Enhanced Topology Aware Routing For WSN

Conference Paper · December 2014

5 authors, including:

Poornima Govindaswamy
BMS College of Engineering

Raja K B
University Visvesvaraya College of Engineering

Venugopal K R
University Visvesvaraya College of Engineering

Lalit M Patnaik
Indian Institute of Science

ENHANCED TOPOLOGY AWARE ROUTING FOR WSN

POORNIMA G
Dept of Electronics and Communication Engineering, BMSCE, Bangalore, India
gpoornima.ece@bmsce.ac.in

IRFANA, K SURESH BABU, K B RAJA, K R VENUGOPAL
Dept of Computer Science Engineering, UVCE, Bangalore, India
ksb1559@gmail.com

L M PATNAIK
Honenarory Professor, Indian Institute of Science, Bangalore, India

ABSTRACT: In this paper Enhanced Topology Aware Routing (ETAR) is proposed for point to point routing in wireless sensor network. Each node is characterized by a coordinate vector consisting of the shortest path hop distances to a subset of nodes, named anchors. The ETAR algorithm efficiently maps a network topology into a low-dimensional virtual coordinate space where hop distances between pairwise nodes are preserved. It assist greedy forwarding to find the right neighbor that is one hop closer to the destination by eliminating the local minimum problem and achieve high success ratio of packet delivery and throughput without location information.

KEYWORDS: Wireless Sensor Networks, Virtual Coordinate System, Topology Mapping,Multidimensional Scaling, Energy Efficient Routing.

INTRODUCTION

Virtual Coordinate System (VCS) can be used for signal strength measurements as an alternate addressing scheme. In VCS, each node is characterized by a length vector, where each ordinate corresponds to the shortest path hop distance to a subset of nodes, called anchors. Therefore, the number of anchor node placement defines the network's dimensionality. This hop-based coordinate system is independent of noise and interference. Additionally, VCS has connectivity information embedded in each ordinate, so VC routing is less susceptible to 'local minima' caused by physical voids. Performance of algorithms based on VCS is highly sensitive to the number of anchors and their placement. The coordinates of a node may not be unique due to the insufficient number of anchors and/or their improper placement. The existence of nodes with identical coordinates degrades the routability, which is defined as the percentage of packets that successfully reach their intended destination.

In virtual domain routing a packet is greedily forwarded to the closest neighbor to the destination similar to its counterparts in physical domain, Greedy forwarding decisions are based on information locally available to a node, i.e., coordinates of its neighbors. However, the distance function from the current node to the destination does not monotonically decrease due to the imperfections of virtual space, causing local minima that degrade the routability. These minima are referred to as logical voids and are analogous to physical voids in the physical domain. As identified, improper anchor placement and over/under placement of anchors are the main causes for this local minima problem. While increasing the number of anchors decreases the likelihood of having multiple nodes with identical coordinates, it may increase the local minima encounters during routing. Finding the overall best anchor placement is extremely challenging and, even if found, it is not likely to eliminate the local minima problem except in a limited set of network topology classes as 1D networks and 2D full grids.

Contribution

The focus of this work is to reduce the dimensionality (minimize the number of anchors required for optimal routing) of the networks Virtual Coordinate System (VCS) using multidimensional scaling method. The nodes are repositioned in Virtual domain (or logical domain). Routing is based on a set of virtual coordinates that capture the position and route information.

Organization

The rest of the paper is organized as follows: In section 2, survey of related work is detailed; the proposed model is described in section 3 and its implementation in section 4. Simulation results and performance analysis is elaborated in section 5. In section 6 concluding remarks are stated.

LITERATURE SURVEY

Scott Shenker et al.,[1] proposed a data-centric storage (DCS) method. In DCS, relevant data are stored by name at nodes and queries for data with a particular name can then be sent directly to the node storing those names, without the loading required in some data-centric routing proposals. Greedy Perimeter Stateless Routing (GPSR), for wireless datagram networks is discussed in [2] that use the positions of routers and a packet's destination to make packet forwarding decisions. GPSR makes greedy forwarding decisions using only information about a router's immediate neighbors in the network topology. When a packet reaches a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region. A new geometric routing algorithm in [3] discusses the theory asymptotically worst-case optimal routing considering different classes of cost metrics in ad-hoc networks.

