

Proximity-Based Data Dissemination Model for Large Scale Wireless Sensor Networks

Maan Khedr ⁺, Mohamad Abou El-Nasr and Wael Hosny Fouad Aly

Computer Engineering Department, College of Engineering, AAST

Abstract. In wireless sensor networks new challenges appear when we target a large –scale sensor network as scalability issues arise in dense sensor networks where multiple sources need to communicate with multiple sinks. New protocols are always being developed to tackle the efficiency in routing and power management. The Proximity Based Data Dissemination “PBDD” approach aims to provide high efficiency in data dissemination from multiple sources to multiple mobile sinks. The proposed model reduces the communication overhead between source, and sinks through eliminating most of the nodes from joining in the dissemination process. Each source builds its own grid structure while being location unaware and the sinks send their queries throughout the field to request data while updating their positions when they are on the move which will enable them to continuously receive data while moving. The performance of PBDD is examined through analytical equations and is found to perform best in high dense large scale networks in comparison to other dissemination models.

Keywords: wireless sensor networks, data dissemination, mobile sinks, grid structure, communication overhead, proximity information, large scale.

1. Introduction

A sensor network is composed of a large number of sensor nodes, which are densely deployed either inside the phenomenon or very close to it [1]. Sensor nodes positions need not be engineered nor pre-determined, which allows random deployment in inaccessible terrains or disaster relief operations. This imposes challenges for sensor network protocols as they need to possess self-organizing capabilities. Another unique feature of sensor networks is the cooperative effort of sensor nodes. Sensor nodes are fitted with an on-board processor, which gives them the capability to carry out some simple computations and preprocessing to the data before forwarding them to other nodes.

These features expand the range of applications for sensor networks that vary between, but not limited to: health, military, and security. It is expected that in the future wireless sensor networks will be an integral part of our lives.

Realization of these and other sensor network applications require wireless ad hoc networking techniques. Although many protocols and algorithms have been proposed for traditional wireless ad hoc networks, they are not well suited for the unique features and application requirements of sensor networks. To illustrate this point, the differences between sensor networks and ad hoc networks [2] are outlined below:

- The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network and are densely deployed and are prone to failures.
- Sensor nodes are limited in power, computational capacities, and memory.
- Sensor nodes may not have global identification (ID) because of the large amount of overhead and large number of sensors.

⁺ Corresponding author. Tel.: + 201004002119.
E-mail address: maan.khedr@gmail.com.

Large scale wireless sensor networks impose the problem of scalable and efficient data dissemination from multiple sources to multiple mobile sinks. Where when developing a protocol power management should be taken in consideration as well as efficient routing, communication overhead, and being prone to failure [3],[4],[5].

The objective of a WSN as mentioned before is to be able to route data between sources and sinks, a source in our scope is a sensor node that detects an event of interest, and generates data report, and a sink is defined as a user that collects these data reports from the sensor network. Both the number of sources and that of the sinks may vary over time.

In this paper a new model for data dissemination is proposed that is called Proximity-Based Data Dissemination (PBDD), the proposed model is based on the Two-Tier Data Dissemination model (TTDD) [8], where modifications were applied to the TTDD in order to decrease the communication overhead and help it construct a dissemination grid without the use of GPS, and studies the effect of the applied modification to its performance.

Section 2 reviews the related work. Section 3 describes the design of the PBDD. Section 4 analyzes the communication overhead with varying system parameters. Section 5 concludes the paper.

2. Related Work

A lot of data dissemination approaches have been developed for sensor networks such as Directed Diffusion [3], Declarative Routing Protocol [6] and GRAB [7], they all operate in a manner that mobile sinks continuously updates their location information throughout the sensor field, this may lead to excessive collisions as well as high power consumption, which in case is not suitable for WSN.

In the TTDD approach, the goal is to use GPS-Enabled nodes that use their location information to construct a source-based grid to announce the data collected by the source for sinks. Once the grid is constructed a sink with interest in the data queries the grid for the data, and the query is disseminated to the upstreams till it reaches the source, which then forwards data to the sink or multiple sinks in case of multiple queries by different sinks.

As explained in [9], queries and data undergo two tier dissemination for query and data forwarding, and the paper proposes some technique to maintain the constructed grid.

Another approach was proposed by CBDD [9], which uses a permanent grid and cluster concepts, as well as cross-shape trajectory forwarding to transmit forwarding information to a particular sensor node rather than to every sensor node. Moreover, whereas TTDD dynamically creates a grid every time an interest event occurs, CBDD uses a permanent grid structure to reduce the number of packets used in creating and maintaining a grid structure that can be produced when multiple events occur simultaneously.

