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Research paper

Improved LEACH protocol using cache nodes for wireless sensor network

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Abstract

The wireless sensor network is the decentralized type of network which can sense information and pass it to base station. The energy consumption is the major issue of WSN due to small of sensor nodes and far deployment of the network. The clustering is the efficient approach to increase lifetime of the sensor network. In the approach of clustering cluster head are selected for the data aggregation. The fuzzy logic rules are derived based on node energy, distance to base station for the cluster head selection, which increase lifetime of sensor nodes in the existing system. In this research work, cache nodes are deployed in the network which reduce energy consumption of WSN. In the proposed approach cluster head send data to cache nodes and it will forward data to base station. The simulation is performed in MATLAB and proposed technique performs well in terms of number of packets transmitted, number of dead nodes, network lifetime, throughput and remaining energy.

Keywords: *WSN; Fuzzy; Lifetime; Cache Nodes*

1. Introduction

There is an increase in demand of wireless sensor networks today. There are different types of sensor nodes present within the networks. The applications are completely based on the several types of sensors involved within them. The surrounding environments of applications are monitored within these networks such that any kinds of activities being performed can be brought to notice of the concerned authorities [1]. The temperature, pressure, humidity and so on are several factors that are included within the information that is gathered from surrounding environments. There are several low-powered, cheap as well as multifunctional sensor nodes deployed within the network that utilize wireless communication in order to transmit important information. Most of the applications are based on power of batteries due to which the recharging or replacement of these batteries is impossible which minimizes the efficiency of nodes deployed within the network applications. Data redundancy is another factor that affects the performance of nodes. In order to increase the lifetime of networks and increase their efficiency in terms of energy consumption, several techniques have been proposed here. The selection of cluster head (CH) amongst the sensor nodes present in the network and assigning them special tasks is highly beneficial within hierarchical routing. With the help of data aggregation and fusion, the energy consumption is minimized due to application of hierarchical routing. [2].

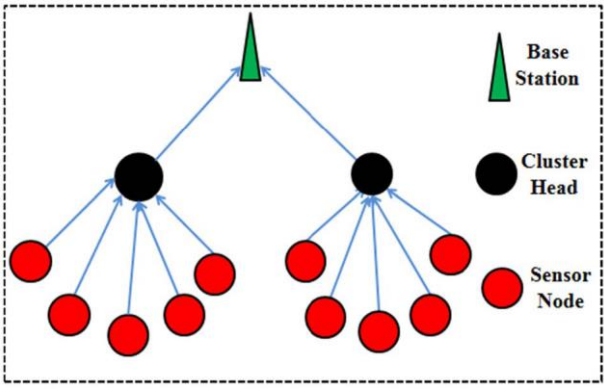


Fig. 1: General System Model for Cluster Based WSN [9].

The numbers of transmissions being made towards the base station are minimized here. Low Energy Adaptive Clustering Hierarchy is known as the first hierarchical protocol, which is introduced. The generation of clusters through gathering of sensor nodes on the basis of received signal strength is the major function of LEACH. In the form of routers towards the sink, local CHs are utilized by LEACH [3]. As all the transmissions will be done by the cluster heads instead of involving all the sensor nodes in the network, the energy consumption within the networks is improved. On the basis of idea of LEACH, several hierarchical protocols have been developed. In order to enhance the lifetime of network, LEACH is the most commonly used clustering algorithms. An adaptive, self-organizing and clustering protocol is proposed which is named as LEACH which utilizes the concept of rounds within it. There is fixed BS assumed to be available within LEACH and is placed at distant far from all other sensors. All the sensor nodes are homogeneous in nature and limited amount of source energy is present within them. At fixed rate, the environment is sensed by the sen-

