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Improving Maximum Data Collection Based On Pre-Specified Path Using a Mobile Sink for WSN

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Abstract*-Data aggregation is one of the challenging issues which are faced in the wireless sensor network by using Energy Harvesting Sensors. Data collection in a fixed pre-defined path with time varying characteristic forms a major problem in Energy Harvesting Sensor Networks. In the proposed work the Adjustment based allocation method is used to allocate fixed time slots to each sensor nodes in which the network throughput can be increased with less energy consumption. The mobile sink transmits the polling message to all the nodes within the transmission range and makes decision based on the profits gained by the sensor nodes in each timeslot. The NP-Hard problem is defined with the form of reducing the complexity of the sensor nodes where larger number of data can be collected from the environment. The data collection throughput is maximized with the use of optimized path for the mobile sink in the network.*

Keywords: *Data collection, Energy Harvesting Sensor Network, Mobile sink, Pre-defined path, Throughput performance, Time slots.*

1. Introduction

Wireless Sensor Networks (WSNs) consists of large number of sensor nodes being grouped together in a field. Each sensor node has the capability of collecting and processing the data, and forwards it to the one or more sink nodes which are connected with each other through wired or wireless communications. This sensor node consumes energy for the purpose of transmission and they may be provided from the external environment. The data transmission between the sensor node and the mobile sink may be single-hop or multi-hop transmissions. In multi-hop transmission it includes the collection of data from all the neighboring nodes in the network. The energy consumption also increases to a larger extent and also leads to increase in data delivery rate. Conventional sensor network consists of sensor nodes which has a limited power consumption which must be preserved for the entire data collection in the network. The mobile sink which is used for the purpose of data collection can be single or multiple sinks. With the use of single sink node the data can be collected in the form of random, controlled and fixed mobility pattern. In order to collect data from the densely deployed sensor nodes the conventional sensor networks may not be sufficient for the data maximization. The sensor nodes require energy for performing data collection and it is done by using some renewable energy sources. Hence we use the Energy Harvesting Sensor Networks which can be used with harvesting the energy whenever it is necessary for the sensor nodes for the data transfer to the mobile sink.

The structure of the paper is followed as: In Section 2 the taxonomy for throughput improvement is discussed. In Section 3, various models that are used in this work are discussed. In Section 4, various methodologies along with the Adjustment based allocation method which is proposed for the increase in network throughput is proved. Section 5 introduces the simulation performance and its evaluation with the proposed work and Section 6 includes the conclusion of the paper.

2. Taxonomy for Throughput Improvement

In [1][3][6][7] Wireless sensor network has an effective and emerging use in the recent applications. In the traditional architectures most of the sensor nodes are static and are deployed over the dense area networks. Since the nodes are static the data collection has large data delivery rate and more energy consumption. In the recent architectures, the data collection is developed by using the mobile elements (MEs). The mobility will provide larger part of collecting the data from the other sensor nodes by reducing the energy consumption. The throughput can also be increased with the amount of data that are collected with low energy expenditure and less data delivery rate. In route discovery phase it takes more number of packets to discover the path along the network. Due to the mobility in the network there is the possibility of occurrence of packet loss may be increased. Energy Harvesting Sensor Networks has the capability of harvesting the energy from the other renewable resources like wind and other resources from the environment [2][4]. The EH-WSNs has the capability of using over dense networks in which the sensor nodes can recharge themselves from the surrounding environment so they can collect large amount of data and transfer the data to the mobile sink.

In [5][10] the use of the mobile elements has become a greater extent to reduce and balance the energy consumption in the wireless sensor networks. The data collection latency in the network becomes higher due to the constant speed of the mobile elements. They did not fully explore the chance to additionally improve the tour by exploiting the wireless communication range between the sensor nodes and the mobile sink. The travelling salesman problem with neighborhood due to its NP-Hardness provides approximation and heuristic algorithm with larger approximation factors is being designed.

