
Institute of Embedded Systems (InES)

Wireless group

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A Battery-less switch for 802.15.4 wireless
networks

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2nd European zigBee developer's conference

June 2008

Outline

1. Introduction and proposal
2. Challenges
3. Assumptions
4. Design
5. Results
6. Open points and future work
7. Conclusions + Demonstration (?)

Who we are

University of applied sciences at Winterthur (Kanton Zuerich)

Largest of that type in Switzerland

Interdisciplinary

Institute of embedded Systems (teaching + research)

Active in Industrial communications (wired and wireless)

Real time communication using ethernet

More than 7 Lecturers and 20 engineers

Projects with industry

Who we are (Wireless group of InES)

Wireless PAN systems (BT, 802.15.4, ZigBee),
PSoC

WirelessUSB, ANTS, nanotron...

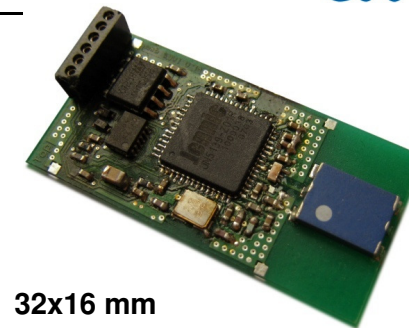
RFID (125 KHz...UHF), RFID radar, pairing

Activities in energy harvesting, positioning

**Multichannel 802.15.4 Sniffer (all channels,
several locations, real time, less than 1
microsec resolution)**

WireBee

Ethernet to 802.15.4 / ZigBee Gateway with
Power Over Ethernet implementation (range > 1
Km) **Install and Forget**



32x16 mm

32-bit micro+radio

802.15.4 / ZigBee compatible

Portable RFID reader
with Wireless link

Single chip (PSoC)



27.06.2008

4

1. Introduction and proposal

Switches are basic elements, and have many uses in a network.

Turn lamps ON/OFF.

Control opening / closing of doors, control motors.

Send an alarm or an attention request signal (patients needing attention of nurse). ...

**Very simple elements, but used in millions.
Fundamental in automation, and also in wireless automation.**

1. Introduction and proposal

There are switches in use in wireless automation.

Wireless switches often need batteries.

Not maintenance friendly.

Add up costs.

Does not encourage people to install them in large quantities.

Batteries needed because of the autonomy and the amount of energy needed to do the job.

1. Introduction and proposal

There are also wireless switches on the market that do not need batteries.

Replace battery by energy harvester (piezzo or electro-dynamic energy generator).

Firm EnOcean has some very good products.

Data is sent with little overhead. Unidirectional communication.

Short messages, sent several times at high Bit Rate.

Reliable products, needing little energy.

1. Introduction and proposal

Drawbacks

Proprietary.

Unidirectional (not easy to work with other elements).

Little overhead is good, but also means less flexibility.

Advantages of 802.15.4 based wireless systems.

more flexibility, more manufacturers (hopefully also users in the future), broader base.

Cheaper components, better acceptance.

1. Introduction and proposal

Proposal

Design a simple switch for 802.15.4 based networks,
that does not need batteries.

Starting point:

Low power 802.15.4 compatible devices.

Use a popular EH module .

Get it to work with some ZB nodes.

2. Challenges

Energy needs

Get enough power to do the work

Get the work to fit the power available

There are constraints for 802.15.4 / ZB networks

Large overhead

TX / RX (at least CCA for a switch)

Profiles (which mean compatibility and more overhead)

2. Challenges

Different types of EH (approximate power with 1kOhm load)

Electro dynamic (90 μ J)

Shake (21 mJ)

Hand dynamo (23mJ, 42mJ)

Piezzo (not used here)

Work done with ECO100



2. Challenges

Energy used for:

Sending data, receiving own data

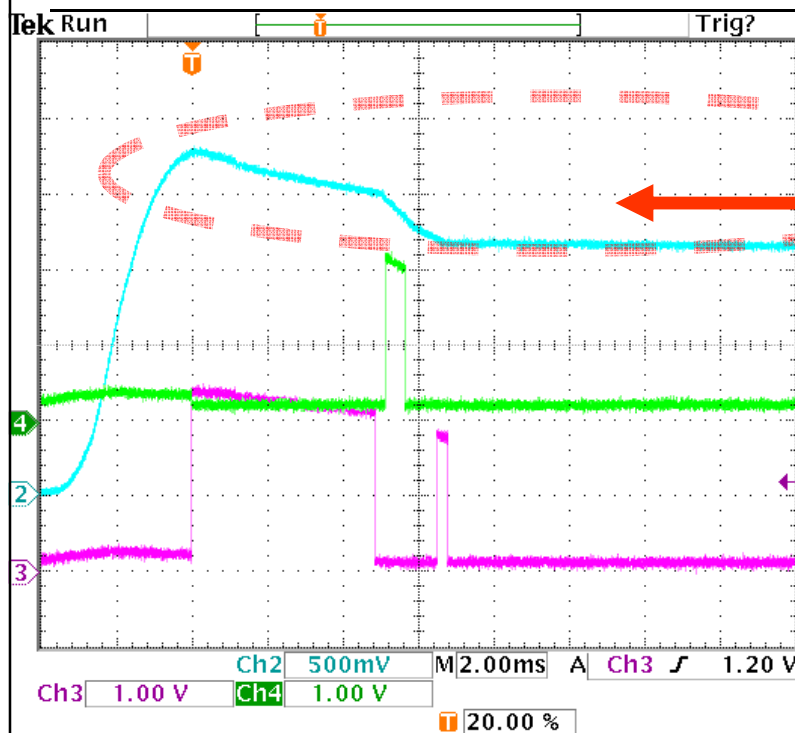
Listening to traffic (data of others)

