Autonomous Sensor Networks

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- Wireless Sensing & Acting Networks (WSANs)
- Short report on the EEC-funded project EYES
- Hardware implementation considerations and application driven development
- Standardisation issues

Introduction

- Wireless Sensing and Acting Networks are a key technology platform for a wide range of applications emerging out of academic work today

Infrastructure

Agriculture environmental monitoring

Automotive

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WSAN features

- Very low raw data rate: few kBits/s
- Very low amount of data: couple of Bytes
- Short to medium ranges: tens of feet/meters
- Very long lifetime requirements
  - up to several years
  - unattended operation
- Energy aware design
  - over all layers of protocol stack
  - utilising energy aware hardware building blocks and design methodology
- Harsh environment
- Self-(re)configuring, ad-hoc establishment and maintenance of network
- Embedded Systems offering redundancy due to high number of nodes within network

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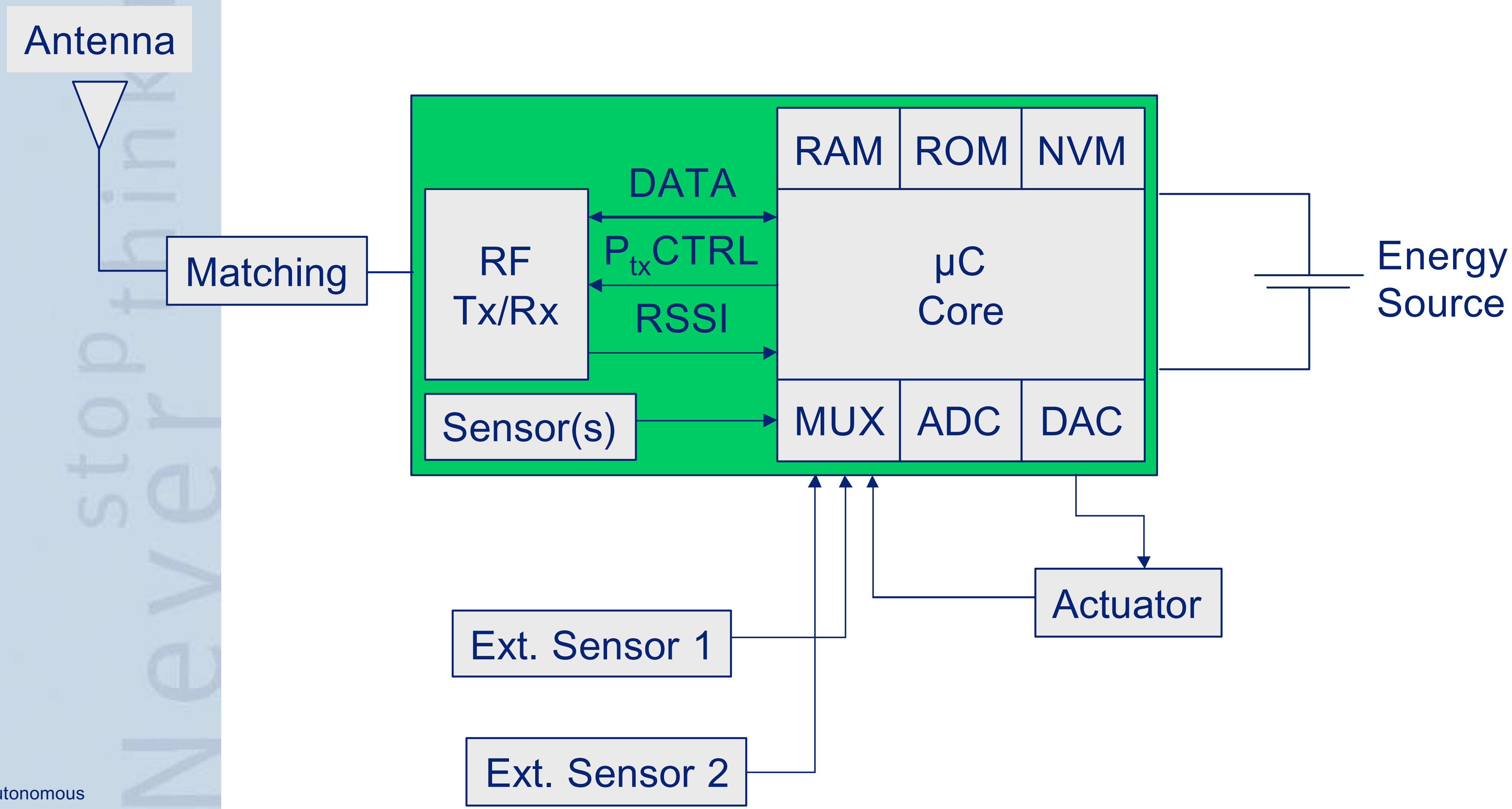
WSANs vs. Bluetooth