In [8] The sensor nodes are deployed along a path and due to the mobility of the sink node it can move along the path periodically and collects the data from the sensor nodes. The sensors are powered by the renewable energy resources which are available in the environment. The time varying characteristics of the sensor nodes has a great challenge for the data collection over the network. The distributed algorithm is established to resolve this difficulty without the total information of each sensor nodes. Energy harvesting sensor networks does not have the adaptive response for the changes of the energy rates of sensor nodes.

In [9][12][13] Data collection is done with the sensor nodes that are arranged in dense area network with a pre-defined path along with one hop distance sensor networks. For the data collection maximization problem multi-rate transmission and time slot scheduling for the sensor nodes is proposed. The NP-Hardness of the problem can be solved an offline algorithm is used in which the total information of each sensor node with its network topology and the transmission range, location and rate is provided. On further implementation of the algorithm a fast and scalable form of online distributed solution is developed in which the total information of the sensor nodes is not known to the sink node. The energy supply rate of each sensor nodes is much slower than the energy consumption rate.

While using in dense location multiple sensor nodes share same time slots and hence each nodes has a competition with each to decide in which time slot they can send their own data. Each of the sensor nodes has a pre-defined transmission power and hence a polynomial solution is being obtained.

In [11] For the large scale monitoring of heterogeneous wireless sensor network architecture is developed which consist of sensor nodes, gateway nodes and mobile sink. When the sensor nodes is in the need to transmit the data to the base station, the sensor nodes collects the data from the neighboring nodes and store them in the gateway nodes which act as a temporary storage. The mobile sink then travels through its pre-specified intermediate path and collects the data from the gateway nodes in the network. The approximation algorithm is developed in which the approximation ratio is obtained with the various set of inputs. This approximation ratio identification technique is suitable not only for the realistic inputs but also for the various set of optimization problems which are under wireless networks.

Table I: Comparison of the various techniques for maximum data collection

AUTHORS NAME	PROPOSED METHOD	ADVANTAGES	DISADVANTAGES
M. Di Francesco et.al.[1]	Scheduled rendezvous and on-demand schemes	Maximizing throughput with low energy consumption	Packet loss occurrence due to the mobility based data collection
L. Song and D. Hatzinakos[2]	Transmission scheduling algorithm	Successful information collection with minimization of energy consumption	Higher storage of data that leads to packet failure
L. He et.al.[5]	Travelling salesman problem with neighborhood elements	Reduction in the data collection latency by lowering the data delivery rate	There is no possibility of using the optimized communication range between the sensor nodes and the mobile sink
X. Ren and W. Liang[8]	Energy harvesting with distributed algorithm	Without the use of the total information the data delivery rate is reduced by the faster movement of the sink node	The sensor nodes are powered by energy limited batteries and hence the energy harvesting sensor are not capable during dynamic changes
X. Ren and W. Liang[9]	Multi Rate Transmission and Time Slot Scheduling Method	Fast and scalable data collection is provides with lower energy consumption	Not possible for the dense area networks since multiple sensor nodes share the time slot for the transmission
W. Liang et.al.[11]	Approximation algorithm	Maintain high quality monitoring using the sensor network	Limited amount of data collected due to poor data quality
R. S. Liu et.al.[13]	Joint rate allocation and routing algorithm	Heuristic algorithms jointly compute the rate assignment and the routes simultaneously	High data replication occurs and cannot determine the path randomly

3. Energy Harvesting Sensor Model

The sensor nodes require energy sources to recharge themselves for larger data collection since they are static nodes in the network [3][9][15]. The Energy Harvesting Sensors are used where these sensors provide energy to the sensor nodes whenever it is necessary by gaining energy from the environment. By the use of these sensors the data collection is increased by use of the energy from the surroundings. The recharge of the sensor nodes is done at the beginning of each time slots and it is derived with a simple equation (1),

$$b_i(k) = \min\{b_i(k-1) + h_i(k-1) - c_i(k-1), B_i\} \qquad (1)$$

where, $b_i(k)$ energy budget of sensor nodes s_i at time interval k, $h_i(k)$ amount of harvested energy by sensor nodes s_i at time interval k, $c_i(k)$ energy consumption of sensor node s_i at time interval k, B_i battery capacity of sensor node s_i.

