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TDMA Scheduling with Wireless Sensor Networks

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Abstract: *To solve the scheduling problem in clustered wireless sensor networks (WSNs). The main objective is to provide network-wide optimized time division multiple access (TDMA) schedules that can achieve high power efficiency, zero conflict, and reduced end-to-end delay. To achieve this objective, we first build a cross-layer optimization model involving the network, medium access control (MAC), and physical layers, which aims at reducing the overall energy consumption. Based on the network-wide flow distribution calculated from the optimization model and transmission power on every link, we then propose an algorithm for deriving the TDMA schedules, utilizing the slot reuse concept to achieve minimum TDMA frame length.*

Keywords: *TDMA,MAC, Wireless Sensors*

I. Introduction

Scheduling of medium access plays an important role in the performance of wireless sensor networks (WSNs). In the literature, time division multiple access (TDMA) and carrier sensing multiple access (CSMA) are two major medium access approaches in WSNs. This work will only focus on the TDMA approach because the scenario specification of our research is a static network in which TDMA is said to be more effective than CSMA, especially under medium to high traffic load.

We aim at deriving TDMA schedules with optimized power consumption and minimum latency in clustered WSNs. Energy efficiency is a major concern in WSNs, since the batteries are often impossible to be replaced or recharged in many cases. In TDMA, a node can be active only if it is scheduled to send or receive data, which give it advantages in power efficiency. In the medium access control (MAC) protocol of many WSN and ad hoc network proposals is TDMA based. We build a cross-layer nonlinear optimization model to adopted to achieve least energy consumption in TDMA-achieve energy efficiency with specified link reliability and based WSNs. In addition to energy efficiency, quality of service (QoS) metrics such as end-to-end delay needs to be taken into account in some applications or under certain scenarios, for instance, delivering real-time data in radio harsh environments.

To achieve the objective, we propose a two-step approach to derive TDMA schedules supporting both high energy efficiency and minimum delay in WSNs. In the first step, we formulate the problem via cross-layer optimization, aiming at deriving the most energy-efficient flows on every link. Based on the calculated per-link flows, in the second step, we propose an algorithm to obtain a TDMA schedule with the least frame length.

We consider the application of the proposed two-step approach in clustered WSNs. It is widely known that clustering technique can provide scalability for large-size WSNs, since most of the operations can be accomplished at cluster heads (CHs) and gateways (if present), whose number is much less than the number of sensing nodes. Instead of only addressing intra cluster slot assignment, as is mostly focus on the more challenging inter cluster slot assignment more challenging inter cluster slot assignment.

The main contributions are twofold. First, we build a cross-layer nonlinear optimization model to achieve energy efficiency with specified link reliability and bandwidth constraints. Second, we propose a scheduling algorithm for slot assignment in clustered WSNs. This scheduling algorithm incorporates the slot reuse concept (from cellular Networks) in calculating the schedules based on the optimal flows derived from the proposed optimization model. The slot reuse concept significantly reduces the end-to-end latency without penalty in the energy efficiency.

II. Related Work

These approaches obtain local topology and interference information at each node, and compose schedules by exchanging messages between local nodes within a certain range (i.e., the architecture and models of the physical, MAC, and network interference range). Compared to the approaches demanding global topology information, distributed scheduling is more flexible, but at a cost of increased schedule length. Working on a single layer only may lead to inefficiency in utilizing the network resources. Recently, cross-layer design approach is combined with TDMA scheduling in order to obtain prolonged network lifetime. Interference-free TDMA schedules for a small-scale network by joint optimization of the physical, MAC, and network layers. A single frame without slot reuse for the whole network guarantees no interference. However, this also leads to significant end-to-end delay, which makes this approach unsuitable for large-size WSNs.

Consider both joint layer optimization and slot reuse to derive energy-efficient schedules. A convex cross-layer optimization model is proposed and solved iteratively to maximize the network life time. The link schedules evolve at each iteration until a specific energy consumption goal is reached or no more optimal solution can be found.

Their exhibits three differences: First, the proposed framework (i.e., cross-layer-based energy optimization model and scheduling algorithm) achieves energy efficiency for minimizing the delay. Second, we incorporate the slot reuse concept for the purpose of reducing the delay of the optimal flows obtained from the cross-layer optimization model. Third, the proposed scheduling heuristic is flexible, applicable to both clustered and non clustered WSN architectures.

III. SYSTEM MODEL

We present the wireless sensor network architecture and models of the physical layers. These models serve as input to the cross-layer optimization model.

3.1 Network Architecture:

The nodes in the network are divided into multiple clusters, each comprising a CH and cluster members that communicate via one hop to the CH. For example, the clustering scheme proposed in can be used to form clusters, as development of clustering algorithms is outside the scope. A gateway is a cluster member belonging to the cluster represented by one of the CHs it connects. We do not constrain the transmission range of CHs and gateways within one hop though. Only the intracluster communication (i.e., communication from cluster members to the CH) is restricted to one hop. To simplify the network model the sensor nodes inside each cluster are not shown explicitly. Instead, we represent the total traffic generated by the entire active members of a cluster and sent to the CH by a “virtual” link.

