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Fuzzy based data gathering scheme for secure routing in Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSN) consist of sensor node under the control of base station. Data gathering plays a major role in WSN whereas network lifetime depends on data collection. In dynamic nature, the nodes are get depleted and it leads to low energy because of data lost. To ensure more data collection rate, there is a need of effective data collection protocol with stable routing. In this research work, we develop Fuzzy based Data Gathering Scheme (FDGS) to increase the data collection rate irrespective of dynamic environment. It consists of three different phases. Stable multicast routing is deployed in the first phase to avoid unstable link failures. In second phase, cluster head among cluster members is chosen based on fuzzy decision mechanism. In third phase, data gathering scheme is deployed to increase the availability of data whenever the node requires. Based on the simulation analysis, the proposed method helps us to achieve a better performance than previous work in terms of packet delivery ratio, data gathering rate, packet loss rate, propagation delay, end to end delay, energy efficiency and communication overhead.

Keywords: WSN, FDGS, network lifetime, data gathering, delay, residual energy and throughput.

1. INTRODUCTION

1.1. Wireless Sensor Networks (WSNs)

Wireless sensor network (WSN) is a set of sensor nodes (SNs) operating in uncontrolled areas and structured into supportive network. It consists of huge number of sensor nodes that monitors the environment by means of collecting, processing and transmitting the collected information to the remote sink node either through direct or multi hop transmission mode. Recently, WSNs have attracted lots of attention due to their extensive applications such as wildlife monitoring, battlefield surveillance, inventory, smart home and healthcare etc. In the previous works that use the explicit communication. In the previous works [17,18] the explicit communication approach, fuzzy based optimized routing was used for data gathering based on compression, a communication channel is abstracted as a point-to-point link, which ignores the fact that wireless channels transmit information by broadcasting it, which makes it available to any receiver of the right type. In wireless networks, when one node transmits data to its destination node, other nodes within the communication range of the node which receives the data and may use it to compress their own information. Herein, we propose a framework for data gathering that exploits the broadcasting characteristic of the wireless medium, thereby achieving greater energy efficiency.

1.2. Data Gathering issues in WSN [5]

1) In order to deliver packets from sensor node to the base station an active node will be the neighbor node. The delay is incurred as the packets from sensor node are collected by the collector node and sends it to base station

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2) Energy consumption is a major issue in WSN. The usage of energy plays major role in WSN and it should be utilized effectively.

3) Balancing the data gathering and energy is a major task in WSN. Multiple sensor nodes take more data and it can reduce energy.

1.3. Challenges of Data Gathering in WSN

1) Establishment of routes based on network topology between sensor node and base station.

2) Without choosing alternative path, the same path can be utilized to pass the data to base station to save the energy.

3) The data packets to base station are delivered by various sensor nodes frequently that result in more data loss, high energy consumption and more delay.

