A Novel and Reliable Data Aggregation Aware Routing Protocol for Wireless Sensor Networks

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Abstract: Due to different data correlation among events in driven Wireless Sensor Networks (WSNs), over-overlapping paths from events in order to maximize the data aggregation will emanculate the monitoring ability of WSNs instead of amending the network performance. There should be a tradeoff between data aggregation maximization and energy balance. Excessive pursuit of high data aggregation regardless of the genuine state of network could bring about premature death of some backbone nodes, leading to unstable network structure. Based on the quandaries, in this paper, a novel adaptive state aware routing algorithm for data aggregation is proposed. The algorithm maximizes the possible data aggregation by building and updating a Hop-Tree, takes the local state of nodes to build and maintain Hop-Tree to gain more preponderant adaptation to heterogeneous wireless sensor networks, depends on Time-To-Live (TTL) mechanism to limit the Hop-Tree update range to evade over-overlapping of paths according to the correlation of events, and designs a coerced path building strategy to balance the data load on the backbone nodes of Hop-Tree to further balance the energy consumption. Theoretical analysis and simulation results show that our algorithm can maximize the possible data aggregation while balance the energy consumption among nodes and enhance the monitoring ability of WSNs significantly.

Keywords: Wireless Sensor Networks, Hop-Tree, Cluster, Data Aggregation, Energy Balance, In-Network Aggregation.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of sensor nodes deployed over a geographical area for cooperate-vably monitoring physical phenomena. Generally, sensor nodes are powered by batteries with inhibited energy budget which is infeasible or inconvenient to recharge because of the unpractical environment or the astronomically immense numbers of sensor nodes. Energy is very scarce for WSNs. Many researches show that the energy spent on data transmission dominates the whole energy consumption for sensor nodes. Normally, the density of WSNs is high and there is an immensely colossal amount of redundant data transmitted in network being accumulated by nodes which are spatially close. In order to reduce the energy consumption, in-networking data aggregation is often executed for reducing the amount of data transmission by eliminating the innate redundancy in raw data accumulated by source sensor nodes. Essentially, data aggregation depends on where and when data meet together, that is, raw data accumulated by source nodes should be convergent in space and time. Routing plays an paramount role in data aggregation process. How to route data in order to achieve efficacious data aggregation is a paramount topic in WSNs. In event driven WSNs, a fine-tuned routing structure is not felicitous for data aggregation because it does not capitalize on the correlation between data to reduce data redundancy, resulting in immensely colossal data load. It is consequential to dynamically build routes overlapping as much as possible according to the events for efficient data aggregation.

Under mundane circumstances, the more proximate the nodes are apart, the more correlated data they amass and the higher the degree of data aggregation is, and the farther, the less and the lower. So, when the events are far apart, over-overlapping of routes will not gain benefit from data aggregation because of the low data correlation which averts high degree aggregation, but withal results in uneven energy consumption which leads to unstable network structure. A good routing protocol for data aggregation should overlap routes according to data correlation and local state and balance the energy consumption for the whole network in order to enhance the monitoring ability of WSNs. Here we propose a Novel Adaptive State-Aware Routing Algorithm for data aggregation (ASARA). Our algorithm constructs an adaptive routing tree with shortest paths predicated on
events and nodes’ local states, which can maximize data aggregation according to data correlation, well balance node energy consumption and route data in a reliable way.

II. RELATED WORK

For more preponderant data aggregation, cluster and tree structure are often utilized. The Low-Energy Adaptive Clustering Hierarchy (LEACH) [1] algorithm is the first work predicated on cluster, in which cluster-heads act as aggregation nodes and communicate directly with the Sink. Hybrid Energy-Efficient Distributed Clustering (HEED)[2] algorithm periodically culls cluster heads according to a hybrid of their residual energy and a secondary parameter (e.g. node degree), balancing load among cluster heads to elongate the lifetime of WSN. CPCP [3] is a coverage-vigilant clustering algorithm designed for applications with the coverage preservation requisites. Lejguo Yu et al. proposed EADC algorithm [4] to cope with clustering for non-uniform distributed WSN. Shortest Path Tree routing (SPT) [5] is one of the most typical routing strategies predicated on tree in WSNs. It makes each node transmit its accumulated data along the shortest path from itself to the Sink, with data aggregation occurring at any intersection of paths. All of the algorithms above do not consider the data correlation while clustering or building tree. DACP [6] makes full use of southerly data to avoid cluster heads decide whether send aggregated data or not, ameliorating the efficiency of data aggregation.