3. Proximity-Based Data Dissemination Model

In this section we present the basic design of PBDD which is based on the following assumptions:

- A vast field is densely covered by a large number of sensor nodes which communicate with each other through short-range radios.
- Data is disseminated between source and sink across multiple hops and each sensor node is unaware of its location and is stationary.
- Sinks are unaware of their locations and can be mobile.
- In case of an event, the sensors surrounding it collectively process the signal and one of them becomes the source to generate data reports.
- Sinks query the network to collect sensing data. There can be multiple sinks moving around in the field and the number of sinks may vary over time.

As soon as a source generates data, it starts preparing for data dissemination by building a grid structure. The source starts with itself as one crossing point of the grid, and sends a data announcement message to each of its four adjacent crossing points and appoints them as dissemination nodes. That is done through an

elimination process that will be further investigated in the grid construction subsection. Thereafter each of the elected dissemination nodes starts recruiting its neighboring dissemination nodes.

Once the grid is constructed, and sinks receive the announcement, a sink with an interest in the announced data can then send a query over the constructed grid through its nearest dissemination node, the query traverses the upstream path till it reaches the source, which then sends the data to the sink over the reverse path.

In the following subsections the grid construction process is explained, followed by the query and data dissemination through the network and finally how the grid is maintained.

3.1. Grid construction

We assume that a sensor field spans a two-dimensional plane. A source divides the plane into a grid of cells. Each cell is a $\alpha \times \alpha$ square. A source itself is at one crossing point of the grid. It propagates data announcements to reach all other crossings, called dissemination points, on the grid [8].

Bearing the fact that the nodes in the field have no means in obtaining its own location nor the locations for its neighbors, the source node must locate the neighboring four crossings in proximity to itself discarding orientation of directions.

That is done through a process of announcement forwarding using geometrical properties. As shown in fig.1 a relation between the neighboring dissemination nodes can be formulated in terms of the broadcast range of the source node.

Initially as the source broadcasts an announcement message with power E_t to traverse distance α , nodes located at distance α will receive the announcement with a power E_r that lies within a certain threshold specified in the announcement message, upon which these nodes will take action of acknowledging back to the source. The source then elects its first neighboring dissemination node.

The elected node then retransmits the announcement message but this time with different power that is sufficient to traverse 0.8α , and resets the threshold field to match the required recipient power threshold. Nodes receiving both announcements from the source and the first elected dissemination node fulfilling the threshold criteria are claimed to be *Temporary nodes* that are used to relay the announcement message to other dissemination nodes. Temporary nodes then relays the announcement message forward, and recipients fulfilling the same criteria of receiving source announcement and relayed announcement from temporary node with matching threshold powers are elected as dissemination nodes. This process is repeated once more till the fourth dissemination node is acquired.

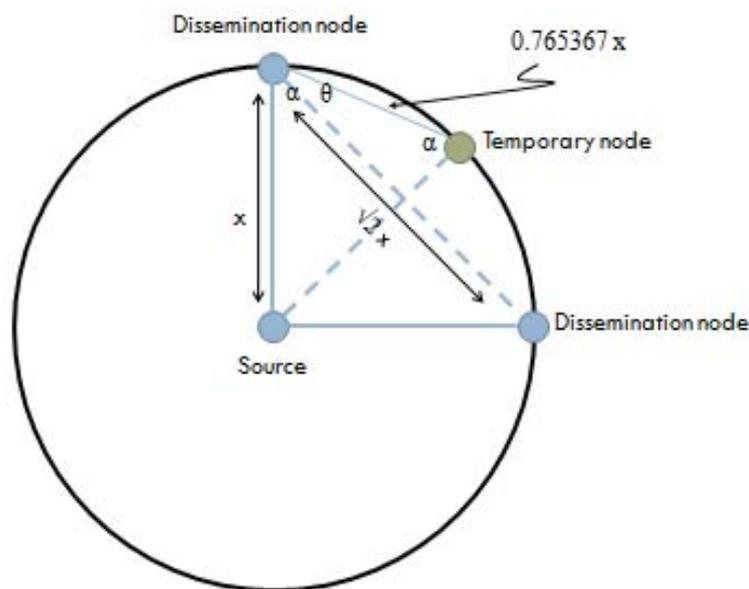


Fig. 1: DNs displacement relation

Similarly each of the dissemination nodes elected will repeat the same steps initiated by the source to obtain its neighboring dissemination nodes until the grid is fully constructed.

