Microsoft Research

Wake on Wireless – a Case for Multi Radio Wireless LAN

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Joint work with

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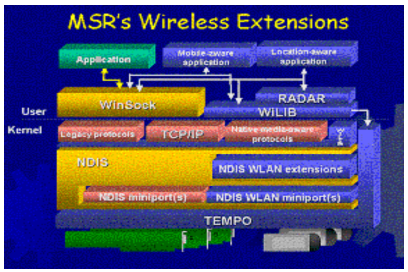
Our Vision, Our Projects

To enhance wireless functionality in the local area and to push local area wireless system performance and functionality into the wide area



Wireless Network Programmability

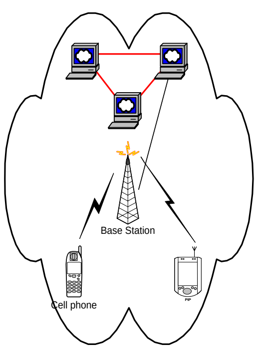
Microsoft Research

Radar

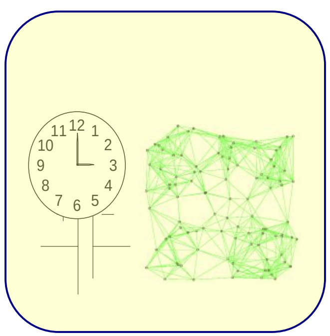
Location: Determination, Management, Services & Applications

The Choice Network

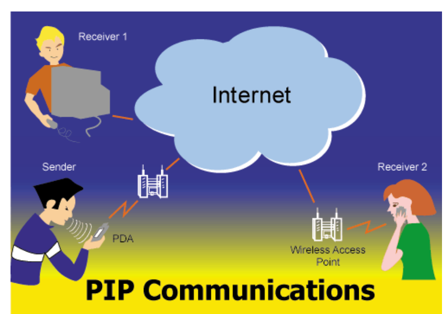
Public Networks: Authentication, Security, Access & Services



Wireless Web Browse & Alert Analysis



Topology control, Fairness & Energy management



Voice Communications Multi-radio wireless LANs

External Engagement

Standards, Gov. Panels, Academic Conf. & Journals etc.

Outline

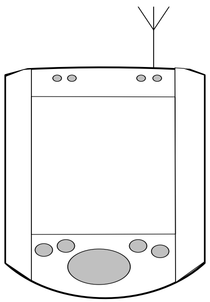
- Research Motivation & Goals
- The Problem & our Proposal
- Proof of Concept System Design & Implementation
- Performance Results
- Comparison with Alternate Strategies
- Additional Benefits & Further Investigation
- Feasibility Discussions

Motivation:

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

...wanted a

Universal CoMunicator



Creating a UCoM

Take a PDA (a Pocket PC) with WiFi capabilities and enable it for voice communications

……..fairly straightforward

UCoM Usage Scenarios

Scenario 1: Handheld Internet Phone

For enterprise networks – requires presence establishment; real-time secure audio communications

Scenario 2: Walkie-Talkie (P2P Direct)

Server-less presence establishment; real-time secure audio communications; low to zero dependence on infra-structure; may require multi-hop routing

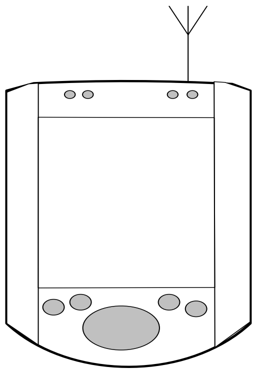
Scenario 3: Internet Voice Messaging

For wide-area Internet -- Instant message based audio communications; server required

Scenario 4: Voice Email

Non real-time, disconnected operation possible

Goal: download software from a web site
and convert your PDA to do all of above



PIP

MSR's UCoM (802.11)
- PPC 2002

AudioVox Thera
(CDMA2000)
- PPC 2002 OS

Siemens SX 45
(GPRS) - PPC 2002 OS

Nokia 9110
(GSM) - GEOS OS

MS SmartPhone
- WinCE 3.0 OS

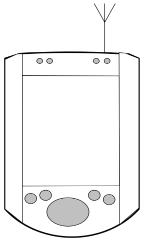
Samsung I300
- Palm OS

Handspring Treo 180
- Palm OS (GSM)

Kyocera QCP 6035
(CDMA) - Palm 3.5 OS

49 million PDA-Phones by the year 2007 [Cellular News 1/23/02]

UCoM is different because its a



A high-quality secure interactive data & voice communicator that works over an all-IP infrastructure.

A platform for building software and hardware enhancements for wirelessly connected IP-based handheld devices, and supporting infra-structure Internet devices.

A platform for carrying out low-power wireless systems research.

A platform for exploring new functionality for small devices with sensors and low-power communications.

The Energy Consumption Problem

A big obstacle in deploying
WLAN-based VoIP devices is battery lifetime

Previous Work in Optimizing Energy Consumption

Battery capacity doubles in energy density every 35 years [Pow95]

Many things can be improved:

- Build energy efficient CMOS and VLSI circuits [Cha95]
- Lower CPU frequencies [Gon96];
- Move devices into different power modes [Sim00] [Sri96] [Pou01]
- Enhance and modify network protocols [Kra98] [Woe98]
- Vary signal level depending on proximity [Bam96]
- Shut off wireless NIC [Stem97]
- Scale voltage dynamically [Lor96] [Min00] [Per98]

Bottom line: Many techniques exists, each has limited effectiveness and many suffer from high latency issues.

Managing Power: Basics

Definitions:

Active Power – Power required to perform specified operations on the device

Idle Power – Power required to keep the device turned on (in low power mode), ready to react to unforeseen events.

