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Energy Efficient Routing with Mobile Collector in Wireless Sensor Networks (WSNs)

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Abstract — Energy consumption is a primary concern in the Wireless Sensor Network. This leads to pursue the maximum energy saving at sensor nodes, where a relay is used to transfer the data packet. This leads to the increase in the data gathering latency due to low moving velocity of the mobile collector. In this paper we study the tradeoff between energy saving and data gathering latency in mobile data gathering by exploring a balance between the relay hop count of local data aggregation and the moving tour length of the mobile collector. In this we propose a polling based mobile gathering approach, which leads to optimization problem named bounded relay hop mobile data gathering (BHR - MDG). A subset of sensors are used for the polling points. Thus these are the two efficient algorithms for selecting polling points among sensors.

Keywords—*Wireless sensor networks, mobile data gathering, relay hop count, polling points, moving tour*

I. INTRODUCTION

Recent years have witnessed the emergence of wireless sensor networks (WSNs) as a new information-gathering paradigm, in which a large number of sensors scatter over a surveillance field and extract data of interests by reading real-world phenomena from the physical environment. Since sensors are typically battery-powered and left unattended after the initial deployment, it is generally infeasible to replenish the power supplies once they deplete the energy. Thus, energy consumption becomes a primary concern in a WSN, as it is crucial for the network to functionally operate for an expected period of time. Besides the energy consumed on monitoring the environment with periodical sampling, a major portion of energy expenditure in WSNs is attributed to the activities of aggregating data to the data sink. Due to the stringent energy constraints in WSNs, recent research has striven to address the issue of energy saving in data aggregation. One trend of the research, see, for example, [1], [2], [3], [4], [5],[6], focused on sensor nodes themselves. In such schemes, data packets are forwarded to the data sink via multi hop relays among sensors. Some related issues, such as schedule pattern [1], load balance [2], and data redundancy [3], [4],[5], [6], were also jointly considered along with routing to further improve energy efficiency. However, due to the inherent nature of multi hop routing, packets have to experience multiple relays before reaching the data sink. As a result, much energy is consumed on data forwarding along the path. Moreover, minimizing energy consumption on the forwarding path does not necessarily prolong network lifetime as some popular sensors on the path may run out of energy faster than others, which may cause non uniform energy consumption across the network. A typical scenario is that a mobile collector roams over a sensing field, "transports" data while moving, or pauses at some anchor points on its moving path to collect data from sensors via short-range communications. In this way, energy consumption at sensors can be greatly reduced since the mobility of the collector effectively dampens the relay hops of each packet. Intuitively, to pursue maximum energy saving, a mobile collector should traverse the transmission range of each sensor in the field so that each packet can be transmitted to the mobile collector in a single hop. However, due to the low velocity of the mobile collector, it would incur long latency in data gathering, which may not meet the delay requirement of time-sensitive applications. Hence, in general, the latency of multi hop relay routing and its variants is much shorter than that of the mobile data gathering. Whereas, as aforementioned, mobile data gathering pursues energy saving by simply reducing the relay hops among sensors. In this paper, we address this issue by proposing a polling based approach that pursues a tradeoff between the energy saving and data gathering latency, which achieves a balance between the relay hop count for local data aggregation and the moving tour length of the mobile collector.

The main contributions of this paper can be summarized as follows: We characterize the polling-based mobile data gathering as an optimization problem, named bounded relay hop mobile data gathering, or BRH-MDG for short. We then formulate it into an integer linear program (ILP) and

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prove its NP-hardness. We propose two efficient algorithms to find a set of PPs among sensors. The first algorithm is a centralized algorithm that places the PPs on the shortest path trees rooted at the sensors closest to the data sink, and takes into consideration the constraints on relay hops for local aggregation while shortening the tour length of the mobile collector. The second algorithm is a distributed algorithm, where sensors compete to be a PP based on their priorities in a distributed manner. We evaluate the performance of the proposed algorithms by comparing them not only with the Simulation results demonstrate that the proposed algorithms achieve superior performance.

Paper Statement

- Energy Consumption is the consumption of energy or power.
- In a network, latency, a synonym for *delay*, is an expression of how much time it takes for a packet of data to get from one designated point to another.

Motivation

- In this section, we first give an overview of the proposed polling-based mobile data gathering scheme and then formulate it into an optimization problem.

