Efficient Sink Location Service for Prolonging the Network Lifetime in Wireless Sensor Networks

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***Abstract*—Quorum-based schemes have been receiving much attention since they can efficiently provide the Sink Location Service (SLS) with large-scale networks and lightweight sensor nodes. Recently, researchers try to adopt them to real irregular fields with voids as well as non-rectangular shapes. However, such schemes make quorums only on particular path such as boundary or selected circle, thus leading to rapid energy exhaustion of nodes on the path. In this paper, we propose an energy-balanced SLS scheme. By constructing a quadrangle quorum per each sink connected by four random points, the scheme costs a balanced energy consumption of nodes, thus can prolong the network lifetime.**

***Keywords*—wireless sensor networks, sink location service, quorum, crossing points, energy-balancing.**

I. Introduction

In wireless sensor networks, the design of energy-efficient sink location service scheme is an important challenge due to resource-constrained sensor nodes. Recently, a quorum-based approach has been proposed in the literature [1][2]. It provides sink location service by exploiting crossing points between Sink Location Announcement (SLA) and Sink Location Query (SLQ) quorums instead of using high-cost flooding. The simplest quorum-based sink location service solution is the so-called column-row method that a sink sends a SLA message from its location in the north-south direction while a source sends a SLQ message from its location in the east-west direction. It is simple yet cost-effective, however, remaining problem is how to guarantee the crossing point in irregular shaped networks. In such networks which have void (called hole or local minimum) areas or are non-rectangle shapes such as circle, ellipse, convex, and concave shape, the two SLA and SLQ quorums may be difficult to guarantee at least one crossing point. To handle this problem, previous schemes construct quorums only on sensor nodes of particular paths such as the network boundary [1] or the explicitly selected circles [2]. However, they might cause fast energy exhaustion of the particular sensor nodes and hence lead to short network lifetime.

Therefore, this paper proposes an energy-efficient quorum-based sink location scheme which can balance the energy consumption of sensor nodes and thus achieve long-lived sensor networks. For guaranteeing a crossing point, a SLA quorum is constructed on a quadrangle path consisting of four points; a SLQ quorum is constructed on a line path where its two ends is inside and outside of the quadrangle path, respectively. For achieve energy-balancing, the four points for a SLA quorum are randomly selected on four orthogonal lines from the network center, and the two end points for a SLQ quorum are randomly selected around the network center or the network boundary, respectively.

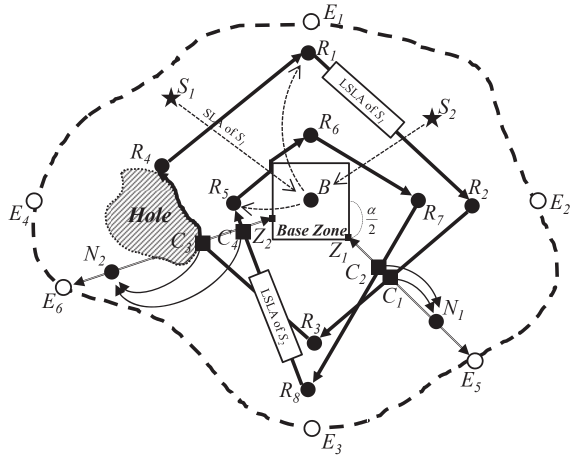

Fig. 1. Our energy-balanced quorum-based sink location service scheme. A sink constructs a quadrangle SLA quorum connected by four random points. Then, a source constructs a line SLQ quorum connected by two random points of inside and outside the SLQ quorum.

II. The Proposed Scheme

We consider each node can get its own location by GPS or localization schemes. Each node is able to know the center location of the network by pre-installed information. The closest sensor node from the center location becomes a Base Node (BN). In order to prevent the congestion of the control packets proximity to the BN, it shares these information to nodes within the Base Zone predefined by an administrator.

As shown in Fig. 1, when a sink S_1 exists in the sensor network, the sink sends a SLA packet toward the center location of the network. The closest node B receives the packet and sends a Line-based SLA (LSLA) packet including geographical routes of the packet with a list of intermediate destinations as follows:

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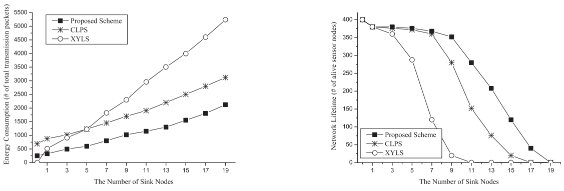

(a) (b)

