

Exploiting Platform Heterogeneity in Wireless Sensor Networks for Cooperative Data Processing



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Image source: www.dreamstime.com



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Traffic Characteristics in Wireless Sensor Networks

- Problem statement

Benefits of Platform Heterogeneity

- Comparison of current mote platforms
- Analysis of their energy consumptions

Exemplary Application Scenarios for Heterogeneous WSNs

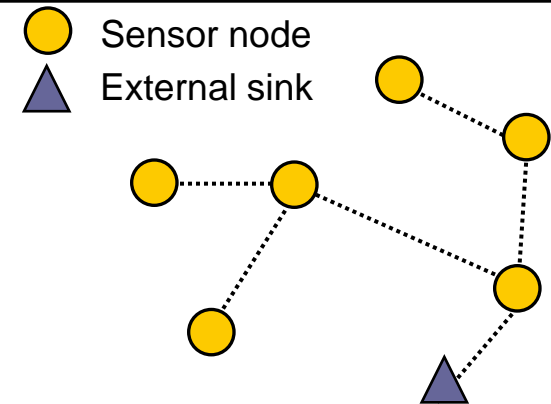
- Data compression
- Cryptographic operations
- High data rate sample processing

Summary and Outlook

Sensor Network Characteristics

General Traffic Characteristics

- Limited number of connections
 - Network management – to immediate neighbors
 - Data transport – to sink node
- WSNs are often organized in a convergecast manner
 - All sensor data is routed to the sink

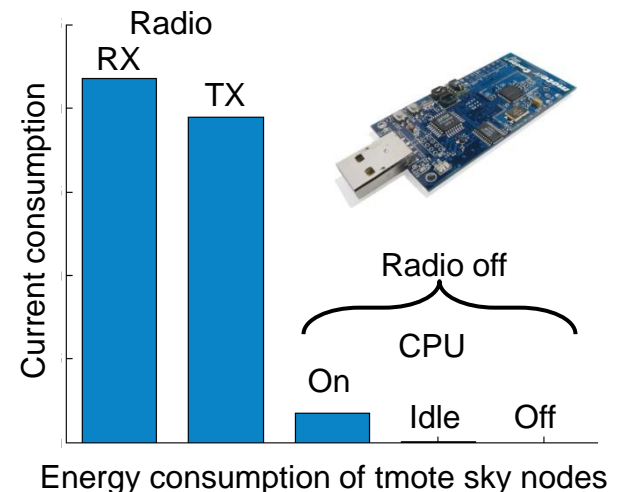


Energy is a crucial aspect in WSNs...

- Battery charge limits node and network lifetime

...but radio operation is expensive

- CC2420 radio transceiver
 - RX: 19.7 mA, TX: 17.4mA, off: 1 μ A
- MSP430 microcontroller
 - on: 0.33mA, idle: 1.9 μ A, off: 0.2 μ A

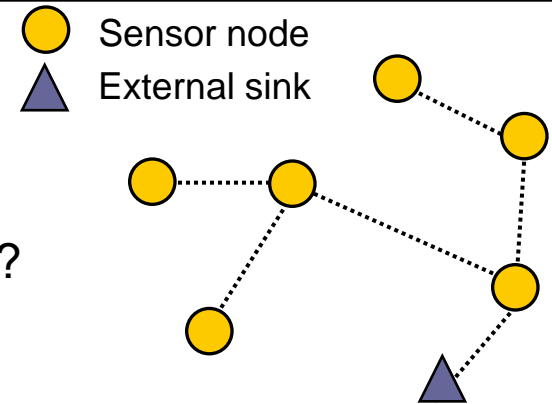


Problem Statement

Local and/or in-network data processing

- Perform operations on the sensor data
 - Averaging, min/max, basic compression...
 - But are more complex operations (FFT, ...) feasible?
- Limited due to mote hardware constraints
 - Low computational power
 - Available memory (RAM / Flash)
 - Cost
- Data processed at external sink node instead
 - Necessitating (multi-hop) radio transmissions

} desired properties for long battery lifetime



Find means to shift processing tasks into the WSN

- At an overall saving in energy consumption

Integrate (computationally) heterogeneous mote platforms

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Benefits of Platform Heterogeneity (I)

Comparison of current mote platforms



| | Mica2 | TelosB | SunSPOT | Imote2 |
|--------------|----------|---------|---------|----------|
| RAM size | 4 kB | 10 kB | 512 kB | 32 MB |
| System clock | 7.37 MHz | 8 MHz | 180 MHz | 104 MHz* |
| Word size | 8 bits | 16 bits | 32 bits | 32 bits |

* The Imote2 can dynamically scale its frequency from 4 – 416 MHz

Significant differences in system clock and RAM size

- Mica2 and TelosB well suited for sensing and simple processing
- SunSPOT and Imote2 well suited for processing tasks

Does deploying dedicated processing nodes make sense?

