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ENERGY-EFFICIENT OPTIMAL SUB-SINK SELECTION FOR DATA COLLECTION IN WIRELESS SENSOR NETWORKS

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Abstract. In Wireless Sensor Networks, data collection by the Mobile Sink (MS) from the sensor nodes is a challenging task. In the proposed approach, the MS visits an optimal set of subsinks in order to collect data instead of visiting all the nodes in the network. In this paper, the subsink selection has been proven to be optimal since the subsinks are chosen by the Critical Path Method (CPM). Initially the nodes within the transmission range of the MS are chosen, which are termed as the subsinks. An optimal set of subsinks are selected using CPM method such that MS is scheduled to visit only the optimal subsinks. The member nodes relay the data to their assigned subsink. The MS visits the subsink for data collection. The energy consumption of the MS is minimized since the MS visits only the optimal subsinks. Another factor taken into consideration is that the constrained visit of the MS does not impact the collection from all the nodes. Simulation results prove that the collection of data through CPM provides an effective solution for efficient data collection.

Keywords: mobile sink, wireless sensor networks, critical path method, data collection, energy, subsink.

AMS Subject Classification: 90B18.

1. Introduction

In Wireless Sensor Networks (WSN) data collection from the sensor nodes without data loss is a challenging field of research. Recent researchers have proved that collection of data by the MS as an effective solution for efficient data collection. Initially, the sensor nodes are deployed randomly in the field of study such as endangered areas. The real time applications are habitat monitoring, environmental monitoring, seismic structural analysis etc. The nodes relay the data through a multi-hop approach to a static Base Station (BS). These leads to the battery drain of nodes near the BS since these nodes have to constantly relay the data to the BS.

Researchers have proved [1] that Mobile Element (ME) which acts as the Mobile Sink (MS) is efficient for data collection. In the previous approaches the MS has to visit the nodes which are deployed randomly in the region of study. This paves way for the battery drain of the MS. In order to minimize the energy drain of the MS, various approaches have been exploited in the literature. In [2], a constrained path has been chosen by the MS depending upon the proximity of the sensor nodes such that the MS traverses through it. In the proposed approach, the nodes are visited based on the rate of data collected by them. If the rate of data collection is more, then energy of these nodes will be the first to be drained off. This can be avoided by identifying the critical path nodes from which the MS has to collect data. The critical path nodes are the optimal nodes that the MS has to visit. These nodes are identified as the sub-data collectors from which the MS collects the data. These sub-data collectors are chosen optimally using PERT-CPM method. These critical path nodes are the optimal subsink nodes that lie within the transmission range of the MS.

2. Related work

Several solutions to address the data collection by the MS have been discussed in the literature. This literature is categorized based on the mobility of the MS: random path, path-constrained and path-controllable mobility.

2.1. Random path:

Here the mobile sinks are mounted on some people or animals moving randomly to collect interested information sensed by the sensor nodes. In [3] each data sensed is queued in the sensor node. When a sink comes in the range of the sensor node, it sends its queued data to the sink. In [4] the network is a two dimensional grid. Grid points are occupied by sensors and access points. Every sink moves on the grid with equal probability to any of the four neighbours' from its current grid position. The sinks communicate with the sensors or access points only when they are co-located at the grid points. Due to the random mobility, it is difficult to achieve a balance between the data transfer latency and the data delivery ratio.

2.2 Path-Constrained Sink Mobility

In [5] the mobile sink is installed on a public transport vehicle which moves along a fixed path periodically. Nodes in the single-hop with sink send its sensed data when the sink comes in its range. Single-hop communication between all sensor nodes and the mobile sink may be infeasible due to the limits of the road infrastructure and communication power. An architecture of wireless sensor networks with mobile sinks (MSSN) is proposed in [6] for a traffic surveillance application. The best time slot with minimum transmission power is found at which we transmit data to sink. This approach assumes that only one node is in the communication range of the sink at a time. Somasundara and Srivastava proposed a load balancing algorithm [7] for the multiple mobile elements, to ensure each mobile element serves almost same number of sensor nodes. A node is selected as a leader through which data is sent to the sink. A routing protocol, called MobiRoute, is suggested for WSNs with a path predictable mobile sink in [8] prolongs the network lifetime and improves the packet delivery ratio. Here the mobile sink sojourns at some anchor points to collect data from the nodes.

