Efficiently Reprogramming Heterogeneous Wireless Sensor Networks

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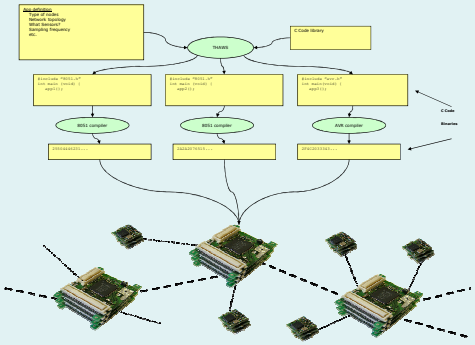
1. Tyndall Heterogeneous Network

- Multiple node *TYPES*
- Multiple node *FUNCTIONS*
- Two node types in our network:
  - Tyndall 10mm node is small, cheap and very energy efficient, but low processing capability
  - Tyndall 25mm node is larger, more expensive, not as energy efficient, but has much more processing capability
- In a single network, they can minimize cost, increase possible applications, while retaining all functionality



2. Wireless reprogramming

Why?

- To reduce time required for programming network
- Add ability to change network functionality after deployment
- Fix errors/bugs

How?

- Currently running code (program memory)
- Separate memory to store new code area
- Unchanging boot-loader to copy new code to program memory

Problem

- Uses a lot of energy
- Sending 15kB program removes 20 days from 12 month node lifespan (based on typical WSN environmental monitoring application)

3. Delta encoding

Algorithm (Bsdiff) analyses old and new code for similarities

Produce commands to convert old code into new code:

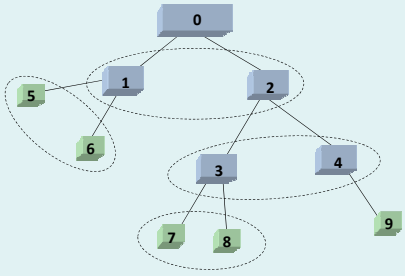
- Copy with modification
- Write new data

Change	Full Size	Delta-encoded size	Compression Ratio
Changing sampling frequency	3407 bytes	14 bytes	0.41 %
Enabling CSMA	3419 bytes	78 bytes	2.28 %
Changing sensor	3365 bytes	1054 bytes	31.32 %
Different application	4238 bytes	3323 bytes	78.41 %

4. Delta encoding for heterogeneous networks

Tree network topology

Using multicast messages to communicate with child nodes



5. Improvements for heterogeneous network

Analyse code operating on each node for similarities between nodes

Calculate lowest energy cost to reprogram, using multicast messages

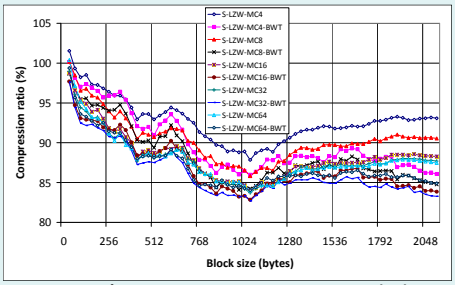
Set	Energy Cost
S_a = {0}	0 J
S_b = {1}	0.0436 J
S_c = {2, 3, 4}	0.1179 J
S_d = {5, 6}	0.2844 J
S_e = {7, 8, 9}	0.6412 J

Method	Energy Cost	Energy cost compared to uncompressed
Uncompressed	16.54 J	100 %
All nodes separate	1.971 J	11.91 %
Grouping nodes into sets	1.087 J	6.57 %

6. Data compression?

Low complexity LZW (Lempel-Ziv-Welch) lossless data compression algorithm

Tuning of algorithm: block size, cache size, use of Burrows-Wheeler-Transform?



Energy cost to transmit/receive dominates energy cost to (de)compress

Savings in energy (88.14%) are almost same as compression ratio (87.70%)

7. Conclusions

Delta encoding greatly reduces energy requirements of wireless reprogramming sensor networks

Suitable for devices with very low computational power

8. Wireless Programming for GENESI?

Analysis of the proposed topology for the GENESI deployment suggests that the implementation of subnets/sets/grouping is possible (multiple node *TYPES* and *FUNCTIONS*) –and it can be shown that by doing so, significant energy savings can be made

What's next?

- Full port to the GENESI platform (MSP430)
- Enhanced automation (currently very manual), usability (GUI) and functionality (OS support?, in-network command support?, etc.)

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