# A Novel Data Retrieving Mechanism in Wireless Sensor Networks with Path-Limited Mobile Sink

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***Abstract***

*Sink mobility has been proposed to optimize energy efficiency and lifetime for wireless sensor networks (WSNs). Many novel data retrieving algorithms or protocols are proposed based on sink mobility; they can be divided into two classes, namely path-unlimited and path-limited algorithms. In terms of application range, the path-limited algorithms are more applicable in many scenarios. In path-limited WSNs, the challenge is optimizing network energy utilization and lifetime based on the limited conditions. In this paper, we propose a novel data retrieving mechanism named Multiple Enhanced Specified-deployed Subsinks (MESS) mechanism for WSNs with path-limited mobile sink. We argue that deploying some enhanced wireless nodes, namely subsinks to retrieve data locally, and then mobile sink passes though these subsinks and harvests data from them. Simulation results show that MES mechanism can dramatically improve network lifetime compare to traditional mechanism.*

***Keywords:*** *Enhanced subsink, wireless sensor network, path-limited sink mobility*

## 1. Introduction

Wireless sensor networks (WSNs) are usually composed of hundreds or thousands of low-cost wireless nodes which are deployed randomly in sensor fields. WSNs have been widely used to many applications such as military surveillance and battlefield, environmental monitoring, wildlife animal protection, home automation and health care etc. In most application scenarios, sensor fields are not accessible, and this asks WSNs for random deployed and communication protocols for self-organized ability [1].

As we know, one reason to deploy sensor nodes randomly is sensor fields are not easy to access by people like storm area, everglade or pestilence region. In past decades, many regions like mountain areas, forest, wilderness, etc are laid roads or accessible trajectories of other patterns. This enables the emergence of sink mobility which is validated to undoubtedly improve the performance of WSNs [2-5]. For applications where sensor fields are totally accessible, many protocols are proposed to formulate the optimum moving trajectories of mobile sinks [4, 5, 7]. In most scenarios, sensor fields are partly accessible and reachable trajectories are limited. For instance, sensor nodes are randomly deployed in a wilderness area which is traversed by a road and their sensed data should be collected in a fixed interval. In applications like this, we argue that the mobile sink can be assembled in public transportation vehicles (e.g., buses) that repeatedly pass fixed trajectories in sensor fields [8]. Because these vehicles usually move in one direction only and pass only once in one period, so how to guarantee the successful data transmission between nodes and moving sink needs to be considered. Many existing algorithms were proposed to deal with this issue such as TSA-MSSN [6], SAFE [9], and TTDD [10]. Data retrieving algorithms based on sink mobility should also consider efficient data harvesting and network lifetime prolongation, it mainly refers to how to use those randomly deployed sensors efficiently to prolong network lifetime. Some of existing algorithms based on path-limited mobile sink aims at this [6, 11].

Based on the discussion above, in our work, we propose a novel reliable and efficient data retrieving mechanism named Multiple Enhanced Specified-deployed Subsinks (MESS) for WSNs with path-limited trajectory. It can guarantee successful data harvesting and abate communication load of normal sensor nodes to improve energy usage efficiency of sensor nodes and lifetime of networks by shifting these load to those enhanced specified-deployed subsinks.

## 2. Related Work

Based on the activity range of mobile sink in sensor fields, existing data retrieving algorithms for WSNs with single mobile sink can be divided into two classes, namely algorithms based on non-location-limitation mobile sink [4, 5, 7, 12, 13] and algorithms based on path-limited mobile sink [6, 11, 14, 15, 16]. Actually, non-location-limitation mobile sink is not familiar in most real applications.

In [6], the architecture of MSSNs is proposed. And based on this, authors consider that sensors are sparsely deployed on both sides of roads, and then further propose a transmission scheduling algorithm for MSSN (TSA-MSSN). However, TSA-MSSN considers the direct transmission between nodes and mobile sink and is only applicable to sparsely and along-roads deployed WSNs.

Reference [11] proposes a data collection scheme called the Maximum Amount Shortest Path (MASP) for WSNs with mobile sinks. It poses significant challenges in jointly to improve the amount of data collected and reduce the energy consumption. It needs to store much data in subsinks and it chooses subsinks from sensor nodes directly which is obviously not fair to those ordinary nodes because their mass storage is useless.

