Structure-based ID Assignment for Sensor Networks

Jung Hun Kang, Myong-Soon Park[†]*,*

Department of Computer Science and Engineering
Korea University, Seoul, 136-713, Korea

Summary

A sensor network consists of a set of battery-powered nodes, which collaborate to perform sensing tasks in a given environment. Globally unique ID allocation is usually not applicable in a sensor network due to the massive production of cheap sensor nodes, the limited bandwidth, and the size of the payload. However, locally unique IDs are still necessary for nodes to implement communications to save energy consumption. Already several solutions have been proposed for locally unique ID assignment in sensor networks. However, they bring much communication overhead, and they are complex to implement. We present a structure-based algorithm to solve the unique ID assignment problem. This algorithm can save energy consumption by reducing communication overhead while IDs are assigned.

Key words:
Structure; unique, ID assignment; sensor networks

1. Introduction

A sensor network consists of a large number of sensor nodes simultaneously engaged in environment monitoring and wireless communications. In traditional distributed systems, the name or address of a node is independent of its geographical location and is based on the network topology. However, in sensor networks, it has been widely proposed to use attributes external to the network topology and relevant to the application for low-level naming [1]. Solution gradually makes some neighbor nodes into a group and simultaneously assigns the unique ID to each node. Unique IDs are assigned by a header node of each group. Globally unique IDs are useful in providing many network functions, e.g. configuration, monitoring of individual nodes, and various security mechanisms.

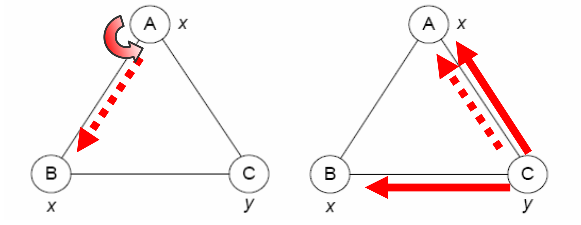

Fig. 1 ID Conflict problems in sensor networks.

ID conflict problem is a major issue of the ID assignment in sensor networks [2]. In the fig. 1, nodes ***A***, ***B***, and ***C*** are connected to each other. Nodes ***A*** and ***B*** have the same ID of *x*, node ***C*** has a different ID of *y*. If node ***A*** wants to send a packet to node ***B***, a traditional network layer protocol usually considers packet destined for itself and will not deliver the packet to the underlying data link layer because the destination has the same address of the source. If node ***C*** wants to send a packet to either node ***A*** or node ***B***, because they both have the same address, both will receive the packet and process it, which will waste power. Thus, how uniquely and efficiently assigning ID in sensor network is the biggest issue.

An obvious ID assignment strategy is to have each node randomly choose an ID such that the probability of any two nodes choosing the same ID is very low. However, for this probability to be low, we need to the IDs to be very long, which is again costly in terms of energy [3]. Any ID assignment solution should produce the shortest possible addresses because sensor networks are energy-constrained. The usage of the minimum number of bytes required in motivated by the need to limit the size of transmitted packets, in particular the header. In fact, communication is usually the main source of energy drain in sensor node [4].

This paper proposes a structure-based ID assignment, which is an efficient ID assignment in a sensor network. This paper is constructed as follows: Section 2 introduces work related to ID assignment in sensor networks. Structure-based ID assignment is distributed in Section 3. Then the efficiency of the scheme is supported by simulation results in Section 4. Finally, Section 5 concludes the paper and future works.

2. Related Work

In general, network-wide unique addresses are not needed to identify the destination node of a specific packet in sensor networks. In fact, attribute-based addressing fits better with the specificities of sensor networks [5]. In this case, an attribute such as node location and sensor type is used to identify the final destination. However, different

Manuscript received July 5, 2006.
Manuscript revised July 25, 2006.

nodes can have the same attribute value, in particular in the same neighborhood. Thus, there is a need to uniquely identify the next hop node during packet routing [6]. Several schemes have been proposed to assign locally unique addresses in sensor networks.

