Accurate Sensor Node Energy Consumption Estimation Using EdiMote Prototyping Platform

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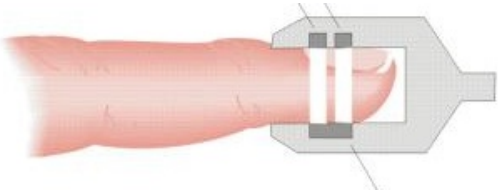
The Third International Workshop on Networks of Cooperating Objects

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Motivation

- WSN application spectrum is wide
  - Medicine
  - ...
  - agriculture

Pulse-oximeter sensor



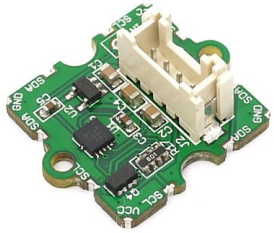
Humidity and temperature sensor



Light sensor



Accelerometer



Commercially available sensor nodes



EPIC



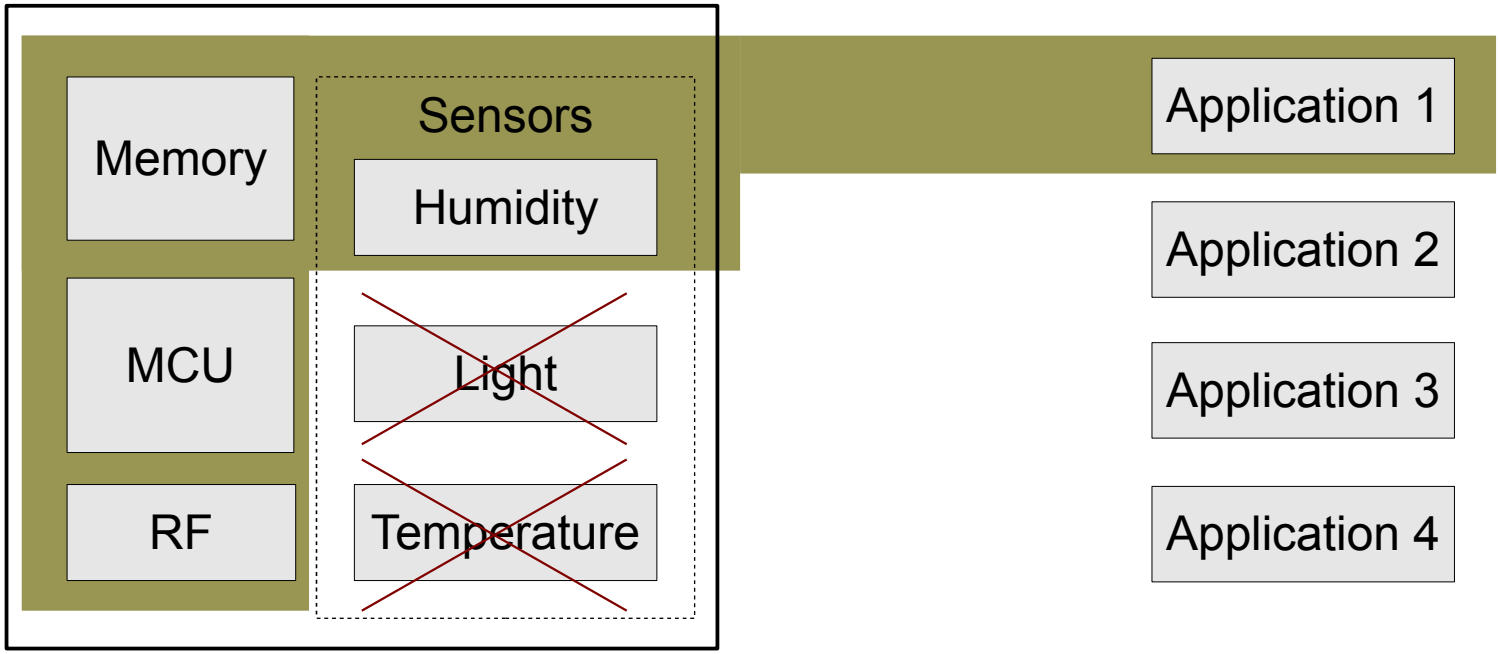
MicaZ



TelosB

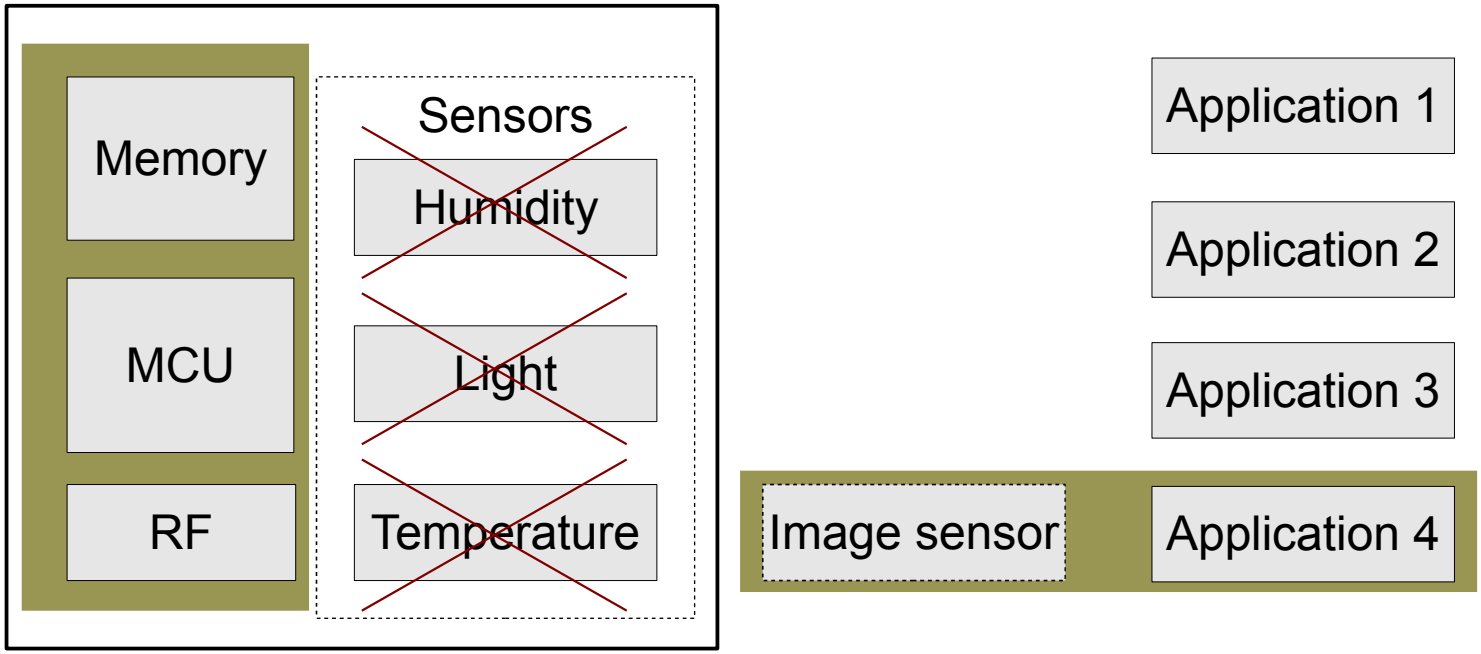
Motivation

- Problems with commercially available WSN nodes:
  - **Redundant components**
  - Limited degree of hardware flexibility

