

Wake on Wireless: An Event Driven Energy Saving Strategy for Battery Operated Devices

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Motivation

Wanted a single handheld computing device capable of both voice and data processing and communications

Desire for “Universal Communicator”
(UCoM)

Straightforward Solution

Take PDA, add WiFi and enable voice capabilities using VoIP



Compaq iPAQ
(with wireless card)



Toshiba e740
(Integrated 802.11b)

Big Problem: Energy Consumption

- Devices have limited energy supply
 - Use better batteries or other energy storage
- **Reduce energy consumption**—many possible techniques:
 - Design energy efficient circuits
 - Use dynamic power management
 - Redesign protocols or radios

Must interoperate with existing wireless LANs

Basic Idea

Save energy by **eliminating** energy consumption of device when device is idle

Most people use their PDA 10-15 times a day generally for 30-45 seconds at a time. [Kam01]

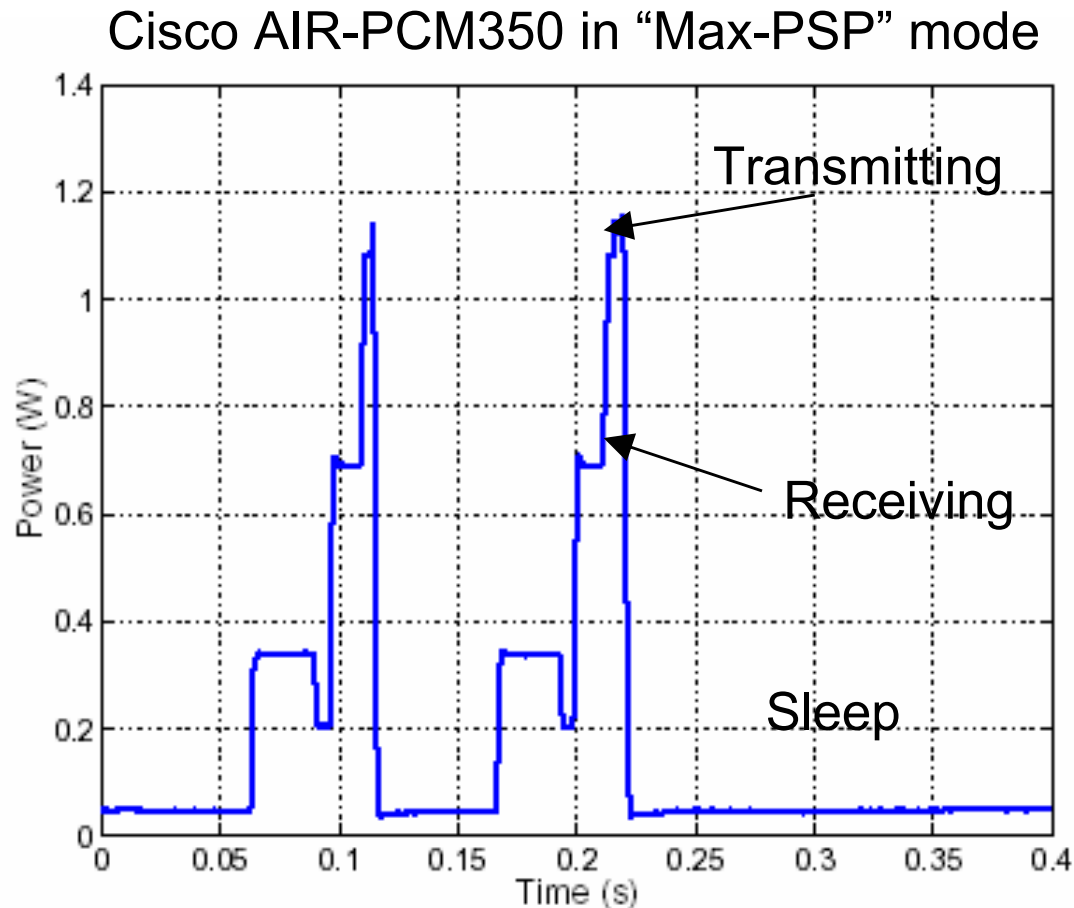
Power Consumption in PDAs

■ Basic definitions

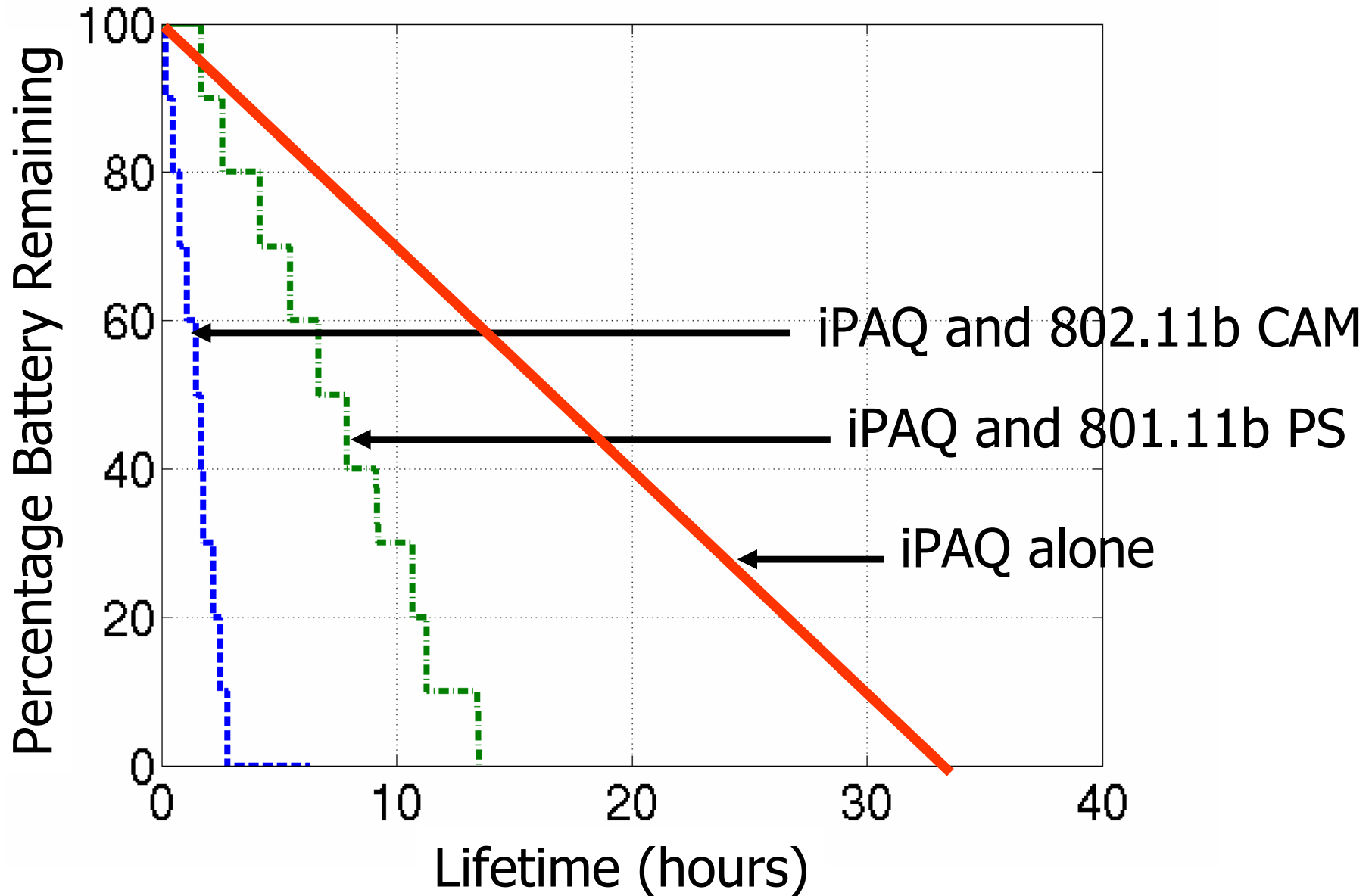
- *Active power*: power consumed to transmit/receive data
- *Idle power*: power consumed to maintain state and respond to asynchronous events

IEEE 802.11b Power-Save Mode

- Sleep most of the time, wakeup periodically to listen and poll for messages
- Typical poll period: 100 ms



State-of-the-Art Standby Lifetime

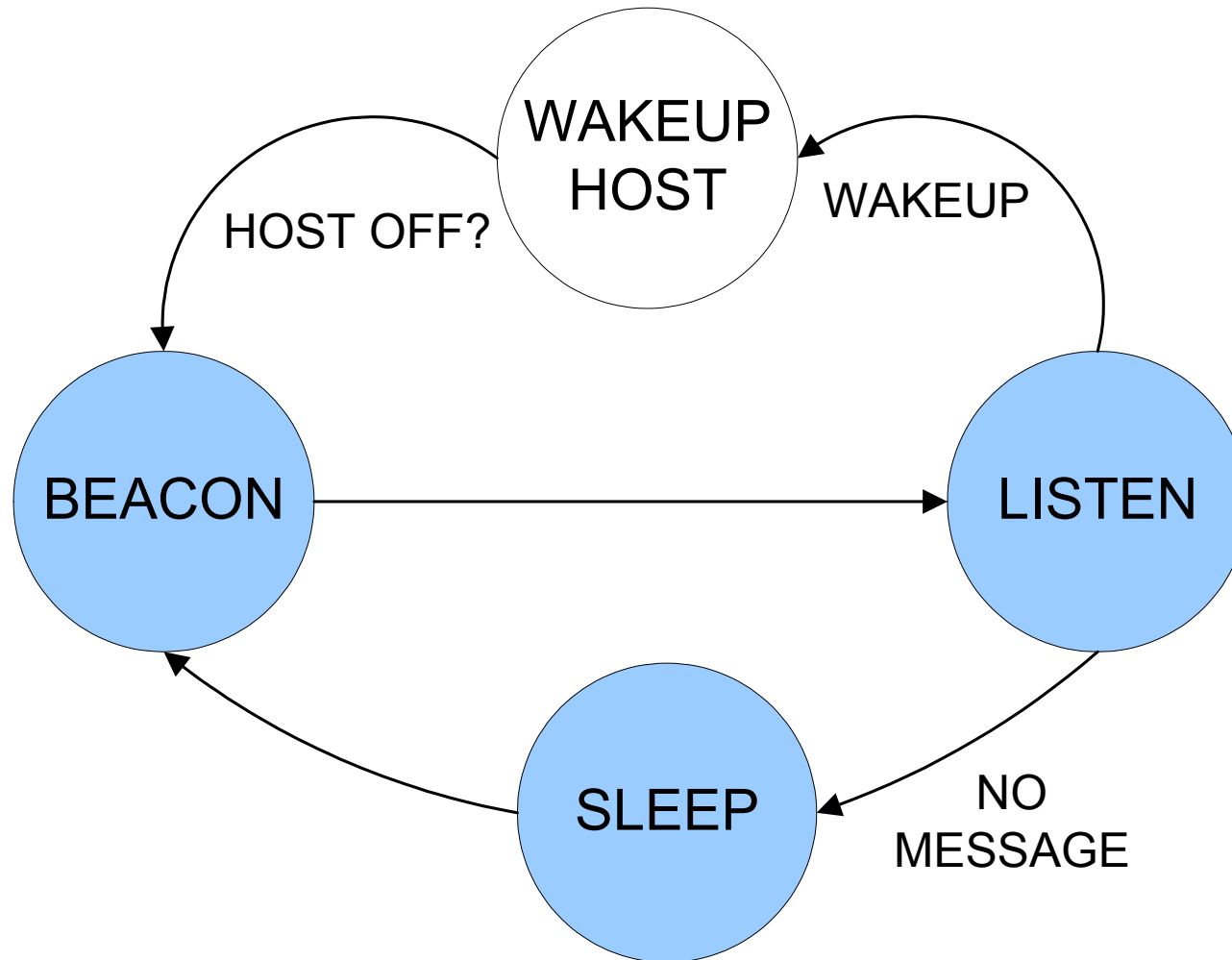


Our Approach

- Eliminate idle power by:
 - Turning off the wireless NIC and the host PDA
- Problem:
 - We cannot receive phone calls if NIC is off
- Do beaconing, listening, and sleeping on a separate, ultra low-power control

