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Research Paper

SDRINA: SECURED AND RELIABLE DATA ROUTING APPROACH FOR IN-NETWORK AGGREGATION IN WIRELESS SENSOR NETWORKS

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The fundamental challenge in the design of Wireless Sensor Networks (WSNs) is to maximize their lifetime. Data aggregation has emerged as a basic approach in WSNs in order to reduce the number of transmissions of sensor nodes, hence minimizing the overall power consumption in the network. Data aggregation is affected by several factors, such as the placement of aggregation points, the aggregation function, and the density of sensors in the network. The determination of an optimal selection of aggregation points is thus extremely important. We present exact and approximate algorithms to find the minimum number of aggregation points in order to maximize the network lifetime. Our results clearly indicate that the routing tree built by SDRINA provides the best aggregation quality when compared to existing algorithms. The obtained results show that our proposed solution outperforms in different performance metrics and in different scenarios required by WSNs. We also study the tradeoffs between energy savings and the potential delay involved in the data aggregation process.

Keywords: In-network aggregation, Routing protocol, Wireless sensor networks, Clusters, Hop trees

INTRODUCTION

Information gathering is a fast growing and challenging field in today's world of computing. Sensors provide a cheap and easy solution to these applications especially in the inhospitable and low-maintenance areas where conventional approaches prove to be very costly. Sensors are tiny devices that are capable of gathering physical information like heat, light or motion of an object or environment. Generally, a sensor node does not have sufficient power to send the data or message directly to the base station. Hence, along with sensing the data the sensor node

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act as a router to propagate the data of its neighbour. In wireless sensor network, due to the high density of nodes, the redundant data will be detected by neighbouring nodes while sensing an event. In order to save energy all these redundant data will be aggregated at an intermediate node and then it will send to the sink node (Zhang *et al.*, 2011).

Wireless sensor network has some key constraints such as limited energy resources, lack of infrastructure. A possible strategy to optimize the routing task is to use the available processing capacity provided by the intermediate sensor nodes along the routing paths. This is known as data-centric routing or in-network data aggregation (Abdel Salam and Olariu, 2009; and Villas *et al.*, 2010). One of the main challenges in routing algorithms for WSNs is how to guarantee the delivery of the sensed data even in the presence of nodes failures and interruptions in communications. These failures become even more critical when data aggregation is performed along the routing paths since packets with aggregated data contain information from various sources and whenever one of these packets is lost a considerable amount of information will also be lost. In the context of WSN, data aggregation aware routing protocols should present some desirable characteristics such as: a reduced number of messages for setting up a routing tree, maximized number of overlapping routes, high aggregation rate and also a reliable data transmission. In order to overcome these challenges, in this work, we propose a novel Data Routing algorithm for In-Network Aggregation for WSNs, which we refer to as SDRINA algorithm (Chatzigiannakis *et al.*, 2005; and Villas *et al.*, 2010).

RELATED WORK

Routing Challenges and Design Issues in WSN

- Node deployment
- Energy consumption without losing accuracy
- Node addressing and location awareness
- Sensor network are mostly data centric
- Reliable data aggregation and transmission
- Node/link heterogeneity and network dynamics
- Transmission media
- Coverage area
- Scalability
- QoS

