Power Mgt Techniques for Mobile Communication

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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)

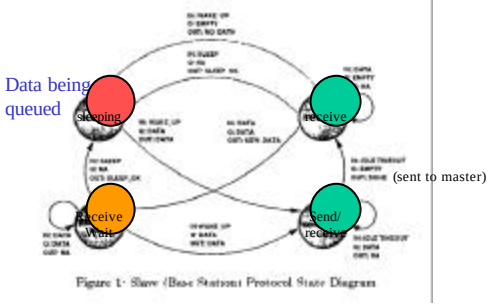
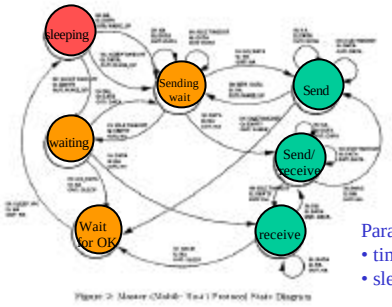


Figure 1: Slave (Base Station) Protocol State Diagram

Master (Laptop)



Parameters:
- timeout
- sleep duration

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

Product	Lucent WaveLAN	Proxim RangeLAN2	Aironet 4800
Range open/office	400-600' / 1200' 130' / 300'	700' 400'	500-1800' 100-350'
Thruput	2 Mbps	1.6 Mbps	1-11 Mbps
Price Access point/ PC card	$1295/$295	$500/$200	$1695/$595
Power (mA) send/rec/doze	300/250/15 330/280/9	300/150/5/2	490/280/5
Compatibility	Windows *	WinCE	Windows*
Technology	DSSS	FHSS	DSSS/FHSS

Simulated Workloads for Experiments to Evaluate Protocol

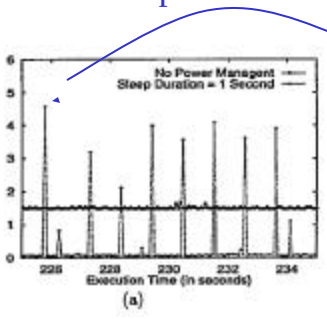
- WEB - data transmitted from 5 to 30KB; data received from 300 to 1200 KB; 1 send to 10 receives; user sleep time 10-300 sec.
- JointWork - data sent and received from 5 to 500 KB; user sleeps 10-300 sec.
- Email - data sent and received from 5 to 300KB; from 10-600 sec user sleep time.

Pattern	User Sleep Time Min (sec)	Max (sec)	Avg (sec)	Average Time Transmitting (sec)	Receiving (sec)	Sleeping (sec)	Average Percent Sleeping
WEB	10	300	155	0.116	10	134.9	67.7%
JW	10	300	155	1.52	1.52	151.96	98%
EMAIL	10	600	305	1.02	1.02	302.96	99%

Results (Summary)

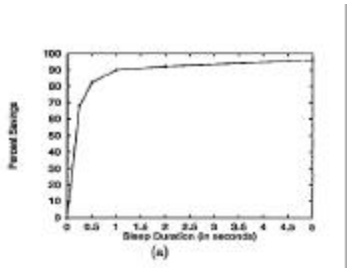
Even with relatively short sleep durations, overhead or transition to/from sleep mode is still significantly less than energy consumed by WaveLAN card left in ready-to-receive mode.

Power Consumption During Idle

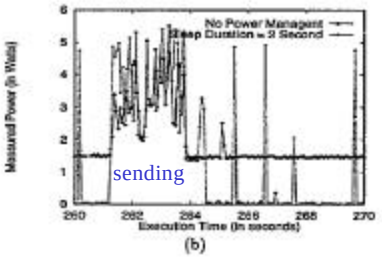


Wakeup and check if slave has data for me (master) [msg sent/rec with no data].

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?

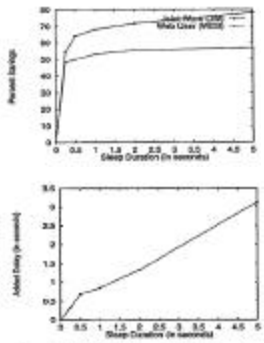


Figure 7: Added Delay based on Sleep Duration

WEB appl.

"Real" Machines: HP Palmtop / Windows CE

Machine	Power Requirements Idle w/o WaveLAN Card	Idle w/ WaveLAN Card
NEC Versa 6020	14W	15.5W
Toshiba Libretto 60	7W	8.5W
HP Palmtop PC 95LX	1.2W	1.7W

Estimates

- NEC total system results
  - JW 6.2-8.9%
  - WEB 8-9.5%

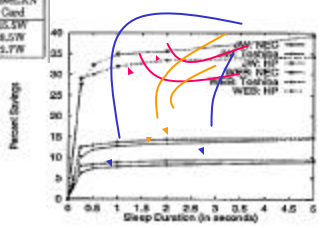


Figure 8: Savings for Three Types of Machines

Adaptive Algorithms

- For determining sleep time
  - respond to activity by reducing to 250ms
  - respond to idle periods by doubling up to 5min.
  - WEB: 58% savings over 5 sec static; 2.7 sec delay vs. 3.1 sec delay
- Learning techniques?
- API for hints as in informed prefetching.

Other Work

- Stemm and Katz - Application-level control over sleep modes. (email and web browsing)
  - Sleeping during user think time
  - Sleeping during predicted response time of server
- Transcoding studies (Brewer, Chandra)
- Rover - Joseph et al, SOSP 1995.