Objectives

- Reduced data gathering delay in Wireless Sensor Network
- Low energy consumption in Wireless Sensor Network

Contributions

- The wireless node will be created and they are interconnected with each other and they can communicate independently and the node will be created.
- Network formation is an aspect of network that seeks to model how a network evolves by identifying which factors affect its structure and how these mechanisms operate.

II. RELATED WORKS

In previous method data packets are forwarded to the data sink via multi hop relays among sensors. However, due to the inherent nature of multi hop routing, packets have to experience multiple relays before reaching the data sink. As a result, much energy is consumed on data forwarding along the path. Another recent trend of the research indicated a focus shift to mobile data gathering, which employs one or more mobile collectors that are robots or vehicles equipped with powerful transceivers and batteries. Moreover, minimizing energy consumption on the forwarding path does not necessarily prolong network lifetime which may cause non uniform energy consumption across the network.

In single-hop data gathering (SHDG) each sensor directly uploads data to mobile collector in a single hop when it arrives within its transmission range. In Controlled Mobile Element scheme (CME) some sensors close to the tracks upload the data to mobile collector when it comes. A typical scenario is that a mobile collector roams over a sensing field, "transports" data while moving, or pauses at some anchor points on its moving path to collect data from sensors via short-range communications. In this way, energy consumption at sensors can be greatly reduced. But due to the low velocity of the mobile collector, it would incur long latency in data gathering, which may not meet the delay requirement of time-sensitive applications.

III. BRH-MDG PROBLEM STATEMENT/OBJECTIVE

BRH-MDG PROBLEM

In this section, we first give an overview of the proposed polling-based mobile data gathering scheme and then formulate it into an optimization problem.

OVERVIEW

Since the mobile collector has the freedom to move to any location in the sensing field, it provides an opportunity to plan an optimal tour for it. Our basic idea is to find a set of special nodes referred to as PPs in the network and determine the tour of the mobile collector by visiting each PP in a specific sequence. With sensors properly affiliated with these PPs, the relay routing for local data aggregation can be constrained within d hops, where d is a system parameter for the relay hop bound. Or, alternatively, we can say that a PP covers its affiliated sensors within d hops. The setting of d is based on the user-application needs, which reflects how to balance the tradeoff between the energy saving and data gathering latency. For example, when the energy supply of sensors is not sufficient or the data gathering service is somewhat delay-tolerant, we typically set d to a small value. The PPs can simply be a subset of sensors in the network or some other special devices, such as storage nodes [29] with larger memory and more battery power. In the latter case, the storage nodes are not necessarily be placed at the positions of sensors, which may bring more flexibility for the tour planning. However, such special devices would incur a significant amount of extra cost. Therefore, in this paper, we focus on selecting a subset of sensors as the PPs. Each PP temporarily buffers the data originated from its affiliated sensors. When the mobile collector arrives, it polls each PP to request data uploading. Upon receiving the polling message, a PP uploads data packets to the mobile collector in a single hop. The mobile collector starts its tour from the static data sink, which is located either inside or outside the sensing collects data packets at the PPs and then returns the data to the data sink. Since the data sink is the starting and ending points of the data gathering tour, it can also be considered as a special

PP. We refer to this scheme as the polling-based mobile data gathering scheme. It is further illustrated in Fig. 2, where the sensors in the shadowed area will locally aggregate data packets to their affiliated PP within two hops (i.e., d ¼ 2). For generality, we do not make any assumption on the distribution of the sensors or node capability, such as location-awareness. Each sensor is only assumed to be able to communicate with its neighbors, that is, the nodes within its proximity. In practice, there are several reasons that the relay hop count should be bounded. First, a sensor network may be expected to achieve a certain level of energy efficiency system wide. For instance, if each transmission costs one unit of energy and the energy efficiency of 0.33 energy unit/packet is expected, each packet should be forwarded from its originating sensor to the data sink in no more than three hops on average, i.e., each packet should be relayed to its PP within two hops. Second, the bound is necessary dueto buffer constraint on the sensors. Since the PPs need to buffer the locally aggregated data before the mobile collector arrives, it is not desirable to associate too many sensors with a PP. Otherwise, the buffer of the PP may not be able to accommodate all the data packets. For example, consider a sensor network with an average node degree of four. If a sensor is selected as a PP and the local relaying is constrained within two hops, there will be up to 17 sensors affiliated with this PP. Therefore, the buffer capacity of the PPs and the sensor density impose a limit on relay hops.