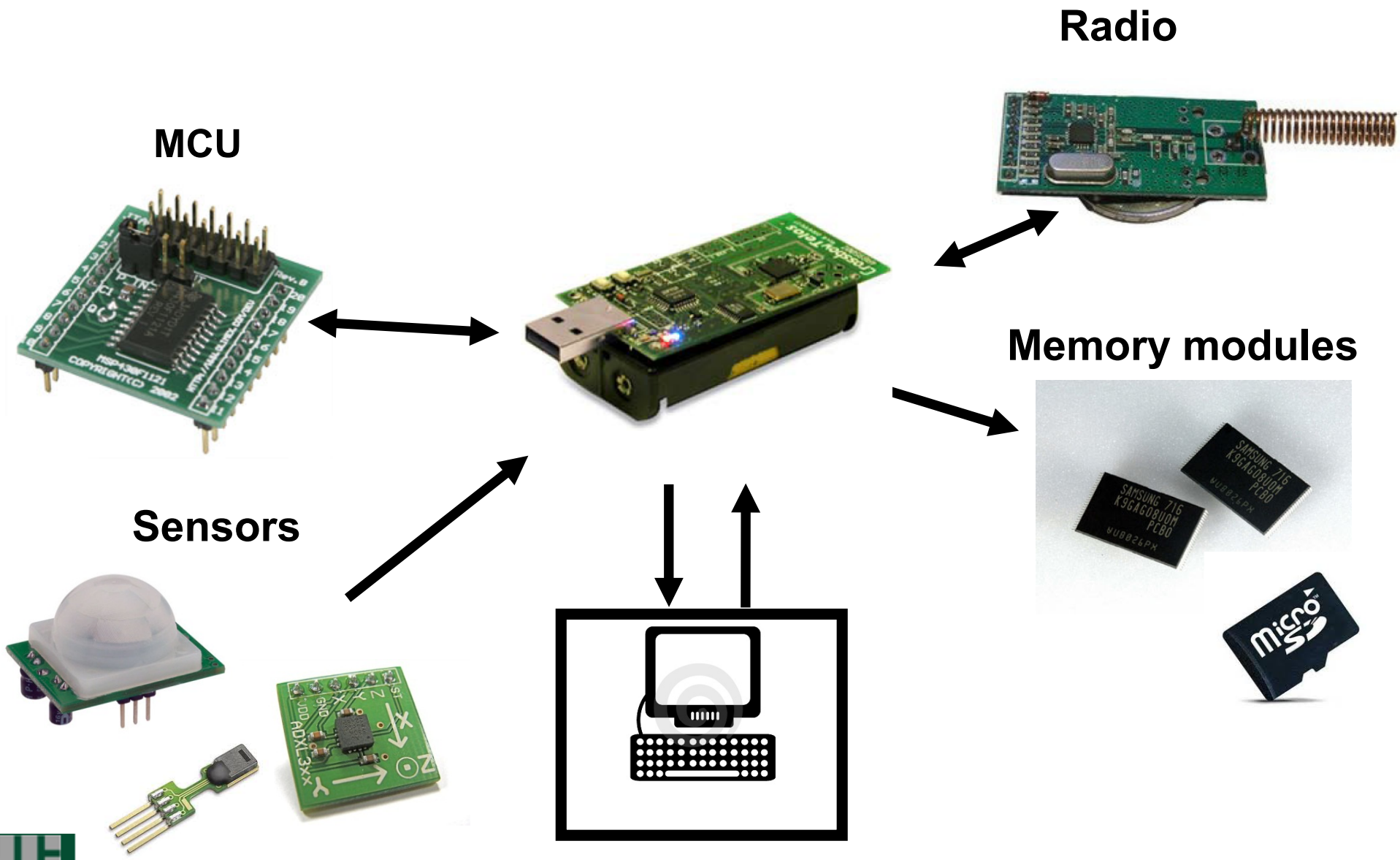


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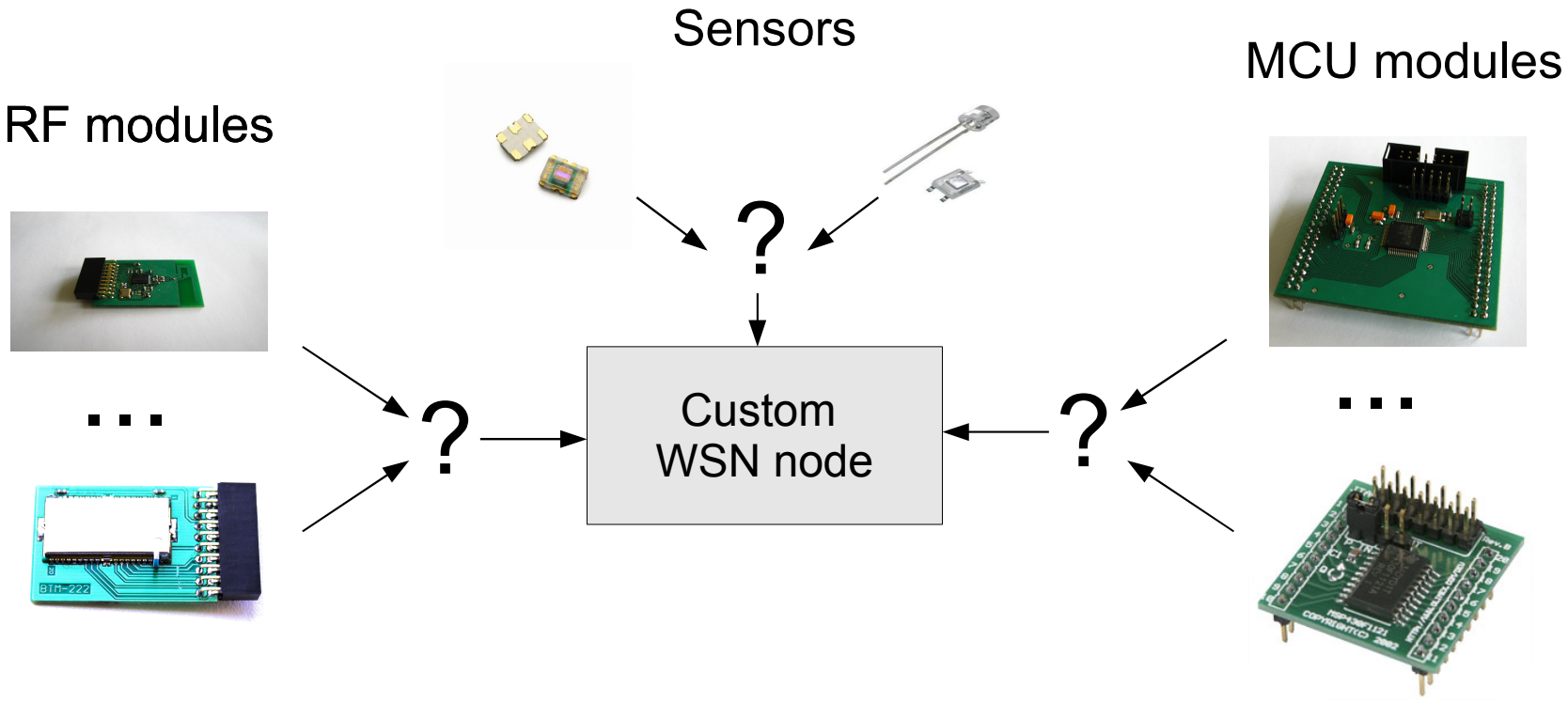