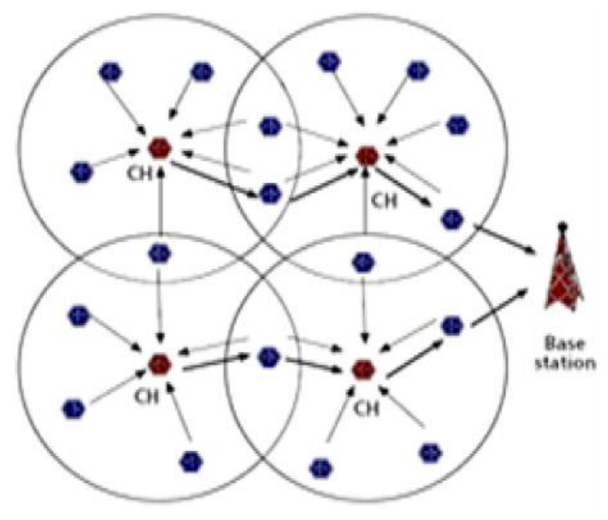
Hierarchical Routing Protocol

Traditional routing protocols for WSN may not be optimal in terms of energy consumption. Clustering techniques can be efficient in terms of energy and scalability (Jamal Al-Karaki and Ahmad Kamal, 2004). The objective of clustering is to minimize the total transmission power aggregated over the nodes. Every cluster selects a Cluster Head (CH) responsible for coordinating the data transmission among the nodes in a cluster, which collects the data and transmit it to the Base Station (BS) (Figure 1).

Main advantages of hierarchical routing protocols are:

- Minimization of intra-cluster and inter cluster energy consumption.
- Scalability and Prolong network life time.

Figure 1: Clustering of Sensor Network



- Reducing data packet delay.
- Handling node heterogeneity.

Existing System: Information Fusion-Based Role Assignment (InFRA)

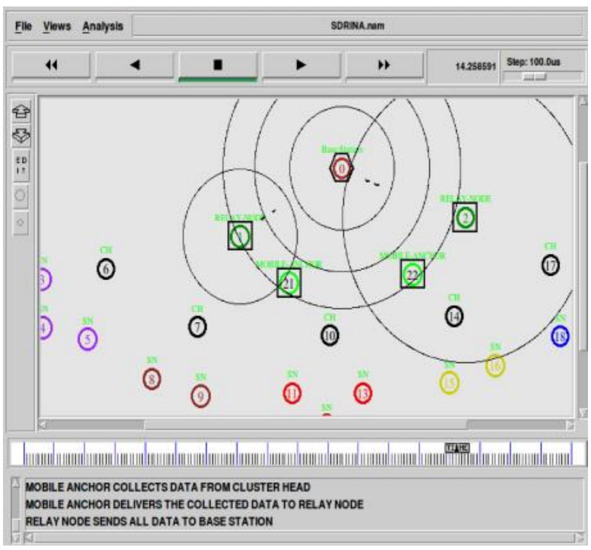
The Information Fusion-based Role Assignment (In-FRA) algorithm builds a cluster for each event including only those nodes that were able to detect it. Then, cluster heads merge the data within the cluster and send the result toward the sink node. The InFRA algorithm aims at building the shortest path tree that maximizes information fusion (Figure 2). A disadvantage of the InFRA algorithm is that for each new event that arises in the network, the information about the event must be flooded throughout the network to inform other nodes about its occurrence and to update the aggregated coordinators distance. This procedure increases the communication cost of the algorithm and thus limits its scalability (Nakamura *et al.*, 2006). In the context of WSN, data aggregation aware routing protocols should present some desirable characteristics such as: a reduced number of messages for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, reliable data transmission and also a route repair mechanism. In order to overcome these challenges, in this work, we propose a Secured and Reliable Data Routing algorithm for Network Aggregation in WSNs, which we refer to as SDRINA algorithm. Our proposed algorithm was conceived to maximize information fusion along the communication route in reliable way, through a fault-tolerant routing mechanism.

Figure 2: NAM Output of Existing System (InFRA)

Proposed System: SDRINA (Enhancement)

The proposed system presents a secure and reliable data gathering scheme, which ensures that the trajectory of the mobile anchor node minimizes the energy consumption of nodes and guarantees that all of the sensor nodes can retain higher energy levels, a single mobile anchor node moves randomly through the sensing field broadcasting periodic three

Figure 3: NAM Output of Proposed System (SDRINA)



beacon messages containing its current coordinates. The locations of the individual sensor nodes are determined by exploiting the fact that the perpendicular bisector of a chord of a mobile anchor passes through the center of the circle twice. The mobile anchor collects the data from sensor nodes (CHs) and delivers these aggregated data to the sink node through intermediate nodes (Figure 3).

SDRINA: SECURED AND RELIABLE DATA ROUTING FOR IN-NETWORK AGGREGATION IN WSNS

The main goal of DRINA is to build a routing tree and find out the shortest path which connects all source nodes to the sink, while maximizing the data aggregations. In SDRINA following roles are consider for building the routing tree (Leandro Villas *et al.*, 2013).