2. PREVIOUS WORK

Kazuhiko Kinoshita et al. [1] discussed that precise and adaptive energy evaluation method. Optimization of data gathering proposal for the environmental energy-based sensor network is done which in turn extend the lifetime of energy-based sensor networks. Sudhakar and Sangeetha [2] initiated the Delay bounded Sink Mobility (DeSM) difficulty through allotment of sensor node to sinks. A polynomial-time best possible algorithm was used for the source problem. Extended Sink Scheduling Data Routing (E-SSDR) algorithm was also applied for assigning schedule to destination node. Roseline & Srinivas [3] have proposed secure energy efficient location aware data gathering approach. The properties of node location and energy were hardened to improve the span of the node and network. Elliptic Curve Diffie Hellman Key Exchange was incorporated for secure data gathering between source and receiver. The routing was performed based on the neighbor node and highest energy node selection. Mehala & Balamurugan [4] presented Clustering-based Data aggregation algorithm by means of two mobile sinks, in order to improve the network span and to decrease the transmission distance between each nodes. Using this process the data from the sensors are collected efficiently which lowers data latency. Shanmugam et al. [5] introduced an energy efficient mobile element based data gathering using tinybee. It improved energy efficiency in data gathering. Mobile element dispatched the tinybees by reducing the trip length. Anagha & Binu [6] have chosen the rendezvous points(RPs) from the sensor network according to the weight and other nodes will send their data to this rendezvous nodes in an energy efficient way Whenever an event was detected by the mobile sink it need not visit every nodes to collect information. Mingming Lu & Jie Wu [7] modelled the data-gathering problem as a major problem. NP-hardness was proposed for both the broadcast tree and the multicast tree problems in reverse. Simulation was used to study the effects of different parameters and to compare the performance of various approaches. Shilpy Ghai et al. [8] introduced an energy-efficient security protocols to provide strong security and to decrease energy consumption. The data was compressed and then transmit it to the other node. With the help of compression, the energy consumption of the nodes was decreased because fewer amounts of data were spent. Borrong Chen et al. [9] have presented the Adaptive Demand-driven Multicast Routing (ADMR) protocol which is based on CC2420-based motes using the TinyOS operating system. It was preferred as it supports multicast communication, a critical requirement for many persistent and mobile applications. Priyadharshini et al. [10] observed that manifold channel method was useful in dropping schedule span. The link-dependent channel transfer schemes were more energy efficient which removes intrusion. The primary restrictions due to interference explored techniques which overcame the same issues. Palekar [11] demonstrated a tree based multicast steering convention, MAODV (Multicast Ad hoc On-interest Vector) in lightweight specially appointed systems. The effect of system load on MAODV convention and proposed Multicast Ad hoc On-interest Vector with Backup Branches to enhance the strength of the MAODV convention by joining focal points of the tree structure and the lattice structure. The shorter tree limbs can be enhanced as well as build a multicast tree with reinforcement branches. Liu & Wu [12] have proposed neighbor monitor application that provides the trust executive system. In this system, the expectation value was calculated by the neighbor monitoring mechanism, and the direct assessment and the indirect assessment were combined to set up the distributed model to find the malicious nodes. This reliable check algorithm was competent of shielding against the attacks on the trust system. Thenral and Sikamani [13] introduced Angle based Multicast Routing Algorithm (AMRA) for reducing communication overhead and to increase the performance in the wireless mesh networks. Every intermediate node towards the destination was chosen based on the angle towards the forwarding nodes. The next intermediate node was selected in the forwarding direction, if the angle is within 60° of the current node. This method reduced the number of hops in transmitting data. Distributed source coding (DSC) [14] and virtual multiple-input multiple-output (MIMO) was developed and then proposed a new data transmission scheme called DSC-MIMO. It compressed the source data using distributed source coding before transmitting from the existing communication schemes. Data compression can reduced the length of the data and improve the energy efficiency.

3. IMPLEMENTATION OF PROPOSED PROTOCOL

In our proposed fuzzy based data gathering scheme, multicast routing is implemented in WSNs to increase the data availability ratio and provide data. In first phase, multicast route is established from cluster head (CH) to cluster member or neighbor nodes to provide connectivity. To provide an uninterrupted data communication, stability is integrated in all paths. Cluster heads are also transferring their information via multicast routes. In second phase of this approach, fuzzy mechanism is implemented to provide decision making on packet selection, route selection and data availability between neighbor nodes. In third phase of this work, data gathering scheme is implemented in the cluster regions to increase the availability of packets whenever the node requires.

3.1. Stability based multicast routing

Stability means the node or path can withstand in the presence of dynamic environment, link failures or node failures etc. If the fault tolerant rate of path is high, the stability will also be high. In this proposed multicast routing, stability is integrated in all the paths, once the path is discovered from cluster head to cluster members or another cluster head. Path is discovered based on acknowledgement received from destination node. Initially Cluster Head (CH) floods a Group Join Request (GJR) packet to all cluster members based on the location information. If any node receives GJR packet, it will send Group Joint Acceptance (GJA) to join the group. Cluster head upon receiving GJA, it records the location of cluster members and authenticate them by giving ID. Thus the path is created based on the control packets. Multicast route is formed by this way to increase the performance of the network. Multicast provides less overhead and more delivery rate and it supports the data gathering. Stability is calculated depends on the strength of the signal, path capacity and SNR value. Number of repeated transmissions will be limited once the stability is integrated in all the paths. Signal strength is measured in terms of amount of data can be successfully delivered to the nodes. If the delivery rate is more, then signal strength will be high.

Path Capacity (P_c) is derived as,

$$P_c = \frac{\sum \gamma}{\sum \delta}$$

Where γ is number of packets travelling in the path and δ is total number of packets dropped by the paths. If packet dropping is less, path capacity will be more. Stability will be integrated once the high path capacity is arrived.

