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Novel Approach for Dynamic Data Collection in Tree Based Wireless Sensor Networks

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ABSTRACT
In the wireless sensor networks the energy of the nodes present in the network is limited. Due to the low manufacturing costs of sensor nodes, they can be organized in large numbers and containing more challenges in routing, topology and data management protocols. These challenges are complicated by severe energy constraints and the inherently unreliable nature of wireless communications which have yielded work in increasing network efficiency. Our main objective is to increase the tolerance level and decrease the complexity of the wireless sensor network. In this primarily visualize time scheduling on a single frequency channel with the aim of reducing the number of time slots necessary to entire a convergecast. After we mingle scheduling with communication power control to moderate the effects of interference, and demonstrate that while power control helps in reducing the schedule length under a on its own frequency, forecast transmissions using several frequencies is more capable. We present lower bounds on the schedule length when interference is completely removed, and recommend algorithms that achieve these bounds. We also estimate the performance of different channel assignment methods, the use of multi-frequency scheduling can sufficient to eliminate most of the interference. After that the data collection rate increases by reducing the interference by the topology of the routing tree.

Index Terms: *Convergecast, Data Collection, Degree constrained spanning tree, Hybrid convergecast tree, Minimal Spanning Tree Time Division Multiple Access Scheduling*

I. INTRODUCTION

Wireless sensor networks consist of distributed self-governing sensor nodes which are used in various applications areas such as health, home, military. Each node receives data from surroundings and it will forward the data to its base station. The location of each sensor node is not predetermined and each sensor nodes contains its own self organizing capabilities. The unique feature of sensor nodes is the cooperative effort of sensor nodes. As an unconventional of sending the raw data to the nodes responsible for the synthesis, sensor nodes make use of their processing capabilities to locally carry out simple computations and it will transmit only the required and partially processed data. Sensor nodes are used for continuous sensing, detecting events, event ID, and sensing the location. The sensor nodes are scattered in the sensor network. Each scattered sensor nodes has the ability to collect and route data to the sink.

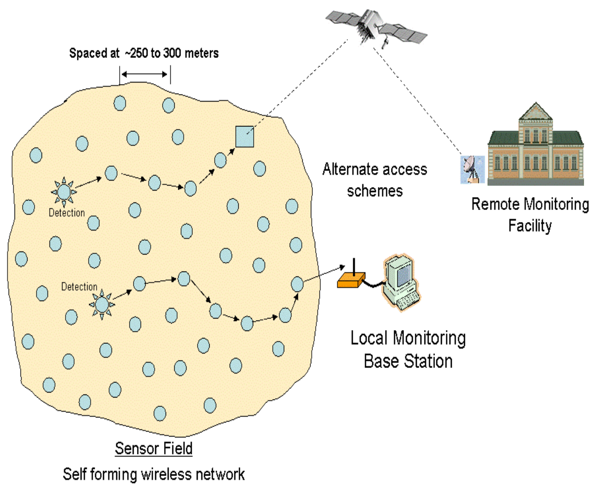


Fig.1: Self forming Wireless Sensor Networks

Convergecast is the collection of data from a set of sensors toward a general sink over a tree based routing topology, is a primary operation in wireless sensor networks. In many applications, it is critical to offer a guarantee on the delivery time as well as increase the rate of such data collection. For example, in security and mission-critical applications where sensor nodes are organized to detect oil/gas leak or structural damage, the actuators and controllers need to take delivery of data from all the sensors within an exact deadline, failure of which might lead to unpredictable and catastrophic events. The other applications such as permafrost monitoring require periodic and fast data delivery over long periods of time, which falls beneath the grouping of permanent data collection. For periodic traffic, it is well known that contention free medium access control (MAC) protocols such as Time Division Multiple Access are better fit for fast data collection, since they can reduce collisions and retransmissions and provide guarantee on the completion time as divergent to contention-based protocols. The problem of building conflict free Time Division Multiple Access schedules even under the simple graph-based interference model has been proved to be NP-complete. In this work, we consider a DMA framework and design polynomial-time heuristics to minimize the schedule length for both types of convergecast. We furthermore find lower bounds on the achievable schedule lengths and compare the performance of our heuristics with these bounds.

In Time Division Multiple Access schedule, time slotted and each slot is long enough to transmit and receive of a single packet. Hence the time slots are grouped as a non – overlapping frames and the schedule for each frame is repeated when the data collection is periodic. The main objective of Time Division Multiple Access design is to minimize schedule length, minimize Latency, minimizing energy consumption, maximizing capacity, maximizing fairness, minimizing communication costs, maximizing the parallel transmission, meeting deadlines, and minimizing interference. A Wireless sensor networks has small or no infrastructure. It contains of a number of sensor nodes which works together to monitor a region and it is used to obtain data about the environment. The Wireless sensor networks are classified into two types such as structured and unstructured. An unstructured WSN contains the dense collection of sensor nodes. The Sensor nodes are deployed in an ad hoc manner into the field. Once deployed, the network is kept unattended to perform monitoring and reporting functions. Hence network maintenance and failure detection is difficult since there are so many nodes. In structured network, all or some of the nodes are deployed in a pre planned manner. Due to small number of nodes network maintenance is easy and management cost is reduced.