	Bluetooth	Wireless Sensor and Acting Networks
Frequency	2.4 GHz	315/45, 434, 868, 915 MHz 2,4 and 5,6GHz
Frequency Allocation	worldwide available	f < 1GHz: country dependent f > 1GHz: worldwide available
Protocol scheme	Bluetooth SIG	mostly proprietary 802.15.4 / ZigBee, etc.
Datarate	typ. 730 kbit/s max. 2 Mbit/s	typ. 10 kbit/s max. 100 kbit/s
Power Emission	1 mW (0 dBm) 10 mW (10 dBm)	frequency dependent max. 10 mW
Power Consumption	active (0 dBm) = 30 mA idle = 300 µA	active (0 dBm) = 10 mA idle < 100 nA
BoM	~ 7 €	< 2 €

WSAN node architecture – general overview



EYES - Energy Efficient Sensor Networks

The goal of the *EYES* project was to develop the **architecture** and the **technology** which enables the creation of a new generation of **self-organising** and **collaborative** sensors that can effectively **network** together so as to provide a flexible platform for the support of a large variety of mobile sensor network applications

- An EEC funded project – first of it's kind in Europe
- Fundamental research to provide theoretical foundation for future work
- Exploration of architectural and protocol options
- Principal insights into tradeoffs and design criteria not available at the beginning of the project
- Definition of requirements for hardware and software

