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INVESTIGATION ON ENERGY BASED DATA GATHERING APPROACH FOR WSN

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ABSTRACT

Wireless Sensor Networks plays a vital role in all emerging areas of Wireless Platforms like Interne of Things (IoT), WIFI, WiMAX etc. Sensor nodes are communicated with or without the presence of administrator. Data gathering is a major issue in WSN which influences the throughput, energy and data delivery. In previous research, there was not taken efforts to focus on balanced data gathering. In this research, we propose Reliable Energy Efficient Data Gathering Approach (REEDGA) to balance data gathering and overhead. To achieve this, proposed work consists of three phases. In first phase, estimation of information gathering is implemented through stable paths. Stable paths are found based on link cost. In second phase, data gathering phase is initialized to save energy in the presence of mobile sensor nodes. Overhead is kept low while keeping round trip time of gathered data. From the analytical simulation using NS2, the proposed approach achieves better performance in terms of data delivery rate, data gathering rate, throughput, delay, link availability and control overhead.

Keywords: WSN, Data Gathering Rate, Path Reselection, Estimation of information gathering, overhead, round trip time and link availability.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) are emerging field in wireless technology which requires development of many sensor nodes that communicate with one another to perform a standard task. The sensor nodes are battery operated that is a vital limitation of WSN. Many algorithms to conserve power are found in literature. These algorithms are designed to control in numerous layers of the network to decrease power and to extend the life of the sensor node. Sensor networks, particularly Wireless Sensor Networks, exhibit different vital peculiarities that create the data gathering issue challenging. First, sensor nodes are usually computationally controlled and have restricted memories. Hence, it may not be possible to run refined data collection algorithm on them. Second, the communication in wireless sensor networks is usually wiped out a broadcast manner – once a node transmits a message, all nodes inside the radio vary will receive the message.

In [1] it is stated that packet transmissions will account for up to 70% of the power consumed in typical sensor node and substantial energy saving is feasible if the amount of the communicated data packets is reduced using compression. From [2], it is understood that cluster may be a well-established technique for reducing the data collection costs in WSN. The clustering algorithms vary in their objective which incorporates load leveling, fault tolerance, augmented property, reduced delay and maximal network lifetime. Sensor nodes are clustered and an efficient data gathering algorithm using wavelet based compression algorithm is enforced at the sensor node to scale back energy. A new cooperative data reduction technique was proposed to get rid of the redundancy existing in data gathering from multiple sensor nodes moreover as from one sensor node.

In a sensor data gathering application, sensors are typically deployed at the locations fixed by the application requirements to gather data. The collected sensing data are then forwarded back to a central base station for more process. Traditionally, these sensors are connected by wires that are used for data transmission and power supply. However, the wired approach is found to wish great efforts for development and maintenance.

Sensor data collection, however, needs all sensing information are properly and accurately collected and forwarded to the base station, since the process of those information desires the global knowledge and is far additional complicated than that in different applications like target tracking.

This feature also prevents data aggregation/fusion techniques to boost the network performance. As a result, the most important traffic in sensor data collection is that the according information from every sensor node to the base station. Such "many-to-one" traffic pattern, if not carefully handled, can cause high unbalanced and less energy efficiency within the whole network. As a concrete example, the energy hole drawback was according and mentioned in [3], wherever sensor nodes near the base station are depleted quickly due to traffic relays and create a hole shape area that leaves the remaining network disconnected from the base station. One possible solution to alleviate such problems is mobile agents that proactively move around and collect information within the sensing field. However, due to the harshness of the sensing atmosphere moreover on minimize the disturbances, such an answer is commonly infeasible within the context of sensor data collection.

2. RELATED WORK

In [4], authors introduced the concept of distributed data-gathering scheme with an autonomous underwater vehicle (AUV) to gather data where the clustered network forms. The overall transmission power of sensor network is reduced by means of selection of path nodes. The overhead is also reduced with AUV method and energy consumption of entire network was also minimized. Mobile Sink-based Self Adaptive and Energy Efficient Proactive Data Collection Protocol [5] was proposed by Dheeraj et.al. To avoid the frequent updation about destination node location status, mobile sink bases data collection method has been introduced. This method was differed from two things i.e. permission of node flexibility while terrestrial reform and there is no requirement of GPS device. A logical coordinate system was adopted for routing and packet forwarding according to real time applications.