Wake-on-Wireless (WoW)

- Perform announce and listen loop in separate channel
 - Use low-power secondary control channel to wakeup PDA



Proof of Concept

- Use off-the-shelf, commercially available parts to build a UCoM and to test WoW
 - iPAQ PDA with 802.11b card
 - Low-power microcontroller: PIC16LF877
 - Radio: TR1000 ASH Transceiver (115 kbps)
 - Zigbee (802.15.4)
 - Bluetooth
 - TR1100
 - Passive one-way radio
- Built client side hardware (MiniBrick) and infrastructure side (SmartBrick)

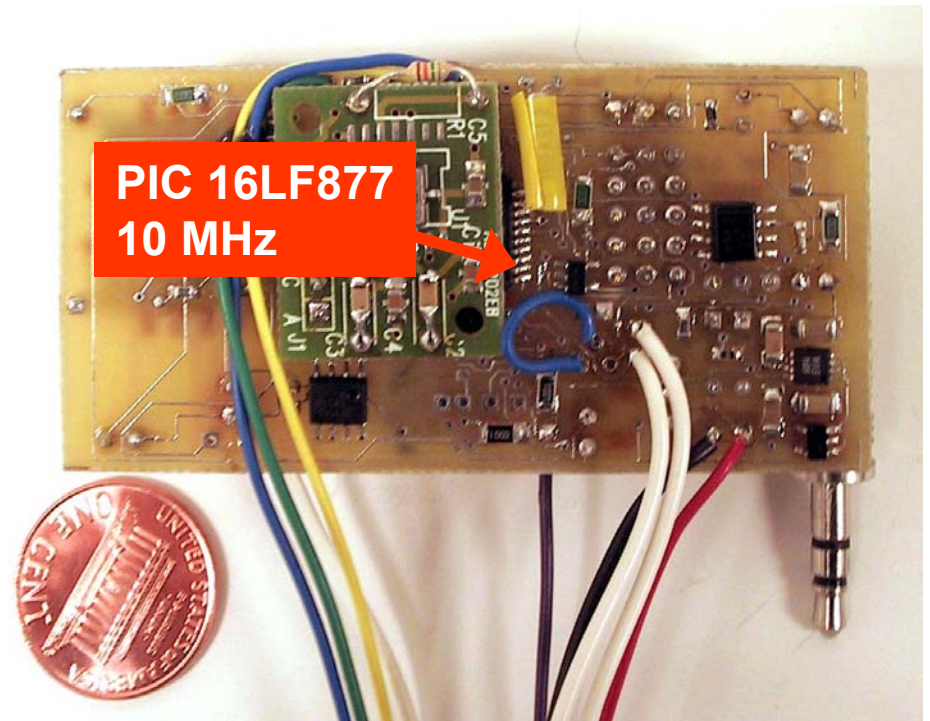


MiniBrick Hardware



915 MHz Radio
RFM TR1000 ASH

Front View



