Power Mgt Techniques for Mobile Communication
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MOBICOM 98

The Problem (Listening)
- Wireless communication cards consume energy continuously while inserted in device
  - 10 to 50% of energy budget for mobile device
- A mobile device with a suspended communication card is unaware if some other host has data to send to it. External events should be the trigger to wake up.
  - Buffer overflows, retransmission costs to sender
- The key to balancing power savings and delay lies in knowing when to suspend & wakeup communications
  - Role for application specific information for guidance.

Their Solution
- Set of mechanisms in the transport layer allowing communication to be suspended and resumed.
- Mobile client and Base station proxy where client is master and base station is slave.
- Goal: to reduce amount of time device sits idle drawing power waiting to receive something.
  - Increases burstiness.
  - How to deal with disconnected communication partner
  - Potential loss of data en-route

Slave (Base Station)

Figure 1: Slave (Base Station) Protocol State Diagram
Master (Laptop)

Opportunities for Application Knowledge

- Application can inform protocol of lack of data to send
- Expected time until response may be predictable as way to determine sleep duration
- Master could inform slave of sleep duration or slave could suggest.

Experimental Setup

- 915MHz Lucent WaveLAN PCMCIA wireless ethernet cards
- Master is NEC Versa Laptop
- Slave is Gateway Solo 2200
- Running Linux with modified drivers
- Multimeter sampling current at 12 times per sec.

WaveLAN Power Requirements

- WaveLAN - suspended 0W
- WaveLAN - receive 1.5W
- WaveLAN - transmit 3W
<table>
<thead>
<tr>
<th>Product</th>
<th>Lucent WaveLAN</th>
<th>Proxim RangeLAN2</th>
<th>Aironet 4800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>400-600' / 1200' / 1300' / 3000'</td>
<td>700' / 400'</td>
<td>500-1800' / 100-350'</td>
</tr>
<tr>
<td>open/office</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thruput</td>
<td>2 Mbps</td>
<td>1.6 Mbps</td>
<td>1.11 Mbps</td>
</tr>
<tr>
<td>Price Access point/PC card</td>
<td>$1295/$295</td>
<td>$5000/$200</td>
<td>$1695/$595</td>
</tr>
<tr>
<td>Power (mA)</td>
<td>send/rec/doze</td>
<td>300/250/15 / 130/280/9</td>
<td>300/150/5/2 / 490/280/5</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Windows*</td>
<td>WinCE</td>
<td>Windows*</td>
</tr>
<tr>
<td>Technology</td>
<td>DSSS / FHSS</td>
<td>DSSS/FHSS</td>
<td></td>
</tr>
</tbody>
</table>

Simulated Workloads for Experiments to Evaluate Protocol
- **WEB** - data transmitted from 5 to 30 KB; data received from 300 to 1200 KB; 1 send to 10 receives; user sleep time 10-300 sec.
- **JointWork** - data sent and received from 5 to 500 KB; user sleeps 10-300 sec.
- **Email** - data sent and received from 5 to 300 KB; from 10-600 sec user sleep time.

<table>
<thead>
<tr>
<th>Pauses</th>
<th>User Sleep</th>
<th>Max Time</th>
<th>Avg Time</th>
<th>Transmission (ms)</th>
<th>Encoding (ms)</th>
<th>Receiving (ms)</th>
<th>Sleeping (ms)</th>
<th>Average Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEB</td>
<td>10</td>
<td>1200</td>
<td>2400</td>
<td>0.75</td>
<td>1.25</td>
<td>0.75</td>
<td>1000</td>
<td>41.46%</td>
</tr>
<tr>
<td>EMAIL</td>
<td>10</td>
<td>1000</td>
<td>2000</td>
<td>1.02</td>
<td>1.02</td>
<td>0.75</td>
<td>1000</td>
<td>41.46%</td>
</tr>
</tbody>
</table>

Results (Summary)
Even with relatively short sleep durations, overhead or transition to/from sleep mode is still significantly less than energy consumed by WaveLAN card left in ready-to-receive mode.

Power Consumption During Idle
Wakeup and check if slave has data for me (master) [msg sent/rec with no data].
Power Savings During Idle

Transmission then Idle

Power Savings for Communication for Each Workload

- WEB - 48-57% savings in energy consumed.
- JW - 54-78%
- Email - 81%
- Max added delay linear in sleep duration
- Acceptable?

“Real” Machines: HP Palmtop / Windows CE

Estimates

- NEC total system results
  - JW 6.2-8.9%
  - WEB 8-9.5%
<table>
<thead>
<tr>
<th>Adaptive Algorithms</th>
<th>Other Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>• For determining sleep time</td>
<td>• Stemm and Katz - Application-level control over sleep modes. (email and web browsing)</td>
</tr>
<tr>
<td>– respond to activity by reducing to 250ms</td>
<td>– Sleeping during user think time</td>
</tr>
<tr>
<td>– respond to idle periods by doubling up to 5min.</td>
<td>– Sleeping during predicted response time of server</td>
</tr>
<tr>
<td>– WEB: 58% savings over 5 sec static;</td>
<td>• Transcoding studies (Brewer, Chandra)</td>
</tr>
<tr>
<td>2.7 sec delay vs. 3.1 sec delay</td>
<td>• Rover - Joseph et al, SOSP 1995.</td>
</tr>
<tr>
<td>• Learning techniques?</td>
<td></td>
</tr>
<tr>
<td>• API for hints as in informed prefetching.</td>
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