Anujaand Raju [6] introduced the Secure periodic Data Gathering scheme which is the combination of that is path establishment and packet transmission. Artificial intelligence was used to set up optimized path with minimal power to destination in terms of path quality, distance between neighbor nodes and energy efficiency. The concept of Rivest Cipher (RC6) Algorithm was adopted to protect the packet transmission from attackers. It efficiently provides the efficient encryption which satisfies the security challenges and consumes less energy for encryption.

Lei Quan et.al [7] developed a neighbor-aided compressive sensing (NACS) scheme for efficient data gathering in varies mode of WSN. In every sensing period, sensor nodes send random readings within sensing period to randomly selected neighbor. The destination node receives compressive sensing measurements which was created by the neighbor nodes.

A three-phase energy-balanced heuristic was introduced by Zahnbing et.al [8] to schedule the packets according the grid cells in order to provide better data availability. Initially, the network region is splitted in to common grid cells in the geographical location. Each cell was assigned to different cluster regions through K dimensional tree algorithm. Based on the destination node movement, clusters are adjusted in the grid cells. Based on data gathering and destination node movement, energy is balanced in all cluster regions.

Dariush Ebrahimi and Chadi [9] introduced the compressive data gathering to recover uncoded transmission from sensor nodes based on coded or compressed measurement, the problem of tree forwarding under physical interference model was studied to collect the sensor data packets. Some of the issues in link scheduling and tree construction were also addressed. The main objective was to gather data at destination with less delay and minimum transmissions. The concept of decentralized method was introduced to solve data gathering problems and link scheduling problems. The link scheduling sub problem mainly depends on interference neighbourhood to limit the interference.

Saud Althunibat et. Al [10] projected a unique information gathering scheme. It simulates a public sale, wherever nodes broadcast their neighbour information consecutively. A node can broadcast its destination in its time interval given that it's beyond all the already-broadcasted results. Otherwise, it'll keep silent. At the particular time, if a selected node has not broadcasted, its result is going to be approximated by generating an even variable below the threshold value. The performance loss was decreased because of the approximation of the results of the non-broadcasting nodes by optimizing the interval of the generated variable.

Songtao Gue et.al [11] have proposed a comprehensive information gathering value reduction framework to outline information gathering value with relevancy the number of information a device uploads to anchor points. To minimize the entire information gathering value with MIMO transmission using the constraints of flow conservation, energy consumption, elastic link capability and compatibility. By applying Lagrangian dualization, the information was decomposed into many sub problems. To calculate information rates, link flow and transmission power for every device, the concept of SenCar framework was introduced.

Congwang et.al [12] considered the several important factors like vehicle's energy consumption, capacity limits, energy efficiency and data latency. A low latency mobile data gathering scheme was introduced to collect packets from all nodes and provide theoretical results. A mathematical model was established to calculate the minimum number of charging vehicles needed, nodes' lifetimes and adaptive recharge thresholds.

Chul Ho Lee et.al [13] addressed the design and development of mobile node collectors to achieve successful data gathering in wireless sensor networks. The problem of network graph with random walk model was analysed to address the issue in data gathering at the destination node under Markovian random-walk movement strategies. Each sensor node was assigned with minimum buffer size and low data arrival rate. The optimal movement strategy was also obtained to reduce packet loss rate over all sensor nodes.

In [14], Abdullah et.al proposed the data gathering algorithm to divide the sensor network into four partitions. Centroid node is setup with symmetrical properties. In each partition, data is aggregated from the cluster members with cluster heads with hierarchical properties. Only a prescribed number of sensor nodes are arrived in each partition. Almost equal weight of nodes are identified and data packets are aggregated.

