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A Geographic Routing Oriented Sleep Scheduling Algorithm in Duty-Cycled Mobile Sensor Networks Methodology

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Abstract: ***Geographic routing is a constructive and scalable point-to-point communication primitive for mobile sensor networks. Conversely, earlier job on geographic routing makes the improbable hypothesis that every node in the network is aware through routing. This overlooks the common consumption situation where sensor nodes are duty-cycled to save energy. In this paper we inspect a number of significant aspects of geographic routing over duty-cycled nodes. First, we expand offered geographic routing algorithms to handle the extremely dynamic networks ensuing from duty-cycling. Second, we offer the first prescribed analysis of the presentation of geographic routing on duty-cycled nodes. Third, we employ this analysis to develop a capable decentralized sleep scheduling algorithm for reducing the number of awake nodes while maintaining both network coverage and a (tunable) objective routing latency. Finally, we estimate via simulation the performance of our approach versus consecutively existing geographic routing algorithms on sensors duty-cycled according to preceding sleep scheduling algorithms. Our outcome show, possibly unexpectedly, that a network of duty-cycled nodes can have somewhat better routing presentation than a static network that uses equivalent energy. Our outcome further show that compared to preceding algorithms, our sleep scheduling algorithm considerably improves routing latency and network lifetime. Again we implement different routing algorithm with high performance.***

Keywords: Connected-*k* neighborhood (CKN), duty-cycle, geographic routing algorithm, mobility, wireless sensor networks (WSNs).

1. Introduction

Geographic routing [1]–[4] is one of the essentially promising routing scheme in mobile sensor networks (MSNs) [5], due to its simplicity, scalability, and efficiency [6]. In such a scheme, apart from the network size, the forwarding resolution is determined entirely based on the location of each node and it can be done even when there are asymmetrical 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]. **C**onversely, nearly all these works overlook one important fact that sensors can actually be mobile to gain superior energy efficiency, channel capacity, etc., and allow a lot of new

Application scenarios [11]–[14]. For example, because sensors can move, they can broadcast their data from different locations and avoid the difficulty that sensors near the gateway or sink always exhaust their energy first; thus, energy usage can be more proficient [15]. Also, mobile sensors such as mobile phones or cars can become the interface between the information center and the mobile customers;

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.

This paper addresses the sleep scheduling problem in duty-cycled WSNs with mobile nodes (referred as mobile WSNs in the following) employing geographic routing. We propose two geographic-distance-based connected-*k* neighbor-hood (GCKN) sleep scheduling algorithms. The first one is the *geographic-distance-based connected-k neighborhood for first path*[1] (GCKNF) sleep scheduling algorithm, aiming at geographic routing utilizing only the first transmission path in duty-cycled mobile WSNs. The second one is the *geographic-distance-based connected-k neighborhood for all paths*[2] (GCKNA) sleep scheduling algorithm, for geographic routing concerning all paths explored in duty-cycled mobile WSNs. By theoretical analysis and performance evaluations by simulations, we show that when there are mobile sensors, geographic routing can achieve much shorter average lengths for the first transmission paths searched in mobile WSNs employing GCKNF sleep scheduling and all transmission paths in mobile WSNs employing GCKNA sleep scheduling compared with those in mobile WSNs employing CKN or GSS sleep scheduling. The main contributions of this paper are summarized as follows.

1) The GCKNF sleep scheduling algorithm is designed to explore shorter first transmission paths for geographic routing in duty-cycled mobile WSNs. The GCKNA sleep scheduling algorithm aims at shortening all routing paths for multipath transmissions in duty-cycled mobile WSNs. These GCKN algorithms incorporate the connected-*k* neighbor-

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hood requirement and geographic routing requirement to change the asleep or awake state of sensor nodes.

For the rest of this paper, Section II reviews the basic idea and related work about geographic routing and sleep scheduling. The detailed designs and theoretical analysis of the GCKN algorithms are presented in Section III. Section IV evaluates the performance of the GCKN algorithms. Section V concludes the paper.

2. Related Work

A. Geographic Routing

Since the paper is mainly focusing on duty-cycled WSNs, we mainly review the related works on low duty-cycling modes, neighbor discovery mechanisms under such modes, the routing mechanisms and broadcasting mechanism for low duty-cycled WSNs. We do not provide a thorough overview on research works for always-on WSNs, but a general overview for such networks can be found in [2].

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 *label-based 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 proto-cols typically take into account such factors as link uncertainty to adapt routing accordingly. However, few of these works address the local minimum or whole problem, and nearly all these works do not consider the situation that sensor nodes can be mobile.

