Designing the tree-based relaying network in wireless sensor networks

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Abstract

In the environment with multiple heterogeneous wireless sensor networks with a single point of sensed data collection or a gateway (GW), relay points (RPs) may be required for the energy efficient delivery of sensed data from static or mobile sinks to the GW. The optimal placement of RPs becomes an even more difficult problem if static sinks are dynamically added or the trajectory of mobile sinks cannot be known in advance. In order to resolve this problem, we propose a mechanism to deploy RPs in a grid pattern and to use the tree-based relaying network for reducing the cost of the RP and for reducing the control overhead incurred by the route setup from sinks to the GW. For the performance evaluation of our proposed mechanism, we have carried out a numerical analysis on a single route setup from a sink to the GW and, for more general performance evaluations, NS-2 based simulations have been carried out. According to the performance evaluation results, our tree-based relaying network mechanism outperforms that based on AODV in terms of the data delivery time, the network service time and the control overhead.

Keywords: *Sensor Network, Tree, Relay Nodes*

1. Introduction

A typical wireless sensor network consists of densely deployed static sensor nodes with one static sink. Because sensed data are collected at the sink, sensors closer to the sink consume more energy and have shorter lifetime. In order to overcome this problem, sensors can be additionally deployed to replace failed sensors, or multiple sinks or a mobile sink can be used.

For a sensor network with static sensors, the optimal trajectory of a mobile sink has been studied in [1-3]. In a heterogeneous sensor network composed of sensors without the relaying functionality, relay nodes (RNs) are used for the delivery of sensed data to a sink (or a base station) and the optimal placement of RNs have been studied by many researchers [4-10].

In a complex and large building or area, multiple heterogeneous sensor networks can be deployed with a single point of sensed data collection or a gateway (GW). And, in this case, sinks may be sparsely deployed and located far from the GW, so an energy efficient delivery mechanism from sinks to the GW is required. For this, relay points (RPs; we use 'relay point' instead of 'relay node' since 'relay node' is for relaying sensed data between sensors and a sink)

[1] corresponding author
[2] This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the HNRC(Home Network Research Center) –ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT Industry Promotion Agency (NIPA-2010- C1090 - 1011 – 0010)

between sinks and the GW can be used, but if static sinks are added dynamically and the trajectory of mobile sinks cannot be known in advance, the optimal placement of RPs becomes a more difficult problem than that for a single heterogeneous sensor network.

Therefore, in this paper, we propose to deploy RPs in a grid pattern so that the flexible placement of sinks can be achieved in the multiple heterogeneous sensor networks. For the connectivity between sinks and the GW, the existing mobile ad hoc network routing protocols can be used, but this may cause significant overhead due to the unique characteristics of the large-scale multiple heterogeneous sensor networks. Hence, we propose to use the tree-based relaying network composed of RPs for providing the network connectivity between sinks and the GW. Because the final destination of data sent from RPs is the GW, the GW becomes the root of the tree and RPs perform only the simple forwarding function. Thus, the cost of the RP can be significantly reduced by eliminating the complex routing function and, as a result, the lifetime of the RP can be improved.

The performance of our proposed tree-based relaying network is compared with that of the AODV-based approach where AODV is used for the route setup from sinks to the GW. For the performance comparison, the signaling cost for setting up a route from a sink to the GW is numerically analyzed and the analytical result shows that the AODV-based approach requires almost 7 times larger signaling cost than the tree-based approach. And, for the general case performance evaluation, the NS-2 based simulations have been carried out and the simulation results indicate that the tree-based approach outperforms the AODV-based approach in terms of the data delivery time, the network service time and the control overhead.

This paper is organized as follows. Section 2 presents the related work. In section 3, the definition of the relaying network, the problem statements and our proposed tree-based relaying network are described in detail. Section 4 gives the performance evaluation by the numerical analysis and the NS-2 based simulations, and finally we conclude in section 5.