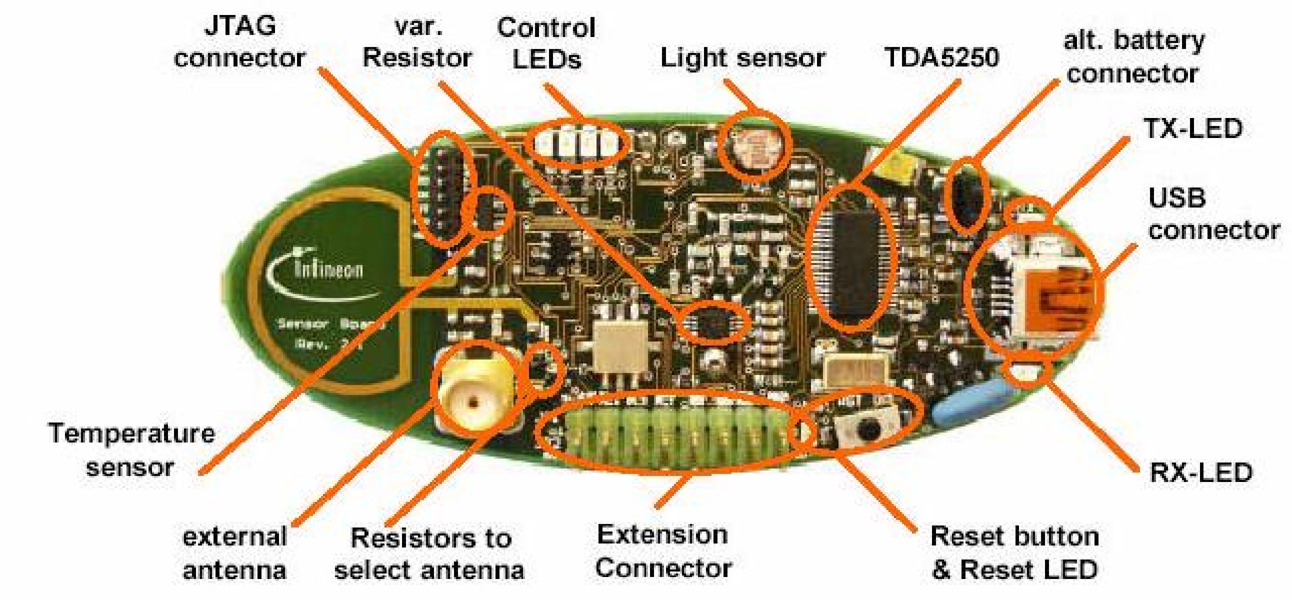
EYES consortium

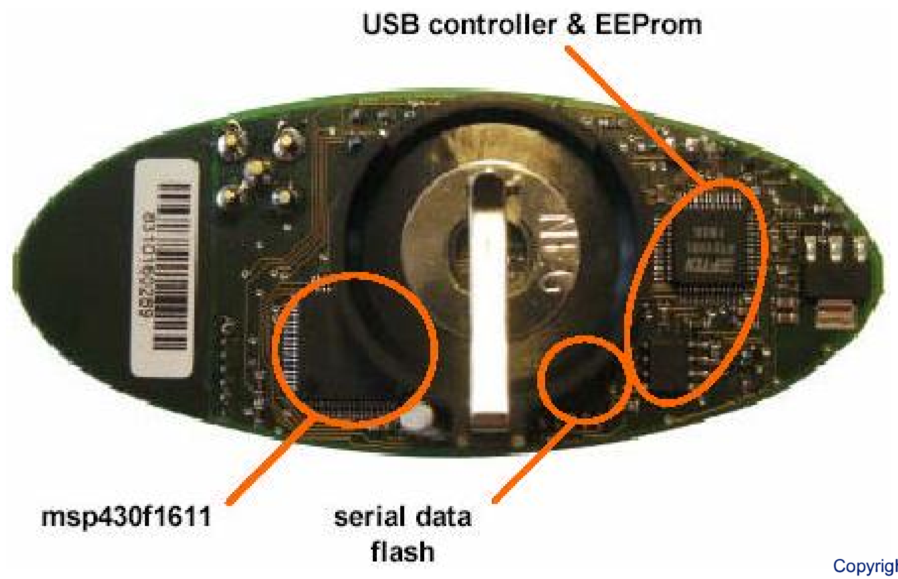
- University of Twente / CTIT, the Netherlands
- NEDAP, the Netherlands
- Technical University of Berlin, Germany
- CNIT, Italy
- University of Rome, Italy
- Infineon Technologies, Austria

