International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064

An Efficient Routing Approach for In-Network Aggregation in Wireless Sensor Networks

D. N. Rewadkar[1], Priti Madhukar Mithari[2]

[1]University of Pune, RMD Sinhgad School of Engineering, Pune, India

[2]University of Pune, Department of Computer Engineering, RMD Sinhgad School of Engineering, Pune, India

Abstract: ***A wireless sensor network (WSNs) consists of many sensor nodes and these networks are deployed in different classes of applications for accurate monitoring. Wireless sensor nodes are limited energy supply has constrained the lifetime of a sensor network. Nodes in wireless sensor network are densely located and there is duplication of sensed data. This happens because of multiple nodes sensing same event. Such data duplication is responsible for wastage of node energy. Since energy conservation is one of the key issue in WSNs. So, data fusion and data aggregation should be used in order to save energy. Data aggregation is effective method to eliminate redundancy and to minimize the number of transmission. In this paper we present an efficient data aggregation strategy based on tree & cluster formation which eliminates such data duplication and improves node energy efficiency provides the best aggregation quality when compared to other existing systems.***

Keywords: Data aggregation, Information fusion, In-Network Aggregation, Routing Protocol

1. Introduction

Wireless sensor network (WSN) is of a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment. WSNs are used to sense environmental or physical conditions like temperature, sound, pollution levels, humidity, pressure, etc.[1], [2]. WSNs have been used in different applications such as environmental or physical monitoring, land security, critical organization systems, manufacturing systems, and communication systems, etc. WSNs are data-driven networks that usually produce a large amount of information that needs to be routed across the networks. This information is routed in multihop fashion toward a sink node, which works as a gateway to monitoring center as shown in Figure 1. In this fig, routing is important task in the data gathering process.

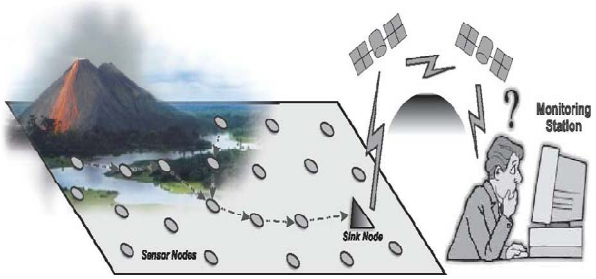

Figure 1: Data aggregation routing

As sensor nodes are energy-constrained devices. The energy consumption is generally associated with the amount of gathered data. Thus, energy conservation is a key issue in Wireless Sensor Network. Data fusion and Data aggregation techniques used in order to save energy [5], [6]. A strategy to optimize the routing task for the available processing capacity can be provided by the intermediate sensor nodes along with the routing paths. Data aggregation defined as a process of aggregating the data from multiple sensor nodes to eliminate redundant transmission and provide fused information to the sink or base station. The goal of data aggregation is to gather and aggregate data in an efficient manner so that lifetime of the network increases by decreasing the number of messages or a packet to be sent to sink or base station [7], intern decreasing the communication costs and energy consumption.

In routing algorithms for WSNs the main challenges are no assured guarantee to the delivery of the sensed data for the presence of nodes failures and interruptions in communications. As packets contain aggregated data information from different sources. Most of the time node failures become more critical in data aggregation performed along the routing paths. Whenever one of these packet is lost amount of information will also be lost. In WSN, data aggregation routing protocols should present some characteristics such as reduced number of messages for setting up a routing tree, maximizing number of overlapping routes, maximum aggregation rate, and reliable data transmission.

2. In-Network Data Aggregation

In this process the intermediate nodes forward data packets toward the sink node while combining the data gathered from various source nodes. A query requesting aggregate data is injected into the sensor network at a host node, also known as a *sink*. The query is forwarded by the host to the other nodes in the network. The simplest and least optimal query plan requires each node to report its own readings back to the host node for processing. After receiving all data packets from the *source* nodes, the host node aggregate all of the data into a final value and report the value back to the user. The design of a data aggregation routing protocol is a key component of in-network data aggregation.

In data aggregation routing algorithms, nodes route packets based on their data and choose the next hop that maximizes the overlap of routes in network data aggregation. A key aspect of in-network data aggregation is the synchronization of data transmission among the nodes. In these algorithms, a node usually waits to receive data from neighboring nodes may lead to better data aggregation opportunities. It will improve the performance of the algorithm and save energy.

For data aggregation periodic synchronization can be classified into three groups.

- **Periodic simple** aggregation means that each node waits a predefined amount of time, aggregates all data received, and then forwards the data toward the host node. Such algorithm is simple to implement, but does not guarantee accuracy of the data.
- **Periodic per-hop** aggregation means that each node waits until it receives data from all children after aggregates the data and then forwards it toward the host node. This approach requires timeout may be used in case some of the children do not respond to the query.
- **Periodic per-hop adjusted** is similar to the per-hop approach, except the timeout is based on the node's position in the routing tree. Nodes lower in the routing tree should experience a timeout before nodes closer to the host.

