or CH to member node feedback trust. Inter-cluster communication involves direct trust between CHs or base station to CH feedback trust. Figure 2 shows the flow diagram of the hierarchical clustering energy-based CH selection and trust-based data routing protocol. The main steps of HeTDR include forming clusters hierarchically, selecting the CH based on residual energy, and implementing trust-based feedback mechanisms for intra-cluster and inter-cluster routing.

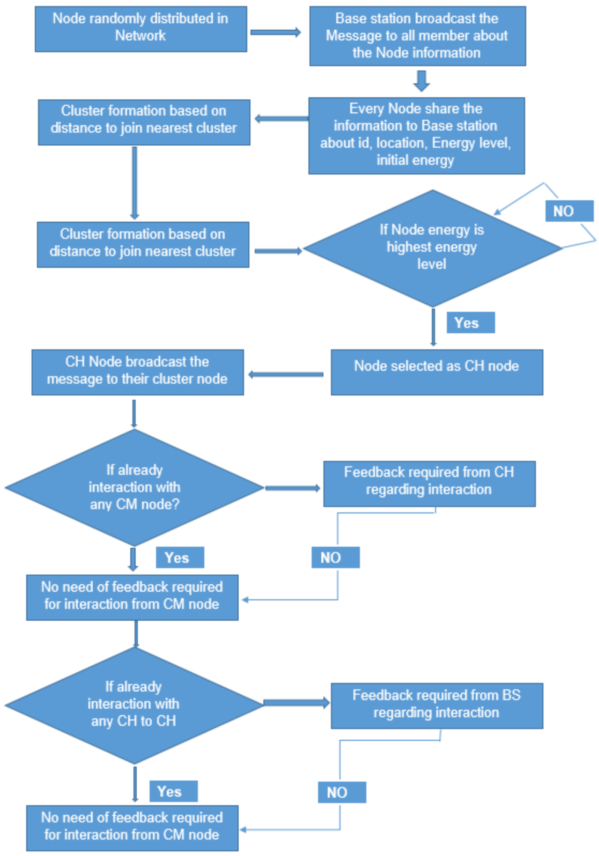

Fig. 2 Flowchart of HeTDR

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A) HIERARCHICAL CLUSTERING

There are many methods for cluster formation based on the network structure selected for the experimental set-up. For cluster formation, hierarchical, distributed, grid-based and node partition or density-based clustering techniques are popular in a sensor network. The role and cluster forming structure are different from all the above methods. The hierarchical and distributed clustering methods are popular. The radio energy model uses calculation of energy consumption at transmitting side as well receiving side. The Fig. 3[5] indicates the radio energy model. 'k' indicates the length of message, 'd' is distance, 'Eele' is energy level and 'Eamp' is amplifier energy level.

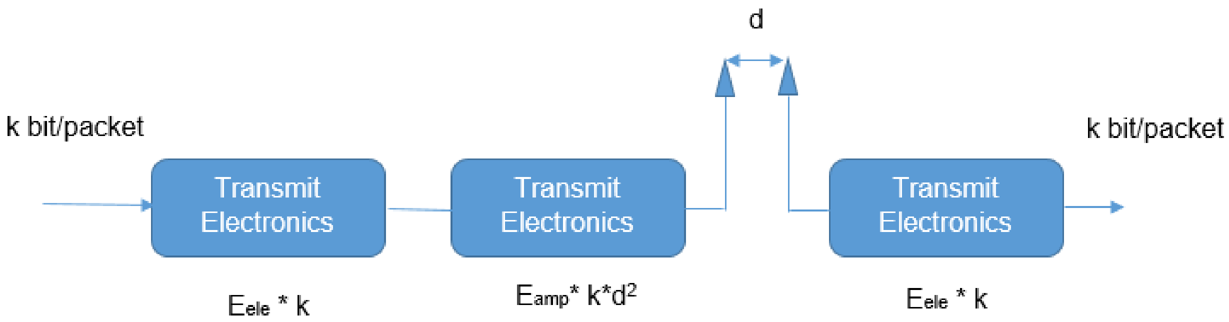

Fig. 3 Radio energy model

The HeTDR protocol hierarchical clustering energy-based CH selection and trust-based data routing can be divided into three stages: Region-based cluster formation, highest energy level-based CH selection and Trust-based routing. In-network sensor nodes are distributed or deployed randomly. Initially, the base station broadcasts the message to all member nodes for the information collected about every node. The information includes node id, location, energy level and neighbor node id. The base station forms the cluster based on the region with this information. The number of clusters depends on the diameter of the cluster. Once the cluster forms the next step is the election of head node in every cluster. Initially, the selection of CH node is random in first round because every node energy level is same. The next round onward, highest energy level node become CH and every round check the same procedure for CH. Once CH elected, it broadcast the message to all member node about it. The next process is data routing at cluster level through CH node and last at BS.

The following Eq. 1 & 2[13][14] indicates the number of k bits transmitted ($E_{T(k,d)}$) to the node and k-bit received at node ($E_{R(k)}$).

$$E_t(k,d) = \begin{cases} k * E_{ele} + k * E_{ele} * d^2 & if\ d < d_0 \\ k * E_{ele} + k * E_{amp} * d^4 & if\ d \geq d_0 \end{cases} \quad (1)$$

$$E_R(k) = k * E_{ele} \quad (2)$$

B) ENERGY-BASED CH SELECTION

The base station forms the cluster after BS inform all member node about their cluster id. The role of the all members is to sense the environment and forward that data to the base station. If the node directly does the communication, it consumes lots of energy for data forwarding to a base station. To overcome this issue, once member node (CH) takes responsibility for collecting the data from the member node and forwarding it to a base station. The selection process of CH in this HeTDR system is based on their residual energy level. For every round, the CH selection is based on an energy level. The first time the base station selects any random node for CH. The CH selection in the first round through the following Eq. 3.