In [4], Schurgers, et al., developed a distributed allocation scheme where local addresses are spatially reused to reduce the required number of bits. The preexisting MAC addresses are converted into locally unique addresses. Each locally unique ad-dress is combined with an attribute-based address to uniquely determine the final destination of a packet. This use of locally unique addresses instead of global ad-dresses does not affect the operations of the existing routing protocols. This solution assumes the pre-existence of globally unique addresses, which is not realistic in the case of sensor networks.

The scheme proposed in [7] utilized a proactive conflict detection method for a general sensor network, including a mobile sensor network, and a stationary sensor network with new members joining. When a node boots up, it first chooses a random physical address and then announces it with periodic broadcasts of HELLO messages with the interval of 10 seconds. All the nodes record the source address of the HELLO message in a neighbor table, which is included in the subsequent HELLO messages. Therefore, every node will have 2-hop neighbor information, which is utilized to resolve address conflicts among 2-hop neighbors. If a node finds that one of its neighbors chooses a duplicate address, it will notify this neighbor to change the ad-dress.

Reactive ID Assignment [2] is introduced next. This algorithm defers ID conflict resolution until data communications are initiated. It leads to save communication overhead. However, every node can not choose a random ID in the beginning. Sensor network is getting enlarged; the number of communication is being increased extremely. In addition, many kinds of messages make this algorithm more complex.

As the globally unique ID assigning scheme, Distributed ID Assignment is introduced in [8]. In order to assign ID, Tree structure is used to compute the size of the network. Then Unique IDs are assigned using the minimum number of bytes. However, this scheme uses not only assigning temporary ID and final unique ID but also obtaining sub-tree size. In order to assign temporal ID and final unique ID, high communication cost is needed.

In [9], Ali, et al., proposed an addressing scheme for cluster-based sensor net-works [10]. To prevent collisions, nodes within the same cluster are assigned different local addresses. Non-member one-hop and two-hop neighbors must also have different local addresses to avoid the hidden-terminal problem. The network is divided into hierarchical layers where the number of layers increases with the number of nodes in the network. Global IDs are obtained by putting together the local address and the addresses of the head nodes of the different layers. This solution suffers from the fact that the address size increases with the number of layers as 6 bits are added for each layer. However, this makes this solution less attractive due to the energy cost of using global IDs in the case of large sensor networks. In addition, this solution can be used only with cluster-based routing and does not extend to the case of multi-hop routing [11].

3. Structure-based ID Assignment Algorithm

We proposed a structure-based algorithm that assigns globally unique IDs to sensor nodes. In this section, the assumptions for our proposed ID assignment scheme are given first, and then the message types and proposed algorithms are described in detail.

3.1 Assumption

Initially, we define some assumptions like below:

(1) The nodes in a sensor network are usually manufactured in batches.

(2) Neighbour node IDs must be stored in the memory of the sensor node during all its lifetime

(3) ID Assigned field is combined as 3 parts: Group ID, Section ID, and Node ID. (For example, assigned ID, 0123 means Group ID (01), Section ID (2), and Node ID (3))

(4) The number of nodes in a group should be less than 9.

3.2 Message Types

Totally 4 kinds of messages are used to assign IDs in each node.

① ***Level1_SEARCH message***: Within 1-hop, a SINK node or a Header node searches neighbor nodes that have no assigned ID. After collecting neighbor node Information, it assigns sequence ID to searched neighbor nodes.

② ***Level2_SEARCH message***: Within 2-hops, sink node let just assigned neighbor nodes to search the other neighbor nodes that have no assigned ID. After collecting neighbor node Information, it assigns sequence ID to searched neighbor nodes.

③ ***Child_GROUPING message***: Sink node can make extended other groups by unicasting this message to ID assigned border node in level 2. Border node broadcasts this message to neighbor nodes and choose one node (fastest responding time) to make it as a header node.

④ ***Sink_REPORTING message***: All header nodes can send the grouping information and ID assigning status to sink node at the end of assigning ID task in each header.

3.3 Grouping and ID assigning Algorithm

In order to assign globally unique IDs to each node, we divided the proposed ID assignment scheme into two parts: Parent grouping algorithm and Children grouping algorithm. They assign globally unique IDs to each node while they build groups.

