Energy Harvesting for Mobile Data Collection in an Optimization Framework using WSN

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Abstract—**Environmental energy harvesting has emerged as a promising technique to provide able to maintain energy sources for battery-powered wireless sensor networks (WSNs), whose network long life is constrained by battery capacity. In this paper, we develop an adaptive algorithm to search for nodes based on their energy and guarantee data collection tour length is bounded. Second, we focus on designing distributed algorithms to achieve maximum network utility by adjusting data rates, link scheduling and flow routing that adjust to something to the spatial-temporal environmental energy variation. In this paper the problem of finding optimal mobile data collecting in any field for energy harvesting sensor networks. The proposed system is an adaptive anchor selection algorithm based on sensor's energy level which achieves a attractive balance between the amount of data collected and data collecting latency. We then formulate the problem into convex optimization problem in which the SenCar spends variable short time at each anchor and each sensor tunes the data rate, scheduling and routing based on the individual energy harvesting rate such that the overall network utility can be maximized. The proposed scheme can converge to optimum, react to the dynamics of energy income effectively, maintain lasting forever network operation and improve network utility significantly compared to the network with a static data sink.**

Keywords—Wireless sensor networks, energy harvesting, adaptive algorithm, mobile data gathering, distributed algorithms, anchor selection algorithm.

I. INTRODUCTION

Wireless Sensor Network is a self-configuring network of small sensor nodes commuting among themselves using radio signal and deployed in quantity to sense, monitor and understand the physical world. A Wireless Sensor Network (WSN) consists of a large number of sensors which are densely deployed over a large area. Each sensor monitors a physical environment and communicates via wireless signals. In many sensor network applications, such as environment monitoring systems, sensor nodes need to collect data periodically and transmit them to the data sink through multi-hops. With the advancements in hardware miniaturization and wireless communication technologies, WSNs have been used in various applications such as education, warfare, and traffic monitoring.

Environmental energy harvesting has emerged as a promising technique to provide sustainable energy sources for battery-powered wireless sensor networks (WSNs), whose network longevity is constrained by battery capacity. Renewable energy sources such as solar, wind, thermal necessitates Cyber Physical Systems (a network consists of sensors and actuators to interact with the physical world) for achieving energy efficiency and cost effectiveness. For example, solar harvesting is proven to be useful to provide energy to sensors from a solar panel of relatively similar size of sensors. Thermoelectric conversion offers opportunities to harvest energy via heat transfer when the temperatures of objects or environments are different. When power from an ambient energy source (such as solar, wind or thermal, etc.) is brought into a WSN, it becomes rechargeable, and is possible to achieve infinite network lifetime by careful network planning and energy harvesting-aware designs.

Admittedly, there have been a great amount of research efforts on energy harvesting-aware designs for WSNs . Most of them either focused on optimizing performance of individual sensor or studied how to route packets in an energy efficient manner (energy-aware routing). However, to the best of our knowledge, these works have overlooked impact from nonuniform spatial distributions of environmental energy while sensors are working together from different geographical locations, so they would still suffer from traffic bottlenecks if energy shortage is inevitable in certain regions. In order to circumvent possible energy constraints caused by nonuniform environmental energy distribution, we approach the problem from a new perspective by employing a mobile actuator (called SenCar henceforth) for data gathering.