Gaurav and Amrit [15] introduced the energy conservation and data collection in Wireless Sensor Networks. Energy was preserved at every and each level of network. There are several node levels utilized for static node level, the trail choice level, the job-scheduling level, delay mitigation level, bunch level, motion management level and residual energy. These levels are determined for energy conservation purpose only.

Mariam et.al [16] developed an Economical information assortment algorithmic program with ferry node while focusing on roundtrip time of overall consuming energy within the network region. The sensing field is divided into virtual grids with varied sensing time. The selection of cluster heads is predicted in their residual energy with the shortest distance.

Santhi and Ramya [17] proposed the Double Cluster Head Model (DCHM) for secure data collection in WSNs. The fusion of information is integrated to divide the traffic during energy conservation period. It was considered that every cluster has two cluster heads with reliability. A trust table was maintained to find compromised nodes. Common data packets are sent to the base station which satisfying threshold level and it was shared by all the nodes.

Mohammed Eshafri et.al [18] developed a as Load-balancing Cluster Based Protocol (LCP) which contains inter cluster scheme to increase the network lifetime. In each election of cluster head in all clusters, only highest residual energy is mandatory. In re-clustering concept, the overhead is kept small and network operation time was reduced. A predefined time interval of each round, the Cluster head was chosen.

In [19], energy consumption of Hybrid Clustering routing was evaluated with the gradient value k=1. All the nodes are communicated with the destination directly. Based on the considerations of relay node selection and tunable cost function, the data is gathered with minimum energy consumption.

In [20]. it was studied that energy efficient routing with chosen CH based on Dijkstra Alogrithm. A shortest path was discovered between CH and cluster member with minimum cost function and power consumption. Only the distance to BS, the distance to CHs and energy of nodes were considered for the estimation of power consumption.

3. PROPOSED ROUTING PROTOCOL

In the proposed protocol, cluster head initiates the path establishment between source and destination cluster members. It also builds the location table to obtain the exact geographical position of destination node. In first phase, the optimal path is constructed between the nodes to reduce the packet loss during data collection period. The concept of convex hull procedure is established to identify shortest collection path to store the data packets. All the cluster heads are added in optimal path and it will be included to the starting path. Based on shortest path gathering phase, the probability of packet loss is reduced.

3.1 Evaluation of Transmission Information Through Link Availability and Energy

In this phase, MCH and remaining CHs are communicated and exchanged the information about link quality and energy availability through cluster members. The link availability can be easily determined based on energy information. Thus, the CH can easily find the status of energy levels of cluster members and choose the best one to forward the packets. Energy tables and routing information table are updated during data gathering phase. There are two parameters used to obtain transmitted information.

Cluster members combined information (M_{ER}) can be estimated based on Energy (E) and Reliability value (R). It is used to judge whether the cluster member's reliability and energy are enough for it to be an eligible data collector or a forwarding node. The parameter is estimated to identify best data collector and forwarding nodes in cluster region. It is given as below,

$$M_{ER} = \frac{R \times E}{Init(R) \times Init(E)}$$

Where M_{ER} is assigned to all cluster members which consists of reliability value and energy.

The link availability L_{mn} is estimated between two cluster members i.e. m & n. It is expressed as,

$$L_{mn} = \frac{Init(R_{mn}) \cdot Init(E_n)}{R_{mn} \cdot E_n}, \; E_n > \phi_E^{fnode}, R_{mn} > \phi_R^{link}$$

Where R_{mn} represents the reliability of node *n* evaluated by node *m*, E_n is the remaining energy of node *n*, ϕ_E^{fnode} is the minimum remaining energy value of node *n* to transmit the data packets. ϕ_R^{link} is the minimum acceptable value for reliability, which is node *n*'s as evaluated by node *m*. Let's consider there are two hop nodes i.e. *m* and *n*. $L(m,n)$ is the link availability of nodes between *m* and *n*. The whole link availability between node *m* and *n* is denoted as $Link(m,n)$. It is expressed as,

$$Link(m,n) = L(m,n) + \sum_{k=1}^{q} \min\left(L(m,s_k), L(s_k,n)\right).$$

Based on the Link Error Rate (LER), path reliability is estimated. It is required to choose a path which consists of links with to increase the data transfer reliability.