2. Related work

Most of the previous works on the wireless sensor network focus on prolonging the network lifetime, providing the network connectivity among sensing related devices and guaranteeing the network coverage. A heterogeneous sensor network is composed of diverse devices, such as a sink, RNs and sensors, each of which has different functionalities and power/computing/communication capabilities. The overall performance of the heterogeneous sensor network can be affected by the placement of RNs and, in recent years, there has been extensive research done on the optimal placement of RNs [4-10].

In [4], the authors try to solve the energy provisioning and the RN placement problems jointly, and show that this joint problem can be formulated into a mixed-integer non-linear programming problem and propose a heuristic algorithm SPINDS which iteratively moves an RN to a better location. Their mechanism is not appropriate for a large-scale randomly deployed network.

[5] is the first work to optimize the random device deployment by using the density function in a large-scale wireless heterogeneous sensor network and propose three random deployment strategies for RNs, the connectivity-oriented deployment, the lifetime-oriented deployment and the hybrid deployment. [6] solves the optimal RN placement with concerning the network lifetime and the connectivity and proposes a

two-phase placement solution in which the first phase deploys RNs to provide the connectivity to sensors and the second phase places more RNs to relay the traffic for the RNs deployed in the first phase so that lifetime constraints on the whole network are satisfied.

[7] formulates a generalized wireless sensor network design problem with the objective of the minimum device cost with considering the network coverage, the connectivity and the network lifetime and show that this problem is equivalent to the minimum set covering problem [11] and solve this problem by proposing a recursive algorithm.

The objective of [8] is to place the minimum number of RNs such that each sensor can communicate with at least one RN and the network of RNs is connected. Two optimization problems, namely, the connected relay node single cover (CRNSC) problem and the 2-connected relay node double cover (2CRNDC) problem, are formulated to ensure survivability of the network in the event of a single RN failure and two polynomial time approximation algorithms are presented. In [9], the problem of deploying RNs in a heterogeneous wireless sensor network where sensors have different transmission radii is defined and, depending on the level of desired fault-tolerance (here, 'fault' means 'RN failure'), the problem becomes the full fault-tolerance RN placement problem where the minimum number of RNs is deployed to establish k vertex-disjoint paths between every pair of sensor and/or RNs, or the partial fault-tolerance RN placement problem where the minimum number of RNs is deployed to establish k vertex-disjoint paths only between every pair of sensors. Also, they develop polynomial time approximation algorithms for those problems. [10] formulates two RN placement problems where RNs have different transmission radii from sensors. The first RN placement problem is to deploy the minimum number of RNs so that, between each pair of sensors, there is a connecting path consisting of RNs and/or sensors. And the second one is to deploy the minimum number of relay nodes so that, between each pair of sensor nodes, there is a connecting path consisting solely of RNs. For each problem, they propose a polynomial time approximation algorithm. However, all of these research efforts focus on the optimal deployment of RNs in a heterogeneous sensor network with a single sink and cannot be applied to the multiple heterogeneous sensor networks where static sinks are added dynamically and the trajectory of mobile sinks cannot be known in advance.

3. Tree-based relaying network in wireless sensor networks

3.1. Definition of the relaying network

As described in section 2, previous works on the sensor network deployment focus on providing the network connectivity between sensors and sinks and guaranteeing the sensing coverage within a single sensor network. When multiple heterogeneous sensor networks are deployed within a large area and the sensed information from these networks has to be collected via a GW, the issues to be resolved may be different from those for the single heterogeneous sensor network. Figure 1 shows an example of the multiple heterogeneous sensor network environment; a museum is deployed with a number of different types of sensor networks, one for detecting intruders and another for monitoring the status of the exhibits, etc., and the sensed information from those heterogeneous sensor networks has to be collected at the security center. This type of scenarios can happen in complex and large buildings or areas such as the airport or the battlefield.