We assume that the operation of the network is divided into rounds, each composed of an initialization phase followed by a data relay phase.. A new round is initiated when a WSN is deployed or the available power of a CH or gateway reaches a specified threshold, or after a fixed time interval. A contention-based protocol, such as CSMA, is used in the initialization phase of each round to form clusters, and allows the only sink node in the network to obtain the topology of the backbone network composed of CHs and gateways. The sink then calculates the optimized schedule (i.e., number of slots required on each link and the ID number of the slot in a TDMA frame to be assigned to each required slot) and informs all nodes(e.g., broadcasts the schedule directly to all nodes), after which the network enters the data relay phase. The duration of the initialization phase, t1, is far less than that of the data relay phase, t2, so that the energy consumption during the initialization phase can be neglected. This operation round repeats until a certain percentage of nodes run out of energy or their energy is below a certain threshold. We only focus on the data relay phase and investigate TDMA scheduling during this phase, under optimized power consumption and minimum latency.

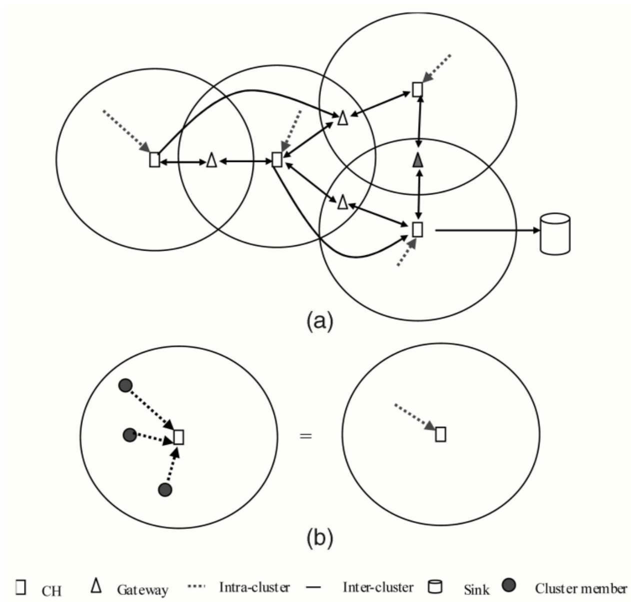

Fig1: Network Architecture

3.2 Physical Layer:

To some extent, the physical layer model determines the accuracy of the cross-layer optimization model. A realistic physical layer model considers the propagation model, modulation, encoding, demodulation, and decoding techniques, thus linking major parameters such as power, signal to noise ratio (SNR), and bit error rate together.

3.3 MAC Layer:

TDMA scheme is the MAC layer protocol employed during the data relay phase. A TDMA frame consists of a number of slots, each with fixed length assume that NACKs and retransmissions are used at the MAC layer. However, to simplify the analysis and the scheduling algorithm, we neglect the cost of NACKs by assuming that a NACK is only generated once in each fixed feedback period to inform the source nodes of packets not correctly received in the last period. By properly setting the feedback period, energy cost of NACKs is negligible compared to that of data packets loss rate, the per-hop average number of total transmissions for a packet to be successfully received.

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3.4 Network Layer:

Multihop, multipath routing is performed at the network layer. Every CH or gateway has knowledge of its next hops and the proportion of data traffic to every next hop. The sink provides this information to every CH or gateway after deriving the optimal schedules at the end of the initialization phase of each operation round.

IV. CROSS-LAYER OPTIMIZATION

Cross layer Optimization model is the per bit average transmission energy consumed at node when transmitting to node using Transmission power is the packet loss rate on link is the data flow rate (in bits per second) from node. Which is composed of transmission and receiving mode energy consumption (the energy consumed at the sink is neglected because its power source is replaceable), and the energy consumed by each active sensor node (cluster member) in sensing and transmitting the data to its CH. Note that retransmissions are ignored for the intra cluster. The optimization model depicted by is cross-layer based because it jointly combines network layer traffic loads, MAC layer retransmission scheme, and physical layer modulation scheme and bit error rate together, in order to derive appropriate transmission power and flow rate at every link.

V. MINIMUM DELAY SCHEDULING ALGORITHM

However, this results in very long TDMA frame length, and thus, unacceptable delay in large size WSNs. Our goal then is to derive a relationship between the delay incurred by a data packet (along its path to the sink) and the TDMA frame length M so that, by reducing the frame length through slot reuse, the delay is minimized. For this analysis, we determine the node delay from the instant the first bit arrives at the node until the time the last bit exits the node. With the TDMA MAC adopted, the nodal delay can be approximated by the time interval between the input time slot where the data are read and the output time slot from which the data are read out the data packet is received at a node. Our proposed algorithm can be applied to both uniform and non uniform traffic. In addition, the abstraction of intra cluster communication by virtual links makes it easy to apply this algorithm to clustered WSNs, which is said to have advantage in large-scale deployment compared to non clustered WSNs.

VI. CONCLUSIONS

Efficient, Collision-Free Medium Access Control for Wireless Realizing the relationship between the transmission power and retransmissions on a link determining the optimal transmission power, we build a cross-layer design-based optimization model which aims at minimizing the network-wide

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