Journal of Scientific & Industrial Research
Vol. 79, May 2020, pp. 391-394

Fuzzy based Secure Data Gathering Approach for Ad hoc Sensor Networks

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Received 22 May 2019; revised 21 December 2019; accepted 17 March 2020

Data gathering is one of the difficult tasks in Ad hoc Sensor networks. Sensor Networks consist of limited power sensor nodes located with high density and deployed for various applications such as military, industry and environmental tracking etc. However energy constraint of sensor nodes is one of the biggest challenges in sensor networks. Balancing of data gathering and energy efficiency is the biggest task in sensor networks. In the proposed system, Fuzzy based Secure Data Gathering Approach (FSDGA) is introduced based on slot based scheduling and asymmetric key crypto scheme. Cluster region is formed and Cluster Head (CH) is chosen through voting system to determine the remaining energy, node flexibility, connectivity ratio and node stability. The routes are found with authentication metric based on key identifiers to reduce the vulnerability of attackers. Mamdani Fuzzy decision scheme is introduced with data gathering algorithm to improve the data availability ratio.

Keywords: Cluster region, Data gathering, Connectivity ratio, Fuzzy decision mechanism, Authentication metric, Node stability

Introduction

Wireless sensor networks (WSNs)

Wireless sensor networks consist of nodes which contains monitoring unit, data processing unit and power unit. During the maintenance of multipath routing, the gathered information is propagated to reach the sink node. During the energy saving period, the used sensor nodes may not be adaptable to increase the network lifetime. The energy consumption is mostly spent on data delivery, tracking and data processing. The energy budget is mostly dominated by the data delivery process. Accordingly the high residual energy and data gathering approach is the major key to improve the network lifetime. There are two categories of data gathering approaches for sensor networks i.e. Data gathering approaches through mobile destination and static destination based data gathering approaches. Designing of path towards destination and node speed are the major obstacles due to more delay in mobile destination based data gathering approach. These problems are avoided by the static destination based data gathering approaches. Fuzzy aware reliable routing methods[1–5] was introduced based on decision model to choose cluster head and to achieve maximum data gathering using compressed method. Energy efficient models based on data gathering scheme were developed to reduce packet loss and improve energy efficiency of network through the implementation of data gathering schemes.[6–11] Network lifetime of sensor network is improved through multi-clustered energy efficient routing method[12,13] in the presence of base station.

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Materials and Methods

In the proposed scheme, Data gathering is accomplished through the time slot based scheduling. To achieve maximum data gathering, cluster creation is required to improve data availability and reduce overhead. There are two kinds of Cluster Head in the proposed cluster formation i.e. stable and dynamic. Stable CH is used to track the routing behavior of routes and history of packet forwarding in the particular routes. Dynamic CH is used to gather the issues in the routing and node behavior and rectify the issues as soon as possible. The time slots are assigned to each packet by the Stable CH to increase the data gathering. Here the network topology is derived in the graph G (M,E) where M is the set of sensor nodes and E indicates the edge that connects sensor nodes. Each sensor node m defines a location w.r.t coordinates p,q. The network cost is determined according to the number of packets sent to source node. This cost is estimated based on total hop count, transmission and reception energy. The node lifetime is measured as the energy drain ratio for packet transmission.

Initially, the top performing cluster member node is selected from the high residual energy and stability of a node. The energy and data gathering rate of a network is balanced according to the density of network and packet loss rate. If both are low, both energy and data gathering can be balanced well at any cost. The data transmission is initiated to protect the data from the attackers and to increase the gathered data. The concept of distributed approach is followed in the proposed approach and Low Energy Adaptive Cluster Hierarchy (LEACH) protocol is used as basic sensor routing protocol. Following three phases are involved to provide secure data gathering.

1. Formation of cluster zone
2. Establishment of Secure Path Creation
3. Fuzzy based data gathering model

Formation of cluster zone

In this phase, sensor nodes are grouped to form a cluster region with high density. All cluster members are joined together to choose a CH through voting system. This system contains some basic election metrics such as node stability, node residual energy, node flexibility and connectivity of a node. Random routes are discovered before the election of CH. Cluster members forward data packets randomly and check the status of performance metrics. The four best nodes are chosen based on the metrics and voting system will be adopted. This system ensures to elect two best CH out of four nodes. If the primary node contains high residual energy, more connectivity and more stability, it will be chosen as Static CH. The secondary one is elected as secondary CH. The path status and packet forwarding is monitored by Stable CH. Dynamic CH is the responsible for tracking the issues in data gathering. Stable CH propagates data packets to sink node via multi-hop routes. The packet contains sink id, hop count, data gathering rate and location of neighbor cluster members. All eligible cluster members send C join request packets to stable CH to reduce the collision. The collision between the request packets is reduced by collision avoidance mechanism. Data is gathered through stable roués between CH and cluster members to reduce more energy consumption.