In the environment with coexisting heterogeneous sensor networks with one GW (i.e., the multiple heterogeneous sensor networks), it is likely that sinks are located far from the GW and sparsely dispersed, so it may be hard to provide the network connectivity between sinks and the GW. Therefore, a second-tier network consisting of relay points (RPs) (for short, the relaying network), as shown in Figure 2, is required for the effective (energy efficient) delivery of the information processed by sinks to the GW (that is, to provide the network connectivity between sinks and the GW). The placement of RPs affects the overall performance of the multiple heterogeneous sensor networks, so this can be one of the important issues related to the relaying network. In this paper, we assume the relaying network with both static and mobile sinks and, in this case, if the location of static sinks and the trajectory of mobile sinks are known in advance, the optimal placement of RPs becomes very similar to the optimal placement of RPs in a single heterogeneous sensor network mentioned in section 2. However, if static sinks are added or the trajectory of mobile sinks changes, the optimal placement mechanism mentioned in section 2 cannot cope with this dynamics in an appropriate way. Therefore, in this paper, we propose to deploy RPs in a grid pattern so that the flexible placement of sinks can be achieved in the multiple heterogeneous sensor networks.

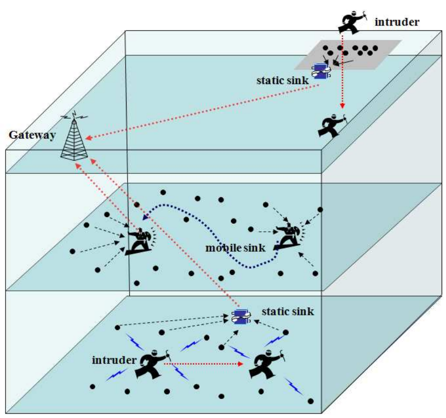

Figure 1. Sensor network usage scenario in a museum.

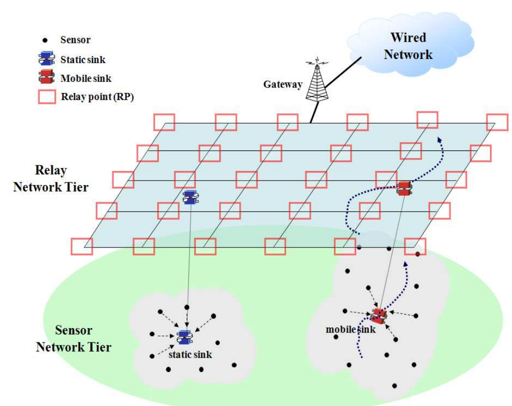

Figure 2. Three-tiered wireless sensor network.

3.2. Problem statements

We can use the existing mobile ad hoc network (MANET) routing protocols (such as AODV [12] or DSDV [13]) for the connectivity between sinks and the GW, but this may cause significant overhead due to the unique characteristics of the large-scale multiple heterogeneous sensor networks.

The MANET routing protocols can be classified into the table-driven approach (e.g., DSDV) and the on-demand approach (e.g., AODV). If we use a table-driven routing protocol, an RP can deliver the data from a sink to the GW without causing route setup delay since a route from any RP to the GW has already been set up. Besides, a mobile sink can deliver its data to the GW with no delay even when it moves around. In this paper, since we assume that sinks are located sparsely, most RPs do not have any sinks in their transmission range and, even for this case, the table driven routing protocol sets up routes for all RPs to the GW, most of which are useless. On the other hand, the on-demand routing protocol resolves the above-mentioned problem of the table-driven routing protocol by setting up routes for only RPs with data to the GW. But the on-demand routing protocol initiates the route setup procedure upon receiving data from a sink, which causes delay, and, as a result, increases the data delivery time. Also, the route setup procedure of most on-demand routing protocols is based on flooding which causes a substantial overhead.