Signal to Noise ratio (SNR) is generally measured based on Bit Error Rate (BER). Both are inversely proportional to each other. In this routing scheme, BER is chosen as minimum value. The three parameters are linked together to estimate the stability metric. Once the optimum value of these three parameters estimated, then stability will be integrated in all the paths.

3.2. Fuzzy based Cluster Head Election system

Fuzzy method is an effective approach to classify the complex objective in the decision objective domain and to provide optimal solution in the presence of fuzzy logic. Cluster head is chosen based on the following factors i.e Residual energy, number of cluster member nodes connected and stability of nodes. All these factors are included in simplistic and objective way. The fuzzy mathematics approach is adopted to obtain inclusive assessment and the attribute weights are found through the entropies based on the positive values of the samples. In the cluster region, perfect solution and negative solution are estimated. The distance between perfect solution and attribute samples can be found using weighted Euclidean distance. If any nodes with maximum optimum value, it is chosen as cluster head. The steps for cluster head election using fuzzy method is as follows,

Step 1: $F = \{S_1, S_2 \ldots. S_n\}$ is a separate set of sensor nodes and $W = \{w_1, w_2 \ldots. w_n\}$ is a group of sample attributes for valuation. The viewing matrix V can be calculated as follows,

$$V = \begin{bmatrix} v_{11} & v_{1n} \\ v_{k1} & v_{kn} \end{bmatrix}$$

Where v_{pq} mentions the attribute value of q from node p

Step 2: The computation overhead is reduced based on optimization method. The degree of derivation is given as,

$$_{pq} = \frac{v_{pq} - \breve{v}_q}{\sigma_q}$$

Where $\breve{v}_q$ is mean value of the attributes and σ_q is standard deviation of attributes

Step 3: To select the cluster head, the optimum function can be described as follows,

$$\mu = \arg\min_{p \in F} \sum_{x=1}^{N} J_x f_x(p), \; p = 1, \; 2, \; \ldots. \; l$$

Where J_x is weighting factor and it is always greater than 0.

Step 4: Choose the J_{opt} to select cluster head with more residual energy, more number of nodes connected to it.

3.3. Data gathering Approach

Data gathering is initiated once the reference point between cluster head and cluster member is identified. It means the centrality degree between two nodes should be less than 45 degree. Cluster member initiates this phase to increase the rate of data availability. The steps for data availability is given as,

Step 1: Choose the reference point between cluster head and cluster member below 45 degree. Reference point is selected if any event occurs. i.e. transmission or reception.

Step 2: Cluster member node transmits the Enquiry packet (EP) to reference point once the event occurs. Enquiry packet includes the following fields i.e. cluster member ID, cluster member size, distance travelled and hop count.

Step 3: Reference point broadcasts Enquiry Reply Packet (ERP) with zero hop count to cluster member nodes.

Step 4: Once the ERP received by the cluster member nodes, the hop count will be incremented by 1.

Step 5: If the next hop cluster member node is greater than 1,

Then

Compare packet arrival time and packet propagation delay

Choose the less packet arrival time and propagation delay

Start the data transmission

Endif

Cluster head sends the Stable Path Initiation Request (SPIR) to cluster member. Cluster member replies via Stable Path Join Reply (SPJR) as next hop node. Cluster members moves in the radio range of reference point and it receives gathered packets from the point.

Step 6: If an unknown node enters the cluster region, it sends the request packet to CH. CH authenticates it and sends the approval message. CH also measures whether unknown node is inside the coverage region of reference point or not.

Step 7: CH calculates the data gathering rate (φ) from the cluster members. It is estimated as follows,

$$\varphi = \frac{\sum_{k=0}^{N} f(w_k)}{\sum w}$$

Where $\sum W$ is total number of packets. $f(w_k)$ means number of packets gathered.

Step 8: CH announces data gathering rate to all the cluster member nodes.

3.4. Packet Format of the proposed algorithm

In Figure 1, the packet format of proposed algorithm is shown. Here source and destination id field occupies 4 bytes. The second field is a 2 byte field which gives details on how much data is collected successfully. In next field, hop count fills 1 byte which says the hop count from cluster head. Energy efficiency is a 2 byte field to find how much energy spent for transmission and reception. Load balancing rate occupies 2 byte field where the data is sent through different paths. Error correction and detection is given by Cyclic Redundancy Check (CRC) which occupies 4 byte. The proposed packet format of SDGP is given below;

4. PERFORMANCE ANALYSIS

Our proposed protocol is simulated using Network Simulator (NS2.34). C++ is used as Backend language and Front end language is Tool Command Language (TCL). Our simulation settings and the used parameters are summarized in table 1. Table 2 summarizes the performance metrics comparison of proposed and previous schemes.