Best 802.15.4 Transceivers on the market still need about 15mA(RX), 10-20 mA to send (beware typical and max values). But getting better.

Microcontrollers need about 0.5 mA – 0.1 mA at 1 Mips

Most components need at least 1.8 V

2. Challenges



You need energy, but the voltage must also be high enough

Work must be done here

Voltage too high you loose energy

Too low: the system does not work

ch2 is voltage from the harvester with transceiver + micro as load

ch3 and ch4 show micro activity

27.06.2008

23 Jan 2008
14:53:39

13

2. Challenges

Some calculations:

Receive for 100 microsec @ 15 mA / 2V (3 microJ)

Send for 1 millisecc with 15 mA / 2V (30 microJ)

Add microcontroller activity (initialise transceiver)

Add microcontroller start up energy

Add oscillator stabilisation energy (needed for transceiver)

Add energy needed for Non-Volatile memory

Good energy management needed

Low power devices

Get rid of all that is not needed in the communication protocol

3. Assumptions

There is very little energy available. So we use it only for the vital functions.

Send a message to inform the corresponding end point about the state of the switch.

MAC acknowledgement is not necessary

APS acknowledgement is not necessary (If the lamp is not switched on, the user will press the switch again)

This will correspond to about 30 bytes on the MAC layer

3. Assumptions

This means that the switch needs to do the following when activated

CCA to ensure that the channel is not busy

(this will cost receive power for some microseconds)

Send the needed bytes

(Most of the power is used here)

Update a counter and save it in non volatile memory (or generate the counter value in a random way)

(The power needed depends on the type of non volatile memory)

Eventually one could also:

Switch on the receiver for a MAC acknowledge and resend data

(Extra power needed for receive and transmit)

3. Assumptions

Raw data in hex (set up used with Adhoco switch)

61 88 64 23 00 00 00 6F 79 48 00 00 00 6F 79 0A D1 00 0A 06 00 04 01 10 5C 11 53 02

02 00 64 (ACK)

61 88 64 23 00 00 00 6F 79 48 00 00 00 6F 79 0A D1 00 0A 06 00 04 01 10 5D 11 53 02

02 00 64 (ACK)

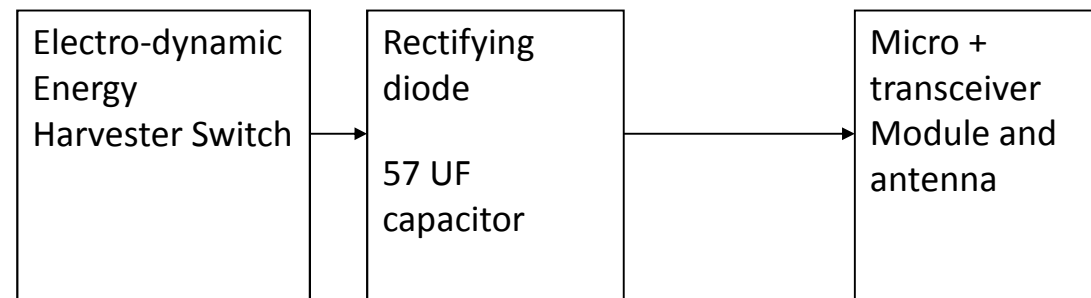
Counter

Message blocks with different network set ups to send switch data

Length	Frame control field						Sequence number	Dest. PAN	Dest. Address	Source Address
	Type	Sec	Pnd	Ack.req	PAN_compr					
31	DATA	0	0	1	1	0x64	0x1AAA	0x0000	0x796F	
MAC payload						NWK Frame control field				
4E 00 00 00 6F 79 0A D1 00 08						Type Version DR GA Sec				
0E 00 04 01 08 3F 11 53 02 00						DATA 0x2 1 0 0				
NWK Dest. Address		NWK Src. Address		Broadcast Radius	Broadcast Seq.num	NWK payload				
0x0000		0x796F		0x0A	0xD1	00 08 06 00 04 01 08 3F 11 53 02 00				
APS Frame control field				APS Dest. Endpoint	APS Cluster Id	APS Profile Id	APS Src. Endpoint	APS Payload	LQI	FCS
Type	Del.mode	Ind.am	Sec Ack	0x08	0x06	0x0400	0x01	08 3F 11 53 02 00	188	OK
Data Unicast				0	0	0				