A dissemination node stores a few pieces of information for the grid structure, including the data announcement message, and the upstream dissemination nodes. Note that for all dissemination nodes –except the ones recruited by the source- there exists two upstream nodes, information for both upstreams will be stored.

The constructed grid is used for multiple sinks requesting data from the same source, while on the other hand if another source has a data announcement it will construct its own grid, which gives better load balancing instead of exhaustively using existing dissemination nodes. But in case a source coincidentally lies on the grid, as in being a dissemination node or within a single hop neighbor list of a dissemination node it uses the same constructed grid.

3.2. Query and data forwarding

When a sink is interested in the data announced, it generates a query to be sent back to the source. In order for the sink to send the query it broadcasts the query within a transmission range of 0.71α –which is half the diagonal of the cell- so that the closest dissemination node to it will receive the query and hence forth disseminates it through the upstream path till it reaches the source. Each dissemination node stores the information of the downstream dissemination node that relayed the query up to it. Data forwarded from the source to the sink will traverse a reverse path to that traversed by the query which is called the downstream.

3.3. Grid maintenance

There are two issues that can arise in the grid that needs to be handled, these issues are:

Grid states

To avoid keeping grid states at dissemination nodes indefinitely, a source includes a Grid Lifetime in the data announcement message when sending it out to build the grid. If the grid idles for a time greater than the grid lifetime, and no update messages for updating the lifetime are received by the dissemination nodes, the grid is dropped. That is each dissemination nodes drops the information of its upstreams and downstreams. Proper grid lifetime values depend on the data availability period and the mission of the sensor network.

Node failure

Due to the possible failure of nodes in WSN, a mechanism is needed to maintain the grid and handle the unexpected component failures for robustness. To handle a dissemination node failure an upstream information duplication mechanism is used, in which each dissemination node recruits from its neighborhood several sensor nodes and replicates in them the location of its upstream and downstream dissemination nodes. When this dissemination node fails, one of the replicas will overhear the upstream update message from the downstream without the response of its replicator and will take action of forwarding the query up to the upstream nodes.

Since this new replacement dissemination node does not know which downstream dissemination node neighbors need data, it simply queries the downstreams for upstream update message to know which of them needs the data and then downstreams the data to the responders. Note that this mechanism also handles the scenario where multiple dissemination nodes fail simultaneously along the forwarding path.

4. Analytical Results

In this section we show analytical result comparisons between PBDD, TTDD, and CBDD. Results are obtained through evaluation in the communication overhead equations for each of them under different conditions, namely: number of nodes in field, number of sinks, cell size, varying mobility factors, and number of sources.

From the comparison it is found that in all the variations of the variables in the equations for communication overhead, the PBDD performs better than the TTDD and CBDD especially as the size of field represented in the number of nodes increases. Results are shown in fig. 2.

5. Conclusion

In this paper PBDD was proposed as a means of efficient data routing in WSN. The model proposes a means for constructing a non permanent infrastructure which is a grid that is source based without the use of any location information for disseminating queries and data efficiently throughout the network between sources and sinks. Our analysis and extensive simulations have confirmed the effectiveness and efficiency of the proposed design, demonstrating the feasibility and benefits of building an infrastructure in stationary sensor networks.

