IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727 PP 69-74
www.iosrjournals.org

Collision-Free Data Aggregation for Data Transmission

Abstract: *Over the past few decades, Wireless Sensor Networks (WSNs) have attracted much attention from academia and business and are now integrated into the Internet. The restricted energy of WSNs directly impacts the lifespan of WSNs. Data transfer from sensor nodes to the base station is a significant energy consumer. Therefore, every practical option that aims to cut down on data transmissions has been considered by researchers. Collision is one of the main problems with data aggregation that increases energy waste. A data aggregation collision issue causes aggregation latency and data loss. Data must be retransmitted due to the problem of data loss, which costs more energy to transport the same data.As a result, when the collision problem is solved, the energy optimization of data aggregation may be considerably enhanced. The energy efficiency of the sensor nodes is increased in this research,and a hybrid method for collision-free data aggregation integrated with Hybridized Collision free Data Aggregation on a delay-aware data aggregation (DA-HCDA) tree is proposed. The existing state-of-art technique is compared with the proposed approach,whereas the proposed method outperforms.*

I. Introduction

Wireless Sensor Network (WSNs) can be described as a self-designed and infrastructure-less wireless network for screening physical or natural scenarios namely temperature, weight, sound, vibration, movement, strain, motion, or pollutants that are observed and investigated. Wireless technological innovation can reach virtually across and outside of the earth. The enormous success of wireless voice and messaging services has enabled its utilization in the field of private, commercial, biological, and other computing fields [1, 2].

A sink or base station (BS) can act as an interface among clients and the network where necessary data can be retrieved from the network by infusing queries and assembling the results from the sink. WSN could be well-defined as a system of a network in which the gathered information is communicated through wireless links [3]. This information is passed through several nodes and linked to various types of networks. Generally, WSN is a collection of a vast amount of sensor nodes (SNs) [4, 5] which can impart among them utilizes radio signs. A wireless sensor node is equipped with, radio transceivers, power segments, detecting, and computing gadgets. These SNs can communicate directly to a BS.

In WSN, the network is dispersed widely and nodes in the network are lightweight. Moreover, a large number of sensor nodes sense a substantial area, and each node can individually perform some processing as well as sensing tasks. Furthermore, sensor hubs communicate with one another to forward their detected data to a CPU or direct reside in some nearby coordination, for example, information fusion [6].

WSN comprises of many tiny sensor nodes with one or more base stations. Due to their small size, the sensor nodes (SN) have limited energy, memory, bandwidth and processing capabilities [7, 8]. The constrained energy has a direct impact on the lifetime of WSNs. Data transmission from SN to the base station is a significant energy consumption source. Thus every feasible solution that intends to reduce data transmissions is widely discussed. Data aggregation, a technique for saving energy and maximizing the network lifetime, has been frequently explored by researchers. By exploiting correlations among the sensory data, data aggregation minimizes the count of data transmissions, thereby saving energy and increasing the lifetime of WSNs [9].

Collision is one of the significant issues of data aggregation, which leads to more energy wastage. The collision problem of data aggregation leads to aggregation delay and data loss problems. The data loss problem requires retransmission, which uses more energy sources to send the same data. Hence the energy optimization of data aggregation can be significantly improved when resolving the collision issue [10]. To increase the energy efficiency of the sensor nodes, this research suggests a hybrid method for collision-free data aggregation termed DA-HCDA on a delay-aware data aggregation tree [11]. The necessity for collision-free data aggregation in WSN is stated in the following section [12].

In WSNs, many data aggregation scheduling algorithms have been proposed to resolve collision issues [13]. But the combined solution that resolves the collision problem with minimum delay is not much discussed in the existing models. The drawbacks of the current collision-free data aggregation algorithms are discussed in related works that identify the need for collision-free data aggregation algorithms [14]. Developing a collision-free data aggregation technique on the delay-minimized data aggregation tree further enhances the energy optimization of sensor networks. This motivates the development of a collision-free data aggregation algorithm. Moreover, the solution which resolves the delay and collision-related issues significantly improve energy efficiency. Therefore, to improve the life span of the WSNs, it is vital to propose a hybrid collision-free data aggregation algorithm.

Section 1 gives an abstract introduction to the DA-HCDA. Section 3 defines the system model used to evaluate the proposed Algorithm and a detailed description of the collision-free data aggregation algorithm. Approximations and complexity have been examined in section 4, along with a formal demonstration of the correctness of DA-HCDA. Additionally, simulation data are used to demonstrate the superior performance of DA-HCDA in terms of throughput, delivery ratio, and packet latency. Finally, the article is concluded with the future recommendation .