Switch data used with BeeKit (counter is 3F)

4. Design



Block diagram of the wireless switch

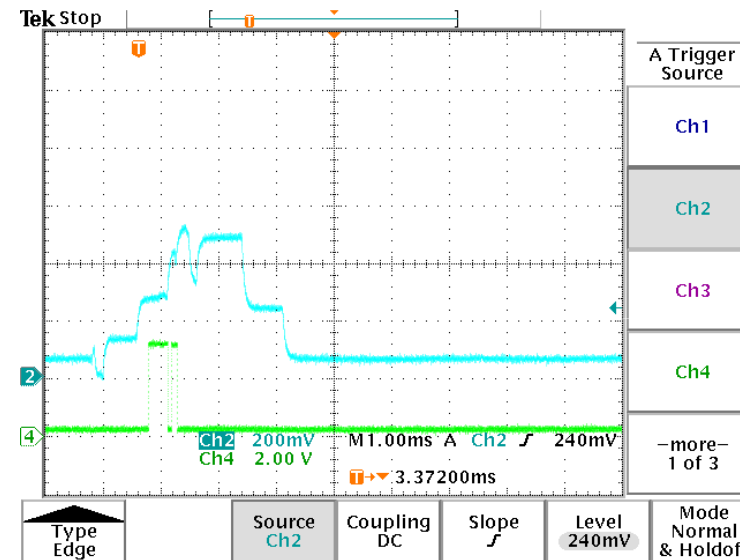
4. Effect of non volatile EEPROM

Current measurement at
3Volts (ch 2) Micro
activity (ch 4) ($I(\text{mA}) =$
 0.075 vout (mV))

Micro at 8MHz

EEPROM Read/write

CCA and Switch data
sent



4. Design

Electro-dynamic harvester

Battery-less module

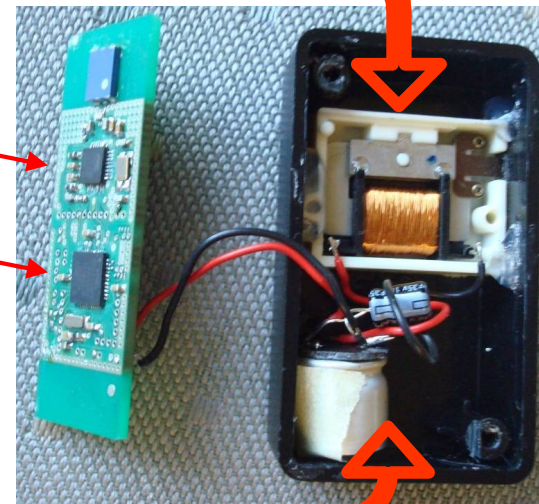
Transceiver RF230 (Atmel)

8-bit micro from Atmel, with
EEPROM (e.g. For APS
counter)

Module Programmed as End
point

Diode and capacitors

Only 1 direction is used to
generate energy (possible to
use 2 directions for more
energy)



5. Results (Lamp)

220 V lamp

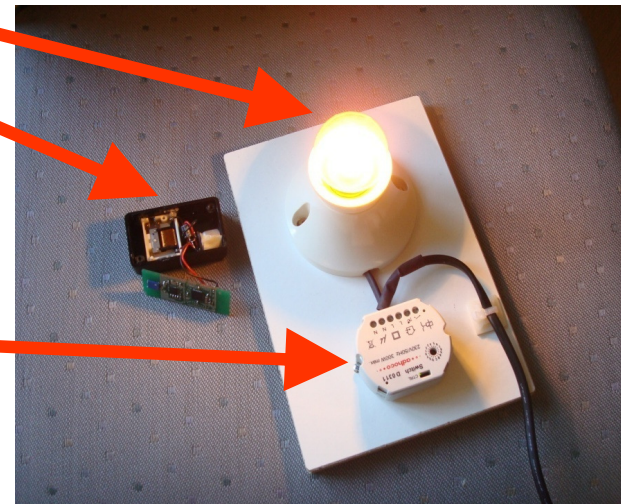
Battery-less module

ZB compatible relays from
Adhoco

TI micro + transceiver

Would also work with other systems

We have tried Beekit of
Freescale



5. Results

Setup with Adhoco relais
Processor running at 8 MHz, channel 0x1A,
EEPROM update, Max radio output