Aiming event-driven scenarios, the Information Fusion-predicated Role Assignment (InFRA) algorithm [7] clusters source nodes detecting the same event and maximizes the overlap of shortest paths from clusters to the Sink. Woo-Sung Jung et al. [8] Proposed a clustering technique predicated on the status of the network to ameliorate the data aggregation and energy efficiency. Leandro A. Villas et al. proposed the Dynamic and Scalable Tree (DST) [9] algorithm, which reduces the number of working nodes according to the correlation requisite of applications and maximizes the overlap of routes regardless of the order of event occurrence. Under the postulation of perfect aggregation for both of intra- and inter- event data, the routing optimization quandary for best data aggregation is equipollent to the Steiner Tree Quandary, DRINA [10] is a routing algorithm for data aggregation with the aim to find an approximate Steiner tree, with a reduced number of messages for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, and reliable data aggregation and transmission. When the postulation is not held, such quandary is no longer equipollent to finding the Steiner Tree. It involves many aspects, such as the correlation of data, load balance, duration of event, and so on. So, there are some shortcomings of DRINA as follows:

- The earlier the path is built, the heavier the load of the nodes on the path is. This will cause premature death of those nodes.
- It might cause some data to be transmitted along longer paths, which would increase the total energy consumption.
- It does not consider the correlation of events, and surmises that the data from different event areas could be aggregated impeccably (that is n packets could be aggregated into one packet), which is fictitious in many cases. For example, if two events are far apart, making their paths overlap cannot gain benefit from data aggregation because the data from the two events cannot be aggregated or can be aggregated just a diminutive, but leading to more imbalanced energy consumption on the overlapping part of the paths.

In this work, we amend DRINA and propose a novel Adaptive State-Aware Routing Algorithm for data aggregation (ASARA). ASARA utilizes the local states of nodes to build and update a Hop-Tree for data routing and aggregation, balancing energy consumption. It builds shortest paths from the events area to the Hop-Tree or the Sink predicated on the correlation between the events and the energy state of the Hop-Tree to compose incipient backbones of the Hop-Tree. It can maximize the overlapping of routes to achieve more preponderant data aggregation when events are in close proximity, abbreviate the data transmission paths while the correlation of events is low, and further balance the energy consumption of the Hop-Tree to enhance the network monitoring capabilities. Simulation results corroborate the efficacy of ASARA.

III. ALGORITHM FOR DATA AGGREGATION IN WSNS (ASARA)

A. Hop-Tree Building

In this work, a Hop-Tree rooted at Sink is composed after deploying sensor nodes, with the shortest paths (in hops) that connect all source nodes to the Sink while maximizing the possible data aggregation and balancing energy consumption. Each node has two parameters: HTT (Hop-To-Tree) and HTS (Hop-To-Sink), recording the minimum number of hops from the node to the Hop Tree and to the Sink respectively. The value of HTT for a node might be transmutted when the Hop-Tree updates because of some incipient events, while the value of HTS for each node does not change. At the beginning, the HTT and the HTS are equipollent, then different as events occur one after another. The HTT of the Sink and any node on the backbone of the Hop-Tree is 0. The farther the node is away from the backbone of the Hop-Tree, the more immensely colossal the HTT is. The HTT of any node vicissitudes in 2 cases: (a) it becomes a backbone node of the Hop-Tree, or (b) it receives a Hop Configuration Message (HCM) which promulgates more preponderant distance. HCM is a four-tuple as < Type, ID, HTT, State>, where Type designates HCM message, ID is the identifier of a node that commenced or retransmitted the HCM message, HTT is the distance by which an HCM message has passed, and State records the State of the sender.
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B. Cluster Formation
When an event occurs, a cluster predicated on the nodes which detect it (we may call them event nodes) will be composed. The key process of the cluster formation phase shown in Table II is the election of the bellwether node (called Coordinator) for the cluster, and the information distribution in this phase is by designates of Cluster Configuration Message (CCM). CCM is additionally a four-tuple: <Type, ID, HTT, State>, where ID is the identifier of the node that commenced the MCC message, HTT and State fields store the HTT and State value of the node with the identifier ID discretely. At the beginning, all event nodes are eligible candidates. Any node that has detected the event sets its role Coordinator, constructs a CCM message and sends it out, as shown in Lines 1-3. The node with the shortest path to the Hop-Tree will become the Coordinator, shown in Lines 5-7. If there are several nodes have the most minuscule HTT value, the one with the best state will be the final victor, detailed Lines 8-10. Other nodes in the event area will downgrade to the Collaborators.