II. Related Works

kaur Er, S., & Sharma, E. S. (2018) [14] proposed an energy aware protocol for WSN, which reduce overall energy consumption as much as possible and improve the performance by using inter-cluster-based data aggregation. This technique is divided into many phases, a cluster leaders acquire information from their group members and then send it to the base station through single-node communication. New coordinates are chosen once each step is completed. As a result, the sensor nodes start out with similar energy, and the goal is to distribute the power burden evenly among all the sensor network nodes.

Kafi, M. A., et al (2013) [15] detailed the significance of a well-functioning network traffic congestion range and connection difficulties. In addition to clustering, it is critical to efficiently transmit time-specific and event-driven Internet of things applications for sensor networks. Large or small, they may be placed in any type of geographical location that enables accurate sensing and network coverage. The count of SN in a flow pattern might be one to several or vice versa. These devices are left unsupervised once placed in distant and hazardous areas where human interaction is impossible. Furthermore, sensors with non-rechargeable batteries are resource restricted and difficult to manage in critical situations.

Babu, M. V., et al (2018) [16] explained the most challenging problem is developing a data collection strategy that uses minimal energy. This is because each sensor node in the network only has a certain amount of energy resources. Clustering improves energy efficiency, network connectivity, and delay minimization. Therefore, due to cluster head election and data aggregation, clustering-based approaches for data collection play a crucial role in energy saving and extending the network's lifetime. The Integration of Distributed Autonomous Fashion with Fuzzy If-then Rules (IDAFFIT) algorithm is suggested for clustering in this approach. The Cluster Head (CH) is also elected in the interim. The routing concept then transfers the packet from the source to the target node by selecting the best route. ASLPP-RR, an adaptive source location privacy preservation technique, is proposed for routing in this context.

Agarwal, A., et al (2022) [17]proposed a protocol for data aggregation. WSNs are intelligent objects that can monitor their immediate environment and transmit data to BS for gathering information. These cutting-edge gadgets have an energy cap. This restriction has been encountered in several research articles, and solutions to get around it has been offered. Various routing techniques exist to lower cost for transmission and offer effective solutions. Data transmission is another aspect of advancement, though. To increase performance, this study suggests a Buffer-based linear filtering (BFL) approach for Data Aggregation while minimizing correlations. The proposed method decreases the data burden by removing spatial and temporal correlations.

Jain, K., & Singh, A. (2022) [18] proposed Normalized Quantile Regression (NQR) for Data Aggregation and it successfully achieve energy savings in synchronized data collection cycles. The newly developed NQR algorithm offers high-accuracy prediction. Energy use is decreased with correct estimates. It also prolongs the life of the network. The predicted sensor reading is coordinated in intracluster transmissions by NQR using a two-vector data-prediction method, which minimizes cumulative inefficiencies from unbroken forecasts. It is possible to combine the NQR algorithm with both homogeneous and heterogeneous WSNs.

III. Proposed Methodology

A hybrid technique for collision-free data aggregation called DA-HCDA is proposed in this study. DA-HCDA offers efficient and effective data aggregation among the sensor network. It consists of two sections:

- Node Discovery Algorithm (NDA): A collision-free data aggregation tree is created, and each node locates its neighbours and selects the matching child nodes of those neighbours. The node with the most energy is chosen as the sink in creating an NDA tree. Based on the distance between neighbours and their energy level, other nodes pick their appropriate parent and child node from among their neighbours. The number of seconds it takes for each node to respond to the broadcast request is a distance measure. A node builds the aggregate tree using a binary search tree model after choosing its parent and children. The binary search tree model was used for aggregation tree construction because of the two-hop tree structure. The development of NDA Trees uses a binary search tree structure, dramatically reducing aggregation latency and energy usage.
- Hybrid Data Aggregation (HDA): The sink node achieves quick data aggregation in a collision-free topology by applying the HDA Algorithm on the NDA aggregation tree. Data aggregation in HDA is carried out in a distributed fashion. In the first time slot, the minor offspring nodes submit their data to their parent nodes.

The data is then sent to the upstream nodes via the parent nodes. Data aggregation has been carried out at the root node via all of its child nodes' parent nodes. Applying this HDA to the NDA tree has examined the simulation findings. The outcomes demonstrate that DA-HCDA offers good data correctness and freshness while providing collision-free data aggregation. Furthermore, DA-HCDA works effectively in hostile conditions that are static.

The construction of a collision-free tree-balanced 2-hop Dominating Sets is a significant contribution made by DA-HCDA. The resulting Tree has a few dominators, referred to as Parents, among which there are concurrent transmissions that have not collided with one another. This allows for collision-free communication, which can lower aggregation latency. Next, DA-HCDA employs a unique hybrid algorithm—a blend of distributed and centralized algorithms—to build a collision-free aggregation schedule. Another critical aspect of the architecture is that all nodes execute the aggregation schedule simultaneously, and the building of the aggregation tree is distinct due to its binary tree form. This approach varies from the current models in tree building and aggregation methodology. However, even if it builds a sizable aggregation tree on a sizable WSN, It manages to aggregate data across all nodes without collisions and with little energy consumption.The overall methodology is given in Figure 1.

