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# RADIO TRIGGERED ASYNCHRONOUS PROTOCOL FOR ULP SENSOR NETWORK BASED ON A UWB SUB-GHz COMMUNICATION LINK

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## 1) Context / Study motivation

UWB impulse radios show interesting features for the RF transmission link. The more interesting characteristics of such RF front-end for low power sensor networks are (i) very low energy per bit consumption, (ii) very simple architecture leading in low cost deployment, (iii) capability to achieve high data rates. In addition, the use of the sub-GHz UWB channel allows to reduce the path loss in comparison with traditional UWB channels using high frequency bands and also to benefit from better hardware performances because active components are used far away their cutoff frequencies. In this paper we investigate the sub-GHz UWB RF link capabilities regarding energy consumption in low power sensor networks. The sub-GHz UWB RF link is used in a Radio triggered asynchronous protocol and the energy consumption of the corresponding network is modeled as a function of the number of network nodes and of the network activity.

## 2) Description of approach and techniques

### Sub-GHz UWB radio link optimization

Peak power magnitude and average power magnitude of UWB communications are regulated by FCC which sets a peak value of -7.9dBm and an average value of -49.1dBm/MHz for the PSD in the sub-GHz band [1]. These regulations limit the peak to peak magnitude of the emitted wave lower than 0.9V on a 50Ω antenna when data rates higher than 100kbit/s are achieved [2]. This limitation can be exceeded by emitting UWB pulses in a burst mode with long interval idle periods in order to achieve a low mean bit rate [3]. In this study a peak bit rate of 100Mbit/s is used during bursts of 1μs duration while 1ms idle periods allows achieving a mean data rate of 100kbit/s with 0.9V emitted magnitude according to FCC regulation. Moreover this burst emission mode allows power to be saved thanks to a very efficient duty cycling of the radio front-end.

### Radio triggered asynchronous protocol using sub-GHz UWB radio link

The Radio link presented in the last section allows transmission of 100bits packets with an energy efficient method. It can be used in a radio triggered asynchronous protocol for achieving Ultra Low Power sensor networks. The proposed data exchange protocol between two network nodes is depicted in Fig 1. To save power, data exchange is initiated with a wake-up radio using a passive receiver able to achieve very low power consumption [4]. The wake-up signal is a 433MHz continuous wave which duration can be lower than 10us when short communication range are targeted. Indeed, such passive wake up receivers exhibits turn on times which increase with the communication range.

The wake-up signal turns on all the sensor nodes in the vicinity of the emitter node. Then the Request To Send (RTS) signal emitted by the sub-GHz UWB radio is used to shut down all the nodes excepting the destination node which emits a Clear To Send (CTS) with its main radio after 1ms. This delay corresponds to the idle time necessary to comply with UWB regulation. After the data and the Acknowledgement exchange, the network lies in the low power wake-up mode.

### Power consumption modelling of Radio triggered asynchronous protocol using sub GHz radio link

To investigate the potentialities of such communication protocol, we developed an energy consumption model of the sensor network. The sensor node architecture is given in Fig 2. It includes a sub-GHz UWB main radio, a 433MHz wake-up radio with a passive receiver, a low power microcontroller, sensors and an interface module which enables the data transmission between the high data rate UWB receiver and the microcontroller. The microcontroller allows several power consumption modes regarding used sub-units and clock frequency [5]. The asynchronous protocol allows the use of the most saving power mode during the long inactivity periods in the network, limiting power hungry microcontroller modes activities only when bursts of data are exchanged. Table 1 summarizes the power consumption of the different constitutive blocks of the sensor node. Excepting for the microcontroller and the wake-up radio transmitter, the values used in our modelling are based on state of the art published values. Finally, knowing the power consumption of each constitutive blocks and the data exchange protocol schedule given in Fig 1, it is possible to compute the power consumption of the sensor network as a function of the number of its nodes and its activity rate.

## 3) Results / Conclusions / Perspectives

The model presented in the last section has been used to study the power consumption in a sensor network using the proposed Radio triggered asynchronous protocol with a sub-GHz UWB radio link. Fig 3 shows contributions regarding energy consumption of hardware components in the active mode and in the watch mode for a 20 nodes sensor network as a function of the network activity. We can note that using an UWB sub-GHz communication link the RF communication power budget remains low in comparison with other hardware power budgets even for high network activity rates. We can also note that outside high activities rate in the network, the wake-up radio receiver is one of the major contributor in energy consumption even if a passive Wake-Up Radio receiver with a very low power consumption has been used in this study.