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sors and communication is performed amongst each other. With the BS there is direct communication amongst the sensors [4]. In order to distribute the energy amongst sensor nodes within the network, the nodes are organized into clusters within LEACH. Here, a cluster head (CH) is chosen amongst all the nodes present in a cluster and each cluster can have only once CH. The sensing and communication within the WSNs is the major effect that affects their functionality. The characteristics and effects of energy holes are presented here. When the nodes are deployed randomly within sensor networks, the major issue is the unbalanced energy consumption. As being a data originator and data router the sensor nodes perform functions. There is huge load present on the sensor nodes that are near to that of sink in the network. Thus, the energy being consumed by these nodes is higher in comparison to other sensor nodes present in the network. [5]Thus, higher energy is depleted by the nodes present near to sink and in comparison to other nodes, they die quickly. Thus, around the sink, EHP is caused around the sink in this scenario. There is overlapping of higher number of sensor nodes because of the dense deployment within particular region due to which the hardware cost also increases. In order to generate the issues of holes within WSNs however, another cause is the dense deployment of networks [6]. There is higher depletion of energy within the routing paths due to the utilization of optimal path intermediate nodes within several routing mechanisms. Due to this the energy hole expands within the area of network. There are two broader categorizations of energy holes in the networks on the basis of types of transmission which are the outer area as well as the area near to sink. In order to transmit the data towards the sink node through direct transmission, higher transmission power is required for nodes that are at large distances [7]. Thus, in comparison to the nodes that are closer to the sink, the depletion of energy is higher within the far nodes. However, the energy holes are created within multi-hop communications near to sinks. This is due to the reason that there is huge traffic load upon the nodes present near to the sink.[8-10] There is depletion of nodes along with the battery power over time

2. Literature review

Nattapong Kitsuwan, et.al presented the location of cache nodes is determined by the proposed practical approach using which number of hops in CCN is reduced. In order to determine optimum cache node location, the drastically reducing time is required [11]. The issues of determining cache node location are formulated using the ILP approach. If the size of the network is large then more time is taken by the issues in ILP approach. Hence, to mitigate this they introduced the approach of using betweenness centrality. As per simulation results, it is demonstrated that proposed BC approach provides faster results as compared to ILP approach for the issues related to real life. Padmalaya Nayak, et.al presented the crucial issues faced in the wireless sensor network is the decrease in network lifetime. It is not practically possible for human to monitor or access this network all the time as it operates in the unattended environment. Hence, a powerful technique is utilized to arrange all the operations of this system in terms of scalability, minimize energy consumption, increase in network lifetime. This technique is known as clustering. Therefore, to overcome this issue various clustering algorithms has been proposed so far by researchers. Most of the researchers used the idea of fuzzy logic for making decisions in WSN [12]. The main focused of this algorithm is to manage efficiency of CH. In order to enhance the lifetime of the network, this algorithm distribute the load among the sensor nodes effectively. Type-1 FL (T1FL) model has been utilized by most of the algorithms. They proposed a clustering algorithm on the basis of interval type-2 FL model. It is assumed that proposed method handle uncertain level decision better than T1FL model.

Ayesha Naureen, et.al proposed a novel protocol names as aggregation-based topology learning protocol [13]. Within a hierarchical WSN which is deployed in random manner, this protocol aims to recognize the energy holes. The routing topology of a tree-structure HWSN in real time can be learned in order to design this protocol. As per the experiments conducted it is seen that there is similar cost required to gather data through proposed mechanism as well as process that does not include proposed mechanism. Thus it concludes that there is negligible cost added within the topology-learning mechanism proposed here. Ismaeel Al Ridhawi, et.al proposed a cache node selection strategy in this paper in order to provide faster access by keeping most accessed media content available to nearby client nodes. This paper considers the partial client-side data caching for the cloud storage [14]. There are some devices on which the selection process is based such as hardware and software resources, flow time, residual power, mobility characteristics and transmission capabilities. They also proposed a fuzzy-induced service-specific overlay composition technique so that on-demand composed services can be provided easily. As per simulation results, it is concluded that there is minimization in the bandwidth consumption and job execution times. Proposed method shows success rate in high overlay composition by reducing delays associated with superimpose compositions.