In this paper, we propose the tree-based relaying network which is not based on flooding and takes the advantages of both approaches, i.e., no route setup delay and only necessary route setups. In the tree-based relaying network, since the final destination of data sent from any RP is the GW, the GW becomes the root of the tree and RPs perform only the forwarding function which is much simpler than the routing function. Therefore, the cost of RPs can be significantly reduced by eliminating the routing function requiring lots of processing power, memory, energy and so on, and the lifetime of RPs can be increased by avoiding the exchange of routing related control messages; thus, the network service time (the time duration providing the network connectivity between RPs with sinks within their transmission range and the GW) can be improved.

3.3. Tree construction

In this section, we describe the tree construction mechanism which is initiated by an RP for the delivery of data from a sink to the GW when a mobile sink enters in the RP's service area or when a static sink in the RP's service area is powered on for the first time. If the effective transmission range of an RP is r and one RP is placed at each corner of grids, the size of a grid is r x r and an RP has 4 neighboring RPs. And, we assume that the transmission channels for the communication between sinks and RPs and those for the communication between RPs are separately maintained. Each RP can be a non-BranchRP, BranchRP, ServingRP or CandidateBranchRP. The operation of the tree construction mechanism is as follows:

Phase 1. Hop Count Information Setup: At the initial setup stage of a network, the GW floods a PROBE message to the entire network so that each RP can know the minimum number of hops to the GW from itself. The initial status of each RP is set to the non-BranchRP status.

Phase 2. ServingRP Election: When a non-BranchRP receives data from a new sink for the first time, it sets its delay timer to some value which is determined from a function linearly proportional to the hop count to the GW.

- If the RP has not received any ADVERTISEMENT message from its neighboring RPs before its delay timer expires, it changes its status to the ServingRP of the sink and sends an ADVERTISEMENT message to its neighboring RPs.
- Otherwise (i.e., the RP has received an ADVERTISEMENT message from one of its neighboring RP), the RP knows that one of its neighboring RP has already become the ServingRP of the sink and cancels its delay timer.

Phase 3. Tree Branch Setup: The ServingRP sends a CONSTRUCT message to its neighboring RPs to set up a tree branch from itself to the GW. In the CONSTRUCT message, the hop count information of the ServingRP is included.

- When a non-BranchRP receives a CONSTRUCT message from one of its neighboring RPs, it becomes a CandidateBranchRP (which is a candidate of becoming a new BranchRP) if its hop count to the GW is less than that in the received CONSTRUCT message, and sets its delay timer to some value which is determined from a function linearly proportional to the hop count to the GW.
  - If a CandidateBranchRP has not received any SUPPRESS message before the delay timer expires, it recognizes itself as a BranchRP which belongs to the tree branch and sends a CONSTRUCT message to its neighboring RPs for the establishment of the tree branch from itself to the GW. In this case, the CONSTRUCT message has the hop count information from this BranchRP to the GW.
    - Upon receiving the CONSTRUCT message from the newly chosen BranchRP, the ServingRP sends a SUPPRESS message to its neighboring RPs to notify them of its parent BranchRP having been determined.
  - When a CandidateBranchRP receives any SUPPRESS message from its neighboring RPs before its delay timer expires, it knows that a new BranchRP has been determined and cancels its delay timer.
  - When a CandidateBranchRP receives an AFFILIATE message (described in the following item) before its delay timer expires, it sets the RP which has sent the AFFILIATE message as its parent BranchRP, and becomes a BranchRP, and sends a SUPPRESS message to its neighboring RPs to notify them of the fact that its parent BranchRP has already been determined.
- When a BranchRP receives a CONSTRUCT message, if the hop count of the BranchRP is smaller than that in the received CONSTRUCT message, it sends out an AFFILIATE message immediately so that this tree branch construction request can be resolved quickly. In this case, this BranchRP becomes the merging point of the newly establish tree branch and the existing tree branch.

Phase 4. Tree Branch Construction Completion: When the GW receives a CONSTRUCT message, the tree branch construction is completed. Or, when a CandidateBranchRP receives an AFFILIATE message and becomes a BranchRP, the tree branch construction is completed.

