An Effectual Routing Protocol for In-Network Aggregation in Wireless Sensor Networks

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ABSTRACT

The aggregation technique is used to limit the communication cost thereby extending the lifetime of the network. In this work, an alternate is made to resolve how the routing protocol is structured to improve an information-fusion. Heavy traffic occurs and nodes may get failed when multiple sensor nodes detect multiple events. The proposed INASDR (In-Network Aggregation Sensor Data Routing) algorithm minimizes the cost and also saves the resource consumption by constructing the dynamic routes in case of node failure and eliminates the redundant data. The performance of the INASDR compared to three other known routing protocols: The Data Routing for In-Network Aggregation (DRINA), the Information Fusion-based Role Assignment (InFRA) and Shortest Path Tree (SPT) algorithms. Objective: The proposed INASDR algorithm and correlate its performance with other three algorithm. INASDR exceeds other three whereas DRINA and InFRA exceeds SPT in the case of longer event duration alone. INASDR technique achieves 5 to 8% more energy consumption variation when compared to the existing system. This new INASDR Protocol is then compared to the SPT, and DRINA. The Simulation results give that the INASDR will efficiently and effectively minimizes the network delay. The proposed algorithm will outperform the other three algorithms with respect to minimal waiting time.

INTRODUCTION

A Wireless Sensor Network (WSN) contains hundreds or thousands of sensor nodes. Each sensor node is able to communicate together or directly communicate to an external base station (I. Akyildiz, Sankarasubramaniam, and E. Cyirci, 2002) (G. Anastasi, M. Conti, M. Francesco, and A. Passarella, 2009). Each sensor node has several parts radio transceiver, microcontroller and battery. The cost of the sensor nodes ranging from few to hundreds of dollars based on the complexity of the individual sensor nodes. Routing acts an important role in aggregation. In-network-aggregation is the process of collecting the information via multi hop network (A. Boukerche, R.B. Araujo, and L. Villas, 2007) and process the data at intermediate nodes and hence lifetime of the network gets increased. Two approaches are used as follows

With Size Reduction:

The process of compressing the information at different sources with the intension of reducing the information which in turn sends towards the networks (L.A. Villas, D.L Guidoni, R.B. Araujo, A. Boukerche, and A.A. Loureiro) (E.F. Nakamura, A.A.F. Loureiro, and A.C. Frey, 2007). For example, If multiple packets from multiple sources are received by a single node, then in spite of forwarding the multiple packets, it computes the average of all the multiple readings and sends a single packet.

Without Size Reduction:

It is the process of combining the packets from multiple sources and grouping into a same packet. For example, If two packets can carry different physical quantities, then these two packets are unable to process together. Even though it can’t be processed together, it can transmit it in a single packet.

In-Network Aggregation (E.F. Nakamura, A.A.F. Loureiro, and A.C. Frey, 2007) concept consists of three fundamental ingredients: Routing protocols, aggregation functions and data representations (Fig 1).

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Depending on the content of the packet (J. Al-Karaki and A. Kamal, 2004) (E. Fasolo, M. Rossi, J. Widmer, and M. Zorzi, 2007) the nodes can choose the packet to route and also choose the next hop to improve the in-network aggregation. The timing strategies are needed when sensor nodes report the readings to the sink node periodically.

The main functionalities of in-network aggregation technique is to combine the data arising from different nodes. Functions involved in this technique are Lossy and Lossless (J. Al-Karaki, R. Ul-Mustafa, and A. Kamal, 2004) (I. Solis and K. Obrazcka, 2004), Duplicate sensitive and Duplicate insensitive.

Fig. 1: In-Network Aggregation Techniques and their relation.

By using the in-network aggregation routing concepts SPT, InFRA, DRINA and INASDR algorithms play a vital role in delivering the packets to the sink.

Related Works:

SPT AND InFRA:

Shortest Path Tree (SPT) depends on a hierarchical structure of the nodes in the network (i.e.) tree based. Before routing takes place, tree structure should be framed. During routing, aggregation takes place. This approach is well suited for designing optimal aggregation function (J. Al-Karaki, R. Ul-Mustafa, and A. Kamal, 2004). Each node must know the shortest path of all the nodes in the network. Main drawback in this SPT algorithm is it requires fault tolerant mechanism. It follows distributed fashion in building the routing tree. Fig 2 shows the non-overlapping routes. No fusion takes place between the cluster data.

