e-SENSE Project: WP3

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Efficient and Light-weight Wireless Sensor Network Communications

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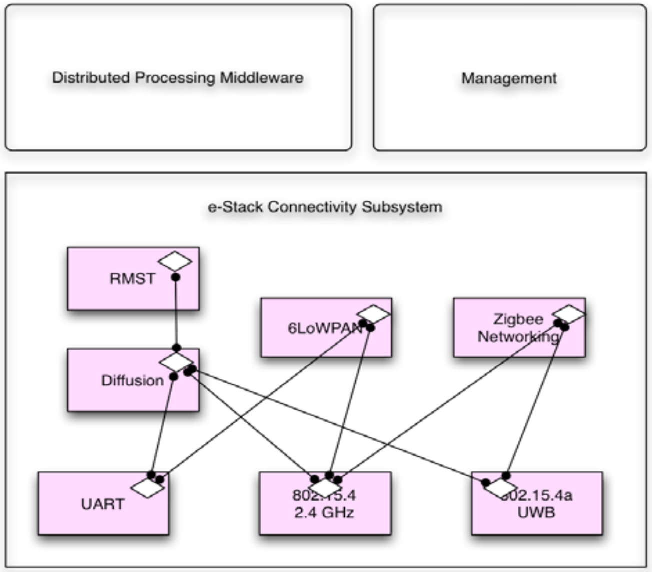
Introduction

- The e-SENSE project aims at providing outstanding architectural and communication solutions especially for convergent sensor networks.
- Use case themes:
  - Lifestyle management
  - Wireless healthcare
  - Asset management
- Aims at:
  - radio SoC solutions with 1/10th power consumption of commercial chips.
  - A reconfigurable protocol stack concept, e-Stack.
- The overall goal:
  - Optimise the key metrics of any use-case scenario.
  - Still provide flexibility and context to the upper layers.



Energy Efficient Air Interfaces for WSNs

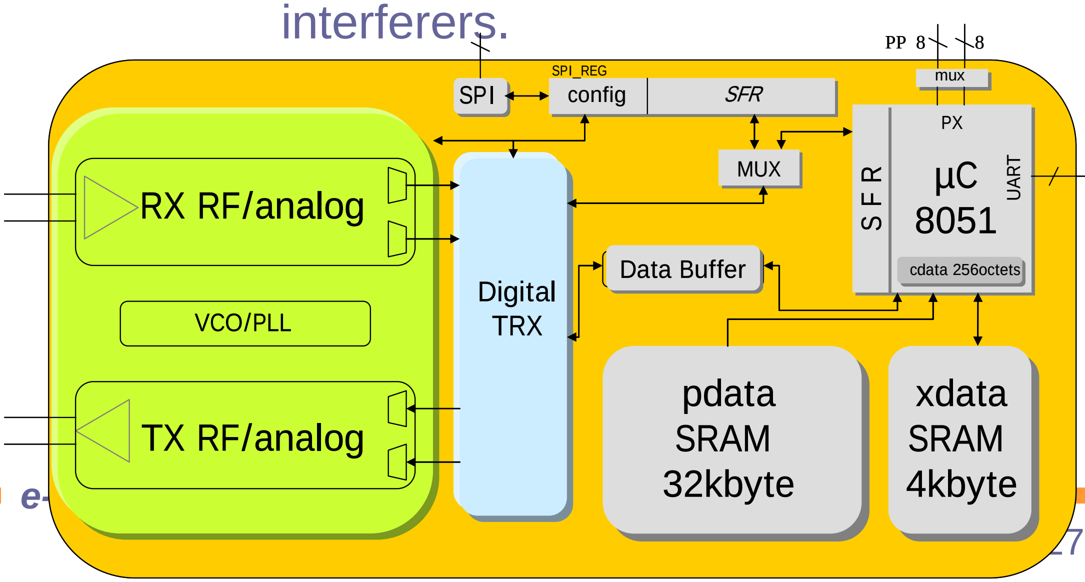
A. Adaptation of existing interfaces

- Since IEEE 802.15.4x are defined to fulfil WSN applications:
  - Use as starting points.
  - The 15.4 PHY layer will be used to benchmark energy efficient RF design and implementation.
  - The 15.4a UWB PHY will be studied at architecture and model levels.
- RF front end goals of e-Sense:
  - Find aggressive architectural and design compromises towards 1/10th power consumption.
  - To exploit new RF component characteristics such as RF MEMs.
    - possible to rethink RF architecture choices form the start.
- The goals for UWB:
  - To provide PHY layer abstraction models compatible with the IEEE 802.1.5.4a draft standard which are usable for cross-layer analyses, simulations, and optimisations.

Energy Efficient Air Interfaces for WSNs (cont.)

B. Physical layer modelling

- Mostly by Matlab and C/C++ tools.
  - Used to characterise the theoretical PHY layer performance:
    - packet error rate in different channel conditions,
    - the transceiver performance upon design; implementation losses and sensitivity to in-band and out-of-band interferers.



