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Fast Data Collection in Tree-Based Wireless Sensor Networks

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ABSTRACT

The below work is done to address the things like *how fast can information be collected from a wireless sensor network organized as tree* using realistic simulation models under the many-to-one communication paradigm known as *converge cast.* We first consider time scheduling on a single frequency channel with the aim of minimizing the number of time slots required to complete a converge cast. Next, we combine scheduling with transmission power control to mitigate the effects of interference, and show that while power control helps in reducing the schedule length under a single frequency, scheduling transmissions using multiple frequencies is more efficient. To this end, we construct degree-constrained spanning trees and capacitated minimal spanning trees, and show significant improvement in scheduling performance over different deployment densities. Lastly, we evaluate the impact of different interference and channel models on the schedule length.

Keywords**:** Convergecast, TDMA scheduling, multiple channels, power-control, routing trees

1. INTRODUCTION

The collection of data from a set of sensors toward a common sink over a tree based routing topology, is a fundamental operation in wireless sensor networks (WSN). In many applications, it is crucial to provide a guarantee on the delivery time as well as increase the rate

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of such data collection. For instance, in safety and mission-critical applications where sensor nodes are deployed to detect oil/gas leak or structural damage, the actuators and controllers need to receive data from all the sensors within a specific deadline, failure of which might lead to unpredictable and catastrophic events. This falls under the category of one-shot data collection. On the other hand, applications such as permafrost monitoring require periodic and fast data delivery over long periods of time, which falls under the category of continuous data collection. In this work, we consider such applications and focus on the following fundamental question: "How fast can data are streamed from a set of sensors to a sink over a tree based topology?"

We study two types of data collection: (i) aggregated converge cast where packets are aggregated at each hop, and (ii) raw-data converge cast where packets are individually relayed toward the sink. Aggregated con-verge cast is applicable when a strong spatial correlation exists in the data, or the goal is to collect summarized information such as the maximum sensor reading. Raw data converge cast, on the other hand, is applicable when every sensor reading is equally important, or the correlation is minimal. We study aggregated converge cast in the context of continuous data collection, and raw data converge cast for one-shot data collection.

These two types correspond to two extreme cases of data collection. In an earlier work, the problem of applying different aggregation factors, i.e., data compression factors, was studied, and the latency of data collection was shown to be within the performance bounds of the two extreme cases of no data compression and full data compression. For periodic traffic, it is well known that contention free medium access control (MAC) protocols such as TDMA (Time Division Multiple Access) are better fit for fast data collection, since they can eliminate collisions and retransmissions and provide guarantee on the completion time as opposed to contention-based protocols [1]. However, the problem of constructing conflict free TDMA schedules even under the Simple graph-based interference model has been proved to be NP-complete. In this work, we consider a TDMA framework and design polynomial-time heuristics to minimize the schedule length for both types of converge cast. We also find lower bounds on the achievable schedule lengths and compare the performance of our heuristics with these bounds.

2. LITERATURE SURVEY

It is the most important step in software development process. Before developing the tool it is necessary to determine the time factor, economy n company strength. Once these things r satisfied, ten next step is to determine which operating system and language can be used for developing the tool. Once the programmers start building the tool the programmers need lot of external support. This support can be obtained from senior programmers, from book or from websites. Before building the system the above consideration r taken into account for developing the proposed system.

The use of orthogonal codes to eliminate interference has been studied by Annamalai *et al.* [10], where nodes are assigned time slots from the bottom of the tree to the top such that a parent node does not transmit before it receives all the packets from its children. This problem and the one addressed by Chen *et al.* [11] are for one-shot raw-data converge cast. In this work, since we construct degree-constrained routing topologies to enhance the data collection rate, it may not always lead to schedules that have low latency, because the number of hops in a tree goes up as its degree goes down. Therefore, if minimizing latency is also a requirement, then further optimization, such as constructing bounded-degree, bounded-diameter trees, is needed. A study along this line with the objective to minimize the maximum latency is presented by Pan and Tseng [15], where they assign a beacon period to each node in a Zigbee network during which it can receive data from all its children. For raw-data convergecast, Song *et al.* [12] presented a time-optimal, energy-efficient, packet scheduling algorithm with periodic traffic from all the nodes to the sink. Once interference is eliminated, their algorithm achieves the bound that we present here, however, they briefly mention a 3-coloring channel assignment scheme, and it is not clear whether the channels are frequencies, codes, or any other method to eliminate interference. Moreover, they assume a simple interference model where each node has a circular transmission range and cumulative interference from concurrent multiple senders is avoided.

Different from their work, we consider multiple *frequencies* and evaluate the performance of three different channel assignment methods together with evaluating the effects of transmission power control using realistic interference and channel models, i.e., physical interference model and overlapping channels and considering the impact of routing topologies. Song *et al.* [12] extended their work and proposed a TDMA based MAC protocol for high data rate WSNs in [16-28].