3.2 Path Reselection

When a path is broken, the MCH chooses available and stable paths from the optimal paths and data transmission will be initiated. Path with minimum cost and better stability will be chosen as optimal path. Let us assume that optimal path is U, and it is broken at this moment, so it demands the steps of link establishment and path reselection. MCH will select a route with minimum host and better stability from the back up paths i.e. V, W, and U for next data transmission. The cost of link is expressed as,

$$MC_{LK} = b_1 \cdot \frac{D_{mn}}{C_r} + b_2 . \frac{\max .hop}{h_{\ln}}$$

b_1, b_2, are the positive constants. *Max.hop* is the maximum hop number. h_{ln} is the hop between the link and destination node *n.* C_r is the communication range. D_{mn} is the data transferred from node *m* to *n.*

3.3 Data Gathering Phase

The Main Cluster Head (MCH) creates the path moving table between other cluster heads and cluster members to find their location information. MCH distributes the table to other cluster heads. CH can reunite the location of destination node and data gathering time. This time is calculated as,

$$\tau = \frac{\sqrt{(MCH - H_1)^2 +)(MCH - H_2)}^2}{D_s}$$

Where H_1, H_2 are the cluster heads and D_s is the speed of the destination node. There are some of the assumptions made here.

i. In the communication range of mobile destination node, some of the nodes may present in the range. It is possible to gather the data between them.

ii. When the mobile node and cluster head are within the range of communication, packet errors may not be occurred.

If the optimal path is established, mobile destination node starts collecting the data in route maintenance phase. When MCH is located inside the transmission range, the destination node collects the data from its cluster head. The transmission cycle of the identified node will initiate to data collection in the cluster head during the occurrence of query event. If the cache memory is low in the CH, it will lead to more packet loss.

To avoid this issue, the proposed scheme uses the packet transmission policy. In this policy, CH sets threshold value. Due the query event process, the cluster members send the sensing data values to CH. If the amount of stored data goes beyond threshold value, the flood event query will occur. In this case, the stored data in CH is transmitted to destination node.

During flood event there are three metrics used to improve the data availability and to minimize the packet loss. The metrics are data gathering ratio, residual time period and packet loss rate. Data gathering ratio means that data collected in the header field of MCH for a particular time period. Residual time period is the time to reach the MCH header from the position of current mobile destination node. It is also calculated as Common Time Period (CTP) and Present Time Period (PTP). CTP is the total time to pass through all cluster headers by the destination node in mobile environment. PTP is the current time where the data is being collected by the destination node in the present round. Packet loss rate is also measured in terms of packets lost to the total packets received. Data gathering ratio, Residual time period and packet loss rate occurs during overflow event period.

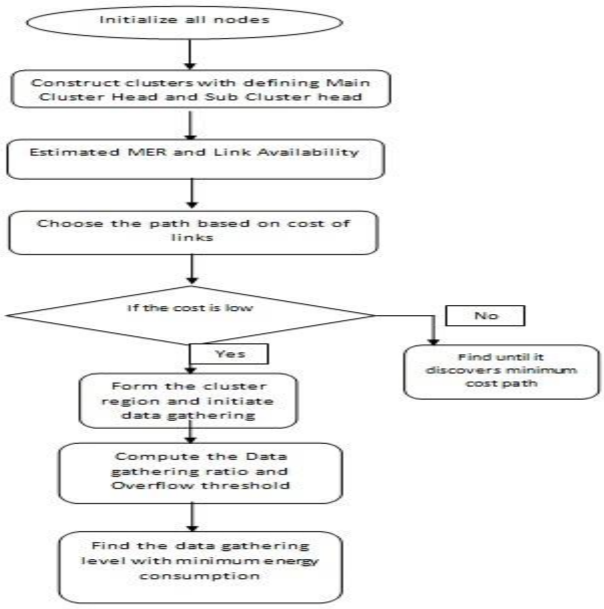

Fig. 1: Flow of Proposed Data Gathering Approach

The Data Gathering Ratio (DGR) is calculated as,

$$DGR = \frac{Gathereddata(D(\tau_2) - D(\tau_1))}{Timeperiod(\tau_2 - \tau_1)}$$

Where τ_1, τ_2 is time delay during data collection.