Typical WSN node



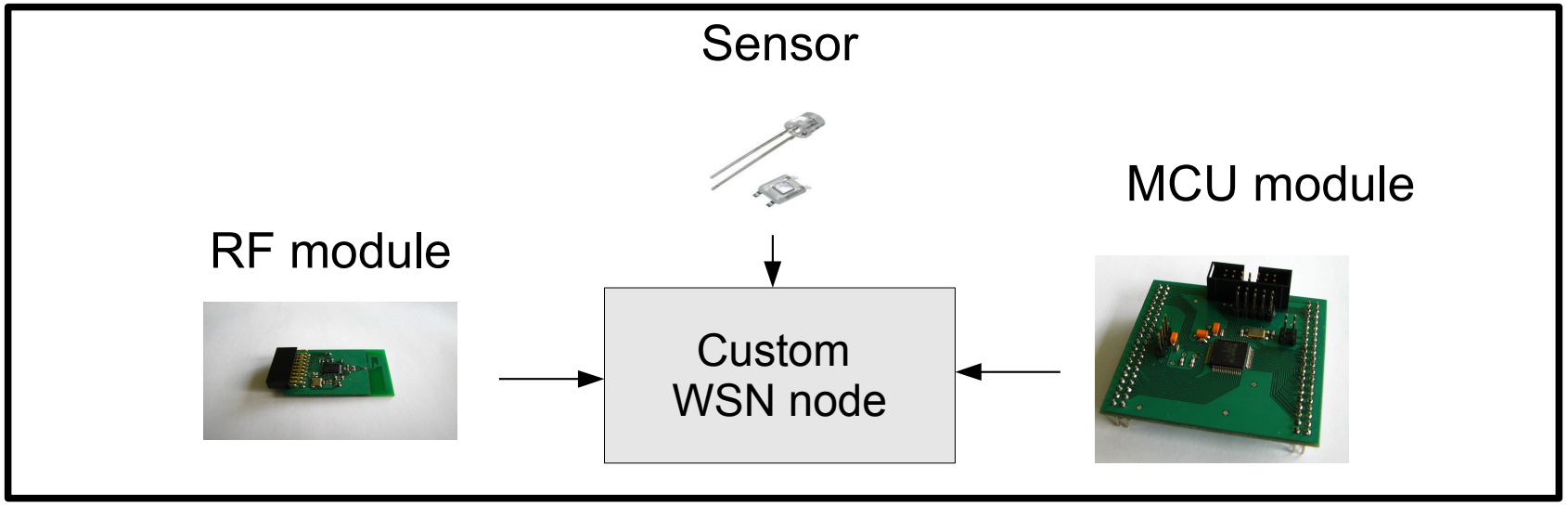
Problems when designing WSN nodes

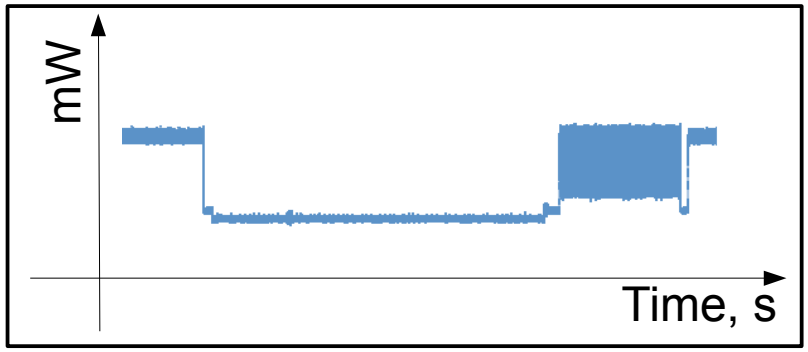
1. Test different hardware components to meet system requirements