2.3 Path-Controllable Sink Mobility

In [9] a scheme is proposed to maximize the sensor networks lifetime. The mobile sink collects data from nodes with high residual energy so as to maximize the network lifetime. In [10] an optimal path for the mobile sink is found to achieve smallest data delivery latency and to minimise energy consumption at each sensor node. Each sensor within the range of the sink sends it data directly to the sink. A Rendezvous Algorithm is proposed in [11] to find a path for the mobile sink so that each rendezvous points in the network are visited. In [12] a scheme is proposed to find the path so that no energy holes are formed in the network. The sink changes its location when the nearby sensor's energy becomes low and moves to zones with richer sensor energy.

3. Problem Formulation

Initially, the sensor nodes are deployed randomly in the monitored area. The MS collects data from sensor nodes when it moves closer to them. The sensor nodes are classified into two types based on the transmission range of the mobile sink. The nodes within the Transmission Range Area (TRA) of the sink are called subsinks and the other nodes outside the TRA are called members. The members relay the data to the subsinks which relays its data finally to the mobile sink. This is illustrated in Fig.1. The MS is said to complete one cycle when it visits all the subsinks as it reaches the end of the path and comes back to the starting point.

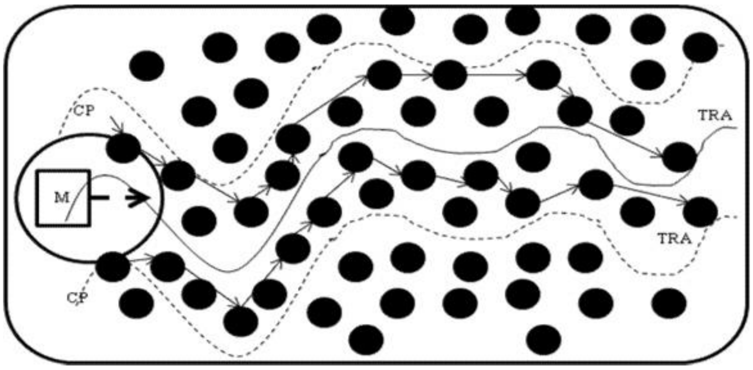

Fig.1 Movement of the MS for data collection

The communication time between the mobile sink and the subsink is assumed to be fixed due to the fixed movement and constant speed of mobile sink. The throughput of the wireless sensor networks depends on the total amount data that is collected and the optimal selection of subsinks along with the optimal assignment of members to subsinks. The optimal selection of subsinks results in a critical path (CP) for the sink to collect data from. The sink must collect data from the subsinks before the buffer for the sensor nodes overflows. The main challenge here is to find the optimal subsinks among the subsinks within the communication range of MS and the assignment of members to subsinks so as to maximize the amount of data collected in addition to reduce the total energy consumed by the subsinks and the MS.

In our scenario, let n sensor nodes be deployed randomly and let n_s nodes close to the trajectory of the mobile sink be chosen as subsinks. The other n_m nodes away from the mobile sink choose different subsinks as their destinations. Instead of collecting data from all subsinks within the transmission range of the sink unlike the previous approaches we select optimal subsinks among them. A critical path among the subsinks is selected and the subsinks in the critical path are the optimal subsinks. These optimal subsinks are selected based on the buffer overflow time for the subsinks.

The MS moves along a fixed path periodically with constant speed to collect data before the overflow in buffer of subsinks occurs. We assume that the MS has unlimited memory, and computing resources and limited energy. Each sensor node continuously collects data and transmits them either directly to the mobile sink or to one of the optimal subsinks selected which finally delivers the data to the MS. We assume that the sink has enough storage to buffer data. In our scenario, each member needs to choose one and only one subsink as its destination. In this paper, our objective is to improve the energy efficiency for data gathering, which minimizes the energy consumption of entire network under the condition of maximizing the total amount of data collected by the mobile sink.

4. Results

The proposed optimal subsink selection solution for data collection proves to give prominent results. This is illustrated in Fig.2 which presents the total amount of data collected by the mobile sink in one cycle. This cycle defines the visit of all the optimal subsinks by the MS. The theoretical maximum amount of data collected is the amount of data sensed by the sensor nodes. While collecting data via subsinks the total amount collected is only half of the theoretical value. But when collecting data via optimal subsinks the data collected is almost equal to the theoretic value. As the total number of nodes increases, there is more number of nodes within the transmission range of the sink and hence the total amount of data collected also increases. Data is effectively collected from nodes before their buffers overflow.