ChunnuLal proposed various techniques that has been utilized by various researchers in order to detect the presence of the denial-of-service attack in WSN. Due to the limited resources for the WSN devices, these attacks are more vulnerable to the consumption and destruction of these inadequate resources. In the wireless senor networks there are various attacks that degrade the functionality of the network but among those attacks denial of services attack is considered as the major attack [15]. Therefore, it becomes major challenge for many researchers to develop effective and lightweight security mechanism that minimizes and prevents the various attacks for WSN such as Denial-of-Service (DoS) attack. Author in this paper consider only effective detection techniques in order to detect the presence of the DoS attack and reduce the power consumption in the wireless sensor network. There is large number of detection mechanisms that exists in the network but due to limited power and processing capability of sensor nodes in order to reduce the power consumption hence, it is necessary to design an energy preserving DoS detection mechanism in WSNs. Alka Singh, et al. [16] discussed in this paper, Low Energy Adaptive Clustering Hierarchy(LEACH) a well-known cluster based protocol. LEACH protocol is used for enhance the life time of the network. LEACH operation is divided into following rounds 1)Set up phase- In this phase nodes are selected as a cluster head(CH) on the basis of energy and distance. 2) Steady state phase- this stage is for data transmission. In this nodes sense data and send this data to their respective CH node. Then processed data will be sending to the base station. Therefore, LEACH is a balanced energy consumption protocol for wireless sensor network.

JuRen, et.al proposed an analytic model for estimating the overall lifetime of network from the time of its generation to the time when it has disabled completely [17]. In addition, within the data-collecting WSN, the boundary of energy hole is determined. During the complete lifespan of a network, the traffic load, energy consumption as well as lifetime of sensor nodes is computed theoretically. In order to calculate the analytical results for routing in WSN the temporal and spatial evolution of energy hole is studied along with the application of analytical results. Thus, the lifetime of network is enhanced. In order to demonstrate the validity of proposed analytic model, the extensive simulation results are generated here and the lifetime of network and the evolution process of energy hole are estimated. Hemant Kumar R, et.al [18], Proposed in this paper, that data is collected by the sensor nodes and routed to the sink. The functionality of both the dynamic sink and mobile sink is disused. The parameters used compare the performance of dynamic sink and mobile sink was latency and energy. High energy efficiency was shown by dynamic sink as compare to mobile sink.

KatarzynaMazur, et.al presented the issue of DDoS attack and its multilevel analysis in the wireless sensor network as it degrades the functionality of the whole system. They proposed the two security levels with eight defined scenarios and different number

of compromised devices. Author in this paper investigated the sink's performance and energy consumption under the DDoS attack using simulations. After obtaining all the results from the simulations, a new kind of (DDDoS) attack is identified [19]. All the processed packets in the network are not encrypted hence, there impacts on the network is dangerous as it bring down the whole network down and draining valuable energy resources. On the basis of conclusion it is also known that the security level can be possibly adjusted on the basis of the type of the DDoS attack as it prevents different types of attacks. It is also possible to avoid DDoS or delay in the network by lowering security level in certain conditions.

M. Guerroumi et.al [20], this paper proposed new data dissemination protocol based energy-efficient called energy-based data dissemination protocol. In this phase, sensor sink may move toward any cluster based on its sensed data frequency to minimize energy consumption of sensor nodes near the fixed sinks due to relaying of large amount of data.

SeyyitAlperSert, et.al [21], a distribution-independent approach is proposed here in this paper for clustering in WSN. A multi-objective fuzzy clustering algorithm (MOFCA) is proposed which addresses both hotspots and energy whole problems in stationary and evolving networks. In terms of efficiency metrics such as First Node Dies (FND), Half of Nodes Alive (HNA) and Total Remaining Energy (TRE) are used for estimating the lifetime of WSNs, which proved that MOFCA outperforms other techniques.

Chu-Fu Wang et al. [22], this paper proposed a network lifetime enhancement method for sink relocation. Energy-Aware Sink Relocation (EASR) is a method, which is used to enhance the lifetime of wireless sensor network. The focus in this paper is on residual energy of sensor node. According to that, residual energy of sensor node the transmission range of sensor would adjust and also the relocation of sink is taken place according to the residual energy of sensor node.

Maciej Nikodem et al. [23], the paper investigates whether clustering itself (with no data aggregation) can improve network lifetime in particular application when compared to non-clustered networks. Results show that clustering itself cannot improve network lifetime so additional techniques and means are required to be used in synergy with clustering.