Our objective is to design a comprehensive framework such that data gathering network utility is maximized and packet latency is bounded by a predetermined threshold. To solve this problem, we propose a two-step approach. In the first step, we determine where the SenCar stops to collect data packets while guaranteeing that the total migration tour length is bounded by a threshold. These node positions are called anchors. In the second step, after the anchors have been selected, we formulate the optimization problem into a network utility maximization problem under the constraints of flow, energy balance, battery and link capacity. In particular, in our formulation, energy conservation captures the time-varying and spatial variations of energy harvesting rates. To achieve maximized utility, we need to answer the following questions. First, for each sensor, what is the optimal rate to send data to the SenCar at a specific anchor? Second, how to route data from sensors to various anchors with constraints of energy and link capacity? Third, for the SenCar, what would be the optimal sojourn time at each anchor that ensures the time of a data collection tour is bounded and the amount of data collected is maximized? To tackle these challenges, we first determine anchors and then optimize communications and SenCar's sojourn time at different anchors. We formulate the communication problem into a non-convex maximization problem and convert the non-concave objective function into a strictly concave objective function by introducing auxiliary variables. Further, we take proximal approximation algorithm in and hierarchical decomposition to transform the non-convex maximization problem into an equivalent two-level convex maximization problem.

The equivalence between the original problem and the transformed problem means that their optimal values coincide with each other. Then we decompose the convex problem into separate subproblems of data rate, flow routing and sojourn time allocation, and provide a distributed algorithm to tackle each subproblem. The main contributions of our work are summarized below. First, we propose a new framework by introducing mobile data collection for energy harvesting sensor networks. Second, we develop an adaptive anchor selection algorithm for the SenCar to achieve a balance between data collection amount and latency. Third, given the selected anchors, we propose distributed algorithms to find optimal data rates, link flows for sensors and sojourn time allocation for the SenCar. Finally, we provide extensive evaluations to demonstrate that the proposed scheme can converge to optimum, react to the dynamics of energy income effectively, maintain perpetual network operation and improve network utility significantly compared to the network with a static data sink. To the best of our knowledge, this is the first work that gives a comprehensive solution from where the SenCar should stop for data gathering to how to optimize network utility under spatial-temporal energy variations.

II. EXISTING METHOD

A. Energy Efficient Designs for Harvesting Sensor Networks

Advances in energy harvesting devices have provided alternatives to extend network lifetime of WSNs by capturing renewable energy from the environment. Most of the works so far have focused on considering fluctuations of environmental energy income and designing algorithms based on energy neutral operations. The data collection in an energy harvesting sensor network where sensors are deployed along a given path and a mobile sink travels along the path periodically for data collection. Such a typical application scenario is to employ a mobile vehicle for traffic surveillance of a given highway. As the sensors in this network are powered by renewable energy sources, the time-varying characteristics of energy harvesting poses great challenges on the design of efficient routing protocols for data collection in harvesting sensor networks. The optimal sampling rates based on the energy harvesting rate was explored and a local algorithm was developed to adapt the dynamics of battery states. These works mainly focused on developing local algorithms to accommodate energy consumption of sensors to the varying environmental energy and most of them treated energy income from different sensors equally in evaluations.

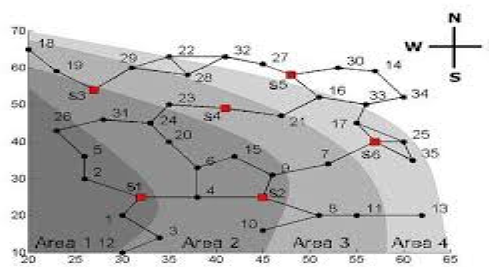

Fig.1.Network configuration

B. Mobile Data Collection

Recent work has shown that sink mobility along a constrained path can improve the energy efficiency in wireless sensor networks. However, due to the path constraint, a mobile sink with constant speed has limited communication time to collect data from the sensor nodes deployed randomly. This poses significant challenges in jointly improving the amount of data collected and reducing the energy consumption. To address this issue, we propose a novel data collection scheme, called the Maximum Amount Shortest Path (MASP), that increases network throughput as well as conserves energy by optimizing the assignment of sensor nodes. MASP is formulated as an integer linear programming problem and then solved with the help of a genetic algorithm. A two-phase communication protocol based on zone partition is designed to implement the MASP scheme. We also develop a practical distributed approximate algorithm to solve the MASP problem.