B. Sleep Scheduling

The basic mechanism for sleep scheduling is to select a sub-set 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 duty-cycled 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.

3. GCKN Algorithms

A. Network Model

We consider a multi-hop WSN with N sensor nodes, which can be modeled by a communication graph $G = (P, Q)$, where $P = \{p_1, p_2. . . p_N\}$ is the set of normal sensor nodes excluding the source and the sink node and Q is the set of links. The default transmission radius of each sensor is tr and the maximum transmission radius of each sensor is tr_m. 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 $q_{(u,v)} \in Q$ if nodes u and v can communicate with each other directly without relaying. Two sensors are two-hop neighbors if $q_{(u,v)}$ _$\in Q$ and there exists another node w satisfying $q_{(u,w)} \in Q$, $q_{(w,v)} \in Q$, or $q_{(v,w)} \in Q$, $q_{(w,u)} \in Q$.

B. Assumptions

We suppose that each node knows its own position by using a Global Position System (GPS) recipient or several mobility-based localization algorithm. We additional imagine that each node also knows the locations of the source and Mobile sensor node by flooding or opportunistic flooding. Specifically, as each sensor knows its own location, if the sensor is static and normal sensor nodes are mobile, the senor node location information only needs to be flooded once. If the sensor node is mobile and normal sensor nodes are static,

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the sensor node location information needs to be flooded when it moves to a new location.

C. Design Factors

For both GCKNF and GCKNA, we incorporate the connected-k neighborhood[3] requirement and geographic routing requirement in their designs. 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 geo-graphic 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, we further take the following factor into consideration.
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.

In contrast with CKN and GSS, the fourth design factor of both GCKNF and GCKNA is the extra consideration that makes it easier for each node to satisfy the connected-k neighborhood requirement during sleep scheduling. In addition, the fifth design factors for both GCKNF and GCKNA to meet the geographic routing requirement in case they encounter mobile sensor nodes or mobile sinks are ignored by the CKN and GSS schemes.

D. GCKN Algorithms

The pseudo code of GCKNF and GCKNA is shown. Specifically, in GCKNF, each node sends probe packets to its neighbor nodes and receives the ACK packet from its neighbor nodes (Step 1 of the first part of GCKNF). With that, each node calculates whether it currently satisfies the connected-k neighborhood requirement or not (Step 2 of the first part of GCKNF). If it already belongs to a connected-k neighborhood or its transmission radius is the maximum, the node maintains its transmission radius. Otherwise, the node increases its trans-mission radius until the connected-k neighborhood appears (Step 3 of the first part of GCKNF). In the second part of GCKNF, the geographic locations (e.g., g_u) of each node u and the sink are obtained (Step 1 of the second part of GCKNF) and the each node's neighbor that is nearest to sink is identified (Step 3 of the second part of GCKNF). In the third part of GCKNF, a random rank $rank_u$[4] of each node u is picked (Step 1 of the third part of GCKNF) and the subset C_u of u's currently awake neighbors having rank > $rank_u$ is computed (Step 5 of the third part of GCKNF). Before u can go to sleep, it needs to ensure that 1) all nodes in C_u are connected by nodes with rank < $rank_u$, 2) each of its neighbors has at least k neighbors from C_u, and 3) it is not the neighbor node closest to the sink for any other node (Step 6 of the third part of GCKNF). In GCKNA, each node u also sends a probe packet to each neighbor node and receives the corresponding ACK packet (Step 1 of the first part of GCKNA). Then, whether it currently belongs to a connected-k neighborhood is also checked (Step 2 of the first part of GCKNA). The transmission radius of the node is increased if the connected-k neighborhood requirement is not satisfied and the transmission radius is maintained if the nodes form a connected-k neighborhood or the transmission radius is already the maximum (Step 3 of the first part of GCKNA) [38]. In the second part of GCKNA, the geographic distance between itself and the sink $grank_u$[5] is picked (Step 1 of the second part of GCKNA) and the subset C_u of u's currently awake neighbors having $grank < grank_u$ is computed (Step 5 of the second part of GCKNA). Before u can go to sleep, it needs to ensure that 1) all nodes in C_u are connected by nodes with $grank < grank_u$ and 2) each of its neighbors has at least k neighbors from C_u (Step 6 of the second part of GCKNA).