3. Problem formulation

The wireless sensor networks is the type of network in which sensor nodes sense network the environmental conditions and pass the sensed information to the base station. The sizes of the sensor nodes are very small, due to which battery of sensor nodes is very limited. In the recent times various techniques has been proposed to reduce energy consumption of the sensor networks. The clustering is the most efficient technique which increase network lifetime. In the LEACH protocol, the network is divided into fixed size clusters using location based clustering. In each cluster, cluster heads are selected on the basis of energy consumption and distance. In the existing system, technique of fuzzy logic is been applied for the selection of cluster heads in the network.

4. Proposed work

The proposed methodology is based on the selection of cluster head for the data transmission, for the selection of cache nodes which aggregate data to the base station.

Step 1: Cluster head selection: One of the requirements of clustered WSNs application is the monotony distribution of nodes. Balanced cluster heads are generated here that have several benefits of their own due to the suitable distribution conducted here. The disposability of fertility balance of cluster heads is avoided due to energy. Long distance communications amongst cluster head and nodes below it is also avoided here. The nodes that are not perfectly suitable as cluster heads are not chosen by the intended standards. This is due to the reason that few nodes that are present within the net areas cannot be present within the cluster center because of the condition in which they are present in the network [13]. Due to the increment in intra-cluster energy, such nodes are used as cluster heads. In comparison to ordinary nodes, there is higher amount of energy being consumed by receiver and sender nodes. The battery within the nodes can be finished by providing two expensive spectrums synchronically to the node. Thus, for separating the two actions to increase the productivity, the parent nodes are chosen for each cluster. For determining each sensory node competence such that the node can be chosen as cluster head or sender, two value functions are generated here. On the basis of computing nodes degree standard second power average of the neighboring nodes through special ray along with the distance to base station, the generation of functions is performed here. In order to generate cluster head, the nodes that have high degree are found to be appropriate. Higher number of nodes could be covered by less cluster head which can prevent expensive communications to occur here. Thus, the consumption and equiposing can be minimized such that the lifetime of network can be increased here. A HELLO-MSG is broadcasted that holds ID within it, in the entire network as the initial step. The distance of base station from each node is calculated here on the basis of signal strength attained and an INITIAL-MSG is broadcasted all over the network in which the ID and the distance of node to the base station are present. From that node, the adjacent nodes can possibly compute their distances. Equation (1) presents the calculation method that is used by each node to compute its cluster head R_{CH} as:

$$R_{CH} = R_{min} * [1 + (\frac{d_{BS} - d_{BSmin}}{d_{BSmax} - d_{BSmin}})] \quad (1)$$

Here, the minimum cluster size is denoted by $R_{min}$and is also included as parameters of protocol. The distance amongst nearest node and the Base station is denoted as d_{BSmin}. The distance amongst farthest node and base station is denoted by d_{BSmax}. With the help of value function, a value amount is computed for each node such that the node can be volunteered to be chosen as cluster head for the cluster.

$$F_{CH-value} = \alpha * N_{deg} + \frac{\beta}{MSD_{deg}} + \frac{\gamma}{d_{BS}} \quad (2)$$

In the above equation, the constant weights amongst zero and one where sum is equal to one are represented as α, β and γ. These values are similar as well as adjustable for all the nodes present in the network. The number of neighboring nodes that have R_{CH} radius are denoted by N_{deg}. The mean square of distance amongst the neighboring nodes with R_{CH} radius is denoted by MSD_{deg}. The distance amongst each node and base station is represented by d_{BS}. The values of total number of volunteered cluster heads within some time are set by the expected values. Thus, for each node, the enhanced amount of $F_{CH-value}$is achieved. On the basis of enhanced numerical value amongst zero and one, other nodes are noticed by each node. Further, a random value in between zero and one is created by each node. The node considers itself as candidate cluster head node if the value achieved is less in comparison to corrected and normalized value of $F_{CH-value}$. On the basis of R_{CH} radius and residual energy, comparisons are made amongst each candidate cluster head node and other candidate cluster heads. The node that has highest residual energy is chosen here and represents itself as cluster head that includes ID as well as broadcast code. The cluster head status is announced to the complete network nodes. On the basis of received signal strength, the nearest cluster head is determined by any non-cluster head node.

