

# ACTIVE RFID – VLSI ARCHITECTURES FOR SMALL AREA, LOW POWER WIRELESS DEVICES

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The use of Radio Frequency Identification systems (RFID) is growing rapidly. Today, mostly “passive” RFID systems are used because no onboard energy source is needed on the transponders. However, “active” RFID technology, with onboard power sources in the transponders, gives a range of opportunities not possible with passive systems. To obtain energy efficiency in an Active RFID system the data communication protocol to be used should be carefully designed with energy optimization in mind. Also, new architectural solutions for small-area, low-power baseband processing as well as for small-area, low-power RF blocks will be required. This industrial PhD student project focuses on relevant research questions related to these issues.

**Keywords:** RFID, active RFID, protocol, back-off, carrier sense, energy efficient, wireless networks, active tag, energy consumption, low-power CMOS ASIC

## 1. Background and Motivation

Radio Frequency Identification, RFID, is used to remotely and wirelessly identify a device named transponder (or tag) by using an interrogator (or reader), see Figure 1. The tag has a unique identity (could be used as an electronic product code, EPC) used to identify the object it is attached to.

The RFID technology can be divided into two main categories, Passive RFID (P-RFID) and Active RFID (A-RFID), where the most common is the P-RFID.

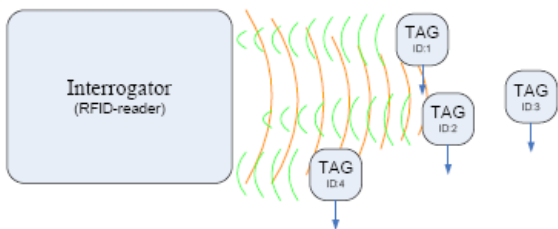


Figure 1. An RFID-system where tags are passing a reader. The tags in range of the RFID-reader identify themselves by transmitting their unique identities.

Scenarios for RFID might for instance be in the logistic chain, tracking goods from the producer to the consumer, where the goods can be a single product or up to several hundred products on a single pallet. Items must be identified fast by the RFID-reader when e.g. a fork lifter transports them (Figure 2, lower) and passes an RFID-reader. In this realm, RFID could also be used for automatic inventory of the stock in a warehouse (Figure 2, upper), where the reading delay is not critical but where there is a huge amount of tagged goods to identify.

In the fork lifter scenario (assuming there is a narrow passage) only a small amount of transmitted and received

energy is needed, due to the short distance, but fast readings are needed due to the vehicle velocity. For the warehouse scenario, with long distances, more energy is needed, but this scenario has no hard time restrictions.

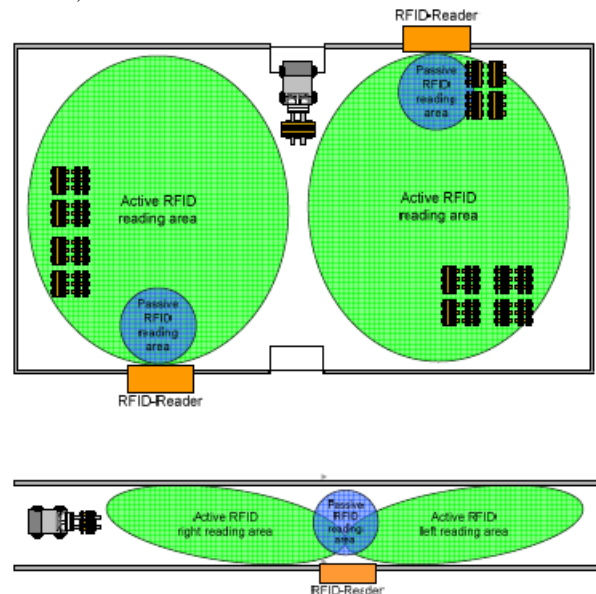


Figure 2. The fork lifter scenario, where the goods on the pallet have to deliver their identity fast when the fork lifter passes the RFID-reader (lower). The warehouse scenario, where a large amount of goods are stored and have to be continuously updated in the inventory database (upper).

## 2. Problem and Results

To obtain energy efficiency in an **Active RFID** system the data communication protocol to be used should be carefully designed with energy optimization in mind. This has been the primary focus of the first two years of the project, and the results of this work have been presented

in Björn Nilsson's licentiate thesis. The 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 air collisions 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 an Active RFID tag is increased.

For all types of protocols using an air channel for transmitting and receiving information it is obvious that the utilization of that channel is maximized when no collisions occur. To avoid and minimize collisions in the air interface it is possible to listen to the channel (carrier sense) and know its status. Knowing 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. The effects 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) protocols for Active RFID communication are studied. It is shown that, by selecting the proper back-off algorithm coefficients (based on the number of tags), i.e. the initial contention window size and back-off interval coefficient, the tag energy consumption and read-out delays can be significantly lowered. Thus the **adaptation** of the protocol parameters to the **usage scenario** is a significant key to lowering energy consumption and thereby extending the lifetime of the tags.

The post LIC studies are now focused on the design and evaluation of a complete Active-RFID system. While for the RFID-reader there are no hard constraints in power consumption, the tag needs to be carefully designed to get long working life time. The production cost of a tag is also more sensitive than that of an RFID-reader because of the great number of tags produced. This implies that keeping the external components on the tag as few as possible decreases the production cost. Therefore it is important to optimize the CMOS ASIC design for the tag to fulfill constraints on both power consumption and production cost.

Another ongoing project at CERES, "Egon – Active Backscatter Radio", is focused on designing a low power wake up radio, resulting in a CMOS ASIC that is on its way. The fusion between the research on protocols and the Egon project has resulted in the design of a new protocol and a completely new Active RFID system. An ongoing work at Halmstad University in collaboration with Chalmers University of Technology is aiming at building a new test platform for a complete Active RFID system. Potential patents have been identified during this work.

## PARTNERS AND STATUS

Industrial partner: Free2move AB.

Project funding: SME PhD student funding from the Knowledge Foundation, Free2move AB.

Project period: February 2005 – February 2010.

PhD student: Björn Nilsson, employed by Free2move AB.

Researchers: Lars Bengtsson and Bertil Svensson (project leader) from CERES; Per-Arne Wiberg from Free2move and CERES.

Results from the project formed the licentiate thesis of Björn Nilsson, presented in November, 2007.

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