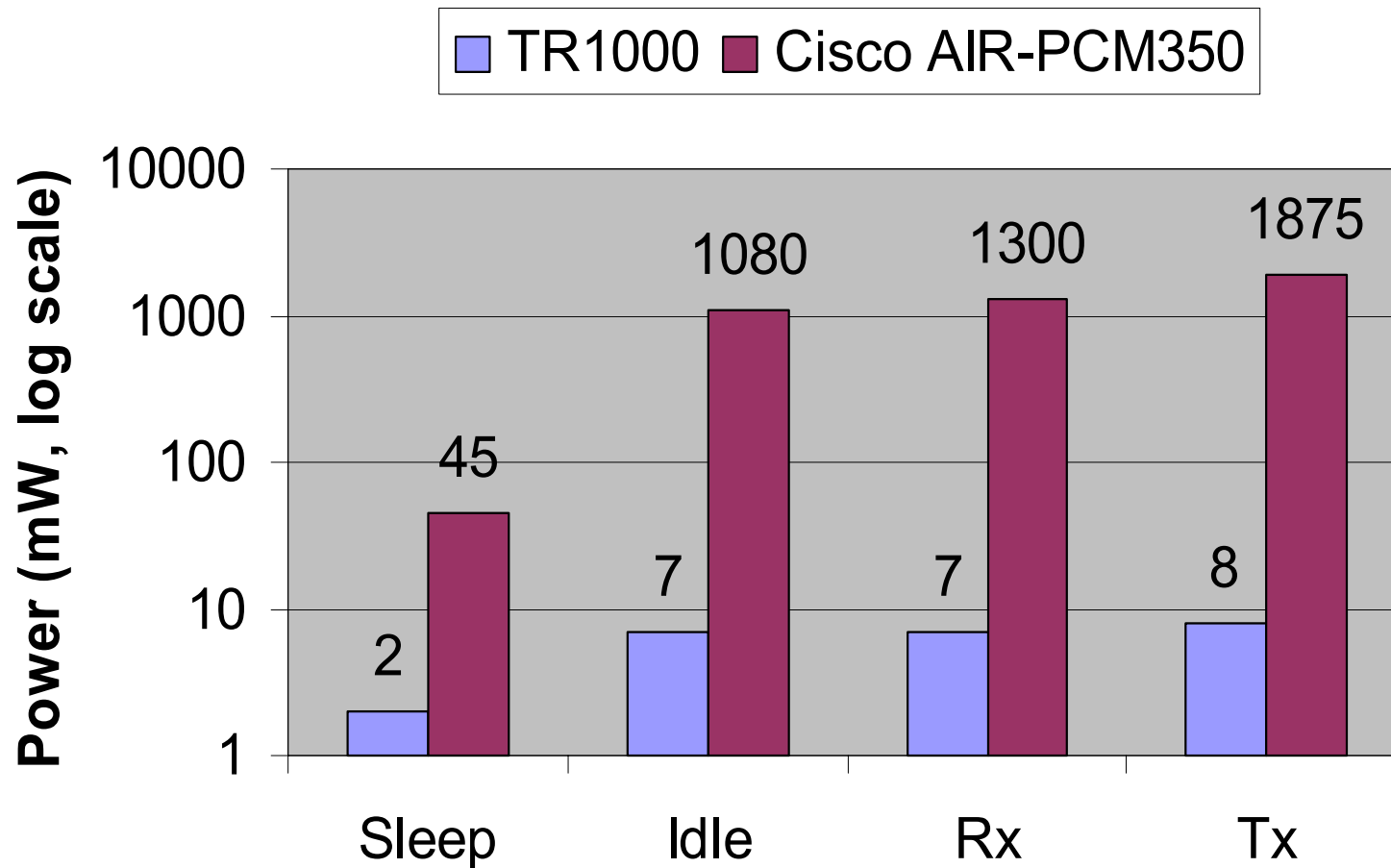
PIC 16LF877
10 MHz

Back View

- Key components:
 - PIC 16LF877, 10 MHz
 - RFM TR1000 ASH Transceiver

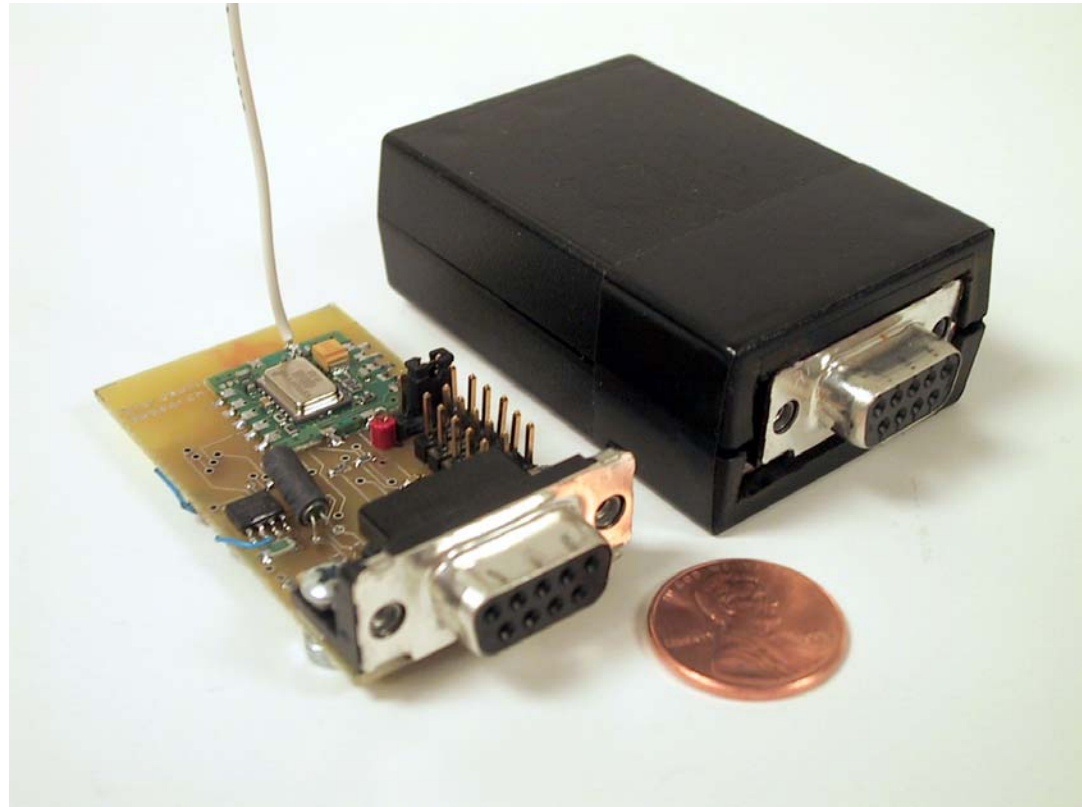
MiniBrick Power Consumption

- Power consumed by MiniBrick (TR1000 and PIC) compared to Cisco WLAN Card

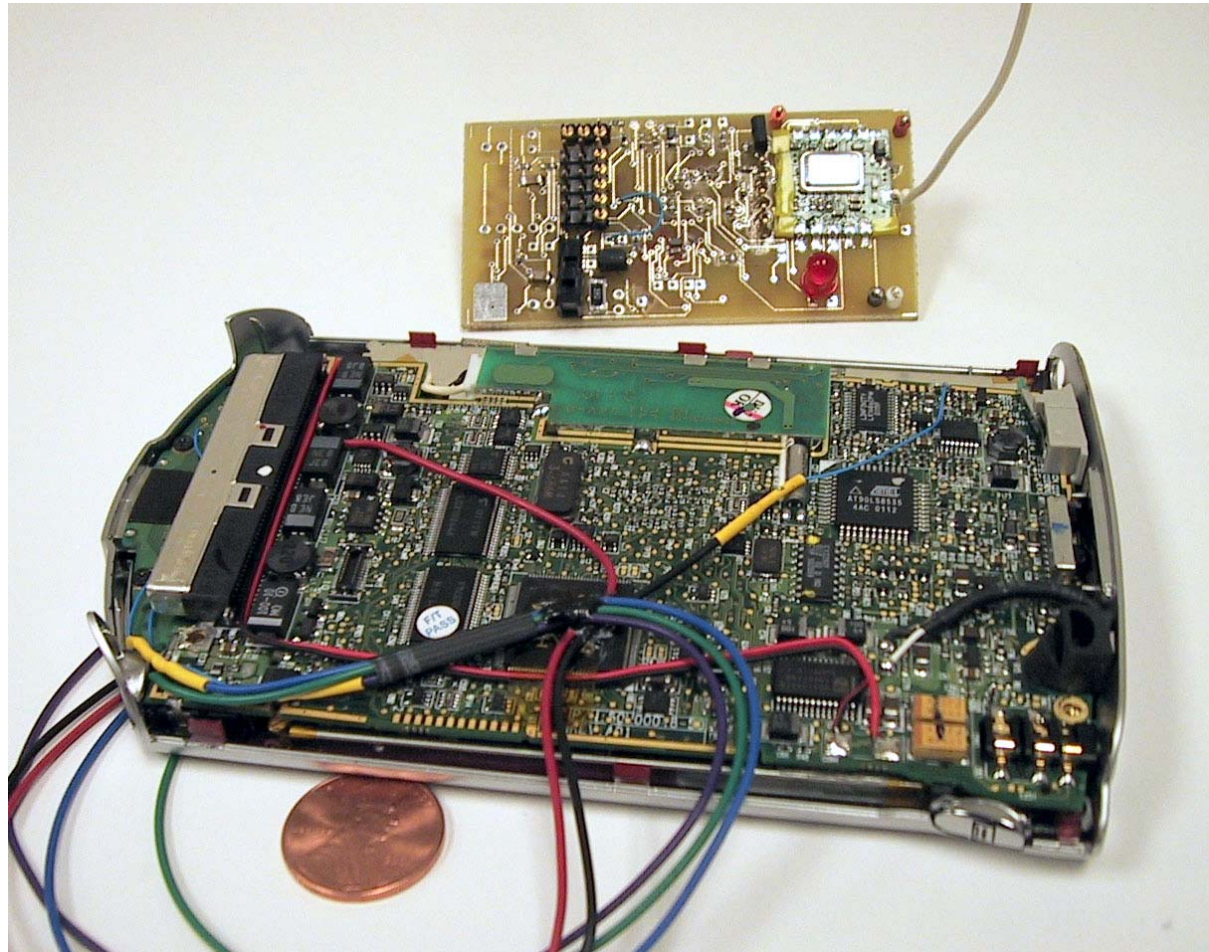


SmartBrick Hardware

- Power derived from serial port on PC
- Could be included in other infrastructure devices



The UCoM Device



- MiniBrick power derived directly from iPAQ battery
- MiniBrick turns on iPAQ by toggling Data Carrier Detect (DCD) line on serial port