Fig. 2. Simulation Results

$$1^{st}(X_B,\ \ R(Y_B+\tfrac{\alpha}{2}, Y_{E1})), 2^{nd}(R(X_B+\tfrac{\alpha}{2}, X_{E2}),\ \ Y_B),$$

$$3^{rd}(X_B,\ \ R(Y_{E3}, Y_B-\tfrac{\alpha}{2})), 4^{th}(R(X_{E4}, X_B-\tfrac{\alpha}{2}),\ \ Y_B),$$

where $R(a, b)$ represents the random value between a and b. When a node receives the LSLA packet, it saves the location and interest of the Sink S_1 to its sink information table during $Duration$ seconds, and then forwards the SLA packet to another neighbor node according to the same rule. When the LSLA packet of S_1 arrives at the node R_1 that is the closest node from the first destination, the R_1 relays the packet toward the second destination. This process is repeated when the packet has been returned to the R_1, so that the LSLA packet successfully travels the whole network as a closed-shaped geometrical figure that includes the *Base Zone* inside, made by random lines.

When a sensor node detects events and becomes a source node, e. g., node N_1, it sends a SLQ packet toward the center location of the network as the path N_1Z_1. Basically when a node in the network receives the SLQ packet, the node saves the source node location and the detected event type in the SLQ packet to its source information table. However, if a sensor node in the *Base Zone* receives the SLQ packets, it just drops the SLQ packet. This policy prevents the congestion and collision problem due to the SLQ packets in the *Base Zone*. The N_1 also sends a copy of the SLQ packet to the farthest neighbor node from the center location of the network than itself. If an intermediate node cannot find the farther neighbor node, the node forwards the SLQ packet to the previous intermediate node. The previous intermediate node marks the node and reforwards the SLQ packet to another neighbor node that is farther than the *Base Node B* from itself. This process stops at a network edge node E_5 which received the SLQ packet. The solid line $Z_1N_1E_5$ shows the line track of the SLQ packets.

Observation: Given a closed-shaped geometrical figure and a line, if one end of the line is inside the figure and the other end of the line is outside of the figure, then the figure and the line have at least one crossing point.

According to the above observation, the proposed scheme can guarantee that the LSLA path and the SLQ line path have at least one crossing point as shown in Fig. 1.

III. Performance Evaluation

We implemented XYLS, CLPS, and the proposed scheme in QualNet network simulator 4.0 [3]. The model of sensor nodes are followed by the specification of MICA2 [4]. The transmission range of nodes is 10m and their transmitting and receiving energy consumption rates are 49mW and 29mW, respectively. We consider a sensor network of 1000m x 1000m where 400 sensor nodes are randomly deployed. In our simulation, one sink and one source are randomly located in the network every 100 sec.

Fig. 2(a) shows the energy consumption for the number of sinks. We can observe that the energy consumption of XYLS is remarkably increased than other schemes. In XYLS, every SLA packet should be forwarded according to the network boundary in order to guarantee at least one crossing point on SLQ lines, while other schemes do not require any boundary forwarding to guarantee the crossing point. We can observe that the slope of the CLPS graph and that of the proposed scheme are similar because both the SLA and SLQ distances in each scheme are almost same on average; however, the proposed scheme shows the smaller energy consumption overall than CLPS because of its low-cost process for network initialization.

Fig. 2(b) shows the network lifetime for the number of sinks according to the number of alive sensor nodes after repeated simulation rounds. The number of simulation rounds is set to 500. As the number of sink nodes increases, the number of alive nodes of XYLS is greatly reduced. Because in XYLS, all SLA packets of sinks travel the all network boundary nodes, the nodes suffer from both energy and congestion. In case of CLPS, since each SLA packet travels toward its own designated circle line, the network lifetime of CLPS is longer than XYLS. However, nodes on designated circle lines still suffer from both energy and congestion. Therefore, the energy of the nodes would be rapidly exhausted. This problem would be deepened as the number of sink nodes increases. On the other hand, since SLA packets of the proposed scheme travel toward random lines, the network lifetime of the proposed scheme is longer than other schemes.

IV. Conclusion

In this paper, we proposed an energy-balanced quorum-based sink location service scheme to increase the network lifetime in wireless sensor networks. To provide sink location service in irregular sensor fields, our scheme guaranteed a crossing point between a quadrangle SLA quorum and a line SLQ quorum. Then, our scheme selected four random points for constructing the quadrangle SLA quorum and two random points for constructing the line SLQ quorum to balance the energy consumption of sensor nodes. Simulation results verified that our scheme reduced the energy consumption and thus raised the network lifetime compared with previous schemes, XYLS and CLPS.

References

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