To increase battery lifetime:

- Reduce active power
- Reduce idle power

Ir

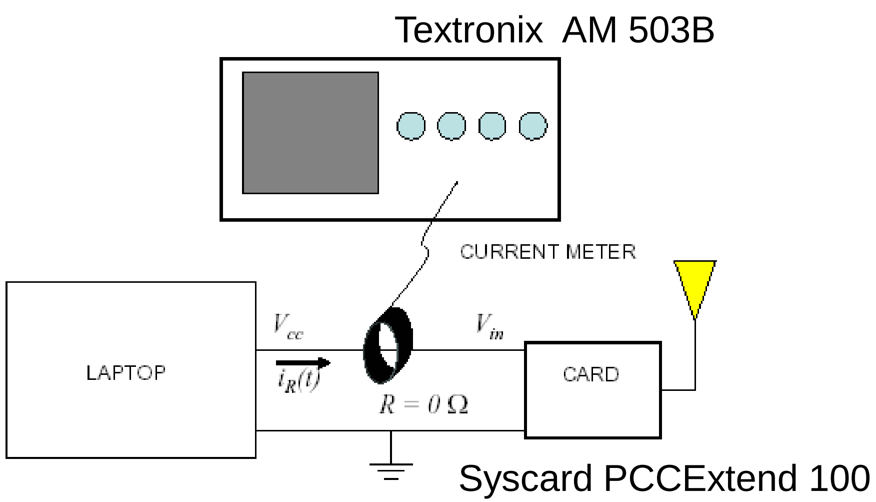
The PPC expends energy in idle state most of the time

h

Idle power consumption is as large as receive power [Fee01]

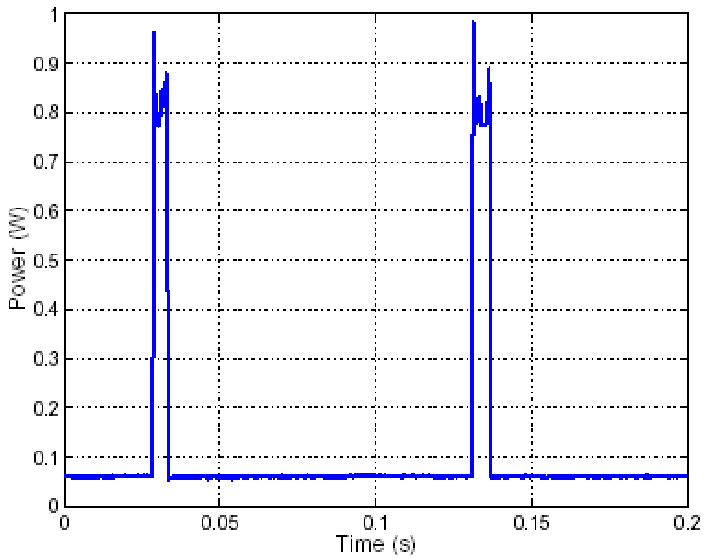
Most people use their PPC 10-15 times a day generally for 30-45 seconds at a time. [Kam01]

Measuring I_{Avg} of popular IEEE 802.11b NICs



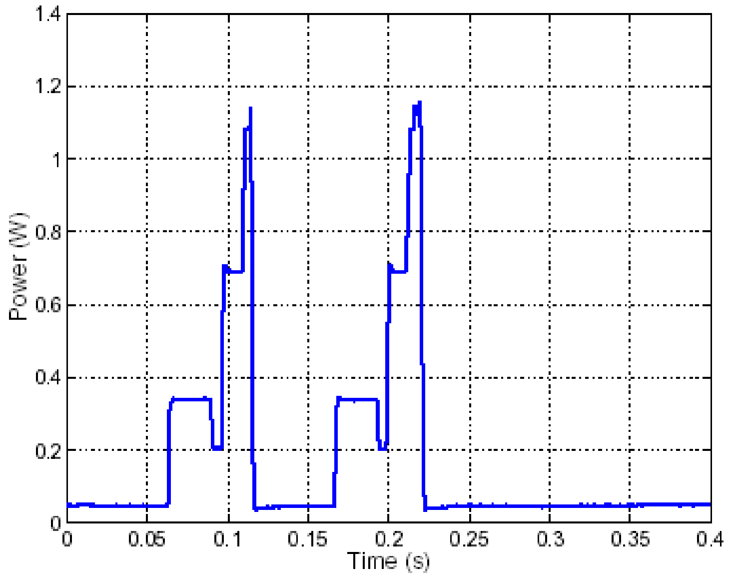
Chipset	Sleep (mA)	Idle (mA)	Receive (mA)	Transmit (mA)
ORiNOCO PC Gold	12	161	190	280
Cisco AIR-PCM350	9	216	260	375