Ziguo Zhong et al.,[4] proposed a range-free approach to capturing a relative distance between 1-hop neighboring nodes from their neighborhood orderings that serve as unique high-dimensional location signatures for nodes in the network. With little overhead, the proposed design can be conveniently applied as a transparent supporting layer to achieve better positioning accuracy. TIAN HE et al.,[5] proposed APIT, a novel localization algorithm that is range-free. The APIT scheme is suggested for an irregular radio pattern and random node placement with low communication overhead. Douglas S. J. De Couto et al.,[6] proposed the expected transmission count metric (ETX), which finds high-throughput paths on multi-hop wireless networks. ETX minimizes the expected total number of packet transmissions (including retransmissions) required to successfully deliver a packet to the ultimate destination. The ETX metric incorporates the effects of link loss ratios, asymmetry in the loss ratios between the two directions of each link, and interference among the successive links of a path. In contrast, to the minimum hop-count metric chooses arbitrarily among the different paths of the same minimum length, regardless of the often large differences in throughput among those paths, and ignoring the possibility that a longer path might offer higher throughput.

The solution for persistent failures in geographic routing for static topologies by real radios is proposed in Cross-Link Detection Protocol (CLDP) [7], which enables probably correct geographic routing on *arbitrary* connectivity graphs. Greedy Distributed Spanning Tree Routing discussed in [8] finds shorter routes and generates less maintenance traffic and also handle dead ends by switching instead to routing on a spanning tree. Each GDSTR node maintains a summary of the area covered by the sub tree below each of its tree neighbors. James Newsome et al.,[9] proposed GEM (Graph Embedding for sensor networks); an infrastructure for node-to-node routing, data-centric storage and information processing in sensor networks. Here a labeled graph that can be embedded in the original network topology is constructed.

Shigang Chen et al.,[10] proposed a new geographic routing algorithm that forwards packets from sensors to base stations along efficient routes. The algorithm eliminates the voids that cause non-optimal routing paths in geographic routing. It replaces the right-hand rule by distance upgrading. It is fully distributed and responds to topology changes instantly with localized operations. Bin Yu et al.,[11] proposed geographic routing in distributed sensor systems without location information. The problem is addressed by introducing a lightweight and distributed virtual coordinate assignment protocol. Ke Liu et al., [12] proposed aligned virtual coordinate system (AVCS) to address anomalies in VCS. In [13] weak-link problem is addressed and also distance-hop trade-off. Energy Efficient Geographic forwarding that must strike a balance between shorter, high-quality links, and longer lossy links with and without automatic repeat request (ARQ) is studied.

Background

In [14] topology aware routing for local minimum problem is suggested. TAR guides the GF along the near-optimal paths in terms of global metrics. The topology awareness is achieved via constructing a virtual coordinate space (VCS) where the geometric distance between two arbitrary nodes reflects the actual distance in corresponding global metric space. F Bao et al.,[15] proposed a highly scalable cluster-based hierarchical trust management protocol for wireless sensor networks (WSNs) to effectively deal with selfish or malicious nodes. The scheme uses multidimensional trust attributes to evaluate the overall trust of a sensor node for trust-based geographic routing and trust-based intrusion detection. Jun-Won Ho et al.,[16] proposed a zone-based node compromise detection and revocation scheme in wireless sensor networks. The scheme focus on the use sequential hypothesis testing to detect suspect regions in which compromised nodes are likely placed. Additionally, they modeled the detection problem using a game theoretic analysis.

PROPOSED METHODOLOGY

Problem Definition

The Multi-dimensional Scaling can be generalized as assigning coordinates to data points such that Euclidean distances estimated from the coordinates that can best fit measured distances. The rate of change of the topology and the number of routers in the routing domain are the two dominant factors in the scaling of a routing algorithm. The proposed method i.e. Enhanced Topology Aware routing method encodes a network topology into a low-dimensional virtual coordinate space where hop distances between pairwise nodes are preserved.