In addition, the impact of different overlapping time partition methods is studied. The proposed algorithms and protocols are validated through simulation experiments using OMNET++. A similar problem was studied in [21] in which a different approach was taken by partitioning the sensor field into zones and developing an approximate algorithm to maximize network throughput while conserving energy consumption.

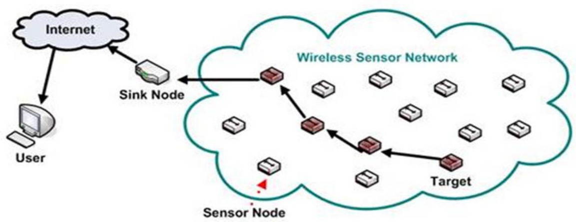

Fig.2. Mobile data collection

C.Mobility in Energy Harvesting WSNs

Recent advances in energy harvesting materials and ultra-low- power communications will soon enable the realization of networks composed of energy harvesting devices. These devices will operate using very low ambient energy, such as indoor light energy. We focus on characterizing the energy availability in indoor environments and on developing energy allocation algorithms for energy harvesting devices. First, we present results of our long-term indoor radiant energy measurements, which provide important inputs required for algorithm and system design (e.g., determining the required battery sizes). Then, we focus on algorithm development, which requires nontraditional approaches, since energy harvesting shifts the nature of energy-aware protocols from minimizing energy expenditure to optimizing it. Moreover, in many cases, different energy storage types (rechargeable battery and a capacitor) require different algorithms. We develop algorithms for determining time fair energy allocation in systems with predictable energy inputs, as well as in systems where energy inputs are stochastic.

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D.Current System

Environmental energy harvesting has emerged as a promising technique to provide sustainable energy sources for battery-powered wireless sensor networks (WSNs), whose network longevity is constrained by battery capacity. Renewable energy sources such as solar, wind, thermal necessitates Cyber Physical Systems (a network consists of sensors and actuators to interact with the physical world) for achieving energy efficiency and cost effectiveness. For example, solar harvesting is proven to be useful to provide energy to sensors from a solar panel of relatively similar size of sensors.

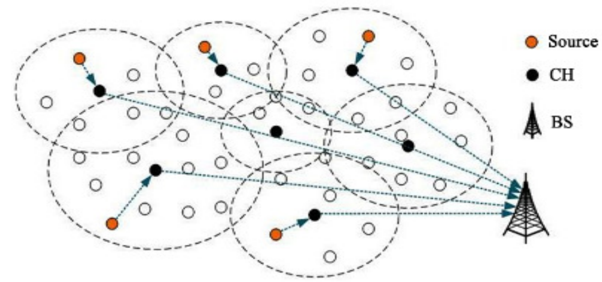


Fig.3. Different Sensor Nodes

Shortcomings Of The Current System

The introduction of mobility not only alleviates routing burdens on the congested nodes to save energy , but also shows flexibility to circumvent congested area that lacks of energy supply. We can easily direct the SenCar to collect packets from designated regions to avoid draining sensor's battery where the environmental energy supply is not sufficient at that time. Mobile computing is the control for creating an information management stand, which is liberated from spatial and temporal constraints. The independence from these constraints allows its users to contact and method desired information from everywhere in the space. The state of the user, static or mobile, does not affect the information management capability of the mobile platform. A user can continue to access and control required data while traveling on plane, in car, on ship, etc. consequently, the regulation create an delusion that the required data and plenty dispensation power are accessible on the spot, where as in reality they may be located far away. Otherwise Mobile computing is a generic term used to refer to a multiplicity of devices that allow people to access data and information from where ever they are.