Power Consumed during PS Mode



Power consumed by Orinoco Gold during Power Save Mode

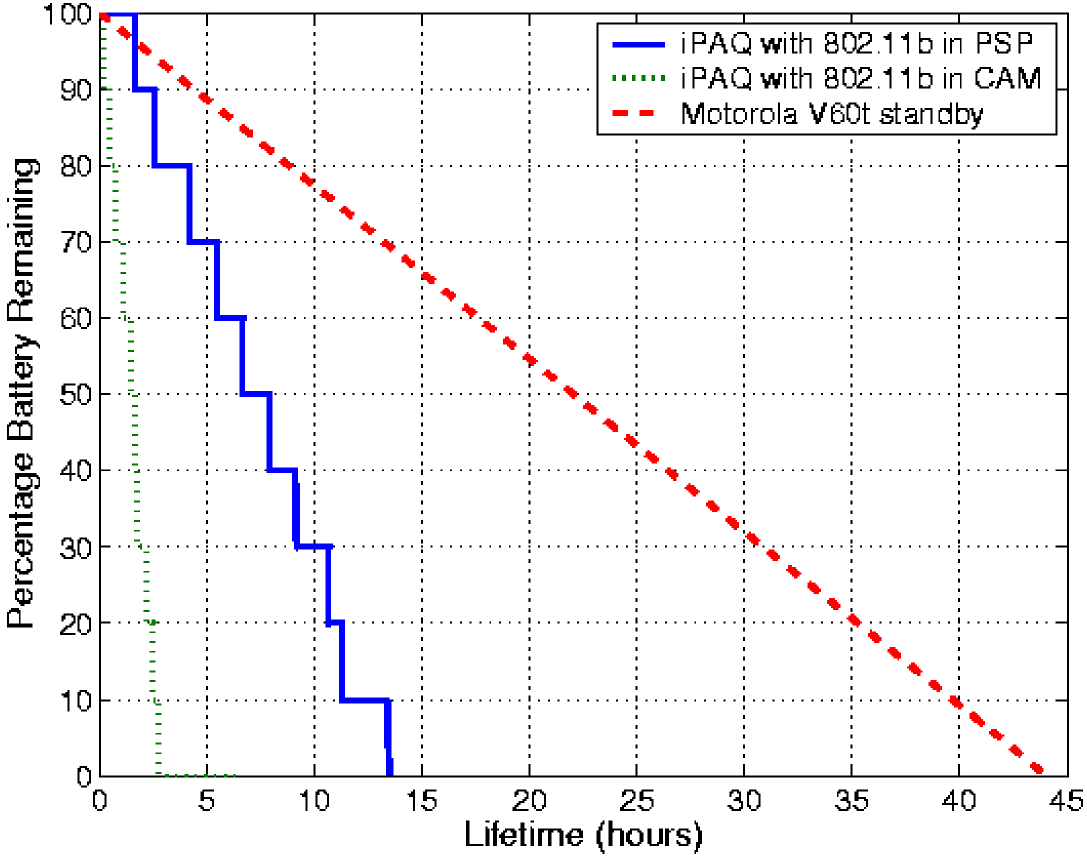
$E_{cycle}\,(n,t) = 0.060nt + 3300,\ \ 0 =< n =< 65535$



Power consumed by Cisco AIR-PCM350 during Power Save Mode

$E_{cycle}\,(n,t) = 0.060nt + 3300,\ \ 0 =< n =< 65535$

Standby Lifetime of an 802.11 iPAQ & a Cell Phone



Reducing Idle Power

The Problem

To receive a phone call the device and the wireless NIC has to be in a “listening” state i.e. they have to be on.

Our Proposal

When not in use, turn the wireless NIC and the device off.

Create a separate control channel. Operate the control channel using very low power, possibly in a different freq. band. Use this channel to “wake-up” device when necessary.

Proof of Concept & Implementation

Short Term: Add a low power RF transceiver to the 802.11 enabled handheld device

Long term: Integrate lower power functionality into 802.11 or integrate lower power radio into mother board and/or 802.11 Access Points.

Proof of Concept
System Design and Implementation

Hardware Components

A low-power RF transceiver added to the handheld

We call this a “MiniBrick” or “Mbrick”

A low-power RF transceiver added to the infrastructure

We call this a “SmartBrick” or “Sbrick”

Requirements:

- Sbrick has to be connected to a network
- Sbrick talks to an Mbrick using a defined protocol

Design alternatives

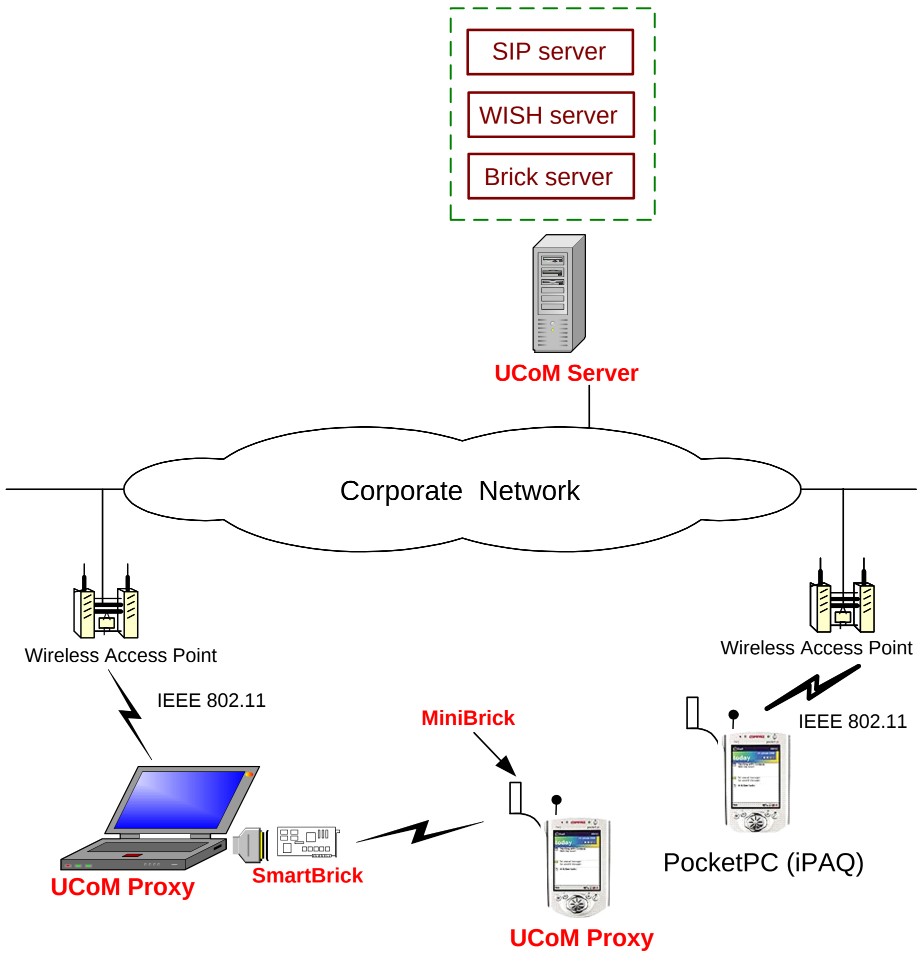
→ Incorporate the Sbrick into a Wireless LAN AP