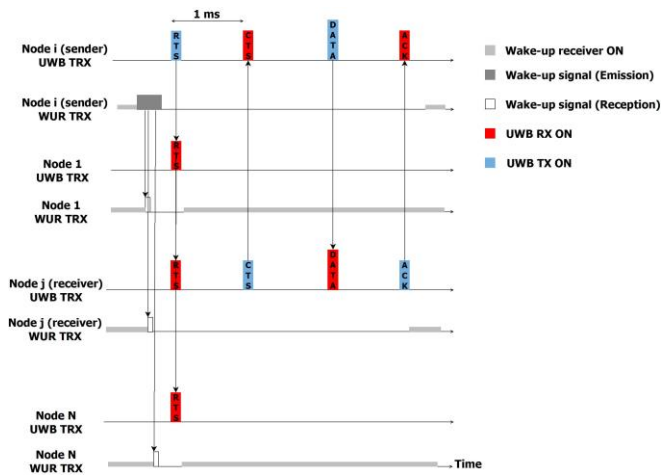


Figure 1- Timing of the proposed exchange protocol

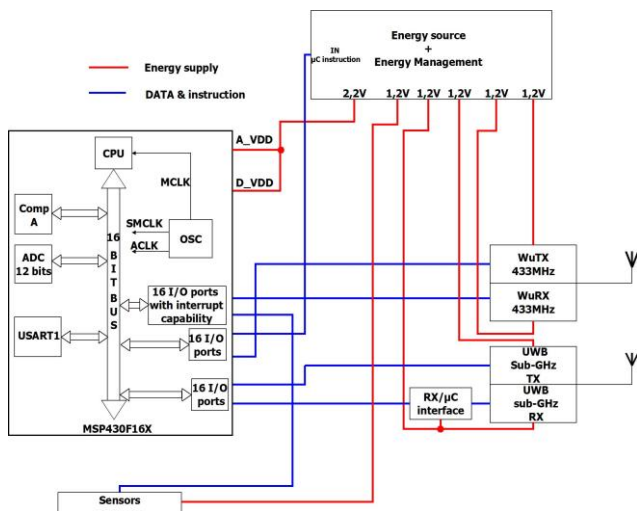


Figure 2- Sensor node's architecture

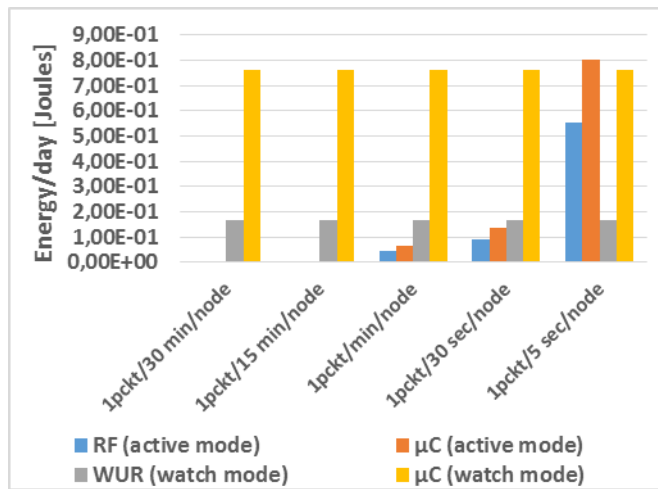


Figure 3- Energy consumption by day of hardware components as function of network activity for 20 nodes sensor network

Function	Power consumption	ref
Sub-GHz UWB TX	0.1mW @ 1Mbps	[6]
Sub-GHz UWB RX	0.6mW @ 1Mbps	[6]
Wake-up transceiver	VCO=2.16µA PA=7.7mA	*
Wake-up receiver	98nW	[4]
CPU MSP430f16 microcontroller	Active mode : 330µA @ 1MHz LPM0 : 50 µA @ 1MHz LPM2 : 11µA LPM3 : 1,1µA LPM4 : 0,2µA	[5]
ADC 12bit	0,65mA @ VDD=2,2V	[5]
CompA	25µA @ VDD=2,2V	[5]

Table 1- Power consumption of the sensor node's hardware components (\* : custom design in a 130nm CMOS technology base on architecture published in [7] [8])

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