InFRA (Information fusion based role assignment) is a LRA (Local Role Assignment) (E.F. Nakamura, H.A.B.F. de Oliveira, L.F. Pontello, and A.A.F. Loureiro, 2006) (A.P. Chandrakasan, A.C. Smith, and W.B. Heinzelman, 2002). It is based on the assignment of neighbour states roles. To find a smaller transmission tree, LRA is used. Routing tree is defined to minimize the exchanged messages for detecting an event at the end of the role assignment. It contains hierarchical structure. Nodes contain several clusters. Among the several cluster, one node acts as a special node called (cluster head) (L. Villas, A. Boukerche, R.B. de Araujo, and A.A.F. Loureiro, 2010). By performing election algorithm, cluster heads are selected. Here there is a need of calculating the aggregated coordinator distance, to maximize the fusion.

The formula for calculating aggregated coordinator distance is as follows

\[
\text{dist} - \text{co}(v_i) = \sum_{u \in \text{CoordSet}} \text{distance}(v_i, u)
\]

Where distance \((v, u)\) is the distance between nodes \(v\) and \(u\) in terms of hops. In the Fig 3 shows that in the routing tree, after cluster gets formed, each and every coordinator passes the control message, coordinator distance is calculated. Here node H, X and O performs this function contiguously and reduce the collisions. After this process, node B can recognize that it is one hop distance from coordinator H, 4 hops from coordinator X and three hops from coordinator O. Therefore the total sum of all the distance is 8 hops. With the use of InFRA, node L and node F, aggregates data streams from nodes H and X and Land O respectively. Here Information fusion takes place either intra-cluster or inter-cluster fusion.
Drina:
Routing tree is constructed to improve the data aggregation using DRINA (Data Routing For In-Network Aggregation). Like InFRA algorithm (A.P. Chandrakasan, A.C. Smith, and W.B. Heinzelman, 2002), DRINA also assigns roles to the nodes.
- **Collaborator (Cluster Member):** It collects the raw data and forwards to a coordinator node when an event identifies.
- **Coordinator (Cluster Head):** Raw data is identified from the collaborator and is then aggregated and the results send to its sink.
- **Sink:** A node which is capable of receiving the data from both collaborator and coordinator.
- **Relay:** Receives data from another node and forwards sink.

This algorithm constructs the routing tree in terms of hops (Leandro Aparecido Villas, Azzedine Boukerche, Heitor Soares Rames, Horacio A.B. Fernandes de olivinerva, Regina Borges d Araujo and Antonio Alfredo ferrecia Loureiro, 2013). It involves three phases.

**A. Hop Tree Construction:**
Hop tree is constructed by sending HCM (Hop Configuration Message). This HCM consists of two fields: HopToTree Value and Node Identifier.

HopToTree value is a value which is a distance from the sink. It constructs the route depending on the minimum HopToTree value from the sink (Leandro Aparecido Villas, Azzedine Boukerche, Heitor Soares Rames, Horacio A.B. Fernandes de olivinerva, Regina Borges d Araujo and Antonio Alfredo ferrecia Loureiro, 2013). If already constructed, route has minimum HopToTree value than the present HopToTree value then the route never changes. Previous route must be preferable.

**B. Cluster Formation:**
After the hop tree construction, cluster election algorithm should be made. The main thing in this cluster formation is to select the cluster head. Based on the following paradigm: 1. Cluster head is a node which is immediate to the sink. 2. If one node is immediate to the sink, then the tie arises. Basically each node contains
the ID (identifier). The node which has least possible ID will revolve as a cluster head. 3. If tie arises, precedent constructed shortest route as a cluster head. This node is in turn dispatched to the neighbour Next Hop node. This process is reciprocated until all the nodes in the network have reached. After routes are established, HopTree is updated. Relay nodes are bonded for this process.

**Fig. 4: DRINA routing tree.**

**Proposed Work:**

INASDR (In-Network Aggregation for Sensor Data Routing) Algorithm increases the efficiency of sending the packets even in the case of node failure. It is similar to DRINA but it determines the node failure and chooses the alternative route dynamically and delivers the packets in a very little delay. The failure node is then recovered by route repair mechanism.

In this proposed routing approach, each node preserves a node vector functions. All the nodes can achieve a node probability vector. It increases the network lifetime effectively, decreases the delay and number of hop count.

**Node Vector Function Construction:**

Each node in the network sustains its own node vector function and this vector function emulates the network performance.

\[ \psi_j = |u_1 j|u_2 j| ... |u_{ij} ... |u_{Nj}| \]

Where \(|u_{ij}| is the node vector partition function. \(u_{ij}\) is again decomposed into 

\[ |u_{ij}| = M_1 e_1 + M_2 e_2 + ... + M_m e_m \]

\(E_1, E_2, E_m\) represents a set of linearly independent unit vector groups. \(M_i\) has shown the sensitivity.

**Dynamic route construction:**

The main important step in constructing the dynamic route construction is to formulate the applicable branch matrix and operation matrix. Operation matrix is built according to the adjacency matrix. Branch matrix is used for raising the probability of solution path and lowering the probability of non-solution path simultaneously (L.A. Villas, D.L Guidoni, R.B. Araujo, A. Boukerche, and A.A.Loureiro). After constructing branch and operation matrix, matrix operation is represented between them to optimize the probability of detecting solution path.