→ Plug the Sbrick into an electrical outlet

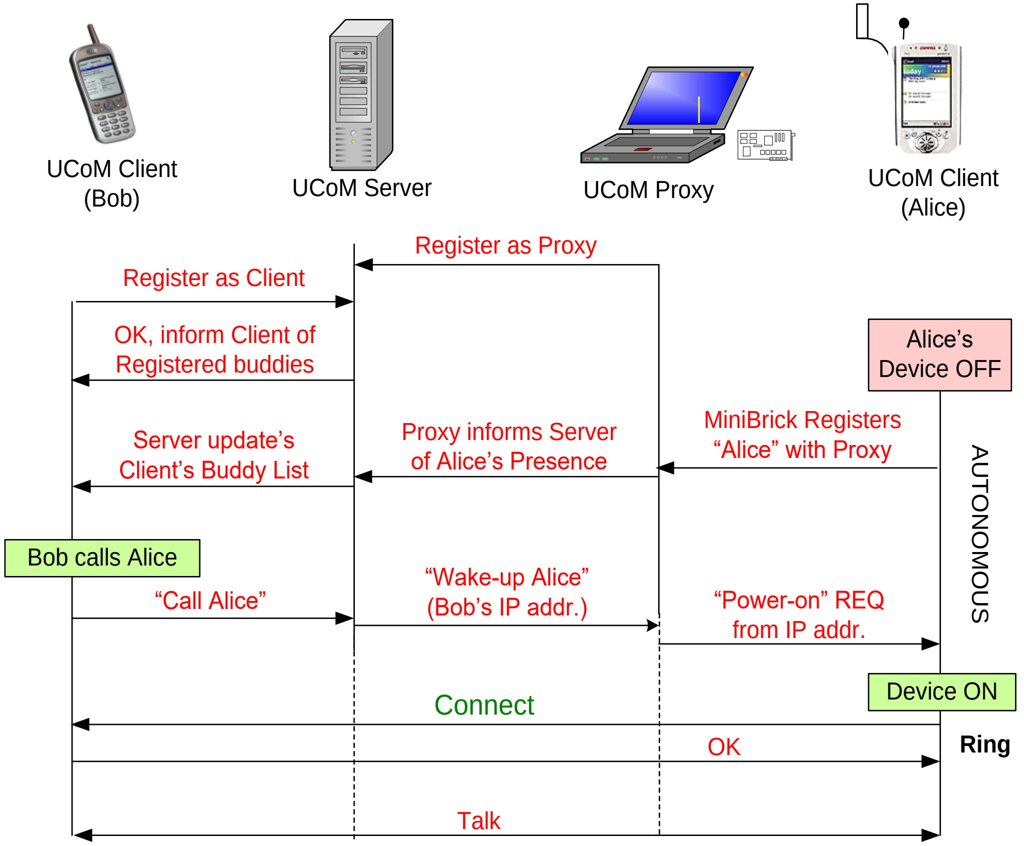
→ Incorporate the Sbrick into a computer’s motherboard

