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Demo: Distance Measurement in Wireless Sensor Networks with low cost components

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I. INTRODUCTION

The estimation of a position of a node within a wireless sensor network (WSN) is still a technical challenge. A localization solution should be energy efficient, low-cost and very accurate. There are several approaches to solve this task, however there is always a drawback concerning the mentioned constraints.

If the WSN is located in an outdoor environment, standard solutions like GPS can be applied. If GPS is not available it is possible to measure the radio propagation properties beforehand or install beacons on known positions to allow a WSN node to determine its position. In our scenario we suffer from the problem that we do not have any a priori information about the environment, as we want to localize WSN nodes within an ad hoc network. Known solutions without special hardware support usually exploit the received signal strength indicator (RSSI) to approximate the distance to an anchor node. In several publications and own experiments the RSSI based approach performed very bad concerning accuracy in unknown environments [6].

An alternative solution is to measure the time a signal travels between two nodes. This time is called time of flight (TOF) and as the TOF is in the magnitude of nanoseconds it is hard to measure it with low-performance sensor nodes. Several different commercial vendors provide proprietary special purpose localization transceivers, which use special hardware support to measure the TOF or derivatives of that value. In recent projects we used such a commercial transceiver. A major drawback of this solution is that the transceiver was rather expensive and hard to integrate due to a proprietary interface. Also the accuracy of the measured distances and the energy consumption did not match our expectations.

In this paper we present a TOF based distance measurement system based on the MSB-A2 [1] sensor platform, which is assembled with off-the-shelf hardware components. The core components of the MSB-A2 platform are a LPC2387 microcontroller [3] and a CC1101 radio transceiver [4]. We will use the hardware-timer capabilities of the LPC2387 and the CC1101 signaling features to measure the round-trip time of flight (RTOF) between two sensor nodes and estimate the distance between the nodes using the measured value.

In the following, section II describes the hardware and the system setup of our demonstration system. A conclusion follows in Section III.

II. SYSTEM ARCHITECTURE AND IMPLEMENTATION

A. The System Setup

For our reference implementation MSB-A2 sensor nodes are used. The MSB-A2 has an LPC2387 microcontroller [3] and a CC1101 radio transceiver [4]. The microcontroller has an ARM7 core and a 72MHz clock. The CC1101 is driven with a 26MHz clock and uses the 868MHz radio band.

As operation system we are using the FireKernel microkernel [5].

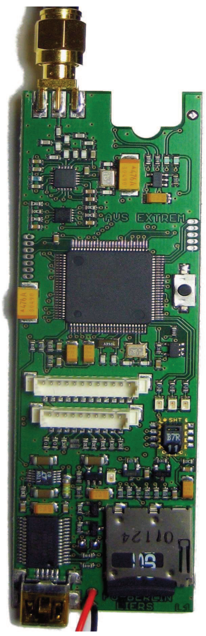

Figure 1 MSB-A2 Sensor Node

B. The Measurement Process

For precise measurement of the TOF on a common microcontroller we need an appropriate signal as source for the time measurements. The CC1101 transceiver used on the MSB-A2 sensor node provides several trigger sources like *first bit of packet*, *last bit of preamble*, or *last bit of packet* which are signaled through changing edges on a certain pin. All of these signals could be used while processing a packet. The preamble normally is an alternation of ones and zeros to provide bit synchronization to the receiving radio. So all indicators referring to the preamble like first bit of packet are not reliable. Because a packet could only be detected after bit synchronization and therefore the span between the incoming first bit of the preamble and the recognition of a packet is variable. A better approach is to use the sync word as an indicator, because it is sent directly after the preamble. The sync word is used for byte synchronization and multiplexing of the media. Because the sync word directly follows bit synchronization, it has the lowest possible bit jitter. In the rest of this paper we are using the *last bit of sync word* as the trigger for all time measurements on transmitter and receiver.

The *last bit of sync word* -signal is directly attached to a hardware timer of the LPC2387 which has shown the best accuracy in comparison with hardware interrupt handlers.

To improve accuracy we have implemented a two way range measurement protocol, which allows us to measure the TOF from node *A* to *B* and from node *B* to *A* in one cycle of our algorithm. First node *A* sends a ranging request (RR) to *B*, which answers with a ranging acknowledge (RACK). In this step the TOF timer of *A* is started and *B* has measured the computation time and also started a TOF timer on sending out the RACK. *A* stops the TOF time on receiving the RACK and starts measuring the computation time immediately and sends out another packet to *B* (REACK). On receiving this packet *B* stops its TOF timer. The last step is to transmit the measured TOF and the computation time to node *A*. Node *A* now has two measured TOFs and the corresponding computation times. Because we normally have more than one of these measurements, we skip the last packet which only transmits the measured times to node *A* and piggyback those values in the RACK of the next step. This can be done because the length of the RACK is not included in any measurement.

C. The Demo Setting

In our setup we will show a prototype of our system, which is able to measure the distance between two sensor nodes. A sensor node *A* will be attached to the serial console of a laptop which is used to display the distance to a node *B*. Node *B* is portable and can be carried around in the room by a user or the presenting person. We will measure the distance to several fix-points in the room beforehand to show the difference between the real and the measured values.

We will show that the distance measurement has a maximum error of approximately 5m or less if the distance between the node *A* and *B* is at least 10m. If the distance between the nodes is less then 10m we expect a bigger error but will show some improvements to reduce this problem.

III. Conclusion

The main contribution of this work is that our setup has some great advantages to common methods for range determination in WSNs without special hardware, especially to RSSI based methods. As the TOF measurement is not as heavily environment depended as the RSSI method [6] our system is much more accurate for ad hoc scenarios where map matching or other methods cannot be applied.

We propose our work as a generic solution for range measurements in existing WSNs or WSNs where the use of special hardware is not possible.

Future work will address the fusion of RSSI and link quality based methods to increase the accuracy. If we could estimate the distance to the anchors with a single packet, we could use the available bandwidth for ranging only with promising anchors. Also more sophisticated statistical approaches are needed to lower the used bandwidth by fewer ranging packets.

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