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Research Article

Energy Efficient Approach for In-Network Aggregation in Wireless Sensor Networks

Ameya S. Bhatlavande† **and Amol A. Phatak**‡

†Computer Science & Engineering, NBNSCOE, Solapur University, Maharashtra, India

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Abstract

The term Wireless Sensor Network (WSN) is nothing but collection of small sensor devices without any physical infrastructure used for communication. The communication in this network is done by radio frequencies and wireless routing. In WSN, data aggregation is main task which is used to collect information from sensor nodes on behalf of sink node. In-network aggregation is nothing but global process of gathering and routing information through a multihop network, processing data at intermediate nodes with the objective of reducing resource consumption (in particular energy), thereby increasing network lifetime. For efficient data aggregation there are many methods presented by researchers with goal of improving energy efficiency. DRINA was the recent and most efficient technique for In-network aggregation for wireless sensor networks in terms of scalability, delivery efficiency, aggregation rate, and aggregated data delivery rate. DRINA has delivered the best performances against the existing methods like SPT. In this paper we are instigating the performances of DRINA approach by extending for routing efficiency. We will presented the evaluation of this proposed DRINA against the SPT in terms of average throughput, end to end delay, packet delivery ratio and average energy consumption for scalable and varying network scenarios. For routing efficiency we proposed new algorithm as addition in DRINA. Hence this new protocol is named as Improved DRINA (IDRINA). Our simulations studied with carry using NS2.

Keywords: *The DRINA, Data Aggregation, Sensor Nodes, WSN, SPT, Energy Consumption, Throughput*

1. Introduction

There are number of research are going over wireless sensor networks [WSNs] day by day all over world due to its usability in many real time applications like security, forecasting, military, hospital etc. Wireless sensor networks are being used in various applications, initially for military networks as well as in other areas like environment, health, habitat monitoring and commercial purposes. With the recent break-through of "Micro Electro Mechanical Systems (MEMS)" technology (E. Cohen *et al*, 2004) whereby sensors are becoming smaller and more versatile, WSN promises many new application areas in the future. WSN is resource constrained network, and hence this is main reason for different research ideas or methods presented by researchers. Resource constrained WSN is becomes interesting research problem for many researchers since from last two decades. Sensor nodes in WSN are tiny and hence very limited battery power. If battery of sensor node finishes, it means network is failed due to nodes expiry. To use this energy of sensor nodes efficiently with goal of extending the WSN lifetime, many methods have been presented so far.

*Corresponding author **Ameya S. Bhatlavande** is a Research Scholar **and Amol A. Phatak** is working as HOD

Data aggregation is technique used in WSN for reducing the energy consumption. Data aggregation minimizes redundant data which in turn reduces the number of packets transmitted to the base station resulting in conservation of energy and bandwidth. Since data aggregation transmits only the useful or resultant information to the end point, the problem of network congestion, traffic implosion and overlap can be overcome (A. Sharaf *et al*, 2004). In classic flooding, nodes do not modify their activities based on the amount of energy available to them at a given time. Data aggregation techniques make the nodes of the network to be "re-source-aware", i.e. adapt their communication and computation to the state of their energy resources.

The main goal of data aggregation is to collect and 'combine' data in an energy efficient manner so that the lifespan of the WSN is maximized. The design of an efficient data aggregation algorithm is a challenging re-search problem.

In the start, in-network aggregation techniques involved different ways to route packets in order to combine data coming from different sources but directed towards the same destination(s). In other words, these protocols were simply routing algorithms which differed from more traditional ad hoc routing protocols in the metric they used to select the routing paths. More recently, many additional studies have been published, addressing not only the routing problem but also mechanisms to represent and combine data more efficiently. In-network data aggregation is a complex problem that involves many layers of the protocol stack and different aspects of protocol design, and a characterization and classification of concepts and algorithms is still lacking in the literature.