BRH-MDG PROBLEM FORMULATION

Having described the polling-based mobile data gathering scheme, in this section, we formulate it into an optimization problem, named BRH-MDG. Our objective is to find a subset of sensors as the PPs and a set of routing paths that connect each sensor in the field to a PP within d hops, such that the tour length of the mobile collector can be minimized. The problem is formally defined as follows:

Definition 1 (Bounded Relay Hop Mobile Data Gathering Problem). Given a set of sensors S and a relay hop bound d, find 1) A subset of S, denoted by P (P S), which represents the PPs; 2) A set of geometric trees {Ti (Vi, Ei)} that are rooted at each PP in P and $\cup_i$ Vi = S. The depth of each geometric tree is at most d; 3) The data gathering tour U by visiting each PP in P and the data sink π exactly once, such that is minimized, where u,v ϵ P {π} , (u.v) is a line segment on the tour and $|uv|$ is its Euclidean distance.

BJECTIVE

To maximize the network life time with minimizing data gathering delay in Wireless Sensor Network by mobile collector though short range communications.

IV. HYPOTHESIS

The basic idea is to find a set of special nodes referred to as polling points in the network and determine the tour of the mobile collector by visiting each polling points in a specific sequence. In our method the data uploading is done by the polling points buffer the local aggregated packet and upload them to mobile collector when it arrives at Polling Points System. We characterize the polling-based mobile data gathering as an optimization problem, named Bounded Relay Hop Mobile Data Gathering, or BRH-MDG for short. We propose two efficient algorithms to find a set of Polling Points system among sensors. The first algorithm is a centralized algorithm that places the PPs on the shortest path trees rooted at the sensors closest to the data sink, and takes into consideration the constraints on relay hops for local aggregation while shortening the tour length of the mobile collector. The second algorithm is a distributed algorithm, where sensors complete to be a Polling Points based on their priorities in a distributed manner. Polling points buffer the local aggregated packets and upload them to mobile collectors when it arrives at PPs.

V. METHODOLOGY

Destination-Sequenced Distance-Vector Routing (DSDV) is a table-driven routing scheme for ad hoc mobile networks based on the Bellman–Ford algorithm The main contribution of the algorithm was to solve the routing loop problem. Each entry in the routing table contains a sequence number, the sequence numbers are generally even if a link is present; else, an odd number is used. The number is generated by the destination, and the emitter needs to send out the next update with this number. Routing information is distributed between nodes by sending *full dumps* infrequently and smaller incremental updates more frequently.

MODELS AND PRELIMINARIES

In this section, Node Creation, Network Formation and (BHR - MDG) are presented.
The modules are explained as follows.

NODE CREATION

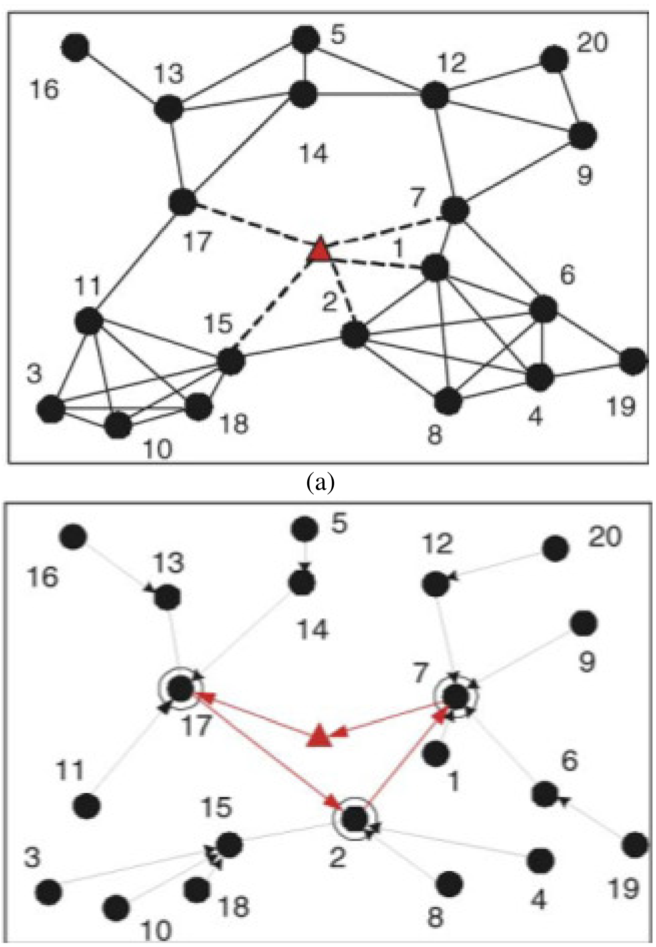
The wireless node will be created and they are interconnected with each other and they can communicate independently and the node will be created.