The UCoM Device



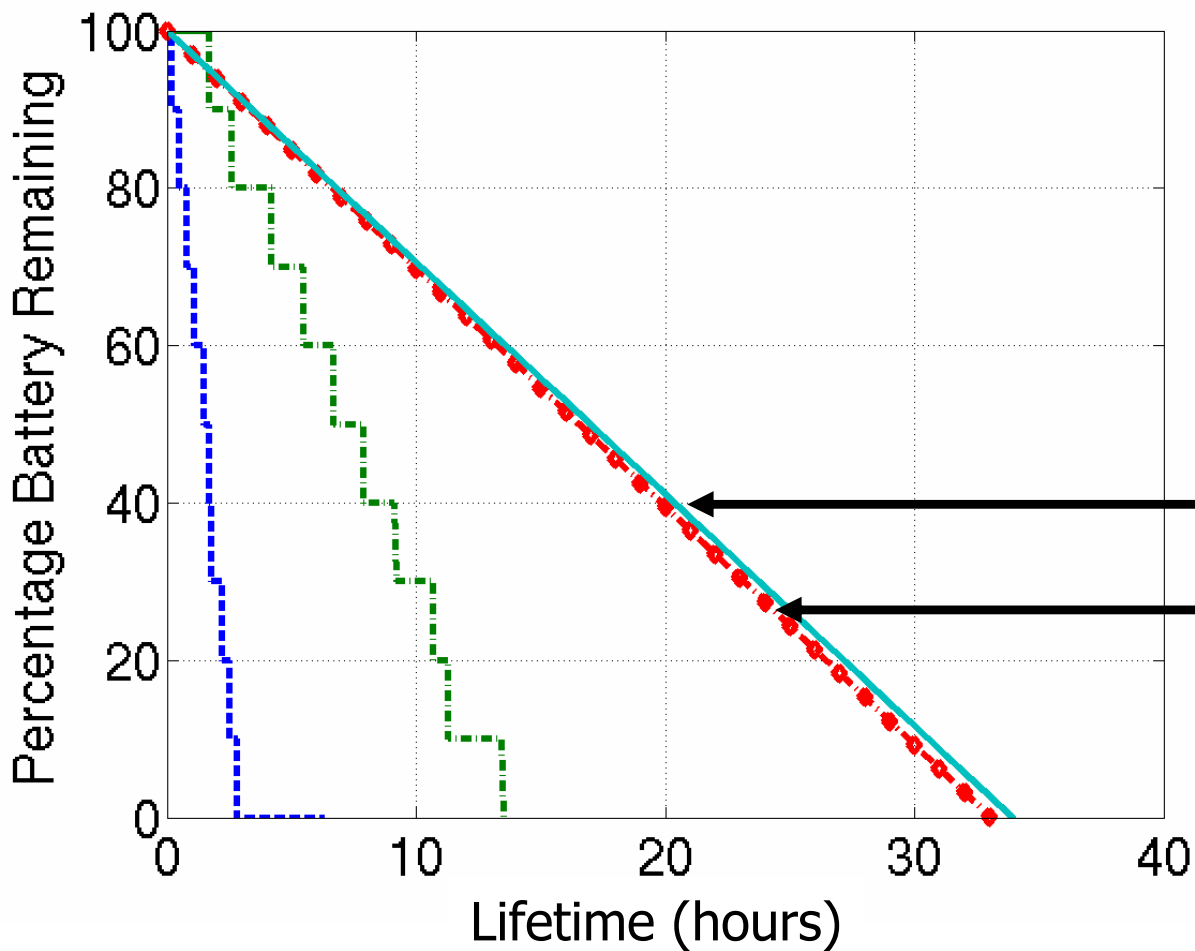
Power Consumption of UCoM Device

- Power consumption of UCoM device in different modes

iPAQ Mode	MiniBrick Mode	Power Consumed (W)
ACTIVE	"OFF"	2.92
"OFF"	Autonomous	0.114

System Performance

Standby Time



The idle power consumption for iPAQ H3650 is 112 mW (No wireless card)