From our study we noticed that in-network data aggregation having its key elements such as data dissemination and query mechanisms (with particular focus on the routing and MAC layer), aggregation functions, and data structure. Due to its varying nature, in-network aggregation concerns several layers of the protocol stack, and any efficient solution is likely to require a cross-layer design. But we note that most of the existing research focuses on networking issues such as routing, often considering only very simple approaches to aggregate data. In addition, much work still remains to be done to provide cross-layer solutions, accounting for application, data representation, routing and MAC aspects. In fact, the schemes proposed so far often focus on only a subset of these aspects, typically trying to merge routing and data aggregation techniques, but ignoring MAC, application or data representation issues. Finally, another aspect still not deeply investigated concerns the memory and the computational resources allow to sustain data aggregation processing.

Therefore during this paper we are focusing on in-network aggregation and data management in WSNs. These techniques allow to trade off communication for computational complexity. Given the application area, network resource constraints, and the fact that local computation often consumes significantly less energy than communication, in-network data aggregation and management are at the very heart of sensor network research. In particular, resource efficiency, timely delivery of data to the sink node, and accuracy or granularity of the results is conflicting goals and the optimal tradeoff among them largely depends on the specific application. Thus to overcome above said issues with existing techniques, recently many other approaches are presented as we studied in (Leandro *et al,* 2013). DRINA (Leandro *et al,* 2013) recently presented. However DRINA further needs to be investigated as well as extended by considering the vital network performance parameters like average throughput, end to end delay, packet delivery ratio and the most important factor is average energy consumption. In this paper we are further presenting the new version of this DRINA method called EDRINA (Extended DRINA). In next section II we are presenting the literature review on the various opportunistic routing protocols presented for mobile ad hoc networks. In section III, the proposed approach and its system block diagram is depicted. In section IV we are presenting the practical analysis and comparative results with discussions. Finally conclusion and future work is predicted in section V.

2. Literature Survey

During this section we are presenting previous research work done over network data aggregation for efficient utilization of energy in WSN.

In (E. Cohen *et al,* 2004), authors presented first improvement to a simple data aggregation function to take into account the spatial correlation. In this strategy, the dependence on the distance among nodes is quantified by a decay function which may, e.g., decay exponentially with an increasing hop distance (E. Cohen *et al,* 2004). During the data aggregation, each reading is weighed by a decaying factor which decreases with the distance to its source. The framework can be extended by additionally accounting for temporal and semantic correlation. However, this remains an open and mostly unaddressed issue.

In (A. Sharaf *et al,* 2004), authors presented TiNA [Temporal coherency-aware in-Network Aggregation] (A. Sharaf *et al,* 2004). (TiNA) works on top of a routing tree (i.e., TAG or Cougar, see Section IV-A) having the data gathering point (sink) as its root. It exploits the temporal correlation in a sequence of sensor readings to reduce energy consumption by suppressing those values that do not affect the expected quality of the aggregated data.

In (E. Cayirci,2003), authors presented DADMA Data Aggregation and Dilution by Modulus Addressing (DADMA) is a distributed data aggregation and dilution technique for sensor networks where nodes aggregate or dilute sensed values according to the rules given in an SQL statement. DADMA treats a wireless sensor network as a distributed relational database.

In (T. Abdelzaher *et al,* 2004), authors presented the data Aggregation by means of Feedback Control. The authors of define a strategy to tune the degree of data aggregation while maintaining specified latency bounds on data delivery and minimizing the energy consumption. They consider time-constrained reference scenarios dealing with real-time applications which impose specific time constraints to the delivery of sensor measurements. Data is grouped into different classes associated with different bounds on the delivery time. The aim is to guarantee the delivery of all data at the minimum energy cost while satisfying all time constraints. The data aggregation degree is adapted accordingly to meet these requirements.

In (S. Nath *et al,* 2004) authors presented the synopsis Diffusion Framework (S. Nath *et al,* 2004): A recent solution to the data aggregation problem has been proposed. The main contribution of the paper is to define aggregation functions and data structures which are robust to considering the same sensor readings in the data aggregation process multiple times (double-counting problem). This is crucial when data aggregation is used in conjunction with multi-path routing schemes.