Collaborator: It is the node which detects an event and reports the collected data to the Coordinator node.

Coordinator: It is the node that also detect an event but after using election algorithm. This node is responsible for aggregating the collected data received from other collaborator and send aggregated results to the sink node.

Sink Node: This node is interested in receiving the data from set of coordinator nodes and collaborator node.

Relay Node: This is the intermediate node between Coordinator and Sink node and it is responsible for forwarding data toward the Sink.

Mobile Anchor: This node is responsible for coordinating the location of each Cluster members and it collects the data from Coordinator (CHs) and delivers these aggregated data to the Sink node through intermediate nodes.

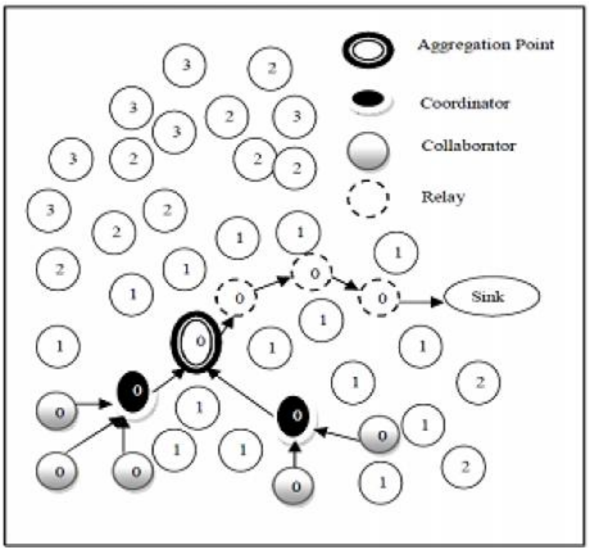
SDRINA algorithm is divided into five phase:

1. Constructing the Hop tree from sensor nodes to the Sink node.
2. Cluster formation and electing a cluster head among the Collaborator which becomes a Coordinator.
3. Setting up a route for reliable delivery of data packets and updating the hop tree.
4. Secure and Reliable Data gathering scheme.
5. Route Repair Mechanism.

Constructing the Hop Tree

Hop tree is constructed from sensor node to the Sink node. The distance is computed in hops from the sink node to each node in the network. The Sink node sends Hop Configuration Message (HCM) to all nodes

Figure 4: SDRINA Routing Tree Establishment and Updating



through flooding. This is the distance through which the HCM message has passed called HopToTree. The initial value of HopToTree is 1 at the sink. This HCM message is passed to its neighbours, when receiving this message, each node verifies if the stored HopToTree value is greater than the value of HopToTree in the received HCM message. If the condition is true then the node updates the stored HopToTree value with the value in the HCM message else the node discards the received HCM message (Figure 4).

Cluster Formation

Formation of cluster and cluster head election algorithm should be done when one or more nodes detect the same event. All sensing nodes are eligible for this election. Cluster Head will be one that is closest to the Sink node or node that is closest to an already established route. In case of a tie, i.e., two or more concurrent nodes have the same distance in hops to the sink (or to an established route) then Energy level is used as a tiebreak criterion. Based on the result of this algorithm, roles are assigned to the nodes. Elected leader will be declared as the Coordinator and remaining nodes that detect the same event will be the Collaborators. The advantage of this algorithm is that the information collected by the nodes which are sensing the same event will be aggregated at the single point (called aggregation point) which is more efficient.

Routing Formation and Hop Tree Updates

New route is established by the Coordinator for the event dissemination. To establish the route, Coordinator sends a route establishment message to its NextHop node. When this node receives a route establishment message, it establishes the route and forwards the message to its NextHop, after the route establishment, HopToTree updating process is started. The main aim of this phase is to update the value of the HopToTree in all nodes so that newly established route can taken into consideration. Relay nodes are responsible for this process. Each node will send only one packet so that the whole cost of this process is same as flooding.

