Data Collection In Tree-based Wireless Sensor Network using TDMA Scheduling

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Abstract— this paper describes the basic idea about the different methods of data collection in WSN. The freshness of data is maintained as the process of data collection is as much faster as possible. Many existing techniques have ability to cope with the issues like energy consumption, packet collision, retransmission, delay etc. For quick data collection, schemes are required to be scheduled in effective manner. One of the good techniques is TDMA. It is a type of MAC in contention-free medium, allocating the time slots to links or nodes. In TDMA, the node becomes active during only during the particular time slot allocated to it. Thus, it reduces energy consumption with very less possibility of conflicts. It supports the fair data collection in WSN with minimum delay and less number of retransmission. Scheduling with TDMA can be done with minimum scheduling length and fair use of bandwidth and time.

Keywords — Data Collection in WSN, TDMA Scheduling, Scheduling length, Slot Assignment.

I. INTRODUCTION

Wireless sensor network is group of scattered sensor devices placed at physical location for the purpose of measuring environmental attributes. They are small in size so can easily deployed. Sensor Node has ability of sensing and measuring. WSN supports observing and scheming of physical environments from remote locations with good accuracy of data. They have applications in a variety of fields such as environmental observing, military purposes and assembling sensing information in unfriendly locations.

The sensor has processor with memory and computational power. It requires communication devices to transmit data to the required node. Devices may be radio transreceiver and power source. Thus, it generates information and send them at required node called sink (or base station). Base station can be any gateway, for instance internet, which connects the sensors to external word. Sensor node measures attributes such as temperature, noise, pressure and forwards the information through the network to required node. As such networks will have thousands of battery-controlled nodes that would be required to prolong periods of time. A challenge in WSNs is to meet the end-to-end delay requirement of control applications under wireless interferences and the severely limited resource constraints of WSNs. A number of protocols have been proposed in the literature for data collection in WSNs that balance the communication cost, delay, and reliability.

A. Characteristics and Limitations of WSN
- Ability to handle node failure
- Mobile nodes
- Heterogeneity of nodes
- Can withstand environmental conditions
- Power is constraint

II. DATA COLLECTION IN WSN

Data collection is basic task in WSN. Sensor nodes measures the attribute (of interested nodes) and sends to common base station (also called sink). Data is collected in three stages: (a) *Deployment stage:* It is initial stage for designing a WSN. It includes how deployment is done in the sensing environment. There are different deployment strategies as per the requirement of application. (b) *Data delivery stage:* Second step is data delivery approach; It tells that how the sensed data is forwarded from each sensor node to the sink. (c) *Control message dissemination stage:* In "one-to-many" traffic pattern where control messages such as network setup/management or collection commands are disseminated from the sink to all sensor nodes.

Data collection from sensors to common sink over a tree-based routing topology creates traffic pattern in which data flows from many nodes to single node is known as *convergecast*. It is many-to-one communication. An opposite view is broadcast(or multicast) in which data propagates from a single node to one or more nodes in the network. The figure-2 shows the working of (a) convergecast (b)broadcast
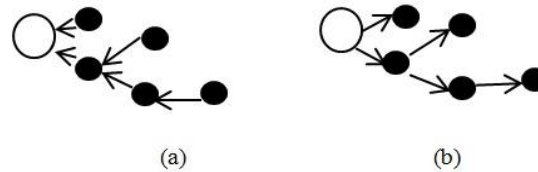
Figure- 2 Data transmission in WSNs (a) Convergecast and (b) Broadcast [3]

A Data Convergecast

In WSN, two types of convergecast: *(a)Row-data Convergecast*, Where each packet is relayed individually and (2)*Aggregated convergecast*, where packets are aggregated at each hop before being relayed.[2]

