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Geographic Routing in Duty Cycled Wireless Sensor Networks

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Abstract- Recently, the research focus on geographic routing, a promising routing scheme in wireless sensor networks (WSNs), is shifting toward duty-cycled WSNs in which sensors are sleep scheduled to reduce energy consumption. However, except the connected-k neighborhood (CKN) sleep scheduling algorithm and the geographic routing oriented sleep scheduling (GSS) algorithm, nearly all research work about geographic routing in duty cycled WSNs has focused on the geographic forwarding mechanism; further, most of the existing work has ignored the fact that sensors can be mobile. In this project, we focused on sleep scheduling for geographic routing in duty-cycled WSNs with mobile sensors and proposed two geographic-distance-based connected-k neighborhood (GCKN) sleep scheduling algorithms. The first one is the geographic-distance-based connected-k neighborhood for first path (GCKNF) sleep scheduling algorithm. The second one is the geographic-distance-based connected-k neighborhood for all paths (GCKNA) sleep scheduling algorithm. By theoretical analysis and simulations, we show that when there are mobile sensors, geographic routing can achieve much shorter average lengths for the first transmission path explored in WSNs employing GCKNF sleep scheduling and all transmission paths searched in WSNs employing GCKNA sleep scheduling compared with those in WSNs employing CKN and GSS sleep scheduling.

1. INTRODUCTION

Geographic routing [1]–[4] is one of the most promising routing schemes in wireless sensor networks (WSNs) [5], due to its simplicity, scalability, and efficiency [6]. In such a scheme, regardless of the network size, the forwarding decision is determined purely based on the location of each node and it can be done even when there are irregular radio ranges and localization errors. Recently, the research focus of geographic routing is centering on WSNs with duty-cycles, since duty cycled WSNs have a natural advantage of saving energy by dynamically putting nodes to sleep and waking them according to some sleep scheduling algorithms [7]–[10]. However, nearly all these works overlook one important fact that sensors can actually be mobile to gain better energy efficiency, channel capacity, etc., and enable a lot of new application scenarios [11]–[14]. For example, because sensors can move, they can transmit their data from different locations and avoid the problem that sensors near the gateway or sink always exhaust their energy first; thus, energy usage can be more efficient [15]. Also, mobile sensors such as mobile phones or cars can become the interface between the information center and the mobile customers; thus, real-time information (e.g., traffic information) transmitted from the information center to these mobile objects can be provided to nearby customers [16], [17]. Moreover, almost all current works about geographic routing in duty-cycled WSNs [18]–[21] try to change the geographic forwarding mechanism to deal with the dynamic topology caused by some nodes being cycled off or going to sleep mode.

For instance, it is suggested in [18] to wait for the appearance of the expected forwarding successor first and select a backup node if the first mechanism fails. In [19], the sensor field is sliced into some k-coverage fields, then some always-on cluster heads are selected to collect the data from their nearby sensors and finally transmit all data to the sink. Apart from the connected-k neighborhood (CKN) sleep scheduling algorithm proposed in [22] and the geographic routing oriented sleep scheduling (GSS) algorithm presented in [23], few research works have tackled the node availability uncertainty issue in duty-cycled WSNs from the view of sleep scheduling.

2. RELATED WORK

2.1. Geographic Routing

The basic idea of geographic routing is greedy routing. Specifically, each packet is tagged with the coordinates of its destination, all nodes know their own coordinates, and a node forward the packet to its neighbor that is geographically closest to the destination. The earliest proposal for geographic routing is in [24], which has a local minimum problem in that a node may have no closer neighbor to the destination. For this reason, face routing [1] and its variants are proposed to use geometric rules (e.g., right hand rule) to route around voids near the local minimum in case it happens. However, these algorithms require converting the network into a planar graph (e.g., [25]) or removing the problematic cross links from the network (e.g., [3], which are not very applicable in realistic conditions [26]. Moreover, there is also a hole problem in geographic routing, in that a hole can be formed by a set of dead sensor nodes running out of energy or being damaged. To solve this problem, some research work (e.g., [27]) try to identify the hole boundary nodes first and then use these boundary nodes to avoid the hole. Others (e.g., [28]) try to use geometric modeling to find an optimized hole bypassing routing path. Recently, by using a *step back and mark* strategy when it cannot find the next-hop node, a two-phase geographic forwarding (TPGF), which does not have the local minimum or the hole problem, is shown in [29]. With a *labelbased optimization* method, TPGF can optimize the routing paths by finding one with the least number of hops. However, all these works only consider WSNs with static nodes. Recently, many opportunistic routing protocols [18], [19], [30], [31]) have been proposed to extend geographic routing to duty-cycled WSNs. They all try to achieve this goal by dynamically choosing the forwarding node based on the best potential node that can transmit packets. Specially, these protocols typically take into account such factors as link uncertainty to adapt routing accordingly. However, few of these works address the local minimum or hole problem, and nearly all these works do not consider the situation that sensor nodes can be mobile.

