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Report: "A Distributed TDMA Slot Assignment Algorithm for Wireless Sensor Networks"

Overview

The paper provides a solution for the problem of creating a TDMA schedule in a wireless sensor network. The proposed algorithm is tailored to networks with sensor nodes and computes a TDMA schedule in a distributed manner. Thereby an upper bound on the number of nodes in a neighborhood is assumed. The algorithm consists of five parts running concurrently in and endless loop. Shared variables are propagated to the neighbors of a node by message exchange in a globally synchronized CSMA / CA slot. The whole process is expected to converge locally in constant time and globally in sub linear time.

The algorithm distributedly calculates a solution to the distance-two graph coloring problem. The colors relate to time slots. The number of colors used not only needs to be globally minimal but minimal for the two-neighborhood of each node to allow the creation of an optimal TDMA schedule.

Flaws in the Network Model

One assumption, which does not seem to be realistic, is the requirement of synchronized clocks at all nodes. The synchronized clocks are used to make sure that each node enters the CSMA / CA phase to propagate variables and to update the schedule at the same time. With software means only it is not possible to synchronize a large amount of clocks, so there need to be hardware solutions. Synchronization among nodes could be achieved by using GPS. However, there are many applications where this is not possible due to environmental constraints.

Another assumption made in the paper is that an upper bound for the node density exists. There is no statement about how to choose such an upper bound. If the bound is set too high, this could lead to the worst case where most of the bandwidth is used to maintain the TDMA schedule and only a small part would be left for data exchange.

The paper does not cover the topic of how to choose the length of the CSMA / CA slot. Moreover there is no upper bound for it. If this slot becomes too large compared to the time of actual data exchange between nodes, the usable bandwidth decreases highly. I think there is a trade off between the length of the CSMA / CA slot and the convergence time. If the slot is small, there have to be more CSMA / CA slots to stabilize the schedule as compared to larger slots. With more CSMA / CA slots needed to establish a schedule, the algorithm only reacts slowly to topology changes which would be especially bad in the case of highly dynamic nodes.

The model proposes bidirectional communication. In reality, it is possible that sensors only have unidirectional communication channels caused by different communication ranges of individual nodes.

Flaws in the Algorithm

All algorithms should converge locally in constant time by expectation. This has been proved by the authors, but still is very arguable. The sub linear global convergence time is also doubtful.

The algorithm would not be correct anymore if we allowed unidirectional communication, like it could be possible in practice. For example, the part of the algorithm electing leaders via a maximal independent set would not work anymore as the underlying graph is directed.

The slot assignment algorithm assigns time slots from the beforehand computed coloring. But the slot assignment does not necessarily choose the same time slot for nodes with the same colors unlike stated in the distance two graph coloring examples at the beginning of the paper.

The paper does not explain why the authors choose the leaders by using a maximal independent set or why they choose leaders at all. One could imagine nodes which just assign colors to themselves without a leader involved.

If we allowed nodes which are moving over time, the whole process would not stabilize and not lead to a usable schedule anymore. If a node leaves the range of a 3-neighborhood for example, a lot of id's have to be reassigned. If the node moved constantly, all id's would have to be changed all the time. So the subsequent algorithms also would not work anymore and hence no usable schedule be created. Nevertheless, sensor networks are assumed to be quite stable.

As there are 5 algorithms running concurrently, there are a lot of messages which have to be exchanged. So it could be possible that one algorithm disturbs the variable propagation of another algorithm by using too much bandwidth in the CSMA / CA channel.

Conclusion

The whole paper has a lot of flaws. Starting with a network model which is not suitable for most applications in practice and continuing with algorithms whose constant convergence times are very arguable.

At the beginning of the paper the authors say their MAC protocol should be energy efficient. However, there is no statement about the actual energy economization after that. I would expect a comparison between the proposed MAC protocol and MAC protocols already in use. Without energy economization, there would not be any motivation to implement this protocol in a sensor node as a TDMA protocol not necessarily improves the bandwidth compared to other contention based MAC protocols.