Poster Abstract: WiseMAC, an Ultra Low Power MAC Protocol for the WiseNET Wireless Sensor Network*

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ABSTRACT

WiseMAC is a medium access control protocol designed for the WiseNET^{TM}wireless sensor network. It is based on CSMA and uses the preamble sampling technique to minimize the power consumed when listening to an idle medium. A unique feature of this protocol is to exploit the knowledge of the sampling schedule of its direct neighbors in order to use a wake-up preamble of minimized size. This scheme allows not only to reduce the transmit and the receive power consumption, but also brings a drastic reduction of the energy wasted due to overhearing. Backoff and medium reservation schemes have been selected to provide fairness and collision avoidance. WiseMAC requires no set-up signaling, no network-wide time synchronization and is adaptive to the traffic load. It provides an ultra-low average power consumption in low traffic conditions and a high energy efficiency in high traffic conditions.

Categories and Subject Descriptors

C.2.1 [**Computer-Communications Networks**]: Network Architecture and Design—*Wireless communication*

General Terms

Algorithms, Performance, Design

Keywords

Medium access control, wireless, sensor network, low power, energy efficient, CSMA, preamble sampling

1. INTRODUCTION

The WiseMAC protocol has been designed to operate on the WiseNET system-on-a-chip developed at CSEM, which includes a low power FSK radio transceiver (dual-band 434 and 868 MHz), the CoolRISC 8 bits low power microcontroller core, a random access memory as well as digital and analog interfaces [2]. The WiseNET chip is designed on the 0.18 μm standard digital CMOS process. It is operating from 1.5 V to 0.9 V, such that a single inexpensive alkaline battery can be used as the energy source. The WiseNET transceiver targets an ultra-low power consumption of 2 mA in receive mode, as well as a short power-on latency of 800 μs. These characteristics will permit the usage of the preamble sampling technique at a low average power cost. In transmit mode, the power consumption will be of about 30 mA to reach 10 dBm output power (before the antenna).

2. WISEMAC

WiseMAC uses the preamble sampling technique to minimize the energy wasted during idle listening [1]. Preamble sampling consists in regularly sampling the medium to check for activity. By sampling the medium, it is meant listening to the radio channel for a short duration, e.g. the duration of a modulation symbol. In a network, all nodes sample the medium with the same constant period T_W, independently of the actual traffic. Their relative sampling schedule offsets are independent. If the medium is found busy, the receiver continues to listen until a data packet is received or until the medium becomes idle again. At the transmitter, a wake-up preamble is transmitted in front of every message to ensure that the receiver will be awake when the data portion of the message will arrive. The wake-up preamble introduces a power consumption overhead both in transmission and in reception. To minimize this overhead, sensor nodes learn the offset between the sampling schedule of their direct neighbors and their own one. Knowing the sampling schedule of the destination, sensor nodes send messages just at the right time with a wake-up preamble of minimized length T_P (see Fig. 1). As nodes have independent sampling schedule offsets, this scheme naturally mitigates overhearing, since such short transmissions are likely to fall in between sampling instants of potential overhearers.

Every node keeps an up-to-date table with the sampling schedule offset of its direct neighbors. The sampling schedule offset information is gained through the inclusion in every acknowledgement packet of the remaining duration until the next scheduled preamble sampling. Because the clocks running on the sender and the destination can be inaccurate, a drift will accumulate in between two transmissions. To compensate this drift, it can be shown that the wake-up preamble must have a duration of $4\theta L$, if both quartz have an accuracy within $\pm\theta$ parts per million. L is the

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time elapsed since the last acknowledgement message was received from the destination. WiseMAC is hence adaptive to the traffic load, in the sense that the higher the traffic (the smaller L), the smaller the wake-up overhead ($4\theta L$). With this scheme, it is not necessary to regularly exchange data frames to keep the synchronization. If the interval between two communications is so large that $4\theta L > T_W$, a wake-up preamble of length T_W will be used. This also applies to the first communication between two nodes.

In those cases where the wake-up preamble is longer than the data frame, it is composed of a repetition of the data frame. This permits to reduce the frame error rate, mitigate overhearing and detect interferences.

To mitigate collisions, WiseMAC uses non-persistent carrier sensing, with a backoff chosen as a random integer multiplied by the turn-around time of the transceiver.