→ Connect the Sbrick to a networked computer

Software Components

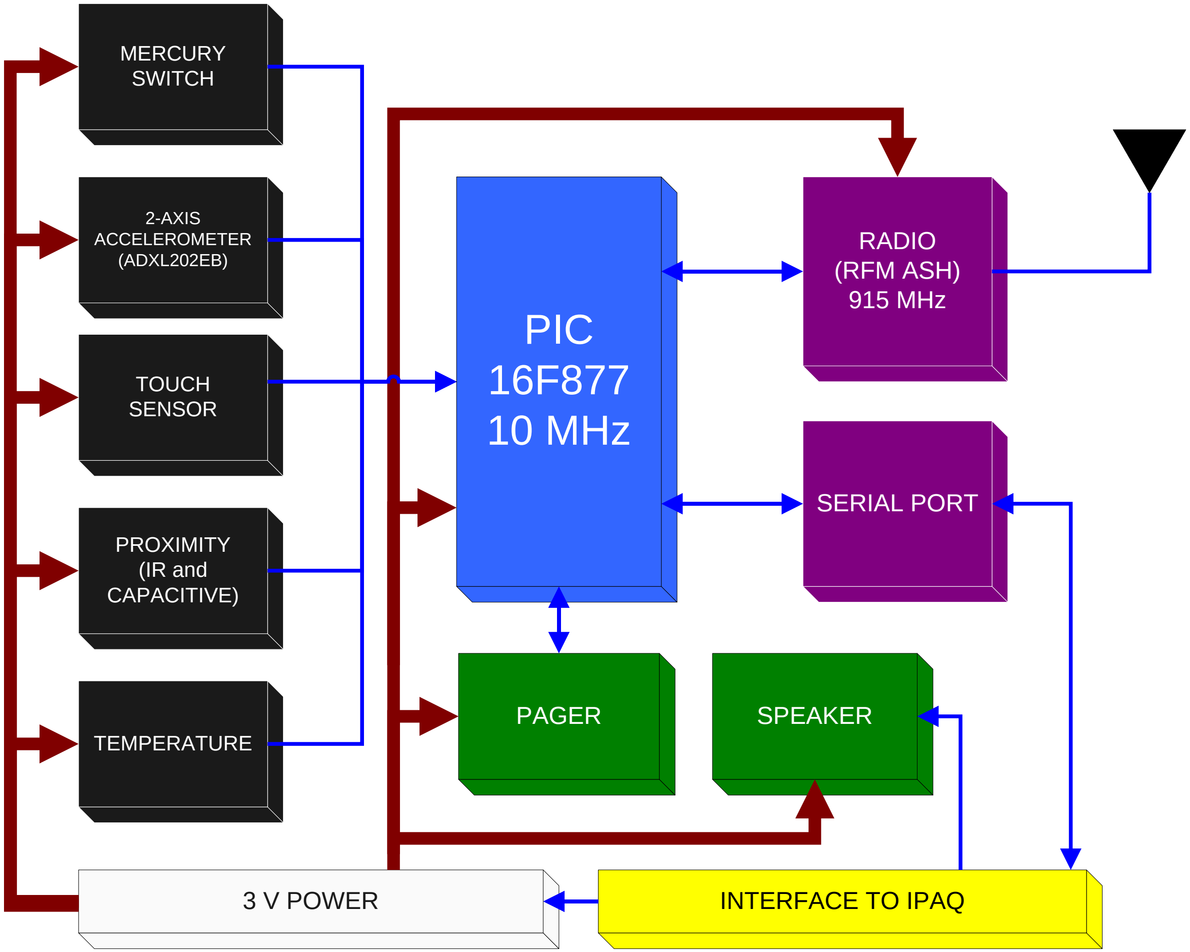


Call Setup

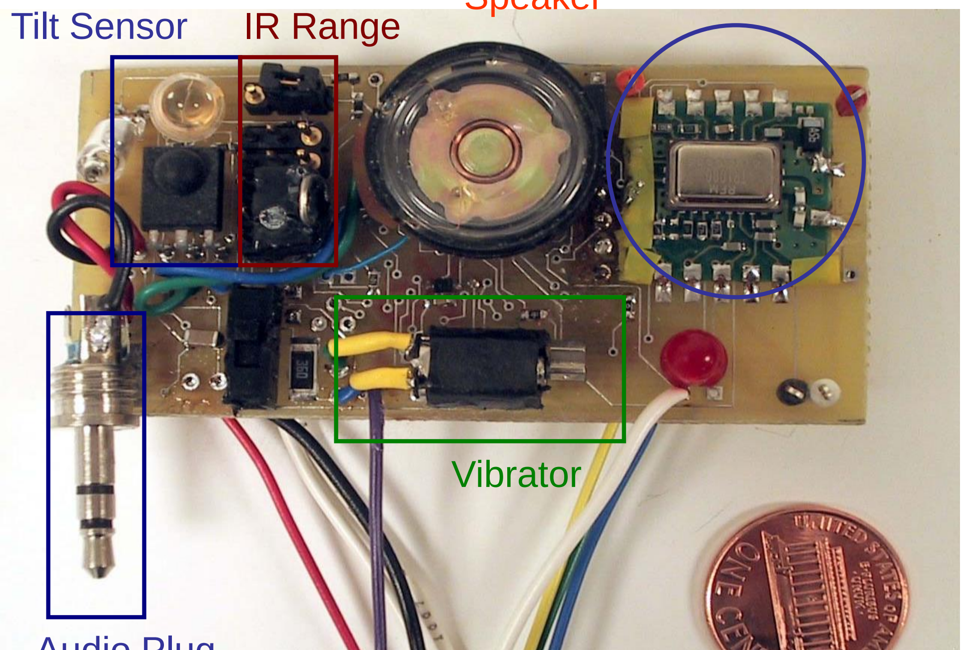


UCoM Client
(Bob)
UCoM Server
UCoM Proxy
UCoM Client
(Alice)
Register as Proxy
Register as Client
OK, inform Client of
Registered buddies
Alice's
Device OFF
MiniBrick Registers
"Alice" with Proxy
Proxy informs Server
of Alice's Presence
Server update's
Client's Buddy List
AUTONOMOUS
Bob calls Alice
"Call Alice"
"Wake-up Alice"
(Bob's IP addr.)
"Power-on" REQ
from IP addr.
Device ON
Connect
OK
Ring
Talk

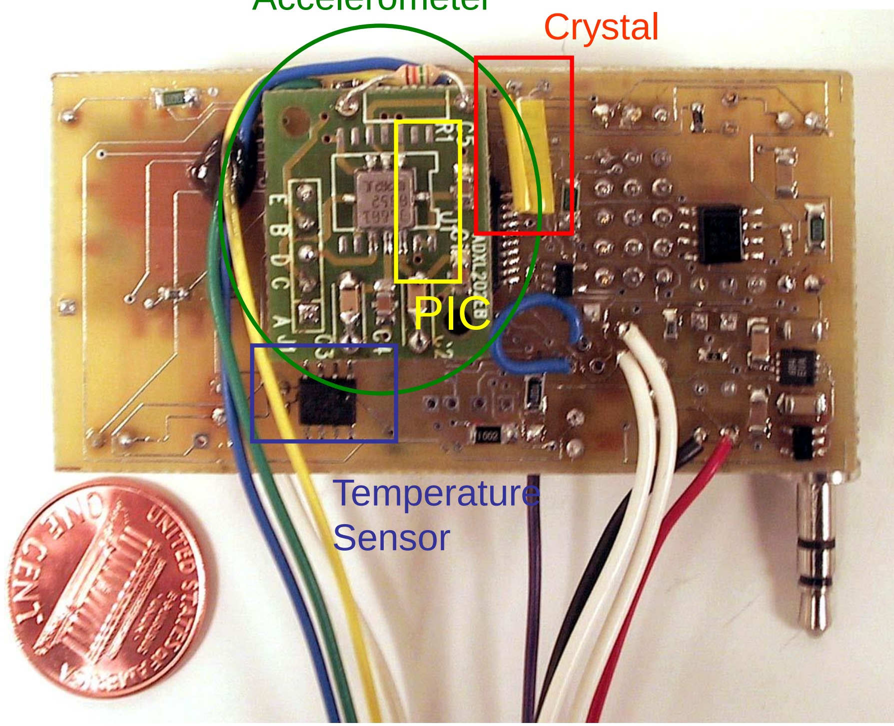
The MiniBrick Architecture



The MiniBrick PCB



Front View



Back View

Modular design allows removal of components

Radio Power Consumption

Radio:

- RFM TR 1000 ASH
- Modulation: ASK
- Voltage: 3V
- Range: 30 feet (approx)