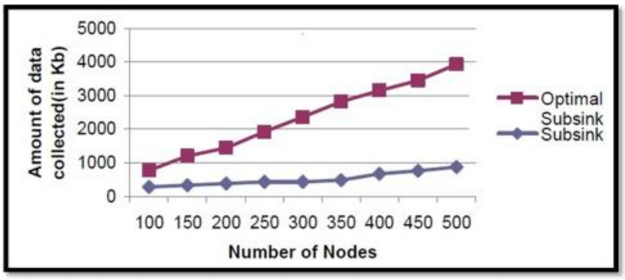

Fig.2 Amount of data collected

The energy consumption of the MS is calculated in terms of the power required to collect the data from the MS. The MS approximately consumes 1Joule to receive the data from the sensor nodes. Therefore energy is calculated over the time required to receive the data. This energy of the MS will be high compared to data collection via the subsinks, since MS using optimal subsinks collects larger set of data. Let d_A be the amount of data collected by the MS from the optimal subsinks. Let m_E be the energy of the MS for receiving the data from the sensor node. Since m_E depends on the amount of data collected d_A, m_E will be higher for the MS. Hence, there is a trade-off between the amount of data collected and the energy consumption of the MS.

5. Conclusion

The collection of data by the optimal set of subsinks through the MS has been determined through CPM. The members are assigned to an optimal subsink by identifying the average number of nodes that are nearer to the assigned subsink. When the MS arrives near the optimal subsink, the data from the members of the optimal subsinks are also collected. As the total number of nodes grows larger, the margin of difference in the data collection also differs. The energy consumption will vary depending on the amount of data collected by the MS. Since the data collected using optimal subsinks is more compared to the existing subsink collection approach, the energy consumption will be slightly higher. But this is negligible when the amount of data collection is taken into consideration.

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Simsiz sensor şəbəkələrində məlumatların toplanması üçün optimal mənbənin seçilməsinin enerji-səmərəli üsulu

K.I. Qandi

XÜLASƏ

Simsiz sensor şəbəkələrində mobil mənbələr (MM) vasitəsilə ilə sensor qovşaqlarından məlumatların toplanması mürəkkəb məsələdir. Təklif olunan yanaşmada, MM verilənləri toplamaq üçün şəbəkənin bütün qovşaqları əvəzinə yalnız alt mənbələrin optimal çoxluğuna müraciət edir. Bu işdə isbat olunur ki, altmənbələrin seçimi optimaldır, çünki onlar kritik yollar metodu ilə (KYM) seçilirlər. Əvvəlcə, mobil stansiyanın ötürmə diapazonu daxilində qovşaqlar seçilir. Mənbələrinin optimal dəsti isə KYM metodu ilə elə seçilir ki, MM yalnız optimal mənbələrə müraciət etsin. . Qovşaqlar verilənləri təyin olunmuş mənbəyə ötürür. MM isə mənbələrə məlumat toplamaq üçün müraciət edir. Bu zaman MM enerji istehlakı minimallaşır, çünki MM yalnız optimal mənbələrə müraciət edir. Bu prosesdə nəzərə alınan başqa amil ondan ibartədir ki, MM-nin məhdud müraciətləri bütün qovşaqlardan məlumat toplanmasına təsir etmir. Modelləşdirmənin nəticələri isbat edir ki, KYM vasitəsilə məlumatların toplanması baxılan məsələnin effektiv həllini təmin edir.

Açar sözlər: mobil mənbə, simsiz sensor şəbəkələri, kritik yol metodu, məlumatlarının toplanması, enerji, altmənbə.

Энергоэффективный выбор оптимального источника для сбора данных в беспроводных сенсорных сетях

К.И. Ганди

РЕЗЮМЕ

В беспроводных сенсорных сетях сбор данных по мобильному источнику (МИ) от узлов датчиков является сложной задачей. В предлагаемом подходе, МИ посещает оптимальный набор под источников с целью сбора данных вместо посещения всех узлов в сети. В данной работе доказывается, что выбор под источников является оптимальным, так как они выбираются методом критического пути (МКП). Первоначально выбираются узлы в пределах диапазона передачи мобильной станции, которые выбраны в качестве источника. Оптимальный набор источников выбираются с помощью метода МКП, таким образом, что МИ контактирует только с оптимальными источниками. Узлы перемещают данные к назначенному источнику. МИ контактируют источникам для сбора данных. Потребление энергии МИ минимизируется, так как МИ контактирует только оптимальными источниками. Другой фактор который учитывается в процессе является то, что ограниченный контакт МИ не влияет на сбор информации со всех узлов. Результаты моделирования доказывают, что сбор данных через МКП обеспечивает эффективное решение задачи сбора данных.

Ключевые слова: мобильный источник, беспроводные сенсорные сети, метод критического пути, сбор данных, энергия, подисточник.