Energy Efficient and Data Priority Based Routing Approach for in-Network Aggregation in Wireless Sensor Networks

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***Abstract*— Wireless Sensor Network (WSN) consists of very large of sensor nodes which are deployed close to the area which is to be monitored to sense various environmental conditions. Sensor nodes are energy-limited devices and their energy consumption is mainly associated with data routing. Therefore it is necessary to perform redundant data aggregation to save energy. In this paper, a data routing approach for In-Network data aggregation is proposed, which has some key features like reliable cluster formation , high data aggregation rate, priority of packets, minimized overhead, dynamic routes, reduced energy consumption which improves network lifetime. The proposed work is compared with the existing algorithms using Network Simulator. The results obtained here show that proposed algorithm outperforms the existing results in different evaluation scenarios.**

Keywords*—Cluster based structure, in-network aggregation, Data routing, network simulator.

I. INTRODUCTION

Wireless Sensor Network is a network of spatially distributed autonomous sensor nodes which are capable of sensing environmental or physical phenomenon's like sound, temperature, pressure, motion, vibration, or various pollutants at different parts of the monitoring region [9]. WSNs are useful in large number of applications like industrial automation, power network, transportation, forest environment monitoring, military applications, medical applications, communication and in many more critical applications.[1]

WSN consists of nodes from few to several hundreds or thousands and they co-operatively sense the data and there topology can be a simple star topology and varies to multi-hop mesh topology. The size and cost constraints of sensor result in corresponding limitation of resources like energy, memory, speed.[3]

The main resource is energy which is mainly consumed during data gathering and forwarding. For that reason, protocols designed for WSNs must consider the energy consumption in their conception. [2]

WSNs are data-driven networks that usually produce a large amount of information that needs to be routed, often in a multi-hop fashion, toward a sink node, which transfers data to the monitoring center. Therefore it is necessary to optimize the routing task. The *Fig.1* below shows the working of wireless sensor nodes in sensor network. If any node has sensed data, then it forwards the data towards the sink using routing path. The data from sink can be transferred to the monitoring station.

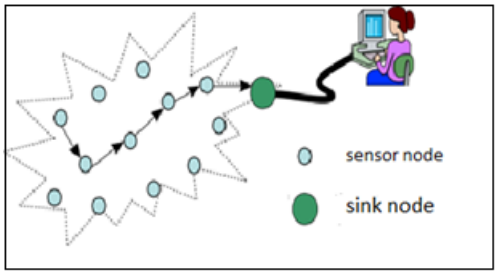


Fig.1: working of WSNs

One of the possible ways to achieve this is to use a technique called as In-Network aggregation of data which is also called as data-centric routing. In this technique, a node does not send data as soon as it is available instead it waits for the data from neighboring nodes which leads to better aggregation of data, improved performance and reduced communication load.

Guaranteed delivering of the sensed data to the sink using this technique is very critical because if one of the sensed packets is lost then reliable amount of information will be lost. Hence the routing algorithms for WSNs designed using this technique must have some important desirable characteristics such as reliable data transmission, high aggregation rate, more number of overlapping routes, dynamic routes, route repairing capability.

II RELATED WORK

The different approaches to enable data aggregation during the routing in WSNs are proposed. They are mainly classified as tree based approaches, cluster based approaches and structure-less approaches.

Tree based approaches uses hierarchical organization of the nodes. Here a routing tree is constructed first and is used to route the data and also to aggregate the packets at intermediate nodes. The cluster-based approach is also similar but in this nodes are divided into groups called clusters. A special node

called cluster-head is elected among the group members and this node performs aggregation of data locally and forwards the aggregated packet towards the sink node. Whereas in structure-less approach a random path will be chosen to route the data and here opportunistic aggregation of data occurs.[2]

1. Shortest Path Tree (SPT) algorithm [5]
It comes under tree based approach, wherein every node that detects an event reports its collected data by using a shortest path towards the sink node. The data aggregation occurs whenever routing paths overlap.

2. Center at Nearest (CNS) algorithm [5]
It is also a tree based approach. In this, every node that senses an event sends its data to a specific node, called as as aggregator, by using shortest path.

3. Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm [6]
It is based on cluster-based approach. In this, the clusters are formed, the cluster-head acts as an aggregator and forwards the aggregated packet directly to the sink node. Every node in the cluster gets an opportunity to be the cluster-head. This is done to evenly distribute energy consumption among all nodes.

4. The Information Fusion-based Role Assignment (InFRA) algorithm [7]
This is based on cluster-based approach. In this, the clusters are formed and the cluster-head builds shortest path to the sink and uses that path to route the merged data.

5. Data-Aware Anycast (DAA) algorithm [4]
It is a structure-less approach. This uses any route to send the packets to one-hop neighbors that have data for fusion. But the approach does not guarantee aggregation of all packets and this increases transmission of packets without fusion.