The Residual Time Period (RTP) is estimated as,

$$RTP = CTP - PTP$$

The Packet Loss Rate (PLR) is defined as the ratio of number of packets loss during data gathering period to total number of packets sent successfully. The overflow threshold is obtained as,

$$(DGR \times RTP) - PLR > \frac{Threshold}{2}$$

R If the above condition is satisfied, data gathering rate from the cluster members is very fast. It also means that destination node is far from MCH. So, the probability of overflow event query occurrence is more until the destination node accesses MCH. All the stored data will be sent to the dynamic path of destination node. Once MCH sends all the data, its memory will be empty. Therefore, the proposed protocol updates the moving path of destination node. During packet overflow event, the MCH transmits only partial data. It will lead to minimum energy consumption and less packet loss. The destination node will not navigate the partial transmission unlike entire data transmission. In Figure 1, the flow of proposed data gathering approach is illustrated. Initially, paths are computed with stability. Link availability and data gathering rate plays major impact in the proposed routing.

3.4 Proposed Packet Format

Cluster head ID	Cluster member ID	GR	RTP	MC	RC

2 2 4 4 4 2

Fig. 2: Proposed Packet Format

In Figure. 2 the proposed packet format is shown. Here the cluster head and cluster member ID carries 2 bytes. Third one is data gathering ratio for entire network. It means the information about reliability and energy which is stored in routing table of MCH. RTP is the fourth field to initiate residual period to MCH. MC is the minimum cost in fifth field, used to indicate minimum energy consumption of optimal path. The last filed CRC i.e. Cyclic Redundancy Check which is used for error correction and detection.

4. PERFORMANCE EVALUATION

4.1 Simulation Model and Parameters

The planned routing scheme is simulated with Network machine tool (NS 2.34). In our simulation, one hundred and one mobile nodes move during a 1500-meter x 1500-meter sq. region for one hundred seconds simulation time. We have a tendency to assume every node moves severally with identical average speed. All nodes have identical transmission vary of 200 meters. The simulated traffic is Constant Bit Rate (CBR).

Our simulation settings and parameters are summarized in Table 1.

Table 1: Simulation Parameter

No. of Nodes	100
Area Size	1500 X 1500 sq.
Mac	802.15.4
Radio Range	250 m
Simulation Time	100 secs
Traffic Source	CBR
Packet Size	80 bytes
Mobility Model	Random Walk
Protocol	LEACH

4.2 Performance Metrics

The evaluate mainly the performance according to the following metrics.

End to end delay: The end to end delay is averaged over all surviving data packets from the sources to the destinations.

Packet delivery ratio: It is defined as the ratio of packets sent to the packet received.

Data Gathering ratio: It means the ratio of gathered data packets to total available packets.

Throughput: It is the number of packets received successfully at the destination with some loss of packets.

Control overhead: It defines the number of excessive control packets to the total normalized packets.

The simulation results are presented in the next part. We compare our proposed approach REEDGA with NSTCDG [7], ADGS [10] and MDF [12] in presence of data gathering environment.

4.3 Results

Figure. 3 shows the results of packet delivery ratio while mobility. Clearly our approach REEDGA achieves more packet delivery ratio (22-95%) than previous schemes. Packet is delivered via reliable nodes through stable link. Successfully all the packets are delivered to the destination.