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$$C(n) = \begin{cases} \frac{N}{1 - N(rmod(\frac{1}{N}))} & for\ first\ round\ only \\ 0\ otherwise \end{cases} \quad (3)$$

In the Eq. 3'N' indicates the probability [0,1], 'C(n)' indicates the value for CH selection.

The CH selection is only based on random/probability in the first round without considering energy level. After the first round, each node transfers the data to CH and consumes some amount of energy. From the next round onward, the CH selection is based on their residual energy level and gives a chance to all nodes to become CH with respect to their energy level. The value is calculated by adding energy parameters to existing Eq.

$$C(n) = \frac{N}{(1 - N(mod(\frac{1}{N}))} * \frac{E_{(res_{eng})}}{E_{int_{eng}}} * C_{opt} \quad (4)$$

In Eq. 4,'E_{res_eng}' indicates the residual energy of node, 'E_{init_eng}' indicates the initial energy, 'N' indicates the probability, and 'C_{opt}' indicates the number of clusters. The calculation of 'C_{opt}' as per Eq. 5.

$$C_{opt} = \sqrt{n/2\pi}\sqrt{(E_e)/(E_{amp} * d^4 * (2m - 1) * E_0 - mE_{DA})} * m \quad (5)$$

'm' indicates the network diameter,'Eda' energy dissipated, 'Ee' node energy level,'E_{amp}' is the transmission parameter and'E_o' indicates the initial energy assigned to a node. Whichever node's energy level is higher than average energy or threshold level and highest energy among the cluster node becomes the CH for next round. The node broadcast messages about the CH information to their respective cluster member node. Next phase, every node transmits the data to the newly elected CH. The CH receives the data, aggregates it, and forwards it to the Base station via a trust-based approach. The exact process follows in every round of data transmission. The lowest energy node never becomes CH with this approach and achieves network-level efficiency.

The energy consumed by CH through data received from the member node, processing and aggregating of the collected data and transmitted to the base station. The Eq. 6 for energy dissipate during CH selection.

$$E_{CH} = k * E_e(P - 1) + k * E_{da} * P + k * E_e \quad (6)$$

Where the 'P' indicates the total member no cluster, 'E_{da}' energy dissipated by CH.

The energy dissipated during member nodes transmitted their data to CH through the following Eq. 7.

$$E_M = k * E_e + k * E_{ele} * d_{CH} \quad (7)$$

'd_{CH}' indicates the distance between member node to CH node.

The total energy consumed by one cluster can be calculated through Eq. 8.

$$E_{ene\_cluster} = E_{CH} + \left(\frac{N}{K}\right) * E_M \quad (8)$$

C) TRUST BASED DATA ROUTING

Once a Cluster Head (CH) is elected in the network, it broadcasts its status to all other member nodes. Member nodes then send their data to the CH, which aggregates and transmits it to the base station. Communication in the network involves four types: member node to member node (CM to CM), member node to CH, CH to CH, and CH to base station (BS). Energy is consumed during data transmission and reception for both sending and receiving nodes, especially during initial communications where feedback from the receiver is required. Subsequent communications along the same path do not require feedback, reducing energy consumption at the network level. Acknowledgments are only necessary for member nodes to CH and CH to BS communications. Minimizing feedback operations is achieved through trust mechanisms established at intra-cluster and inter-cluster levels. Trust factor calculations for member nodes involve feedback mechanisms and direct communications, where successful and unsuccessful interactions are evaluated to determine trustworthiness.

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D) TRUST SYSTEM: MEMBER NODE TO CH

In-network data routing uses the broadcast-based mechanism for data transmission and gets feedback from the destination node about packets successfully received. The trust-based decision-making at cluster node depends on the trust value between x and y nodes. The node calculates the trust value based on two different parameters: direct observation and feedback mechanism. In direct trust, decision factors can be calculated based on successful packet interactions and unsuccessful communication.

The trust level in cluster member node to other member node calculate using following Eq. 9.

$$T_{(a,b)}(t) = \frac{N_{(a,b)}(t)}{\left(N_{(a,b)}(t) + M_{(a,b)}(t)\right)} * \left(\frac{1}{\sqrt{M_{(a,b)}(t)}}\right) \tag{9}$$

'T' indicates the window time, 'a' and 'b' indicates the name of a node, 'N' indicates the successful interaction and 'M' indicates the unsuccessful interaction.

If CM nodes ask for feedback on every transaction, network overhead increases, and network efficiency decreases. The feedback mechanism is only applicable to reduce network overhead if there is no past interaction record of any two nodes that can ask for feedback from CH and calculate through Eq. 10.

$$FR_{(CH,a)} = \frac{x+1}{x+y+2} \tag{10}$$

'X' indicates the positive feedback toward 'b', and 'Y' indicates the negative feedback toward 'b'.

E) TRUST SYSTEM: CH NODE TO BS

During inter-cluster communication, one CH interacts with another CH. The CH node contains past communication data with other CH nodes with the same approach as CM. The DTD value calculates between CH to other CH nodes using Eq. 11.

$$C_{(p,q)}(t) = \frac{N_{(p,q)}(t)}{\left(N_{(p,q)}(t) + M_{(p,q)}(t)\right)} * \left(\frac{1}{\sqrt{M_{(p,q)}(t)}}\right) \tag{11}$$

The 'p' and 'q' indicates the CH node, 'N' and 'M' indicates the successful and unsuccessful interaction between CHs. If any direct communication exists between one CH to another CH, then there is no need for a feedback mechanism from BS. However, if there is no interaction during the stipulated time, feedback process is required from BS to CH node and calculate through Eq. 12.

$$FR_{(BS,a)} = \frac{k+1}{k+l+2} \tag{12}$$

The 'k' and 'l' are positive feedback and negative feedback towards CH, respectively.