In (F. Hu *et al,* 2005), Author has analyzed the issue of timing when aggregating data in Wireless Sensor Networks. They have shown, both through mathematical analysis and simulation that their proposed protocol can save energy by reducing the amount of data transmitted in a WSN.

In (I. Solis *et al,* 2004), this paper evaluates the effect of timing in data aggregation algorithms. In-network aggregation achieves energy-efficient data propagation by processing data as it flows from information sources to sinks. The main goal was to show that the decision of when to "clock out" data as it is processed by nodes have significant performance impact in terms of data accuracy and freshness.

In (B. Krishnamachari *et al,* 2002), this paper author model data-centric routing and compare its performance with traditional end-to-end routing schemes. It was examined the impact of source-destination placement and communication network density on the energy costs and delay associated with data aggregation. It was shown that data-centric routing offers significant performance gains across a wide range of operational scenarios.

Since it is an NP-hard problem, some heuristics for the Steiner tree problem can be found in the literature. Approximate solutions to the problem are presented in (J. Al-Karaki *et al,* 2002) and (G. Robins *et al,* 2000). However, these solutions are not appropriate for resource-constrained networks, such as WSNs, since their distributed implementation require a large number of messages exchange when setting up the routing tree and, consequently, resulting in high energy consumption.

3. Proposed Methodology

3.1. Problem Definition

From recent study, different methods presented for in-network data aggregation in WSNs. In (Leandro *et al,* 2013) author presented a novel Data Routing for In-Network Aggregation, called DRINA, that has some key aspects such as 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. The proposed DRINA algorithm was extensively compared to two other known solutions: the Information Fusion-based Role Assignment (InFRA) and Shortest Path Tree (SPT) algorithms. The results presented their clearly showing that the routing tree built by DRINA provides the best aggregation quality when compared to these other algorithms. Authors have checked the performance of DRINA for data packets, overhead, tree cost as well as efficiency those can only define the efficiency of this method for network scalability, communication costs, delivery efficiency, aggregation rate, and aggregated data delivery rate as compared to existing one. However, along with just building efficient In-Network Aggregation method routing efficiency is also most important factor to decide the best method further. There is still ambiguity as per as networking and routing performance of DRINA.

3.2. Proposed Method

To address the research problem associated existing methods for data aggregation in WSN, in this paper we introducing the hybrid method called IDRINA for routing efficiency and energy efficiency. As per stated in problem definition, DRINA was the recent and most efficient technique for In-network aggregation for wireless sensor networks in terms of scalability, delivery efficiency, aggregation rate, and aggregated data delivery rate. DRINA has delivered the best performances against the existing methods like SPT. However the throughput of DRINA protocols not shows the improvements in energy efficiency more. Therefore in this paper we are using energy efficiency algorithm for improving performances. Below figure 3.1 is showing the architecture of proposed work.

3.3. Algorithms

3.3.1. DRINA Fundamentals

DRINA method is divided into three phases.

- In Phase 1, the hop tree from the source nodes to the sink nodes is built. In this phase, the sink node starts building the hop tree that will be used by Coordinators for data forwarding purposes.
- Phase 2 consists of cluster formation and cluster-head election among the nodes that detected the occurrence of a new event in the network.
- Finally, Phase 3 is responsible for both setting up a new route for the reliable delivering of packets and updating the hop tree.

For all three phase below algorithms are used:

Algorithm 1: Tree Formation Algorithm
Notations
HCM: Hop Configuration Message
HTT: HopeToTree
1. The Sink floods an HCM message with HTT=1;
2. For each node u that received an HCM message
3. If HTT(u)> HTT(HCM)
4. NH(u)=ID(HCM); % NH (u) stores the next hop of node u
5. HTT (u)=HTT (HCM);
ID(HCM)=ID(u);
HTT (HCM)= HTT (u)+1;
State(HCM)=State(u);
6. u transmits the HCM message to its neighbors;
7. Else If (HTT (u)==HTT (HCM) & State(NH(u))< State(HCM))
8. NH(u)=ID(HCM);