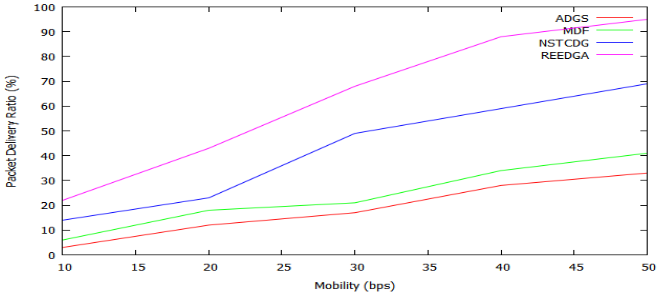

Fig 3 : Speed Vs Packet Delivery Ratio

Figure. 4 shows the results of End to end delay Vs Speed. From the results, we can see that proposed approach has less delay (7.9-21.8 secs) than previous schemes i.e. ADGS, MDF & NSTCDG. Average delay should be kept minimum in order to satisfy QoS. The proposed system reduces delay by means of Stable routing.

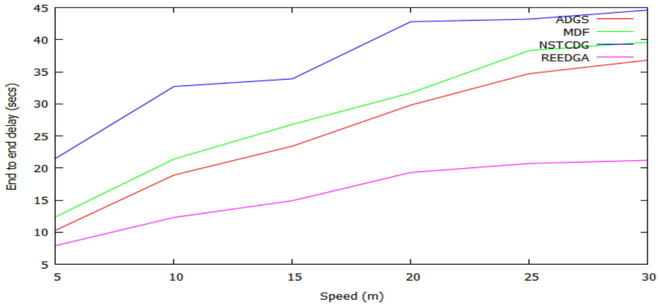

Fig. 4 : End to End Delay Vs Speed

Figure. 5 shows the results of throughput Vs no. of links. From the results, we can see that proposed approach achieved high throughput (32-91) than previous schemes. The proposed system increases throughput by adding data gathering information.

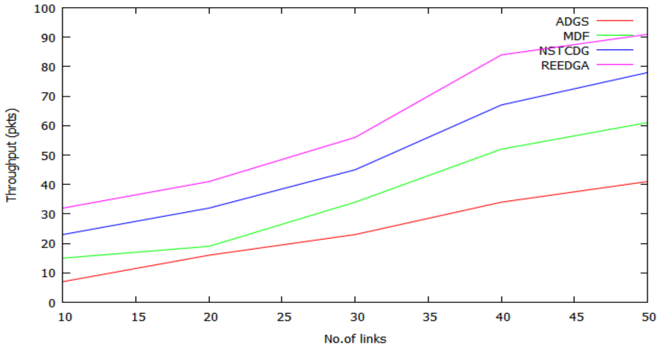

Fig. 5 : Throughput Vs No. of Links

Figure. 6 shows the results of link availability while establishing the number of links. From the results, we can see that proposed approach attains (16-94) links of link availability. The proposed system increases link availability based on minimum link cost.

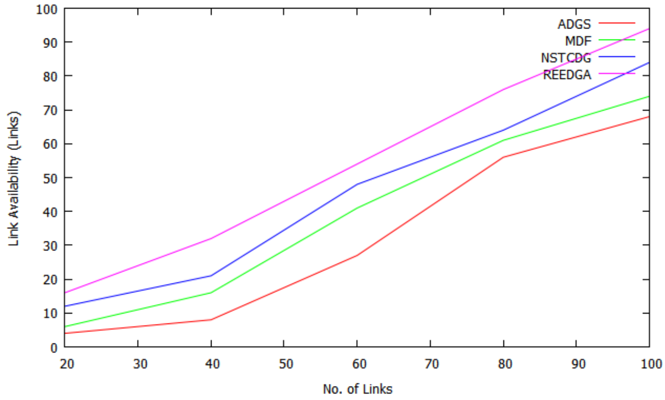

Fig. 6: Link Availability Vs No. of Links

Figure. 7 shows the results of data gathering ratio while increasing the number of nodes. From the results, we can see that proposed approach attains (92-59) % of data gathering level. The proposed system increases data gathering ratio with the help of packet reselection phase.

