무선 센서망에서 위치정보 선제공 기법을 이용한 에너지 효율적인 데이타 전달방안

우부재[O], 최영환, 박수창, 이의신, 전야, 박호성, 김상하

충남대학교 컴퓨터공학과

{yufc, yhchoi, winter, eslee, tianye, hspark}@cclab.cnu.ac.kr and shkim@cnu.ac.kr

Energy-efficient Data Dissemination Scheme via Sink Location Service in Wireless Sensor Networks

Fucai Yu[O], Younghwan Choi, Soochang Park, Euisin Lee, Ye Tian, Hosung Park and Sang-Ha Kim

Dept. of Computer Engineering, Chungnam National University

Abstract

Geographic routing has been considered as an efficient, simple, and scalable routing protocol for wireless sensor networks since it exploits pure location information instead of global topology information to route data packets. Geographic routing requires the sources nodes to be aware of the location of the sinks. In this paper, we propose a scheme named Sink Location Service for geographic routing in wireless Sensor Networks, in which the source nodes can get and update the location of sinks with low overhead. In this scheme, a source and a sink send data announcement and query messages along two paths respectively by geographic routing. The node located on the crossing point of the two paths informs the source about the location of the sink. Then the source can send data packet to the sink by geographic routing. How to guarantee that these two paths have at least one crossing point in any irregular profile of sensor network is the challenge of this paper.

1. Introduction

Geographic routing[1] has been considered as an attractive approach since it exploits pure location information instead of global topology information to route data packets, this location based scheme makes it a more efficient, simple and scalable routing protocol in wireless sensor networks. In geographic routing scheme, a source node encapsulates the destination location in each data packet. After received a data packet, a node sends it to the one-hop neighbor which is geographically closest to the destination. This process repeats until the data packet is eventually received by the destination. This mechanism can minimize the hops from the source to the destination. Geographic routing requires three necessary conditions, i.e., First, each node must know its own location information, GPS service can fulfill this requirement; Second, each node must know the location of its one-hop neighbor nodes. This requirement can be fulfilled by beacon messages[1]; Third, source node must know the location of the destination node. Some well-known geographic routing schemes [1] [2][3][4] just merely assume that source nodes are aware of the location of packet destinations by some location service, how can the source nodes get the destination locations are not addressed in detail.

Flooding[5] is the simplest method for providing the source nodes with the sinks location information. Specially, a sink floods its own location information throughout the sensor network, thus all source nodes in the network can get the location of the sink. This flooding method consumes lots of network resources such as energy and bandwidth if multiple mobile sinks exist in the network.

To avoid the flooding overhead incurred for providing the source nodes with the location of sinks, two grid-based protocols, named TTDD[6] and ALS[7], were proposed. TTDD periodically constructs per-source based global grid structures, each grid point is associated with a dissemination node and each dissemination node is aware of its upstream and downstream dissemination nodes. A sink node broadcasts a data query message within about a grid cell size area to find a dissemination node. Then the query message is relayed by a series of dissemination nodes and eventually received by the source node. Then the source node sends data packets to the sink along the reverse path of the query message. Flooding query messages only within about a grid cell size is an efficient way, however, the bigger the cell size, the wider the flooding area, thus the more flooding overhead, while small grid size incurs more overhead for the grid construction. Periodic per-source based global grid constructions also significantly generate additional overhead.

Other than TTDD, ALS constructs a shared global grid structure for all sinks and sources by assigning the sensors nearest to the grid points as grid nodes. A sink disseminates its location announcement message to the grid nodes on four straight orthogonal directions. A source node also disseminates sink location query message to the grid nodes on four straight orthogonal directions. The grid nodes which received both sink location announcement message and sink location query message inform the source node about the sink location, then the source node sends data packet to the sink node by geographic routing. Though there is no flooding in above processes, the sink location announcement paths and source query paths are quite complex and there are too many redundant signal paths if multiple sources and sinks exist in the network.

