Efficient Localization and Data Routing for Better Usage in Case of Wireless Sensor Networks

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Abstract – Survey of all the receiver-initiated MAC protocols and presents their unique optimization features, which deal with several challenges of the link layer such as mitigation of the energy consumption, collision avoidance, provision of Quality of Service (QoS) and security. Focusing on the particular requirements of an energy harvesting application, the dissertation contin-ues with the presentation of a MAC protocol, named On Demand MAC (ODMAC), which extends the receiver-initiated paradigm with several energy-efficient features that aim to adapt the consumed energy to match the harvested energy, distribute the load with respect to the harvested energy, decrease the overhead of the communication, address the requirements for collision avoidance, prioritize urgent traffic and secure the system against beacon replay attacks.

Keywords:- On Demand MAC, MAC Protocols

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1. INTRODUCTION

The duty cycling algorithms suggested in consists of three parts. The first part tracks past energy input profiles and uses them to identify patterns and predict future energy availability. The second part computes the optimal duty cycle based on the energy prediction. The third part handles the expected prediction errors by dynamically adapting the duty cycle of the sensor in response to the observed energy harvesting in real time. The final part operates as follows. The harvested energy is measured over fixed timeslots and the excess of energy in each slot is calculated. Whenever the excess of energy is negative, the duty cycle is decreased for the future slots giving the battery the opportunity to charge. If the excess of energy is positive, the duty cycle is increased in order to utilize that energy to increase the performance. The approach of does not use energy prediction profiles. Instead, the authors dynamically adjust the duty cycle aiming to maintain the ENO-Max condition. The dynamic duty cycle adaptation algorithm is based on the optimal tracking problem, ad-dressed by adaptive control theory. It refers to the problem of applying external control to a dynamical system in order to keep some output variable at a desired value. The authors choose to map the duty cycling problem to the version of the optimal tracking problem named linear-quadratic. In this version, it is assumed that the dynamics of the system (i.e. battery level, harvested energy, power consumption) are linear while the cost function to be minimized (i.e. average difference of the current and the initial battery level) is quadratic.

2. COLLISION AVOIDANCE

Contention-based MAC protocols for wireless communication are known to be vul-nerable to colliding transmissions, as a radio that is transmitting is unable to detect other transmissions in the wireless medium. Collisions decrease the systems perfor-mance and are also a source of energy wastage. Protocols following the asynchronous receiver-initiated paradigm, may be either vulnerable or resilient to collisions depend-ing on the topological structure of the network and the duty cycles of the nodes. This phenomenon rises because of the fact that beacons constitute indirect transmission timeslots. When the beacon transmission rate is significantly higher than the data trans-mission rate, the stochastic selection of a beacon acts as an indirect proactive collision avoidance mechanism (random channel access). Yet, there is always the chance for multiple nodes to select the same beacon / timeslot. Hence, when the beacon and data transmission rate is at a similar order of magnitude, collisions are significantly increased and the system is lead to a state where the receivers are flooded with more transmissions than they can handle. This scenario appears either in topologies when few receivers have to handle large numbers of transmitters or in the case of low duty cycle receivers serving high duty cycle senders. The latter case requires active Collision Avoidance (CA).

3. THE RECEIVER-INITIATED PARADIGM OF COMMUNICATION

The receiver-initiated paradigm operates as follows. Each node periodically wakes up to check for incoming data. After each wake-up event, a beacon is broadcasted. This beacon announces to the neighbors that it is ready to accept incoming data. After the beacon has been transmitted, the receiver continues to listen to the channel for a short period of time. Whenever a node with data ready to be sent enters the active state, it listens silently to a beacon from the intended receiver. Once the beacon is received, the sender immediately starts transmitting the data, and waits for a time period to receive a frame which acknowledges the reception of the data. If there is no incoming data from the sender after transmitting the beacon, the receiver enters the sleeping state. Both the sender and receiver, then resume their cycles. In comparison to the sender-initiated paradigm, the receiver-initiated communication paradigm significantly reduces the amount of time for which pair of nodes occupy the channel, allowing more contending nodes to communicate with each other, increasing the capacity and throughput of the network. It is more efficient in detecting collisions and recovering lost data, because access to the channel is mainly controlled by the receiver. Since receivers only wait a short period of time for incoming data, after beacon transmission, overhearing is greatly reduced [40, 71, 107].