IV. SIMULATION AND RESULTS

The simulation performs in MATLAB tool. The HeTDR system was simulated and compared with existing traditional LEACH[5], HEED[12] and EECRP[10] with different simulation parameters like energy consumption, throughput, network lifetime, packet delivery ratio, end-to-end delay, bit error rate and jitter with different node size varying from 100 nodes to 500 nods. The existing traditional protocol LEACH, HEED and EECRP also simulated in MATLAB with same parameters. The simulation performs with the following Table 1 parameters.

Table 1 Name and value of simulation parameters for HeTDR

Parameter	Value
Network size	100 x 100 m
Number of nodes	100
Number of clusters	Maximum 0 4

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Base station position	(150,150)
Data packet size	256 bits
Transmitting energy consumption	50 nJ/bit
The initial energy of node	2 J
Transmission type	Constant
Simulation time	500 s

The network size was 100 x 100 m for the node deployment for the simulation. The node deployment in network randomly. Fig. 4 indicates the node deployment and network size. The base station node location is fixed and at (150,150). Once the node is deployed in a network, the location is fixed for the whole process.

Fig. 5 indicates the number of cluster formation and CH selection. There is four cluster form shown in different color. The residual energy-based CH selection algorithm was applied, and the CH node is shown in pink color.

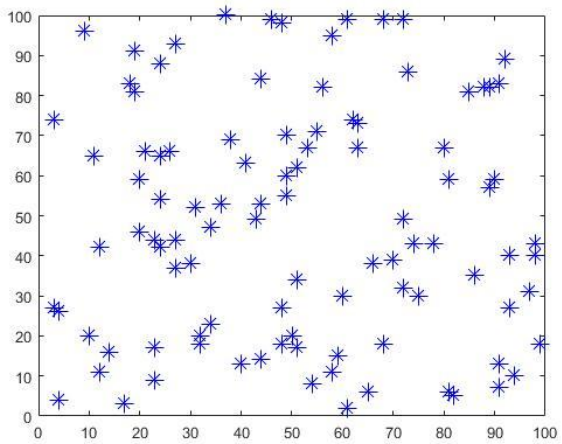

Fig. 4 Node deployment

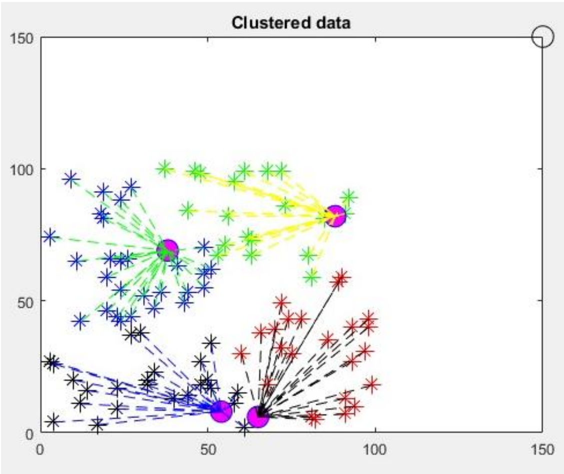

Fig. 5 Clustering formation(HeTDR)

The HeTDR protocol hierarchical clustering energy-based CH selection trust-based routing protocol data routing with dark back color dotted line in Fig. 6. The data route from member node to CH, CH to another CH node, and CH to finally base station. It indicates the one round data routing through multiple hop routing.

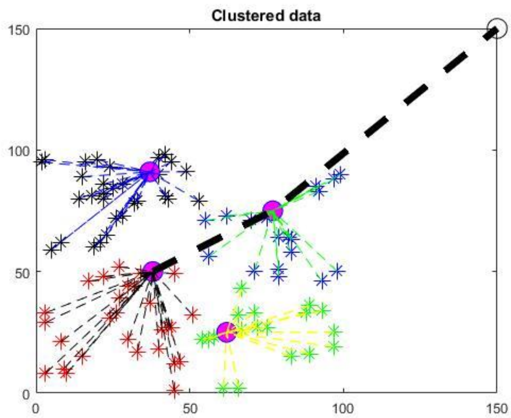

Fig. 6 Data routing to BS(HeTDR)

The simulation runs and generates the following result with different node sizes. The red color line indicates the HeTDR system, green color for EECRP, blue for HEED and yellowcolor line for LEACH protocol. The following

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simulation results are x-axis number of nodes and y-axis: energy consumption, Throughput, PDR, network lifetime, end to end delay, bit error rate, and jitter.

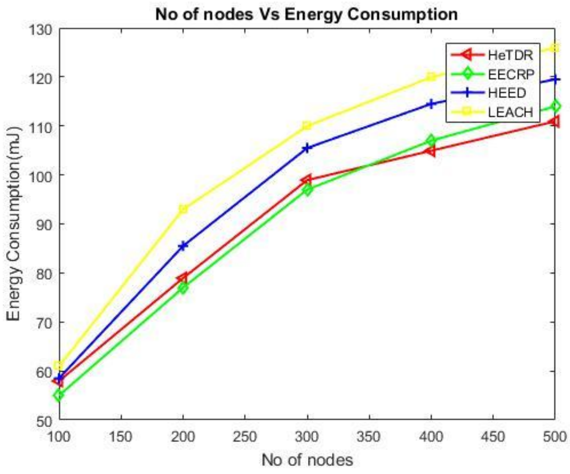

Fig. 7 No of nodes vs. Energy consumption (HeTDR)