Comparing against 802.11 and BT Radios

Chipset	Receive (mW)	Transmit (mW)	Standby (mW)	Rate (Mbps)
Intersil PRISM 2 (802.11b)	400	1000	20	11
Silicon Wave SiW1502 (BT)	160	140	20	1
RFM TR1000	**14**	**36**	**0.015**	**0.115**

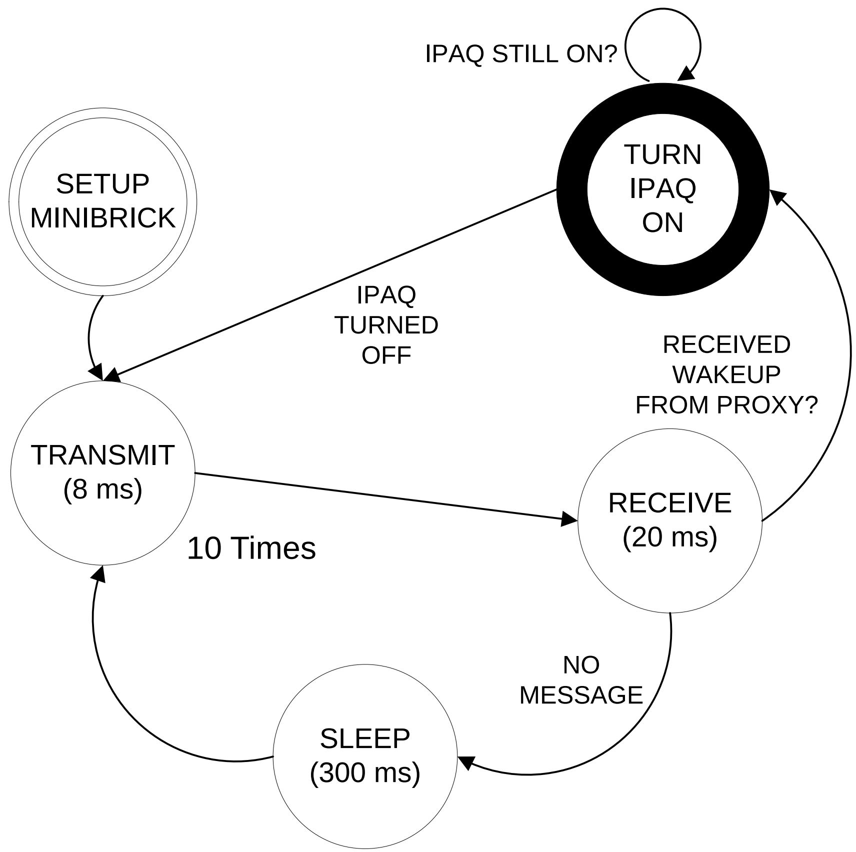
MiniBrick Power Consumption

Mode	Power Consumption
Transmit	39 mW
Receive	16 mW
Standby	7.8 mW

Theses numbers include the power consumption by the PIC Microcontroller and the RFM TR1000