3.1. Sink Mobility and Data Collection Model

Data collection is obtained by using the sink node which has the mobility pattern in the network. The sink node which is the only moving node along the network travels along the transmission range of each sensor nodes and collects the data which is being collected by the sensor nodes from the surroundings[14][17]. In order to reduce the packet loss in the network the sink node allocates the time slots to each and every sensor nodes that are deployed in the network. The mobile node consumes energy from the resources that are available in the transmission range during its movement in the network. The data is collected from the sensor nodes in the form of one-hop communication link [16][18][19]. The mobile sink node has the pre-knowledge information of all the sensor nodes in the network and by using this information the sink node travels along each sensor node and increases the data collection.

4. Methodologies

4.1. C- Schedule Algorithm

The group of sensor nodes is deployed in the environment and the mobile node called the sink node travels along the path which is allocated and collects the data from the sensor nodes. Energy for the sensor nodes is obtained from the renewable sources and for providing the routing protocol has a time varying characteristics that forms a great issue in the network. An optimization problem is obtained by using a multi-rate communication mechanism with the sensor nodes. The centralized schedule algorithm is developed by providing the total information of all the sensor nodes to the sink node. The data collection maximization is a problem which is proved to be a NP-Hard. The total information of each sensor nodes is exactly been known to the mobile sink i.e, the current profile of each of the sensor nodes along with its transmission rate is known to the mobile sink. At the initial stage the sensor nodes are arranged in the form of increase in time slot from its starting. If two or more nodes having the same starting time period and in such cases it is being broken arbitrarily among the sensor nodes without the loss of any data. Hence the mobile sink node starts collecting data from the sensor nodes that are allocated in the increasing order of the time slots.

4.2. The Proposed Adjustment Based Allocation Algorithm

Based on the condition provided for the sensor nodes the allocation of time slots for different time intervals the profit is calculated for the two available time slots in the time intervals. The time slots are allocated to the set of sensor nodes that are deployed in the network with various time intervals of data collection. For a given time interval there is a separation of two different available time slots based on the data collection between the sensor nodes in the current interval. The mobile sink node sends a sampling message for the set of sensor nodes in the network. The sensor nodes sends back a response message to the sink node with its location, range and the transmission rate of the sensor nodes for data collection. The profit is calculated for all the set of sensor nodes V in the network with the two different time slots in time interval. The mobile sink relates the two profits and identifies the first maximum profit which is obtained among the set of allocated time slots. The maximum profit is identified by using the condition with the length of the sensor node having the time slots with transmission range R_i as (2),

$$L \geq \max(\mathrm{R_i}), 1 \leq \mathrm{i} \leq |\mathrm{V}| \qquad (2)$$

The throughput is increased when compared with the transmission range of the set of other sensor nodes. By identifying the probability of the calculated increase in the throughput it is recognized that there is an approximate increase in the throughput performance.

Algorithm: Adjustment Based Allocation Algorithm

Inputs:
t : total time slots on the path; total_t1 : total time intervals on the path
Output:
Distribution of |V| sensor nodes to |t| time slots
Set interval portioning {2,2,….,$|t|/2$};
For interval = 1 to total_t1 do
  T_1 = first time slot of the time interval;
  T_2 = second time slot of the time interval;
  Mobile sink sends sampling message;
  Sensor node in two time slots response with the message (location,trange,trate);
  Run the decision phase;
End for