Fields of work within the EYES - project

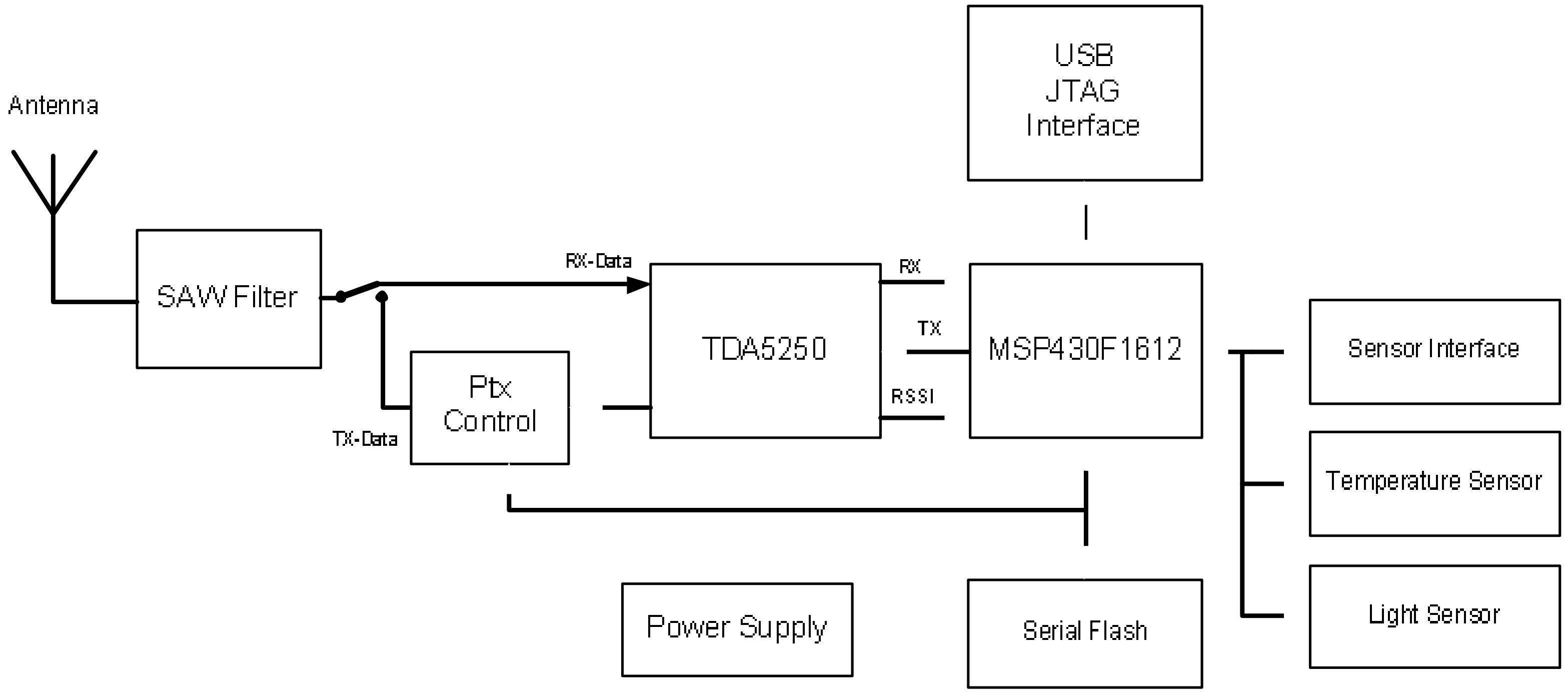
- Energy efficient node hardware investigations and designs
- Porting of TinyOS on MSP430 and EYESnode hardware
- Protocol design
  - Lightweight Medium Access Protocols
  - Multipath Routing Protocols
  - Geographic Random Forwarding Algorithms
- Localization
- Distributed services
  - Consensus
  - Semantic addressing
  - Service discovery
  - Security
    - Cryptographic primitives, Key management schemes
    - Link layer security against jamming
    - Authentication and efficient key discovery, Intrusion response

The *eyesIFX* WSAN node





eyesIFX WSAN node architecture



eyesIFX node specification

- Supply Voltage: 3V, Li-coin cell
- Current consumption:
  - Sleep mode 8.95 µA
  - Transmit mode 11,95mA @ 4dBm
  - Receive mode: 9.42mA
- Modulation: FSK
- Transmit frequency: 868,3 MHz
- Data rate: 19,2 kBps
- Adjustable transmit power (-35 to +4dBm)

