International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 9 (2018) pp. 6655-6659

Energy Modernization Approach for Data Collection Maximization using Mobile Sink in WSNs

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Abstract

In this paper a novel approach of data collection maximization using mobile sink is considered for Modernization of energy in wireless sensor network. Mobile sink improves the energy of the system by travelling along the path to collect data from one-hop sensors periodically. Sensor are powered by energy renewable resources and depleted along a path. Whenever we design a network, time varying characteristics of EH poses a great challenge. So, in this paper we formulate a network that deals with multi-rate transmission and parallel transmission–time scheduling. An improved protocol is derived where not only considers the renewable of energy, node having higher rate of renewable capacity will be enrolled to participate more into data transmission. Reliability of the network is studied and is proved that QoS parameters shows better results with higher energy expense. The proposed algorithms and protocols are validated through simulation experiments using Network Simulator (NS2).

Keywords: Energy Consumption Rate (ECR), Energy Renewable Rate (ERR), Energy Harvesting (EH).

INTRODUCTION

Wireless Sensor Network has various application in different field such as in monitoring, environment parameter, health parameter and in surveillance area including traffic parameter etc. Wireless sensor network consists of thousands of tiny low cost and low power devices known as sensor nodes (SNs), where each transmitting node in the network is responsible for [1] [2] collecting and processing the data or information and transmits to the MS or base station. In traditional sensor network [3] thousands of sensors are deployed in random or predefined manner. Sensor nodes sense the data and transmit to the static sink / BS through multi hop transmission. , nodes near to sink suffer with heavy load and deplete their energy faster .A hole is created around the sink and information cannot be routed to sink due to absence of data forwarding nodes, which reduces the network performance. So, the sink mobility comes out with remedy to overcome energy hole problem.

For the improvement [4][5] of network performance such as reducing the energy dissipation and enhancing the network lifetime, sink mobility concept has been taken. Most existing studies focused on the energy consumption because sensors are powered by energy limited batteries. So, there are various method to reduce the limitation of battery such as, deployed sensor can charge their battery from [7] [11] solar energy, vibration energy, wind energy, etc. So, in the concept of energy harvesting, sensors recharge their batteries from their surroundings. To sustain the network operation in EH-WSN energy consumption rate (ECR) should always be greater than the energy renewable rate otherwise sensor will lose their energy. Data collection in WSN using MS having fixed mobility has different objectives as,

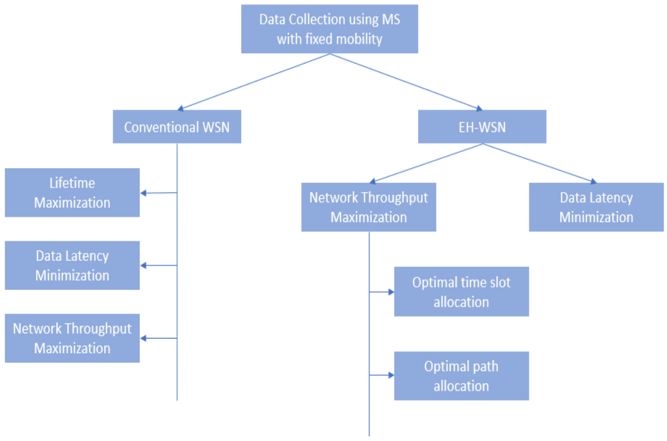


Figure 1. Data collection in WSN using mobile elements with fixed mobility patterns under different objectives

In conventional WSN for the data collection maximization problem, an integer linear programming (ILP) [13] model is formulated. But in EH-WSN, each deployed sensor charges their batteries from the surroundings, which poses time varying characteristics. To respond time varying nature traditional ILP method takes too much time and suffers from poor scalability and will not applicable due to quick changes in energy profiles of sensors.

So, in this paper, data collection in EH-WSN is considered with mobile sink, which aims to formulate an optimization problem for finding an optimal path for MS and time scheduling for each sensors deployed at different locations to maximize the collected data, including multi-rate transmission and slot scheduling of transmission time for each sensor.