2.2. Sleep Scheduling

The basic mechanism for sleep scheduling is to select a subset of nodes to be awake in a given epoch while the remaining nodes are in the sleep state that minimizes power consumption, so that the overall energy consumption can be reduced.

Existing works on sleep scheduling in WSNs mainly focus on two targets: *point coverage* and *node coverage*. For *point coverage* (also known as spatial coverage), the awake nodes in each epoch are chosen to cover every point of the deployed field. Existing *point coverage* oriented algorithms differ in their sleep scheduling goals: minimizing energy consumption [7], or minimizing average event detection latency [8]. For *node coverage* (also called network coverage), awake nodes are selected to construct a globally connected network such that each asleep node is an immediate neighbor of at least one awake node [32], [33]. However, all these works generally focused on the medium access layer of static WSNs with static nodes. The only recent works addressing sleep scheduling in dutycycled WSNs employing geographic routing are the CKN scheme proposed in [22] and the GSS method presented in [23]. CKN is a sleep scheduling method providing node coverage and a probabilistic point coverage, which tunes the number of awake nodes in the network by changing the value of *k* in CKN. GSS is based on CKN and differs from CKN only by making the potential nearest neighbor nodes to the sink to be awake. However, both CKN and GSS do not consider the scenarios in which sensor nodes can be mobile, and both CKN and GSS determine the awake or asleep state of each node based only on a random rank, which may keep awake many nodes far away from the destination and thus degrade the performance of geographic routing.

Threats in mobile environment are social engineering, web browser exploitation and OS vulnerability, compromised devices, vulnerable applications. Some of threats in mobile environment are similar to traditional desktop environment such as malware, data interception, and loss or theft of devices [3]. Figure 1 highlights some of the major threats in mobile environment.

3. ANALYSIS OF PROBLEM

Geographic routing is centering on WSNs with duty-cycles, since duty- cycled WSNs have a natural advantage of saving energy by dynamically putting nodes to sleep and waking them according to some sleep scheduling algorithms .However, nearly all these works overlook one important fact that sensors can actually be mobile to gain better energy efficiency, channel capacity, etc., and enable a lot of new application scenarios.

Disadvantages of Existing System:

- Geographical forwarding mechanism failure.
- Tackle the node availability uncertainty issue in duty-cycled WSNs from the view of sleep scheduling.

4. OBJECTIVES

Objectives are as follows:

- Addresses the sleep scheduling problem in duty cycled WSNs with mobile nodes.
- Implementation geographic-distance-based connected-kneighborhood for first path1 (GCKNF) sleep scheduling algorithm.
- Implementation geographic-distance-based connected-kneighborhood for all paths2 (GCKNA) sleep scheduling algorithm.
- Implementation geographic-distance-based connected-kneighborhood for all paths2 (GCKNA) sleep scheduling algorithm.

5. PROPOSED WORK

In this project, we have explored geographic routing in duty-cycled mobile WSNs and proposed two geographic-distance-based connected-k neighbourhood (GCKN) sleep scheduling algorithms for geographic routing schemes to be applied into duty-cycled mobile WSNs which can incorporate the advantage of sleep scheduling and mobility.

The first geographic-distance- based connected-k neighborhood for first path (GCKNF) sleep scheduling algorithm minimizes the length of first transmission path explored by geographic routing in duty-cycled mobile WSNs.

The second geographic-distance based connected-kneighborhood for all paths (GCKNA) sleep scheduling algorithm reduces the length of all paths searched by geographic routing in duty-cycled mobile WSNs.

Advantages of Proposed System:

- The GCKNF and GCKNA are very effective in shortening the length of the transmission path explored by geographic routing in duty-cycled mobile WSNs compared with the CKN sleep scheduling algorithm and the GSS algorithm.
- Our work will show that sleep scheduling is a worthy research direction to adapt geographic forwarding methods into duty-cycled mobile WSNs.

6. ALGORITHM EXPLANATION

6.1. Network Model

We consider a multihop WSN with N sensor nodes, which can be modeled by a communication graph $G = (U,L)$, where $U = \{u1, u2, . . . , uN\}$ is the set of normal sensor nodes excluding the source and the sink node and L is the set of links. The default transmission radius of each sensor is *tr* and the maximum transmission radius of each sensor is *trm*. The source and sink are always-on and both assumed to have unlimited energy supplies. The sink or a normal sensor can move to a randomly chosen position with a randomly selected speed within the WSN boundary and it will pause for a time period after it reaches the selected position, according to the random waypoint model in [34], [35]. Normal sensors can dynamically change states between asleep and awake. Two sensors are neighbors if they are within the transmission range of each other and a link $l(u,v) \in L$ if nodes u and v can communicate with each other directly without relaying. Two sensors are two hop neighbors if $l(u,v)$ _$\in L$ and there exists another node w satisfying $l(u,w) \in L$, $l(w,v) \in L$, or $l(v,w) \in L$, $l(w,u) \in L$.