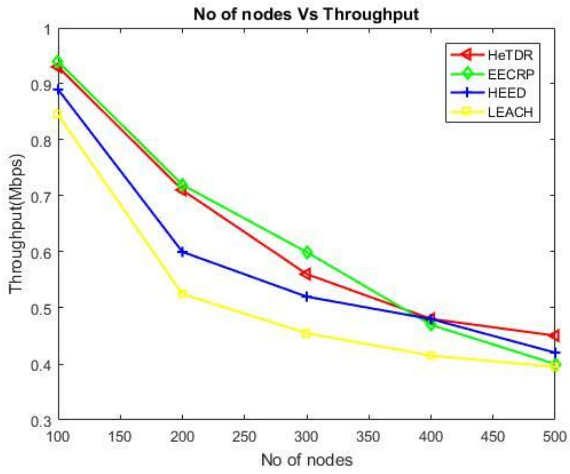

Fig. 8 No of nodes vs. Throughput (HeTDR)

The Fig. 7 indicates number nodes vs. energy consumption with different node sizes compared to traditional protocol and HeTDR system. The Fig. 8 indicates number nodes vs. throughput with different node sizes.

The Fig. 9 indicates number nodes vs. packet delivery ratio with different node sizes comparedto traditional

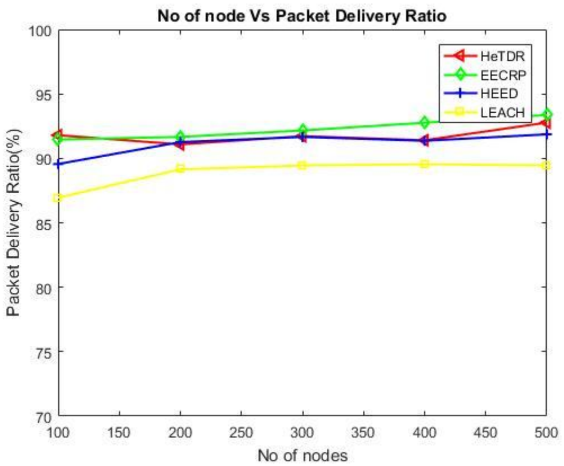

Fig. 9 No of nodes vs. PDR (HeTDR)

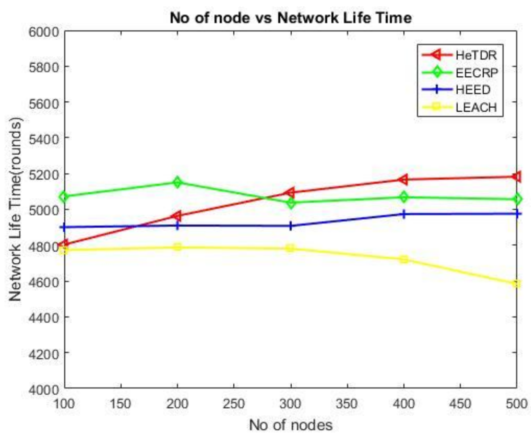

Fig. 10 No of nodes vs. Network lifetime (HeTDR)

protocol and HeTDR system. Fig. 10 indicates number nodes vs. network lifetime with different node sizes.

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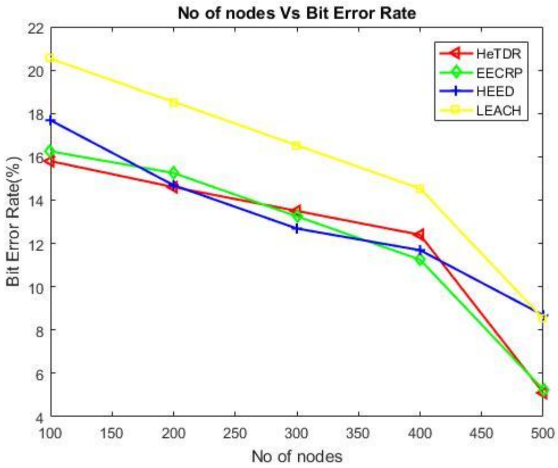

Fig. 11 No of nodes vs. E2E Delay (HeTDR)

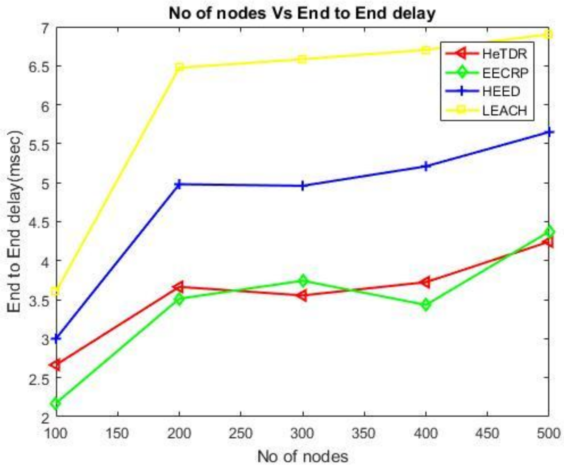

Fig. 12 No of nodes vs. Bit error rate (HeTDR)

The Fig. 11 indicates number nodes vs. bit error rate with different node sizes. The comparison between traditional protocol and HeTDR system. Fig. 12 indicates number nodes vs. end-to-end delay with different node sizes.

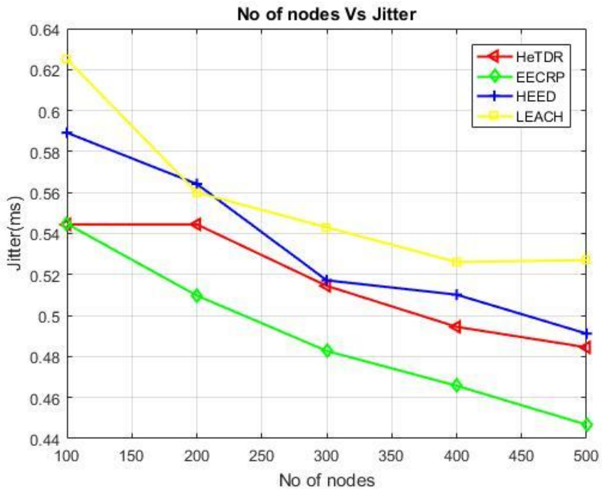

Fig. 13 No of nodes vs. Jitter (HeTDR)

The Fig. 13 indicates number nodes vs. jitter with different node sizes. The Performance of HeTDR good compare with traditional HEED and LEACH but below EECRP.