Network Formation

Network formation is an aspect of network that seeks to model how a network evolves by identifying which factors affect its structure and how these mechanisms operate. Network formation hypothesis are tested by using either a dynamic model with an increasing network size or by making an agent-based model to determine which network structure is the equilibrium in a fixed-size network.

DISTRIBUTED ALGORITHM FOR BRH-MDG PROBLEM

Given the complete knowledge of sensor distribution, the centralized SPT-DGA algorithm can work well in finding a good data gathering tour. However, in practice, such global information is difficult to obtain. In this section, we proposed distributed algorithm searching for suitable sensors as the PPs to achieve better scalability, which follows the same basic idea as the centralized algorithm. As discussed in the previous section, two factors greatly affect the suitability of a sensor to be a PP. One is the number of sensors within its d-hop range and the other is its distance to the data sink. A sensor that can cover more sensors in its d-hop neighborhood and is close to the data sink will be more favorable to be a PP since it leads to a smaller total number of PPs and more compacted distribution among the PPs. Considering these factors, we propose an algorithm named priority based PP selection algorithm, or PB-PSA for short. Two parameters are used to prioritize each sensor in the network, which can be easily obtained in a distributed manner. The primary parameter is the number of d-hop neighbors, which are the sensors in its d-hop range.



(a)

(b)

Fig. 1: (a) Network configuration. (b)Tour along the PPs.

We now describe PB-PSA in more detail. The pseudo code for each sensor is given in Algorithm 2. Before a sensor makes the decision on whether it becomes a PP, d rounds of local information exchange are performed to ensure that each sensor can gather the node information in its d-hop neighborhood. In each round, each sensor locally maintains a structure, named TENTA_PP, based on the information exchange. TENTA_PP is the selected sensor temporarily considered as a preferred PP in a particular round by the sensor. TENTA_PP has three sub domains: TENTA_PP.ID, TENTA_PP.d_Nbrs, and TENTA_PP.Hop which denote the node identification, the number of its d-hop neighbors and the minimum hop count of the tentative PP to the data sink, respectively. Initially, each sensor treats itself as its TENTA_PP and labels its status as "Tentative." In a particular round, each sensor first broadcasts the information of its TENTA_PP to its one-hop neighbors. When it has heard from all the neighbors, the sensor will update its TENTA_PP according to the following rule: among the pool of all the received TENTA_PPs and its own TENTA_PP, choose the one with maximum TENTA_PP.d_Nbrs to set it as its updated TENTA_PP. If there are more than one such TENTA_PP, choose the one with minimum TENTA_PP. Hop After d rounds of iterations are completed, each sensor is able to tell whether it is the one with the highest priority among its dhop neighbors. If a sensor finds that its TENTA_PP is still itself after d rounds of information exchange, it will declare to be a PP instantly by sending out a declaration message and change its status accordingly. This message will then be propagated up to d hops. For other sensors still with "Tentative" status, they will be delayed for a period of time. The delay time for a sensor consists of a major part proportional to its hop count to the data sink plus a small random time duration to differentiate the sensors with the same hop count. During the delay period, a sensor keeps listening and receiving the declaration messages from others. Once its own delay timer expires, a sensor with "Tentative" status will check whether it has received any declaration message. If yes, the sensor will affiliate itself with the nearest PP among those whose declaration messages are received. Otherwise, the sensor itself will declare to be a PP since there is no PP in its d-hop neighborhood for the moment.

VI. RESULT & DISCUSSION

PERFORMANCE EVALUATION

In the previous sections, we have provided two efficient algorithms for the BRH-MDG problem. To evaluate their performance, in this section, we first implement the ILP formulation given in Section 3 for a small network as an illustrative example and compare the optimal solution with the proposed algorithms, and then we conduct extensive simulations in large networks and compare the results of the proposed algorithms with other two existing mobile data gathering schemes.