Secured and Reliable Data Gathering Scheme

Mobile anchor is responsible for coordinating the location of each Cluster members. It minimizes the energy consumption of nodes and guarantees that all of the sensor nodes can retain higher energy levels, a single mobile anchor node moves randomly through the sensing field broadcasting periodic three beacon messages containing its current coordinates and it collects the data from

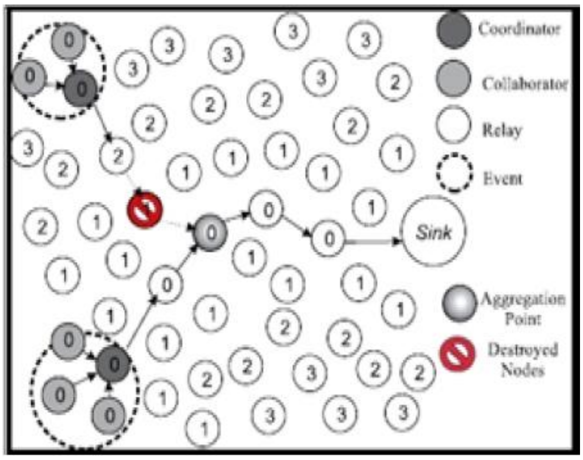
Coordinator and delivers to Sink node. The closer the event take place, the lower the communication cost, thus the best case will be achieved when the events happen on the routing tree, and mobile anchor is responsible for this action.

Route Repair Mechanism

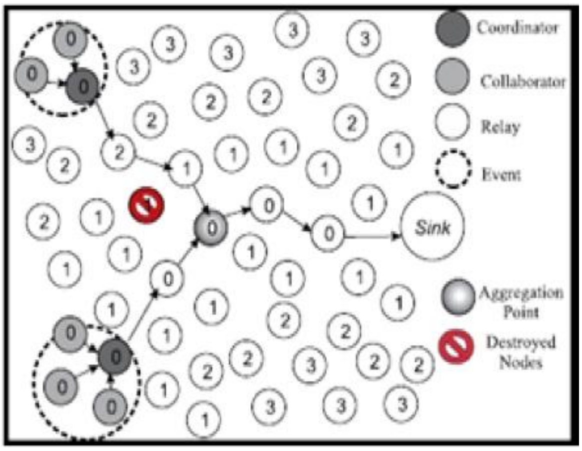
A route repair mechanism is used to send information in a reliable way. SDRINA algorithm has piggybacked and ACK-based route repair mechanism, which consists of two parts: failure detection at the NextHop node, and selection of a new NextHop. When a relay node needs to forward data to its NextHop node, it simply sends the data packet, sets a timeout, and waits for the retransmission of the data packet by its NextHop. This re-transmission is also considered an ACK message. If the sender receives its ACK from the NextHop node, it can infer that the NextHop node is alive and, for now, everything is ok. However, if the sender node does not receive the ACK from the NextHop node within the predetermined timeout, then it recognizes that particular node get failed and another one should be selected as the new NextHop node. For this, the sender chooses the neighbor with the lowest hop-to-tree level to be its new NextHop; in case of a tie, it chooses the neighbor with the highest energy level. A newly reconstructed path is created after the repairing mechanism is used for retransmission, as shown in Figures 5a-5b.

Figure 5: Example of Path Repair

(a) Region with Destroyed Nodes



(b) Repaired Path



RESULTS AND ANALYSIS

The simulations were performed using Network Simulator-2 (Ns-2), particularly popular in the wireless networking community. The traffic sources are Continuous Bit Rate (CBR). The source-destination pairs are spread randomly over the network. The mobility model uses 'random waypoint model'

Table 1: Simulation Parameters

Parameter	Value
Simulator	Network Simulator-2
Simulation area	700 x 700
No. of nodes	30
Communication radius (m)	50
Initial energy (J)	100
Traffic type	CBR (UDP)
Node placement model	Random waypoint

in a rectangular filed of 700 m x 700 m with 20-30 nodes.

