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High-Speed Pool of Aggregated Data in Multi-hop Wireless Network

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Abstract

Data aggregation is a key functionality in wireless sensor networks (WSNs). Focuses on data aggregation scheduling problem to minimize the delay (or latency). The project proposes an efficient distributed algorithm that produces a collision-free schedule for data aggregation in WSNs. The project proves that the delay of the aggregation schedule generated by the algorithm is at most 16R + Δ -14 time slots. Here, R is the network radius and Δ is the maximum node degree in the communication graph of the original network. The algorithm significantly improves the previously known best data aggregation algorithm with an upper bound of delay of 24D + 6Δ+ 16 time slots, where D is the network diameter (note that D can be as large as 2R). Extensive simulations are conducted to study the practical performances of the proposed data aggregation algorithm. The simulation results corroborate the theoretical results and show that the algorithms perform better in practice. The two converge cast mechanism named Aggregate converge cast and One-Shot Raw-Data converge cast algorithms are implemented. The minimum slot length is calculated and shown the edges in the tree that are communicated in the respective time slots.

Keywords: Convergecast, Wireless Sensor Network, Data Aggregation.

Introduction

A wireless sensor network (WSN) is a collection of large number of sensor node that are deployed in particular region. Wireless Sensor Network are used to provide a wireless communication infrastructure among the sensor deployed in a specific application domain. The military applications was originally motivated by wireless sensor network. However, wireless sensor networks are now used in many area of application like civilian application, and also environment, habitat and healthcare monitoring applications, home automation, and traffic control. Two types of Communication paradigms in WSN i.e., Convergecast and Broadcast, where Convergecast means collect information from all nodes towards central node. Broadcast means scattering of information from a central node. Convergecast is crucial to provide a guarantee on the delivery time as well as increase the rate of such data collection. Two fundamental types of data collection in Convergecast are identified: (i) *raw-data* convergecast, where every packet is relayed individually, and (ii) *aggregated* convergecast, where packets are collected together at each hop before being relayed. These two types correspond to two extreme cases of data collection in sensor networks.Data collection can be periodic or one-shot. One-shot data collection is typically query-based that provides a snapshot of the monitored conditions, or event-based where nodes report data if an event of interest occurs.

In WSN, saving the battery power is most important issue, by which we can increase the lifetime of the network. Sensor nodes are assumed to be dead when they are out of battery. Another issue is fast and efficient query response, so that every change in the environment can be detected immediately. On the bases of above characteristics, the proposed TDMA protocol must be energy efficient by reducing the potential energy wastes and send the senses data to the sink without delay. TDMA protocols reduce the retransmission of data because collision does not occur in TDMA protocol. The types of communication patterns that are observed in sensor network applications should be investigated, since these patterns resolves the behavior of the sensor network traffic that has to be handled by TDMA protocol. There are two common approaches to model interference: (i) protocol model,

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and (ii) physical model, also known as the SINR model. The protocol model states that a message is correctly received if there is no other sender transmitting at the same time within a close proximity of the intended receiver. The physical model is richer in the sense that it can the capture cumulative interference from multiple concurrent transmissions, and considers a message to be received successfully if the SINR at the receiver is greater than a certain threshold. Tree-based routing topologies are most common in many to- one communication, however, line, star, or dynamic routing topologies have also been considered. Many of the works undertake a fixed topology while some others consider dynamic routing, where the next-hop forwarding node is selected based on some criteria, such as level of the battery or reliability.

Related Work

In [3] the author discussed that, Most sensor applications involve both convergecasting and broadcasting. The time taken to end either of them has to be kept minimal. This can be fulfilled by constructing an efficient tree for both broadcasting as well as converge-casting and allocating wireless communication channels to ensure collision-free data collection. There exist various works on broadcasting in multi-hop radio networks which can also be used for broadcasting in WSNs. These algorithms create a broadcast tree and compute a schedule for transmitting and receiving for each node to achieve collision-free broadcasting. In this paper we show that we introduce a new algorithm for applications which involve both convergecasting and broadcasting since the broadcast tree may not be efficient for convergecasting. So they proposed a heuristic algorithm (Convergecasting Tree Construction and Channel Allocation Algorithm (CTCCAA)) which constructs a tree with schedules assigned to nodes for collision free convergecasting. The algorithm is competent of code allocation (Direct Sequence Spread Spectrum (DSSS)/ Frequency Hopping Spread Spectrum (FHSS)), in case multiple codes are available, to reduce the total duration required for convergecasting. They also showed that the same tree can be used for broadcasting and is as efficient as a tree exclusively constructed for broadcasting.