5. Simulation Performance

In this section, the comparison performance of both the C-Schedule algorithm and Adjustment based allocation method is established for the throughput increase. In Fig 1 the gap between the total collected data is recognized among the two different algorithms. This performance is developed based on the pre-specified path and the fixed route distance. With the comparison of these two algorithms the adjustment based allocation algorithm performs well than the other algorithm. In Fig 2, the simulation is performed based on the characteristic between distances covered by the sink node with the throughput performance of the data collected. When decreasing the distance covered the proposed algorithm has a maximum throughput increase at a particular point and it gradually decreases on further decrease of the distance covered by the sink node. In Fig 3, the result provides the comparison of the energy consumption and the energy budget used during the data collection. The energy provided to each of the sensor nodes participating in the data collection is by the energy harvesting sensor nodes which has the renewable sources in the environment. The energy budget denotes the total energy capacity that the sensor nodes can take for the data collection. Energy consumption is the energy used by the sensor nodes during the data collection. The comparison graph between these two parameters in the form of joules is simulated and the results are obtained.

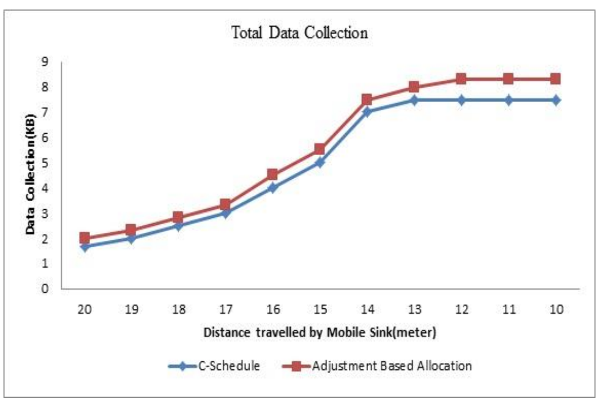

Fig 1: Gap between the total collected data

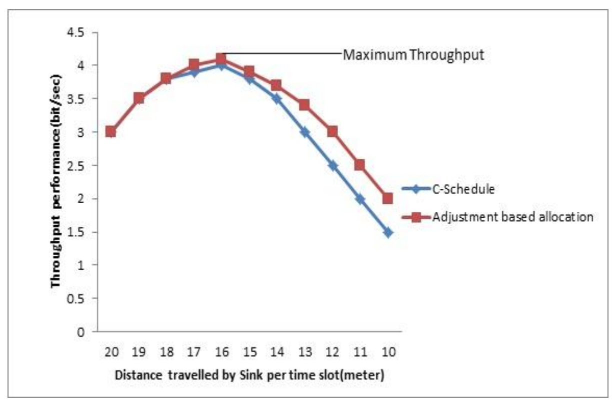

Fig 2: Network throughput graph

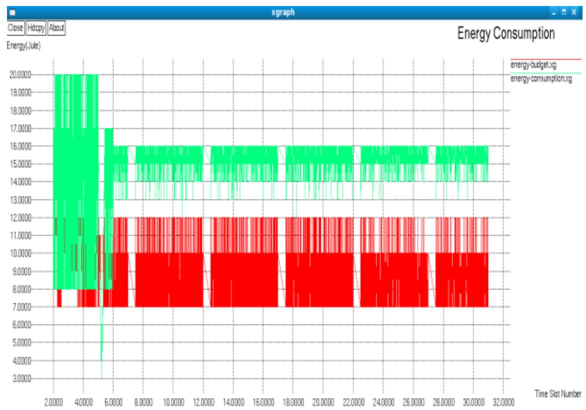

Fig 3: Comparison between energy consumption and energy budget

6. Conclusion

In wireless sensor network the throughput improvement with the maximum data collection is the major issue that has been faced in the recent period. The data delay is reduced when the mobile sink node travels along the fixed path rather than moving towards all the set of nearby nodes in the network. When the time slot is being allocated to the sink along the pre-specified path, the sink node must travel along the allocated time slot for the whole transmission. Since there is a fixed mobility for the sink node in the network is used the complexity of the data collection and the time delay is increased. Furthermore, an optimal speed and path can be allocated for the sink node where a larger amount of data can be collected with the low energy consumption.

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