Problems when designing WSN nodes

2.Monitor parameters of assembled system

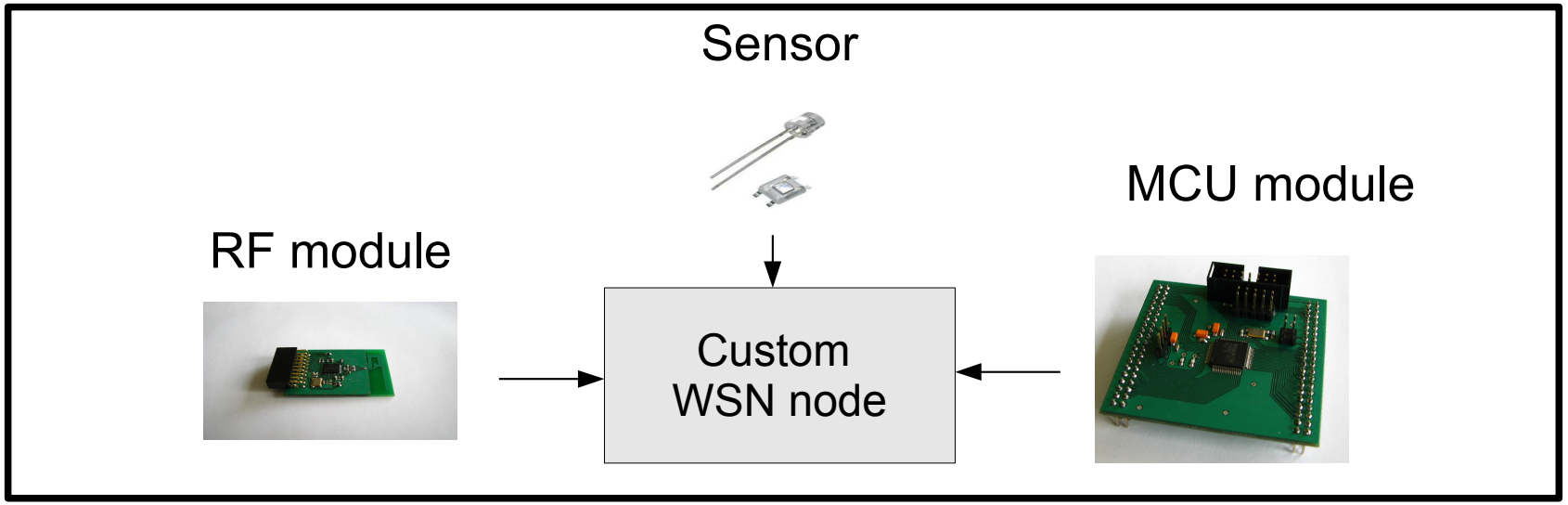


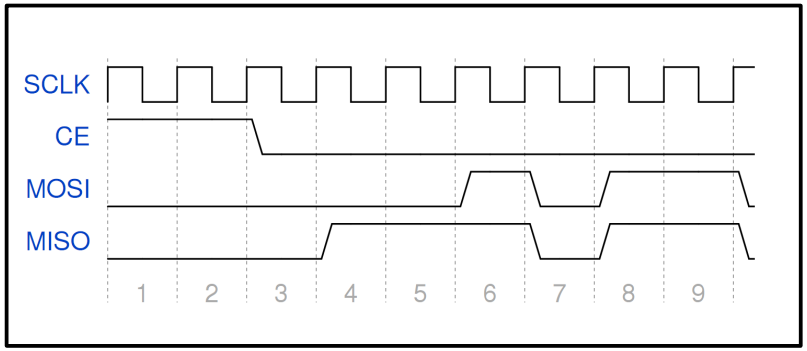


Power consumption estimation

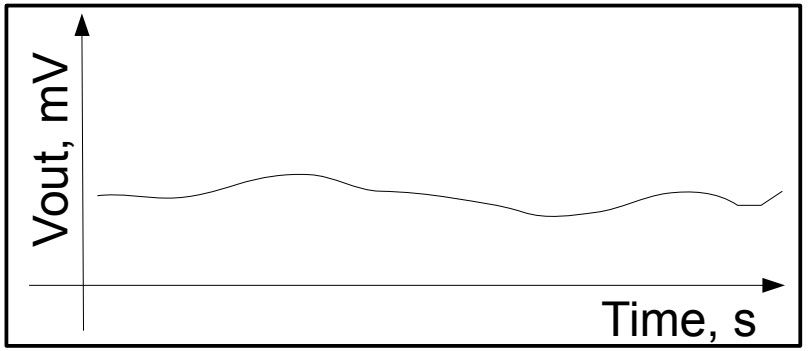
Problems when designing WSN nodes

3.Software and hardware debugging bugs





Digital signal debugging



Analog signal debugging

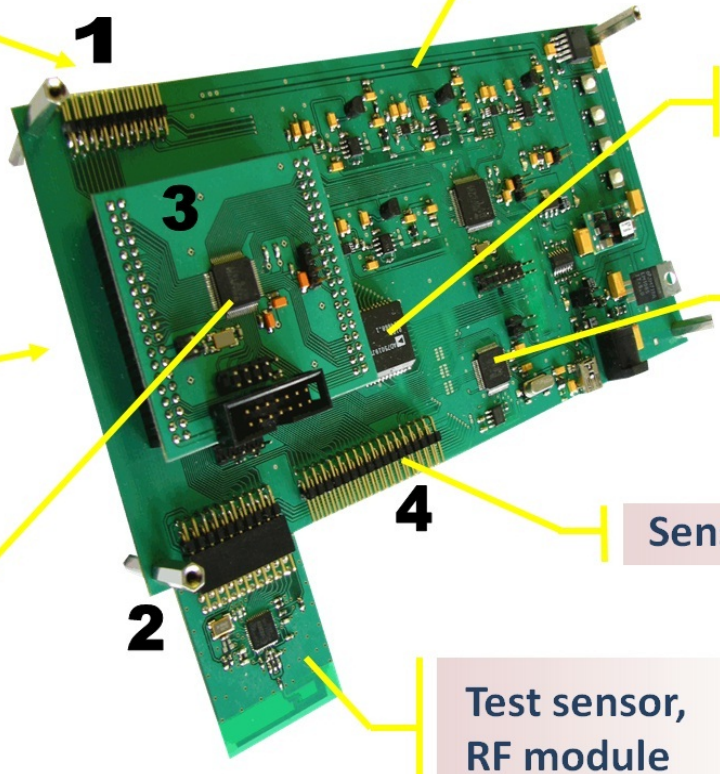
Problems when designing WSN nodes

1. Test different hardware components to meet system requirements
2. Monitor parameters of assembled systems