In most of the applications data aggregation is primary stage in which sensor node periodically generates an information or data and sends to sink node through aggregated node. At the aggregated node queries are stored, processed and forwarded continuously.
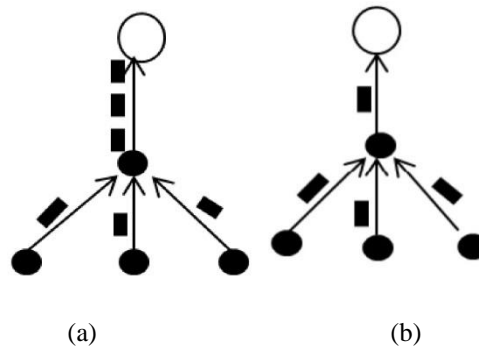

(a)   (b)
Fig. 1: (a) Aggregated data convergecast (b) Row-data convergecast [8]

The aim of data aggregation is avoidance of traffic by reducing the duplication of information [8]. It is also beneficial to save energy and power consumption which prolongs the network life-time. Elena Fosolo, in [15], introduces with "In network aggregation". In these type of network data is collected and routed in multi hop network. There are main types of in network data aggregations: (a) Aggregation of data with reducing the size of data packet (b) Aggregation of data without reducing the size of data-packet. In some applications, all the data are equally important so the data packet is transmitted individually. The data packets have not much similarity among them. It generates more traffic as compare to the aggregated convergecast as the packets are relayed separately.

During data collection, there are many issues regarding to energy consumption, collision, retransmission, overload and time. So data collection should be scheduled effectively for fast data convergence.

III.   SCHEDULING IN DATA COLLECTION

To achieve the freshness of data, the data should be collected as quickly as possible. For that the network should be capable enough to withstand the difficulties like collision, re-transmission, delay, overhead etc.

Key aspects of scheduling are:

- Maximizing Fairness
- Minimizing Scheduling Length
- Minimizing Latency
- Minimizing Energy Consumption

A. TDMA Scheduling

Contention-free medium access control (MAC) protocols, like Time division multiple accesses (TDMA) provide attestable guarantee after collecting the data. In TDMA, each node is allocated time slot. There is group of limited number of time slots called *frame*. Each frame periodically repeated until all nodes complete their transmission process. TDMA scheduling will allocate time slot in such a fashion that each node can get uniform priority to send their data. In this scheme the proper usage of bandwidth is main goal of fairness. As the TDMA scheduling provides the facility of parallel transmission multiple nodes can transmit their data simultaneously without conflicts. It reduces the scheduling length of an algorithm. It is the concept of parallel transmission.

TDMA includes two well-known scheduling methods are node base scheduling and link-base scheduling.

IV.   LITERATURE SURVEY

In last few years data collection in WSNs became more interesting area for research. The existing schemes focus on fair data delivery with minimum delay, low power consumption. The schemes should be scheduled in well-defined manners (e.g TDMA Scheduling, Workload aware Scheduling). Following schemes introduce some scheduling techniques.

A. Proposed Methods For Fair Data Collection
Each node in the network does not generate the data at uniform rate. Some node which generates continuous data may be congested while some node may have light traffic. During the data collection this traffic should be handled fairly to transmit data quickly.

1) *Improved Scheme With Fairness (ISWF):* Occurrence of Congestion affects the throughput of network and also the packet transmission becomes delayed. This results in unfair data collection. An effective congestion detection/control mechanism is required. The goal of fairness is sharing of the channel bandwidth without wastage. In paper [1] some techniques has been described to carry out fairness in data collection. Controlling the transmission rate of congested node reduces the incoming traffic of the congested node and slows down the speed of accumulation into the queue. The aim of increasing the rate of the congested node sending data is to send data of the queue to its parent node quickly, to reduce the queue length. Fairness is achieved on the basis of giving priority according to probability. Probability can be evaluated by getting the size of sub tree of a node. Suppose, SubTree(i) denote the sub tree size of node i, p(l, i)- the probability of node i sending locally generated data, p(r, i) denote the probability of node i forwarding data.
Eqtion:
- $P(l,i)=1/(1+subtree(i))$
- $P(r,i)=1-p(l,i)=1-1/(1+subtree(i))$[1].

AI-LMAC, An Adaptive, Information-centric and Lightweight MAC Protocol [16]**,** AI-LMAC deals with latency and issue of fairness. In this the nodes which are ready to transmit are active and rest of the nodes remains inactive.

