FlexCup – Flexible and Efficient Code Updates for Sensor Networks

Summer School on Wireless Sensor Networks and Smart Objects – Participants Workshop

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Motivation

• Occasional software updates necessary in sensor networks
  ◦ Bug fixes
  ◦ Adaptation to new environmental conditions or new tasks
• However: Close relationship between application and operating system in TinyOS
  ◦ No update of individual application parts possible
  ◦ Exchange of complete code image very energy expensive
  ◦ Missing flexibility for adaptation

General idea

• Exchange of individual components
• Dynamic integration on the sensor nodes
FlexCup – Flexible Code Updates

- Concept: Dynamic exchange of components
  - Preserve and exploit the component structure of nesC
  - Only transmit changed components for code updates
  - Integration of new components on the sensor nodes
    - Exchange the old component
    - Update the references
- FlexCup uses meta data
  - General program information
  - Symbol table with function symbols and object symbols
  - Relocation table

Process on the Sensor Nodes

1) Receiving the new component
2) Updating the symbol table
3) Exchanging the relocation table
4) Adjusting the references
5) Transferring to program memory
Evaluation

• Comparison with two alternative approaches:
  ◦ Exchange the complete code image – Example: Deluge
  ◦ Only transmit change set (Diff approach) – Example: MOAP-Diff

• Practical experiments using
  ◦ Three example applications of different complexity
  ◦ Six changes to the program code of the applications

• Assumptions
  ◦ No collisions and transmission errors, no protocol overhead
  ◦ Each node receives and forwards updates once

• Simulation results obtained using atemu

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Evaluation: Time Consumption

• Less effort for data transfer by investing time into processing
• FlexCup at least 2.5 times faster than Deluge and 2.3 times than MOAP-Diff
Evaluation: Energy Consumption

- Influence of the processing overhead smaller than for MOAP-Diff
- Max. 41 % of the energy of Deluge and 37 % of MOAP-Diff

Summary

- FlexCup realizes the dynamic exchange of components
  - Provides the flexibility required for adaptation
  - Savings during data transfer
- Very good performance compared to related approaches
  - Up to eight times faster
  - Up to 87 % savings concerning energy consumption
  - But: Using FlexCup requires space in the external flash
- In the future…
  - Combine FlexCup with the concepts of the Diff approaches
  - Implement and experiment on different hardware platforms
Thank You a Lot For Your Attention!

Are there any questions?

Backup Slides
FlexCup

- Fragmentation of the application into components
- Selects the required components
- Creates the required meta data

- Integrates the new component
- Updates the meta data
- Updates the references
- Transfers the new code image to program memory
- Restarts the system

Optimizations

- Problem: Access to external flash memory extremely expensive
- Goal: Minimize the number of access operations
- Several approaches implemented:
  - Sensible use of the hardware buffer built into the flash chip
  - Buffering the entries of the symbol table in RAM
  - Buffer spaces ("Slop Space") between the program components
Related Work

- Exchange of complete code image (e.g. Deluge)
  - Transfer of the complete code image to the sensor nodes
    + Simple implementation
    - Large amounts of data to transfer
    - Inefficient for small changes
- Diff approaches (e.g. MOAP-Diff)
  - Only transfer the changes compared to the previous version
    + Only changed sections of the code need to be transmitted
    - Requires knowledge at the base station – no autonomous adaptation
    - Small changes – huge impact?
- Operating system and middleware solutions (e.g. SOS, Contiki)

Complexity of the Example Applications

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<th>AcousticLocalization</th>
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### Transmitted Data Volume (in Bytes)

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<th>Application</th>
<th>Type of update</th>
<th>Deluge</th>
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<td>Change to leaf node</td>
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### Space Consumption in the External Flash (in Bytes)

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<th>MOAP-Diff</th>
<th>FlexCup</th>
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