V. COMPARISON

The comparison is based on different network simulation parameters between HeTDR system and traditional protocol. The parameter is energy consumption, throughput, packet delivery ratio, network lifetime, bit error rate, end-to-end delay and jitter. The simulation was carried out with different node sizes from 100 to 500. The experiment result records the data represent in terms of actual simulation result line chart, table format and histogram.

ENERGY CONSUMPTION

Energy consumption is the total energy consumed or used by any node in the network. Generally, energy used for communication or data transmission by any node is considered energy consumption. Table 2 consist of the energy consumption by LEACH, HEED, EECRP and HeTDR with different node size.

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Table 2 No. of nodes vs. Energy consumption of different protocols (HeTDR)

	ENERGY CONSUMPTION					
Protocol Name	**No of Nodes**	**100**	**200**	**300**	**400**	**500**
	LEACH	61	93	109	117	125
	HEED	60	83	106	112	120
	EECRP	55	74	94	103	107
	HeTDR	59	76	95	105	111

The Fig. 14 indicates the number of nodes vs. energy consumption during simulation. The x-axis indicates the number of nodes from 100 to 500, and the y-axis indicates the energy consumption level in the mJ unit. The energy consumption occurs during the cluster formation, CH selection and data routing (transmission and receiving data).

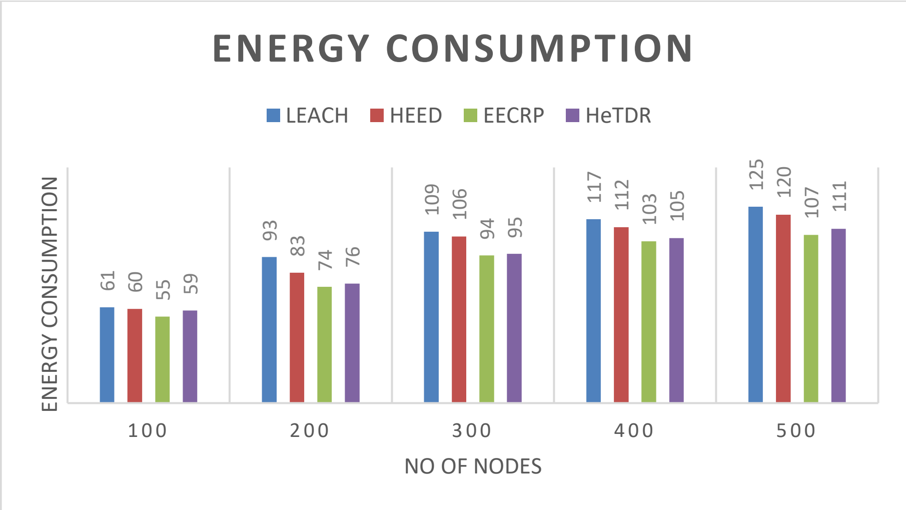

Fig. 14 No. of nodes vs. Energy consumption of different protocols (HeTDR)

The node size increases the energy consumption increase. LEACH consumes higher energy compared with other traditional and HeTDR system. The energy consumption of EECRP is less than other traditional and HeTDR systems.

THROUGHPUT

The throughput of any network is calculated through the number of packets transmitted or delivered successfully over the communication channel. Throughput is measured in bits/sec. Table 3 indicates the throughput network parameter comparison between different protocols with a different node sizes.

Table 3 No. of nodes vs. Throughput of different protocols (HeTDR)

	THROUGHPUT					
Protocol Name	**No of Nodes**	**100**	**200**	**300**	**400**	**500**
	LEACH	0.85	0.55	0.48	0.44	0.42
	HEED	0.9	0.62	0.54	0.5	0.44
	EECRP	0.95	0.75	0.63	0.5	0.43
	HeTDR	0.94	0.75	0.72	0.51	0.46

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The Fig. 15 indicates the number of nodes vs. throughput level during simulation. The x-axis indicates the number of nodes from 100 to 500, and the y-axis indicates the throughput level in bits/sec unit.

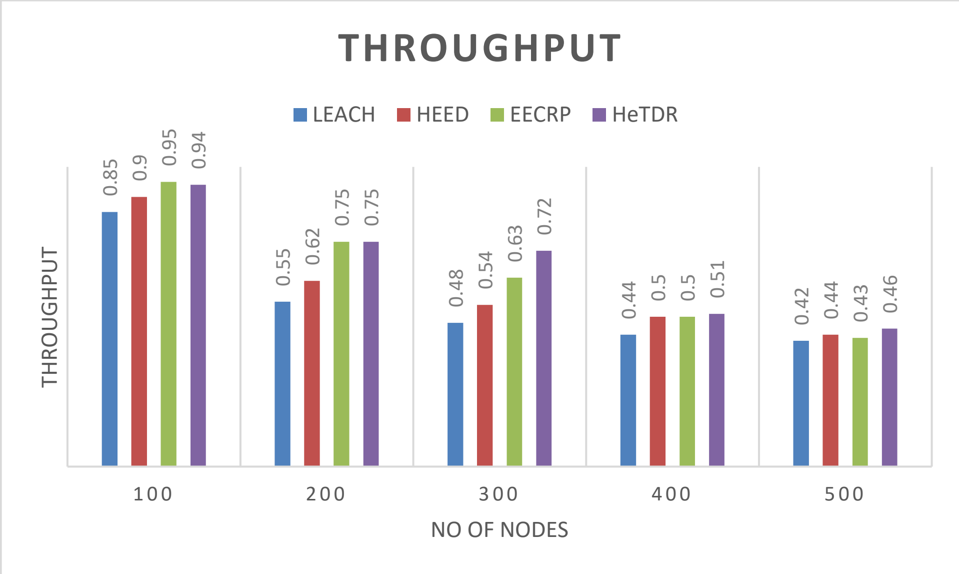

Fig. 15 No. of nodes vs. throughput of different protocols (HeTDR)