We compare our proposed protocol FDGS with SDGP, STCDG [18] and LEACH in the form of clusters

Source Id and Destination ID (2)	Data gathering rate (2)	HopCount (1)	Energy Efficiency (2)	Load balancing rate (2)	C RC (4)

Figure 1: Proposed packet format

Table 1
Simulation Settings and Parameters

No. of Nodes	*120*
Area Size	1200 × 1200 m^2
Mac	802.11
Radio Range	260m
Simulation Time	100 sec
Traffic Source	CBR
Packet Size	512 bytes
Package rate	5 pkt/s
Protocol	LEACH

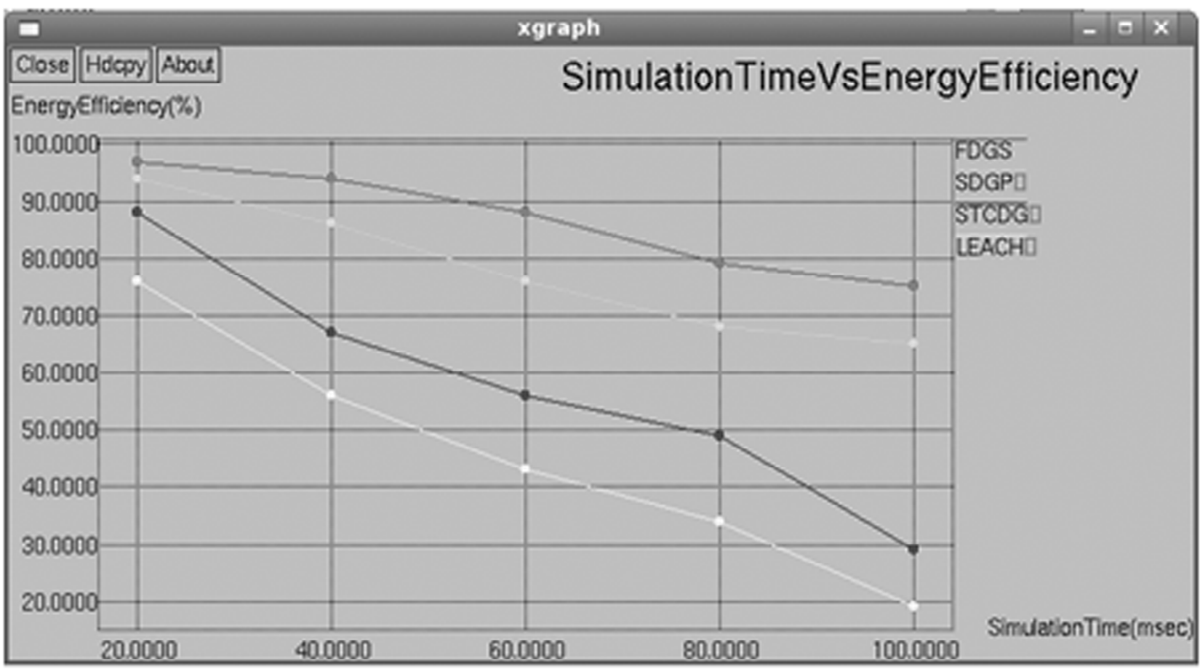

Figure 2: Simulation Time Vs Energy Efficiency

Figure 2 shows the total energy efficiency obtained by varying the simulation time from 20 to 100 msec. From the results, it is proved that FDGS has high energy efficiency when compared to SDGP, LEACH and STCDG scheme. While adopting the data compression, energy level will be saved. At the same time only active sensor node participates in the data transmission.

Figure 3, presents comparison of the network lifetime for FDGS, SDGP, LEACH, STCDG [19]. Network lifetime is improved based on energy balancing of data gathering nodes and link quality. Fuzzy based decision mechanism is deployed to increase the data gathering.

In Figure 4, the comparison of data Gathering rate is shown. The data gathering rate of FDGS is higher than SDGP, LEACH and STCDG. Data gathering is improved based on proper maintenance of cluster region. Cluster members grasp the data and deliver according to fuzzy routing. Figure 5, shows the results of variation in Time as the delay varies. From the results, we can see that FDGS scheme has delay with lesser value than SDGP, STCDG and LEACH due to stable data gathering routes.Figure 6, shows how the communication overhead changes while the mobility is varied from 20 to 100 bps. It is clearly shown that the delay of FDGS is lesser than SDGP, STCDG and LEACH. Due to the implementation of data gathering mechanism, the packet replay is avoided to reduce the packet overhead. Hence the overall network communication overhead will get reduced.