To reduce the overall amount of energy in WSN In-network aggregation is important and it is performed at intermediate nodes to decrease size and the number of packets exchanged across the network. The various algorithms have been proposed that provide data aggregation while routing in WSNs. These routing algorithms are categorized into three types.

2.1 Tree-Based Approach

In a tree based approach, tree is constructed by sensor nodes. Data aggregation is performed at intermediate nodes along the tree. This aggregated data is transmitted to the sink node. In this approach, a tree structure is constructed first. This tree is used to route the gathered data. Data aggregation is performed during the routing when two or more data packets arrive at the same node of the tree. This node then aggregate all received data with its own data and forward only one packet to its neighbor that is lower in the tree. But, this approach has few drawbacks. For instance, when a packet is lost at a certain level of the tree that time the data from the whole sub tree will be lost. Thus, these approaches are required a mechanism for fault tolerance to reliably forward the aggregated data. One of the main aspects of tree-based networks is the construction of an energy efficient data aggregation tree.

2.2 Cluster Based Approach

Cluster-based approach consists of a hierarchical structure of the network. In these approaches, nodes are divided into clusters. In these clusters some nodes, referred to as cluster-heads. Cluster-heads are used to aggregate data locally and forward the result of such aggregation to the sink node. Cluster-heads plays the role of aggregator [10]. Cluster formation in WSN, nodes in a sensor networks often need to organize themselves to form a cluster, and one of the nodes in cluster will be cluster head (CH). Clustering follows hierarchical structures to be built on the nodes and enables more efficient use of resources, such as frequency spectrum, bandwidth, and power. To ensure fair distribution of the workload, the cluster leader is selected randomly at each round of aggregation. The clustering scheme consists of:

- **Sensor Node**: A sensor node is main component of WSN. It can play multiple roles in a network, such as simple sensing, data processing, data storage and routing.
- **Clusters**: Cluster is an organizational unit, the dense nature of these networks needed to be broken down into clusters to simplify tasks such a communication.
- **Cluster-heads**: Cluster-heads of a cluster, are the organization leader, often organize the various activities in the cluster such as data-aggregation and organizing the communication schedule of a cluster so on.
- **Base Station**: The base station of the hierarchical WSN, acts as communication link between the sensor network and the end-user.
- **End User**: who generates the query for sensor network, which depend on the application.

2.3 Structure-Less Approach

Some algorithms for routing of data aggregation have been proposed that use a structure-less approach. The Data-Aware Anycast (DAA) algorithm is a structure-less data aggregation algorithm. This algorithm uses Anycast to forward packets to one-hop neighbors that have packets for aggregation. This approach has mechanisms for increasing the chance of packets meeting at the same node. Structure-Less approach does not guarantee aggregation of all packets and the cost of transmitting packets with no aggregation increases in large networks.

3. Proposed Approach

In the proposed approach first a routing tree constructed with the shortest paths that connect all source nodes to the sink, maximizing data aggregation. The approach is divided into four phases: setup phase, cluster setup phase, inter cluster routing phase and route repair mechanism.

3.1 Setup Phase

In the setup phase, the base station (BS) transmits a level-1 message with the minimum power. Level-1 gets setted by all the nodes which receive the message. After that the base station increases its power to attain the next level and transmit a level-2 message. This procedure continuous until the base station transmits corresponding messages to all level [10]. BS broadcast a hello message shown in figure (2). This message contains the information of upper limit and lower limit of each level. After that each node calculates the distance from the BS based on received signal strength [13].

Ui,Li	.....	U3,L3	U2,L2	U1,L1

Figure 2: Structure of Hello message

Where
Ui: Upper limits of level i
Li: Lower limit of level i

Algorithm 1. Setup phase
#No. of nodes N
BS can transmit i levels; i _1

1. For each level i, message transmitted by BS
2. If(Nodes does not assign previous level and receive new message or BS transmit level i=1)
3. Assign level i
4. End if
5. End for
6. BS broadcast hello message, which contains the information of upper limit and lower limit of each level.
7. Each node calculates the distance from the BS based on received signal strength.

3.2 Cluster Setup Phase

In this phase each level is divided into clusters. For each level i, each node decide the cluster head for the current round by choosing a nodes randomly. The node which has the higher energy level will be considered as cluster head(CH) [14]. The cluster head for the current round, broadcast the message for the rest of the nodes with the same energy. Each node must inform to the cluster head that it will be a cluster member. Once the clusters are created and TDMA schedule is fixed for all nodes in cluster by CH & data transmission can begin. Each node sends data to its cluster heads with minimal transmission power and this power is estimated by received signal strength of the message. So that data transmission uses a minimal amount of energy [19]. When all the data has been received from the cluster members, then the cluster head performs data aggregation function to compress the data into a single signal & process repeats for the next rounds.

