Reduction of power consumption in wireless sensor networks through utilization of wake up strategies.

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Abstract: -Long-time operating wireless sensor networks in remote or harsh environmental conditions where maintenance is not simple or impossible to accomplish becoming more and more demand in industrial applications. Wake up strategies will help to expand the operational life cycle of sensor nodes where long life cycles are required. The lack of energy and no recharge possibilities are challenges of wireless sensors nodes. Wake up strategies can address these challenges by reducing the power consumption of senor nodes. The focus of this work is to compare wake up solutions for wireless sensors applications. The space diversity wake up strategy is described in details.

Key-Words: - Transceivers, Transducers, Shaped beam antennas, Sensor node, wireless Sensor, wake up strategy.

1 Introduction

A wake up strategy is a hardware or software solution added to a system or implemented within a system to reduce power consumption of an electronic device. In this case the electronic device is a wireless sensor node, designed to collect data and transmit data to a host system. A wake up solution allows reducing of the on-time of a sensor node, because thereby the sensor node can be online only when data is transferred to a host system [8].

The investigation of wake up strategies for wireless sensor nodes [1] is the focus of this work. A space diversity approach forms the basis on which the demonstration hardware has been designed.

2 Case studies

Two systems are compared in this case study. The self designed hardware demonstrator has the following specification:

specification	**value**	**description**
communication	2.45GHz	transceiver [6]
life cycle = T_{cycle}	1 year	minimum requirement
data update rate	1/d	once a day
power supply	battery	small lithium polymer
power consumption = P_{system}	30mA at 3,3Volts	
payload = $D_{payload}$	100 bytes	data to transmit
data rate = R_{speed}	250kbit/s	[3]
battery = $L_{Battery}$	4.8Ah	Lithium Polymer

Table 1 specification of hardware demonstrator

The scenario is chosen, because these are values which are commonly seen in industrial applications.

The wireless sensor transmits data only once a day to a data collector.

The comparison is based on the battery size; therefore the Ampere-hours for every solution are calculated.

The fist equation (1) show the battery size of a system where the sensor runs all the time during complete life cycle.

$$Bat_{size} = P_{system} \cdot T_{cycle} \quad (1)$$
$$262800mAh = 30mA \cdot 24h \cdot 365$$

The demand on energy storage capabilities calculated as weight representation in Kilograms is shown in equation (2).

$$weight_{complete\_Battery} = \frac{Bat_{size}}{L_{Battery}} \cdot weight_{cell} \quad (2)$$
$$6.0225kg = \frac{262800mAh}{4800mAh} \cdot 0.11kg$$

If the sensor node runs all the time of the complete operational life cycle, the battery weight will be about 6kg.

For comparison, is the second approach based on a wake up system. The transmit time of the sensor node is calculated in equation (3), it is necessary to get the overall on-time of the sensor node. A settling margin and time for initialization is added. The sensor node will be on for approximately 5s a day, which is $T_{cycle\_wake\_up}$. In equation (4) the on-time is used to calculate the battery size of this system with an implemented wake up functionality. The sensor node is powered up once a day for data collection.

$$t_{transmit} = \frac{D_{payload} \cdot 8}{R_{speed}} \quad (3)$$

$$0.0032s = \frac{100bytes \cdot 8}{250000bit/s}$$

$$Bat_{size} = P_{system} \cdot T_{cycle\_wake\_up} \quad (4)$$

$$15.2mAh = 30mA \cdot 0.001389h \cdot 365$$

A battery with 20mAh weights approx. 0.8g.
A system containing a wake up strategy will be much smaller and lighter when compared with a system without wake up feature.
The above example did not include the power consumption of the wake up strategy it assumes a passive strategy where only self discharge of the battery occurs. The power for wake up will be provided for example over the air-interface, in sleep mode the power consumption is near zero.

3 Overview of wake up strategies

All multiple access [2] strategies which are listed below are suitable for wireless sensor networks.

1. Time diversity [2]
2. Frequency diversity [2]
3. Code diversity [2]
4. Space diversity [2]

3.1 Time diversity

This wake up concept can be divided in two different approaches. First approach, the sender transmits periodically and also the receiver listens periodically. The time slot where the receiver is awake and scans must be longer than the transmit time. An overlapping between receiver and transmitter is therefore forced. A communication link can be established for data exchange.
The second possibility, a clock is running at the receiver side with dedicated wake up times for each sensor node. The clock will be synchronized with the master periodically. Every senor node is dedicated to a different wake up time to avoid communication collisions between sensor nodes.

3.2 Frequency diversity

A second frequency or channel is used to wake up a sensor node. This approach can be implemented in various options. One option could be a second receiver which runs on a complete different frequency band. For example a 2.45GHz sensor node is additionally equipped with a 125 kHz wake up receiver [5]. The second receiver is designed to decode the address and switches on the main communication path on the 2.45GHz band for data exchange.
Another approach, the 2.45GHz Frequency band is divided into channels so that each sensor group or sensor node is assigned to a special channel/frequency.

3.3 Code diversity

This wake up solutions broadcasts to all listener. The approach is often used in standard systems. Every sensor node wakes up and decodes the address. If the sensor node is addressed it stays awake and transmits the data back to the master. Otherwise the sensor node goes back into power saving mode.

3.4 Space diversity

A rotary antenna with a narrow beam or a MIMO antenna is used to divide the physically space around the antenna into fractions. This will allow scanning of single areas where only the sensor node within the scanned area is addressed and communicated to.

4 Space diversity wake up system

The space diversity wake up strategy is implemented at IMTEK to investigate the potentialities and to define the scope of this wake up strategy.