II. RELATED WORK

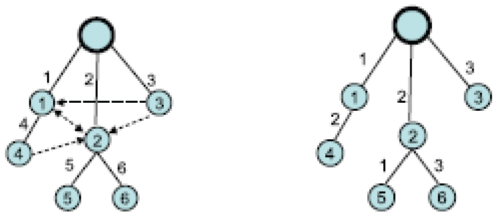
Collecting data is the basic operation in wireless sensor networks. Collecting those data in a well-organized manner is more critical when compared to the performance of sensor networks. Each sensor will measure the values at regular time intervals and it will send that to sink node. The total collection of data is called as snapshot. Here the sensor network is a Time Division Multiple Access based network. In the past, the data collection capacity is based on 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. For this purpose we have to know about the capacity of data collection in a network. The capacity of data collection shows how the sink collects data from sensor nodes quickly by considering its interference conditions. The upper and lower bounds for data collection capacity are constructed based on the protocol interference and disk graph models. A simple BFS tree based method is used to achieve the collection capacity which matches the upper bound.

In sensor networks the packets generated by each and every node have to reach the sink. This many – to –one communication is known as convergecast. A Time Division Multiple Access schedule is used which minimizes the total time required to complete the convergecast. A simple version of problem is considered where every node generates exactly one packet. Yiin Zhang constructed a distributed scheduling algorithm for the tree networks that requires at most max(3nk – 1,N) time slots for convergecast, where nk corresponds to 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 network. The proposed simulation shows that the number of time slots required is about 1.5 N. Two bounds are required for the packets to be buffered at the node during convergecast. Sleep schedules for nodes are considered for conserve energy. It reduces the energy consumption by at least 50% Breadth first search tree is considered for convergecast scheduling. The problem of minimizing the schedule length for raw-data convergecast on single channel is shown to be NP-complete on general graphs. Maximizing the throughput of convergecast by finding a shortest-length, conflict-free schedule is studied, where a greedy graph coloring strategy assigns time slots to the senders and prevents interference and also discussed the impact of routing trees on the schedule length and proposed a routing scheme called *disjoint strips* to transmit data over different shortest paths. Though the sink remains as the restricted access, sending data over different paths does not reduce the schedule length. The improvement due to the routing structure comes from using capacitated minimal spanning trees for raw-data convergecast, where the number of nodes in a sub tree is no additional than half the total number of nodes in the remaining sub trees.

III. TDMA SCHEDULING OF CONVERGECASTS

3.1 Periodic Aggregated Convergecast

In this consider the scheduling problem where packets are aggregated. Data aggregation is a frequently used technique in Wireless Sensor Networks that can eliminate redundancy and minimize the number of transmissions, thus reduction energy and humanizing network lifetime. Aggregation can be achieved in a lot of ways, such as by restraining carbon copy messages; using data compression and packet merging techniques; or taking advantage of the correlation in the sensor readings. We reflect on continuous monitoring applications where perfect aggregation is possible and each node is capable of aggregating all the packets received from its children in addition to that produced by itself into a single packet before transmitting to its parent. The amount of aggregated data transmitted by each node is constant and does not depend on the size of the raw sensor readings. Usual examples of such aggregation functions are MIN, MEDIAN, MAX, AVERAGE, COUNT, etc.



(a) (c)

	Frame 1						Frame 2					
	S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
s	1	2	3	-	-	-	{1,4}	{2,5,6}	3	-	-	-
1	-	-	-	4	-	-	-	-	-	4	-	-
2	-	-	-	-	5	6	-	-	-	-	5	6

(b)

Fig.2: Aggregated convergecast and pipelining:

(a) Schedule length of 6 in the presence of interfering links.
(b) Node ids from which (aggregated) packets are received by their corresponding parents in each time slot over different frames.
(c) Schedule length of 3 using BFSTIMESLOTASSIGNMENT when all the interfering links are eliminated.