Objective

With billions in downloads and annual revenue, smartphone applications offered by Apple iTunes and Android are quickly becoming the dominant computing platform for today's user applications. Within these markets, a new wave of geo-social applications are fully exploiting GPS location services to provide a "social" interface to the physical world. The explosive popularity of mobile social networks such as SCVNGR and FourSquare (3 million new users in 1 year) likely indicate that in the future, social recommendations will be our primary source of information about our surroundings Unfortunately, this new functionality comes with signifi-cantly increased risks topersonal privacy. Geo-social applications operate on fine-grain, time-stamped location information. Mobile computing has changed the complete landscape of human being life. Reduce business operations costs by increasing supply chain visibility, optimizing logistics and accelerating processes.

III. PROPOSED METHOD

We propose a two-step approach. In the first step, we determine where the SenCar stops to collect data packets while guaranteeing that the total migration tour length is bounded by a threshold. These node positions are called anchors. In the second step, after the anchors have been selected, we formulate the optimization problem into a network utility maximization problem under the constraints of flow, energy balance, battery and link capacity. In particular, in our formulation, energy conservation captures the time-varying and spatial variations of energy harvesting rates.

A.System Testing

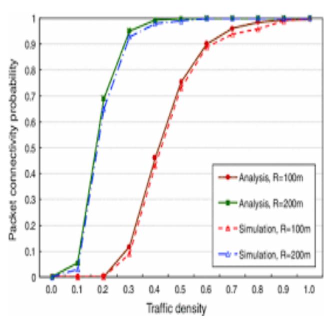
First, we propose a new framework by introducing mobil data collection for energy harvesting sensor networks. Second, we develop an adaptive anchor selection algorithm for the SenCar to achieve a balance between data collection amount and latency. Third, given the selected anchors, we propose distributed algorithms to find optimal data rates, link flows for sensors and sojourn time allocation for the SenCar. Finally, we provide extensive evaluations to demonstrate that the proposed scheme can converge to optimum, react to th dynamics of energy income effectively, maintain perpetual network operation and improve network utility significantly compared to the network with a static data sink.

B.Convergence Property

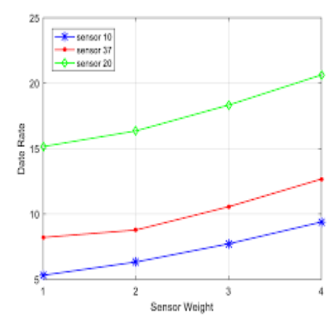
We first demonstrate the convergence property of the proximal approximation based algorithm. Note that for variables to converge in proximal iterations, they have to converge first in subgradient optimizations. We observe that the results oscillate at the beginning of iterations because we have used an incremental subgradient method to solve the problem, which would lead to fluctuation when the solution is close to the optimal solution and the degree of such fluctuation is proportional to the iteration stepsize. As the stepsize gets smaller, the algorithm stabilizes and achieves desirable convergence.. We can observe that all those variables above achieve their optimal values within 300 iterations. In addition, the overhead of the proposed algorithms can be justified as follows. The overhead involves energy consumed to converge to an optimal solution (or within 5% of fluctuations). It is noticed that both the network utility and sojourn time converge very fast in the high-level proximal iterations (within 50 steps). Since the solution for assigning data rates, link flow is pre-computed in a one time effort for each round, the control messages are sent less frequently than data messages. The size of the control messages is also much smaller, compared to the amount of data gathered, the overhead from control messages can be ignored.

C. Performance Analysis of Utility Weight and SenCar Speed

The overall performance is represented by network utility Ui(·) which is the combined data uploading rate of all sensors. There are a number of factors that could have an impact on network utility such as utility weight, energy harvesting rate and the speed of the SenCar. sensors 1, 2 and 4 from 1 to 5 while keeping the utility weight on other sensors unchanged. We can see that the data rates on sensors 1, 2 and 4 increase when we assign a higher utility weight for them. By adjusting the utility weight on each sensor, SenCar could give preference of data collection to sensors with higher weight. On the other hand, the speed of SenCar also has a great impact on network performance. Once the anchors have been determined, the migration tour length is fixed. Thus, the amount of time the SenCar spends on route depends on the speed of the SenCar. First, we can see that the network utility increases with higher energy harvesting rates. Then, at a faster speed of the SenCar, the network utility is also higher. This is because that the less time SenCar spends on traveling, the more time SenCar could sojourn at anchors to collect data in each time interval. Thus, increasing the speed of the SenCar is beneficial to overall performance .