2) *Fairness Provisioning Protocol [9]:* This protocol includes the strategies like, *queue management*: *E*ach node maintains two queues for buffering local packet and relayed packets. *Determination of tree–size*, *Determining the minimum contention window size:* Each node determine the required frequency of media access. *Determining the forwarding probability:* Each node determine the required packet selection probability.

3) *Workload Aware MAC (W-MAC) Protocol [7]:* In tree based WSNs, the workload aware mac protocol defines how efficiently the information of workload of the network can be gathered (using control interval scheduling) from each nodes and how fairly the time pool can be assigned to collect the data(with data interval scheduling). These scheduling decreases the power consumption and also supports low latency. It proposes algorithm which works in iterative manner among sub-trees.
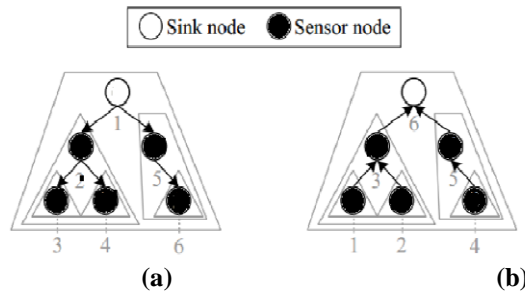

Fig. 2 (a) control interval scheduling (b) data interval scheduling [7]

Figure- Shows the sink node sends control packets to its children to know the total workload of the whole network. After computing overall workload it allocates the time pool to children to transmit the data to their parents. It fairly collects the data from all sub trees. In this algorithm, initially the nodes have the information of total numbers of nodes N. Then each node collects the information about its 2-hop neighbor's id.

B. Various TDMA Scheduling Schemes
The key aspect of TDMA is properly allocation of slot to node to avoid collision which prevents data retransmission. It is also robust to heavy workload and power consumption. A good TDMA scheduling minimizes the number of time slots.
In this paper we describe the TDMA scheduling for tree based WSN. As shown in figure we can allocate time slot to each link. Here, time slot allocation is in BFS manner but we can allocate slots as per different schemes.
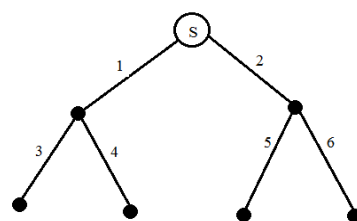

Fig. 3 Unique slot assignment to each link of the tree

In contention-free medium, with MAC protocol, TDMA scheduling can provide good network performance without conflict if it is well designed. Here are some designing objectives to increase lifetime of network.

In paper [8'], TDMA scheduling is performed by graph coloring methods. It describes node-based scheduling and level-based scheduling schemes.

1)   *Node-based and Level-based scheduling [10]:* In node-based scheduling, the scheduling is done based on the coloring of the original network similar to conventional multi-hop scheduling algorithms for simple ad hoc networks. The nodes are colored corresponding to each slot with at least one packet are selected first and other nodes are added afterwards. In Level-based scheduling the original network is first converted into a linear network where each node corresponds to a level in the original network. The scheduling of the actual network is performed by coloring the linear network. This scheduling algorithm schedules a conflict-free nodes associated with each level of the color for the current slot and then schedules additional nodes if possible.

2)   *Congestion-based scheduling :* Vahid Zibakalam has defined in [3], a scheduling algorithm with TDMA, based on congestion rate of nodes. In congestion-based scheduling algorithm, coloring the original network is performed according to congestion degree of the nodes and rest of the scheduling is similar to node-based scheduling or link-based scheduling. First, degree of congestion of each node is computed and compared. The node with highest degree of congestion is prioritized first. The nodes with same degree of congestion are colored with same color and transmit in same time slot. Other nodes are assigned with different color and time slot. It reduces the scheduling length which results in decreasing of overall delay.

3)   *BFS–Time Slot Assignment :* One solution to reduce scheduling length is assigning same time slot to multiple links in such a way that those links can transmit the data simultaneously. Each node assumed to generate data at unique rate (one packet per second). Ozlem Durmaz Incel [6] introduces the BFS - TimeSlotAssignment (allocating time slots in BFS manner) Algorithm for aggregated convergecast). In absence of interference links the slot assignment is done in BFS manner iteratively in each sub tree.