3.4. Tree maintenance

The tree structure is maintained by making each BranchRP keep the information on its parent and child BranchRPs and making each ServingRP keep the information on their parent BranchRP. Each BranchRP periodically sends a HELLO message to its neighboring RPs as its heartbeat. When a child BranchRP does not receive a HELLO message from its parent BranchRP for a given time interval, it recognizes the failure of its parent BranchRP (e.g., due to energy depletion) and sends a CONSTRUCT message to set up an alternate tree branch (in this case, the operation described in section 3.3 is applied). If a BranchRP receives no data for some time interval, it assumes that the tree branch where it belongs does not have any active sinks to serve and resets its BranchRP status to the non-BranchRP status. This makes unnecessary tree branches pruned from the tree structure.

3.5. Data forwarding

Before the tree branch construction is completed, the first data message from the sink is delivered via the directional flooding from the ServingRP towards the GW, which does not delay the delivery of the first message. In other words, the RP having received the first data message from the sink includes its hop count information to the data message and sends the message to its neighboring RPs via the 1-hop flooding. Only the neighboring RP whose hop count is less than that in the message forwards the message to its neighboring RPs. This can significantly reduce the overhead of the original flooding by limiting the transmission of the message only to the direction closer to the GW and remove the delay which can be caused by holding the transmission of the first message until when the tree branch is completely established. Since this directional flooding is applied only to the first data message, the overall network lifetime will not be affected by this.

Once a tree branch has been set up, only the ServingRP forwards data messages to its parent BranchRP. When an RP receives a data message from one of its neighboring RPs, it forwards the message only when it is a BranchRP and the RP from which it has received the message is its child BranchRP. A BranchRP failure can be detected from the periodic exchange of HELLO messages and recovered by establishing an alternate branch, so the possibility of being delayed by a BranchRP failure is low.

4. Performance evaluation

In this section, the performance of our proposed tree-based approach is compared with that of the AODV-based approach which uses AODV to set up routes for the delivery of data from RPs to the GW in the relaying network.

4.1. Analytical results

We compare the AODV and the tree-based approaches in terms of the signaling overhead required for the route or tree branch setup from a ServingRP to the GW. For this, the following assumptions are made:

- Regardless of the type of control messages used in each protocol, the cost for sending one message (e.g., the message sending power) is C_t and the cost for receiving one message (e.g., the message receiving power) is C_r.
- There is no tree branch merging point between the ServingRP and the GW.
- There is no error in sending or receiving a message.

Signaling Cost of the AODV-based Approach:

The route from the ServingRP to the GW is established through two steps. The first step is to flood a RREQ message from the ServingRP to the GW and the second one is to unicast a RREP message from the GW to the ServingRP.

1. Cost induced by the RREQ message.

   All RPs in the grid structure transmits the RREQ message only once since the RREQ message is flooded from the ServingRP to the GW. Since each RP receives the RREQ message sent by its neighboring RPs, the RREQ induced cost becomes as the following if the size of the grid structure is *n*RPs x *m*RPs:

$$C_{AODV}^{RREQ} = (n-2)(m-2)(C_t + 4C_r) + 2[(n-2) + (m-2)](C_t + 3C_r) + 4(C_t + 32) \quad (1)$$

2. Cost induced by the RREP message.

   With assuming that the number of hops from the ServingRP to the GW is *k*, each RP on the route from the ServingRP to the GW receives the RREP message from its higher level RP (i.e., its neighboring RP closer to the GW) and forwards the RREP message to its neighboring RPs. The neighboring RPs at the same level of the RPs on the data route do not forward the RREP message. Therefore, the RREP induced cost of the data route is:

$$C_{AODV}^{RREP} = (C_t + 2C_r)k + (2k + 4)C_r \quad (2)$$

   Thus, the total signaling cost of the AODV-based approach becomes:

$$C_{AODV} = C_{AODV}^{RREQ} + C_{AODV}^{RREP} \quad (3)$$

Signaling Cost of the Tree-based Approach:

We assume that the number of hops from the ServingRP to the GW is *k*. The ServingRP sends a CONSTRUCT message for the tree construction after sending out an ADVERTISEMENT message for the announcement of its being a ServingRP. After that, if the ServingRP receives a CONSTRUCT message from one of its neighboring RPs (i.e., this neighboring RP becomes the parent RP of the ServingRP), it sends a SUPPRESS message to prevent its other neighboring RPs from becoming a higher level RP. Thus, each of the neighboring RPs of the ServingRP which are not the parent RP of the ServingRP receives three control messages, ADVERTISEMENT, CONSTRUCT and SUPPRESS messages. Therefore, the cost at the ServingRP level is:

$$C_{TREE}^{S\_RP} = (3C_t + C_r) + 3 \cdot 3C_r \quad (4)$$

Except for the ServingRP, each RP on the data route from the ServingRP to the GW (i.e., a BranchRP) receives a CONSTRUCT message from its child RP and sends a CONSTRUCT message to establish a route to its higher level. After that, upon receiving a CONSTRUCT message from its parent RP, the BranchRP sends a SUPPRESS message to its neighboring RPs to let them know that its parent RP has been determined, so each neighboring RP of a BranchRP receives a CONSTRUCT message and a SUPPRESS message. Thus, the cost incurred by BranchRPs is:

$$C_{TREE}^{B\_RP} = [(2C_t + C_r) + 2 \cdot 2C_r](k-1) \quad (5)$$

Therefore, the total signaling cost of the tree-based approach becomes:

$$C_{TREE} = C_{TREE}^{S\_RP} + C_{TREE}^{B\_RP} \quad (6)$$

4.2. Experimental results

In this section, we compare the AODV and the tree-based approaches by using the NS-2 simulator [14] and the following performance evaluation factors:

- Data delivery time: the time for a data message from a sink to arrive at the GW.
- Network service time: the time duration for all ServingRPs to have routes to the GW.
- Control overhead: the value computed by dividing the number of control messages required for the route setup/maintenance/recovery by the network service time.

The simulation parameters are shown in Table 1, and we have used the in-building environment of the shadowing model as the radio propagation model. Each sink sends a data packet at every 2 seconds and the number of sinks is chosen to be around 15% of the number of RPs so that sinks are sparsely placed.

Table 1. Simulation parameters.

parameter	value
radio propagation model	shadowing model
mobility model	random waypoint model
MAC	IEEE 802.11
number of RPs	11 x 11
number of sink	20
data generation rate of a sink	1 packet/2 seconds

Figures 3 - 5 show the control overhead, the network service time and the data delivery time when the mobility speed of mobile sinks is changed from 1km/hr to 10km/hr. Each simulation result is normalized by the best result, *Tree*_20% with the mobility speed 1km/hr,; *Tree*_20% represents the tree-based approach with the percentage of mobile sinks being 20%. Also, since the simulation results can be affected by the percentage of mobile sinks, we have carried out simulations with the percentage of mobile sinks being set to 20% and 80%.

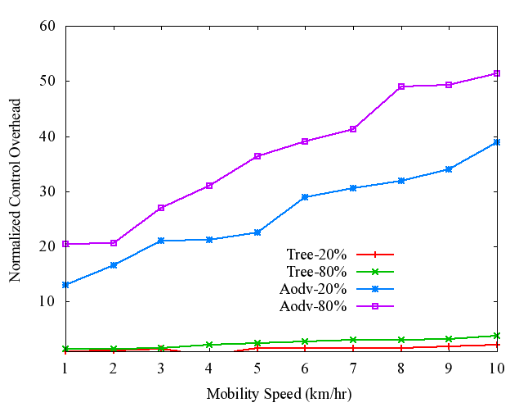

Figure 3. Mobility speed *vs.* normalized control overhead.