3. Software and hardware debugging



These steps can be simplified!

Our solution - EDIMOTE



Energy consumption monitoring, 4 channels

Sensor module connector

Communication with PC

Reconfigurable digital matrix

Reconfigurable analog matrix

Test MCU module

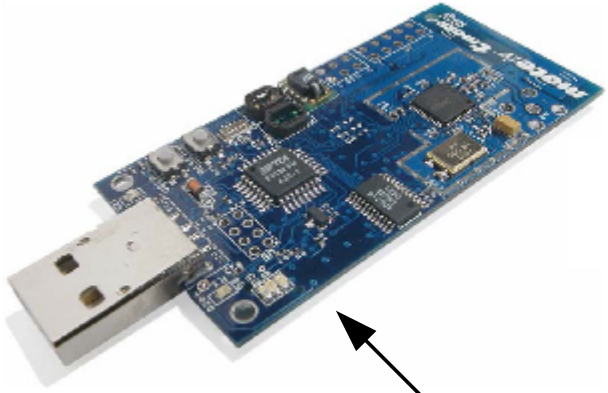
Sensor module connectors

Test sensor, RF module

Power estimation test

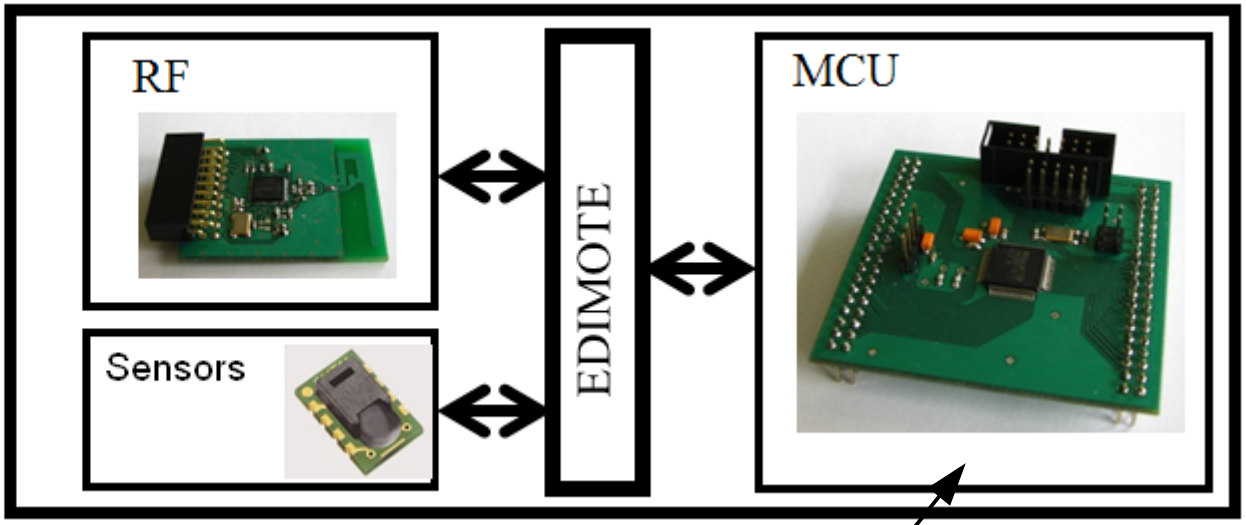
Motivation - compare EDIMOTE energy metering method with others energy metering methods