Establishment of secure path creation

In this step, stable CH forwards the information about secure routes to all cluster members. The route information is recorded in the routing table of stable CH. Dynamic CH tracks the data availability in the cluster member and stable CH. If the availability of data is getting low, the stable CH will be informed immediately by the dynamic CH. Both CH exchanges the data packets through multiple routes in a short span of time. The location and density of Cluster members are fixed by the stable CH to improve data gathering. The secure path is obtained through three cluster regions in the proposed approach. In each group, stable CH is responsible for administration, operation and maintenance of secure routes. Static CH of first cluster group sends the REL_PATH KEY to remaining two groups. Each group receives the key of the particular route and checks the authentication by decrypting the DREL_KEY. There are two reliability keys followed i.e direct key and indirect key. Direct key is common to all group and indirect key is intended to the particular group and it is totally hidden. The confidentiality rate is estimated based on route behavior, packet loss and attacker impact ratio. If any route having high rate, it will be chosen as primary secure path and it will be immediately reported to Static CH of first group. Remaining two group Static CHs follow the rule of first one. If route contains less confidentiality rate, scam reports are generated and reported to first static CH and it will try to use the alternative routes.

Fuzzy based data gathering Model

Once the formation of cluster region and secure route establishment is done, Static CH initiates the data gathering based on time slot based slot scheduling. Contention free slots are used to gather more data. The collisions are avoided by adopting code division with time slot scheduling. Static CH assigns time slot for each data during packet forwarding between cluster members. The data communication cost is reduced by the destination CH. Time slots are used to prevent data loss and to reduce delay during packet transmission. This indicates the completion of first round in data gathering phase. Dynamic CH monitors the issues in data gathering and allocates least hop highly qualified path to reach the packets at the destination. The retransmission of data packets is reduced to increase data gathering ratio by dynamic CH. It will be checked from the sequence number of data packets by CH. CH discovers data gathering by initiating DG_Req packets to cluster members. The cluster members are instructed to gather less data packets and gather more information from the packets. CH uses Slot based Code Division Multiple Access (SCDMA) to schedule the packets from CH to CM. Link quality is identified during packet transmission. If any link drops more packets unnecessarily, it will be isolated from the network based on the recommendation of CH. CH sends data packets to CM through stable routes. The data is aggregated through several cluster heads located in various regions. Authentication of data is done by the source CH. Destination CH accumulates the data from the neighbour cluster and removes redundant transmission of data packets. CH assigns code to cluster members during packet transmission. Once all the information packets are successfully received by CH, the link cost and data communication cost are estimated and reduced by allocating code to each message. Each node uses the code to send the information. Only minimum hop distance paths are used for transmission of packets between CH and CM. The stability index plays a major role to improve the data availability. SI reduces overhead and to locate more information in packets. The packets are segmented into frames and then session between CH and cluster members. The routes are optimized to perform data aggregation to improve energy efficiency. In such cases, the formation of spanning tree is the best approach to provide high data availability rate. In the proposed approach, multi-hop routes are formalized to improve data gathering ratio.

Mamdani Fuzzy model is adopted to choose high data gathering node among several cluster members and this node can be recommended to act as static CH. Fuzzy Inference engine is used for providing high gain and maximum network performance. The following blocks are used to define the function of fuzzy model.

Fuzzifier: In this first step, metrics are converted into crisp values using fuzzifier and each value is assigned with membership degree. The crisp inputs are node stability rate, data gathering ratio and authenticated route metric. The intercession and connection points of crisp membership function are estimated from the fuzzifier.

Mamdani IF THEN rule: In this step, fuzzy IF THEN rules are used to identify the high data gathering node. The crisp membership functions are applied to IF THEN rule based to produce the best output to improve the network performance.

Fuzzy Inference Engine: The inference engine is operated using Fuzzy IF THEN rule to find the final conclusion based on the crisp membership functions. This conclusion will be a input to Defuzzifier.

Defuzzifier: In this step, the mapping of fuzzy set and output value is done to determine maximum data gathering. The threshold value is estimated using defuzzifier. The received output is converted into crisp value i.e. data gathering rate which can either set as 1 or 0.

Results and Discussion

Network simulator (NS 2.34) is used as the simulation tool for analyzing the performance of proposed approach. In this simulation, 400 nodes are grouped to form 3 cluster regions in the coverage area of 1200 x 1200 sq. m. The transmission range between static and dynamic CH is 300 m. Table 1 illustrates the simulation settings and parameters used for proposed approach. The proposed work FSDGA is compared with existing schemes DGSJRCS[6] and TCBDGA.[9]

Network Parameters

Propagation delay: The delay between the packets during packet flow between source and sink node.