In this paper, to minimize the overhead incurred for providing sources with the location of sinks, we propose a sink location

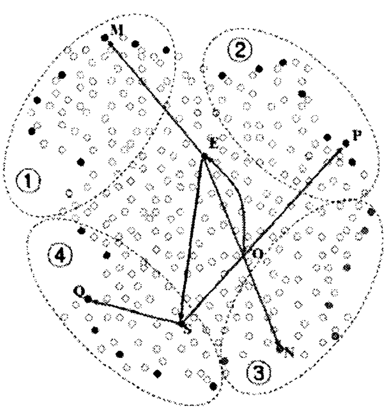

Figure.1 The proposed sink location service.

service for geographic routing in wireless sensor networks. In this scheme, a sink node sends sink location announcement message to two random locations on the edge of the sensor network by geographic routing, thus generating a location announcement path, and a source node sends source location query message to other two random locations on the edge of the sensor network by geographic routing, thus generating a sink location query path, the sensor node located on the crossing point of these two path informs the source about the sink location. Then the source sends data packet to the sink by geographic routing. There is no flooding and redundant signaling during sink location announcement/query phase. The challenge is that how to guarantee these two paths have at least one crossing point in any irregular profile of sensor networks.

2. The Proposed Scheme

We assume in this work that each node can get its own location information either by GPS or other location services [8][9]. Each node can get its one-hop neighbor list and their locations by beacon messages[1]. We consider the topologies where the wireless sensor nodes are roughly in a plane.

A. Sink Location Service

Fig.1 shows the proposed sink location service scheme for wireless sensor networks. The edge of the irregular profile of sensor network is divided into four parts, i.e., ①, ②, ③, and ④. There are a number of *network edge nodes* selected as anchor nodes in each part. Anchor nodes are a set of network edge nodes which are used as the destinations of sink location announcement message or sink location query message.

Upon detecting an event, a sensor node becomes a source node, e.g., node E in Fig.1. Source node E sends *Sink Location Query(SLQ)* message, which contains the source node location and the detected event type, to two random anchor nodes M and N in part ① and ③, respectively by geographic routing, thus generating a sink location query path $\overline{MEN}$, all the sensor nodes which participated in the geographic routing process save the source location and event type in their source list table.

When a sink exists in the sensor network, it sends a *Sink Location Announcement(SLA)* message, which contains the sink location and the sink's interest, to two random anchor nodes P and Q in part ② and ④, respectively by geographic routing, thus generating a sink location announcement path $\overline{PSQ}$, all the sensor nodes which in the geographic routing process save the sink's location and interest in their sink list table.

From Fig.1 we can see, no matter which two anchor nodes in part ① and ③ are select by source as anchor nodes, and no matter which source anchor nodes in part ② and ④ are select by the sink agent as sink anchor nodes; and no matter where the source E and the sink agent S are located in the network, the location query path $\overline{MEN}$ and the sink location announcement path $\overline{PSQ}$ have at least one crossing point O. The sensor node which is located on the crossing point received both *SLQ* and *SLA* and knows the source location, the event type, the sink location, and the sink interest. If the event type matches the sink interest, the sensor node informs the source node about the sink location information. After getting the sink location, the source node sends data packets to the sink by geographic routing. The sink relays the received data packets to the sink.

We have described the sink location service for geographic routing in wireless sensor networks. There are no flooding and residual signal paths for providing the source with the sink location. The issue is that the source node and the sink agent must be aware of their anchor location points. In other words, how to divide the edge of the network into four parts, and how does a sensor node select its anchor points are presented in the next subsection.

B. Network Initialization

a) Anchor nodes selection

The proposed scheme needs to select a number of sensor network edge nodes as anchor nodes. A node can know whether it is located on the edge of a sensor network either by manual identification during network deployment, or by some automatic detection method[10][11] after network deployment.

The anchor nodes selection process starts at a node named Initiator Node which can be a general sensor network edge node or a Personal Digital Assistant (PDA) equipment. First, The Initiator Node initializes a *Anchor Node Selecting*(ANS) message which is used for anchor nodes selection. The ANS message contains the following fields: *Initiator Node ID*, *Initiator Node Location*, *Anchor Interval*, and *Hop-To-Select*. The *Anchor Interval* field defines the number of general network edge nodes between two neighboring anchor nodes. If the *Anchor Interval* field is set to zero, all the sensor network edge nodes will be recruited as anchor nodes. The *Hop-To-Select* field is used by a network edge node to judge whether it should be selected as an anchor node. It is initialized by the Initiator Node to the same value as *Anchor Interval* field. The ANS packet is forwarded through all network edge nodes by the right rule[11](which states that it is possible to visit every wall in a maze by keeping your right hand on the wall while walking forward). When a network edge node receives the ANS packet, it checks whether the value of the *Hop-To-Select* field is zero. If nonzero, the node decrements the value of *Hop-To-Select* field by one. If zero, the node registers itself as an anchor node by inserting its own location into the ANS packet, and resets the *Hop-To-Select* field to the same value as the *Anchor Interval* field of the ANS packet. Then the node sends the ANS packet to its neighboring network edge node by the right hand rule.