III PROPOSED ALGORITHM

The proposed algorithm is divided into five modules.
They are:
Module 1: Constructing the hop distance from the sink
Module 2: Formation of the cluster
Module 3: Route establishment
Module 4: Repairing of the failed routes
Module 5: Multiple paths creation based on data priority

Module 1: Constructing the hop distance from the sink
In this module the hop distance of each of the nodes from the sink (the destination node) is calculated. This is initiated by the sink node, which forwards the hop calculation message to the entire network of nodes and the calculated values are compared and the smallest value is stored in the variable say, hop. This value will be used for further route formation.

Module 2: Formation of the cluster
The proposed algorithm is a cluster based approach. When an event is sensed by one or more nodes, a group these nodes called "cluster" will be formed. The next stage is the selection of the head of the cluster (Cluster Head) which is used to send the data sent by the cluster members in the aggregated form towards the sink node. The selection in the first round is based on the closeness of the cluster members to the sink. During next rounds selection is made based on node identifier or energy of the node. The entire process is shown in *Fig.2*

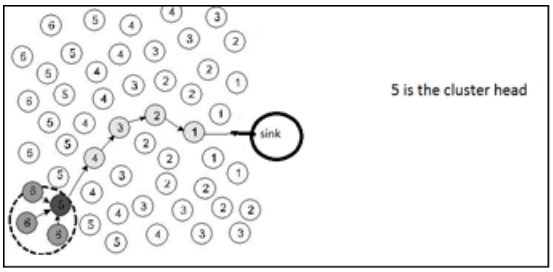
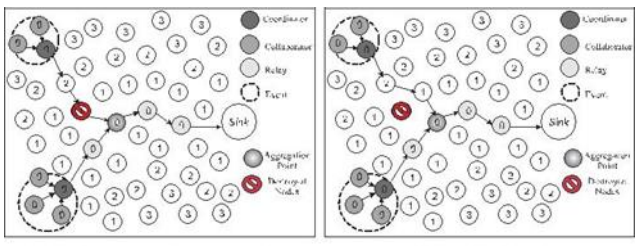


Fig.2: Cluster formation and data routing

Module 3: Route establishment
The selected group leader, begins establishing the new route. This is done by sending message to its Next Hop node. When the Next Hop node receives a route establishment message, it retransmits the message to its Next Hop and starts the hop tree updating process. These stages are repeated until either the sink is reached or a node that is part of an already established route is found. The routes are created by choosing the best neighbor at each hop.

Module 4: Repairing of the failed routes
The failure of the routes created may be caused due to less energy, communication failures, faulty nodes ad physical destruction. To avoid such routes energy of the nodes will be checked regularly during data forwarding, if there is any reduction in energy or any other problem then the new nearest better node will be chosen and except the failed node the rest path is same as the previous route. This stage is shown in the *Fig.3*



(a) Region with destroyed nodes (b) Repaired path

Fig.3: repairing the failed routes

Module 5: Multiple paths creation based on data priority
Some of the data packets have less priority than the other packets. To ensure fast delivery of urgent priority data packets a separate path will be created to route these packets whenever necessary thereby increasing the reliability.
The complete flowchart is shown in *Fig.4*

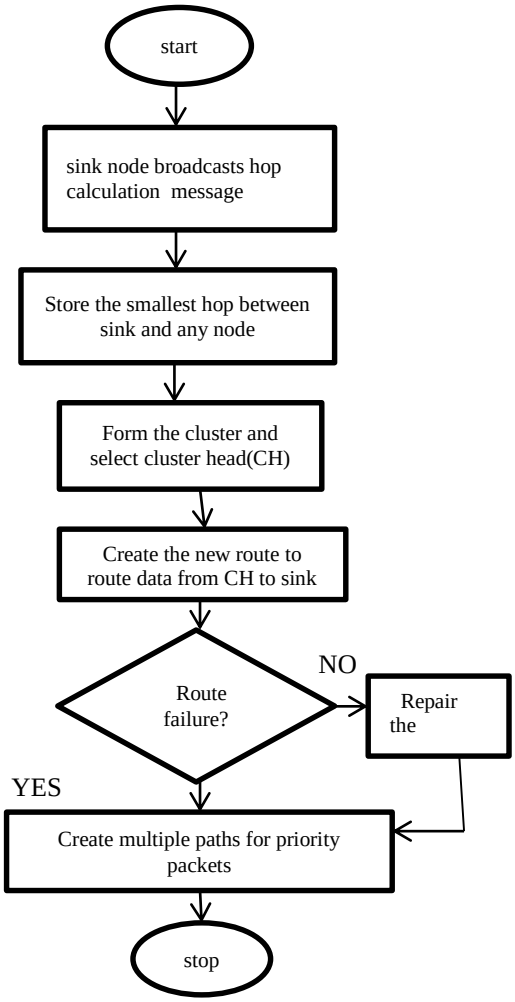


Fig. 4: flowchart of the proposed protocol

IV PERFORMANCE EVALUATION

The performance of the proposed algorithm is evaluated using network simulator. Network Simulator (Version 2), is simply a discrete event driven simulator. It is an open source solution implemented in C++ and Otcl (object oriented tool command language) programming languages.
It provides a highly modular platform for wired network as well as wireless network simulations supporting different network elements, protocols, traffic, and routing types. This can be used to evaluate the performance of routing protocols as well.