This section presents the performance evaluation for SDRINA. Since SDRINA is an improvement on InFRA, we compare both these existing and proposed algorithm using the following performance metrics:

Throughput

This metric indicates that the packets per processed data, Figure 6, shows a graph for the InFRA and SDRINA algorithm on the basis of throughput as a function of pause time and using different number of traffic sources. It is the rate between the total packets transmitted (data and control packets) and the number of data packet received by the sink. It is cleared that SDRINA out performs than InFRA. This is because SDRINA has the route repair mechanism and due to that number of successful and reliable data transmission rate increases.

Packet Delivery Rate (PDR)

This metric indicates that the rate at which number of packets that reaches the sink node, in the SDRINA algorithm data packet transmission increases when the aggregation rate increases in the built tree, SDRINA has a better aggregation rate than InFRA this is due to the fact that lost packets with aggregated data are retransmitted. On the other hand, in InFRA it does not retransmit the data packets which are lost due to communication failures (Figure 7).

Figure 6: Throughput

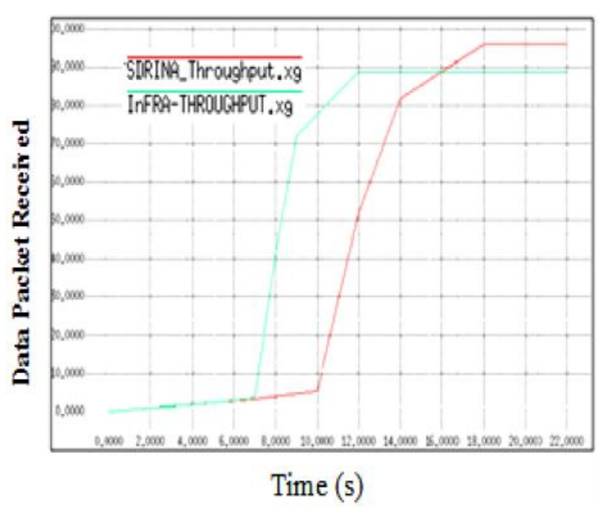
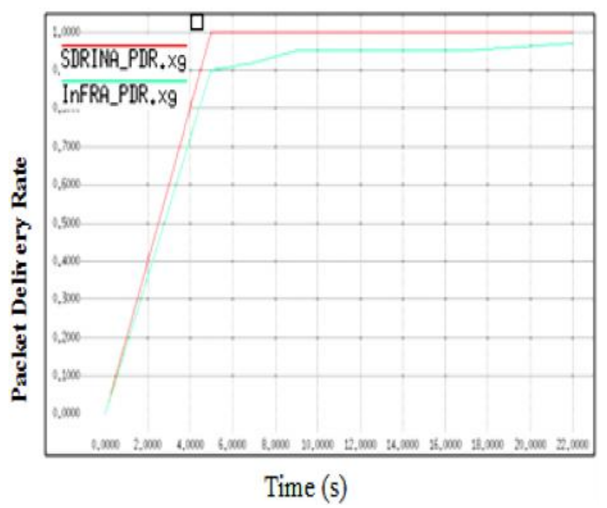


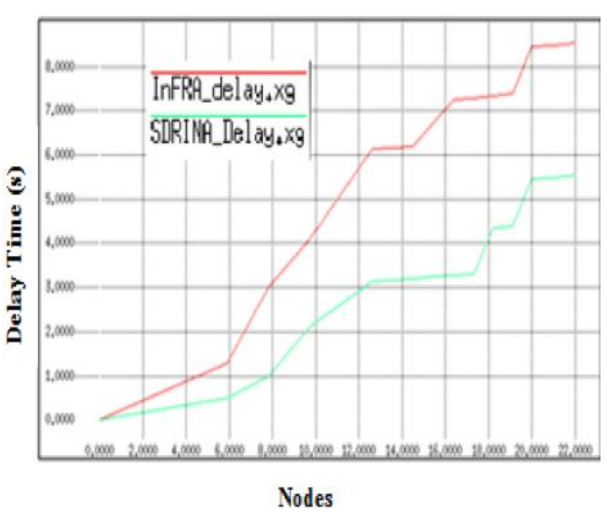
Figure 7: Packet Delivery Rate (PDR)



End To End Delay

This metric indicates the quality of the routing tree built by the algorithms, the delay time