4. RECEIVER INITIATED CYCLED RECEIVER (RICER)

Beyond introducing the paradigm, RICER also defines several features that improve the performance of the protocol. First, it uses a random delay between the reception of the wake-up beacon and the data transmission to avoid collisions. Furthermore, the authors note that a significant reduction of the energy consumption can be achieved by intro- RI-MAC builds on the receiver-initiated paradigm and provides an implementation that is incorporated in RI-MAC extends the paradigm with the following fea-tures. After data transmission and if the sender has more data packets to send, it uses the acknowledgment beacon as a Ready-to-Receive (RTR) indicator, to start transmit-ting the next data packet. If there is no incoming data from the sender after transmitting a beacon, the receiver enters the sleep state. The beacon frame in RI-MAC plays a dual role. It is used both as a RTR, broadcasting the request to initiate data transmission, in essence, creating a timeslot for rendezvous, and as an Acknowledgment (ACK), which informs the sender that the data has been received successfully. An optional destination address field is used in the ACK reply to signify a unicast transmission, so that other nodes waiting for a beacon can ignore it. The duty cycle of the beacon transmissions are controlled by varying the sleep state, L, of the node. To prevent coincidental syn-chronization, a node sets the sleep period randomly between 0:5L and 1:5L, before entering the active state. This essentially makes the average duty cycle of RI-MAC static. An overview of the communication in RI-MAC

5. SUSTAINABLE OPERATION

The following experiments aim to evaluate the sustainable performance of data trans-mission. The cost of using the CO2 sensor does not depend on the communication protocols used. Therefore, the CO2 sensor is deactivated and, instead, dummy data are transmitted to the server. The firmware is set to attempt one transmission every 30 second. The transmission is performed if and only if the voltage of the capacitor is above a threshold. This way, the system automatically finds balance and the sustainable throughput (in packets per minute) is measured. Again, the power input is controlled by positioning the light source in various distances from the solar cells. Figure 9.7 shows the results of the experiments for different levels of constant input power. All experiments were initiated with the voltage of the capacitor below the threshold. The 1 hour continuous operation demonstrates the sustainability of the node. Furthermore, the excess of harvested energy is used to improve the throughput of the application. The throughput increases linearly with the input power. HTTP and UDP seem to perform equally. This phenomenon is attributed to the power consumption of the association and the overhead protocols (DHCP and ARP) which is the same for both schemes and dominates the overall power consumption.

4. COMPARISON WITH ODMAC

Closely resembles the experiments on ODMAC Both figures demonstrate a similar linear behavior where the throughput increases with the power input. Yet, ODMAC appears to require one order of magnitude less power for one order of magnitude more throughput. Moreover, as shown in Figure 8.8, most power consumed in ODMAC in idle listening in order to synchronize the sender to the duty-cycling receiver through the beacons. If the receiver did not have energy constraints, similarly to a Wi-Fi AP, the difference between the two protocols would be significantly higher.

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Furthermore, data encryption has a significant effect on the energy-efficient of Wi-Fi sensor node. We experimentally verified the results shown in , which show that data encryption approximately doubles the energy consumption of the association. Similarly to ODMAC, the actual encryption of the data does not significantly increase the energy consumption of the packet transmission. However, the additional cost of the association to the AP, which occurs once every duty cycle, drives the overall energy consumption high and makes data encryption significantly less energy-efficient than ODMAC. This comparison demonstrates that the benefits of using RTX4100 come at the price of compromising the energy-efficiency of the network. The two orders of magnitude of difference verify in practice that IEEE 802.11 and the TCP/IP stack are not energy-efficient solutions. Nevertheless, the use of IEEE 802.11 is feasible if the running application has loose performance requirements.

CONCLUSION

Lastly, we discuss the idea of using timing channels to promote the energy-efficiency of WSNs. Instead of conveying information in the traditional way, senders can encode the measurement into the duration of the sleeping period. Initial analytical results suggest substantial reduction of the energy consumption under realistic scenarios and motivate future investigations. The MAC layer plays a critical role towards the realization of low-power sensor applications and leads the research community to push the envelope towards increasing the energy-efficiency of wireless communications. In order to meet tight energy constraints, sensing systems need to be optimized as a whole and tailored to the specific environmental conditions of each given application. As there is no globally optimal solution, researchers provide the designers of WSNs with tools and features that can be adapted and used with respect to particular application requirements. It is the belief of the author that this dissertation provides significant insight and valuable tools that can be selected, altered or combined with other tools and contribute towards the realization of long-living and energy-efficient wireless sensing infrastructures.

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