In above Fig. 1(a) and 1(b), illustrates the notion of pipelining in aggregated convergecast and that of a schedule length on a network of 6 source nodes. The hard lines correspond to tree edges, and the scattered lines represent interfere links. The numbers nearby the links correspond to the time slots at which the links are programmed to broadcast, and the numbers within the circles represent node ids. The accesses in the table list the nodes from which packets are received by their corresponding receivers in each time slot. We note that at the last part of frame 1, the sink does not contain packets from nodes 5 and 6; however, as the schedule is repeated, it accepts aggregated packets from 2, 5, and 6 in slot 2 of the next frame. In the same way, the sink also receives aggregated packets from nodes 1 and 4 opening from slot 1 of frame 2. The entries *{*1, 4*}* and *{*2, 5, 6*}* in the table represent single packets including aggregated data from nodes 1 and 4, and from nodes 2, 5, and 6, correspondingly. Thus, a pipeline is recognized from frame 2, and the sink goes on to receive aggregated packets from *all* the nodes once every 6 time slots. Thus, the minimum schedule length is 6.

3.2. Assignment of Timeslots

In every iteration of BFS-TIMESLOT ASSIGNMENT (lines 2-6), an edge *e* is chosen in the Breadth First Search (BFS) order starting from any node, in addition to is allocated the minimum time slot that is different from all its adjacent edges respecting intrusive restrictions. Note that, since we calculate the performance of this algorithm also for the case when the interfering links are present, we make sure for the corresponding constraint in line 4; on the other hand, when interference is removed this check is redundant. The algorithm runs in $O(|E_T|^2)$ time and minimizes the schedule length when there are no intrusive links and demonstrate the same network of 1(a) in 1(c) with all the interfering links removed, and so the network is scheduled in 3 time slots.

Algorithm 1 BFS-TIMESLOTASSIGNMENT

1. Input: $T = (V, E_T)$
2. **while** $E_T \neq \phi$ **do**
3. $e \leftarrow$ next edge from E_T in BFS order
4. Assign minimum time slot t to edge e respecting adjacency and interfering constraints
5. $E_T \leftarrow E_T \setminus \{e\}$
6. **end while**

IV. MULTI-CHANNEL SCHEDULING

Multi-channel communication is an efficient method to eliminate interference by enabling concurrent transmissions over different frequencies. Although typical Wireless Sensor Networks radios operate on a limited bandwidth, their working frequencies can be in the swing of things, thus allowing more simultaneous transmissions and faster data delivery. At this time, we think about fixed-bandwidth channels, which are typical of Wireless Sensor Networks radios, as opposed to the possibility of improving link bandwidth by consolidating frequencies. We explain three channel assignment methods that consider the problem at different levels allowing us to study their pros and cons for both types of convergecast. These methods regard as the channel assignment problem at different levels: the link level (JFTSS), node level (RBCA), or cluster level (TMCP).

4.1 Joint Frequency Time Slot Scheduling (JFTSS)

Joint Frequency Time Slot Scheduling presents a greedy combined solution for constructing a maximal schedule, such that a schedule is called to be maximal if it meets the adjacency and inquisitive constraints, and no more links can be scheduled for synchronized transmissions on any time slot and channel exclusive of breaching the constraints. Joint Frequency Time Slot Scheduling schedules a network starting from the link that has the highest number of packets (load) to be transmitted. While the connection loads are equal, while in aggregated convergecast, the most inhibited ink is measured first, i.e., the link for which the number of other links breaching the interfering and adjacency restriction when scheduled at the same time is the highest. The algorithm starts with an empty schedule and first sorts the links according to the loads or constraints. The mainly loaded or unnatural link in the first accessible slot-channel pair is scheduled first and added to the schedule. All the links that have an adjacency restriction with the programmed link are expelled from the list of the links to be scheduled at a given slot. The links with the purpose of do not have an interfering restriction with the scheduled link can be programmed in the same slot and channel while the links that have an inquisitive constraint should be scheduled on dissimilar channels, if achievable. The algorithm continues to schedule the links according to the most loaded (or most constrained) metric.

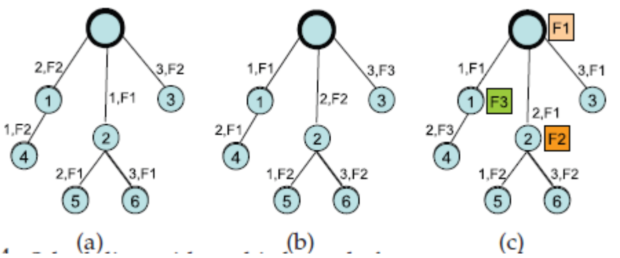


Fig.3: Scheduling with multi-channels for aggregated convergecast:

(a) Schedule generated with JFTSS. (b) Schedule generated with TMCP. (c) Schedule generated with RBCA. (b) Schedule generated with RBCA.

4.2 Tree-Based Multi-Channel Protocol (TMCP)

Tree-Based Multi-Channel Protocol is a greedy, tree-based, multi-channel protocol for data collection applications. It separation the network into several sub trees and minimizes the intra tree interference by assigning dissimilar channels to the nodes residing on unlike branches starting from the top to the bottom of the tree. The nodes on the leftmost branch is allocated frequency $F1$, subsequent branch is allocated frequency $F2$ and the last branch is allocated frequency $F3$ and after the channel assignments, time slots are allocated to the nodes with the BFSTimeSlot Assignment algorithm. The advantage of TMCP is that it is designed to support convergecast traffic and does not require channel switching. Though, disputation inside the branches is not determined since all the nodes on the same branch communicate on the same channel.