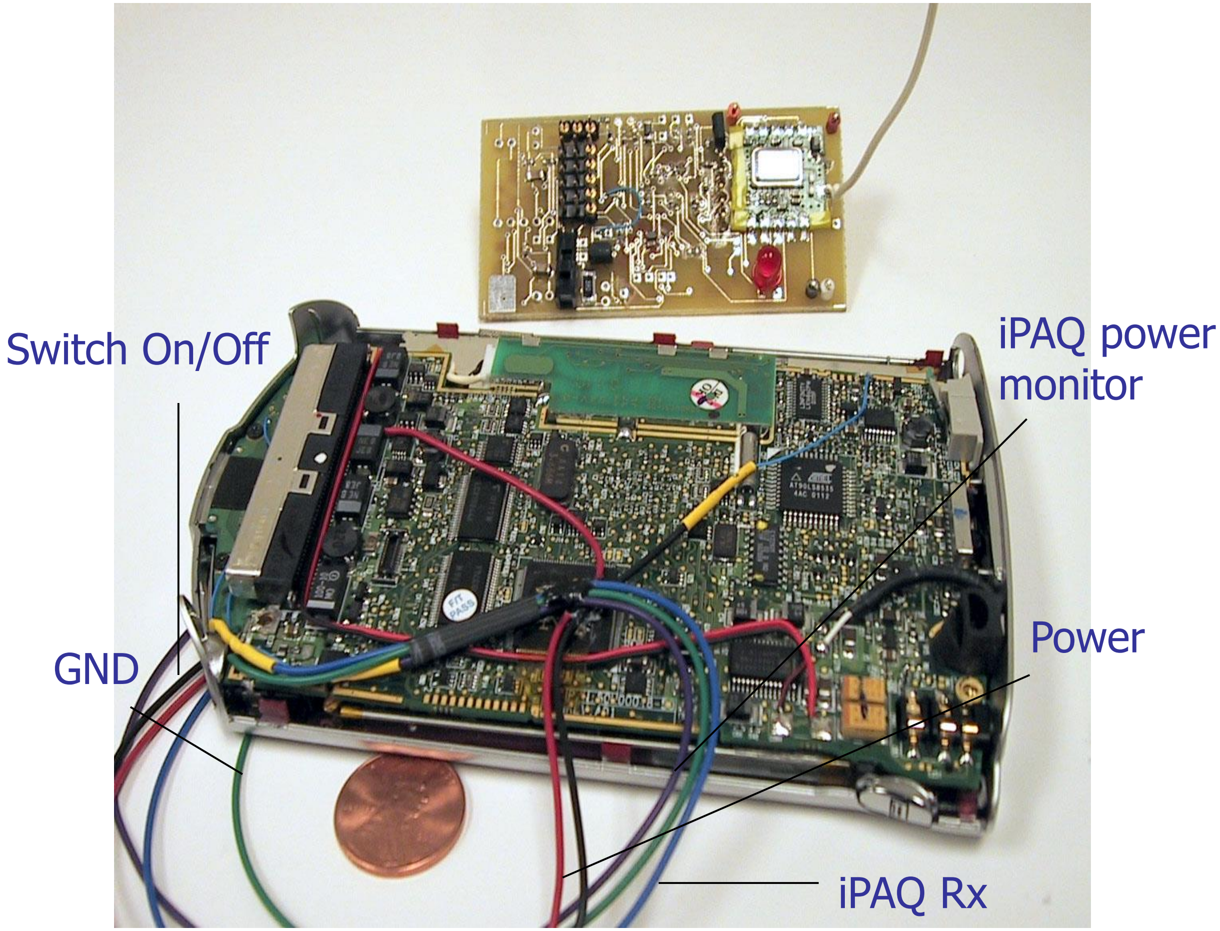
MiniBrick Operating Mode

PREAMBLE	DEST_TYPE	DEST_ID	SRC_TYPE	SRC_ID	DATA_SIZE	DATA	CRC



Autonomous Mode

Integrating MiniBrick & iPAQ



MiniBrick turns on the iPAQ by toggling the Data Carrier Detect (DCD) line on serial port

The UCoM Device

Power Consumption of the UCoM Device

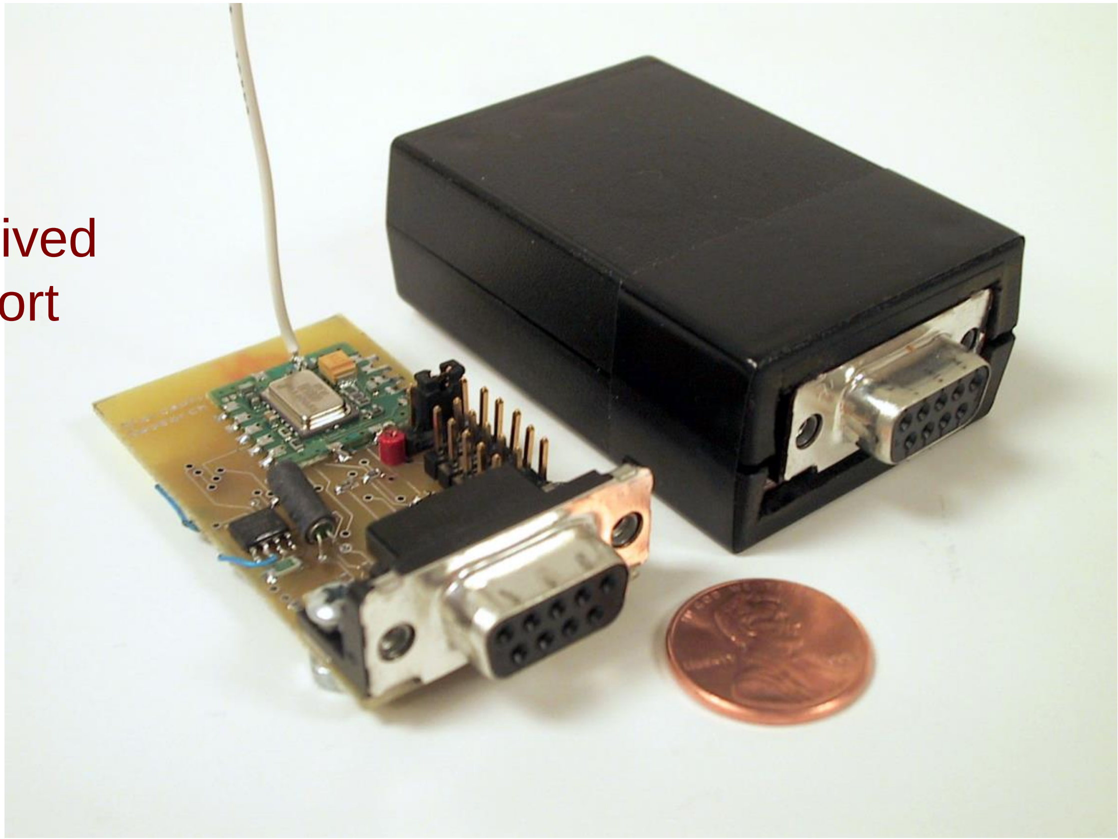
iPAQ Mode	MiniBrick Mode	Power Consumed (W)
ACTIVE	Off	2.92
ATTEMPT	Off	2.92
STANDBY	Autonomous	0.12

ACTIVE – during actual conversation
ATTEMPT – when device is attempting a call
STANDBY – when device is completely OFF