Figure 8: End to End Delay

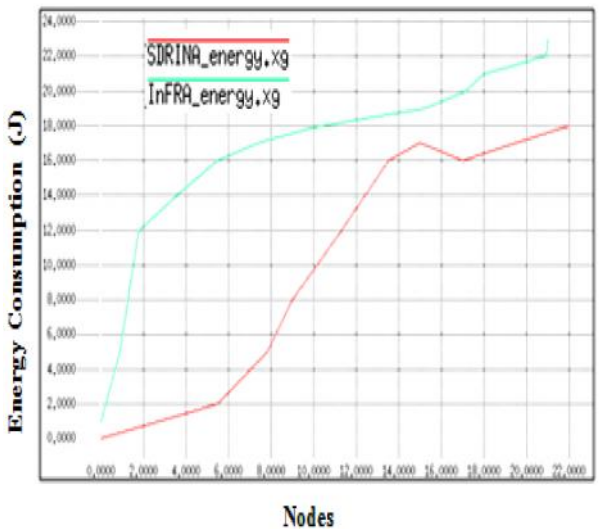


decrease when the probability of the communication failure decreases. For best case scenario i.e., when probability of communication failure is less InFRA has less delay time. For worst case scenario i.e., when probability of communication failure is high then SDRINA exhibits the less delay time and has better compared to InFRA this is due to SDRINA has route repair mechanism which leads less communication failure (Figure 8).

Energy Consumption

Energy consumption is the total energy consumed by the total number of edges in the routing tree structure built by the algorithm. Energy consumption in SDRINA is less this is because it needs less control messages to build the routing tree when compared to InFRA, in SDRINA fault tolerant and In-networking aggregation can often be used to decrease the communication cost by eliminating redundancy and forwarding only smaller aggregated information. Since minimal communication load and less probability of communication failure leads directly to energy savings, which extends the network lifetime (Figure 9).

Figure 9: Energy Consumption



An aggregation aware routing protocol plays an important role in event-based WSNs. The goal of this performance evaluation is a comparison between InFRA and SDRINA data aggregation routing protocols. SDRINA in our simulation experiment shows to have the overall best performance, SDRINA performs better at high packet delivery rate, has a high throughput and better performs in both energy savings, routing delay as compared to InFRA.

Table 2: Performance Comparison

Parameters	Existing System (InFRA)	Proposed System (SDRINA)
Routing Category	Cluster based	Tree-based Cluster
Aggregation node	Cluster heads and Relay nodes	Cluster heads, Mobile anchor and Relay nodes
Scalability	Low	High
Route Repair mechanism	No	Yes
Facts	Maximize overlap routes	Reliable routing and Minimization of delay and energy consumption
Findings	Low scalability and high overhead	Less efficient for dynamic routes

CONCLUSION

In this work we present the secured aggregation aware routing protocol SDRINA in order to achieve two main goals secured, reliable data transmission and increase the energy savings. By maximizing the aggregation points and offering a fault tolerant mechanism can eliminate the redundant transmission which leads reduced communication load. The obtained results clearly show that SDRINA outperformed the existing data aggregation algorithms for different metrics.

The proposed algorithm has some key aspects required by WSNs aggregation aware routing algorithms such as a reduced number of messages for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, secured and reliable data aggregation and transmission. As future work, DRINA performs efficient only in the case of static events of fixed radius. Our future work may consider the Dynamic sizes of events. New strategies will be devised to control the waiting time for aggregator nodes based on two criteria: average distance of the event coordinators, spatial and semantics event correlation.