Pseudo code of GCKNF algorithm

```
First: Run the following at each node $u$.
1) Send probe packet $p_u$ to neighbors and receive the ack packet.
2) Compute whether $u$'s current neighbors $CN_u \geq \min(k, d_u)$.
3) Maintain its transmission radius if the above condition Holds or its current transmission radius is the maximum. Otherwise, increase its transmission radius until $CN_u \geq \min(k, d_u)$.
Second: Run the following at each node $u$.
1) Get its geographic location $g_u$ and sink location $g_s$.
2) Broadcast $g_u$ and receive the geographic locations of its all neighbors $A_u$. Let $G_u$ be the set of these geographic locations.
3) Uncast a flag to $w$, $w \in A_u$ and $g_w$ is the closest to sink in $G_u$.
Third: Run the following at each node $u$.
1) Pick a random rank $rank_u$.
2) Broadcast $rank_u$ and receive the ranks of its currently awake neighbors $N_u$. Let $R_u$ be the set of these ranks.
3) Broadcast $R_u$ and receive $R_v$ from each $v \in N_u$.
4) If $|N_u| < k$ or $|N_v| < k$ for any $v \in N_u$, remain awake. Return.
5) Compute $C_u = \{v | v \in N_u \text{ and } rank_v < rank_u\}$.
6) Go to sleep if the following three conditions hold. Remain awake otherwise.
    • Any two nodes in $C_u$ are connected either directly themselves or indirectly through nodes within u's Two-hop neighborhood that have $rank$ less than $rank_u$.
    • Any node in $N_u$ has at least $k$ neighbors from $C_u$.
    • It does not receive a flag.
7) Return.
```

Pseudo code of GCKNA algorithm

```
First: Run the following at each node $u$.
1) Send probe packet $p_u$ to neighbors and receive the ack packet.
2) Compute whether $u$'s current neighbors $CN_u \geq \min(k, d_u)$.
3) Maintain its transmission radius if the above condition Holds or its current transmission radius is the maximum. Otherwise, increase its transmission radius until $CN_u \geq \min(k, d_u)$.
Second: Run the following at each node $u$.
1) Get its geographic location $g_u$ and sink location $g_s$. Further get the geographic distance between itself and sink $grank_u$.
2) Broadcast $grank_u$ and receive the geographic distance ranks of its currently awake neighbors $N_u$. Let $R_u$ be the set of these ranks.
3) Broadcast $R_u$ and receive $R_v$ from each $v \in N_u$.
4) If $|N_u| < k$ or $|N_v| < k$ for any $v \in N_u$, remain awake. Return.
5) Compute $C_u = \{v | v \in N_u$ and $grank_v < grank_u\}$.
6) Go to sleep if both the following conditions hold. Remain awake otherwise.
    • Any two nodes in $C_u$ are connected either directly themselves or indirectly through nodes within u's two-hop neighborhood that have $grank$ less than $grank_u$.
    • Any node in $N_u$ has at least $k$ neighbors from $C_u$.
7) Return.
```

E. Analysis of GCKN Algorithms

Theorem: Node u will have at least $\min(k, o_u)$ awake neighbors after running GCKN algorithms, if it has o_u neighbors in the original network.

Proof: If $o_u < k$, all of u's neighbors should keep awake (Step 4 of the third part of GCKNF or Step 4 of the second part of GCKNA) and the node will have o_u awake neighbors.

Otherwise, when $o_u \geq k$, we prove the theorem by contradiction [22], [23]. Suppose that node u will not have at least k awake neighbors after running GCKN algorithms, i.e., we can assume that the i'th lowest ranked (for GCKNF) or granked (for GCKNA) neighbor v of u, $i \leq k$, decides to sleep. Then C_u will have at most $i - 1$ nodes that are neighbors of u. But since $i - 1 < k$, v cannot go to sleep according to the Step 6 of third part of GCKNF or Step 6 of second part of GCKNA. This is a contradiction. In other words, the k lowest granked neighbors of u will all remain awake after running the algorithm, and hence, u will have at least k awake neighbors.

Theorem 2: Running GCKN algorithms produce a connected-network if the original network is connected. *Proof:* We prove this theorem by contradiction [22], [23].Assuming that the output network after running GCKN algorithms is not connected. Then, we put the deleted nodes (asleep nodes decided by GCKN algorithms) back in the network in ascending order of their ranks (for GCKNF) or granks (for GCKNA), and let u be the first node that makes the network connected again. Note that by the time we put u back, all the members of C_u are already present and nodes in C_u are already connected since they are connected by nodes with $rank < rank_u$ (for GCKNF) or $grank < grank_u$ (for GCKNA). Let v be a node that was disconnected from C_u but now gets connected to C_u by u. But this contradicts the fact that u can sleep only if all its neighbors (including v) are connected to $\geq k$ nodes in C_u (Step 6 of third part of GCKNF or Step 6 of second part of GCKNA).