In [14, 15], multi-hop communication algorithms based on WSNs with path-constrained mobile sink are proposed. Reference [14] proposes a fluid infrastructure for path-constrained sink based on realistic applications. And reference [15] proposes a communication protocol and a speed control algorithm of the mobile sink to improve the network energy efficiency. In this algorithm, authors assume that mobile sink can control its speed freely which obviously is not practical at present.

Authors in [16] propose a routing protocol called MobiRoute for WSNs with path-constrained mobile sink. It achieves network lifetime prolongation successfully. But it needs every node to maintain current location of sink in real time. When sink moves, it should inform the whole network of the topological changes, and this would cause much extra delay. So it requires that the sojourn time to be much longer than the moving time. In our mechanism, mobile sink pass subsinks once with a steady speed in one period which is more practical.

## 3. Our Proposed ALL Algorithm

### 3.1 Introduction of MESS Mechanism

In WSNs with path-limited mobile sink, it is a good idea to set some subsinks to harvest data from other nodes which are far from the path. This can reduce the long distance transmission between nodes and mobile sink and abate delay caused by long-distance. For these advantages, many researchers choose to select some sensor nodes from the WSNs as subsinks. This method is unfair to those non-subsinks because of their functionality is different from sub-sinks. In WSNs with path-limited mobile sink, after the sensor nodes are deployed, we can further deploy some enhanced wireless nodes along the accessible path to serve as sub-sinks. By doing this, without impacting the random deployed sensor network, these enhanced wireless nodes can retrieve and restore data for end users temporarily.

MESS mechanism has two phases for mobile sink to harvest data from sensor network. To help to comprehend chapters below, we use following symbols to refer to respective concepts as shown in Table 1.

**Table 1. Symbols and Illustration**

| Symbols | Refer to | Units |
|---|---|---|
| $r_{ss}$ | Radio communication range of sub-sinks. | Meter |
| $d$ | Distance between two sub-sinks. | Meter |
| $N_{ss}$ | Number of sub-sinks. | - |
| $Vol_{ss}$ | Storage volume of subsink. | Packet |
| $T_{el}$ | Time of establishing link between mobile sink and subsink. | Second |
| $k$ | Length of each sensed data. In our work, it is fixed. | Bit |
| $Dr$ | Data transfer rate between mobile sink and subsink. | Bit/Second |
| $v$ | Speed of mobile sink, it is fixed. | Meter/Second |
| $L$ | Width of sensor field in road direction. | Meter |

(1) Phase 1: transmission path establishment

The procedure of establishing transmission path can be divided into several sub-procedures and each sub-procedure should be finished in one time slot. In the first time slot, sub-sinks broadcast a message named "ESTABLISHPATH" which contains their ID (denote by S1). Every sensor node who receives ESTABLISHPATH sets its next hop node as S1. If sensor node receives multiple messages of ESTABLISHPATH, it chooses the one with highest signal intensity. As shown in Figure 1, circles refer to radio coverage range of sub-sinks. In first time slot, node 1 and node 2 set their next hop as "S1"; In second time slot, node 3 and node 4 set their next hop as "1" and "2" respectively. In third time slot, node 5 sets its next hop as "4", and in last time slot, node 6 sets its next hop as "5".