PACKET DELIVERY RATIO

PDR is the proportion to the total amount of packet reached the receiver and amount of Packet sent by source. If the amount of malicious node increases, PDR decreases. The higher mobility of nodes causes PDR to decrease.

$$\text{PDR}(\%) = \frac{\text{Number of packet successfully Delivered to destination}}{\text{Number of packet generated by source node}}$$

ENERGY CONSUMPTION

The amount of energy consumed in a process system ,or by an organization or security. Energy Consumption is the consumption of energy or power.

LATENCY

In a network, latency, a synonym for *delay*, is an expression of how much time it takes for a packet of data to get from one designated point to another. In some usages (for example, AT&T), latency is measured by sending a packet that is returned to the sender and the round-trip time is considered the latency.

PERFORMANCE OF SPT-DGA AND PB-PSA

We have also conducted a suite of simulations to evaluate the performance of our proposed algorithms in large sensor networks. In this section, we present the simulation results and compare them with other two existing mobile data gathering schemes. The first scheme is the single-hop data gathering (SHDG) [15], in which a mobile collector stops at some selected points among a set of predefined candidate positions to collect data from each sensor such that single hop data uploading from each sensor to the mobile collector can be guaranteed. Another scheme is the controlled mobile element scheme (CME) [9], where a mobile collector traverses the sensing field along parallel straight tracks and collects data from the sensors nearby with multi hop relays. For clarity, we list the comparisons between the Compared work and our proposed polling-based approach in Table 2.

	Optimum	SPT-DGA	PB-PSA
Sensors Selected as PPs	10, 17, 23, 26	10, 12, 23, 26	9, 10, 26
Tour Length (m)	94.78	97.56	117.86
Ave. Relay Hop Count	1.27	1.17	1.13
Max Num of Affiliated Sensors to a PP	9	14	15
Ave. Num of Affiliated Sensors to a PP	7.5	7.5	10

Table 1:Performance Comparison with Optimal Solution

In the simulation, we consider a generic sensor network with N sensors randomly distributed over an L _ L square area. The data sink is located at the center of the area. The transmission range of a sensor is Rs. Each packet is locally aggregated to a PP within the relay hop bound d before the mobile collector arrives. If not specified otherwise, d is set to2. We adopt the nearest neighbor (NN) algorithm [31] in our simulation for the TSP problem to determine the moving tour, which lets the mobile collector start from the data sink and choose the nearest unvisited PP for the next visit, and finally return to the data sink. Considering the randomness of the network topology, each performance point in the figures is the average of the results in 500 simulation experiments.

TABLE 2
Comparisons among Three Mobile Data Gathering Schemes

	Polling-Based Approach (SPT-DGA and PB-PSA)	Single Hop Data Gathering (SHDG)	Controlled Mobile Element Scheme (CME)
Motion Pattern	Controllable Free to go anywhere	Controllable Free to go anywhere	Uncontrollable With fixed moving tracks
Pausing Locations of Mobile Collector for Data Gathering	Mobile collector pauses at locations of selected sensors (i.e., PPs) and gather buffered data from the PPs	Mobile collector pauses at selected polling points, which are the locations chosen from a set of candidate pausing locations, and gather data from each nearby sensor in a single hop	Exact pausing locations are not explicitly specified. It is assumed that the mobile collector can always gather data while moving along the tracks
Moving Trajectory	Start from the data sink, visit each PP once and go back to data sink	Start from the data sink, visit some locations that cover the transmission range of all the sensors, and finally go back to the data sink	Start from the data sink, go along the parallel straight tracks back and forth, and finally go back to the data sink
Relay for Local Data Aggregation	Multi-hop relays in bounded hops	No local relay	Multi-hop relays without hop bound
Data Uploading	The PPs buffer the local aggregated packets and upload them to mobile collector when it arrives at PPs	Each sensor directly uploads data to the mobile collector in a single hop when it arrives within its transmission range	Some sensors close to the tracks upload aggregated packets to the mobile collector when it comes