Data Gathering Ratio: It is the ratio of data gathered from all cluster regions to data distributed to all cluster regions consuming less energy.

***Control overhead*:** It is the ratio of excessive control packets in the route to the normalized packets.

The performance of data gathering rate for proposed approach is shown in Fig. 1. Due to the implementation of secure route establishment and data gathering approach, the data gathering ratio of proposed scheme FSDGA produces better result than previous schemes while varying the mobility in x axis.

The performance of propagation delay is illustrated in Fig. 2. In x axis, number of nodes is varied from 100 to 400. Cluster creation and maintenance of secure routes are deployed to reduce the propagation

Table 1 — Simulation and Settings parameters

No. of Nodes	400
Area Size	1200 X 1200 sq.m
Mac	802.15.4
Radio Range	300 m
Simulation Time	100 sec
Traffic Source	CBR
Packet Size	80 bytes
Package rate	5 pkt/s
Protocol	LEACH
Mobility model	Random Walk

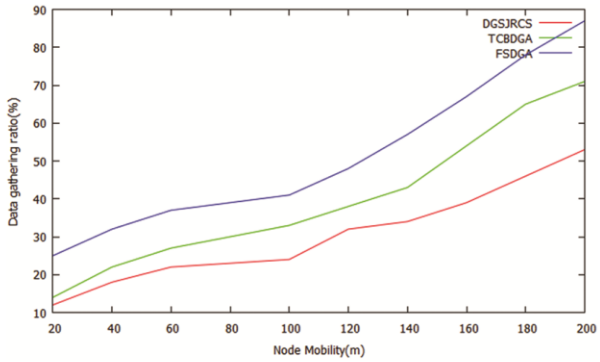

Fig.1 — Data gathering ratio Vs Node mobility

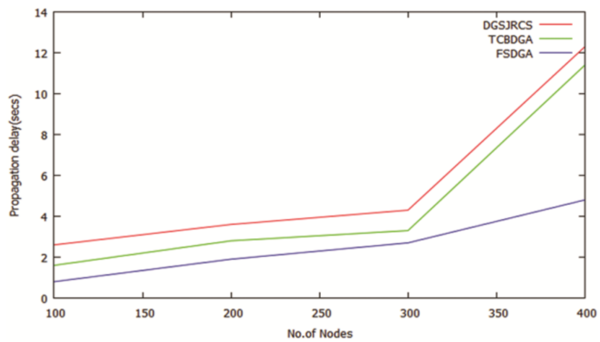

Fig.2 — Propagation delay Vs No. of Nodes

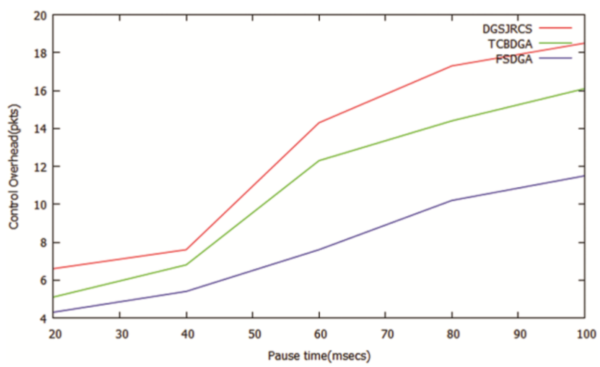

Fig. 3 — Control Overhead Vs Pause time

delay in the proposed approach. FDGA produces less delay while compared to existing schemes.

The performance of control overhead while varying the simulation time from 0 to 100 m secs is shown in Fig. 3. The overhead is reduced in the proposed approach based on slot based time scheduling scheme. Due to the establishment of secure path between CH and cluster members, FSDGA consumes less overhead to improve the performance of routing.

Conclusions

In WSNs, achieving maximum data gathering is one of the biggest tasks in the presence of attackers. During data gathering phase, it is difficult to balance energy and security. If the routes are not optimized, it may lead to high delay, more packet loss and least data availability. In this scenario, scheduling is required to improve the data gathering in an efficient manner. In this research work, both energy and security is balanced while providing maximum data gathering ratio. Secure routes are established in the cluster region to identify the high data gathering node through fuzzy decision model. The results are evaluated using network simulation tool. From the graphical analysis, it is seen that proposed approach provides maximum data gathering rate, less delay and low control overhead. In future, it is planned to implement data gathering in IoT based ad hoc sensor network.

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