Objective

- To address the local minimum problem.
- To assist greedy forwarding to find the correct neighbour that is one hop closer to the destination.
- To achieve high success ratio of packet delivery without location information

Algorithm

Table 1: Enhanced Topology Aware Routing (ETAR)

Input:	Anchors to circulate connectivity request packet
Output:	Base Station to circulate new virtual coordinates
Step 1	To obtain the topology information.
Step 2	Calculate the shortest path distances between the nodes and the anchors.
Step 3	Reposition the nodes use the gradient algorithm.
Step 4	Calculate the new distance with respect to the anchor nodes.
Step 5	Choose the new distance such that, the difference between the distance in the original topology and the new topology (virtual) with respect to the anchor nodes is minimum.
Step 6	Transfer the data using the new distance.

The proposed Enhanced Topology Aware Routing is a time based mechanism and on demand routing algorithm where the data transmission takes place at high rate for whole duration. The algorithm is as shown in Table 1 consist of gathering the node positions i.e., topology information and reduce the network dimension. The aim is to improve point to point routing and also obtain better routing paths in the event of any change in the network dynamics.

IMPLEMENTATION

Distributed network with N nodes randomly placed in a network area of 500m*500m is considered, out of which M nodes can be randomly chosen as anchors. The anchors propagates beacon message to trace the hop count valve to all node in the network. Based on the trace valve received the node gets an estimate of its hop distance to the anchor. The node will communicate to the anchor that has least hop distance to it.

The anchors will report the constructed hop count matrix as in equation (1) to the base station.

$$H = [h_1 h_2 h_3 \ldots \ldots . h_M] \qquad (1)$$

The matrix is now mapped to a low dimensional two norm Euclidean space by the base station and the new coordinates are assigned to the anchor forwarded to the nodes. Now the nodes are repositioned virtually. The node that are not localized by an anchors calculates its virtual coordinate by itself using the least square fitting method to ensure that the differences between hop distances and the corresponding Euclidean distances from the node to all anchors are minimized.

$$d_{ij}^1 = h_{ij} * d_{hop} \qquad (2)$$

$$New\ dist(n_{ij}) = \sum_{x_i x_j \in X} (d_{ij} - d_{ij}^1) \qquad (3)$$

The new distances of the nodes with respect to the anchors are computed using the equation (2) & (3)

RESULTS AND DISCUSSION

To study the performance of the proposed method the network of area 500m*500m is simulated using NS-2 with 100 nodes deployed. The node parameter setting is as per mica2 mote that is equipped with an Atmel ATmega128L and has a CC1000 transceiver. Wireless channel and Omni-directional antenna for transmission and reception of signal is defined. MAC type is 802.11 with Drop tail / Priqueue, with two ray ground propagation type. The traffic generator is UDP; it accepts data in variable size chunks and uses RTP timestamp. The performance parameters are Packet delivery ratio (PDR), throughput, and end to end delay.

Table 2: Repositioning of nodes with MDS

NODE ID	NODE POSITION WITHOUT MDS		NODE POSTION WITH MDS	
	X Co-ordinate	Y Co-ordinate	X Co-ordinate	Y Co-ordinate
0	39.432	395.502	125	125
2	6.6536	166.776	20.6257	148.841
13	433.02	125.882	104.695	163.25
30	220.898	206.664	160.274	124.657
41	45.626	79.452	156.99	104.671
56	193.414	432.916	172.875	182.63
62	108.247	5.240	130.346	159.73
74	338.180	87.394	123.65	135.581
83	263.748	328.463	78.32	86.1173
93	414.016	423.509	71.48	71.3172

The original network topology is compressed virtually. Multidimensional scaling forms virtual positioning for the nodes with minimum distance. i.e., it maps global hop distance space into two norm Euclidean space. Table 2 shows the old and new (X, Y) coordinates for a hundred node network deployment scenario. It is observed that for any node n_i the (X, Y) node coordinates are relocated and over all the positioning of the nodes is reduced due to the mapping of the original topology into Euclidean space based on the metric of probable communication count (PCC).

It is seen from figure 1 that the proposed ETAR increases the packet delivery ratio, the packets are transmitted through the anchor nodes which are placed based on the virtual coordinates , therefore the PDR is high as the path failure is less hence it is suitable for real time application. The packet delivery ratio on an average increases by 72.56% with an end to end delay reduced by 5.42% as compared to the existing work (EGF).

