ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 4, Issue 1, pp: (112-116), Month: January - March 2016, Available at: www.researchpublish.com

A Survey: Geographic Routing Around Connectivity Holes in WSN

MAHESH.B[1], VANI.B[2]

[1]Student, [2]Associate Professor, [12]Department of CSE, Sambhram Institute of Technology Bengaluru, Karnataka, India

***Abstract*: This paper shows a protocol for converge casting in wireless sensor networks. It features the cross-layer integration of geographic routing with contention-based MAC for relay selection and load balancing, as well as a mechanism to detect and route around connectivity holes. This technique solves the problem of routing around a dead end without overhead-intensive techniques such as graph planarization and face routing. This protocol is localized and distributed, and adapts efficiently to varying traffic and node deployments. Through extensive ns2-based simulations, we show that this protocol significantly outperforms other converge casting protocols and solutions for dealing with connectivity holes, especially in critical traffic conditions and low-density networks. Our results show this is an energy-efficient protocol that achieves remarkable performance in terms of packet delivery ratio and end-to-end latency in different scenarios, thus being suitable for real network deployments.**

***Keywords*: cross-layer routing, connectivity holes, geographic routing, localization errors.**

I. INTRODUCTION

Distributed sensing and seamless wireless data gathering are key ingredients of various monitoring applications implemented through the deployment of wireless sensor networks (WSNs). The sensor nodes perform their data collection duties unattended, and the corresponding packets are then transmitted to a data collection point (the sink) via multi hop wireless routes (WSN routing or Converge casting). The majority of the research on protocol design for WSNs has focused on MAC and routing solutions.

An important class of protocols is represented by geographic or location-based routing schemes, where a relay is greedily chosen based on the advancement it provides toward the sink. Being almost stateless, distributed and localized, geographic routing requires little computation and storage resources at the nodes and is therefore very attractive for WSN applications.

Many geographic routing schemes, however, fail to fully address important design challenges, including 1) routing around connectivity holes, 2) resilience to localization errors, and 3) efficient relay selection. Connectivity holes are inherently related to the way greedy forwarding works. Even in a fully connected topology, there may be nodes (called dead ends) that have no neighbors that provide packet advancement toward the sink. Dead ends are, therefore, unable to forward the packets they generate or receive.

These packets will never reach their destination and will eventually be discarded. Many solutions have been proposed to alleviate the impact of dead ends. In particular, those that offer packet delivery guarantees are usually based on making the network topology graph planar, and on the use of face routing [1]. However, planarization does not work well in the presence of localization errors and realistic radio propagation effects [2], as it depends on unrealistic representations of the network, such as a unit disk graph.

In this paper, we propose an approach to the problem of routing around connectivity holes that works in any connected topology without the overhead and inaccuracies incurred by methods based on topology planarization. Specifically, we define a cross-layer protocol, named ALBA for Adaptive Load-Balancing Algorithm, whose main ingredients (geographic routing, load balancing, contention based relay selection) are blended with a mechanism to route packets out and around dead ends, the Rainbow protocol. The combination of the two protocols, called ALBA-R, results in an integrated solution for converge casting in WSNs that, although connected, can be sparse and with connectivity holes.

A succinct version of this paper has appeared in [7]. The current version presents a considerably larger set of experiments and comparisons with previous solutions. Supplemental material, which can be found on the Computer Society Digital http://doi.ieeecomputersociety.org/10.1109/TPDS.2013.60, provides proof of correctness of the Rainbow mechanism, further simulation experiments, and detailed results from testing the deployment of a 40-node network in a vineyard outside of Roma, Italy. Some results on ALBA resilience to localization errors have appeared in [8].

II. RELATED WORK

According to its first and simplest formulation, geographic routing concerns forwarding a packet in the direction of its intended destination by providing maximum per-hop advancement [9], [10]. In dense networks, this greedy approach is quite successful, since nodes are likely to find a path toward the sink traversing a limited number of intermediate relays. Conversely, in sparse networks, packets may get stuck at dead ends, which are located along the edge of a connectivity hole, resulting in poor performance.

A number of ideas have, therefore, been proposed to address the problem of routing around dead ends. A first set of approaches stems from the work of Kranakis et al. [11]. WSN topologies are first “planarized” [12]. Geographic routing over planarized WSNs is then obtained by employing greedy routing as long as possible, resorting to planar routing only when required, for example, to get around connectivity holes.