(a).



(b).

D. Feasibility Study

The feasibility of the project is analyzed in this phase and business proposal is put forth with a very general plan for the project and some cost estimates. During system analysis the feasibility study of the proposed system is to be carried out. This is to ensure that the proposed system is not a burden to the company. For feasibility analysis, some understanding of the major requirements for the system is essential.

E. Economical Feasibility

This study is carried out to check the economic impact that the system will have on the organization. The amount of fund that the company can pour into the research and development of the system is limited. The expenditures must be justified. Thus the developed system as well within the budget and this was achieved because most of the technologies available.

F. Technical Feasibility

This study is carried out to check the technical feasibility, that is, the technical requirements of the system. Any system developed must not have a high demand on the available technical resources. This will lead to high demands on the available technical resources. This will lead to high demands being placed on the client. The developed system must have a modest requirement, as only minimal or null changes are required for implementing this system.

IV SIMULATION RESULT

A. Energy consumption

Energy consumption graph draw between time and energy. It is obvious that the proposed algorithm performs better in terms of energy efficiency over 60% compared to existing algorithm.

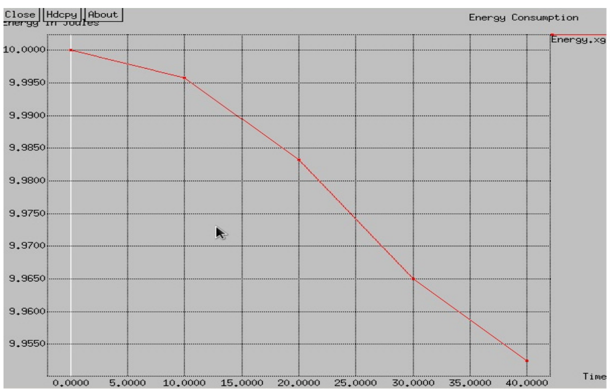


Fig.4. Energy Consumption (graph)

B.Throughput

Throughput is the rate of successful message delivery over a communication network. From this figureit is obvious that the proposed algorithm throughput should be increased as compared to existing algorithm.

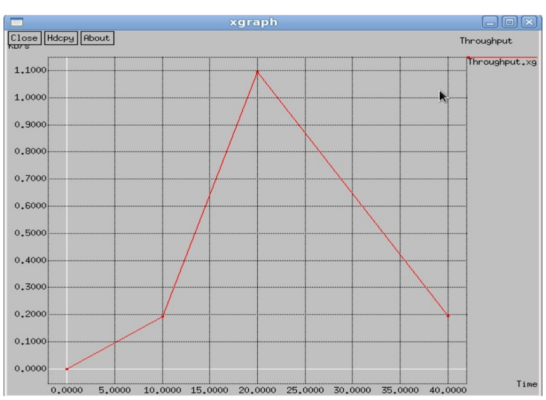


Fig.5.Throughput (graph)

CONCLUSION

In this paper, we have considered the problem of finding opti-mal mobile data gathering strategies for energy harvesting sensor networks. We first examine the impact of spatial-temporally varying energy distribution on the operation of the sensor network through an experimental study .To circumvent the negative effect of limited energy harvesting capability on some sensor nodes, a mobile collector is introduced for gathering data and balancing energy distribution in the network to improve performance. We then propose an adaptive anchor selection algorithm based on sensor's energy level which achieves a desirable balance between the amount of data gathered and data gathering latency. We then formulate the problem into a convex optimization problem in which the SenCar spends variable time at each anchor and each sensor tunes the data rate, scheduling and routing based on the individual energy harvesting rate then the network utility can be maximized**.**

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