Step 2: Cache node selection: There are certain factors on which the intra-cluster communication within an energy cluster depends. The cluster size is one of these factors. There will be more expensive communications within the cluster when the size of cluster is large due to the relation between the energy consumption within the node radio with the distance. Thus, there is increment in intra-

cluster energy. Another factor which is important is the centrality. There is decrement of second power average distance when the receiver node gets closer to central cluster. Thus, there is reduction in intra-cluster energy [13]. Also, several other factors such as density of node also affect the energy of intra-clusters. The nodes that are within the unsuitable conditions as cache nodes are not chosen by the intended standards. For a node to be chosen as volunteer cache node, each non-cluster head node determines a value within this step.

$$\text{Access Time} = H*Tc + (1-H)(Tc+Tm) \quad (3)$$

In the equation 3, H is the cache hit ratio, Tc is the access time , (1-H) cache miss ratio, Tm is the main memory access time. The cache which has least access time is selected maximum time for the data aggregation from the cluster heads. The cluster heads will send the data to the base station.

5. Research method

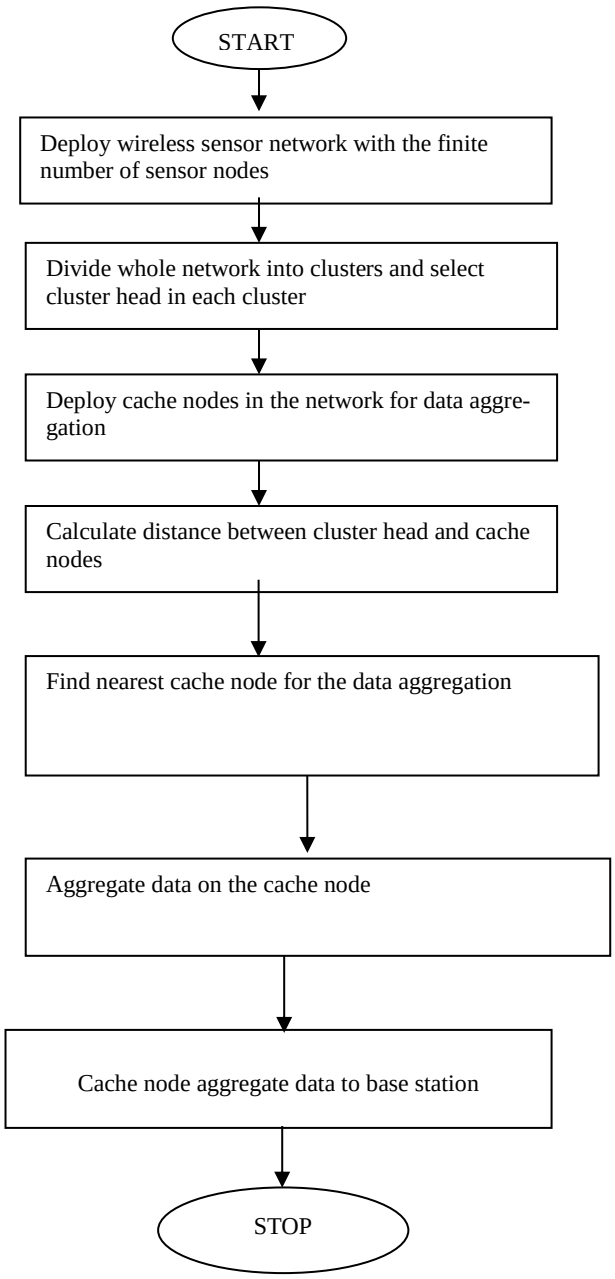


Fig. 2: Proposed Flowchart.

6. Result and discussion

6.1. Simulation environment

The MATLAB is the tool which is used to analyze performance of proposed cache based wireless sensor networks. The performance of proposed algorithm is compared with existing fuzzy logic based wireless sensor networks. The performance of both algorithms is compared in term of number of packets transmitted to base station and number of dead nodes. The simulations parameters are described in table 1.

Table 1: Simulation Parameters

Parameter	Description	Value
A	area of network	(0, 0)–(200, 250)
L-BS	BS location	(150, 250)
N	number of nodes in network	100
$E_{initial}$	initial energy of all nodes	0.5 J
E_{fs}	free space channel model	50 nJ/bit
E_{mp}	multi-path fading channel model	0.0013 pJ/bit/m^4
d_0	distance threshold	87 m
E_{DA}	data aggregation energy	5 nJ/bit/signal
DP size	data packet size in bit	4000
CP size	control packet size in bit	200

6.2. Cache based wireless sensor networks

In the defined simulation environment performance of the fuzzy logic based WSN and cache nodes based WSN are compared in terms of number of dead nodes and packets transmitted to the base station.