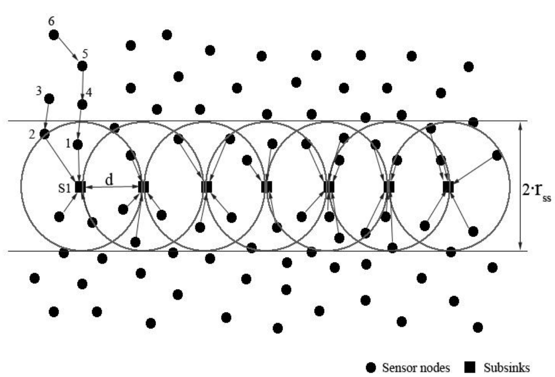


**Figure 1. Communication Path Establishment**

(2) Phase 2: Data storing & retrieving

Our proposed MESS mechanism is highly self-organized. And in MESS mechanism, sensor nodes sense data periodically. In each round, every sensor node generates one k-bits data packet, and then transmits it to next hop node. Its next hop node forwards this packet to own next hop node. This packet is forwarded one by one until meeting a subsink. In this procedure, those sub-sinks who have no leisure storage early can shift those overflow packets to other nodes using our proposed equal distribution of storing load (EDSL) algorithm. The main idea is that after one subsink's storage is full, it forwards the new coming data packet to next adjacent subsink. To avoid duplicated storing, the full subsink first broadcasts a FULL_MSG which contains its ID (denoted by A) to its adjacent subsinks. These adjacent subsinks broadcast this message to their adjacent subsinks respectively, and this operation is repeated until meeting one subink whose volume is not full (denoted by B). The subsink B sends a UNFULL_MSG which contains its ID (B) to subsink A via multihop transmission. When subsink receives two or more UNFULL_MSG, it chooses the first one as the forwarding target.

After all packets are stored at subsink averagely, mobile sink can pass these sub-sinks and harvest sensory data packets at any time.

### 3.2 Problem Formulation

In our simulations we set default values as follows: $r_{ss}$ equals to 20, $r_{sn}$ equals 20 and $L$ equals to 100 which refers to road length of the part in sensor field. we define the network lifetime as the time when half amount of sensor nodes dies.

Firstly, we can know $L$ by measuring width of the sensor field in the road direction as shown in Figure 2.

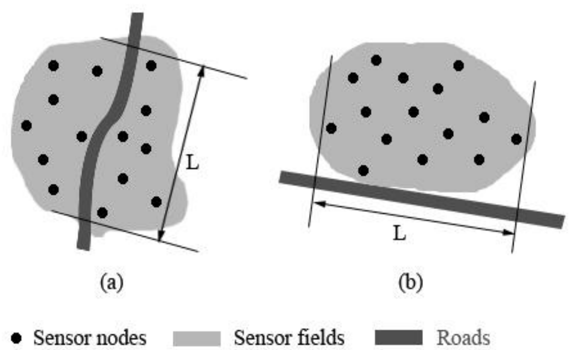


**Figure 2. Compute Width of Sensor Field**

As shown in Figure 3, because each subsink may communicate with its adjacent subsink, $r_{ss}$ subjects to:

$$r_{ss} \geq d \tag{1}$$

Distance between arbitrary two adjacent subsink is fixed, and we deploy subsinks as Figure 3 shows.

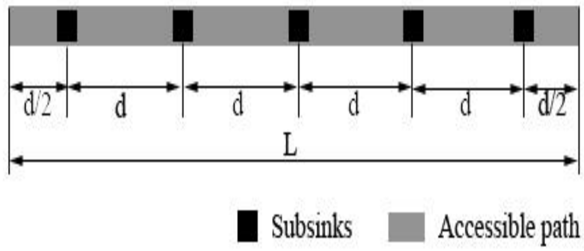


**Figure 3. Deployment Pattern of Subsinks**

From Figure 3, we can conclude the relationship between $d$ , $N_{ss}$ and $L$ .

$$d = \frac{L}{N_{ss}} \quad (2)$$

Subsinks need to store data for all sensor networks, let $N_{sn}$ denotes for number of sensor nodes, so we can compute $Vol_{ss}$ by equation below.

$$Vol_{ss} = \frac{N_{sn}}{N_{ss}} \quad (3)$$

Let $TDL$ stands for total data length (bits) for every subsink to transmit.

$$TDL = Vol_{ss} \times k \quad (4)$$

To make sure all packets can be harvested by mobile sink, the least total communication time ( $TCT$ ) for mobile sink can be computed by equation below.

$$TCT = T_{el} + \frac{TDL}{D_r} \quad (5)$$

We consider that $d$ is much more than the width of road and we think the line segment length for mobile sink can keep a link with one subsink is twice of its radio coverage range, namely $2 * r_{ss}$ . Denote the time of mobile sink passing a subsink as $T_{pass}$ and it can be computed by equation (6) below.