Firstly, Parent grouping algorithm takes roles of building core group and assigning IDs to neighbor nodes from the sink node. In order to expand children groups, these assigned IDs are working as a message forwarder.

Children grouping algorithm takes roles of building expanded groups and assigning ID globally. In each group, sink node sets a header node as a sub-sink node to broadcast messages and collect information instead of the sink node.

Algorithm 1: **Parent Grouping Algorithm.**

Step 1.
Sink node broadcasts ***Level1_SEARCH*** message.

Step 2.
Sink node assigns the sequential IDs to found nodes by upon the responding time.

Step 3
The Sink node transfer ***Level2_SEARCH*** message to level1 nodes

Step 4.
Level1 nodes broadcast received ***Level2_SEARCH*** message to 1-hop neighbor nodes

Step 5.
Level1 node assigns sequential ID for level2 nodes (upon the responding time)

Step 6.
Level1 nodes report ID-assigned results to Sink node by sending ***Sink_REPORTING*** message

In the Parent groping algorithm, the sink node builds the 1st level area within 1-hop range by broadcasting ***Level1_SEARCH*** message. This makes a 1-hop core area from the sink node. ID of sink node is set as 0000. In this core area, node members assign their ID as 0001, 0002 up to the responding time. 2nd level areas are expanded via 1st level members when the sink node broadcasts ***Level2_SEARCH*** message to those members. Up to the member nodes' ID, section IDs are decided in nodes of the 2nd level. After assigning IDs of member nodes in 2nd level, 1st level members report their ID assigned status to the sink node. Via these organized group members, the sink node let them to forward message to header nodes in each group. This makes the sink node to know how many members are assigned, and who can be a message forwarder by sending ***Sink_REPORTING*** message to sink node. Steps of ID assigning in Parent grouping algorithm are illustrated in fig. 2 as well.

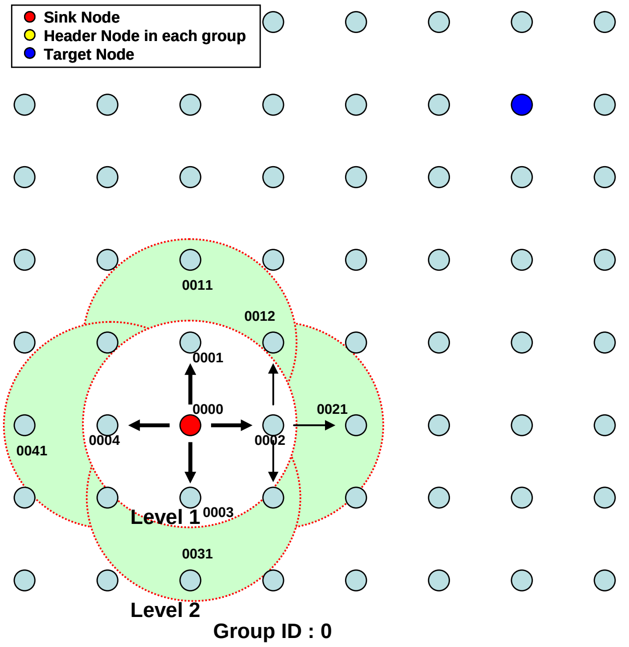

Fig. 2 ID assignment in Parent Grouping Algorithm.

Children grouping algorithm starts with unicasting ***Child_GROUPING*** messages from the sink to 2nd level members. Member nodes in 2nd level choose one node which has the fastest responding time among the neighbor nodes. And then, they unicast the ***Child_GROUPING*** message to the selected node. After receiving this message, this selected node can be a header in a children group. With the given group ID, the header ID (00) is assigned to the chosen header node as a root of a children group. The given group ID is decided by the sink node. By up to the time of creating group, the sink node decides the ID sequentially. This header node broadcasts message to build the 1st level area of the children group. And left processes are same as the Parent grouping algorithm. When the other children group is extended, the intermediate header nodes record the IDs of new created header nodes in newly created children groups by the previous header node, and then report the assigned ID status to the sink node. Detail steps of Children grouping algorithm are illustrated in fig. 3.