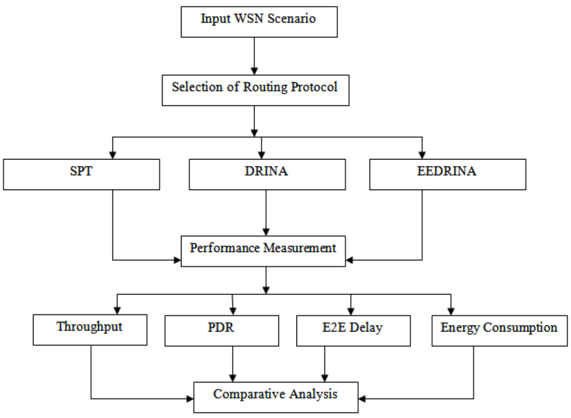

Fig 3.1: Proposed System Architecture

Algorithm 2: Cluster Formation Algorithm

Description: When an event occurs, a cluster based on the nodes which detect it (we may call them event nodes) will be formed. The key process of the cluster formation phase shown in Table II is the election of the leader node (called Coordinator) for the cluster, and the information delivery in this phase is by means of Cluster Configuration Message (CCM). CCM is also a four-tuple: < Type, ID, HTT, State>, where ID is the identifier of the node that started the MCC message, HTT and State fields store the HTT and State value of the node with the identifier ID separately.

Notation:

CCM: Cluster Configuration Message
1. For each node u that detected the event
2. Role(u)=Coordinator;
3. u creates an CCM and broadcasts it;
4. For each node u that received a CCM message of the same event
5. If HTT (CCM)<HTT(u)
6. Role(u)=Collaborator;
7. u retransmits the CCM;
8. Else If HTT(CCM)==HTT(u) & State (CCM)>State (u)
9. Role(u)=Collaborator;
10. u retransmits the CCM

Algorithm 3: Route Establishment and hope Tree Update Algorithm

1. If HTT(v)==0 %Node v is a Coordinator
2. There is no need to build path;
3. Else If Energy(NH(v))<Threshold_Energy& Node v can find a neighbor who satisfies: a) its residual energy is greater than Threshold_Energy, b) with less HTS.
4. v informs (or sends a RM along the Path in reverse direction to inform) the nodes within event field to enter the Forced Path Building phase.
5. Else
6. v appends itself to the Path and sends a PBM message to its next hop;
7. For each node u that received a PBM message
8. If HTT (u)==0
9. Path building successes,;
10. Else
11. u acts similarly to the behaviors shown in the Lines 3-6. % Forced Path Building phase
12. The node with the smallest HTS and best state in the event field will be chosen as the new Coordinator, denoted by u
13. NH(u)=v, v is a neighbor of u with the less HTS and best state;
14. u appends itself to the Path and sends a FPBM to its next hop;
15. For each node w received an FPBM message
16. If w==Sink
17. Forced path building successes.
18. Else
19. w acts similarly to the behaviors shown in the Lines 13-14.

3.3.2. ECORMAN Algorithm

Algorithm 4: Energy Efficient DRINA (EEDRINA) Algorithm

For a packet P, we use hc(P) and lvl(P) to represent the two additional fields of the packet, respectively. The algorithm needs to access other fields in a packet, such as the source, destination, sender and sequence number. Similarly, in the algorithm, they are represented by s(P), d(P), nid(P) and seq(P). We use s-d (P) to represent the source-destination pair of the flow that the packet belongs to. An "overhear table" is maintained at each node.

Notations used:

s(P): Source of packet
d(P): Destination of packet
nid(P): Sender of packet
seq(P): Sequence number of packet
s-d (P): Source-Destination pair of current flow
Algorithm: When node i overhears packet P,
BEGIN
Step 1: Lookup s-d (P) in overhear table;
Step 2: IF no match, add entry e': s-d(e')=s-d(P), seq(e')=seq(P), ov-list(e') initialized with first entry <hc(P),lvl(P),nid(P)>. GOTO END;
Step 3: (Assume a match is found at entry e.) IF seq(P)<seq(e), ignore P. GOTO END;
Step 4: IF seq(P)>seq(e), update e as the following:
seq(e)=seq(P), ovlist(e) reset as having only one