Heuristic rules are then defined for returning to greedy forwarding as soon as next-hop relays can be found greedily. Examples of this approach include. Solutions based on planarization have several drawbacks.

First of all, a spanner graph of the network topology needs to be built (and maintained in the presence of node dynamics), and this incurs non-negligible overhead. Planar routing may then require the exploration of large spanners before being able to switch back to the more efficient greedy forwarding, thus imposing higher latencies.

Moreover, in realistic settings, localization errors and non-ideal signal propagation may lead to disconnected planar graphs or to topology graphs that are non-planar. This is because spanner formation protocols assume that the network topology is modeled by a UDG, and the correctness of the approach cannot be guaranteed when this is not the case, as in most realistic situations. However, this is a transmission intense solution for WSNs, which eventually affects the network performance.

For a comprehensive overview of planar graph routing, the reader is referred to the survey by Frey et al. A different class of solutions for handling dead ends is based on embedding the network topology into coordinate spaces that decrease the probability of connectivity holes.

This category includes algorithms using virtual coordinates, and those that perform some sort of topology warping [26]. In the former case, the coordinates of each node are the vector of the hop distance between the node and each of a set of beacons. Greedy forwarding is typically performed over the virtual coordinate’s space.

III. PROPOSED SYSTEM

The protocol we propose in this paper, ALBA, is a cross layer solution for converge casting in WSNs that integrates awake/asleep schedules, MAC, routing, traffic load balancing, and back-to-back packet transmissions. Nodes alternate between awake/asleep modes according to independent wake-up schedules with fixed duty cycle d. Packet forwarding is implemented by having the sender polling for availability its awake neighbors by broadcasting an RTS packet for jointly performing channel access and communicating relevant routing information (cross-layer approach).

Available neighboring nodes respond with clear-to-send (CTS) packet carrying information through which the sender can choose the best relay. Relay selection is performed by preferring neighbors offering “good performance” in forwarding packets. Positive geographic advancement toward the sink (the main relay selection criterion in many previous solutions) is used to discriminate among relays that have the same forwarding performance.

Every prospective relay is characterized by two parameters: the queue priority index (QPI), and the geographic priority index (GPI). The QPI is calculated as follows: The requested number of packets to be transmitted in a burst (back-to-back transmissions) is NB, and the number of packets in the queue of an eligible relay is Q. The potential relay keeps a moving average M of the number of packets it was able to transmit back-to back, without errors, in the last forwarding attempts.

The QPI is then defined as minfdðQ þ NBÞ=Me;Nqg, where Nq is the maximum allowed QPI. The QPI has been designed so that congested nodes (with a high queue occupancy Q) and “bad” forwarders (experiencing high packet transmission error, i.e., with a lower M) are less frequently chosen as relays. The selection of relays with low QPI, therefore, aims at decreasing latency at each hop by balancing the network load among good forwarders.

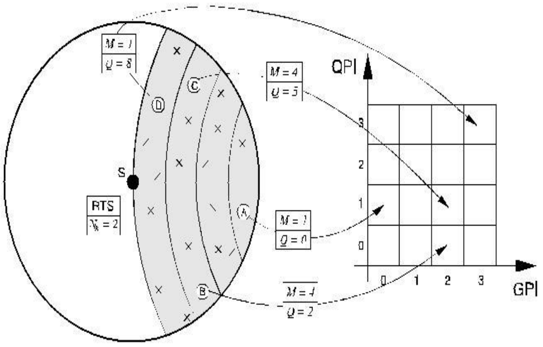


Fig 1 Computing QPI and GPI values.

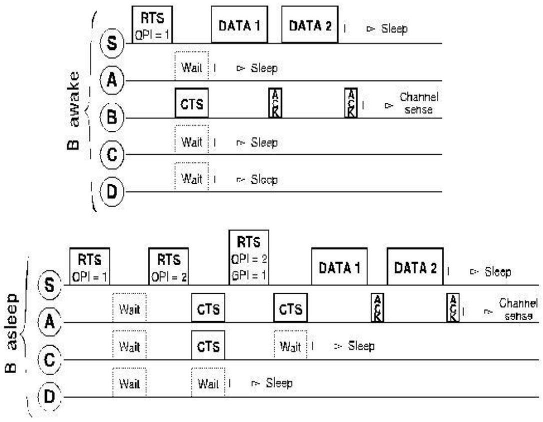


Fig 2 ALBA handshakes.