iPAQ with WOW is 114 mW

iPAQ alone

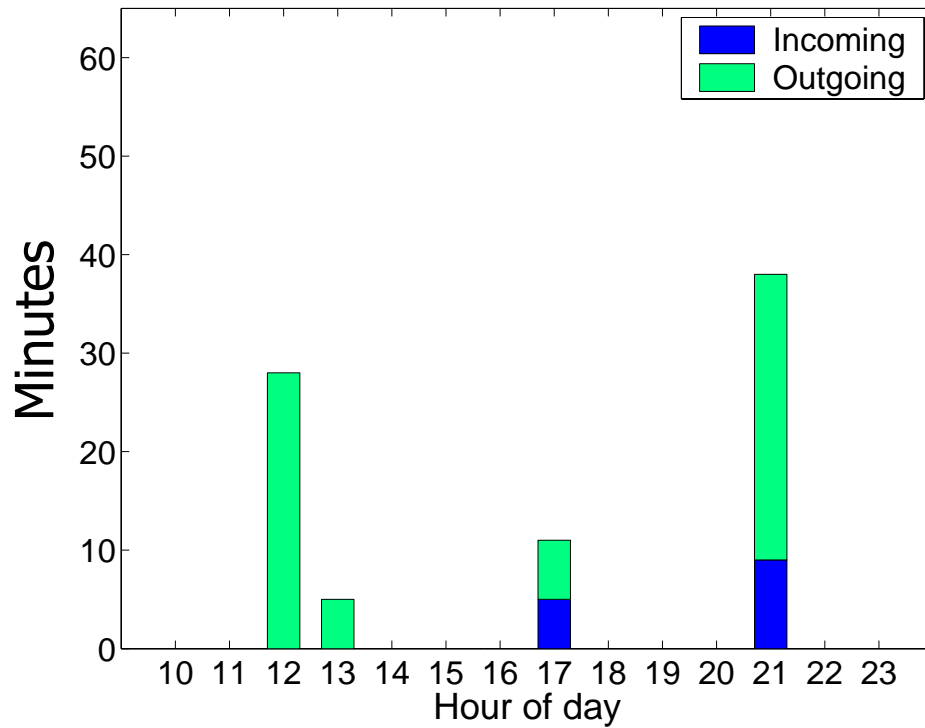
iPAQ with WoW

115% to 120% improvement in battery lifetime over PS mode

Battery Lifetime for Real Application

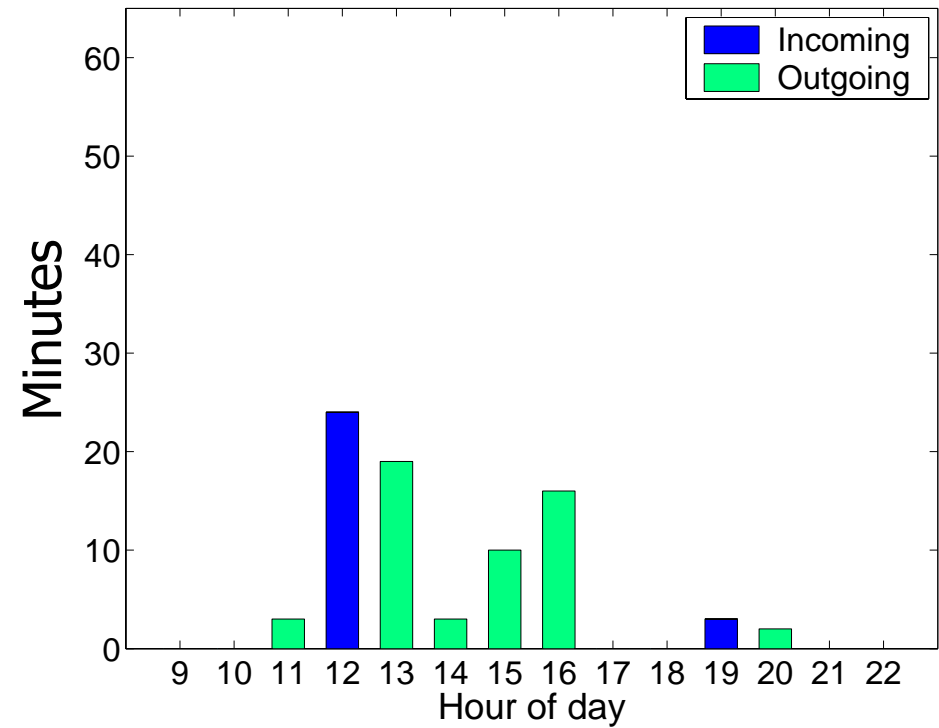
Cellular Phone Daily Usage Profile