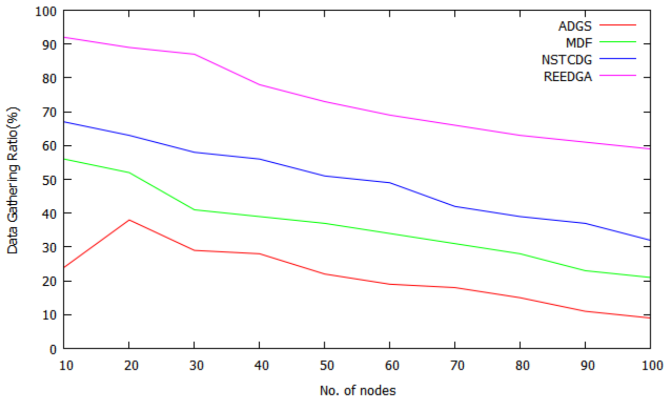

Fig. 7 : Data Gathering Ratio Vs No. of Nodes

Figure. 8 shows the results of Control overhead Vs No. of nodes. From the results, we can see that proposed approach achieved less overhead (6.9-11.3) packets than previous schemes. The proposed system increases network packets integrity based on network model.

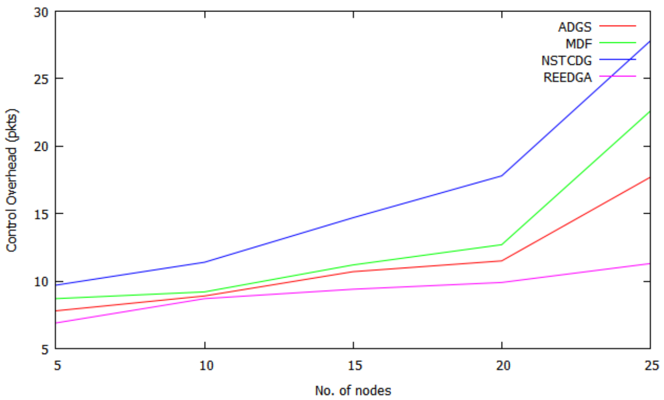

Fig. 8 : Control Overhead Vs No. of Nodes

5. CONCLUSION

In WSN, data gathering plays a major role which influences the power among the sensor nodes. In our approach, we established the path selection procedure to achieve more data gathering rate. Paths are chosen based on link availability y in cluster region. Only optimal path is chosen with more stability and minimum link cost. Cluster consists of

Main Cluster Head (MCH) and Sub Cluster Head (SCH). The information transmission is estimated and stored in MCH. In data gathering phase, packets are arrived with more DGR.

The overflow threshold value is obtained to avoid packet looping. Based on the extensive simulation results, the proposed approach REEDGA achieves more data gathering rate than existing schemes. In future, it is planned to proposed security-based data gathering with symmetric cryptographic scheme to achieve integrity and data confidentiality.