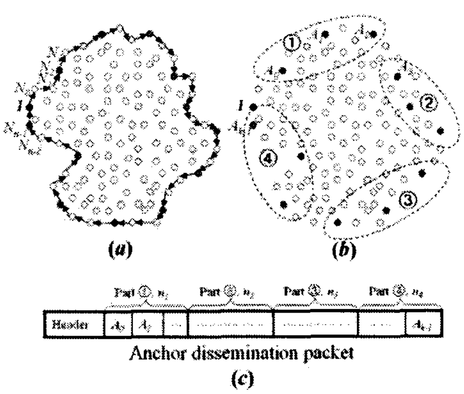

Figure.2 The proposed sink location service.

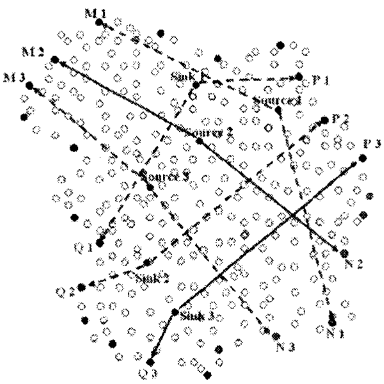

Figure.3 Multiple sources and sinks.

We assume that there are n sensor nodes named $\{N_0, N_1, N_2, N_3 \dots N_{n-1}\}$ located on the edge of the sensor network as shown in Fig.2-a. First, the Initiator Node I initiates and sends an ANS packet to its neighbor network edge node N_0 by the well-known right hand rule. In this ANS packet, the *Initiator Node ID* is set to the ID of the Initiator Node I, the *Initiator Node Location* field is set to the location of the Initiator Node I. Both *Anchor Interval* and *Hop-To-Select* fields are set to '2'. When node N_0 receives the ANS packet, it checks that the value of the *Hop-To-Select* field is nonzero, then it decrements the value of the *Hop-To-Select* field from '2' to '1' and sends the modified ANS packet to its neighboring network edge node N_1 by the right hand rule. Node N_1 implements the same process as node N_0, it decrements the value of the *Hop-To-Select* field from '1' to '0' and sends the modified ANS packet to its neighboring network edge node N_2 by the right hand rule. When node N_2 receives the ANS packet, it checks that the value of the *Hop-To-Select* field is '0', thus it registers itself as an anchor node by inserting its own location into the data packet. Then node N_2 resets the *Hop-To-Select* filed to '2', which is the same to the *Anchor Interval* field of the ANS packet, and sends the modified AMS packet to its neighboring network edge node N_3. These processes repeat until the ANS is transmitted by all network edge nodes and eventually received by the Initiator Node I. Then Initiator Node I gets an anchor node list $\{N_2, N_5, N_8, N_{11} \dots\}$ from the received ANS packet. We assume that there are k anchor nodes in the anchor node list $\{N_2, N_5, N_8, N_{11} \dots\}$. To facilitate discussion, we renumber the anchor node list as $\{A_0, A_1, A_2, \dots A_{k-1}\}$ as shown in Fig 2-b.

b) Anchor nodes dissemination

if (k can be divided by 4 exactly)
  $n_1 = n_2 = n_3 = n_4 = k/4$; (e.g., k=16, n_1=n_2=n_3=n_4=4)
else if (k is a even number but can not be divided by 4 exactly)
  $n_1 = n_2 = \lfloor k/4 \rfloor$, $n_1 = n_2 = \lfloor k/4 \rfloor + 1$; (e.g., k=14, n_1=n_2=3, n_3=n_4=4)
else (k is a odd number)
  { $n_1 + n_2 = \lfloor k/2 \rfloor$, $n_3 + n_4 = \lfloor k/2 \rfloor + 1$;
  If (n_1 + n_2 is a even number)
   $n_1 = n_2 = n_3 = \lfloor k/4 \rfloor$, $n_4 = \lfloor k/4 \rfloor + 1$; (e.g., k=13, n_1=n_2=n_3=3, n_4=4)
  else (n_1 + n_2 is a odd number)
   $n_1 = n_2 = n_3 = \lfloor k/4 \rfloor + 1$, $n_4 = \lfloor k/4 \rfloor$; (e.g., k=15, n_1=n_2=n_3=4, n_4=3)
  }
end