The table 1 shows the simulation parameters under consideration.

Table 1: simulation parameters

Parameter	Value
Topology size	500 X 500
Number of nodes	60
Sink node	1(top right)
Number of events	1
Communication radius	80m
Notification interval	60sec
tool	Network simulator
Version of the tool	2.34

The following performance metrics are considered for evaluation and it is compared with the existing system :

- Throughput (efficiency) : It is the rate between the total packets transmitted (data and control packets) and the number of data received by the sink.
- The hop count: Total number of edges in the routing tree structure built by the algorithm.
- Data packet delivery rate: The number of packets that reach the sink node. This metric indicates the quality of the routing tree built by the algorithms—the lower the packet delivery rate, the greater the aggregation rate of the built tree.
- Average delay: It is the time required for the packets to travel from source node to sink node.
- Total number of transmitted and received packets.

Simulation results

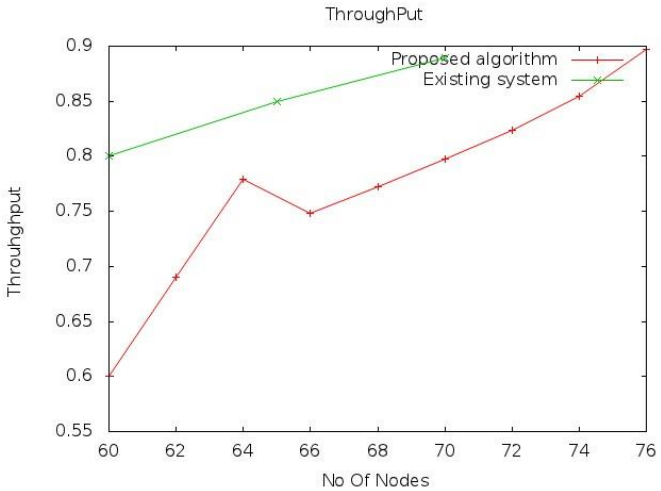


Fig.5: graph of throughput

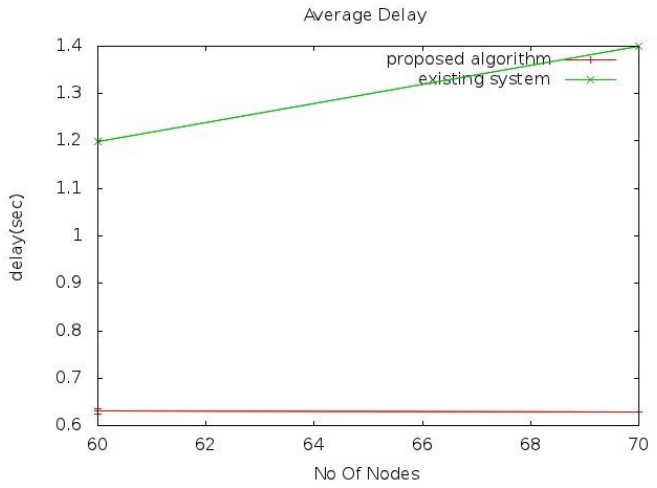


Fig.6: graph of average delay

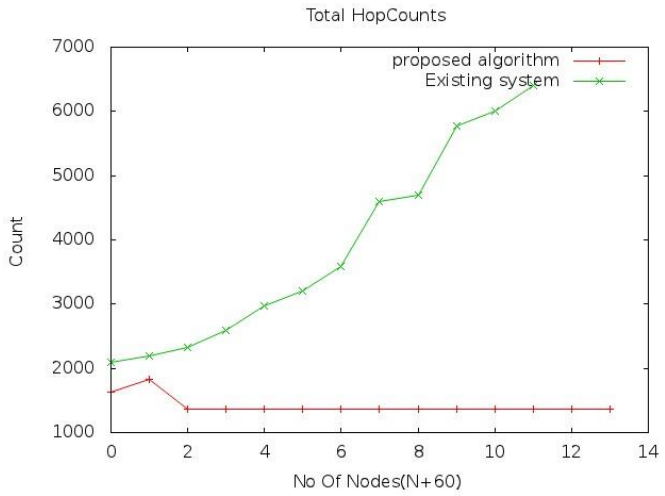


Fig.7: graph of hopcount

V CONCLUSION

The proposed algorithm is useful for routing the cluster based aggregated data packets in wireless sensor networks. This involves a very useful technique called in-network aggregation which improves data aggregation and reliability. It is compared with the existing system using ns-2. The simulation results shows that the proposed work outperforms the existing solution. Thus the algorithm provides high aggregation rate, improved throughput, very less redundancy, multiple paths depending on the packet's priority, reduced delay and overhead. All these points lead to reduction in the energy consumption thereby increasing the network lifetime of WSNs.

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