entry<hc(P),lvl(P),nid(P)>. GOTO END;
Step 5: IF seq(P)==seq(e), do the following:
Step 5.1: Add entry <hc(P),lvl(P),nid(P)> into ovlist(e);
Step 5.2: IF ovlist(e) has three entries A, B, C satisfying the following conditions, a better sub-path is found.
1)hc(C)==hc(B)+1==hc(A)+2;
2)lvl(node i)≥MAX(lvl(A),lvl(C));
3) (lvl(node i)-lvl(B))≥2. Activate this new subpath. Delete entry e from overhear table. GOTO END;
Step 5.3: IF ovlist(e) has two entries A and B, such that hc(B)==hc(A)+1 and lvl(node i) ≥ MAX(lvl(A),lvl(B)+2), add this indicator I in the WaitingIndicator list: candidate(I)=B, seq(I)=seq(e), s-d(I)=s-d(e). GOTO END;
Step 5.4: IF ovlist(e) has two entries B and C, such that hc(C)==hc(B)+1 and lvl(node i) ≤ MAX(lvl(B)+2,lvl(C)), node i broadcast one DRINA informing packet Q as follows: candidate(Q)=B, seq(Q)=seq(e) s-d(Q)=s-d(e);
When node i receives a DRINA informing packet Q, BEGIN

1. Compare fields of Q with any valid entry in Waiting Indicator list;
2. IF there is no match, ignore packet Q; ELSE a better subpath is found.

4. Practical Results and Analysis

In this section we are discussing the practical environment, scenarios, performance metrics used etc.

4.1. Simulation Platform

For the simulation of this work we have to need the following setups requirement for the same

1) Cygwin: for the windows XP
2) Ns-allinone-2.32.

4.2. Network Scenarios

There number scenario and traffic files needs to generate in order to evaluate the performance of the routing protocols under the different network conditions. In this simulation the main parameter which is varied during the simulation is the number of nodes, number of connections, mobility speed etc.

4.3. Performance Metrics

- PDR vs. varying number of sensor nodes
- End to End Delay vs. varying number of sensor nodes
- Avg. Energy Consumed vs. Network Dime varying number of sensor nodes
- Avg. Throughput vs. Network Dime varying number of sensor nodes

Table 4.1 Network Configuration Parameters

Number of Sensor Nodes	220, 240, 260, 280, 300
Traffic Patterns	CBR
Network Size	1000 X 1000
Mobility Speed	1 m/s
Simulation Time	100 s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV/DRINA/IDRINA
MAC Protocol	802.11
Transmission Protocol	CBR

