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Optimal Converge cast Methods for Tree- Based WSNs

Mahammad Irfan Shaik[1], Sayeed Yasin[2]
[1]M. Tech, Nimra College of Engineering & Technology, Vijayawada, A.P., India.
[2]Asst. Professor, Dept.of CSE, Nimra College of Engineering & Technology, Vijayawada, A.P., India

Abstract: *A tree- based wireless sensor network (WSN) is a collection of sensors nodes, such as sink is the root of tree and leaves are the nodes. Data in such a topology flows from sensor nodes (leaves) to the sink (root) node of the tree. Collection of data from a set of sensors to an intermediate parent (sink) in a tree network is known as converge-casting. The delivery time and the data rate are application specific. As an example, in oil and gas refineries the sensor equipment and controllers need to collect data from all the sensors within a specific deadline for any kind of leakage or failures. Whereas applications like weather forecasting, under-water observations needs continuous and quick data delivery for analysis, for longer periods. In this paper our goal is on such applications focusing on fast data streaming from sensor to sink node. The two optimal approaches for data collection proposed in this paper are – aggregated-data convergecast where packets are aggregated at each hop, and raw-data convergecast where each data packet travel towards sink node individually. First method is most suitable where data is highly co-related and objective is to collect maximum sensor reading and second method is used where the reading of each sensor is equally important.*

Keywords: *Broadcast, Converge cast, Data collection, WSN.*

I. Introduction

Data collection from a set of sensors to a common sink over a tree-based network is a fundamental traffic pattern in wireless sensor networks (WSNs). This many-to-one communication paradigm in which data flows from many nodes to a single node is called as convergecast. One may view convergecast as opposite to multicast or broadcast in which data flows from a single node to a set of nodes in the network. The following figures shows a simple example that illustrates the characteristics of a typical broadcast and convergecast. In a broadcast, as shown in Figure 1, node s is the message source and nodes a, b, and c are expected recipients. Node “a” hears the message directly from s and forwards a copy to nodes b and c. In case of a convergecast, as shown in Figure 2, nodes a, b, and c each has a message destinedto the sink node s, and a serves as a relay for b and c.

Once data is collected at the sink node, it can either be recorded and stored for future analysis, or can be processed immediately to take certain actions depending on application requirements. In a sensor network, data collection can either be triggered by external sources, such as queries to get a snapshot view of the network, or events as and when they appear, or can be for the continuous periodic monitoring without any external triggering. In all cases, however, the many-to-one communication pattern is very common. Depending on application requirements, various objectives can be associated with data collection. For instance, in disaster early warning applications, such as forest fire detection [1] and gas/oil leaks [2], or structural damage identification [3], bursty traffic generated by events needs to be delivered to the sink as quickly and as reliably as possible to prevent catastrophes.

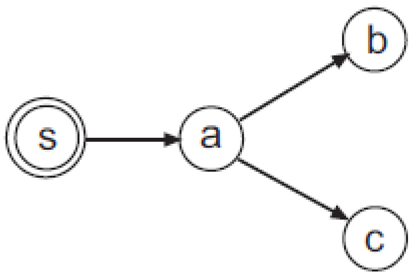

Figure 1: Broadcast

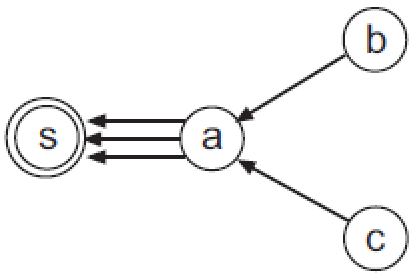

Figure 2: Convergecast

Particularly under regular, heavy traffic conditions, contention-free medium access control (MAC) protocols, such as Time Division Multiple Access (TDMA), where the nodes communicate on different time slots to prevent the conflicts, offer several advantages for data collection as compared to contention-based protocols [4]. They eliminate collisions, idle listening and overhearing, which are the main sources of energy consumption in wireless communications [5].

II. RELATED WORK

In [6], the authors discussed about the hypothetical limits of data collection capacity. Here the wireless sensor network is a TDMA based network. In the past, the data collection capacity is based on very large scale random networks, though most of the sensors are not deployed uniformly and the available sensors will not be as huge as in theory. In [7], the authors discuss about the improvement of communication performance by using multiple channels. The current multi-channel protocols are not suitable for sensor networks due to minimum number of available channels and unavoidable time errors found in such networks. Here a novel tree based multi channel scheme for data collection applications is constructed that allocates disjoint trees and exploits parallel transmissions among trees. In [8], the authors constructed a distributed scheduling algorithm for the tree networks that requires at most $\max(3n_k - 1, N)$ time slots for convergecast, where n_k represents the maximum number of nodes in any sub tree and N represents the number of nodes in network. The Distributed scheduling algorithm requires at most 3N time slots in any sensor network.