RELATED WORK

This section briefly describes the related works carried out by researchers in the area of data collection maximization in EH-WSN using mobile sink. Due to advancement in WSNs architecture based on mobile sink has been studied by several researchers. Use of sink mobility [4][3][10] shows the improvement in the network life time and reduces the energy consumption of sensors by balancing the workload among the sensor. In general sink mobility is divided in three category : sink with fixed mobility which moves along a pre-defined path, sink with random mobility which is often mounted in animals , humans and sink with controlled mobility which is often used for data collection . Franscesco [4] survey the data collection in WSN thoroughly, where sink moves on the fixed trajectories, which found many researchers attention due to its practical application in wide spread range of its practical application [3]. At different time having different location, movement of sink can be determined by using a LP method for the joint problem proposed by Wang. Using a fixed mobility for data collection from single hop sensor node not only improves the network throughput but also reduces the data delivery latency and reduces the energy consumption. For the network throughput point of view in conventional WSN the main aim is to maximize the total collected data. Liang and Juo [5] introduced a joint optimization problem having multiple mobile sink with h-hop constrained for stationary network. For this a three-stage heuristic is devised which consists of calculating time profile at each location and improves the total collected data. With the recent advancement in EH-wireless sensor network, sensors can recharge their batteries from surroundings. So, data collection problem is investigated by X. Ren, et al. [8] most of the works on data collection using a MS in EH-WSNs are defined with the objective of network throughput maximization [9], [10], [14]. Due to various applications for data collection on the single or direct path, the authors in [9], [1] investigate the NTM problem in an EHWSN using a path-constrained mobile sink. Due to some unrealistic assumptions considered in [9] and [10] and in order to further improve the network throughput, the authors in [14] propose a condition on the fixed distance travelled by sink at all given time slots. Based on the proposed condition, they develop an online centralized algorithm which not only has low computational complexity but outperforms the previous works in term of network throughput. Motivated by the drawback of considering fixed distance travelled by sink and its constant speed in [14], in order to further improve the throughput, we propose different scenarios for NTM problem for which practical parameters are optimally utilized. Furthermore, due to the infeasibility of assumption on constant energy harvesting in practical data collection scenarios [12], in contrast to [14], we consider a uniform energy harvesting distribution in this work to statistically model the amount of harvested energy by nodes during different time intervals.

PROPOSED WORK

As wireless sensor networks have special approach with battery power and the conservation of energy. Use of energy harvesting reduces the limitations of battery. Due time varying characteristic of sensor node energy changes every time and will have different power levels. Each node has their individual parameters such as range, distance, location its transmission power level. So due to independent parameter of each sensor output must be as independent as possible, to avoid the convergence to the same maxima. So proposed algorithm estimates the independent components of the sensors its power level intensity by comparing the energy with reliability.

Network is said to consisting of sensors with each having a capability of renewing their energy from surroundings. A model is derived from the above assumption and stated below. A node assumed to be having storing energy capacity of C and energy stored at given time interval is P. With the energy renewable model H, energy at any time $P_i(e)$ is defined using (1),

$$P_i(e) = min\{P_{i-1}(e) + H_{i-1}(e) - D_{i-1}(e), C(e)\} \qquad (1)$$

where, $H_{i-1}(e)$ = harvested energy,

$D_{i-1}(e)$ = depleted energy,

$P_i(e)$ = stored energy at each node

With the assumption as given (2)

$$0 \le P_i(e) \le C(e) \qquad (2)$$

It is well known that signals in wireless systems suffer from path loss, interference, shadowing and other environmental destructions. Signal to Noise Ratio (SNR) determines the performance of the network. The system is reliable if all data packets reach to destination node without any drop. But, efficiency of the network may go down as system is more prioritized to ensure reliability. Higher energy investment may yield improvement in the reliability but introduces unnecessary energy consumption. Taking reliability and efficiency as two odds, we introduce multi speed transmission of mobisink that adds optimal usage of resource also providing reliability to the network.

Given a node n_i and sink node s, the transmission power can be operated in multi-level which is set depending the QoS of network in terms of reliability. It is stated before that, reliability increases with increase in power and decreases if the distance between referenced nodes is higher. Both combinedly defined using (3),

$$r_{i,j} \propto \frac{P_i}{d_{i,j}^{\alpha}} \qquad (3)$$

where, $r_{i,j}$ = reliability

P_i = Power consumption at i

d = distance between node i and sink node

α = path loss factor

Decision making is an important parameter to decide transmission rate of a sensor node. Variable transmission rate can be set if certain conditions are met. Therefore, selection of transmission rate will have decided by the amount of data a node is holding. Assuming, DT_i is the amount of data node $n_i$is about to send, then $DT_i \propto r_i$. Thus, reliability can be related to amount of data being sent.

Problem Definition:

Network is defined to be having energy harvesting system H and number of time slots T assigned by mobisink node per tour. Data collection maximization is to allow the mobisink node to collect maximum data from all nodes within the network within the specified time slots. Renewal of energy and expense of energy for transmission are the two constraints decides data collection strategy.

Intuitively, every sensor node within the network should transmit data to mobisink within the time slots allocated. However, the energy replenishment of each node varies from other. Hence, it may lead to consumption of more time slots for few nodes to transmit data. Again, energy renewal rate will be slower than transmission rate which is important to design the protocol. There are possibilities that multiple sensor node may participate at same time to transmit data and compete each other resulting in collision of packets.