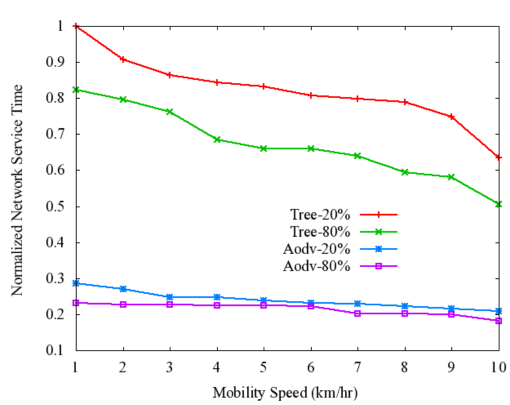

Figure 4. Mobility speed *vs.* normalized network service time.

Figure 3 shows the control overhead with changing the mobility speed. In both approaches, active RPs (BranchRPs in the tree-based approach and RPs with valid routing table entries in the AODV-based approach) generate a HELLO message per second. As the mobility speed of a mobile sink increases, the possibility that the mobile sink moves into a neighboring grid increases, so more route setup requests tend to be generated by ServingRPs. Our simulation results show that the control overhead of the AODV-based approach is 15 times larger on the average and 40 times larger at the maximum. Also, as the percentage of mobile sinks increases, the number of sinks moving into neighboring grids increases and this causes the increased overhead due to more route setup requests. Figure 3 shows that the AODV-based approach incurs much higher control overhead, so the results in Figure 4 show that the number of failed RPs due to energy depletion in the AODV-based approach is larger than that of the tree-based approach. Due to this, the network service time, which is the time duration of providing the network connectivity between all ServingRPs and the GW, of the AODV-based approach decreases almost 40-70% of that of the tree-based approach.

Figure 5 shows the data delivery time with varying the mobility speed. In the AODV protocol, the data delivery has to be delayed until the route setup is completed. On the other hand, in the tree-based approach, this delay problem is resolved by letting a ServingRP forward the first data message from a sink towards the GW using the directional flooding even though the tree branch construction has not been completely constructed yet. The AODV-based approach experiences almost 10 times larger data delivery time than the tree-based approach because a route from a new ServingRP to the GW has to be established whenever a mobile sink moves in a new grid.

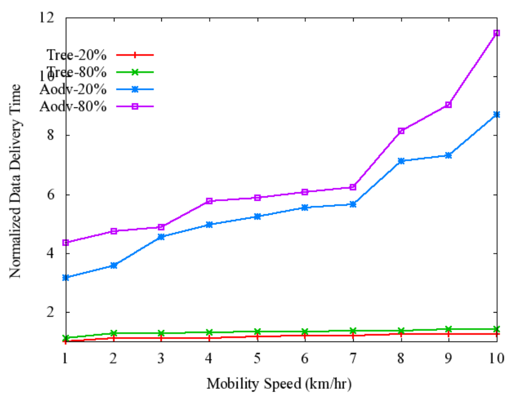

Figure 5. Mobility speed *vs.* normalized data delivery time.

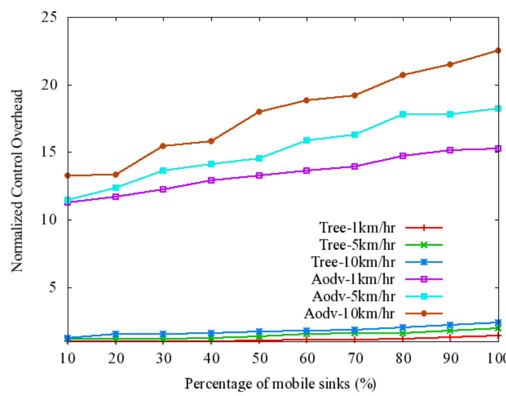

Figure 6. Percentage of mobile sinks *vs.* normalized control overhead.