Monthly cell phone bill of two real users



Alice

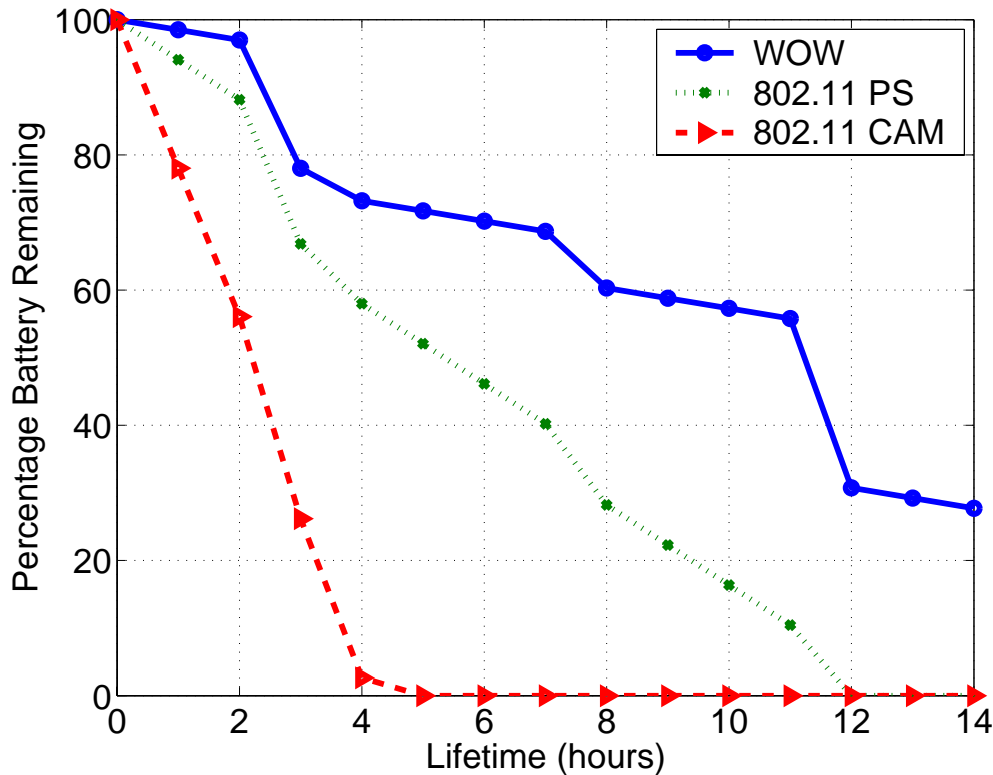
82 active minutes, **mostly idle**
(798 minutes / month)



Bob

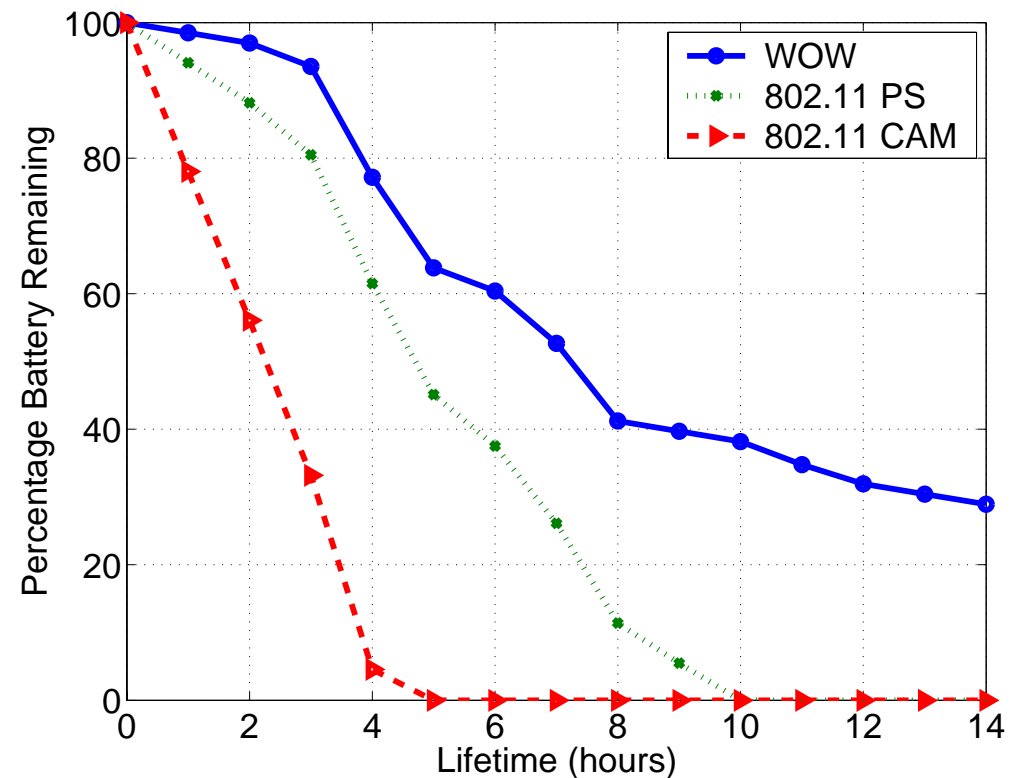
80 active minutes, **mostly idle**
(562 minutes / month)