4.3. Receiver-Based Channel Assignment (RBCA)

In Receiver-Based Channel Assignment, the children of a common parent transmit on the same channel. Each node in the tree, consequently, operates on at most two channels, therefore avoiding pair-wise, per-packet, channel negotiation expenses. The algorithm initially assigns the same channel to all the receivers. Then, for each receiver, it creates a set of interfering parents based on SINR thresholds and iteratively assigns the next available channel starting from the most interfered parent (the parent with the highest number of interfering links). However, due to adjacent channel overlaps, SINR values at the receivers may not always be high enough to tolerate interference, in which case the channels are assigned according to the ability of the transceivers to reject interference. We proved approximation factors for Receiver-Based Channel Assignment when used with greedy scheduling in. Initially all nodes are on frequency F1. Receiver-Based Channel Assignment starts with the most interfered parent, node 2 in this example, and assigns F2. Then it continues to assign F3 to node 3 as the second most interfered parent. Since all interfering parents are assigned different frequencies sink can receive on F1.

V. EVALUATION

We deploy nodes randomly in a region whose dimensions are varied between 20 × 20 m^2 and 300 × 300 m^2 to simulate different levels of density. The number of nodes is kept fixed at 100. For different parameters, we average each point over 1000 runs. We use an exponential path-loss model for signal propagation with the path-loss exponent α varying between 3 and 4, which is typical for indoor environments. We also use the physical interference model and simulate the behavior of CC2420 radios that are used on Telosb and TmoteSky motes and are capable of operating on 16 different frequencies. The transmission power can be adjusted between −24 dBm and 0 dBm over 8 different levels, and the SINR threshold is set to β = −3 dB1. We first evaluate the schedule length for single-channel TDMA, and then its improvement using transmission power control, multiple channels, and routing trees.

5.1. Aggregated Convergecast

It shows the variation of schedule length with density for different values of α on minimum-hop tree. We observe that the schedule length decreases as the deployment gets sparser. This happens because at low densities the interference is less, and so more concurrent transmissions can take place. In the densest deployment (L = 20) when all the nodes are within the range of each other, the sink is the only parent, and the network is scheduled in 99 time slots regardless of power control. However, in sparser scenarios, using power control the network can be scheduled with fewer time slots as the level of interference goes down. We achieve a 10 − 20% reduction in schedule length for the best case.

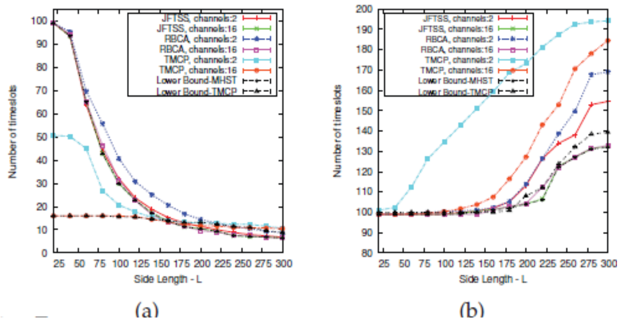


Fig.4: Scheduling on minimum-hop trees with multiple channels: (a) Aggregated convergecast. (b) Raw-data convergecast.

5.2. *Raw Data Convergecast*

It shows the variation of schedule length on CMST. The impact of such routing trees is more prominent in sparser networks ($L \geq 200$) than routing over minimum-hop spanning trees. When $L < 200$, the length is bounded by N. Beyond this point, it is almost always not possible to construct trees where the constraint $2nk-1 < N$ holds. In such cases, the schedule length is some degree of by $2nk - 1$.

VI. CONCLUSION

Wireless sensor networks can be used in various applications areas. A sensor networks consists of large number of nodes and the location of each sensor nodes is predetermined. By using TDMA, the nodes communicate on different time slots in order to prevent conflicts. In order to improve the data collection the capacity at each node is adjusted whenever the packet moves from one sensor node to another sensor node. . A hybrid convergecast tree is projected for transmitting the packets with minimum cost for long suited nodes. Fast convergecast in Wireless Sensor Networks where nodes communicate using a TDMA protocol minimize the schedule length. We deal with the fundamental limitations due to interference and half-duplex transceivers on the nodes and explored techniques to overcome the same. We set up that while transmission power control helps in reducing the schedule length, multiple channels are more effective and also observed that node-based (RBCA) and link-based (JFTSS) channel assignment schemes are more efficient in terms of eliminating interference as compared to assigning different channels on different branches of the tree (TMCP).

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