The performance of the algorithm is measured in terms of EED as shown in figure 2 and throughput as shown in figure 3.With the increase in packet delivery the throughput of network for

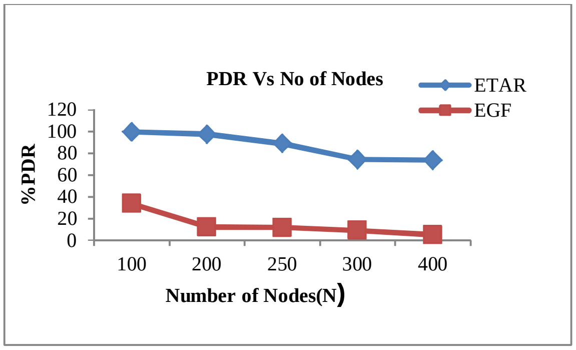

Fig.1: Comparison of PDR with Existing [14]

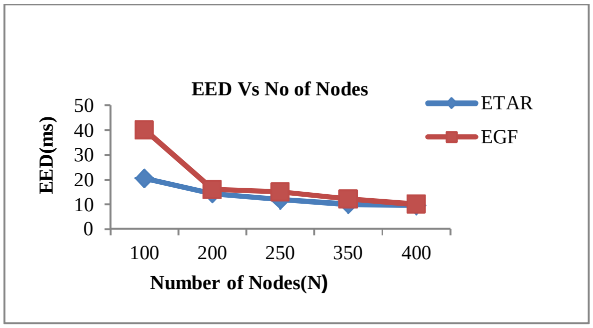

Fig. 2: Comparison of EED with Existing [14]

varying node deployment increases with the end to end delay maintained below 20ms.Based on the hop distances between neighboring nodes the algorithm can find the optimum shortest path between two nodes. The increase in throughput also shows that the routing quality has improved by embedding the network topology into Euclidean space.

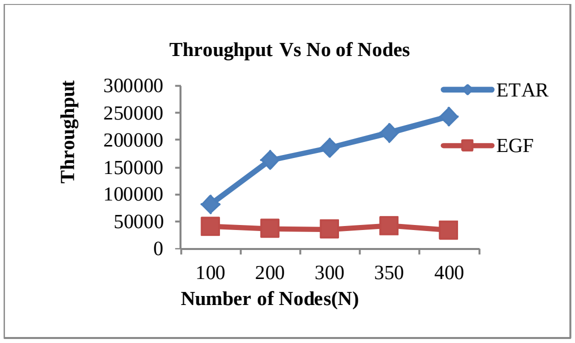

Fig.3: Comparison of Throughput with Existing [14]

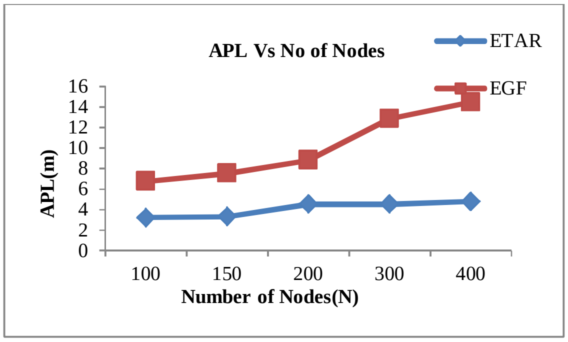

Fig. 4: Comparison of APL with Existing [14]

The average routing length in figure 4 is very less when compared to the existing technique, because the virtual coordinates obtained are placed in reduced area compared to the existing technique there by contributing to increase in throughput. This reduction in length is achieved due to the measurement of hop distances to a set of anchors rather than collecting hop distances from all nodes.

CONCLUSION

ETAR is a routing protocol technique which provides fast delivery of data, reducing energy and power. It uses virtual coordinate spaces to be aware of the network topology eliminating the need for expensive and unreliable localization techniques. The length of the coordinate, local minima problem and identical coordinate problem are directly correlated with the anchor placement. The network is scaled down using multidimensional scaling. This protocol is best suitable for providing QoS, by reducing end to end delay, increasing throughput and packet delivery ratio for maximum bust size. It supports delay sensitive traffic, efficiently manages the limited resources that is available to the network. The characteristics of small average path length in WSN are beneficial to reduce communication costs, save node energy and make the network exhibit a good robust under random attack.