After getting an anchor node list, the Initiator Node I initiates a *Anchor Nodes Dissemination*(AND) packet. This AND packet contain four fields, i.e., *Part* ①, *Part* ②, *Part* ③, and *Part* ④, each field encapsulates a sub-list of anchor nodes as shown in Fig 2-c. Assuming n_1, n_2, n_3, and n_4 are the number of anchor nodes in each part, n_1, n_2, n_3, and n_4 can be calculated as follows:

After AND packet initialization, the Initiator Node I floods the AND packet throughout the sensor network. Each sensor node maintains an anchor nodes table containing *Anchor node* 1, *Anchor node* 2, *Anchor node* 3, and *Anchor node* 4 items. When a sensor node receives the AND packet, it randomly selects four anchor nodes form *Part* ①, *Part* ②, *Part* ③, and *Part* ④ field of the received AND packet and saves them to the *Anchor node* 1, *Anchor node* 2, *Anchor node* 3, and *Anchor node* 4 items of the anchor node table respectively.

Up to now, each sensor node got four anchor nodes in its anchor node table. As shown in Fig.1, if a sensor detected a stimulus, it sends *Sink Location Query(SLQ)* message to *Anchor node* 1 and *Anchor node* 3 in its anchor node table by geographic routing. If a sensor node is recruited as a sink agent, it sends a *Sink Location Announcement(SLA)* message to *Anchor node* 2 and *Anchor node* 4 in its anchor node table by geographic routing. The sensor node located on the crossing point of the two paths informs the source node about the sink location, therefore, the source node sends data packet to the sink agent by geographic routing.

3. Analysis

In this scheme, there is no flooding or global grid construction process during sink location announcement and sink location query phase. Only one time flooding is required during network initialization phase. For a long term monitoring oriented sensor network, just one time flooding will not generate significant overhead.

Fig.3 shows a scenario of the proposed sink location service where multiple sources and sinks exist in the sensor network. In this scenario, the sink location announcement path of any sink and the sink location query of any source must have one crossing point. Once a sink sends a location announcement message to sink anchor nodes, all sources can get the location of the sink from the corresponding crossing nodes; once a source sends a sink location query message, it can get the location information of all sinks form the corresponding crossing nodes.

As mentioned in section II.B.a, the *Anchor Interval* field of *Anchor Node Selecting*(ANS) message defines the number of network edge nodes between two neighboring anchor nodes. If the *Anchor Interval* field was set to zero, then all the network edge nodes will be selected as anchor nodes. In this case, all the sensor network edge nodes have the same probability to be used as the anchor nodes by sources or sinks, thus balancing the energy consumption of network edge nodes. However, since all network edge nodes are recruited as anchor nodes, all these nodes need to inset their location into the ANS packet, therefore, the scalability of the protocol is reduced. In another extreme case, if the *Anchor Interval* field was set to a large enough value so that there are only four network edge nodes selected as anchor nodes. This case can minimize the size of ANS packet, but these four anchor nodes will be used by all sources or sinks in the sensor network, so the energy of the sensor nodes near these four anchor nodes will be significantly consumed. So the network size, density, and the statistic number of sources and sinks should be considered for choosing a proper *Anchor Interval* value.

For a scalable sensor network, it might happen that the ANS packet is fully loaded by the anchor node locations before the received by the Initiator Node *I*. There are two solutions can solve this problem, the first solution is that the Initiator Node *I* reinitiates a new ANS packet with an enough large the *Anchor Interval* value. Another solution is that if a network edge node detects that the ANS packet is fully loaded, it sends a copy of the fully loaded ANS to the Initiator Node *I* by geographic routing, then, it releases all the anchor locations in the ANS packet and sends the empty ANS packet along the network edge continuously.

4. Conclusions and Future Works

In this paper we proposed a sink location service for geographic routing in wireless sensor networks. Each senor node gets four anchor locations during network initialization phase. A source node sends sink location query message to two anchor nodes on the edge of the sensor network, and a sink agent sends sink location announcement to other tow anchor nodes on the edge of the sensor network. The sensor node located on the crossing point of the sink location announcement path and the sink location query path inform the source about the sink location, then the source sends data packet to the sink by geographic routing. No flooding or global grid structure is needed for sink location announcement or query. This sink location service generates lower overhead than the existing protocols. How to support mobile sinks and mobile events is remained in future research works.

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