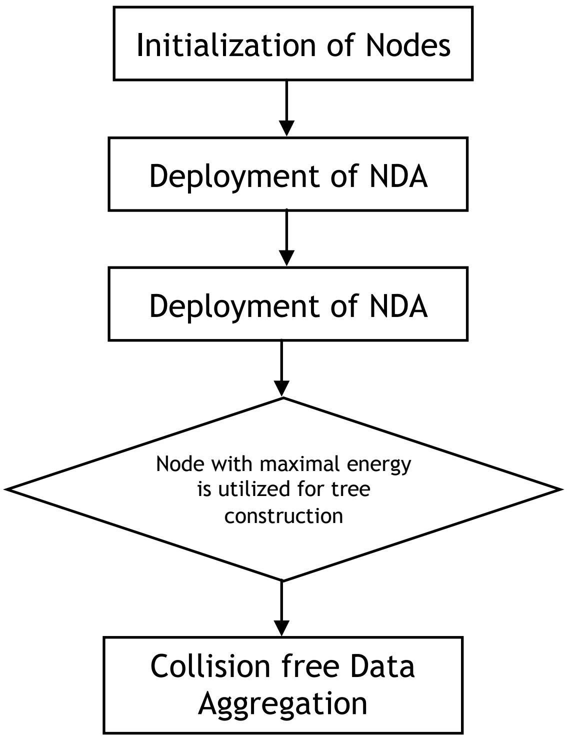

Figure 1. Overall Proposed Methodology

The latency time has decreased significantly compared to all other methods utilized to address the identical data aggregation challenge. The process of tree construction and aggregation is illustrated in Figure 2.Each node in HDA collects data from its left child in the first time slot and from its right child in the second. The node id is deleted from the aggregation node set UA = N_{n1},N_{n2}....N_{ni} once the data has been combined from child nodes. HDA starts the data aggregation as specified in Figure 2(a) in the NDA aggregation tree depicted in Figure 2(b). Data from Nodes N18, N14, N15, N3, N19, and N10 will be combined in the first time slot by Nodes N12, N8, N9, N17, N16, and N6. The aggregate tree and aggregation node set UA are then purge by HDA of the nodes N18, N14, N15, N3, N19, and N10. As seen in Figures 2(c) and 2(d), the data aggregation process also continues in the second and third time slots. The aggregation node set UA will only include N4, N8, N2, N11, N6, and N1 after the third time slot. HDA keeps aggregating data until all of the nodes in the set UA have produced aggregated data.