Algorithm 2: **Children Grouping Algorithm.**

Step 1.
The Sink node unicasts ***Child_GROUPING*** message to a specific border node in level 2

Step 2
Level2 node chooses one node which has the fastest responding time among the neighbor nodes.
Level2 node unicasts ***Child_GROUPING*** message to chosen node.

Step 3.
Group ID and 00(header ID) is assigned to the chosen node as a header node

Step 4.
A header node (Children-header node) broadcast ***Level1_SEARCH*** message to neighbors in a 1-hop distance.

Step 5.
Chosen level1 nodes broadcast ***Level2_SEARCH*** message to set level2 nodes

Step 6.
Header node report ID-assigned result to Sink node by sending ***Sink_REPORTING*** message

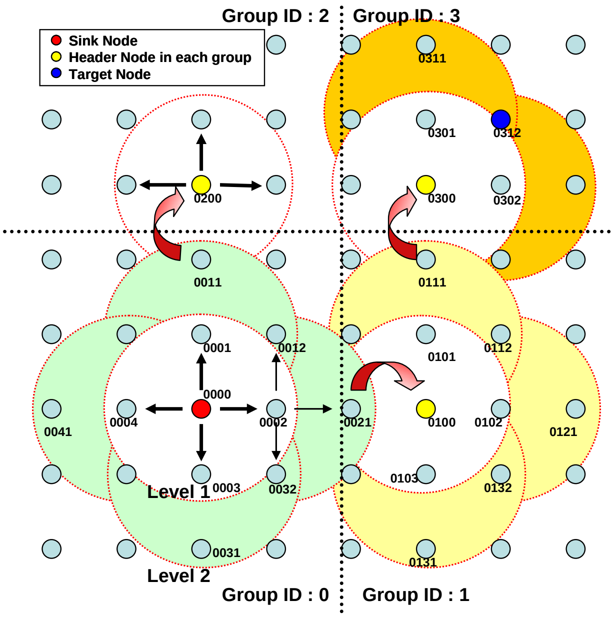

Fig. 3 ID assignment in Children Grouping Algorithm

4. Simulation Results

The simulations are implemented to compare their performance in the NS-2 network simulator (Version 2.27) [12] with the modification of directed diffusion module [13]. The sensor nodes are placed in a 13 x 13 grid for a stationary sensor network. The distance between two nodes is 100 meters so that a node in the middle of the network has 4 direct neighbors. The size for the address is 4 bits. In the fig. 4, it shows the 13 x 13 matrix network topology for this simulation.