4.4. Results Achieved

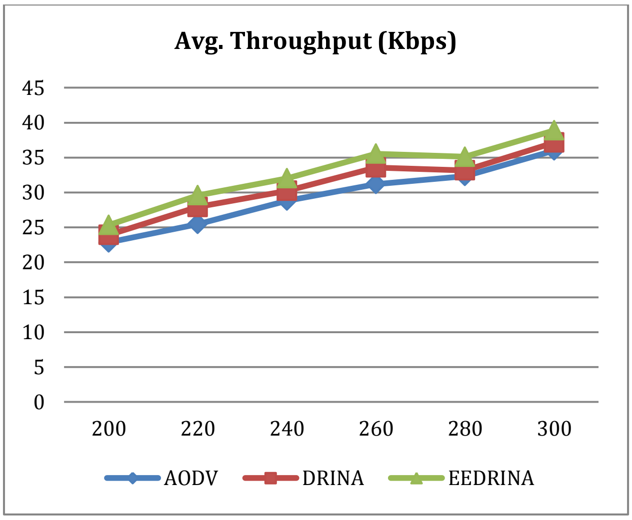

Fig 4.1: Performance Analysis of Throughput

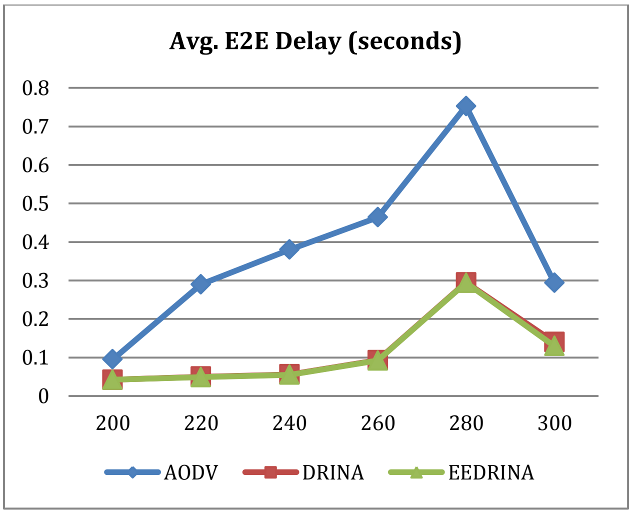

Fig 4.2: Performance Analysis of End to End Delay

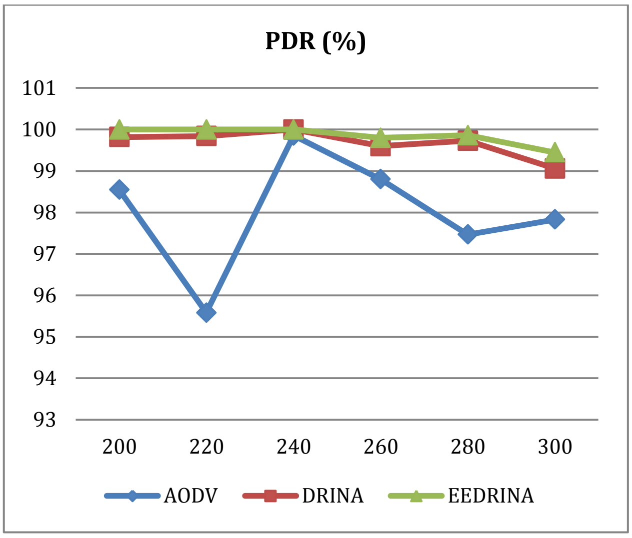

Fig 4.3: Performance analysis of PDR

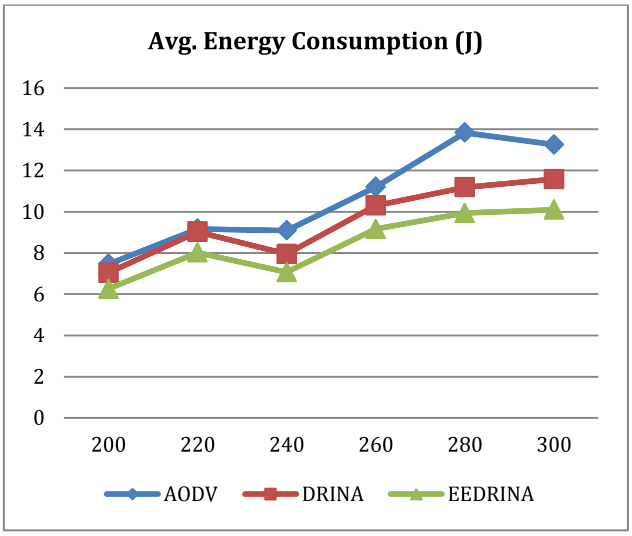

Fig 4.4: Performance Analysis of Average energy consumed

From above results showing in figure 4.1 to 4.4, we observed that performance of proposed IDRINA outperforming DRINA and AODV routing protocols. We have compared performance in terms of varying scalability means varying sensor nodes. This performance results claiming that proposed work is better and improved as compared to existing techniques.

Conclusion and Future Work

For event based wireless sensor networks, aggregation aware routing methods play an important role. In this work, we first presented study over existing the DRINA algorithm, a novel and reliable Data Aggregation Aware Routing Protocol recently presented for WSNs. Based on DRINA we proposed new IDRINA with aim of improving routing performance further. From practical results, we are claiming that our energy efficient algorithm in IDRINA improves performance as compared to existing routing protocols. For future work, we suggest to work on security and different attacks in WSNs to extend the concept of data aggregation.

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