Tmote sky



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Emulated Tmote sky



Modified Contiki radio test application

Contiki radio-test application



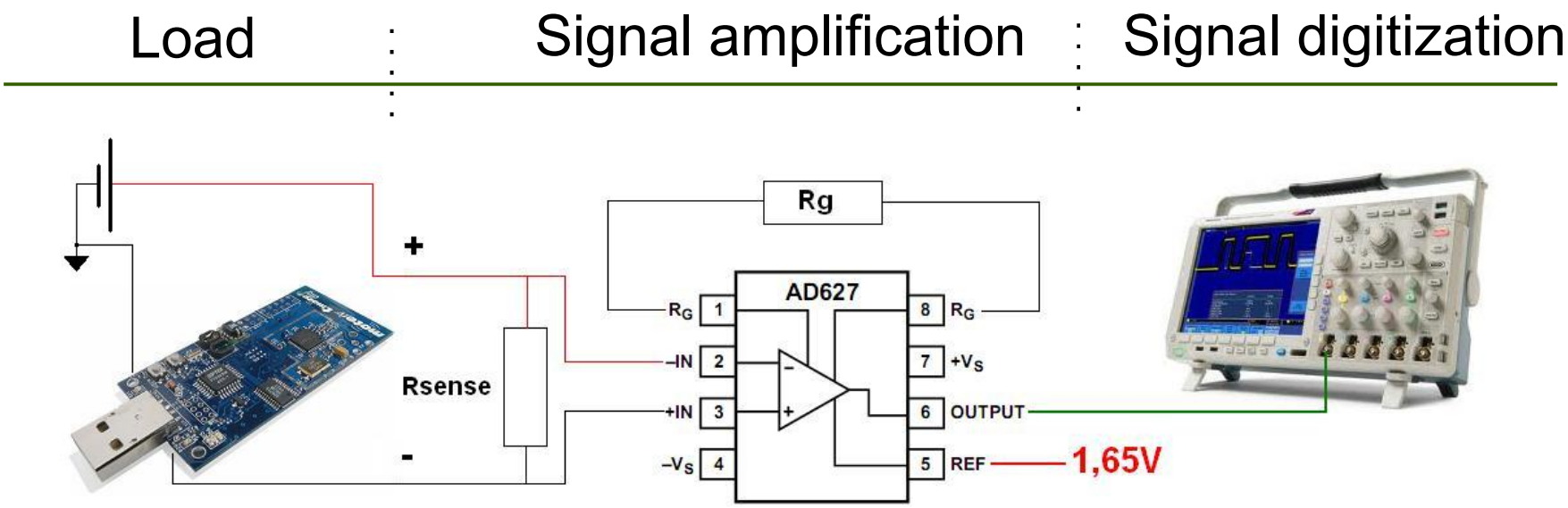
- Sense: temperature sensor is polled 100 times (~14 ms)
- Send: 100 packets with 20 byte payload are sent (~213ms)
- Receive: radio receive mode is turned on (200ms)
- Sleep: the remainder of the second is spent in low-power mode (~570ms)

Used power metering methods

- For real Tmote sky:
  - **Software energy estimation**
  - ADC meter energy estimation

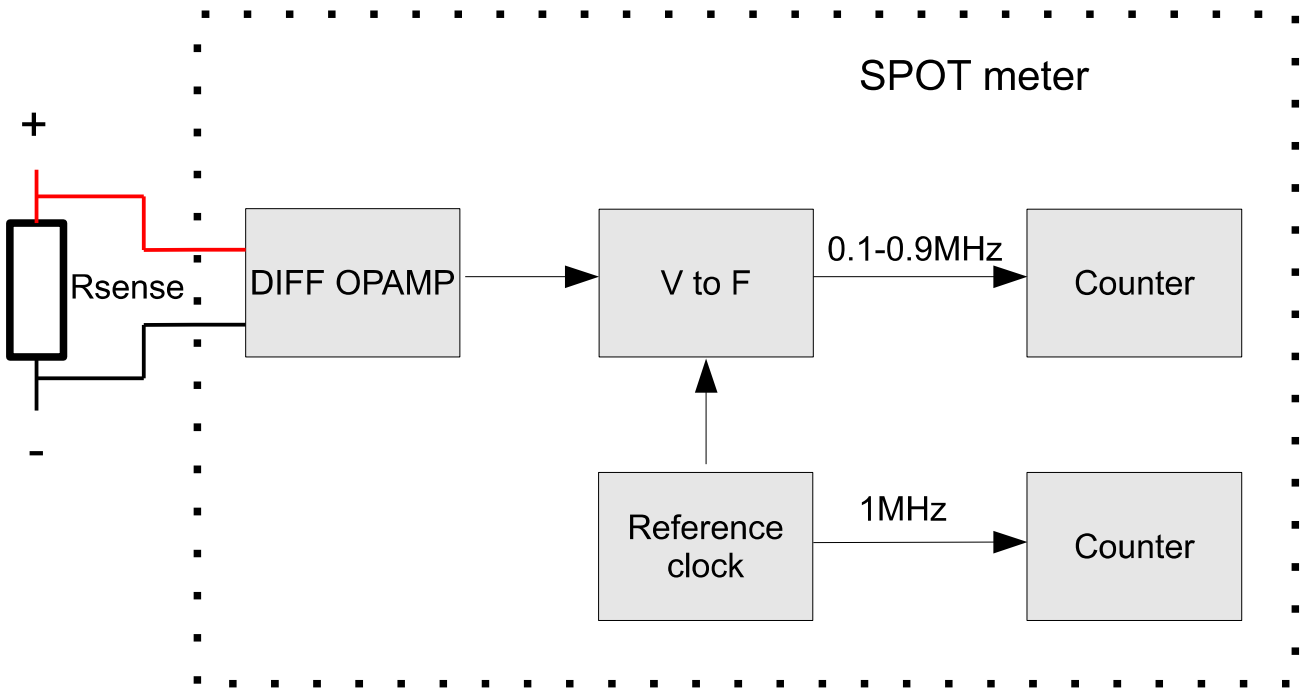
Used power metering methods

- For real Tmote sky:
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  - **ADC meter energy estimation**