TreeMAC considers the differences in load at different levels of a routing tree and assigns time slots according to the depth, i.e. the hop count, of the nodes on the routing tree, such that nodes closer to the sink are assigned more slots than their children in order to mitigate congestion. However, TreeMAC operates on a single channel and achieves 1/3 of the maximum throughput similar to the bounds presented by Gandham *et al.* [1] since the sink can receive every 3 time slots.

3. FEASIBILITY STUDY

The feasibility of the project is analyzed in this phase and business proposal is put forth with a very general plan for the project and some cost estimates. During system analysis the feasibility study of the proposed system is to be carried out. This is to ensure that the proposed system is not a burden to the company. For feasibility analysis, some understanding of the major requirements for the system is essential. Three key considerations involved in the feasibility analysis are:

- ECONOMICAL FEASIBILITY
- TECHNICAL FEASIBILITY
- SOCIAL FEASIBILITY

ECONOMICAL FEASIBILITY

This study is carried out to check the economic impact that the system will have on the organization. The amount of fund that the company can pour into the research and development of the system is limited. The expenditures must be justified. Thus the developed system as well within the budget and this was achieved because most of the technologies used are freely available. Only the customized products had to be purchased.

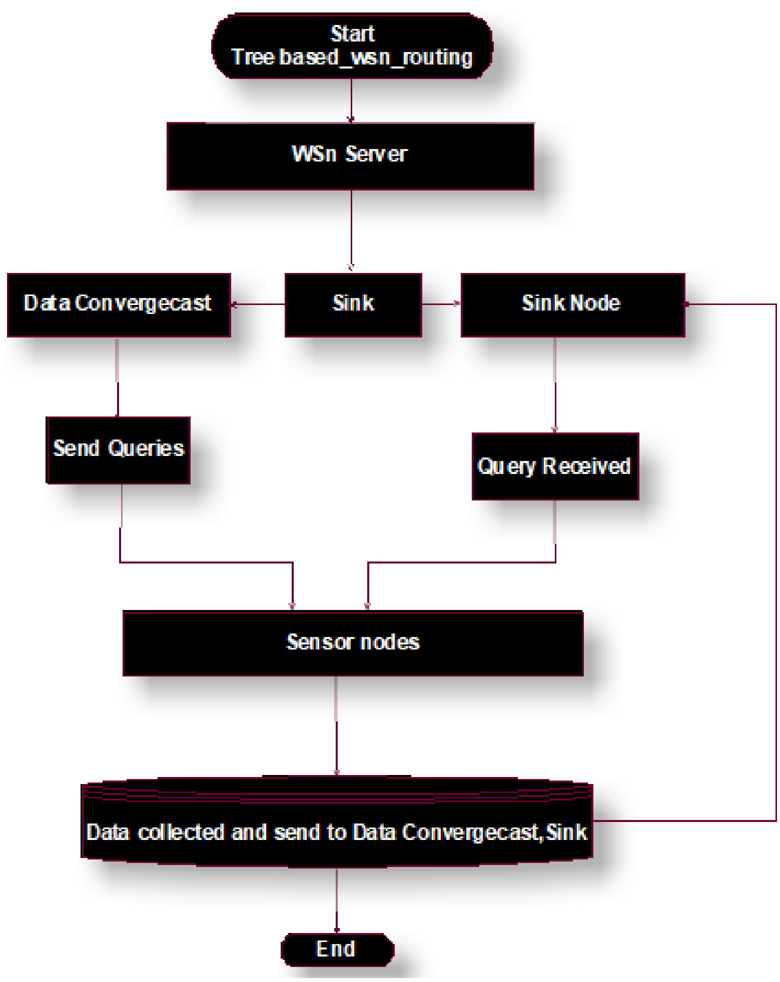
TECHNICAL FEASIBILITY

This study is carried out to check the technical feasibility, that is, the technical requirements of the system. Any system developed must not have a high demand on the available technical resources. This will lead to high demands on the available technical resources. This will lead to high demands being placed on the client. The developed system must have a modest requirement, as only minimal or null changes are required for implementing this system.

SOCIAL FEASIBILITY

The aspect of study is to check the level of acceptance of the system by the user. This includes the process of training the user to use the system efficiently. The user must not feel threatened by the system, instead must accept it as a necessity. The level of acceptance by the users solely depends on the methods that are employed to educate the user about the system and to make him familiar with it. His level of confidence must be raised so that he is also able to make some constructive criticism, which is welcomed, as he is the final user of the system.