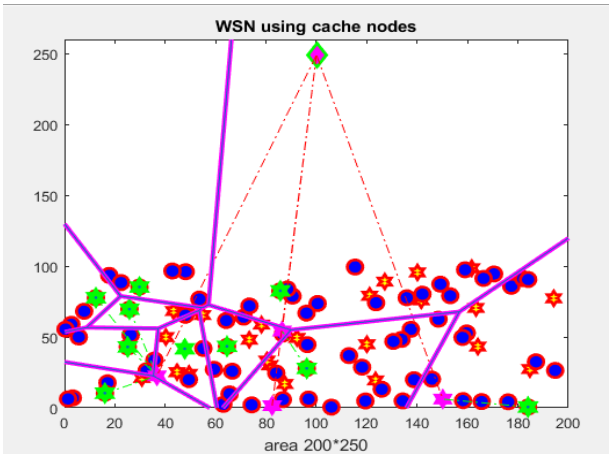


Fig. 3: Results of Cache Based WSN.

As shown in the figure 3, the base station is deployed and cluster heads are represented by the green color, the cache nodes are shown with the pink stars. The clusters are shown with the pink lines. The cluster heads aggregate the data to the cache node which has least distance and minimum access time.

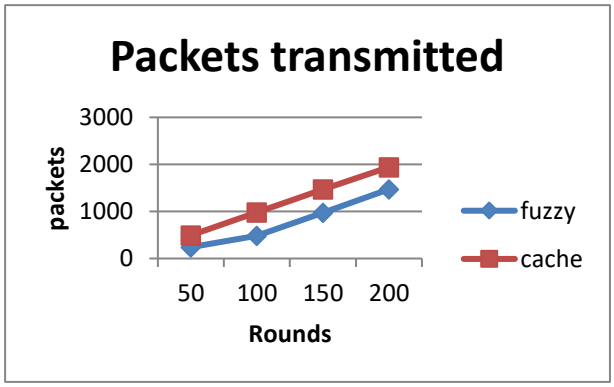


Fig. 4: Number of Packets Transmitted.

As shown in figure 4, the fuzzy and WSN with cache nodes are compared in terms of number of packets transmitted to base station. It is analyzed that more number of packets are transmitted in the proposed technique as compared to existing technique

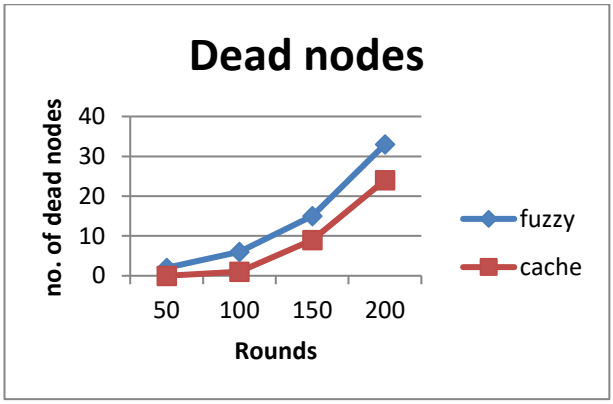


Fig. 5: Last Node Dead Comparisons.

As shown in figure 5, the Fuzzy and WSN with Cache is compared in terms of last node dead. The x-axis represents the number of rounds. The y-axis shows that number of rounds on which all sense nodes die. The comparison shows that in the proposed technique number of sensor nodes alive for more number of rounds.