Algorithm 2. Cluster setup phase

1. for each (node N)
2. if node N has highest energy level
3. N becomes CH.
4. N broadcasts an message for its cluster nodes.
5. Else
6. N becomes a NCH node.
7. N informs the selected CH and become a member of its cluster.
8. End if.
9. for each (CH)
10. CH creates TDMA schedule for each cluster member.
11. Each cluster member communicates to the CH in its time slot.
12. End for

3.3. Inter cluster routing

After the cluster formation, the cluster heads broadcast the aggregate data to the next level. At the next level, the nodes aggregate the data received and sends to their cluster heads. In this way the cluster heads at the last level transmit the final aggregated data to the BS [15].

Algorithm 3.Inter cluster routing

1. For each (level i)
2. for each CH
3. CH receives the data from the cluster member
4. Aggregate the data.
5. If (i ==1)
6. CH transmits data to the BS.
7. Else
8. CH broadcasts data in the next level.
9. End if
10. End for
11. End for

3.4. Data Transmission Phase

The nodes are divided into different subnets including an cluster head and other nodes after cluster set-up phase. The cluster head may include all nodes of its subnet. The Shortest path from nodes to CH in subnet is calculated by Dijkstra algorithm with the product of the maximum energy consumption of the two nodes and the energy required for sending the data package as a weight. Then CH sends the shortest path tree structure to all sensors in the subnet. Every sensor can transmit data along the path of the shortest path tree in its subnet. The operation is divided into rounds. In each round, SPTs are configured and aggregated data is transmitted from sensors to the cluster-head & the process is repeated. The subnet lifetime is expired if the residual energy of a sensor in the subnet is exhausted [14], [15].

Algorithm 4:Data Transmission Phase

1. for each round do
2. for each subnet do
Weight(I,j)=Esend(I,j)*max{Econsume(i),Econsume(j)}
3. SPT=Dijkstra{Weight(i,j)}
4. if Eresidual(k)<=0 then
5. break
6. Ni->Aj::{aggregated data}
7. end if
8. end for
9. end for

3.5. Route Repair Mechanism

The route created to send the data towards the sink node is unique and efficient since it maximizes the points of aggregation. Any failure in one of the node will cause disruption, preventing the delivery of aggregated data [16]. Low energy, physical destruction and communication blockage are possible causes of failure. In the proposed work a piggybacked, ACK-based route repair mechanism is used, which consists of two parts: detection of failure no deand selection of a new Node. When a node needs to forward data to the sink, it simply sends the data packet, sets a timeout, and waits for the ACK message. If the sender node receives ACK from the node within the pre-determined timeout, it will assume that the node is alive .If not, it considers the node as offline and another New node selected. For this, the sender chooses the neighbour with the lowest hop-to-tree level to be its new node; in case of a tie this chooses the neighbor with the highest energy level. After this repair mechanism, a newly reconstructed path is created & proceeding with forwarding aggregated data towards sink [2], [17]. This mechanism also provides secured data aggregation [20].

4. Conclusion

Aggregation routing algorithms play an important role in event based WSN. Node aggregation strategy that eliminates

data duplication in wireless sensor networks. This aggregation is done using tree and cluster based node formation structure. These node structures are then used to route packets to sink in efficient manner. We believe that this will help in building efficient wireless sensor networks.

References

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cyirci, "Wireless Sensor Networks: A Survey," Computer Networks, vol. 38, no. 4, pp. 393-422, Mar. 2002.R. Caves, Multinational Enterprise and Economic Analysis, Cambridge University Press, Cambridge, 1982.

[2] K. Romer and F. Mattern, "The Design Space of Wireless Sensor Networks," IEEE Wireless Comm., vol. 11, no. 6, pp. 54-61, Dec. 2004.

[3] G. Anastasi, M. Conti, M. Francesco, and A. Passarella, "Energy Conservation in Wireless Sensor Networks: A Survey," Ad Hoc Networks, vol. 7, no. 3, pp. 537-568, http://dx.doi.org/10.1016/j.adhoc.2008. 06.003, May 2009.

[4] A. Boukerche, R.B. Araujo, and L. Villas, "Optimal Route Selection for Highly Dynamic Wireless Sensor and Actor Networks Environment," Proc. 10th ACM Symp. Modeling, Analysis, and Simulation of Wireless and Mobile Systems (MSWiM '07), pp. 21-27, 2007.