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REFERENCES

1. AbdelSalam H S and Olariu S (2009), "A Lightweight Skeleton Construction Algorithm for Self-Organizing Sensor Networks", Proc. IEEE Int'l Conf. Comm. (ICC), p. 5.
2. Al-Karaki J and Kamal A (2004), "Routing Techniques in Wireless Sensor Networks: A Survey", *IEEE Wireless Comm.*, Vol. 11, No. 6, pp. 6-28.
3. Al-Karaki J, Ul-Mustafa R and Kamal A (2004), "Data Aggregation in-Wireless Sensor Networks-Exact and Approximate Algorithms", Proc. High Performance Switching and Routing Workshop (HPSR'04), pp. 241-245.
4. Akyildiz I F, Su W, Sankarasubramaniam Y and Cyirci E (2002), "Wireless Sensor Networks: A Survey", *Computer Networks*, Vol. 38, No. 4, pp. 393-422.
5. Anastasi G, Conti M, Francesco M and Passarella A (2009), "Energy Conservation in Wireless Sensor Networks: A Survey", *Ad Hoc Networks*, Vol. 7, No. 3, pp. 537-568.
6. Boukerche A, Araujo R B and Villas L (2007), "Optimal Route Selection for Highly Dynamic Wireless Sensor and Actor Network Environment", Proc. 10th ACM Symp. Modeling, Analysis, andSimulation of Wireless and Mobile Systems (MSWiM'07), pp. 21-27.
7. Boukerche A, Turgut B, Aydin N, Ahmad M Z, Boloni L and Turgut D (2011), "Survey Paper: Routing Protocols in Ad Hoc Networks: A Survey", *IEEE Computer Networks*, Vol. 55, pp. 3032-3080.
8. Chatzigiannakis I, Nikoletseas S and Spirakis P G (2005), "Efficient and Robust Protocols for Local Detection and Propagation in Smart Dust Networks", *Mobile Networks and Applications*, Vol. 10, Nos. 1/2, pp. 133-149.
9. Fasolo E, Rossi M, Widmer J and Zorzi M (2007), "In-Network Aggregation Techniques for Wireless Sensor Networks: A Survey", *IEEE Wireless Comm.*, Vol. 14, No. 2, pp. 70-87.
10. Hu F, Cao X and May C (2005), "Optimized Scheduling for Data Aggregation in Wireless Sensor

Networks", Proc. Int'l Conf. Information Technology: Coding and Computing (ITCC'05), pp. 557- 561.

11. Intanagonwiwat C, Govindan R, Estrin D, Heidemann J and Silva F (2003), "Directed Diffusion for Wireless Sensor Networking", *IEEE/ACM Trans. Networking*, Vol. 11, No. 1, pp. 2-16.

12. Jamal N Al-Karaki and Ahmad E Kamal (2004), "Routing Techniques in Wireless Sensor Networks: A Survey", *IEEE Wireless Communications*, December.

13. Krishnamachari B, Estrin D and Wicker S B (2002), "The Impact of Data Aggregation in Wireless Sensor Networks", Proc. 22nd Int'l Conf. Distributed Computing Systems (ICDCSW'02), pp. 575- 578.

14. Leandro Villas, Azzedine Boukerche, Heitor S Ramos, Horacio A B F de Oliveira, Regina B de Araujo and Antonio A F Loureiro (2013), "DRINA: A Lightweight and Reliable Routing Approach for In-Network Aggregation in Wireless Sensor Networks", *IEEE Computer Networks*, Vol. 62, No. 4, pp. 676-689.

15. Nakamura E F, de Oliveira H A B F, Pontello L F and Loureiro A A F (2006), "On Demand Role Assignment for Event-Detection in Sensor Networks", Proc. IEEE 11th Symp. Computers and Comm. (ISCC'06), pp. 941-947.

16. Nakamura E F, Loureiro A A F and Frery A C (2007), "Information Fusion for Wireless Sensor Networks: Methods, Models, and Classifications", *ACM Computing Surveys*, Vol. 39, No. 3, pp. 9-1/9-55.

17. Solis I and Obraczka K (2004), "The Impact of Timing in Data Aggregation for Sensor Networks", IEEE Int'l Conf. Comm., Vol. 6, pp. 3640-3645.

18. Villas L, Boukerche A, de Araujo R B and Loureiro A A F (2010), "Highly Dynamic Routing Protocol for Data Aggregation in Sensor Networks", Proc. IEEE Symp. Computers and Comm (ISCC), pp. 496-502.

19. Zhang H, Li L, Yan X and Li X (2011), "A Load Balancing Clustering Algorithm of WSN for Data Gathering", 978-1-4577-0536-6/11, IEEE.