4)   *Local Time Slot Assignment:* This scheme is for continuous row data convergecast. Local Time Slot Assignment [6] (allocating time slots locally according to the requirement computed at each node) for row-data convergecast. Here one important thing to be considered is absence of interference. If the transmission of the data takes place within the interference range they cannot be scheduled within the same slot. Here we have to assume that the nodes which transmit their data simultaneously must be out of interference range of each other's. Here, each node generates constant amount of data. Local time slot allocation can be done by choosing top most sub tree. The sub tree with large number of total data packets (including children nodes) is called top most sub tree and gets first priority to transmit. If the number of packets is same at each node then the algorithm allocates slot to random link.

5)   *Distributed Time Optimal Scheduling [12]:* Convergecast in tree network is described using TDMA. It reduces the tree network into multi-line linear network.

a-b-c-d
a-b-f
a-e-g-h
a-e-f

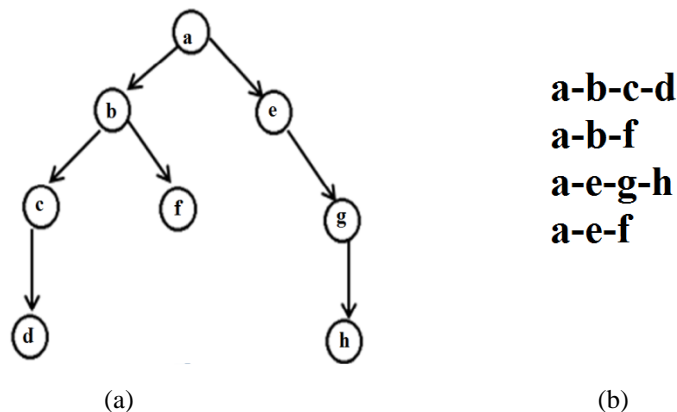(a)   (b)
Fig. 4 (a) Tree Structure (b) Converted to Linear Branches [9]

In above example, the first transmission takes place over the branch a-b-c-d. The data packets generated by node c and d are received at b. Here, there is an assumption that each node generates only one packet. So the total two packets will be forwarded to b. Then branch b-f will be given priority for transmission and the node f will become active. In such manner all other branches will become active as per their turn. It will save energy as only the branch transmitting data will be active and other will be in sleep mode.

6) *Maximize Throughput In Multiple-Source Multiple-Destined WSNs :*The paper [5] describes TDMA-based scheduling for a multiple-source multiple-destination wireless network that operates under the heavy-traffic condition, in which each source always has traffic to transmit. For a given set of sources, each with packets proposed to transmit to a particular single destination. The parallel TDMA transmission schedule that maximizes throughput with low SINR threshold.

V. LITERATURE SURVEY

As described above many research gaps are there which can be filled by extending or combining methods with effective scheduling. A W-MAC protocol can be expanding by applying parallel transmission with TDMA. Thus fair data collection can be done with minimum delay. We can also apply different aggregation techniques on W-MAC protocol.

In TDMA, sometime the slots may remain unused. During that no transmission occurs. These slots should be used fairly which reduces the scheduling length.

In paper [6] [13], time slot assignment schemes are described for constant bit rate (node generates one packet per second). In sensor network all node generates data at variable rate. Some packets generates at very heavy rate while some node generates at very slow rate. So those algorithms can be modified for variable data amount. For that the buffer capacity of each node should be efficiently reused.

VI. CONCLUSIONS

As per my survey there are many issues in data collection relevant to delay and energy consumption. WSN hold a lot of promise in applications where collecting sensing data in remote locations is required. It is a developing field, which offers scope for a lot of research. I also observed various methods proposed for these issues and have given brief introduction of these methods using TDMA Scheduling. The fundamental limitations due to interference explored techniques overcome the same. Once interference is completely eliminated, the achievable schedule length is reduced in the routing tree for aggregated convergecast, and for raw-data convergecast. I will implement these methods for variable data rate applications.

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