It also indicates the data communication link quality. Throughput levels decrease when the number of nodes increases. The throughput value is in the range of [0, 1]. The performance of EECRP is better than traditional approaches and HeTDR system.

PACKET DELIVERY RATIO

The packet delivery ratio can be measured as the total number of packets delivered from source to destination and the number of packets sent. Table 4 indicates the packet delivery ratio network parameter comparison between different protocols with different node sizes.

Table 4 No. of nodes vs. Packet delivery ratio of different protocols (HeTDR)

	PACKET DELIVERY RATIO					
Protocol Name	No of Nodes	100	200	300	400	500
	LEACH	87.6	89.3	89.4	89.9	89.9
	HEED	90.5	91.5	91.6	91.5	91.7
	EECRP	92.3	91.9	92.2	92.6	93
	HeTDR	92	91.2	91.6	91.8	92.2

The Fig. 16 indicates the number of nodes vs. packet delivery ratio during simulation. The x-axis indicates the no of nodes from 100 to 500 number and the y-axis indicates the packet delivery ratio in terms of percentage. The PDR calculates the ratio of the number of packets delivered and total packets sent from source to destination. The PDR indicates the network accuracy in terms of percentage.

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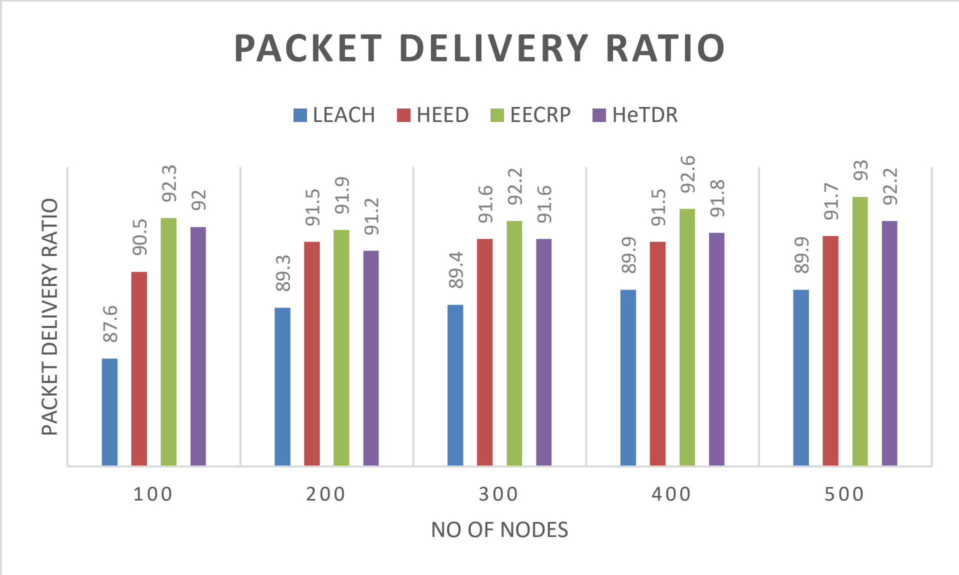

Fig. 16 No. of nodes vs. Packet delivery ratio of different protocols (HeTDR)

The traditional approaches are less accurate compared with HeTDR system due selection process of CH and efficient routing method. Initial with less number of nodes, EECRP performs well compared with others, but a number of nodes increase the HeTDR system's performance better than traditional approaches and In-line with EECRP.

NETWORK LIFETIME

The running time between when the network has been started and when the first node is dead is also called network whole active period or network lifetime. Table 5 indicates the comparison of network lifetime network parameters between different protocols with different node sizes.

Table 5 No. of nodes vs. Network lifetime of different protocols (HeTDR)

	NETWORK LIFETIME					
Protocol Name	No of Nodes	100	200	300	400	500
	LEACH	4795	4822	4807	4773	4600
	HEED	4900	4946	4952	5003	4991
	EECRP	5060	5187	5029	5064	5081
	HeTDR	4862	4991	5023	5096	5112

The Fig. 17 indicates the number of nodes vs. network lifetime during simulation. The x-axis indicates a number of nodes from 100 to 500 and the y-axis indicates the network lifetime in terms of rounds. The network lifetime is amount of running time between network that has started and first node dead.