Based on positioning information (as provided to a node by GPS, or computed through some localization protocol), and on the knowledge of the location of the sink, each node also computes its GPI, which is the number of the geographic region of the forwarding area of the sender where a potential relay is located. The numbering of GPI regions ranges from 0 to Nr _ 1. Numbers are assigned so that the higher the number of the region, further from the sink are the nodes it contains, i.e., nodes in region 0 provide the maximum advancement toward the sink.

An example of QPI and GPI assignment is provided in Fig 1. The sender S is represented by a black circle, while crosses and white circles denote asleep and awake neighbors, respectively. Awake nodes are the only ones available at the time the RTS is broadcast. The forwarding area is colored light gray, and the GPI regions are delimited by arcs centered at the sink (not shown in the figure). In this example, the source S wants to send a burst of NB ¼ 2 packets.

Among the awake nodes, A has an empty queue, but also a bad forwarding record (M ¼ 1); hence, its QPI is 2. Nodes B and C have both M ¼ 4. However, B has a smaller queue and therefore its QPI is 1, whereas that of C is 2. A sender node queries neighbors in increasing order of QPI. The sender performs channel sensing prior to packet transmission, to make collisions with ongoing handshakes unlikely. After channel sensing, the sender proceeds as depicted in Fig 2. It broadcasts a first RTS, asking eligible forwarders to compute their QPI and GPI, and inviting answers from nodes whose QPI is 1.

The RTS contains all the information required by the relays to compute their QPI and GPI, namely, the location of the sender, the location of the sink, and the length of the data burst NB. Only nodes with QPI ¼ 1 are allowed to answer the first RTS with a CTS packet. If nobody answers, other RTS packets are broadcast calling for answers by nodes having an increasingly higher QPI.

If a single node answers, it is immediately sent to the data packets, which it ACKs one by one. In case more nodes with the same requested QPI respond, ties are broken via the GPI. To select the node with the best GPI, a new RTS packet is broadcast calling for answers only from nodes whose GPI is 0, i.e., from nodes providing the highest advancement.

If no nodes are found, successive RTS are broadcast calling for nodes with progressively higher GPI. Further ties from multiple nodes replying with the same (QPI, GPI) pair are broken by a binary splitting tree collision resolution mechanism. This relay selection process can fail in two cases: 1) If no node with any QPI is found or 2) if the contention among nodes with the same QPI and GPI is not resolved within a maximum number of attempts NMaxAtt. Both situations cause the sender to back off. If the sender backs off more than NBoff times, the packet is discarded.

Let us assume that node B is awake and that it is the only available relay whose QPI is 1 after the first RTS (upper part of Fig. 2; all other neighbors are asleep). Node B replies to S with a CTS and is selected as a relay. In the case when B is asleep (lower part of Fig. 2), only A, C, and D would be available. In this case, no node with QPI equal to 1 exists, so that the first RTS is not answered. Both A and C answer the second RTS, as both have the QPI equal to 2. The second phase (best GPI search) is then started, which terminates with the selection of node A, who's GPI is equal to 0.

Once a relay is selected, a burst of data packets is sent (as many as the relay can queue, up to NB), and each packet is individually acknowledged.2 If the ACK for one of the packets is missing, the sender stops the transmission of the burst, rescheduling the unacknowledged packet and the following ones in the burst for a later time, after a back off period.