Theorem: GCKN sleep scheduling-based WSN can provide as short as possible transmission path explored by geographic routing when there are mobile sensor nodes.

Proof: We prove this by analyzing the resultant topology after running GCKNF or GCKNA. Concerning GCKNF, given that there is a network N_{gcknf} resulting from GCKNF, based on the algorithm presentation of GCKNF, we can deduce that the neighbor node that is closest to the sink for any node will be among the awake nodes of the N_{gcknf} (Step 6 of the third part of GCKNF). In other words, no matter which node the geographic routing chooses to be the first forwarding node, all successor nodes closest to sink can be utilized by the geographic routing. Thus, the length of the first transmission path explored by geographic routing can be as short as possible. Regarding GCKNA, assume that there is a network N_{gckna} created by GCKNA. From the algorithm description of GCKNA, we can determine that for any node, say u, if it determines to be asleep, it must make sure that either 1) its all awake 1-hop neighbor nodes are connected by themselves with $grank < grank_u$ or connected by their two-hop neighbor nodes with $grank < grank_u$; 2) any of its awake one-hop neighbor nodes should have at least k neighbor nodes from the subset of the one-hop neighbor nodes with $grank < grank_u$ (Step 6 of the second part of GCKNA). This means that compared with the asleep nodes, the awake nodes generally have closer geographic distance to the sink. In other words, geographic routing can have access to as many as possible closer neighbor nodes to the sink under the priority of network connectivity after sleep scheduling. Thus, the length of all transmission paths searched by geographic routing can also be as short as possible.

4. Description of Protocols

1) AODV (Ad hoc On Demand Distance Vector)

The Ad hoc On Demand Distance Vector (AODV) routing algorithm is a routing protocol planned for ad hoc mobile networks. AODV is proficient of both uncast and multicast routing. It is an on order algorithm, meaning that it build routes between nodes only as `preferred by source nodes. It maintains these routes as long as they are needed by the sources. Furthermore, AODV forms trees which connect multicast group members. The trees are collected of the group members and the nodes required connecting the members. AODV uses sequence numbers to make sure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes.

AODV maintains routes for as long as the path is active. This includes maintaining a multicast tree for the life of the multicast group. Because the network nodes are mobile, it is likely that many link breakages along a route will occur during the lifetime of that route. The papers listed below describe how link breakages are handled. The WMCSA paper describes AODV without multicast but includes detailed simulation results for networks up to 1000 nodes. The Mobicom paper describes AODV's multicast operation and details simulations which show its correct operation. The internet drafts include descriptions of uncast and multicast route discovery, as well as mentioning how QoS and subnet aggregation can be used with AODV. Finally, the IEEE Personal Communications paper and the Infocom paper details an in-depth study of simulations comparing AODV with the Dynamic Source Routing (DSR) protocol, and examine each protocol's respective strength and weakness.

2) DSR

The key attribute of DSR is the use of resource routing. That is, the dispatcher knows the complete hop-by-hop route to the target. These routes are store in a route cache. The information packets carry the resource route in the packet heading. When a node in the ad hoc network attempts to send a data packet to a target for which it does not already know the route, it uses a route innovation process to dynamically determine such a route. Route discovery works by flooding the network with route request (RREQ) packets. Each node receiving a RREQ rebroadcasts it, unless it is the destination or it has a route to the destination in its route cache. Such a node replies to the RREQ with a route reply (RREP) packet that is routed back to the original source. RREQ and RREP packets are also source routed. The RREQ builds up the path traversed so far.

The RREP routes itself back to the source by traversing this path backwards. The route carried back by the RREP packet is cached at the source for future use. If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source, if this route is still needed. DSR makes very aggressive use of source routing and route caching. No special mechanism to detect routing loops is needed. Also, any forwarding node caches the source route in a packet it forwards for possible future use. Several extra optimizations have been projected and have been evaluated to be very effective by the authors of the protocol, as described in the following. (i) Salvaging: An intermediate node can use an alternate route from its own cache, when a data packet meets a failed link on its source route. (ii) Gratuitous route repair: A source node receiving a RERR packet piggybacks the RERR in the following RREQ. This helps clean up the caches of other nodes in the network that may have the failed link in one of the cached source routes. (iii) Promiscuous listening: When a node overhears a packet not addressed to it, it checks whether the packet could be routed via itself to gain a shorter route. If so, the node sends a gratuitous RRE to the source of the route with this new, better route. Aside from this, promiscuous listening helps a node to learn different routes without directly participating in the routing process

HPR (High Performance Routing)

In the High Performance routing protocol used the properties of AODV and DSR protocol that's why it maintain shortest path.