[5] Vaibhav Pandey, Amarjeet kaur & Narottam Chand, "A review on data aggregation techniques in wireless sensor network", in Journal of Electronics & Electrical Engineering, ISSN:0976-8106 vol.1 issue 2010,pp 01-08.

[6] Leandro Villas, Azzedine Boukerche, Heitor S. Ramos, "A Lightweight and Reliable Routing Approach for in-Network aggregation in WSN", in Jounal of IEEE Tranactions on computer networks ,vol 38,Mar 2011,pp 393-422.

[7] Rajagopalan, Ramesh and Varshney, Pramod K., "Data aggregation techniques in sensor networks: A survey", (2006), Electrical Engineering and Computer Science. Paper22.

[8] Jamal N. Al-KarakiRazaUl-Mustafa Ahmed E. Kamal, "Data Aggregation and Routing In wireless sensor networks: optimal and heuristic algorithms" ,A survey IEEE wireless communications,vol 11,Dec 2004,pp 6-28.

[9] Woo-Sung Jung, Keun-Woo Lim, Young-BaeKo, "A Hybrid Approach for Clustering-based Data Aggregation in Wireless Sensor Networks", in IEEE transactions on networking,vol 11,pp2-16,Feb 1999.

[10] Sonam Palden Barfunga, PrativaRai, "Energy Efficient Cluster Based Routing Protocol for Wireless Sensor Networks", in International Conference on Computer and Communication Engineering (ICCCE 2012), 3-5 July 2012, Kuala Lumpur, Malaysia

[11] P. Krishna N. H. Vaidya, M. Chatterjee, "Cluster-based Approach for Routing in Dynamic Networks", Department of Computer Science & Digital Equipment Corporation Texas A&M University,May 2004

[12] J. Al-Karaki and A. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey," IEEE Wireless Comm., vol. 11, no. 6, pp. 6-28, Dec. 2004.

[13] Uk-Pyo Han, Sang-Eon Park, Seung-Nam Kim, "An Enhanced Cluster Based Routing Algorithm for Wireless Sensor Networks" ,Computer Science Department, Kangwon National University, Chunchon, Korea, Vol. 40, Issue 8,pp. 102-114, Aug. 2002

[14] V. Akila, Dr. T. Sheela, Computer Science and Engineering, Bharath University, Chennai , "Overview of Data

[15] Aggregation Based Routing Protocols in Wireless Sensor Networks", in International Conference on Information Systems and Computing, Volume 3, Special Issue 1, January 2013

[16] Zhicheng Dai,Bingwen Wang ,Zhi Li,"An Energy Aware & Cluster Based Data Routing Algorithm for Wireless Sensor & Actor Network", in Information Technology Journal 8,1044-1048,2009

[17] Chris Karlof, David Wagner "Secure routing in wireless sensor networks: attacks and counter measures" ,University of California, Berkeley, CA 94720, USA, (2003) ,pp293–315

[18] B. Kumar, N. Vikram and M. Malla Reddy, "Secure Data Collection in Wireless Sensor Networks Using Random Routing Algorithms", in International Journal of Computer Science and Telecommunications, Volume 2, Issue 4, July 2011.

[19] Harneet Kour,Baba Ghulam Shah Badshah University, Rajouri, "Hierarchical Routing Protocols In Wireless Sensor Networks", in International Journal of Information Technology and Knowledge ManagementDecember 2012, Volume 6, No. 1, pp. 47-52.

[20] Jin Wang, Jianwei Zhang, Jeong-Uk Kim ,"An Energy-based Clustering Algorithm for Wireless Sensor Networks", in Computer Networks, vol.38, no.4, pp.393-422, 2002.

[21] Sanjeev SETIA ,Sankardas ROY, "Secure Data Aggregation in Wireless Sensor Networks ",in Computer Science Department, George Mason University, USA,pp1361-1364, 2004.

Author Profile

Prof. Deepak Naganath Rewadkar received M.E. Computer Technology, from S.R.T.M. University, Nanded. (2000). Currently he is working as an Associate Professor & Head the Department of Computer Engineering, in RMD Sinhgad Technical Institutes Campus, Warje, Pune. He is a Member of Board of Study (BOS) committee of S.R.T. Marathwada University, Nanded for Computer Science & Engineering. His area of interest is Traffic Engineering & Mobile Communication. He has 20 years of teaching experience.

Ms. Priti Madhukar Mithari recived B.E. in Computer Science & Engineering from Computer Department of K.I.T. C.O.E., Kolhapur from Shivaji University, Kolhapur. (2011). Currently she is pursuing M.E. in Computer Engineering from RMD Sinhgad School of Engineering, Warje, Pune. She is also working as an Assistant Professor in the Department of Computer Engineering in Dr. D. Y. Patil I.E.T. Ambi, Pune.