Packet index: 3 Length: 30

Raw data (hex): 61 88 64 23 00 00 00 6F 79 48 00 00 00 6F 79 0A D1 00
0A 06 00 04 01 10 5D 11 53 02

RSSI [dBm]: -58 Correlation value: 108 CRC OK: 1

Packet index: 4 Length: 5

Raw data (hex): 02 00 64

RSSI [dBm]: -59 Correlation value: 107 CRC OK: 1

Packet index: 5 Length: 30

Raw data (hex): 61 88 64 23 00 00 00 6F 79 48 00 00 00 6F 79 0A D1 00
0A 06 00 04 01 10 5E 11 53 02

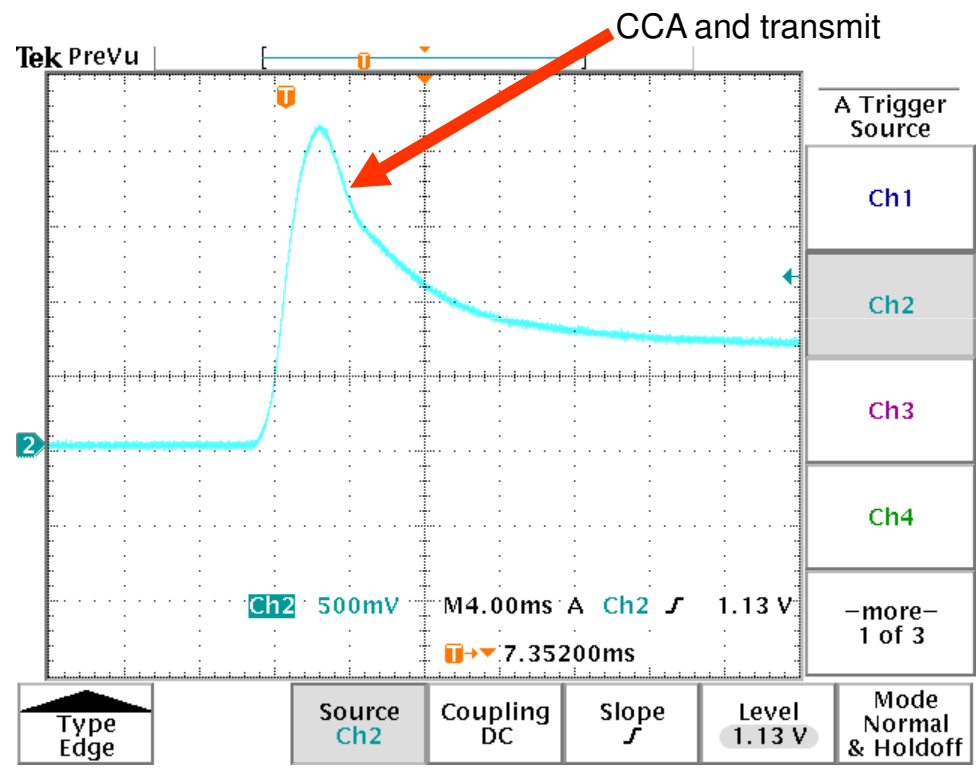
RSSI [dBm]: -53 Correlation value: 104 CRC OK: 1

Packet index: 6 Length: 5

Raw data (hex): 02 00 64

RSSI [dBm]: -57 Correlation value: 107 CRC OK: 1

5. Results



6. What about joining

Use commissioning tools

Use another module that will write the needed data into the switch

Mix battery and EH

Provide more energy at the set up time

6. What about frequency changes

If the network is started anew in another channel.

The battery-less module cannot join on its own using 100 microjoule

What could be done:

Mix battery and battery-less

Provide more energy to get the switch to start a scan and join the network, but keep its pairing parameters.

7. Future work

Improve and optimize power consumption.

Optimize software and reduce leakage.

Use lowest power microcontroller on the market.

(Micro x: $< 100 \mu\text{A}$ @ 1 MIPS, works down to 0.9 V)

Integration in the ZB network.

Add pairing functions.

Install by contact (easy for all).

Investigate different configurations to join network.

Conclusion

Battery-less switches in a 802.15.4 / ZigBee network is feasible.

Easy + no maintenance.

The switch can be associated to a fully compatible device at installation, or can be fitted in the system using commissioning tools or pairing.

User friendliness can be affected if there are frequent channel changes.

Thanks

Adhoco (Winterthur) for providing a ZB relais

Freescale for providing the BeeKit

Meshnetics (DE), Atmel for providing ICs

Anatec (CH) for components

Firm x for infos about new low power 8-Bit
micro (0.9 V, < 100uA @ 1 Mips). Contact with
firm x possible on request (contact author).

Demo

Questions ???

More questions? Need help?

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