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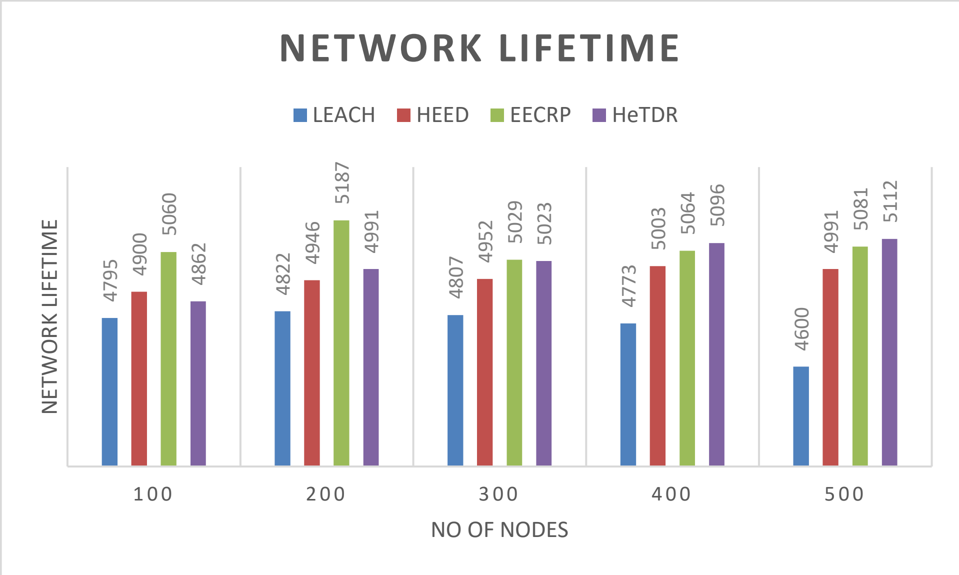

Fig. 17 No. of nodes vs. Network lifetime of different protocols (HeTDR)

The performance of HeTDR system is well compared with all traditional protocols with respect to different node sizes. The HEED and EECRP performance in traditional approaches are nearly the same, but LEACH underperforms compared with others.

END TO END DELAY

End-to-end delay is the time taken from generating the packet from the source node and receiving it at destination node or sink node. Generally difference between the times from sending to receiving. Table 6 indicates the end-to-end delay network parameter comparison between different protocols with node sizes.

Table 6 No. of nodes vs. end to end delay of different protocols (HeTDR)

	END TO END DELAY					
Protocol Name	No of Nodes	100	200	300	400	500
	LEACH	3.5	6.3	6.4	6.6	7
	HEED	3	9	89	5.1	5.6
	EECRP	2.1	3.3	3.4	3.1	3.6
	HeTDR	2.6	3.4	3.4	3.7	3

The Fig. 18 indicates the number of nodes vs. end-to-end delay during simulation. The x-axis indicates a number of nodes 100 to 500 and the y-axis indicates end-to-end delay in terms of msec. The end-to-end delay calculates the difference between time from packet sent from source node and receive at a destination node. The many parts of end-to-end delays include processing, transmission, and propagation delays.

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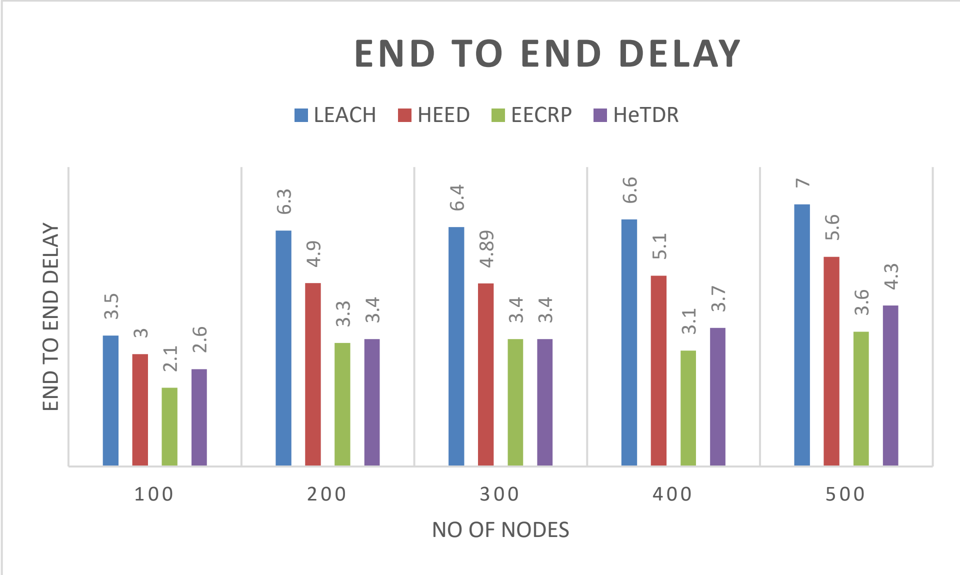

Fig. 18 No. of nodes vs. end to end delay of different protocols (HeTDR)

The number of nodes increases, the delay also increases. The performance of HeTDR system is good compared with traditional approaches(LEACH and HEED); the performance of EECRP end-to-end delay is good than HeTDR system.

BIT ERROR RATE

The bit error rate is calculated through a ratio of the number of wrong bits delivered over the total number of bits transmitted in a network. Table 7 indicates the comparison of bit error rate network parameter between different protocols with different node size.

Table 7 No. of nodes vs. Bit error rate of different protocols (HeTDR)

	BIT ERROR RATE					
Protocol Name	No of Nodes	100	200	300	400	500
	LEACH	20.6	19	17.6	16.3	8.4
	HEED	17.9	15.4	13.7	13.4	8.3
	EECRP	16.1	15.7	14	13.2	5.2
	HeTDR	15.6	17	13.6	12.2	5.2

The Fig. 19 indicates the number of nodes vs. bit error rate during simulation. The x-axis indicates the no of nodes from 100 to 500 number and the y-axis indicates the bit error rate in terms of percentage. The bit error rate calculates the number of bits that are wrongly transmitted over a total number of bits transmitted in a network. This parameter indicates the percentage of wrongly data transmitted.