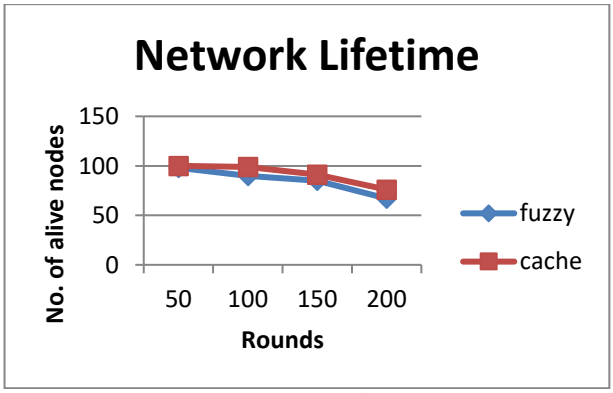


Fig. 6: Network Lifetime.

As shown in figure 6, the network lifetime of proposed algorithm is compared with existing fuzzy technique. It is analyzed that lifetime of cache technique is more than that of fuzzy WSN after 200 rounds.

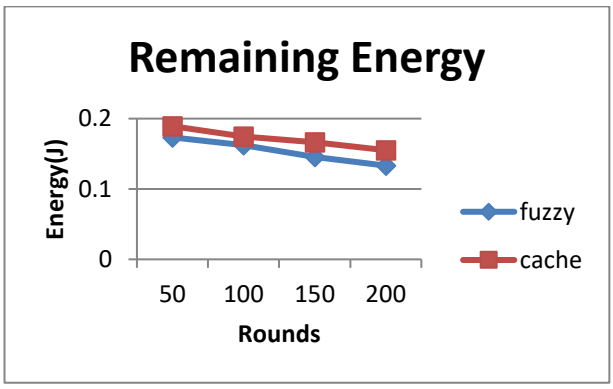


Fig. 7: Energy Comparison.

As shown in figure 7, the energy consumption of fuzzy and cache technique is compared. It is analyzed that energy consumption of cache technique is less as compared to fuzzy technique

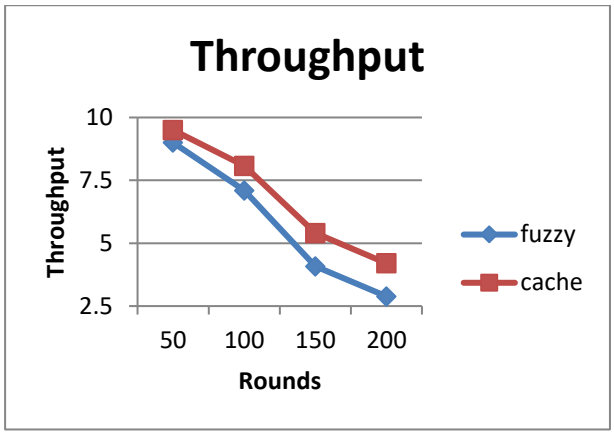


Fig. 8: Throughput Comparison.

As shown in figure 8, the network throughput of proposed algorithm is compared with existing fuzzy technique. It is analyzed that throughput of cache technique is increased at steady rate

Table 2: Comparison Table

Parameter	No. of Rounds	Fuzzy	Cache
Remaining energy(J)	50	0.1733	0.1892
	100	0.1621	0.1746
	150	0.1455	0.166
	200	0.1332	0.1551
No. of dead nodes	50	2	0
	100	6	1
	150	15	9
	200	33	24
Network lifetime	50	98	100
	100	90	99
	150	85	91
	200	67	76
Throughput	50	9	9.5
	100	7.10	8.072
	150	4.078	5.399
	200	2.888	4.203
Packets send to BS	50	241	493
	100	482	981
	150	972	1469
	200	1472	1942

Table 2 describes the comparison of fuzzy WSN and WSN with cache nodes in terms of packet transmission and number of dead nodes, network lifetime, throughput and remaining energy in terms of values. It is analyzed that cache node WSN perform well as compared to fuzzy WSN.

7. Conclusion and future scope

The clustering is the efficient approach which can improve lifetime of wireless sensor networks. In the existing system, the cluster heads are selected in each cluster based on the fuzzy rules. In the research work, the cache nodes are deployed in the network. The cluster heads aggregate data to cache nodes. The cache nodes will transmit data to base station. The cache nodes maintain the flash memory which improve lifetime of sensor networks. The simulation of proposed model is performed in MATLAB and result shows that proposed technique performs well in terms of packet transmission and number of dead nodes, network lifetime, throughput and remaining energy as compared to existing technique. In future, the proposed technique will be further improved to increase security of the network.

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