With all the above parameters, data collection maximization problem can be described below. Given, node $n_i \in N$ total number of nodes, number of time slots τ, data collection is to allocate the time slots such that $\sum_{i \in N} \cdot \sum_{j \in N_i} (x_{i,j} * r_{i,j} * \tau)$ will be maximum, with constraints given in equations (4), (5), (6)

$$x_{i,j} \in \{0,1\}, \ \forall\, n_i \in N, j \in N_i \qquad (4)$$

$$x_{i,j} = 0, \ \forall\, n_i \in N, j \notin N_i \qquad (5)$$

$$\sum_{i=1}^{n} x_{i,j} \leq 1, \forall\, n_i \in N, 1 \leq j \leq N_i \qquad (6)$$

$$\sum_{j=1}^{n} P_{i,j} * x_{i,j} * \tau \leq P_i(e), \forall\, n_i \in N \qquad (7)$$

$$\tau = \frac{DT_i}{\tau_u} \qquad (8)$$

where, $x_{i,j} = \begin{cases} 1, & when\ time\ slot\ t_i\ is\ allocated\ to\ n_i \\ 0, & otherwise \end{cases}$

$\tau = number\ of\ time\ slots$

$\tau_u = single\ unit\ of\ time\ slot$

$N_i = neighbor\ node\ set\ of\ node\ i$

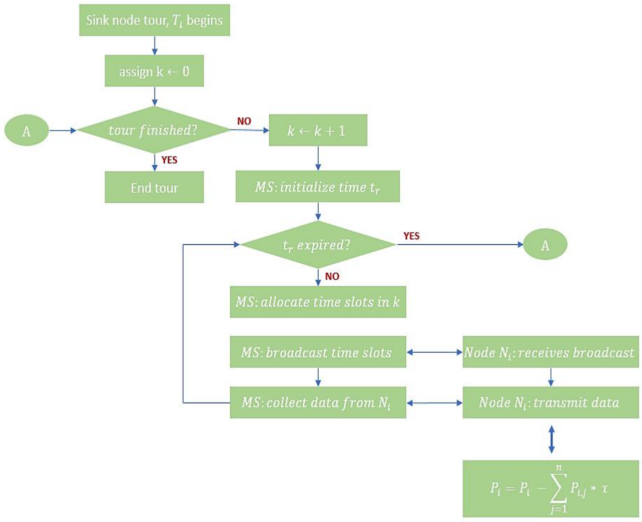
$P_{i,j} =$
$power\ of\ node\ i\ to\ transmit\ data\ to\ node\ j \in N_i$

Proposed Algorithm:

With the above mathematical model derived, the framework for the proposed algorithm presented here. Network with N number of nodes within the network and harvesting energy H total length travelled by mobisink node is termed as tours. Each tour will cover the entire network with predefined path by mobisink node. In each tour, mobisink divides the total time into time slots and allocate time slots to all the nodes within the network. Allocation of time slots is based on energy replenishment and amount of data each node carries. Higher the rate of energy replenishment, more number of time slots will be allocated as it will have more energy to invest for data transmission.

Fig shows the flow diagram of the proposed algorithm where mobisink node will initiate the tour and divides the time slots. After the time slots are framed, mobisink will broadcast this information to all nodes within the network. Every node after receiving the packet will find the slots and tour pattern of mobisink. Every data transmission results in decrement of energy of a node derived from the equation (9)

$$P_i = P_i - \sum_{j=1}^{n} P_{i,j} * \tau \qquad (9)$$



PERFORMANCE ANALYSIS

Simulation parameter

Table 1: Simulation Parameters

Sl. No.	Parameter	Values
1	Network size	$(50 - 150)$
2	Packet transmission rate	$250\ Kbps$
3	Maximum transmission range	$200\ m$
4	Amount of energy collected by EH	$655.15\ mWh\ (sunny\ day)$ $313.70\ mWh\ (cloudy\ day)$
5	Solar panel size	$10\ mm * 10\ mm$
6	Ambient temperature	31.8 ℃
7	Default time –slot duration	$2\ second$

Remaining Energy:

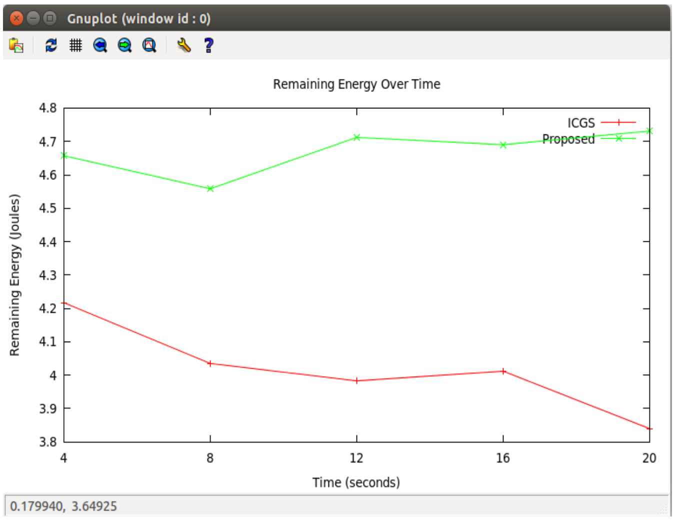


Fig Remaining Energy of Source Nodes

Fig shows the remaining energy of source nodes within the network. The results are compared with ICGS protocol. Participation of nodes in data transmission is proportionated with their energy replenishment as compared to ICGS where renewal energy and node participation in data transmission has not related each other. If the source node is not able to get enough renewable source of energy, then will just forward the data to neighbour nodes who has more opportunity of getting renewable energy. Node which receive this data will take direct participation with mobisink to deliver the data. Thus, source node energy will not be expended much if they are insufficient to gain energy from surroundings. Hence, the result show better performance compared to ICGS protocol.

Packet Delivery Ratio:

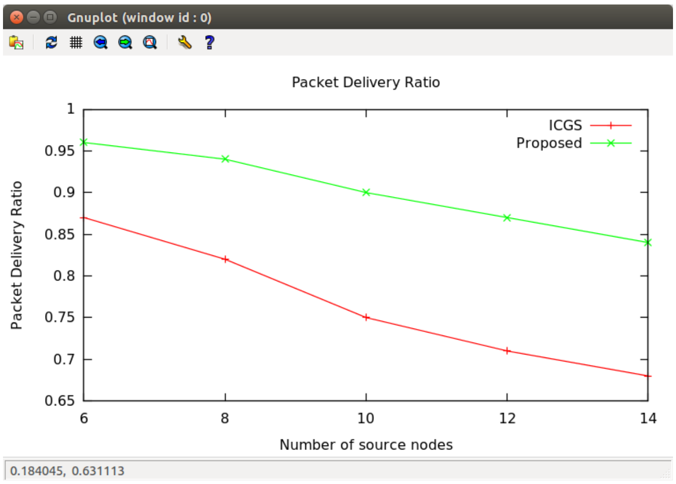


Fig shows the results of packet delivery ration with respect to source nodes. Increase in number of source node lead to allocation of more time slots. But, the tour interval is fixed, then there might be delay in delivering the data. Hence, there will be slight decrease will increase of source nodes. But, proposed algorithm shows better results compared to ICGS. Because, the tour trajectory will be informed well before mobisink begins its travel. Hence, nodes which are fall closer to the route path will be notified in prior and ensured that data will be reached to those nodes by source node ahead of time. This greatly improves the performance of the system in terms of delivering the packets to mobisink.

Throughput:

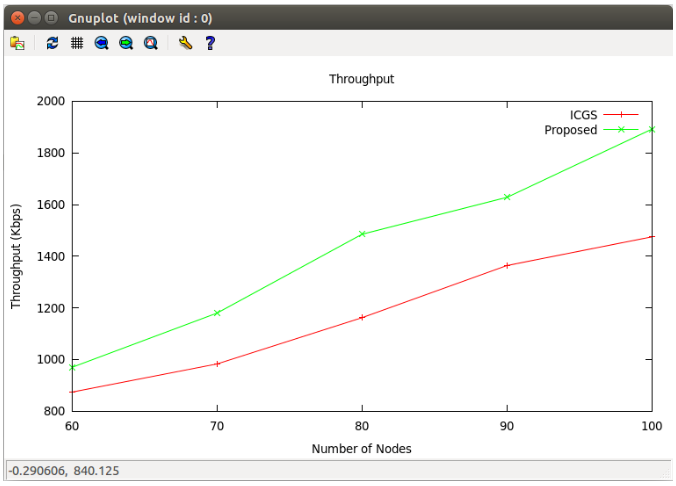


Fig shows the results of throughput with respect to number of nodes in the network. It is already stated that, nodes which have more capability of replenishing their energy will participate in data transmission. And, it is proved from the proposed algorithm that, reliability is directly proportional to expense of energy. Therefore, throughput of the network gives satisfactory results compared to ICGS protocol.

CONCLUSION

In this paper, we have proposed an efficient algorithm to maximize data collection of energy harvesting wireless sensor network using mobile sink. Initially, a problem is defined to understand the use case to increase data collection rate in a network. Problem is formulated further to derive a relationship with renewable energy and amount of data to be transferred. With all these parameters considered, it is proven that data collection can be maximized using mobisink node and renewable energy subject to more involvement of high energy node in data transmission. The reults prove that data collection rate improved upto 35% compared with ICGS protocol. Proposed algorithm is efficient and scalable where it does not have dependency on either location or volume of nodes in the network. Further improvement can be done by using different algorithm with different routing protocols to optimize energy and data buffers for future work. It will improve the performance lifetime of a network with maximizing data collection and will make network reliable and more efficient.

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