- Link level simulations include precise models of analogue impairments.
- System or network simulators can not afford embedding realistic link level simulators.
  - Derive accurate abstraction models either analytical or table-based, to be used in system simulators.

e-SENSE targets to provide such models for the identified standards.

Energy Efficient Air Interfaces for WSNs (cont.)

C. Ultra Low Power Transceivers

- Close cooperation between system/architecture and chip designers.
- The modelling used to compare and to select architectures taking into account design techniques suited for low power.
  - weak inversion in CMOS
  - RF MEMs
  - novel digital compensation techniques an option.
- Channel state information can be used to dynamically adapt the receiver power consumption vs. performance tradeoff.
- The e-SENSE will report on such innovative methodologies:
  - **An ultra low power implementation of an IEEE 802.15.4 compliant transceiver.**

Energy Efficient Air Interfaces for WSNs (cont.)

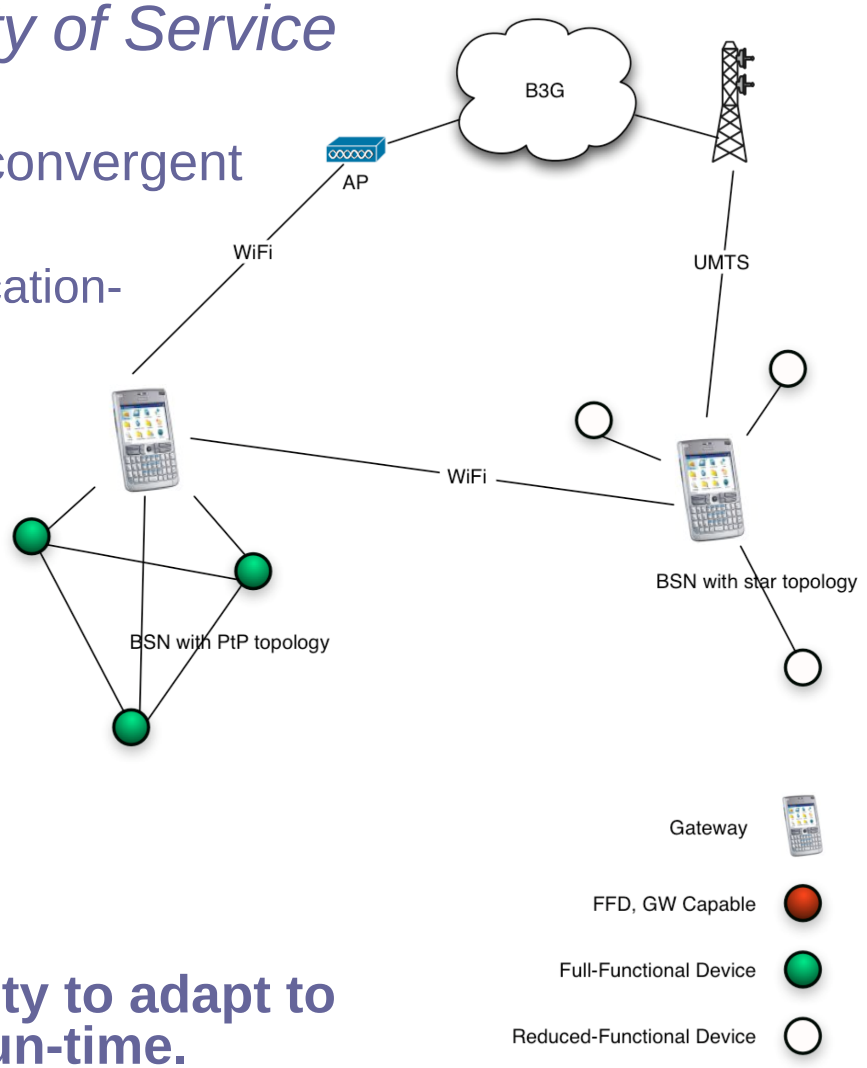
D. RF sensing for Context and Situation Awareness

- The concept embraces metrics and pieces of information separate from the transported payload itself.
  - The parameters are:
    - classically received signal strength,
    - time of arrival and angle of arrival,
    - channel state information, etc.
  - May be available with practically no extra cost and provide meaningful information on the environment and the situation.
  - With the application sensor data, the knowledge of the environment and the context may be enriched for application purposes.
- In e-SENSE the principal investigated technologies:
  - RSSI algorithms,
  - compact antenna arrays for UWB,
  - ranging performance for UWB.

Efficient Protocol Elements

A. Application Dependent Quality of Service

- Need for standard WSN solutions convergent with B3G networks.
  - Flexible enough to solve real application-specific requirements.
- e-SENSE themes:
  - wireless healthcare
  - personal lifestyle management
  - asset tracking
- *Requirements in terms of, e.g.*
  - *topology and network size*
  - *energy and context requirements*
  - *traffic models*
  - *reliability and security.*



- **The e-Stack provides the flexibility to adapt to these either at compile-time or run-time.**

Protocol Elements (cont.)