To prevent collisions between two or more nodes that want to send a data frame to the same relay and at the same target sampling instant, a medium reservation preamble of randomized duration is added in front of the wake-up preamble. After the wake-up preamble, the WiseMAC data frame includes a bit synchronization preamble and a start frame delimiter (see Fig. 2).

Collisions caused by the hidden node effect can represent an important source of energy waste through the required retransmissions. The hidden node effect is mitigated by extending the carrier sense range beyond the interference range, at the cost of the capacity.

The receive threshold has been chosen well above the noise threshold to mitigate useless wake-ups caused by interferences or weak signals. The receiver is hence waken up only when this is really worth it. Here, the lower power consumption is traded against a potential transmission range extension.

The efficient transport of data bursts is made possible through the use of the 'more' bit in the header of data packets, indicating to the receiver to continue to listen for the following packet.

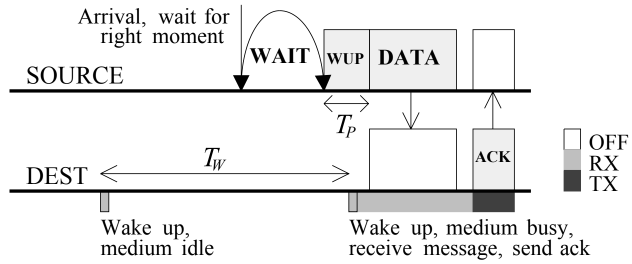

Figure 1: WiseMAC protocol.

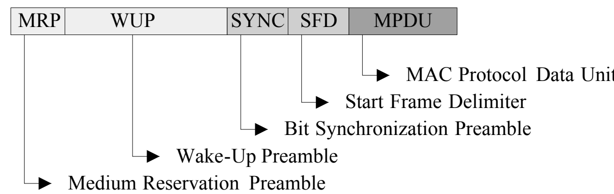

Figure 2: WiseMAC data frame.

3. EVALUATION

The WiseMAC protocol was simulated on the GloMoSim platform. The radio layer of the simulation environment has been modelled to reflect the temporal behavior of the WiseNET transceiver: a setup delay of 800 μs (between off state and ready for receive) and a turn-around delay of 400 μs (between the receive and transmit states). Simulations were run for a 9x9 lattice multihop network. The node density was chosen to be of 9 nodes within a circle of range radius, such as to provide a well-connected topology in a random plane ad-hoc network of equal density. Traffic is generated following a Poisson process by the 9 nodes on the left of the lattice, and carried in a multi-hop fashion towards the right. MPDU frames have a length of 64 bytes. The channel raw bit rate is of 25 kbps. The wake-up period was chosen to be T_W = 200 ms, such that the power consumed by the preamble sampling activity is within the given power budget but not negligible when compared to the battery leakage power.

The statistics collected on a central forwarding node have shown that, when using the WiseNET transceiver, the average power consumption accounts to 25 μW when a message is forwarded in average every 100 seconds. With a single alkaline battery of capacity C=2.6 Ah and constant power leakage of 27 μW, this translates in more than 5 years lifetime. In higher traffic conditions (inter-arrivals between 100 and 5 seconds), the average power consumption of WiseMAC grows up to 200 μW, but the energy efficiency reaches over 75%. Here, we define energy efficiency as the ratio between the energy consumed by an ideal protocol to forward a packet (without any wake-up, idle listening, overhearing or collision overhead) divided by the energy consumed by WiseMAC to forward the same payload. The average hop latency was measured between 140 and 240 ms, depending on the traffic conditions.

4. CONCLUSION

WiseMAC is a CSMA based protocol using the preamble sampling technique to reduce the cost of idle listening. This protocol exploits the knowledge of the sampling schedule of its direct neighbors to minimize the length of the wake-up preamble. It is thereby adaptive to the traffic load, providing an ultra-low power consumption in low traffic conditions and a high energy efficiency in high traffic conditions. WiseMAC can transport sporadic, periodic and bursty traffic. It is scalable and supports mobility as only local synchronization information is used. The preamble sampling period can be chosen to be relatively short, allowing a low hop delay and hence a low end-to-end latency.

For more information on WiseNET and WiseMAC, see `http://www.csem.ch/wisenet`.

5. REFERENCES

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