Benefits of Platform Heterogeneity (II)



Energy consumptions in sleep and active mode

| | Mica2 | TelosB | SunSPOT | Imote2 |
|----------------|------------|-----------|------------|-------------|
| Sleep current | 15 μ A | 1 μ A | 31 μ A | 820 μ A |
| Active current | 8 mA | 1.8 mA | 80 mA | 66 mA |
| Word size | 8 bits | 16 bits | 32 bits | 32 bits |

Energy consumptions by processor platforms significantly higher

- BUT: Higher clock speed leads to shorter duty cycles
- Comparison of the energy demand for a function of 100,000 instructions:

| | Mica2 | TelosB | SunSPOT | Imote2 |
|-----------------|-------------|--------------|--------------|--------------|
| Execution time | 13.6 ms | 12.5 ms | 0.55 ms | 0.96 ms |
| Energy per call | 327 μ J | 67.6 μ J | 82.7 μ J | 98.4 μ J |
| Average power | 3.3 mW | 0.68 mW | 0.85 mW | 1.37 mW |

Power consumption of TelosB and SunSPOT very close

- Emulation overhead when executing 32 bit operations on 16 bit microcontroller

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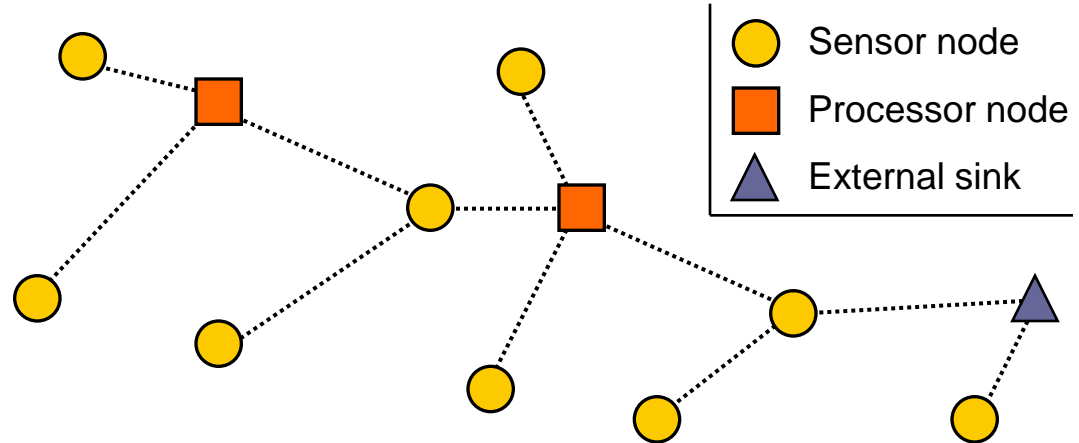
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Summary and Outlook

Exemplary Application Scenarios

Data compression

- Compress results of in-network aggregation
- Allow for more sophisticated compression algorithms



Cryptographic operations

- Often, nodes are incapable of performing strong cryptographic operations
- Form “clouds of trust” around processor nodes
- Only encrypted data may leave the cloud

High data rate signal processing

- Processor nodes can extract features inside the network
- Significant reduction of traffic to the sink

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Summary and Outlook

Summary and Outlook

Heterogeneous wireless sensor networks

- Integration of processing nodes into the WSN
 - More processing power
 - Greater amounts of memory
- Power consumption is similar to motes for equal application sizes
- Amount of multi-hop convergecast radio traffic can be reduced

Heterogeneous sensor networks are a viable way to save energy

Outlook

- Improve energy model of sensor nodes
- Investigate partitioning algorithms
 - Which amount of data to process locally, which amount to forward?
- Perform simulations using tmote sky and SunSPOT nodes
- Verify findings using a real testbed

Thank You for Your Attention!



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