B. Self-organisation and Topology Control

- Energy efficiency in
  - topology formation, management, and maintenance.
- The impact of different logical topologies and organisations on performance and energy efficiency will be assessed.
- The goal:
  - a proposal for application dependant self-organisation.

- Topology control plays a key role in maximising the lifetime of the network
  - power control
  - duty cycling (distributed computation)
- The trade-offs in clustering (performance criteria) analysed
- The boundary to cluster the network (network density and traffic patterns) identified.

Protocol Elements (cont.)

C. Sensor Protocols

- Existing solutions for WSNs are often developed independently.
  - Optimisation of a subset of layers.
  - limited number of performance metrics:
    - network lifetime,
    - power efficiency,
    - delay, etc.
- The need for new protocols is motivated by the lack of truly comprehensive, adaptable, self-starting, and scalable solutions.
  - Joint responsibility in dealing with the constraints arising in WSNs.
- While piconets have many enticing properties, a serious deficiency exists; the inability to communicate with each other without topology changes.
  - A goal is to provide a rapid access channel for piconets.
    - contention access techniques used.
    - provides coexistence and short service communication with low delay.

Protocol Elements (cont.)

D. Mobility and Internetworking

- In a number of scenarios mobility is an issue
  - Take into account during protocol design.
  - e.g., sensors in a shopping mall to offer context-aware services.
    - Inherent mobility of the customers entering the site.
- Augmenting sensor networks with motion.
  - exploit the potential surplus of nodes to enhance sensing while improving the network's performance.
- Mobility needed when the specific area of interest is unknown during deployment.
  - Animal herd migration.
- Nodes closer to the sink suffer from higher energy consumption than nodes far away.
  - Sink movement.

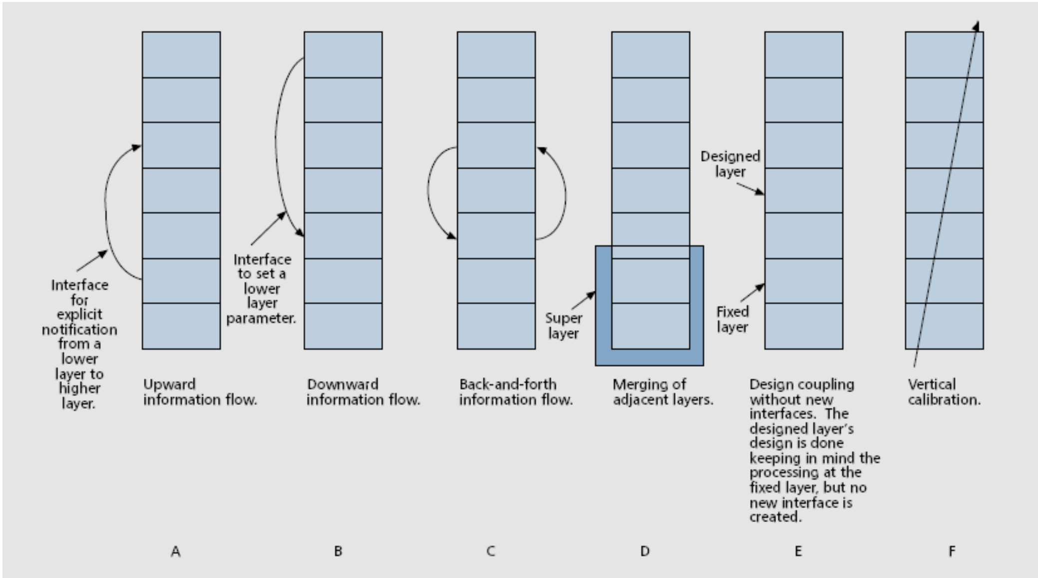
Cross-layer Optimisation

A. Cross-layer Analysis

- Cross-layer design potentially leads to better performance.
  - protocols that actively exploit the dependence between stack layers to obtain performance gains.

Examples:

- Channel condition status used by the link layer to adapt its error-control mechanism.
- The number of retransmissions at the link layer can serve as a measure of channel condition to transport.
- The error control mechanism of the link layer can be adapted according to transport retransmission timer information.



Cross-layer (cont.)

- **Cross-layer design is a crucial topic for the e-SENSE project as it enables further improvements than a single layer design.**

B. Proof of Concept Platform

- hardware proof-of-concept platforms designed.
  - Ultra low-power transceiver targeting an active power consumption of 1/10th of the PHY layer compatible with the IEEE 802.15.4.
  - Compact antenna array suited for UWB in the 6-10 GHz band with beam forming capabilities.
  - e-Stack.

Conclusions

- The FP6 e-SENSE project aims at providing outstanding architectural and communication solutions especially for B3G convergent sensor networks.
- The diversity of use cases demand the development of a new reconfigurable protocol stack concept, called the e-Stack.
- Rather than introducing proprietary solutions, WP3 provides solutions and highly optimised improvements for IEEE 802.15.4 evolution standards.

Thank You

Questions?

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