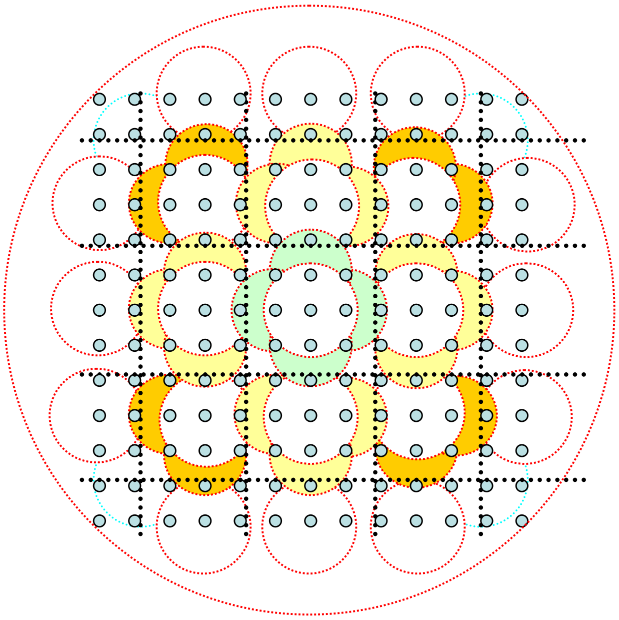

Fig. 4 Idle configuration in 13 x 13 matrix network topology

4.1 Communication Overhead

Fig. 5 shows the sum of received message packets at all the nodes when assigning IDs globally. We set the node density as 100, 169, 225, and 324. In the case of proactive case, it broadcasts periodic HELLO message including its neighbor table. In every transmission, each node broadcast the periodic HELLO message to each other to assign ID. This causes extremely high communication overhead. Reactive scheme broadcasts HELLO message in the end of the simulation to build the neighbor table for analysis. This broadcasting message cause much lower communication overhead than the proactive scheme. However, in order to avoid the ID conflict problem, this scheme keeps going on sending CHANGE message to each other. This overhead is quite high. In the structure-based ID assignment scheme, communication overhead is much lower than the other two schemes because in each group, when ID is assigned to members of groups, it locally communicates the assigning message to member nodes. Also in the header node, they target only a few member nodes to assign ID in each group. Indeed, only reporting messages and control messages like ***Child_GROUPING*** message are transferred to the sink node. The simulation shows the comparison among those three schemes in fig. 5. According to the simulation result, the proposed scheme causes much lower communication overhead than the other two schemes; proactive and reactive ID assignments.

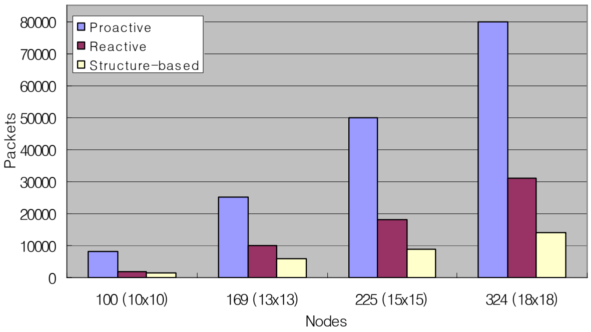

Fig. 5 Communication Overhead.

4.2 Energy Consumption

We compare the energy consumption when ID is assigned in each node. The energy consumption is measured by the sum of energy consumed by all the sensor nodes on the data transmission when IDs are assigned. In order to evaluate the energy consumption, we set parameter values like as Table 1.

Table 1: Parameter settings in simulation

Parameter name	***Value***
Ratio bandwidth	20Kbps
Ratio Transmission Range	100m
Packet Length	10bytes
Transmit Power	8.2mA
Receiver Power	4.6mA

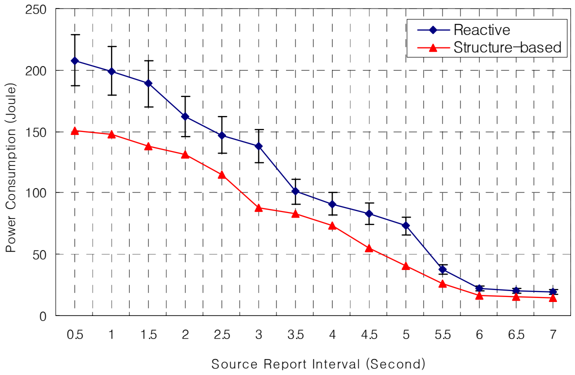

Fig. 6 Energy Consumption.

In the fig 6, it shows the comparison result of the energy consumption. In the reactive ID assignment scheme, in order to avoid the ID conflict problem, it communicates messages in many times. This causes high energy consumption in transferring messages. In contrast, structure-based algorithm consumes lower energy consumption than the reactive scheme because of the globally unique ID. When sink node or header node assign IDs to nodes, it communicates messages with only a few node. And in each children group, each header control to assign ID to neighbor nodes locally. This causes the total of energy consumption lower. Thus, structure-based ID assignment scheme saves both bandwidth and power more than 25%. Furthermore, in each group, header node takes ID assigning task instead of the sink node which leads to shorter length and less power consumption to assign IDs to all nodes.

4.3 Analysis

The total amount of energy consumption of the structure-based ID assignment scheme can be described as the Eq.1. When each parameter is defined as below:
x is the number of sink node, header node i, total number of all created group is $\hat{t}_x$, the total amount of nodes in group is t, $P_{x,i,i}(t)$ is the total amount of communication cost in 1st level, and $P_{x,i,j}(t)$ is the total amount of communication cost in 2nd level

$$\mathrm{E}(x,\hat{t}_x) = \sum_{t=t_1}^{\hat{t}_x}\left[\Delta_i(t)P_{x,i,i}(t) + \sum_{j\in K(x)}\Delta_j(t)P_{x,i,j}(t)\right] \qquad (1)$$

5. Conclusions and future work.

In this paper, we presented a solution to the globally unique ID assignment problem in sensor networks. Our proposed algorithm aims at assigning globally unique IDs to each node by using two grouping algorithms. Through these two grouping algorithms, it structures two levels of groups. In each group, headers take roles of sink and it assigns neighbors' IDs instead of sink node. Sink node can not only easily assign IDs to all other nodes via header nodes but also save the energy consumption up to 25%. We also showed the energy efficiency of our proposed algorithm in the simulation.