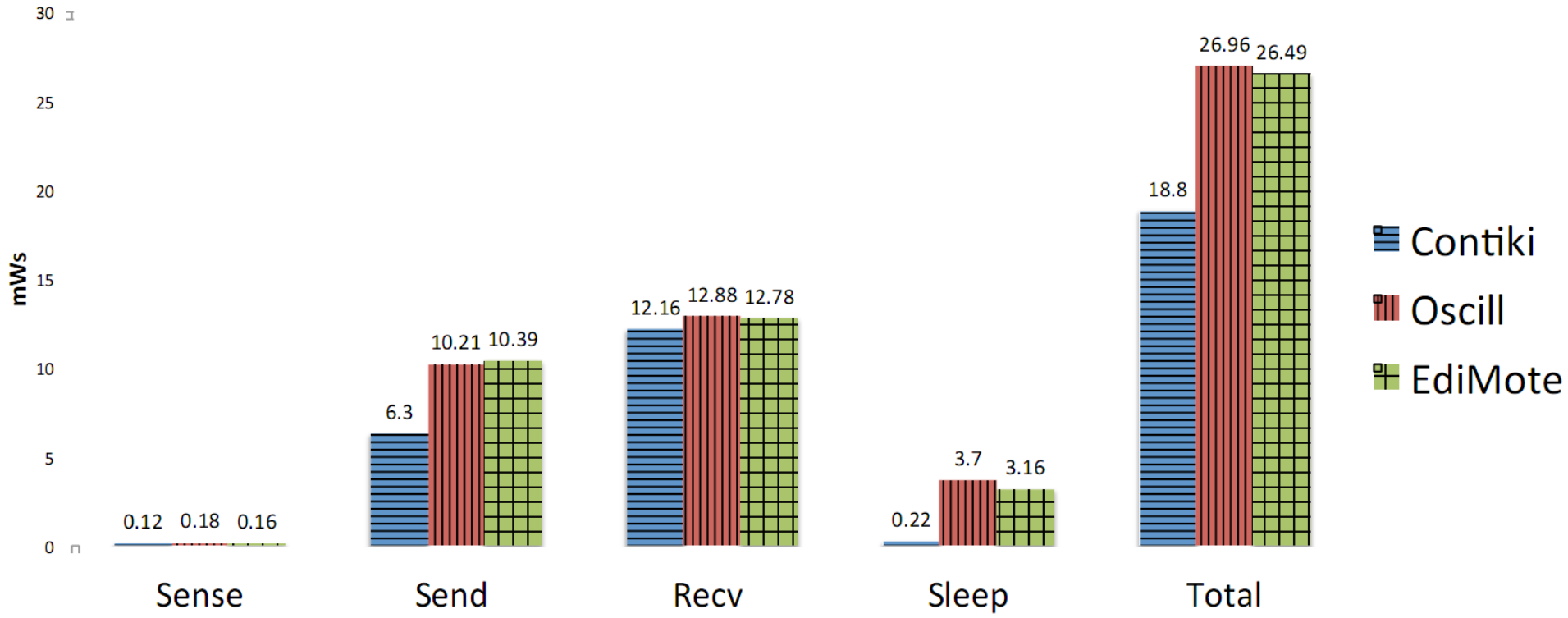


Used power metering methods

- For Tmote sky implemented on EDIMOTE:
  - **SPOT meter energy estimation**



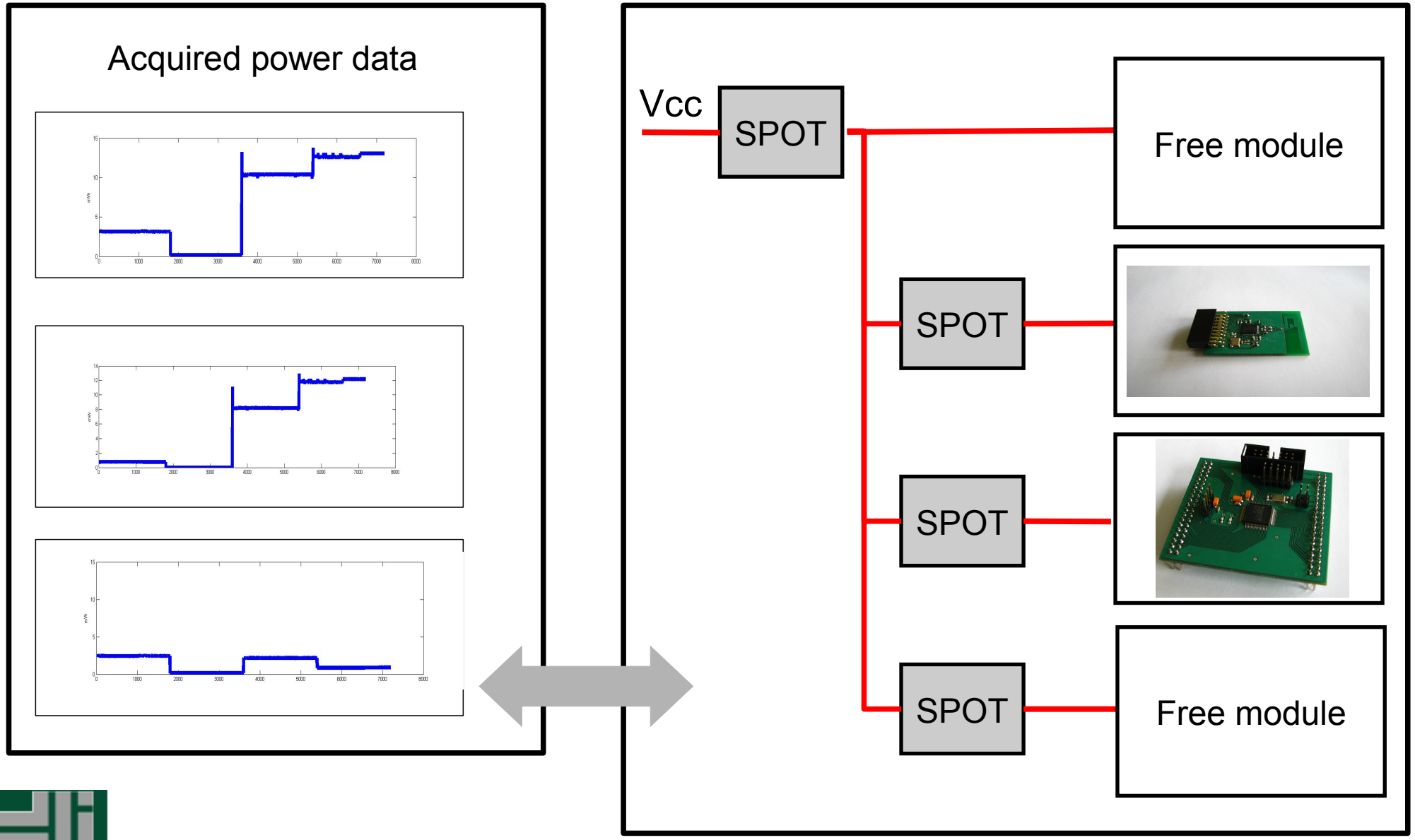
Energy consumption in different application modes