REFERENCE

S. Shenker, S. Ratnasamy, B. Karp, R. Govindan, and D. Estrin, "Data-Centric Storage in Sensornet,"*ACM Transaction on Signal Communication and Computer Communication*, Vol. 33, No. 1, pp. 137-142, 2003.

B. Karp and H.T. Kung, "GPSR: Greedy Perimeter Stateless Routing for Wireless Networks," *Proceeding of Sixth International Conference on Mobile computing and networking*, pp. 243-254, 2000.

F. Kuhn, R. Wattenhofer, Y. Zhang, and A. Zollinger, "Geometric Ad-Hoc Routing: Of Theory and Practice,"*Proceedings of the Twenty Second Annual Symposium on Principles of Distributed Computing*, pp. 63-72, 2003.

Z.Zhong and T.He, "Achieving Range-Free Localization beyond Connectivity," *Proceedings of the Seventh ACM Conference on Embedded Networked Sensor Systems*, pp. 281-294, 2009.

T. He, C. Huang, B.M. Blum, J.A. Stankovic, and T. Abdelzaher, " Range-Free Localization Schemes for Large Scale Sensor Networks," *Proceedings of the Ninth Annual International Conference on Mobile computing and Networking*, pp. 81-95, 2003.

D.S.J.D.Couto,D, Aguayo, J. Bicket, and R. Morris, "A High-Throughput Path Metric for Multi-Hop Wireless Routing," *Journal Wireless Networks*, Vol. 11, Issue 4, pp. 419-434, 2005.

Y.J.Kim, R. Govindan, B. Karp, and S. Shenker, "Geographic Routing Made Practical," *Proceedings of Second Conference Symposium on Networked System Design and Implementation*,Vol. 2, pp. 217-230, 2005.

B.Leong, B.Liskov, and R. Morris, "Geographic Routing without Planarization," *Proceeding of the Conference on Networked Systems Design and Implementation (NSDI)*,Vol. 3, pp. 339-352, 2006.

J. Newsome and D. Song, " GEM: Graph Embedding for Routing and Data-Centric Storage in Sensor Networks without Geographic Information", *Proceedings of the First International conference on Embedded Networked Sensor Systems*, pp. 76-88, 2003.

S. Chen, G. Fan, and J.-H. Cui," Avoid Void in Geographic Routing for Data Aggregation in Sensor Networks," *Proceedings of the First International Conference on Ad Hoc and Ubiquitious Computing*, Vol. 1, Issue 4, pp. 169-178, 2006.

B.Yu and K.Sycara,"Geographic Routing in Distributed Sensor Systems without Location Information," *Proceedings of the First International Conference on Information Fusion*, Vol. 39, Issue 3, 2007.

K. Liu and N. Abu-Ghazaleh,"Aligned Virtual Coordinates for Greedy Routing in WSNs," *Proceedings of the First International Conference on Sensor Networks*, Vol. 3, Issue 4, pp. 252-265, 2008.

K.Seada,M.Zuniga,A.Helmy,andB.Krishnamachari,"Energy Efficient Forwarding Strategies for Geographic Routingin Lossy Wireless Sensor Networks,"*Proceedings of the First International Conference on Embedded Networked Sensor Systems*, pp. 108-121, 2004.

Pei Huang, Chen Wang, and Li Xiao,"Improving End-to-End Routing Performance of Greedy Forwarding in Sensor Networks," *IEEE Transactions on Parallel and Distributed Systems*, Vol. 23, No. 3, 2012

F. Bao, I. R. Chen, M. Chang, and J. H. Cho," Hierarchical Trust Management for Wireless Sensor Networks and Its Applications To Trust-Based Routing And Intrusion Detection," *IEEE Transactions on Network and Service Management*, Vol. 9, No. 2, 2012.

J. Ho, M. Wright, and S.K. Das,"Zone Trust: Fast Zone-Based node compromise Detection and Revocation in Wireless Sensor Networks using Sequential Hypothesis Testing," *IEEE Transactions On Dependable And Secure Computing*, Vol. 9, No. 4, 2012.