Set up at IMTEK:
The Sensors nodes PCBs are equipped with standard non-directional antennas. The communication Protocol is a proprietary design [9] which allows better interaction and transparency to the radio link. The transceiver offers the possibility to read the RSSI information, which will be used to estimate the distance. The Sensor Node is a completely proprietary development. Only the electrical components and parts are of the shelf.

sensor node	
sensors	• pressure, • temperature, • two axis acceleration • signal strength (in CC2420)
transceiver	TI CC2420 ZigBee ready [6]
µController	SiLabs C8051F311 [7]
battery	KOKAM 145 145mAh
size	25 mm x 30 mm

Table 2 specification of sensor code

The final sensor node PCB is shown in Figure 1.

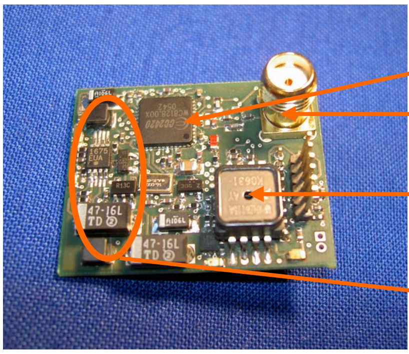

Fig. 1 PCB of wireless sensor node

rotary antenna	
shape	parabolic
opening angle	7.5° horizontally [4]
mechanical resolution	0.1° vertically 0.1° horizontally
size	1.5m x 1.3m

Table 3 specification of rotary antenna

The rotary antenna is a completely proprietary development; the beam antenna itself is bought from a supplier.

A star topology [1] is realized to show the basic principle of the wake up strategy. A master is equipped with a rotatable and inclinable beam antenna with 7.5 degrees opening angle shown in Figure 2.

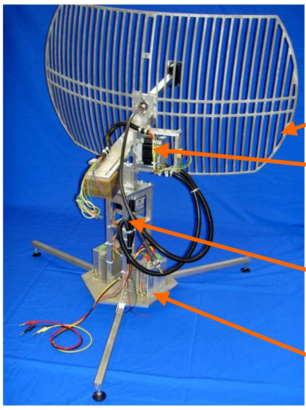

Fig. 2 Beam Antenna

The center of the systems is the master node and the rotary antenna. The sensor nodes are distributed around the centre. The master moves the rotary antenna until a sensor node is within the sector to address a data transmission will be established and data will be exchanged. The principle how the physical space is divided is shown in Figure 3.

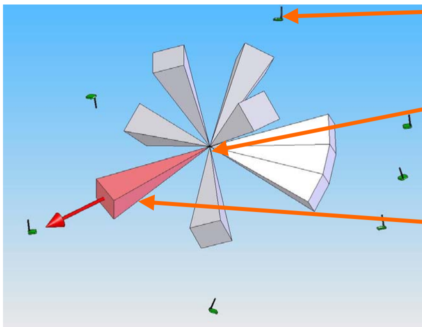

Fig. 3 Shows the principle how the space around the antenna is divided

The Master is used to scan the surrounding and builds up a map of the positions of the distributed sensor nodes. The sensor nodes are characterized by the following parameters.

1. Spherical sector where the strongest signal of the node has been measured. The information of the sector allows a latitude and longitude characterization of the position of the sensor node.

2. RSSI Value which will be interpreted as distance from the master to the node

3. Atmospherically pressure, which has been already, compared to the master atmospherically pressure value and only the difference will be stored. This allows a height estimation of the node. The estimated relative height of the node will be used to adjust the antenna.

4. Gravity measurement, a 2 axis acceleration value will provide the rest position of the node. This will help to judge the value for the distance. Since the RSSI Value is strongly dependent on the rest position of the node.

The parameter will be used to improve the map of the sensor nodes. Therefore a wake up call can be executed with precise position of the rotary antenna. This implies if the antenna is positioned correctly the wake up call will reach only the sensor node which is in the beam area. All other nodes are not affected and stay in power saving mode.

In the first step two power levels are defined for the wake up call. If the RF-power exceeds a limit the RF transceiver is switched on and starts decoding the address.

The RSSI value will also help to reduce the transmit power, which lowers the probability for multipath propagation at the sensor node.

The spherical sector will help to position the antenna in the correct area to avoid scanning of the whole sensor node network scenario again.

The relative altitude of the nodes extracted from the atmospherically pressure will help to judge the position of the antenna. Furthermore the RSSI value will be checked for plausibility corresponding on the atmospherically pressure.

The acceleration sensor on the sensor node will provide the gravity information and therefore the orientation of the antenna of the Sensor node. The RSSI value will be evaluated and compared with the gravity information. If the antenna beam [4] of the master will be oriented horizontally and the Sensor node antenna will not be orientated horizontally they still communicate but the signal strength of the RSSI Value will be weaker and care must be taken for distance approximation based on this weaker RSSI signal.

The above mentioned solution allows a loop back implementation and a kind of self plausibility check. It makes the system more robust and will help to avoid wrong wake up calls which will miss the addressed sensor node.

5. Conclusion

If all parameters are taken into consideration for building the map on the master side, it is possible to address each single sensor node. Furthermore, a communication with sensor nodes can be achieved by not waking up all other nodes. The further work will show how precise the wake up call works in a long term test and will also show the energy saving potential.

6. Expected results

The space diversity wake up principle has to prove it potential for a wake up strategy which will save power and allows sensor nodes to operate over a long time period. Also the functionality of the sensor implemented into the realisation has to show their efficiency and prove the desired functionality in a wake up system.

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