Battery Lifetime for Real Application



Alice

Gain over 802.11b PS > 17%
Gain over 802.11b CAM > 180%

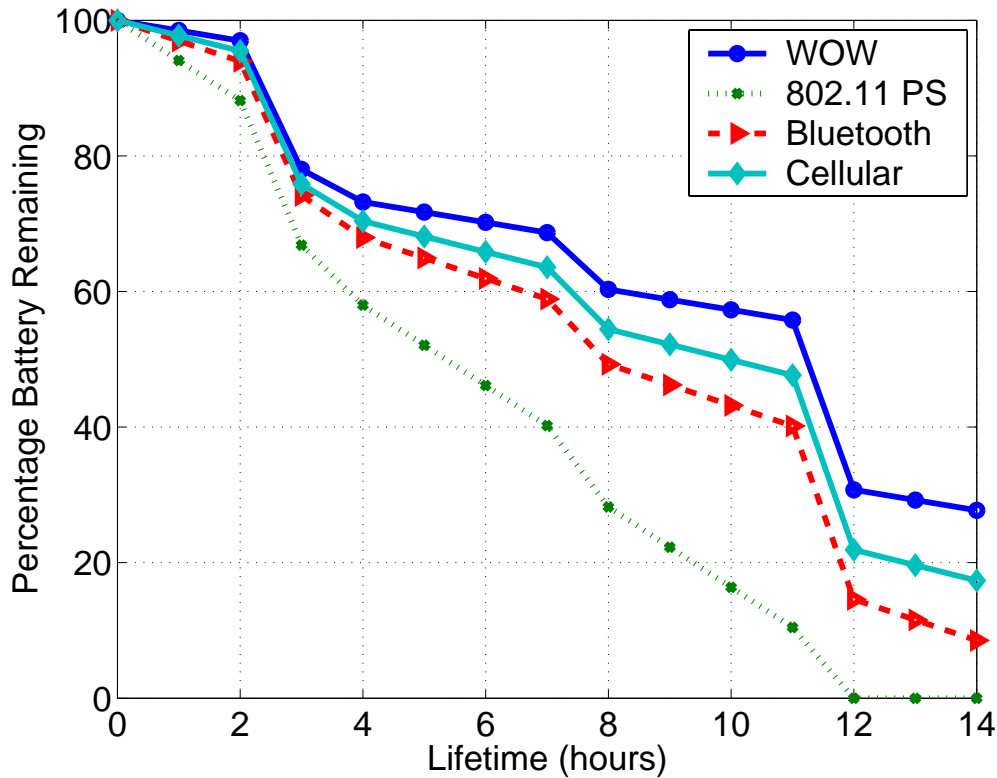


Bob

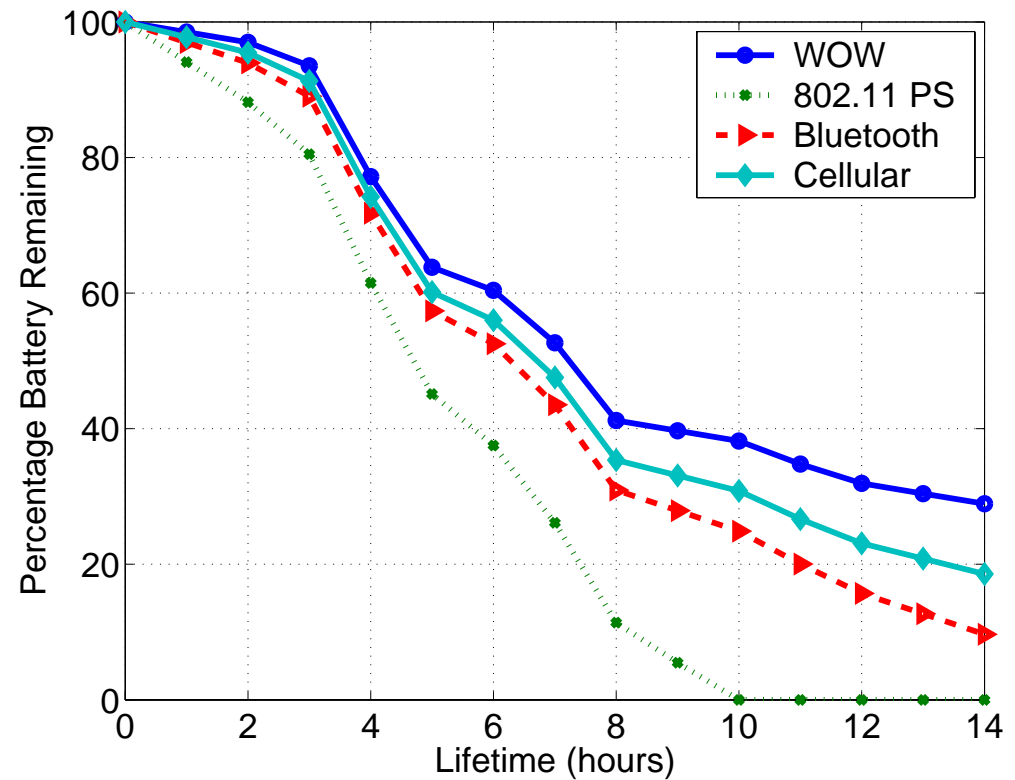
Gain over 802.11b PS > 40%
Gain over 80.11b CAM > 180%

In month: With 802.11b, 11 and 7 midday recharges were required respectively.
With WOW, only Alice required 1 midday recharge

Wakeup-Radio Can Be Anything



Alice



Bob

Multi-radio solutions are ready; WoW technique usable now

Summary

What Have We Achieved?

■ Started with:

- iPAQ without 802.11b has 35 hour standby lifetime
- iPAQ with 802.11b PS has 14 hour standby lifetime

■ Accomplished:

- With WoW, standby lifetime extended **near 35 hour limit**
- For a typical user with 82 minutes daily use; battery lifetime increased by 40%

■ Important Note:

- Technique is not limited to iPAQ or PDAs
- Specific radio is unimportant, any low-power triggering radio can be used

Our Ongoing Work

- Perform traffic scheduling to increase battery lifetime with managed channel access
- Increase battery lifetime with application transparent power-aware communications
- Fast Authentication with Context Migration