In [5] the author discussed that, Data aggregation is an essential operation in wireless sensor network applications. The paper focuses on the data aggregation scheduling problem. Supported on maximal independent sets, a distributed algorithm to create a collision-free schedule for data aggregation in wireless sensor networks is nominated. The time latency of the aggregation schedule generated by the proposed algorithm is minimized using a greedy strategy. The latency boundary of the schedule is 24D +6Δ+16, where D is the network diameter and Δ is the maximum node degree. The preceding data aggregation algorithm with least latency has the latency bound (Δ− 1)R, where R is the network radius. Thus in their algorithm Δ contributes to an additive factor instead of a multiplicative factor, which is a significantly make better. To the best of their knowledge, the proposed algorithm is the first distributed algorithm for data aggregation scheduling. This paper proposed an adaptive strategy for updating the schedule when nodes fail or new nodes join in a network. The analysis results show that the proposed algorithm outperforms other aggregation scheduling algorithms.

TDMA Scheduling

Efficient TDMA protocol is designed for wireless sensor network the following attributes must be considered. Firstly, TDMA protocol should be energy conserving protocol, because energy is a limited resource in wireless sensor network. Secondly, another attribute of wireless sensor network is scalability and adaptability to change. If any change in size of network, density of node, and topology, should be maintained effectively by protocols. Fast and capable for query response is another essential attribute for network performance in wireless sensor networks. Co-channel interference is also a problem, hence interference should be minimized where ever possible. There are other attributes such as latency, throughput, and bandwidth utilization which may be considered secondary for application of sensor networks.

Continuous Aggregated Convergecast

An important factor of sensor network is data fusion/aggregation, whereby the senor node aggregate the local information before relaying. The main goal of data aggregation are to reduce bandwidth usage, media access delay, and power consumption for communication. Data aggregation is a process of aggregating the sensor data using aggregation approaches. The size of aggregated data transmitted by each node is constant and does not depend on the size of the raw sensor readings.

Given the lower bound "Δ(*T*)" on the schedule length in the absence of intervence links, we now present a time slot assignment scheme in Algorithm 1,called BFS TIME SLOT ASSIGNMENT, that achieves this bound. The algorithm runs in O(│ET│^{2}) time and

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minimizes the schedule length when there are no interfering links.

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

With BFS, each node gets continuity time slots, which is advantageous if the energy costs to switch a radio from active to sleep and vice versa are large, since it minimizes such transitions at each node. BFS has also been used for more tightly "packed" channel assignment for a data-gathering tree in a scenario where interference constraints are taken into account to provide spatial reuse. In this slot-allocation scheme, each node performs slots assignment sequentially. At each node's turn, it chooses time slots from the earliest possible slot number for its children. Local message exchanges ensure that the slot does not interfere with any already assigned to nodes within two hops of the child. The number of slots to be assigned to each node is pre-determined based on an earlier max–min fair bandwidth allocation phase.

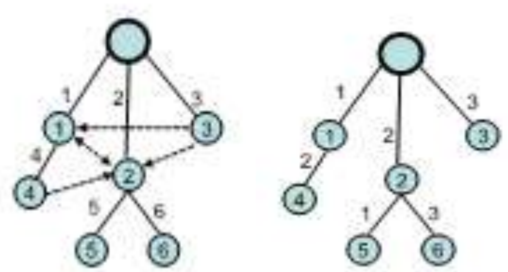

Figure 1 Aggregated convergecast a) Schedule length of 6 in the presence of interfering links. b) Schedule length of 3 using BFS

One-Shot Raw-Data Convergecast

For raw-data convergecast, finding a minimum-length, collision free assignment of time slots, such that every packet generated by a node reaches the sink, is fundamental to efficient network operations. In applications where sensor node are deployed to detect structural damage, failure of which might be unpredictable and catastrophic events. Raw-data convergecast in the context of one-shot data.

The key idea behind this algorithm, which is formally presented in Algorithm 2 as LOCAL TIMESLOTASSIGNMENT, is to: (i) scheduling for transmissions in parallel along multiple branches of the tree, and (ii) keep the sink busy in receiving packets for as many time slots as possible. Each node hold a buffer and its affiliated state, which can be either *full* or *empty* depending on whether it contains a packet or not. Initially, all the buffers are filled completely because every node has a packet to send.

Algorithm 2 LOCAL-TIME SLOT ASSIGNMENT

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 Plan a link (C, node)
7. C[buffer]= EMPTY
8. End If
9. End If

We can deduce a local time slot allotment algorithm for each sensor node with an objective to schedule parallel transmissions and continuously allow sink to collect data packet. We assume that sink node knows the number of available nodes in each top sub-trees. Each sensor node holds 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. 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 suitable, the sink node does not receive any packet during that time slot. Within each top-subtree, sensor nodes are scheduled according to the rules in lines 5-8. We mark out a subtree to be active if there are still packets left in the subtree that are ready to send relay. If a node's buffer is empty and the subtree rooted at this node is performed, then we schedule one of its children at random whose buffer is not empty.