$$T_{pass} = \frac{2 \times r_{ss}}{v} \quad (6)$$

To guarantee the harvesting procedure, $T_{pass}$ must be greater than $TCT$ . Combined with equation (1) to (6), we can draw our conclusion that $r_{ss}$ , $d$ , $N_{sn}$ , $L$ , $T_{el}$ , $k$ , $Dr$ and $v$ should be satisfied with equation (7) below.

$$\frac{2 \times r_{ss}}{v} \geq T_{el} + \frac{d}{L} \times \frac{N_{sn} \times k}{D_r} \quad (7)$$

This equation is significant to practical design of capacities of subsink and mobile sink. If we lead into a tolerance value denoted by $\varepsilon$. Then equation (7) can be written like equation (8).

$$\frac{2 \times r_{ss}}{v} \geq T_{el} + \frac{d}{L} \times \frac{N_{sn} \times k}{D_r} + \varepsilon \quad (8)$$

The practical purport of $\varepsilon$ is the time used to tackle with packet loss, data retransmission or other suddenness.

## 4. Performance Evaluation

In our simulations we set default values as follows: $r_{ss}$ equals to 20, $r_{sn}$ equals 20 and $L$ equals to 100 which refers to road length of the part in sensor field. We define the network lifetime as the time when half amount of sensor nodes dies.

For convictive summary, we count network lifetime based on five experiments with different randomly deployed network. The result is shown in Figure 4 from which we can know the best number of sub-sinks in our simulation background we supposed above is four. We can conclude that this number is not the more the better. We argue that in practical applications, we can firstly design a math model and estimate the best number of sub-sinks.

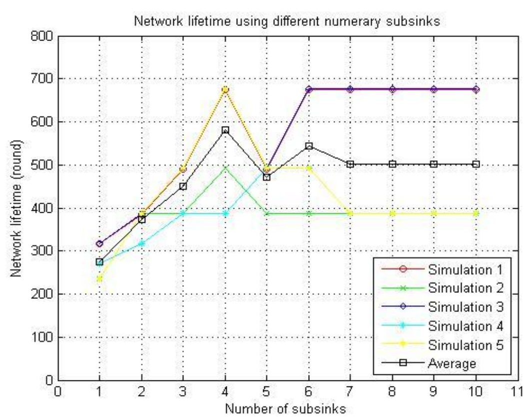


**Figure 4. Network Lifetime using Different Number of Sub-sinks**

Figure 5 shows us the comparison of network time between using MESS and conventional approach of direct choosing from sensors (DCFS). For each different number of sub-sinks, MESS outperforms DCFS obviously. This proves that our proposed MESS is energy efficient and can prolong network lifetime.

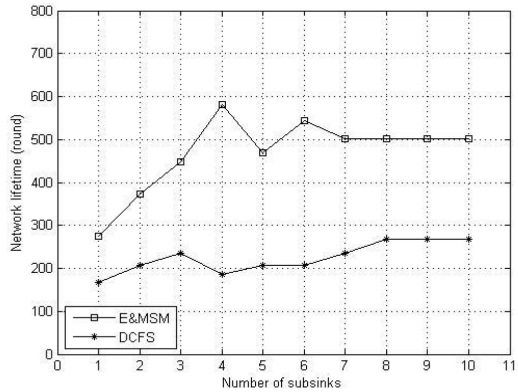


**Figure 5. Comparison of Network Lifetime using MESS and DCFS**

## 5. Conclusions

In this paper, we propose a novel data retrieving mechanism named Multiple Enhanced Specified-deployed Subsinks (MESS) mechanism for WSNs with path-limited mobile sink. Its innovation idea is to combine randomly deployed sensors with specified deployed wireless nodes to achieve reliable and efficient data harvesting. To illustrate this mechanism in detail, we analyze possible and potential problems and pose corresponding solutions. Simulation results validate our proposed mechanism and prove that MESS can improve network lifetime dramatically. By simulating this mechanism, we also conclude some rules for constructing such a network and provide theoretical reference for practical applications. We believe in MESS that it could have good performance in practical applications.

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