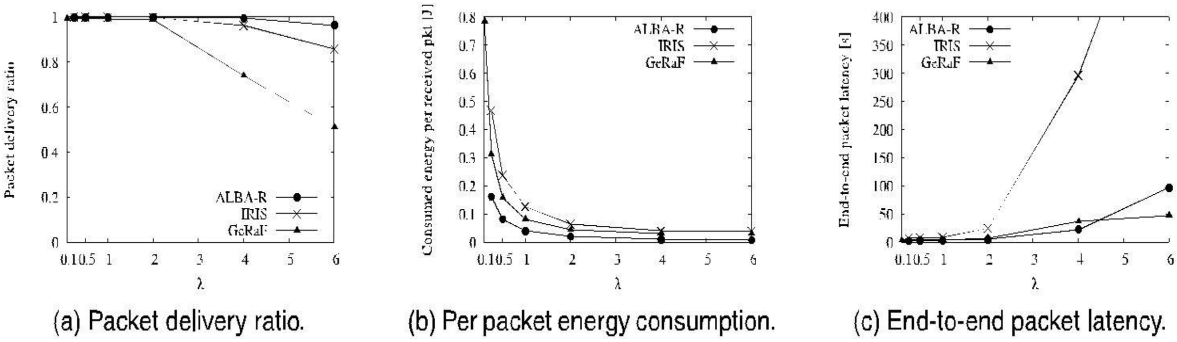
IV. PERFORMANCE EVALUATION

All investigated protocols have been implemented in the ns2 simulator. We used the simulator Friis propagation loss model. The transmission power has been set to achieve successful delivery to nodes within a distance equal to the selected transmission range. The MAC layer is based on CSMA/CA with energy levels and packet reception thresholds typical of carrier sensing. We consider networks with n nodes, where n ranges in {100,200,600}. The sensors are randomly and uniformly deployed in a square area of size 320 _ 320 m2. The node transmission range is set to 40 m. Therefore, the average degree of a node ranges between 5 and 30 nodes, which spans a wide range of realistic values.

All our results have been obtained by averaging the outcomes of 100 simulations, each running for 30,000 s, each time on a different connected topology. The resulting confidence interval of our results has a width within 5 percent of the value shown. Since we are interested in steady-state performance, all metrics have been collected after 1,200 s from the start of each simulation run. We have investigated the following metrics.

the normalized node energy consumption, defined as the ratio between the total energy consumed by all nodes over a given time and the energy that the nodes would consume by strictly following the duty cycle, if there were no packets to transmit and receive; the per packet energy consumption, defined as the average amount of energy spent by all nodes to successfully deliver a packet to the sink; the packet delivery ratio, defined as the fraction of packets that are successfully delivered to the sink; and the end-to-end latency, defined as the time from packet generation to its delivery to the sink.

The latter metric is computed only for successfully delivered packets. We perform three sets of experiments. The first set concerns moderately high-density network scenarios, where dead ends do not occur (higher density results are shown in the supplemental material document, available online). In this setting, we compare the performance of ALBA to that of other cross-layer protocols specifically designed for high-density WSNs.



(a) Packet delivery ratio. (b) Per packet energy consumption. (c) End-to-end packet latency.

Fig.3 Performance comparison of ALBA, GeRaF, and IRIS in networks with 600 nodes.

ALBA VERSUS GERAF AND IRIS:

We compare ALBA with two protocols that are exemplary of cross layer routing in dense WSNs, i.e., in networks where dead ends are not likely to occur. The first protocol is GeRaF, one of the first cross layer protocols based on geographic greedy forwarding [4]. The other protocol is IRIS [5], which performs converge casting based on a hop count metric and on a local cost function. (For details on the description of the two protocols, the reader is referred to the original papers and to the supplemental material document, available online.)

Results are shown in Fig.3 for networks with 600 nodes. ALBA achieves the best performance in terms of all investigated metrics (packet delivery ratio, per packet energy consumption, and end-to-end latency). It scales to increasing traffic much better than the other two protocols because of the effectiveness of the QPI-based selection scheme in balancing the traffic among relays, of its low overhead, and its being able to aggregate packets into burst. A given topology with 300 nodes, it depicts nodes surrounded by "halos" colored depending on the amount of packets they handle. Nodes closer to the sink (square), as expected, are more congested (darker "halos"). However, traffic is fairly shared by the nodes.

Among the three compared protocols, GeRaF shows the worst performance. In GeRaF, a node currently handling a packet stops volunteering as a relay. Therefore, as traffic grows, it becomes harder and harder to find relays, resulting in high number of retransmissions and packet loss. Since GeRaF is based only on geographic advancement, the nodes tend to pick less reliable relays. IRIS finds routes that are shorter than those traveled by packets in ALBA.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we have proposed and investigated the performance of ALBA-R, a cross-layer scheme for converge casting in WSNs. ALBA-R combines geographic routing, handling of dead ends, MAC, awake-asleep scheduling, and back-to-back data packet transmission for achieving an energy-efficient data gathering mechanism. To reduce end to end latency and scale up to high traffic, ALBA-R relies on a cross-layer relay selection mechanism favoring nodes that can forward traffic more effectively and reliably, depending on traffic and link quality.