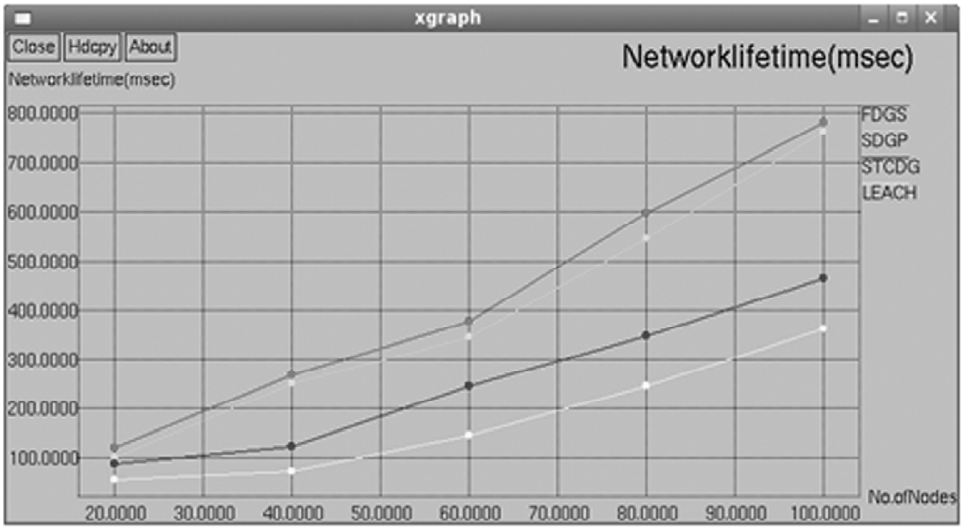

Figure 3: No. of Nodes Vs Network Lifetime

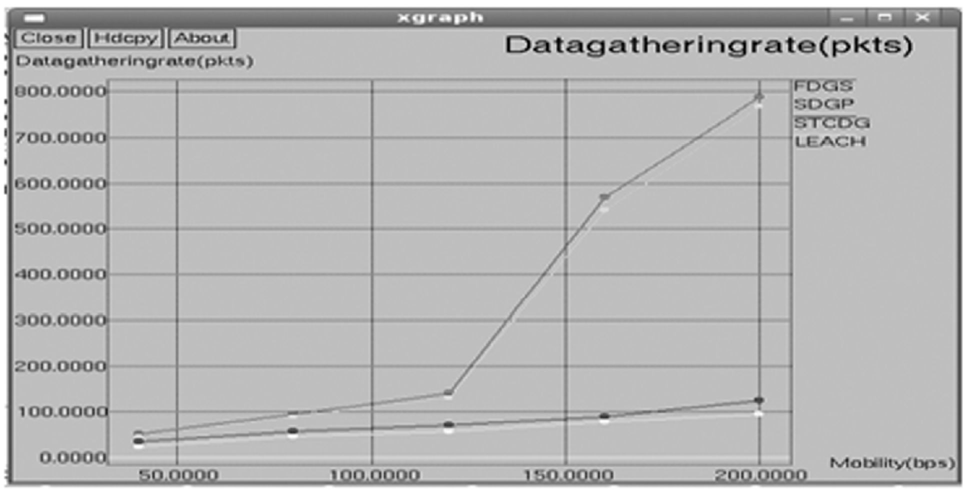

Figure 4: Mobility Vs Data Gathering Rate

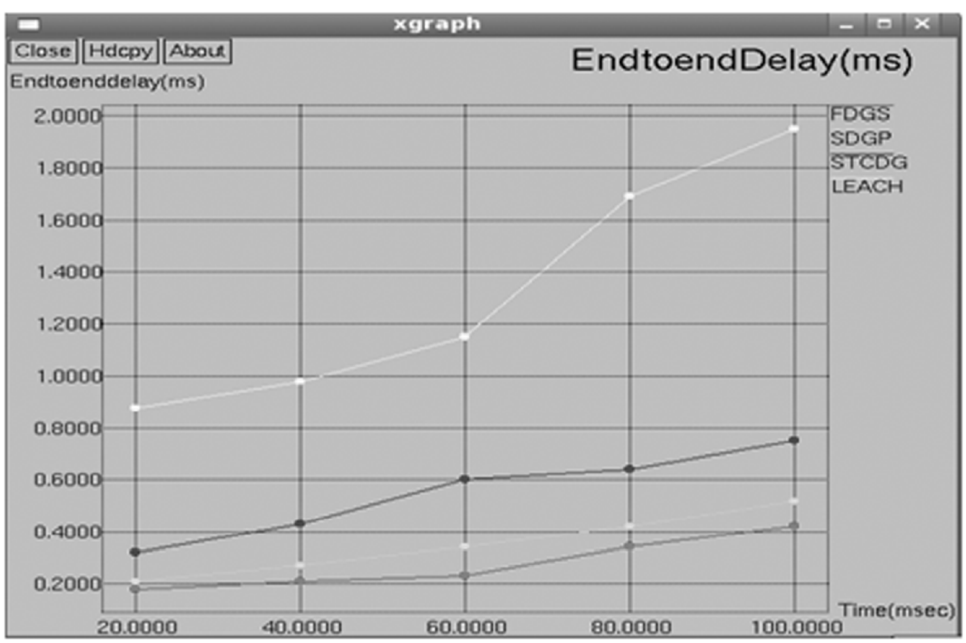

Figure 5: Time Vs End to end delay

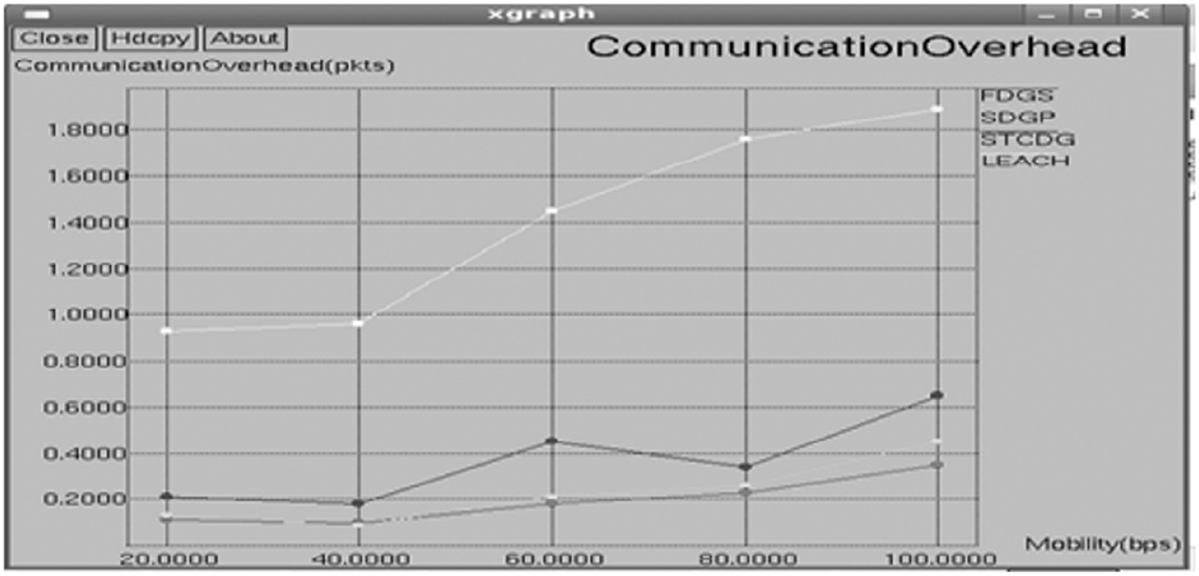

Figure 6: Mobility Vs Communication Overhead

5. CONCLUSION

In WSNs, the stable route can be determined based on link failures between neighbor nodes. To increase the network lifetime, many sensor nodes should be deployed to increase data gathering rate. To perform data gathering, fuzzy decision routing is required to achieve data availability. In this paper, energy model is obtained which provides the sensor nodes with high network life time and throughput by means of balancing the energy consumption and data gathering is achieved through fuzzy based data gathering route. The data gathering estimation is verified for each node. Through simulation results it is shown that FDGS attains very effective data gathering rate, high network lifetime and high energy efficiency while attaining low delay and low overhead than the available schemes LEACH and STCDG and our previous work SDGP while altering the number of nodes, mobility, simulation instant and time.

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