Figures 6 - 8 show the performance when the percentage of mobile sinks is varied from 10% to 100% and the mobility speed is set to 1km/hr, 5km/hr and 10km/hr. And each simulation result is normalized by the best result, *Tree*_1km/hr with the percentage of mobile sinks being set to 10%. Figure 6 shows the control overhead with varying the percentage of mobile sinks. As the number of mobile sinks increases, the route setup control overhead increases due to the increased number of route setup requests from ServingRPs to the GW. In addition to that, the AODV-based approach yields almost 20 times larger control overhead than the tree-based approach because AODV uses the flooding based route setup and the tree-based approach exchanges route setup messages with only neighboring RPs. Even for the same number of mobile sinks, as the mobility speed increases, the control overhead increases since the possibility that mobile sinks move into other grids increases.

In Figure 7, as the percentage of mobile sinks increases, the number of RP failures increases due to the increased control overhead (see Figure 6). Thus, the network service time of the AODV-based approach decreases almost 40-70% compared to the tree-based approach. Figure 8 shows the data delivery time with varying the percentage of mobile sinks. As the percentage of mobile sinks and the mobility speed of mobile sinks increase, the possibility of a mobile sink moving into a neighboring grid increases, so the AODV-based approach experiences more delay due to frequent route setups. On the other hand, the tree-based approach gives lower delay by forwarding data using the directional flooding while the tree branch construction is ongoing.

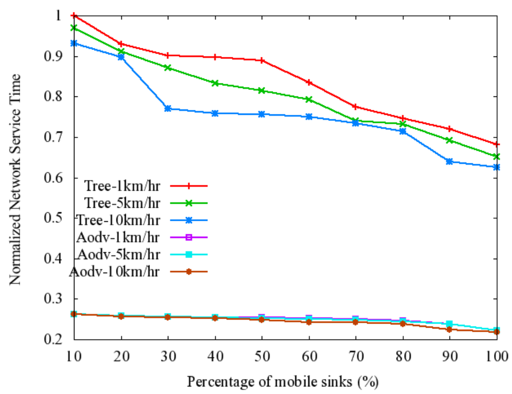

Figure 7. Percentage of mobile sinks *vs.* normalized network service time.

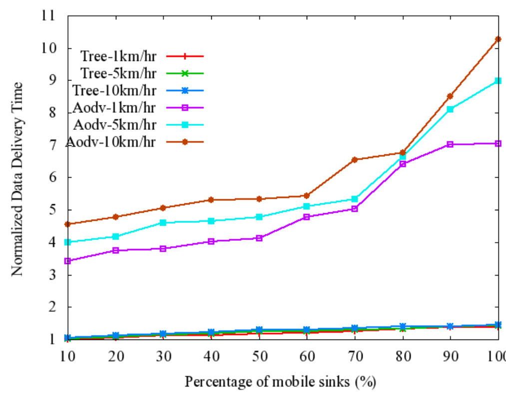

Figure 8. Percentage of mobile sinks *vs.* normalized data delivery time.

5. Conclusion

In a complex and large building or area, multiple heterogeneous sensor networks can be deployed with a single gateway (GW) and, in this case, sinks may be sparsely deployed and located far from the GW. Hence, an energy efficient delivery mechanism from sinks to the GW is required and relay points (RPs) are placed between sinks and the GW for providing the network connectivity between them. In this environment, the optimal placement of RPs becomes an important performance determining factor, so we have proposed a mechanism to deploy RPs in a grid pattern and to use the tree-based relaying network whose root is the GW. In the tree-based relaying network, RPs perform only the simple forwarding function, so the cost of the RP can be significantly reduced and the lifetime of the RP can be increased. The performance of our proposed tree-based relaying network is compared with that of the AODV-based approach where AODV is used for the route setup from sinks to the GW. For the performance comparison, the signaling cost for setting up a route from a sink to the GW is numerically analyzed and the analytical result shows that the AODV-based approach requires almost 7 times larger signaling cost than the tree-based approach. And, for the general case performance evaluation, the NS-2 based simulations have been carried out and the simulation results indicate that the tree-based approach outperforms the AODV-based approach in terms of the data delivery time, the network service time and the control overhead.

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