5. Performance Evaluations

A. Evaluation Setup

To evaluate the performance of the proposed GCKN algorithms when applying geographic routing into duty-cycled mobile WSNs, we conduct extensive simulations in NetTopo. We use TPGF [29] as our geographic routing due to the unique desirable characters of TPGF in dealing with the local minimum or whole problem as well as the shortest and multi-path transmission prosperities of TPGF, which are introduced in Section II. We compare the performance of the proposed GCKN algorithms with CKN and GSS, since CKN and GSS are the only other sleep scheduling algorithms focusing on geographic routing in duty-cycled WSNs, which is also illus-trated in Section II. The performance metric is the lengths of the transmission paths searched by TPGF in duty-cycled WSNs employing GCKN, CKN, and GSS, as the length of geographic routing transmission path is widely used to estimate the transmission time, transmission delay, etc. In addition, the network lifetime of WSNs employing GCKN, CKN, and GSS based are also observed to check whether GCKN degrades the network lifetime.

For both GCKNF and GCKNA, the detailed simulation parameters are shown in Table I. The network size is 800 × 600 m^2. The number of deployed sensor nodes ranges from 1 to 10 (each time increased by 1) and the value of *k* in CKN is changed from 1 to 10 (each time increased by 1). The default transmission radius of each node is 60 m, and the maximum transmission radius of each node is 120 m. There is one constant source node deployed at location (10, 20) and we consider two mobility cases: 1) the sensor node is still at location (750, 550) and all normal sensor nodes randomly move a random number between 10 to 100 times; 2) all normal sensor nodes are static and the sink moves a random number between 10 and 100 times in 100 different network topologies. The mobility model in both cases is the random waypoint model illustrated in Section III. In addition, the initial energy of each normal node is 100 J. The energy consumption of a sensor by transmitting, receiving one byte and transmitting amplifier are 0.0144 J, 0.00576 J, and 0.0288 nJ/m^2, respectively [23]. Each packet is 4 bytes long, and each node transmits 49 packets for each time epoch which is 30 sec.

Table 1: Evaluation Parameters

Parameter	Parameter Value
Network Size	800*600 m^2
Sensor Node Number	49(Randomly)
Default Transmission Radius	60 m
Maximum Transmission Radius	120 m
Source Node Location	(10 ,20)
Sensor Node Movement Time	1-10
Mobility Model	Random Waypoint
Initial Energy	100 Joules
Transmission Energy	0.0144 Joules
Reception Energy	0.00567 Joules
Packet size	4 Byte
Packet Number	49
Time Epoch	30 Second

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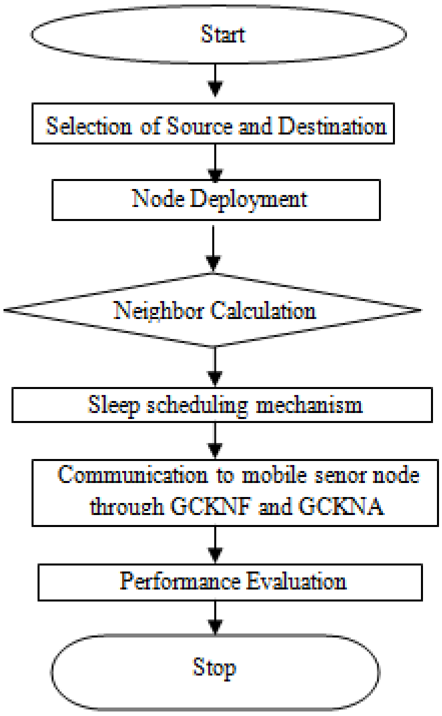
A. Functional Diagram of System

Flow Diagram



6. Conclusion

In this paper, we have explored geographic routing in duty-cycled mobile WSNs and proposed two geographic-distance based connected-*k* neighborhood (GCKN) sleep scheduling 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 geo-graphic routing in duty-cycled mobile WSNs. Again we implement the High performance routing protocol which take the properties of both AODV and DSR routing protocol.

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