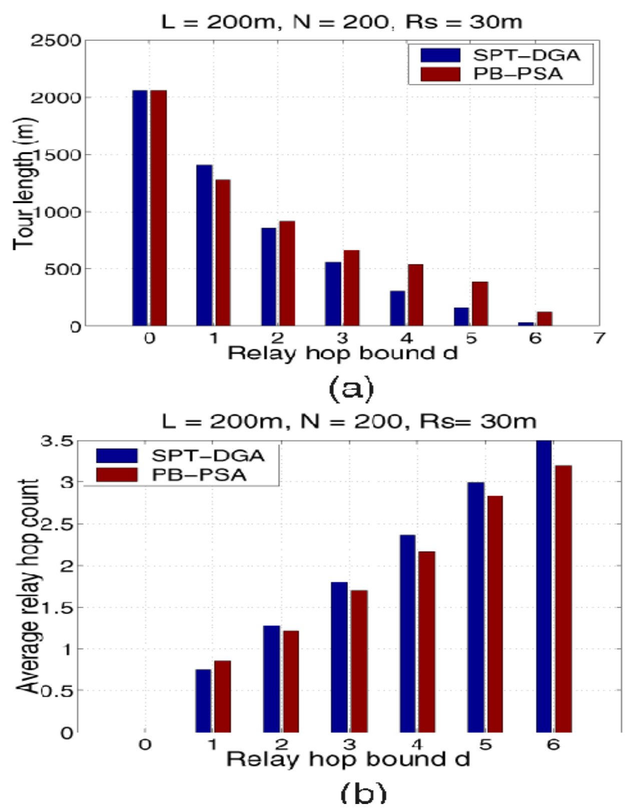


Fig 2. Performance of SPT-DGA and PB-PSA as a function of d.(a) Tour length. (b) Average relay hop count

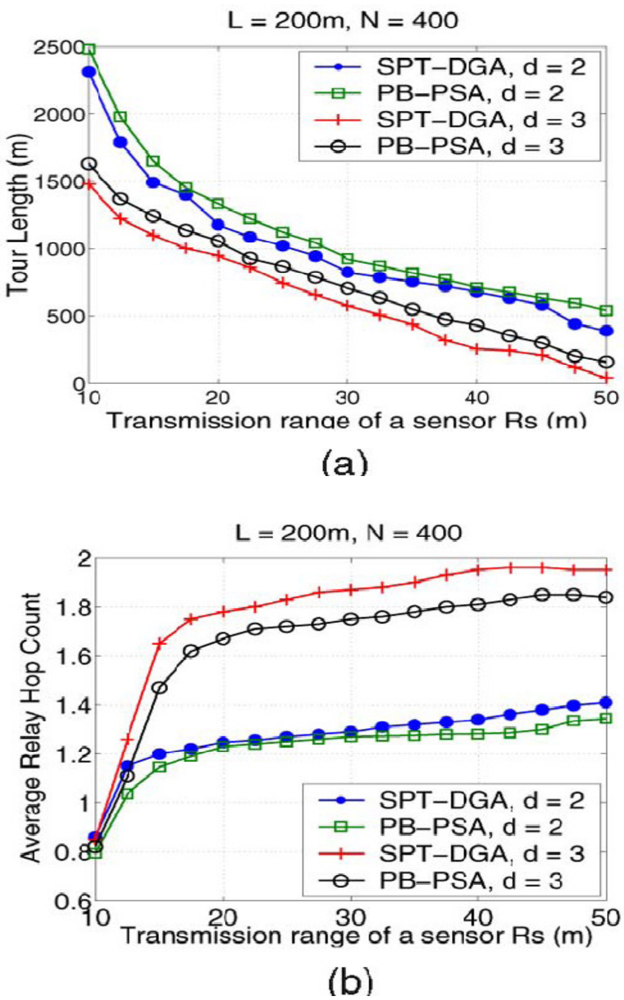
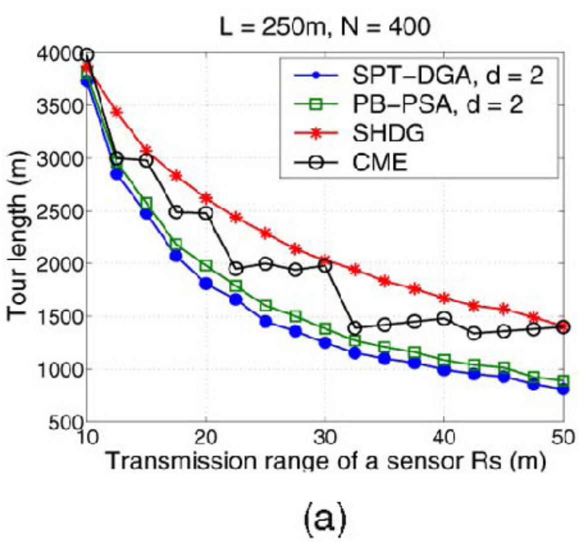