In [9], the authors address the problem of performing the operation of Data Aggregation enhanced Convergecast(DAC) in an energy and latency efficient manner. By assuming as all the nodes in the sensor network have a data item and there is an a priori known application dependent data compression factor, the total data is collected. In [10], the authors describes the contention free Time Division Multiple access scheduling based protocols for collecting data using tree based routing topologies. By using TDMA method, the nodes can communicate on different slots to prevent interference and conflicts. Consecutive time slots are grouped into non- overlapping frames. Hence the schedule for each time frame is repeated when data collection is periodic.

III. PROPOSED WORK

A. Periodic Aggregated Convergecast

Data aggregation is a commonly used technique in sensor networks that can eliminate redundancy and minimize the number of transmissions, thus saving energy and improving network lifetime. Aggregation can be performed in many ways, such as by suppressing duplicate messages; using data compression and various packets merging techniques; or taking advantage of the correlation in the sensor readings. Given the lower bound "$\Delta(T)$" on the schedule length in the absence of interfering links, we now present a time slot assignment scheme in Algorithm 1, called BFSTIMESLOTASSIGNMENT, that achieves this bound. In each iteration of the algorithm, an edge *e* is chosen in the Breadth First Search (BFS) order starting from any node, and is assigned the minimum time slot that is different from all its adjacent edges respecting interfering constraints. Note that, since we evaluate the performance of algorithm 1 also for the case when the interfering links are present, we check for the corresponding constraint in line 4; however, when interference is eliminated this check is always redundant. The algorithm 1 runs in $O(|ET|2)$ time and minimizes the schedule length when there are no interfering links. All the interfering links removed, and so the sensor network is scheduled in 3 time slots.

Algorithm 1 BFS-TIMESLOTASSIGNMENT

1. Let T = (V, ET)
2. while ET is not EMPTY do
3. Select edge (e) from ET using Breadth First Search Manner
4. Allocate minimum time slot *t* to the selected edge *e*
5. Move to next edge in ET.
6. end while

B. Raw Data Convergecast

In raw data convergecast, data of each sensor is equally important, therefore aggregation is not desirable. Each packet is individually scheduled to reach the sink node. The problem of minimizing the scheduling length for raw data convergecast is proved to be NP-complete problem. Figure 3, shows a basic tree structure where {s, 1, 4}, {s, 2, 5}, {s, 3, 6} are branches of tree and {1, 4}, {2, 5}, {3, 6} are sub-trees.

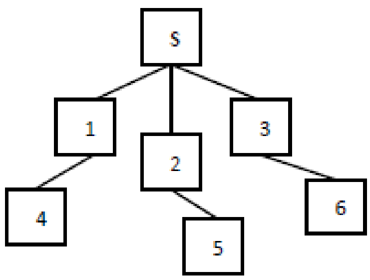

Figure 3: Tree Topology

We can deduce a local time slot allotment algorithm for each sensor node with an objective to schedule parallel transmissions and allow sink to collect data packets continuously. We assume that sink node knows the number of available nodes in each top sub-trees. Each sensor node maintains buffer and state of full or empty if it has data packet available or not. The algorithm for raw data convergecast slot allotment is shown in Algorithm 2.

Algorithm 2 LOCAL-TIMESLOTASSIGNMENT

1. Initialize node[buffer]=FULL
2. Pick a node (N)
3. If (N = Sink) then
Among available sub-tree, select one with largest
number of remaining packets (i).
4. Plan a link (root(i), S)
5. Else IF (N != Sink and node[buffer] = EMPTY)
then
6. Select a child (C) at random whose buffer is full
7. Plan a link (C, node)
8. C[buffer]= EMPTY
9. End If
10 End If

In Algorithm 2, lines 3-4 gives scheduling rules between sink and root node of sub trees. A top subtree is eligible to be elected for transmission if it has at least one packet to be transmitted. If none of the top- subtrees are eligible, the sink node does not receive any packet during that time slot. Inside each top-subtree, sensor nodes are scheduled according to the rules in lines 5-8. We define a subtree to be active if there are still packets left in the subtree that are to be relayed. If a node's buffer is empty and the subtree rooted at this node is active, then we schedule one of its children at random whose buffer is not empty.

IV. CONCLUSION

Wireless Sensor Networks (WSNs) consists of very small sensors. These sensors are wirelessly connected to each other for performing same task collectively such as monitoring weather conditions or specifically parameters like pressure, temperature, sound and vibrations etc. By using time division multiple access, the nodes communicate on different time slots in order to prevent conflicts. In order to improve the data collection, the capacity at each sensor node is adjusted whenever the packet moves from one sensor node to another sensor node. . An optimal convergecast method is proposed for transmitting the packets with minimum cost for long suited nodes.

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