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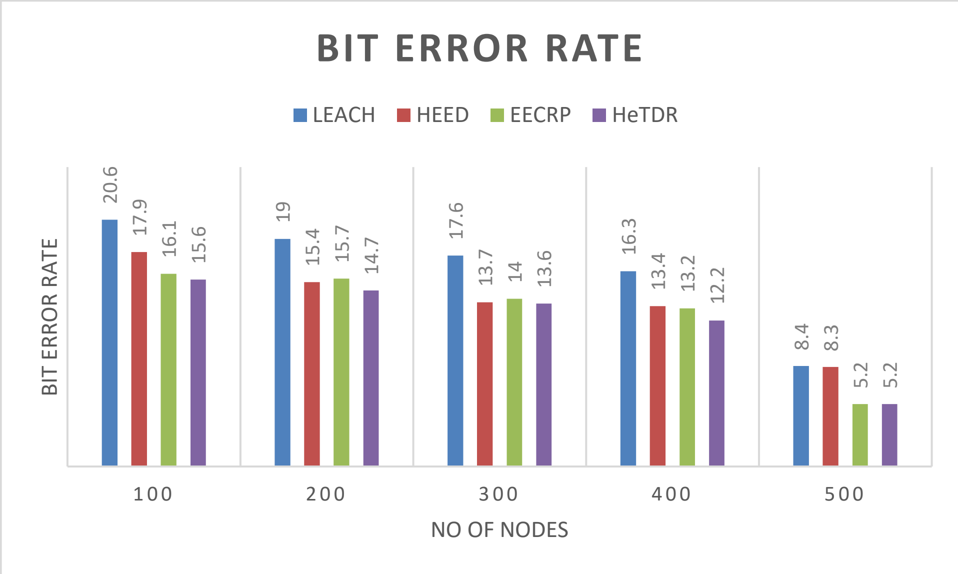

Fig. 19 No. of nodes vs. Bit error rate of different protocols (HeTDR)

As the number of nodes increases, the error rate percentage decreases. The performance HeTDR system is good compared with traditional approaches and in line with EECRP.

JITTER

The jitter defines the delay variation in the receiving packet transmitted from the source node. Table 8 indicates the jitter network parameter comparison between different protocols with node sizes.

Table 8 No. of nodes vs. jitter of different protocols (HeTDR)

	JITTER					
Protocol Name	No of Nodes	100	200	300	400	500
	LEACH	0.63	0.57	0.54	0.53	0.53
	HEED	0.58	0.56	0.52	0.51	0.49
	EECRP	0.54	0.51	0.48	0.46	0.45
	HeTDR	0.55	0.55	0.52	0.5	0.49

The Fig. 20 indicates the no of nodes vs. jitter during simulation. The x-axis indicates the no of nodes from 100 to 500 number and the y-axis indicates the jitter in terms of msec. The variation occurs due to lower network bandwidth or poor hardware quality. The number of nodes increasing the delay value slowly decrease.

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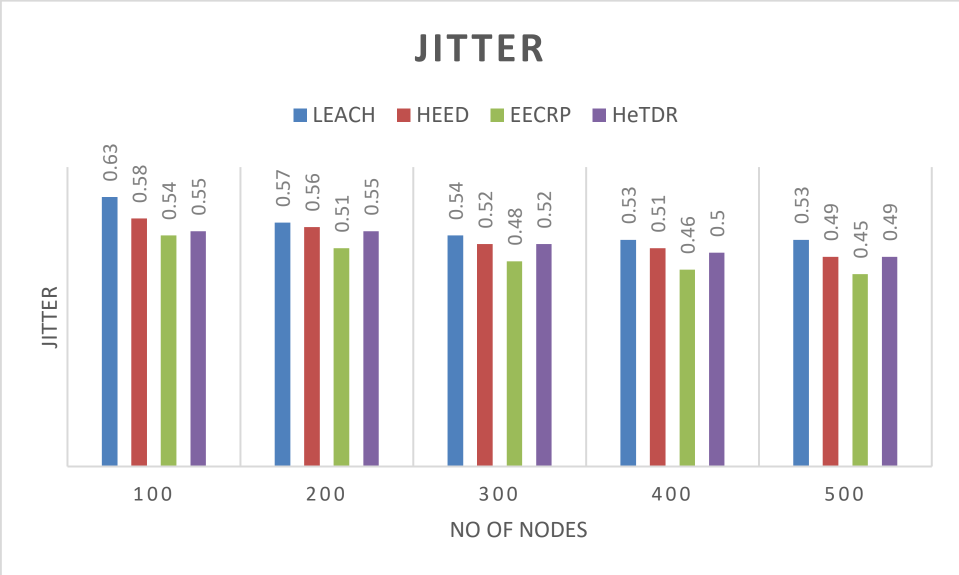

Fig. 20 No. of nodes vs. jitter of different protocols (HeTDR)

VI. CONCLUSION

The growth of wireless sensor networks decreases due to higher energy consumption for the data communication during the intra-cluster and inter-cluster communication. There are many applications like healthcare, industrial monitoring, security surveillance and many more. In this primary application, the motive is to increase network efficiency by reducing power consumption in the network. The proposed hierarchical clustering energy-based CH selection and trust-based data routing protocol were implemented and compared with LEACH, HEED and EECRP. Cluster formation, CH selection and routing are significant steps of any clustering-based routing protocol.

- The proposed method (HeTDR) protocol is simulated in MATLAB with different node sizes.
- The clustering formation approach is based on distance calculated by the base station. The CH selection in each cluster is based on highest residual energy and data routing through CM to CM direct and CM to CH through feedback mechanism same way CH to CH direct communication and BS to CH through feedback.
- The result obtained by HeTDR has better inline performance than existing traditional protocols in terms of all quality of service parameters

VII. FUTURE WORK

It is clear from the above research work that we can further enhance the efficiency of a network through the following: For cluster head selection, we can use following AHP, ELECTRE and MOORA multi-criteria decision-making algorithms for best node selection. Data routing in inter-cluster and intracluster through energy level, the distance between node and communication cost can help us increase the network life.

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