REFERENCES

1. Mt. Ceriotti, L. Mottola, G. P. Picco, A. L. Murphy, S. Guna, M. Corra, ` M. Pozzi, D. Zonta, and P. Zanon, 2009. Monitoring Heritage Buildings with Wireless Sensor Networks: The Torre Aquila Deployment, In ACM/IEEE IPSN.
2. C. Gui and P. Mohapatra, 2004. Power Conservation and Quality of Surveillance in Target Tracking Sensor Networks, In ACM MobiCom.
3. C. Intanagonwiwat, R. Govindan, and D. Estrin, 2000. Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks, In ACM MobiCom.
4. Jawaad Ullah Khan and Ho-Shin Cho, 2015. A Distributed Data-Gathering Protocol using AUV in Underwater Sensor Networks, Sensors, Vol.15, 19331-19350.
5. Dheeraj D. Umardand and Chirchi V. R, 2016. Mobile Sink-based Self Adaptive and Energy Efficient Proactive Data Collection Protocol for Wireless Sensor Network, International Journal of Computer Applications, Vol.144, No.7, 17-24.
6. P. Anuja and Dr.S. Raju, 2016. Energy Efficient, Lifetime Improving and Secure Periodic Data Collection Protocol for Wireless Sensor Networks, International Journal on Computational Science & Applications (IJCSA), Vol.6, No. 3, 1-11.
7. Lei Quan, Song Xiao, Member, IEEE, Xiao Xue, and Cunbo Lu, 2016. Neighbor-Aided Spatial-Temporal Compressive Data Gathering in Wireless Sensor Networks, IEEE Communications Letters, Vol. 20, No. 3, 578-581.
8. ZhangBing Zhou, Member, IEEE, Chu Du, Lei Shu, Member, IEEE, Gerhard Hancke, Senior Member, IEEE, Jianwei Niu, Senior Member, IEEE, and Huansheng Ning, 2016. An Energy-Balanced Heuristic for Mobile Sink Scheduling in Hybrid WSNs, IEEE Transactions on Industrial Informatics, Vol.12, No.1, 28-40.
9. Dariush Ebrahimi and Chadi, 2016. On the Interaction between Scheduling and Compressive Data Gathering in Wireless Sensor Networks, IEEE Transactions on Wireless Communications, Vol. 15, No. 4, 2845-2858.
10. Saud Althunibat, Amir Abu-Al-Aish, Wael F. Abu Shehab, and Wael H. Alsawalmeh, 2016. Auction-based Data Gathering Scheme for Wireless Sensor Networks, IEEE Communications Letters, Vol. 20, No. 6, 1223-1226.
11. Songtao Guo, Member, IEEE, Yuanyuan Yang, Fellow, IEEE, and Cong Wang, 2016. DaGCM: A Concurrent Data Uploading Framework for Mobile Data Gathering in Wireless Sensor Networks, IEEE Transactions on Mobile Computing, Vol. 15, No. 3, 610-626.
12. CongWang, Ji Li, Fan Ye, and Yuanyuan Yang, Fellow, IEEE, 2016. A Mobile Data Gathering Framework for Wireless Rechargeable Sensor Networks with Vehicle Movement Costs and Capacity Constraints, IEEE Transactions on Computers, Vol. 65, No. 8, 2411-2427.
13. Chul-Ho Lee, Jaewook Kwak, and Do Young Eun, 2016. Towards Distributed Optimal Movement Strategy for Data Gathering in Wireless Sensor Networks, IEEE Transactions on Parallel and Distributed Systems, Vol. 27, No. 2, 574-584.
14. Abdullah I. Alhasanat, Ahmad Ali Alhasanat2, Khitam M. Alatoun3, Aws AlQaisi, 2015. Data Gathering in Wireless Sensor Networks Using Intermediate Nodes, International Journal of Computer Networks & Communications (IJCNC), Vol.7, No.1, 113-124.
15. Gaurav Kumar Pandey and Amrit Pal Singh, 2015. Energy Conservation and Efficient Data Collection in WSN-ME: A Survey, Indian Journal of Science and Technology, Vol. 8, No. 17, 1-11.
16. Mariam Alnuaimi, Khaled Shuaib, Klaithem Alnuaimi and Mohammed Abdel-Hafez, 2015. Data Gathering in Delay Tolerant Wireless Sensor Networks Using a Ferry, Sensors, Vol.15, 25809-25830.
17. S.G. Santhi and R. Ramya, 2015. Clustering based Data Collection using Data Fusion in Wireless Sensor Networks, International Journal of Computer Applications, Vol.116, No.9, 21-26.
18. Mohamed Eshaftri, Ahmed Y. Al-Dubai, Imed Romdhani, Muneer Beni Yassien, 2015. A New Energy Efficient Cluster based Protocol for Wireless Sensor Networks, IEEE Proceedings of the Federated Conference on Computer Science and Information Systems, 1209–1214.
19. Zhezhuang Xu, Liquan Chen, Ting Liu, Lianyang Cao and Cailian Chen, 2015. Balancing Energy Consumption with Hybrid Clustering and Routing Strategy in Wireless Sensor Networks, Sensors, 26583-26605.
20. Tran Cong Hung and Phan Thi The, 2015. A Proposal to Reduce Energy Consumption for Wireless Sensor Network, Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT), Vol. 5, No. 7, 1-4.