- RAM size 10 kByte
- ROM size 48 kByte
- Serial data flash size: 4MBit

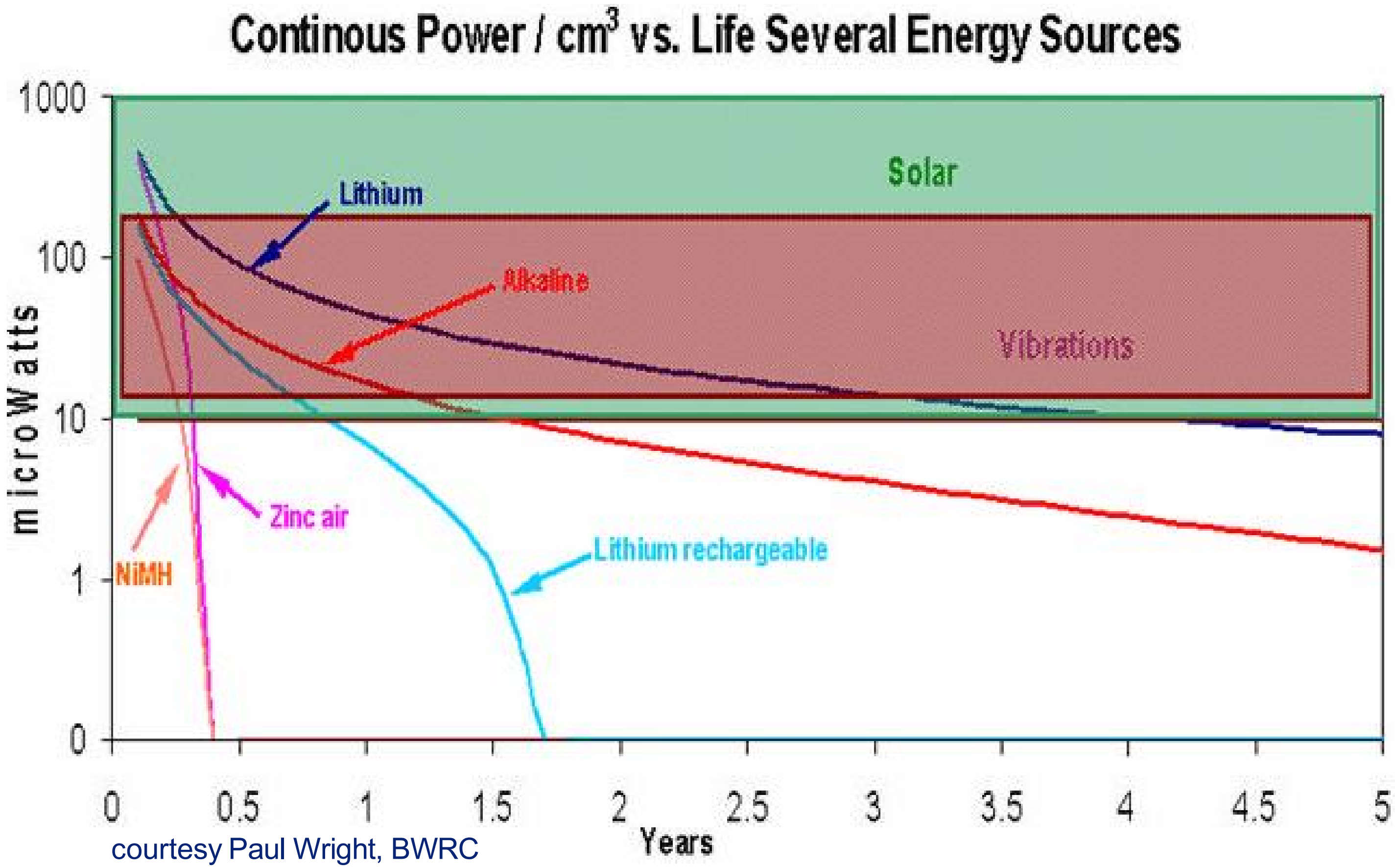
- Sensors on board: Light, Temperature, RSSI
- Multi-I/O port extender, USB-interface, JTAG-interface

