Receiver-driven Channel Rendezvous for Multi-channel Wireless Sensor Networks

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Abstract

In this work, a new receiver-driven channel rendezvous mechanism is proposed for multi-channel communication in Wireless sensor networks (WSNs). The work is a light-weight scheduled scheme, seems to be incurring less overhead in compare to traditional common control channel based rendezvous mechanisms.

1. Introduction

In WSN, due to limited bandwidth capacity of a single shared wireless medium, the data generated for high-rate applications often exceed the network capacity, resulting in *congestion collapse* [1] and packet losses. In order to ensure optimal capacity utilization and avoid congestion losses rate/congestion control protocol [1] has been proposed. However, such protocols cannot meet the goal if the application demands very high rate for the successful perception of an event. In contrast, protocols that advocated on network resource increment for congestion avoidance cannot actually make timely and effective action for the sensed data. Therefore, only capacity enhancement can fulfill the high-throughput demand of these applications; and it can be effectively done through multi-channel communication.

In existing multi-channel solutions for WSNs, channel rendezvous is identified as the most challenging task. As of now, the *channel rendezvous problem* has been solved using a common control channel [2][3]; where at the beginning of a cycle, both sender and receiver switch their radio to the common channel to negotiate (i.e., during broadcast period) about the potential rendezvous for data transmission on a specific channel (i.e., during unicast period). As a result, fine-grained time synchronization is required among the neighbors and often among the two-hop neighbors. Moreover, implementation of such neighbor-wide time synchronization is very complex and not a trivial task. Because, such synchronization incurs huge overhead due to the propagated control messages within a multi-hop wireless environment.

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In this work, we propose a new channel rendezvous mechanism for multi-channel communication in WSNs. This work mainly targets two purposes; first, maintaining an energy-efficient receiver-driven rendezvous scheduling, and second, minimizing the time synchronization overhead.

2. Preliminaries

This work is designed for a typical multi-level tree-based WSNs, where multiple unidirectional data flows are converged toward the sink node. We consider that a single sink-rooted routing tree comprising N sensor nodes. Furthermore, the tree consists of L levels, and each level is identified by l, where starting from the sink having $l=0$, the value is increased by one at the next level and so on. As the proposed channel rendezvous scheme is receiver-driven, so we differentiate the receivers of a routing tree by their specific tree level.

We assume that the network is loosely time synchronized, such a way that each upstream node synchronizes its clock with its immediate downstream node, creating minimal overhead. We further consider that the operational time of a receiver is divided into cycles; let, the cycle of a receiver at l-th level is denoted by T_c^l. Furthermore, the transceiver of a receiver is able to tune to n_{ch} number of non-overlapping channels having identical bandwidth.

3. Proposed Rendezvous Scheduling

In the proposed work, an asynchronous scheme derives the channel rendezvous schedules between each sender-receiver pair, which are expected to be used for future communication. At the beginning, each receiver randomly

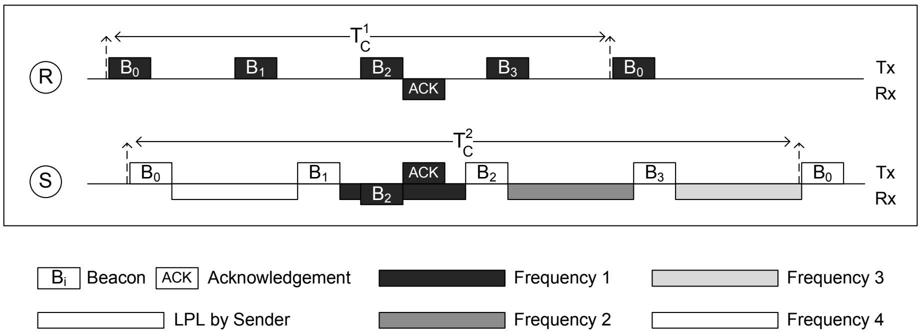

Figure 1: Channel Rendezvous

chooses a channel (i.e., its base-channel) and starts sending a *rendezvous beacon* on that channel at the equally spaced time-interval during the respective cycle. Let, *k* be the number of beacons at each cycle and for the simplicity in description we consider $k=n_{Ch}=4$. As shown in Figure 1, the beacons of different intervals are identified by B_1, B_2, B_3 and B_4.

To make a rendezvous schedule, a receiver *R* (at level *l=1*) starts its cycle T_C^1 at random time. At first, node *R* wakes-up at each of its *k*-th beacon sending time and transmits a beacon on its base-channel if the medium found IDLE, otherwise waits for a back-off period and transmits the beacon afterward. Posterior to beacon transmission, *R* waits till the maximum back-off time; if then it receives any ACK from any of its neighbor, stores that schedule as a potential rendezvous time with that neighbor. Thus, at each cycle the receiver R might have at most *k=4* rendezvous schedules with its senders.

In contrast, a sender *S* (at level *l=2*) also wakes-up at random on its base-channel and first sends a beacon (for its rendezvous as a receiver) in the same way mentioned above. Upon sending the B_1 beacon, the sender goes to *LPL* (Low Power Listening) mode at the base-channel and check for any potential beacon from any potential receiver. If it does not get any beacon then sends the B_2 beacon and switch to another channel for *LPL* again. In this way, the node *S* sequentially switches channel and checks until it receives a rendezvous request beacon from *R*. Note that the *LPL* period (T_{LPL}^2) for node *S* on level *l=2* is derived as:

$$T_{LPL}^2 = \frac{T_C^1}{n_{Ch}} + T_B, \qquad (1)$$

where, T_B is the time to transmit a beacon including the maximum back-off time. Hence, if there is no collision originated loss then by the overlapping principle [4], it can be guaranteed that at least one beacon (out of *k=4*) transmitted by *R* at different intervals on its base-channel, is received by node *S*. Finally, that beacon reception time-offset is the scheduled channel rendezvous for *S* with its receiver *R*. To implement overlapping principle [4], the cycle length of node *S* on level *l=2* needs to be further adjusted as follows (i.e., while *S* acts as a receiver):

$$T_C^2 = T_C^1 + n_{Ch} \times T_B, \qquad (2)$$

The rationale of Eq. 2 is that the node closer to the sink has a smaller cycle with more frequent wake-ups/ beacon transmission schedules. In contrast, a node more distant from the sink or near to the network boundary has a larger cycle and its wake-up frequency is less in compare to the near sink node; and practically it goes with the WSN characteristics.

4. Conclusion and Future Work

In this work, we propose a light-weight mechanism to solve the channel rendezvous problem for multi-channel wireless sensor networks. In future, we need to evaluate the performance of the proposed rendezvous scheduling through simulation, and extend the proposal for a complete multi-channel medium access control protocol for WSN.

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