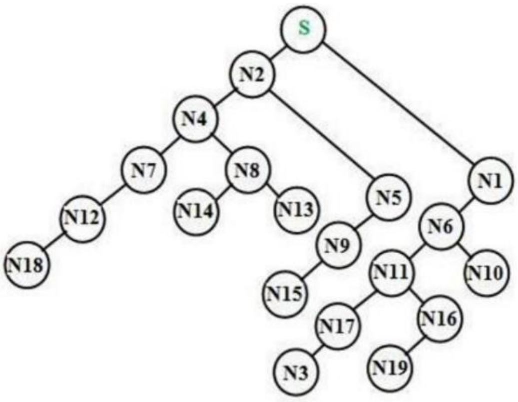

Figure 2(a) NDA Aggregation tree

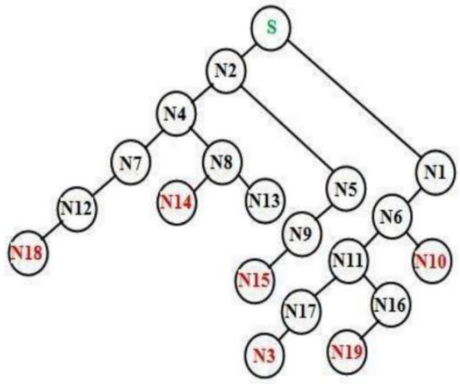

Figure 2(b) Data aggregation tree in 1st time slot

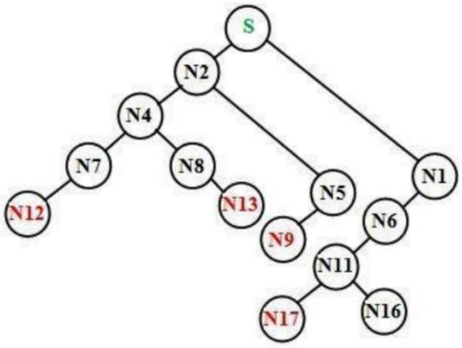

Figure 2(c) Data aggregation tree in 2nd time slot

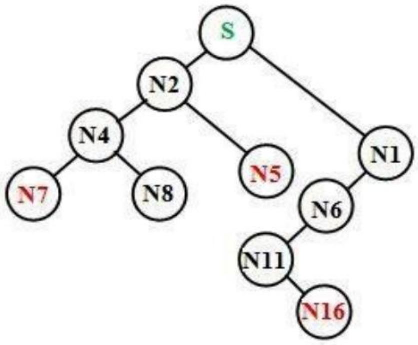

Figure 2(d) Data aggregation tree in 3rd time slot

IV. Result and Discussion

Utilizing Network Simulator (NS-2), the suggested system model DA-HCDA's performance has been evaluated for a WSN scenario. In Table 1, the simulation parameters are listed. For NS-2 on the Linux platform, the research has employed the programming languages C++ and tool command language (TCL). 100 to 1000 nodes with one static sink are considered for the simulation.

Table 1 – Simulation Parameters

PARAMETER	VALUE
Simulator	NS-2.34
Number of BS or sink	1
Topology area	150*300
Initial energy	2J
Number of sensor nodes	20,40,60,80 and 100
Propagation Model	Two Ray Ground
E_{ec}	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4
$dist$	75m
E_{Age}	5nJ/bit/signal
Routing Algorithm	DA-HCDA
Data packet size	500 bytes
Simulation time	200 sec

Energy Consumption

Every sensor node in the WSN is equipped with rechargeable batteries for use in the data transmission environment. However, because these batteries require minimal energy, charging them is challenging. Therefore, without interruption, data transfer is completed over the shortest route possible while utilizing the least energy. This circumstance lessens the energy exhaust in the transmission nodes. The energy consumption is given in Table 1 and illustrated in Figure3.

Table 1. Comparison of Energy Consumption

No of Nodes	ASLPP-RR	BFL	NQR	DA-HCDA
50	0.65	11.48	12.34	0.32
100	3.93	16.21	18.38	0.87
150	8.30	22.48	24.42	1.23
200	9.48	26.12	27.39	3.77

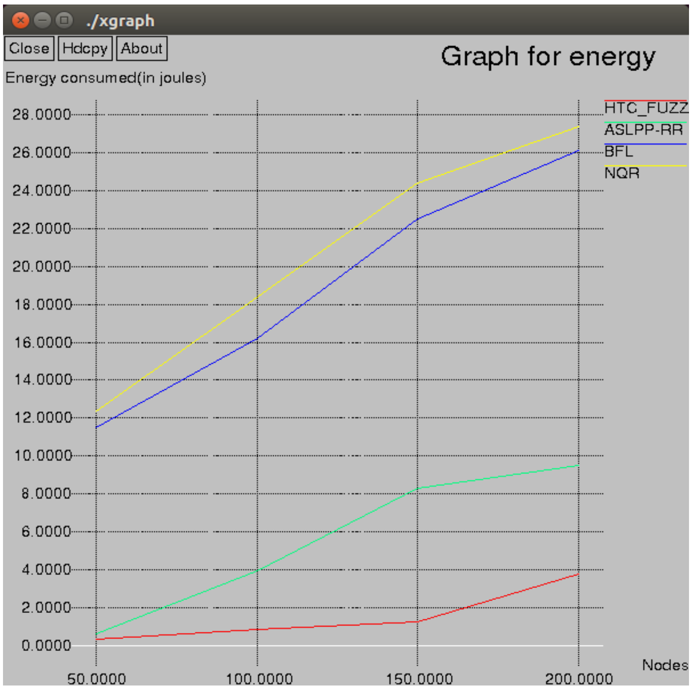

Figure 3. Comparison of Energy Consumption

From the observation of Table 1 and Figure 3, it is identified that the proposed approach has minimal energy consumption, which shows its effectiveness.

V. Conclusion

The delay-aware Tree created by Hybrid Tree Construction (HTC's) technique, based on the binary search tree, is used in this suggested DA-HCDA. The HTC technique lowers the time and assigns a distinct path to each node by building a two-hop data aggregation tree. The proposed DA-HCDA technique aggregates the data in Left-Right-Route (LRR) traversal mode to avoid node collisions in HTC. However, some currently used methods adjust the routing topology dynamically to minimize collisions, which lengthens the time it takes to aggregate data. This chapter suggested a brand-new hybrid technique for effective data aggregation in WSNs. The proposed approach was superior to all other prior methods in terms of energy, network lifetime, and energy consumption.

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