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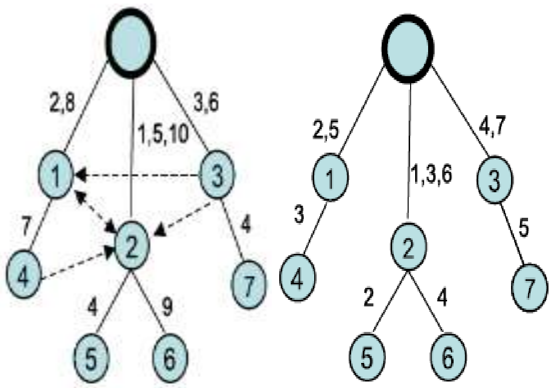

a) b)

Figure 2. Raw-Data Convergecast a) Schedule length of 10 when the interfering links are present. b) Schedule length of 7 when all the interfering links are removed.

Routing Tree

Tree-based routing topologies are most common in many to- one communication, however, line, star, or dynamic routing topologies have also been considered. Many of the works undertake a fixed topology while some others consider dynamic routing, where the next-hop forwarding node is selected based on some condition, such as level of battery or reliability. We describe schemes to construct topologies with specific properties that help to reduce the schedule length. The network topology and the degree of connectivity also affect the scheduling performance.

Aggregated Data Collection

We first construct balanced trees and compare their performance with unbalanced trees. We notice that in both cases, the sink often orginates a high-degree bottleneck. To overcome this, then propose a heuristic (i.e.,) Degree-Constrained tree by modifying Dijkstra's shortest path algorithm.

Algorithm 3. DEGREE-CONSTRAINED TREES

1. Input(V,E),s,max_degree
2. T ← {s}
3. for all i ∈ V do
4. C(i) ← 0; HC(i) ← ∞
5. end for
6. HC(s) ← 0
7. while $|T| \neq |V|$ do
8. Choose i' ₵ T such that
9. (a) (i,i') ∈ E, for some i ∈ T with C(i) < max_degree – 1
10. (b) HC(i') is minimized
11. T ← T ∪ {i'}
12. HC(i') = HC(i) + 1
13. C(i) ← C(i) +1
14. if ∀i ∈ V, C(i) = max_degree then
15. break
16. end if
17. end while

To illustrate the gains of degree-constrained trees, taking into account the case when all the N nodes are in range of each other and that of the sink. If the nodes choose their parents with respect to minimum hop without a degree constraint, then all of them will choose the sink, and this will make a schedule length of N. However, if we restrict the number of children per node to 2, then this will follow in two subtrees rooted at the sink, and if there are enough frequencies to mitigate the interference, the network can be maintained using only two time slots, thus accomplishing a factor of N/2 reduction in the schedule length.

Raw-Data Collection

Routing tree that allow more parallel transmission do not necessarily result in small schedule lengths. For instance, the schedule length is N for a network connected as a topology, whereas it is (2N-1) for a line topology once interference is eliminated. The routing tree should be constructed such that all the branches have a balanced number of nodes and the constraint $n_k < (N+1)/2$ holds. A balanced tree satisfying the above constraint is a variant of a capacitated minimal spanning tree. CMST is to
determine a minimum-hop spanning tree in a vertex weighted graph such that the weight of every subtree linked to the root does not exceed a given capacity. In this case, the weight of each link is 1, and the prescribed capacity is (N + 1)/2. Here, we propose a heuristic, as described in Algorithm 4, based on the greedy scheme, which solves a variant of the CMST problem by searching for routing trees with an equal number of nodes on each branch. We make more scheme with a new set of rules and grow the tree hop by hop outward from the sink. We consider that the nodes know their minimum-hop counts to sink.

Algorithm 4. CAPACITATED-MINIMAL SPANNING TREE

1. Input: G(V ;E), s
2. Initialize:
3. B← roots of top subtrees // the branches
4. T ←{s} Ụ B
5. ¥ i € V , GS(i) ← unconnected neighbors of i at further hops
6. ¥b € B, W(b) ←1
7. h ←2
8. while h ≠ max hop count do
9. N_h ← unconnected nodes at hop distance h
10. Connect nodes N'_h that have a single potential

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parent: T← T Ụ N'$_h$
11. Update N_h ←N_h \ N'$_h$
12. Sort N_h in non-increasing order of
13. for all i € N_h do
14. for all b € B to which i can connect do
15. Construct SS(i, b)
16. end for
17. Connect i to b for which W(b) + │SS(i,b) │is minimum
18. Update GS(i) and W(b)
19. T ←T Ụ{i}Ụ SS(i,b)
20. end for
21. h ←h + 1
22. end while

Conclusion

Data aggregation is critical to the network performance in WSNs and aggregation scheduling is a feasible way of improving the quality. The problem of distributed aggregation scheduling in WSNs has been studied and propose a distributed scheduling method. In addition to that, fast converge cast is studied in WSN where nodes communicate using a TDMA protocol to minimize the schedule length. The fundamental limitations due to interference has been addressed and half-duplex transceivers on the nodes and explored techniques to overcome the same. It has been found that while transmission power control helps in reducing the schedule length, multiple channels are more flexible.

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