Results from an extensive performance evaluation comparing ALBA-R, GeRaF, and IRIS show that ALBA-R achieves remarkable delivery ratio and latency and can greatly limit energy consumption, outperforming all previous solutions considered in this study. The scheme designed to handle dead ends, Rainbow, is fully distributed, has low overhead, and makes it possible to route packets around connectivity holes without resorting to the creation and maintenance of planar topology graphs. Rainbow is shown to guarantee packet delivery under arbitrary localization errors, at the sole cost of a limited increase in route length. The comparison with Rotational Sweep, a set of recently proposed mechanisms for avoiding connectivity holes, shows that Rainbow provides a more robust way of handling dead ends and better performance in terms of end-to-end latency, energy consumption, and packet delivery ratio.

REFERENCES

[1] I. Stojmenovic, "Position Based Routing in Ad Hoc Networks," IEEE Comm. Magazine, vol. 40, no. 7, pp. 128-134, July 2002.

[2] K. Seada, A. Helmy, and R. Govindan, "On the Effect of Localization Errors on Geographic Face Routing in Sensor Networks," Proc. IEEE/ACM Third Int'l Symp. Information Processing in Sensor Networks (IPSN '04), pp. 71-80, Apr. 2004.

[3] B.N. Clark, C.J. Colbourn, and D.S. Johnson, "Unit Disk Graphs," Discrete Math., vol. 86, pp. 165-167, 1990.

[4] M. Zorzi, "A New Contention-Based MAC Protocol for Geographic Forwarding in Ad Hoc and Sensor Networks," Proc. IEEE Int'l Conf. Comm. (ICC '04), vol. 6, pp. 3481-3485, June 2004.

[5] A. Camillo` , M. Nati, C. Petrioli, M. Rossi, and M. Zorzi, "IRIS: Integrated Data Gathering and Interest Dissemination System for Wireless Sensor Networks," Ad Hoc Networks, Special Issue on Cross-Layer Design in Ad Hoc and Sensor Networks, vol. 11, no. 2, pp. 654-671, Mar. 2013.

[6] S. Ru¨ hrup and I. Stojmenovic, "Optimizing Communication Overhead while Reducing Path Length in Beaconless Georouting with Guaranteed Delivery for Wireless Sensor Networks," IEEE Trans. Computers, vol. 62, no. 12, pp. 2240-2253, Dec. 2013.

[7] P. Casari, M. Nati, C. Petrioli, and M. Zorzi, "Efficient Non-Planar Routing around Dead Ends in Sparse Topologies Using Random Forwarding," Proc. IEEE Int'l Conf. Comm. (ICC '07), pp. 3122-3129, June 2007.

[8] S. Basagni, M. Nati, and C. Petrioli, "Localization Error-Resilient Geographic Routing for Wireless Sensor Networks," Proc. IEEE GLOBECOM, pp. 1-6, Nov./Dec. 2008.

[9] H. Takagi and L. Kleinrock, "Optimal Transmission Ranges for Randomly Distributed Packet Radio Terminals," IEEE Trans. Comm., vol. 32, no. 3, pp. 246-257, Mar. 1984.

[10] S. Basagni, I. Chlamtac, V.R. Syrotiuk, and B.A. Woodward, "A Distance Routing Effect Algorithm for Mobility (DREAM)," Proc. ACM MobiCom, pp. 76-84, Oct. 1998.

[11] E. Kranakis, H. Singh, and J. Urrutia, "Compass Routing on Geometric Networks," Proc. 11th Canadian Conf. Computational Geometry, pp. 51-54, Aug. 1999.

[12] J. Gao, L.J. Guibas, J. Hershberger, L. Zhang, and A. Zhu, "Geometric Spanners for Mobile Networks," IEEE J. Selected Areas in Comm., vol. 23, no. 1, pp. 174-185, Jan. 2005.