When a node requires determining the next hop, then operation and branch matrix is constructed based on the adjacency matrix.

**Table I: Comparision Of Spt, Infra, Drina And Inasdr**

<table>
<thead>
<tr>
<th>Schemes</th>
<th>Structure of the route</th>
<th>Availability of repair mechanism</th>
<th>Scalability</th>
<th>Drawback</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPT</td>
<td>Tree-based</td>
<td>No</td>
<td>High</td>
<td>Redundant data because opportunistic</td>
</tr>
<tr>
<td>InfRA</td>
<td>Cluster-based</td>
<td>No</td>
<td>Low</td>
<td>Communication cost high because of flooding</td>
</tr>
<tr>
<td>DRINA</td>
<td>Cluster-based and Hop Tree constructs</td>
<td>Yes</td>
<td>Medium</td>
<td>Not efficient for dynamic routes</td>
</tr>
<tr>
<td>INASDR</td>
<td>Cluster-based and Hop Tree constructs</td>
<td>Yes</td>
<td>High</td>
<td>Efficient for both static and dynamic routes</td>
</tr>
</tbody>
</table>
Simulation And Analysis:
In this section, the proposed INASDR algorithm is fixed its performance is correlated with other three algorithm. Table 1 shows the comparison of the basic characteristics of INASDR, DRINA, InFRA and SPT algorithm. (Leandro Aparecido Villas, Azzedine Boukerche, Heitor Soares Rames, Horacio A. B. Fernandes de olinervira, Regina Borges d Araujo and Antonio Alfredo ferrecia Loureiro, 2013). Following metrics are calculated to measure the performance.

Packet delivery rate:
PDR (Packer Delivery Rate) is expressed as a ratio of Total number of CBR(Constant Bit Rate) sent by all sources to the total number of CBR packets received by the sink.

\[ PDR = \frac{\sum \text{CBR packets sent by all sources}}{\sum \text{CBR packets received by a sink}} \]

Control overhead:
CO (Control Overhead) is expressed as the ratio of total number of control packets forwarded by the sender to the number of data packets delivered to the receivers.

\[ CO = \frac{\text{Total No of the control packets sent by te sender}}{\text{No of data packets delivered to the receivers}} \]

Efficiency:
The rate of total packets (both data and control packets) broadcasted to the number of data accepted by the sink node.

Routing tree cost:
In the structure of the routing tree, the cost is calculated by the number of edges constructed by the algorithm.

Loss of raw data:
The raw data may lose due to aggregation because of redundancy.

Loss of aggregated data:
The number of aggregated data is lost due to overload. This loss will greatly affect the network performance.

Transmission number:
Transmission number is the sum of the data transmits and control overhead.

\[ TN = DT + CO \]

To lengthen the network lifetime and consume the little energy consumption, a WSN is constructed to perform simulation using NS2.34 simulator. We scramble 50 nodes are randomly spread in 1500X1500 square area. The packet delivery rate is calculated by the above formula.

![Fig. 5: Transmission Cost of DRINA and INASDR.](image)

The transmission cost of end-to-end is illustrated using the existing DRINA and proposed INASDR Scheme. Fig 5 graph shows better performance of Proposed INASDR Scheme in terms of node than existing
DRINA Opportunistic Neighbor INASDR technique achieves 7 to 10% more cost consumption variation to when compared with DRINA.

The following graph Fig. 6 will illustrate the energy consumption of SPT, DRINA and INASDR. X-axis indicates the Time in milliseconds and Y-axis indicates the Energy in joules. Based on the above mentioned performance metrics, consumption is calculated.

![Energy Consumption Graph](image)

**Fig. 6: Energy Consumption of SPT, DRINA and INASDR.**

The interpretation shows that INASDR is more efficient than DRINA, and SPT. The proposed algorithm will outperform the other two calculated algorithm. Even though there are short-term events, INASDR exceeds other two whereas DRINA and SPT in the case of longer event duration alone. INASDR technique achieves 5 to 8% more energy consumption variation when compared to the existing system.

**Conclusion:**

A new dynamic routing protocol is proposed in accordance with the DSR (Dynamic Source Routing). Among the different nodes based on their network performance this new routing protocol (INASDR) will build the node vector function which will direct the communication state of the whole network. The High performance routes are selected by using this node vector function. Then routes are constructed dynamically and this new INASDR Protocol is then compared with the SPT, and DRINA. The Simulation results give that the INASDR will efficiently and effectively minimize the network delay. The proposed algorithm will outperform the other three algorithms with respect to minimal waiting time.

**REFERENCES**