6.2. Design Factors

Specifically, we consider the following six factors for both GCKNF and GCKNA.

1) A node should go to sleep assuming that at least k of its neighbors will remain awake so as to save energy as well as keep it k-connected.

2) The asleep or awake state of nodes should be allowed to change between epochs so that all nodes can have the opportunity to sleep and avoid staying awake all the time, thus distributing the sensing, processing, and routing tasks across the network to prolong the network lifetime.

3) Although each node decides to sleep or wake up locally, the whole network should be globally connected so that data transmissions can be performed.

4) Each node should have enough initial neighbors in order to make it easier for the node to satisfy the connected-k neighborhood requirement; thus, it is more likely to be asleep after sleep scheduling. For GCKNF, which emphasizes the first transmission path of geographic routing, we further take the following factor into account.

5) The neighbor of each node, which is closest to sink, should be awake so that geographic routing can utilize these nearest neighbor nodes to make the first transmission path as short as possible. For GCKNA, which considers all transmission paths.

6) For each node, as many as possible of its neighbor nodes that are closer to the sink should be awake so that geographic routing can make all transmission paths as short as possible.

6.3. Pseudocode of GCKNF algorithm

First: Run the following at each node u.

1) Send probe packet *pu* to neighbors and receive the ack packet.

2) Compute whether u's current neighbors $CNu \geq \min(k, du)$.

3) Maintain its transmission radius if the above condition holds or its current transmission radius is the maximum. Otherwise, increase its transmission radius until $CNu \geq \min(k, du)$.

Second: Run the following at each node u.

1) Get its geographic location *gu* and sink location *gs*.

2) Broadcast *gu* and receive the geographic locations of its all neighbors *Au*. Let *Gu* be the set of these geographic locations.

3) Unicast a flag to w, $w \in Au$ and *gw* is the closest to sink in *Gu*.

Third: Run the following at each node u.

1) Pick a random rank *ranku*.

2) Broadcast *ranku* and receive the ranks of its currently awake neighbors *Nu*. Let *Ru* be the set of these ranks.

3) Broadcast *Ru* and receive *Rv* from each $v \in Nu$.

4) If $|Nu| < k$ or $|Nv| < k$ for any $v \in Nu$, remain awake.

Return.

5) Compute *Cu* = *{v|v ∈Nu* and *rankv* < *ranku}*.
6) Go to sleep if the following three conditions hold. Remain awake otherwise.
• Any two nodes in *Cu* are connected either directly themselves or indirectly through nodes within u's two-hop neighborhood that have *rank* less than *ranku*.
• Any node in *Nu* has at least *k* neighbors from *Cu*.
• It does not receive a flag.
7) Return.

6.4. Pseudocode of GCKNA algorithm

First: Run the following at each node *u*.
1) Send probe packet *pu* to neighbors and receive the ack packet.
2) Compute whether *u*'s current neighbors *CNu* ≥ min(*k*, *du*).
3) Maintain its transmission radius if the above condition holds or its current transmission radius is the maximum. Otherwise, increase its transmission radius until *CNu* ≥ min(*k, du*).
Second: Run the following at each node *u*.
1) Get its geographic location *gu* and sink location *gs*. Further get the geographic distance between itself and sink *granku*.
2) Broadcast *granku* and receive the geographic distance ranks of its currently awake neighbors *Nu*. Let *Ru* be the set of these ranks.
3) Broadcast *Ru* and receive *Rv* from each *v ∈Nu*.
4) If |*Nu*| < *k* or |*Nv*| < *k* for any *v ∈ Nu*, remain awake.
Return.
5) Compute *Cu* = *{v|v ∈Nu* and *grankv* < *granku}*.
6) Go to sleep if both the following conditions hold. Remain awake otherwise.
• Any two nodes in *Cu* are connected either directly themselves or indirectly through nodes within u's two-hop neighborhood that have *grank* less than *granku*.
• Any node in *Nu* has at least *k* neighbors from *Cu*.
7) Return.

CONCLUSION

In this paper, we have explored geographic routing in dutycycled mobile WSNs and proposed two geographic-distancebased connected-*k* neighborhood (GCKN) sleep scheduling algorithms for geographic routing schemes to be applied into duty-cycled mobile WSNs which can incorporate the advantage of sleep scheduling and mobility. The first geographic-distance based connected-k neighborhood for first path (GCKNF) sleep scheduling algorithm minimizes the length of first transmission path explored by geographic routing in duty-cycled mobile WSNs. The second geographic-distance based connected k neighborhood for all paths (GCKNA) sleep scheduling algorithm reduces the length of all paths searched by geographic routing in duty-cycled mobile WSNs. In duty-cycled mobile WSNs, from the view of sleep scheduling, GCKNF and GCKNA do not require the geographic routing to change its original geographic forwarding mechanism, and they both consider the connected-*k* neighborhood requirement and geographic routing requirement to change the asleep or awake state of sensor nodes.

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