Node-level Representation and System Support for Network Programming

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Intro – Direct Connection Programming

• Steps for programming wireless sensors
  – The code is developed in a host machine (e.g. PC).
  – And the code is loaded to a single sensor node, typically, with direct connection like parallel cable.

• Problems with the direct connection programming
  – Programming time increases with # of sensor nodes.
  – Involves all the efforts of collecting the sensor nodes placed in different locations and possibly disassembling and reassembling the enclosures.

• Network reprogramming can address scalability and reassembly issues.
Intro – Network Reprogramming.

- Disseminates program code to one or more sensor nodes through radio channel.
- **Network Reprogramming Steps**
  - Program code is stored in external flash.
  - Possible retransmission of lost packets.
  - The boot loader copies the program code from external flash to program memory. Program starts after reboot.
- **Supported in TinyOS 1.1, but not optimized for fast delivery.**
  - Sends all the program code even though the changes from the previous version are small.
Design - Memory Layout

- The program storage (external flash) is organized in multiple sections. For now, each sensor maintains two sections: current and previous sections.
- In each section, each line of the program binary (SREC file) is stored as a 32-byte record.
- Boot loader is modified so that it can copy code from any section on external flash rather than a single location.
Design - Generating update

- We assume that a host machine can keep the program history of the sensor nodes.
- To generate program update, we compare the program image in fixed size blocks.
  - The blocks (256 bytes) from the current and the previous images are compared sequentially.
  - If they match, “copy” command is sent which makes the nodes to copy the block from the previous image to the current one.
  - Otherwise, the block from the current program image is sent.
Experiments

• Case 1 (Original Xnp)
  – Original network reprogramming with XnpCount app.

• Case 2 (Best case)
  – Sending the update for two copies of XnpCount (just timestamps are different.)

• Case 3
  – Sending the update from XnpCount to XnpRfmToLeds.

<table>
<thead>
<tr>
<th>Three scenarios</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td># lines in SREC file</td>
<td>1166 lines</td>
<td>1166</td>
<td>1145</td>
</tr>
<tr>
<td># bytes in SREC file</td>
<td>18.6 KB</td>
<td>18.6 KB</td>
<td>18.3 KB</td>
</tr>
<tr>
<td>Time to complete</td>
<td>223 sec</td>
<td>75 sec</td>
<td>175 sec</td>
</tr>
<tr>
<td>Effective BW</td>
<td>83.4 bytes/sec</td>
<td>248 bytes/sec</td>
<td>104.5 bytes/sec</td>
</tr>
</tbody>
</table>
Discussion & Future works

• Not much of code is shared in binary files.
  – Two scenarios are considered to test the level of sharing the binary code.
  – Considering that the change is small compared to the whole program size, this is far from the optimal.
  – Needs better compiler support for maximizing binary code reuse.

<table>
<thead>
<tr>
<th>Two scenarios</th>
<th>Case 1 (With different timestamp)</th>
<th>Case 2 (Additional lines were added.)</th>
</tr>
</thead>
<tbody>
<tr>
<td># lines in SREC file (old)</td>
<td>1027</td>
<td>1027</td>
</tr>
<tr>
<td># lines in SREC file (new)</td>
<td>1027</td>
<td>1032</td>
</tr>
<tr>
<td># lines to transmit</td>
<td>1</td>
<td>635</td>
</tr>
<tr>
<td># lines to copy</td>
<td>1026</td>
<td>397</td>
</tr>
</tbody>
</table>
Discussion & Future works

• Organizing program storage in directory structure.
  – Currently, a series of contiguous blocks are allocated for the current and the last program image.
  – Sharing blocks in a single pool has some advantages:
    • Economical use of memory: blocks of the same content are shared among different images.
    • Avoids external flash operation overhead by keeping pointer rather than copying a block of lines.
    • A user doesn’t need to keep track of program history of sensor nodes.
  – The directory structure requires major change of network reprogramming modules.

• Modification for multi-hop delivery.