The challenge in our future work is to establish an efficient routing architecture based on our scheme in sensor networks. In addition, we will study the global grouping management and the grouping resilience in the sensor networks.

Acknowledgments

Dr. Myong-Soon Park† is the corresponding author.

References

[1] J. Heidemann, F. Silva, C. Intanagonwiwat, R. Govindan, D. Estrin, and D. Ganesan. "Building Efficient Wireless Sensor Networks with Low-Level Naming," In Proceedings of the Symposium on Operating Systems Principles, pp. 146-159. Chateau Lake Louise, Banff, Alberta, Canada, ACM. October, 2001

[2] Hongbo Zhou, Matt W. Mutka, and Lionel M. Ni, "Reactive ID Assignment for Sensor Networks," In Proceedings of IEEE MASS 2005: 2nd IEEE International Conference on Mobile Ad-Hoc and Sensor Systems, Washington DC, November 2005

[3] J. R. Smith, "Distributing identity," IEEE Robotics and Automation Magazine, Vol.6, No.1, March 1999

[4] C. Schurgers, G. Kulkarni, and M. B. Srivastava, "Distributed On-demand Address Assignment in Wireless Sensor Networks," In Proceedings of IEEE Transactions on Parallel and Distributed Systems Vol.13, October 2002

[5] D. Estrin, J. Heidemann, and S. Kumar, "Next century challenges: Scalable coordination in sensor networks," in Proceedings of MOBICOM,pp. 263–270, 1999.

[6] M. Ali and Z. A. Uzmi, "An energy efficient node address naming scheme for wireless sensor networks," in Proceedings of MOBICOM, pp. 263~270, 1999.

[7] C. Schurgers, G. Kulkarni, and M. B. Srivastava, "Distributed Assignment of Encoded MAC Address Assignment in Wireless Sensor Networks," In Proceedings of MobiHOC 2001, Long Beach, CA, October 2001.

[8] ElMoustapha Ould-Ahmed-Vall, Douglas M. Blough, Bonnie S. Heck and George F. Riley, "Distributed Unique Global ID Assignment for Sensor Networks," In Proceedings of IEEE International Conference on Mobile Ad-Hoc and Sensor Systems, Washington DC, November 2005

[9] M. Ali and Z. A. Uzmi, "An energy efficient node address naming scheme for wireless sensor networks," in Proceedings of the International Networking and Communications Conference (INCC), 2004.

[10] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specifi c protocol architecture for wireless microsensor networks," IEEE Transactions on Wireless Communications, Vol.1, No.4,October 2002.

[11] W. B. Heinzelman, J. W. Kulik, and H. Balakrishnan, "Adaptive protocols for information dissemination in wireless sensor networks," in Proceedings of MOBICOM, 1999.

[12] Network Simulator, http://www.isi.edu/nsnam/ns, July 2006

[13] C. Intanagonwiwat, R. Govindan, D. Estrin, and J. Heidemann, "Directed Diffusion for Wireless Sensor Networking," In Proceedings of IEEE/ACM Transactions on Networking, Vol. 11, No. 1, February 2003.

Jung Hun Kang received the B.S. degrees in Computer Science from Korea University in 2005. He is now studying Computer Science as a Master Student in Korea University since 2005. His research interests include ubiquitous computing, embedded system, Ad Hoc network and wireless sensor network.

Myong-Soon Park received the Ph.D. degree in Electrical and Computer Engineering from the University of Iowa in 1985. He has been with Computer Science and Engineering at Korea University since 1988, and is a full Professor. His research interests include parallel processing, clustering, internet computing, and networks on storage. He is a member of IEEE, KISS, IEEK.