Fig 3. Performance of SPT-DGA and PB-PSA as a function of Rs for the cases of d ¼ 2 and d ¼ 3.
(a) Tour length. (b) Average relay hop count



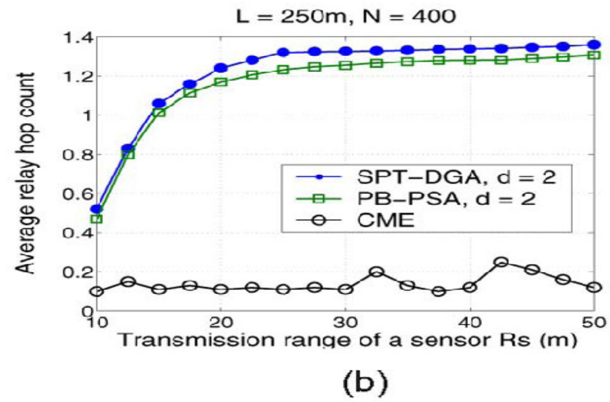


Fig 4.Performance comparison for SPT-DGA, PB-PSA, SHDG, and CME as a function of Rs.
(a) Tour length. (b) Average relay hop count

VII. RECOMMENDATIONS AND SUGGESTIONS

In this section, we briefly review some recent work on mobile data gathering in wireless sensor networks. Based on the mobility pattern, we can divide mobile data gathering schemes into two categories. The first category has uncontrollable mobility, in which the mobile collector either moves randomly or along a fixed track, proposed to use a special type of mobile nodes as forwarding agents to facilitate connectivity among static sensors and transport data with random mobility. Enhanced the work by presenting an analytical model to understand the key performance metrics of the systems that exploit the mobility in data collection, such as data transfer, latency to the destination, and power consumptions. The mobile nodes to move along straight lines to collect data in the vicinity of the lines.. A common feature of these approaches is that they generally have high stability and reliability, and the system maintenance is simple. However, they typically lack the agility and cannot be adaptive to the sensor distribution and environmental dynamics. The second category has controlled mobility, in which mobile collectors can freely move to any location in the field and its trajectory can be planned for specific purposes. Within this category, the schemes can be further divided into three subclasses. In the first subclass, the mobile collector is controlled to visit each sensor or traverse the transmission range of each sensor and gather the sensing data from them within single hop transmissions .The scheduling of mobile elements to ensure no data loss due to buffer overflow. To achieve perfect uniformity of energy consumption, proposed tour planning algorithms for achieving short data gathering tour and ensuring all data uploading to be completed within a single hop. While these approaches minimize the energy cost and balance energy consumption among different sensors by completely avoiding multi hop relays, they may result in long data gathering latency especially in a large-scale sensor network. In the second subclass, mobile collectors gather data from the sensors in the vicinity via multichip transmissions along its trajectory

VIII. CONCLUSION

In this thesis, we have studied mobile data gathering in wireless sensor networks by exploring the tradeoff between the relay hop count of sensors for local data aggregation and the tour length of the mobile collector. We have proposed a polling-based scheme and formulated it into the BRH-MDG problem. We then presented two efficient algorithms to give practically good solutions. Extensive simulations have been carried out to validate the efficiency of the scheme. The results demonstrate that the proposed algorithms can greatly shorten the data gathering energy consumption with a small latency count, and achieve 38 and 80 percent improvement on the tour length compared to SHDG schemes, respectively.

IX. SCOPE FOR FURTHER RESEARCH

Centralized algorithm can be improved by mobile node collection, data collection, server update. Further, point to point routing protocol is used for the link layer protocol performance.

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The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression, “One of us (R. B. G.) thanks . . .” Instead, try “R. B. G. thanks”. Put applicable sponsor acknowledgments here; DO NOT place them on the first page of your paper or as a footnote.

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