TinyOS operating system

- Is an *open-source operating system* designed for *wireless embedded sensor networks*
- Features a *component-based architecture* enabling rapid innovation and implementation while minimizing code size
- It‘s *component library* includes network protocols, distributed services, sensor drivers, and data acquisition tools
- It‘s *event-driven execution model* enables fine-grained power management yet allows the scheduling flexibility made necessary by the unpredictable nature of wireless communication and physical world interfaces
- Was ported to *eyesIFX* network node processor providing a stable platform for investigating protocol implementations e.g. on the TU Berlin large-scale demonstrator network (100^{+} nodes)
- Can be regarded as means for quick evaluation and implementation of Wireless Sensor Networks based on large number of open-source projects
- Proprietary solutions will prevail

Hardware Building Blocks

- Stripline Antenna
- Primary or Secondary Battery, alternatives?



courtesy Paul Wright, BWRC

It all depends on the application …

- The application is determining topics like
  - The amount of data to be transferred
  - The expected throughput
  - The acceptable latency time
  - The environment:
    - Ambient temperature range
    - ISM band frequency, applicable standards
    - Interference scenario
  - Energy supply, possible use of energy scavenging
- Truly energy efficient networks are only possible keeping energy awareness over all layers of the implementation

… to define hardware and protocols

- Amount of data with latency and throughput requirements dictates data rate and duty cycles
- Environment dictates modulation format and choice of error correction (ARQ vs. FEC)
- Trade off distance with robustness of link
- The system is most likely battery-powered
- Alternatively the energy needed is generated from the environment, by energy scavenging
- Hardware has to consume minimum power

Technical Demands and Constraints for Heterogeneous Machine Interoperation

- Simple installation and configuration of the system.
- Transparent and dynamic inter-device communication (e.g. wireless ad-hoc network, power line).

⇨ Cheap and low-power technical implementation.

⇨ Device interaction must rely on a

– widely accepted,

– open, and

– extensible standard

on the application layer regarding the “language” for device control.

⇨ Device control must be semantic.

Universal Plug and Play

- Open standard for machine-to-machine communication based on internet protocols
- Peer-to-peer networking architecture based on common protocols
- UPnP is platform and operating system independent
- Devices can
  - dynamically join a network
  - obtain an IP address
  - convey their capabilities
  - learn about the presence and capabilities of other devices
  - control other devices and be controlled by other devices using standardized access mechanisms (control and eventing)

Universal Plug and Play Standardization

- **UPnP Device Architecture** specifies a general framework common to each UPnP device
  - Current version is 1.01
  - Version 2.0 is still in draft with limited momentum
- Specification of the UPnP Device Architecture is driven by Steering Committee (20 major companies, e.g. Microsoft, Intel, IBM, Samsung, Siemens, …)
- **Device Specifications** (DCPs) are driven by Working Groups of the UPnP Forum (>700 member companies):
  - Definition of minimal functionality a certain device must have, but vendors may implement additional functionalities
  - Open review before standardization (including at least three reference implementations), final decision by Steering Committee

Other standards: EIB/KNX RF

- **Home automation present in modern real estate since years in wired systems, EIB, standardised in ISO**
- **Open platform (no royalties as opposed to competing emerging standards)**
- **European Installation Bus** (**EIB**) is the world's leading system for "intelligent" electrical installation networking. The bus cable installed in addition to the supply cable combines devices and systems (e.g. heating, lighting or ventilation), which previously functioned separately from one another, into an economical system optimally adapted to individual requirements. Both now and in the future, this domestic network provides new functions which previously were either very difficult to implement or could not be implemented at all.

Outlook

- The next years will see development of single-chip or multi-chip modules dedicated to ultra-low power WSAN hardware
- 3-dimensional integration will provide low feature sizes and low cost
- The node energy consumption will be as low as to allow for energy scavenging
- New frequency bands will be addressed
- New standards will evolve and/or exisiting will be enhanced to allow for ultra-low power operation

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Thank you for your attention!

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