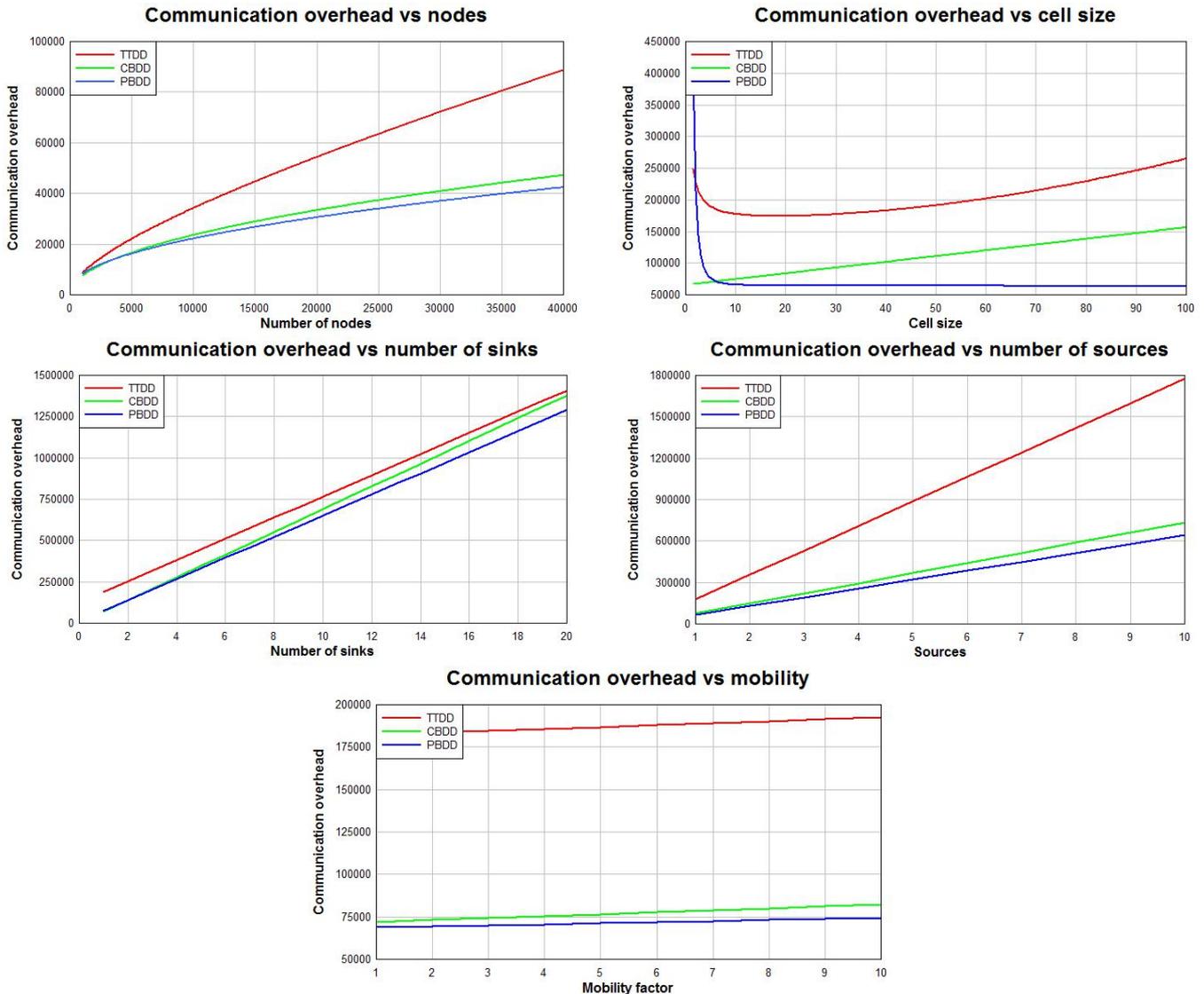


Fig. 2: Analysis results

6. References

- [1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci. Wireless sensor networks: a survey. *Computer Networks*, 38(4):393–422, March 2002.
- [2] C. Perkins, *Ad Hoc Networks*, Addison-Wesley, Reading, MA, 2000.
- [3] C. Intanagonwiwat, R. Govindan, and D. Estrin. Directed diffusion: a scalable and robust communication paradigm for sensor networks. *Proc. of MobiCom '00*, Boston, MA, USA, August 2000, pp. 56–67.
- [4] G. J. Pottie and W. J. Kaiser. Wireless integrated network sensors. *Communications of the ACM*, 43:51–58, May 2000.
- [5] J. M. Kahn, R. H. Katz, and K. S. J. Pister. Next century challenges: mobile networking for “smart dust.” In *Proc. of ACM MobiCom '99*, Seattle, WA, USA, August 1999, pp. 271–278.

- [6] D. Coffin, D. V. Hook, S. McGarry, and S. Kolek. Declarative ad-hoc sensor networking. *Proc. Of SPIE Integrated Command Environments*, July 2000.
- [7] F. Ye, S. Lu, and L. Zhang. GRAdient Broadcast: A Robust, Long-lived Large Sensor Network. <http://irl.cs.ucla.edu/papers/grab-tech-report.ps>, 2001.
- [8] H. Luo, F. Ye, J. Cheng, S. Lu, and L. Zhang. TTDD: A Two tier Data Dissemination Model for Large scale Wireless Sensor Networks. *MOBICOM2002*, Atlanta, Georgia, USA, September 2002.
- [9] J. Cho, J. Choe. An Energy-efficient Data Dissemination Method in a Cluster-Based Sensor Network. AINTEC '08, *Proc. of the 4th Asian Conference on Internet Engineering ACM*, New York, USA ©2008.