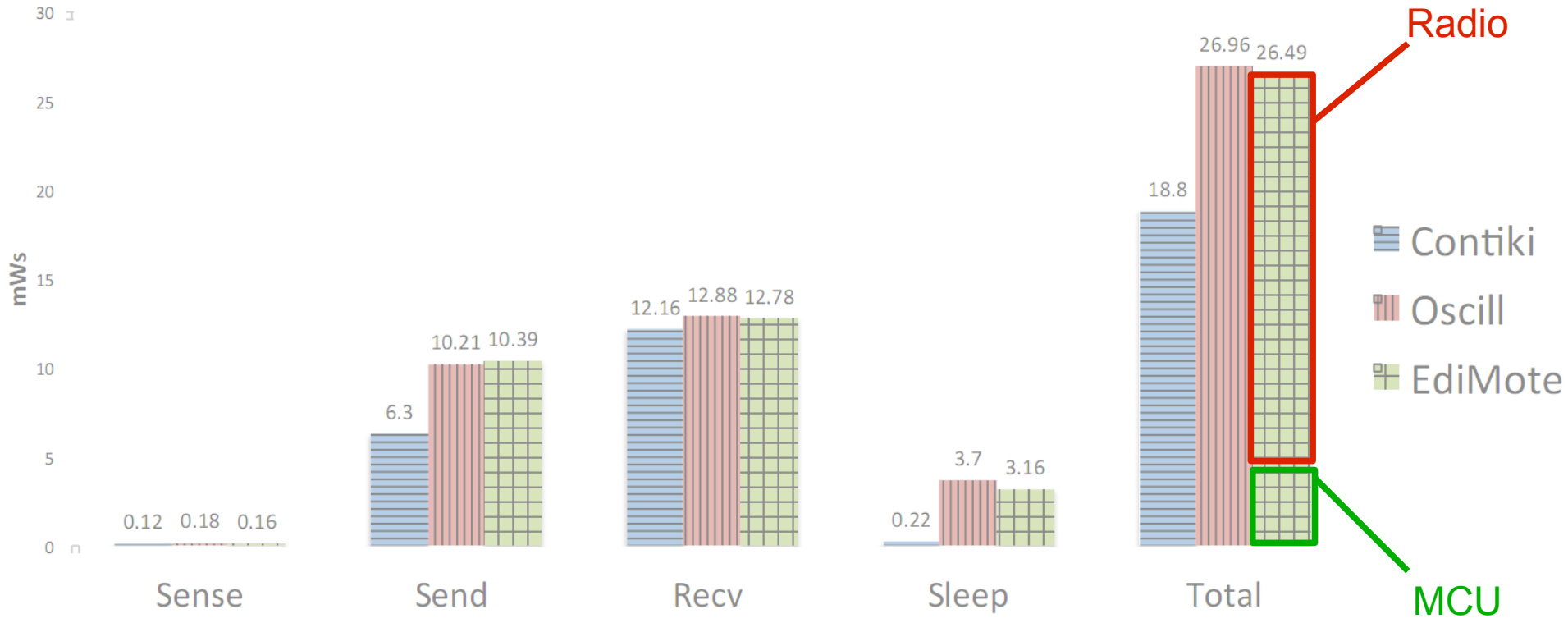
Oscilloscope method was considered as ground truth

1. EdiMote's precision is near to oscill. precision

EDIMOTES power meters architecture



Energy consumption in different application modes



Radio – 20.869 mWs

MCU – 5.603 mWs

2. WSN node power distribution

Conclusions

- Software energy accounting is reasonable in application modes with stable consumption pattern (radio idle listen, sensor sampling)
- In dynamic application modes, such as radio transmission, energy estimation using SPOT provides higher accuracy compared to software methods
- EdiMote SPOT energy profiling is a helpful tool in software debugging. In the particular test application it helped to identify inactive MCU sleep mode, where ADC and UART modules were consuming significant amount of energy in idle mode

Thank you!

Backup slides

Software energy estimation

- **Contiki powertrace**
- **Current consumtion constants in different modes were collected from datasheet**
- **TMote sky logged information about current mode and time of each mode**
- **Energy estimation was acquired by multiplying constants with time**

Table 1: Energy consumption of MCU and radio modules in original test application and modified version with explicitly turning ADC and UART off

Application	MCU, mWs	Radio, mWs	Total, mWs
Original	2.448	0.769	3.156
ADC&UART off	0.758	0.323	1.071