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Energy Efficient Protocols for Active RFID

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Energy Efficient Protocols for Active RFID

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Abstract

Radio frequency identification (RFID) systems come in different flavours; passive, active, semi-passive, or semi-active. Those different types of RFID are supported by different, internationally accepted protocol standards as well as by several accepted proprietary protocols. Even though the diversity is large between the flavours and between the standards, the RFID technology has evolved to be a mature technology, which is ready to be used in a large variety of applications. This thesis explores active RFID technology and how to develop and apply data communication protocols that are energy efficient and which comply with the different application constraints.

The use of RFID technology is growing rapidly, and today mostly “passive” RFID systems are used because no onboard energy source is needed on the transponder (tag). However, the use of “active” RFID-tags with onboard power sources adds a range of opportunities not possible with passive tags. Besides that Active RFID offers increased working distance between the interrogator (RFID-reader) and tags, the onboard power source also enables the tags to do sensor measurements, calculations and storage even when no RFID-reader is in the vicinity of the tags.

To obtain energy efficiency in an Active RFID system the communication protocol to be used should be carefully designed. This thesis describes how energy consumption can be calculated, to be used in protocol definition, and how evaluation of protocols in this respect can be made. The performance of such a new protocol, in terms of energy efficiency, aggregated throughput, delay, and number of collisions in the radio channel is evaluated and compared to an existing, commercially available protocol for Active RFID, as well as to the IEEE standard 802.15.4 (used, e.g., in the Zigbee medium-access layer). Simulations show that, by acknowledging the payload and using deep sleep mode on the tag, the lifetime of a tag is increased.

For all types of protocols using a radio channel, when arbitrating information, it is obvious that the utilization of that channel is maximized when no collisions occur. To avoid and minimize collisions in the media it is possible to intercept channel interference by using carrier sense technology. The knowledge that the channel is occupied should result in a back-off and a later retry, instead of persistently listening to the channel which would require constant energy consumption. We study the effect on tag energy cost and packet delay incurred by some typical back-off algorithms (constant, linear, and exponential) used in a contention based CSMA/CA (Carrier Sense Multiple Access/ Collision Avoidance) protocol for Active RFID communication. The study shows that, by selecting the proper back-off algorithm coefficients (based on the number of tags and the application constraints), i.e., the initial contention window size and back-off interval coefficient, the tag energy consumption and read-out delays can be significantly lowered. The initial communication between reader and tag, on a control channel, establishes those important protocol parameters in the tag so that it tries to deliver its information according to the current application scenario in an energy efficient way. The decision making involved in calculating the protocol parameters is conducted in the local RFID-reader for highest efficiency. This can be done by using local statistics or based on knowledge provided by the logistic backbone databases.

As the CMOS circuit technology evolves, new possibilities arise for mass production of low price and long life active tags. The use of wake-up radio technology makes it possible for active tags to react on an RFID-reader at any time, in contrast to tags with cyclic wake-up behaviour. The two main drawbacks with an additional wake-up circuit in a tag are the added die area and the added energy consumption. Within this project the solution is a complete wake-up radio transceiver consisting of only one hi-frequency very low power, and small area oscillator. To support this tag topology we propose and investigate a novel reader-tag communication protocol, the frequency binary tree protocol.

Keywords: RFID, Active RFID, protocol, energy efficient, power consumption, back-off, wake-up radio, throughput, delay, RFID-system