C. Path Building
Each Coordinator, the elected group bellwether, commences establishing a path which will be the incipient part of the backbone of the Hop-Tree with the avail of Paths Building Message (PBM), Coerced Paths Building Message (FPBM) and Rebuilding Message (RM), all of which are 2-tuple: <Type, Path> where Path records the nodes in the path from the Coordinator to the backbone of the Hop-Tree or the Sink depending on the Type. If the Coordinator on the backbone of the Hop-Tree, there is no need to build a incipient path to act as an incipient backbone of the Hop-Tree. Otherwise, the Coordinator might engender a PBM message and sends the PBM to its next hop or enter the coerced path building phase according to the residual energy of the next hop.

D. Hop-Tree Update
A Hop-Tree should be updated for gaining shortest paths connecting all source nodes while maximizing data aggregation and balancing energy distribution as events occur piecemeal. We update the HTT value of each node congruously to achieve this goal.

E. Routes Maintaining
The Hop-Tree is unique, and any failure of nodes will cause disruption in data transmission. The route repair mechanism in DRINA algorithm is a kind of piggybacked, ACK-predicated mechanism, and it may cause such quandaries as a longer delay due to several faulty nodes in the path and routing loops. ASARA takes a pretreatment for route repair to settle those quandaries. By designates of periodic MAC communication, nodes can determine whether a neighbor dies or not. Any node that finds its next hop died culls a neighbor which has lower HTT level and more preponderant state as its next hop. If a node could not find a neighbor as its next hop, the node will set its HTT illimitability (called anomalous node) and apprise its neighbors to transmute their next hop if indispensable. When such case appears, it shows the local state around the node is impecunious.

IV. MODULES DESCRIPTION

A. Modules

Nodes Creation: The user can dynamically create any number of nodes in to a network. Those nodes are dynamically changed by time to time. The team coordinator is selected based on the position(the node which is near to sink node).

Data transfer (packets): The packets collected from the collaborator nodes are transferred to the team leader. The coordinator node performs the data aggregation and removes the redundant data.

View the Collected Data: In this module we can see the data collected by the team leader and the data which is shown is the result of data aggregation performed by team leader.

View Team Lead Information: The team leader is present in every event and there could be many team leaders in the path of data transmission. We can also see the changing team leaders information.

In-Network Aggregation: In network collecting the related data from neighbour nodes and send to the intermediate nodes.

B. Routing Protocols
In the context of WSN’s ,data aggregation aware routing protocols should present some desirable characteristics such as a reduced number of messages for setting up a routing tree, maximizing number of overlapping routes and high aggregation rate. User will upload the file and then it will send to sink node through intermediate nodes. The intermediate nodes which in between sink node and sender node, having the same node number are called collaborative nodes as follows:

Fig.1.
The intermediate node which is in between sink node and sender node, not having the node with same number beside it is called Event node and it will give the acknowledgement also as follows:

![Diagram]

Fig.2.

V. CONCLUSION

In this paper, we study the routing problems for facilitating data aggregation in event-driven WSNs, and propose a novel Adaptive State-Aware Routing Algorithm for data aggregation (ASARA) to improve the DRINA algorithm designed by Leandro Villas et al. ASARA builds a Hop-Tree based on sensor local state calculated with residual energy, memory and link packet loss rate which is more appropriate to heterogeneous WSNs. It utilizes TTL to limit the update scope for the Hop-Tree, making the paths for the events with high correlation overlap as early as possible to maximize the degree of data aggregation and ones for the events with low correlation avoid over-overlapping and curving to save data transmission energy. If the energy of nodes on the path, which is intended to be overlapped by the latter path, is low, ASARA will build a new path forcedly to avoid overlapping with the paths in poor state, in order to balance the data load. Theoretical analysis and experiments show that ASARA can maximize the possible data aggregation while balancing the energy consumption, making WSNs monitor more events.

VI. REFERENCES


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