4. DESIGN METHODOLOGY



5. SYSTEM ANALYSIS

Existing work had the objective of minimizing the completion time of converge casts. However, none of the previous work discussed the effect of multi-channel scheduling together with the comparisons of different channel assignment techniques and the impact of routing trees and none considered the problems of aggregated and raw converge cast, which represents two extreme cases of data collection. Fast data collection with the goal to minimize the schedule length for aggregated converge cast has been studied by us in, and also by others in, we experimentally investigated the impact of transmission power control and multiple frequency channels on the schedule length. Our present work is different from the above in that we evaluate transmission power control under realistic settings and compute lower bounds on the schedule length for tree networks with algorithms to achieve these bounds. We also compare the efficiency of different channel assignment methods and interference models, and propose schemes for constructing specific routing tree topologies that enhance the data collection rate for both aggregated and raw-data converge cast.

6. CONDUCTION

Implementation is the stage of the project when the theoretical design is turned out into a working system. Thus it can be considered to be the most critical stage in achieving a successful new system and in giving the user, confidence that the new system will work and be effective. The implementation stage involves careful planning, investigation of the existing system and it's constraints on implementation, designing of methods to achieve changeover and evaluation of changeover methods.

1. Periodic Aggregated Converge cast
2. Transmission Power Control
3. Aggregated Data Collection
4. Raw Data Collection
5. Tree-Based Multi-Channel Protocol (TMCP)
6. Periodic Aggregated Converge cast.

Data aggregation is a commonly used technique in WSN 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 packet merging techniques; or taking advantage of the correlation in the sensor readings. We consider continuous monitoring applications where perfect aggregation is possible, i.e., each node is capable of aggregating all the packets received from its children as well as that generated by itself into a single packet before transmitting to its parent. The size of aggregated data transmitted by each node is constant and does not depend on the size of the raw sensor readings.

Transmission Power Control

We evaluate the impact of transmission power control, multiple channels, and routing trees on the scheduling performance for both aggregated and raw-data converge cast. Although the techniques of transmission power control and multi-channel scheduling have been well studied for eliminating interference in general wireless networks, their performances for bounding the completion of data collection in WSNs have not been explored in detail in the previous studies. The fundamental novelty of our approach lies in the extensive exploration of the efficiency of transmission power control and multichannel communication on achieving fast converge cast operations in WSNs.

Aggregated Data Collection

We augment their scheme with a new set of rules and grow the tree hop by hop outwards from the sink. We assume that the nodes know their minimum-hop counts to sink.

Raw Data Collection

The data collection rate often no longer remains limited by interference but by the topology of the network. Thus, in the final step, we construct network topologies with specific properties that help in further enhancing the rate. Our primary conclusion is that, combining these different techniques can provide an order of magnitude improvement for aggregated converge cast, and a factor of two improvement for raw-data converge cast, compared to single-channel TDMA scheduling on minimum-hop routing trees.

Tree-Based Multi-Channel Protocol (TMCP)

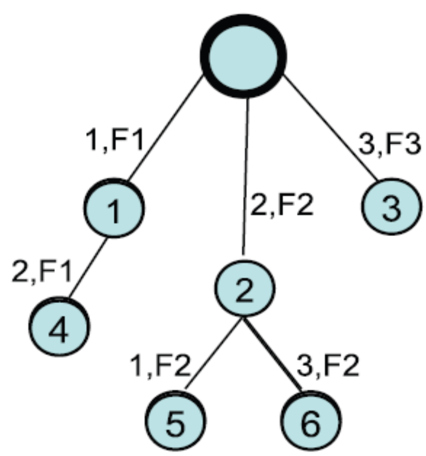


Fig. 1. Schedule generated with TMCP

TMCP is a greedy, tree-based, multi-channel protocol for data collection applications. It partitions the network into multiple sub trees and minimizes the intra tree interference by assigning different channels to the nodes residing on different branches starting from the top to the bottom of the tree. Figure shows the same tree given in Fig. which is scheduled according to TMCP for aggregated data collection. Here, the nodes on the leftmost branch is assigned frequency F1, second branch is assigned frequency F2 and the last branch is assigned frequency F3 and after the channel assignments, time slots are assigned to the nodes with the BFSTimeSlotAssignment algorithm. Advantage of TMCP is that it is designed to support converge cast traffic and does not require channel switching. However, contention inside the branches is not resolved since all the nodes on the same branch communicate on the same channel.

7. CONCLUSIONS

In this paper, we studied fast converge cast in WSN where nodes communicate using a TDMA protocol to minimize the schedule length. We addressed the fundamental limitations due to interference and half-duplex transceivers on the nodes and explored techniques to overcome the same. We found that while transmission power control helps in reducing the schedule length, multiple channels are more effective. We 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).

Once interference is completely eliminated, we proved that with half-duplex radios the achievable schedule length is lower-bounded by the maximum degree in the routing tree for aggregated converge cast, and by max $(2nk - 1, N)$ for raw-data converge cast. Using optimal converge cast scheduling algorithms, we showed that the lower bounds are achievable once a suitable routing scheme is used. Through extensive simulations, we demonstrated up to an order of magnitude reduction in the schedule length for aggregated, and a 50% reduction for raw-data converge cast. In future, we will explore scenarios with variable amounts of data and implement and evaluate the combination of the schemes considered.

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