The SmartBrick

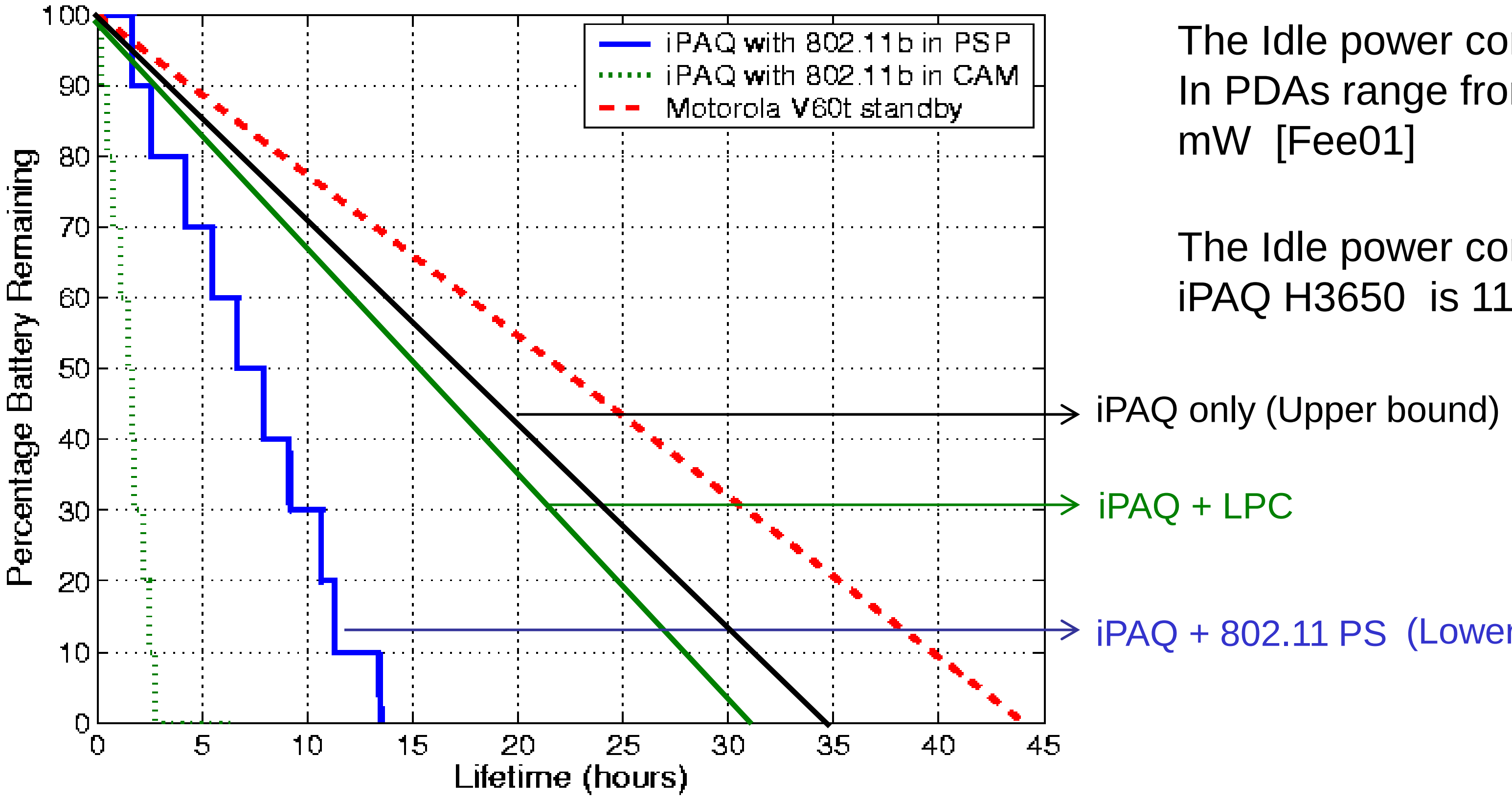
Cool

Power is derived from serial port



System Performance

How did we do on Standby Time?



The Idle power consumption In PDAs range from 100 to 200 mW [Fee01]

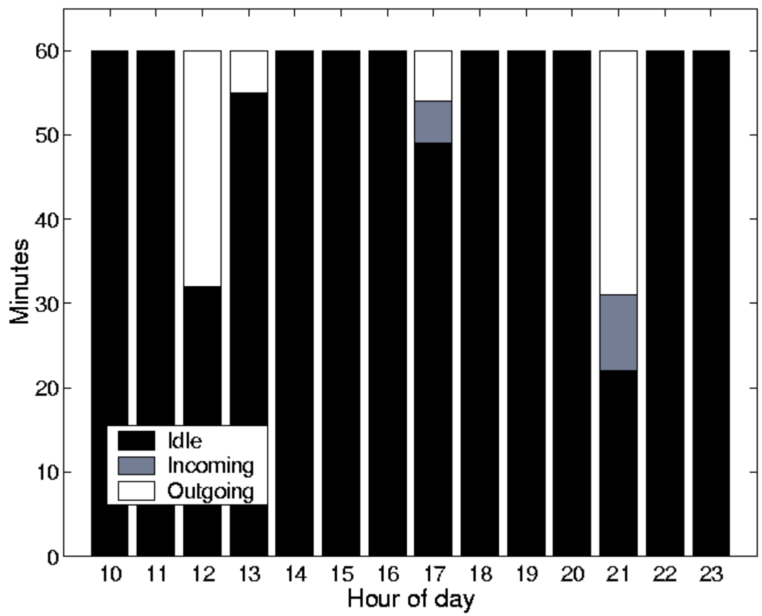
The Idle power consumption for iPAQ H3650 is 112 mW

115% improvement in battery lifetime over PS mode with lower latency

How do we do for real users?

Cellular Phone Usage Profile

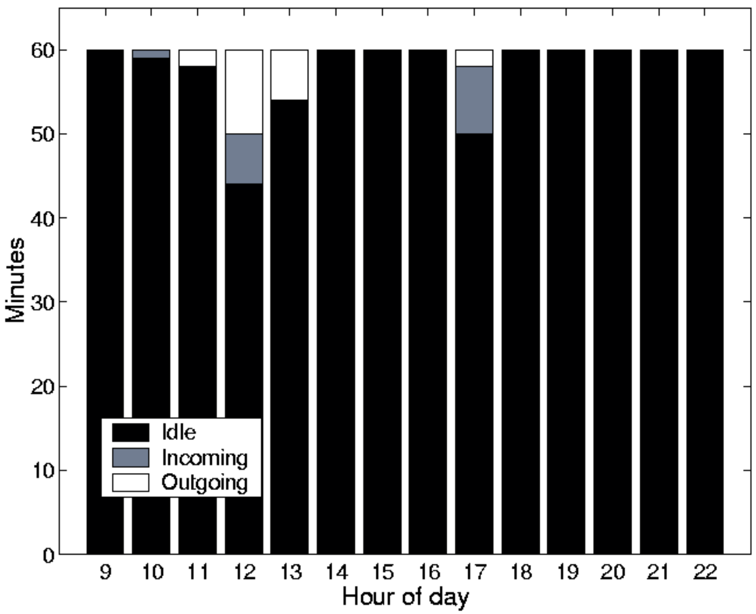
From one month's cell phone bills of two real users



Alice

82 minutes talk time

(798 minutes / month)



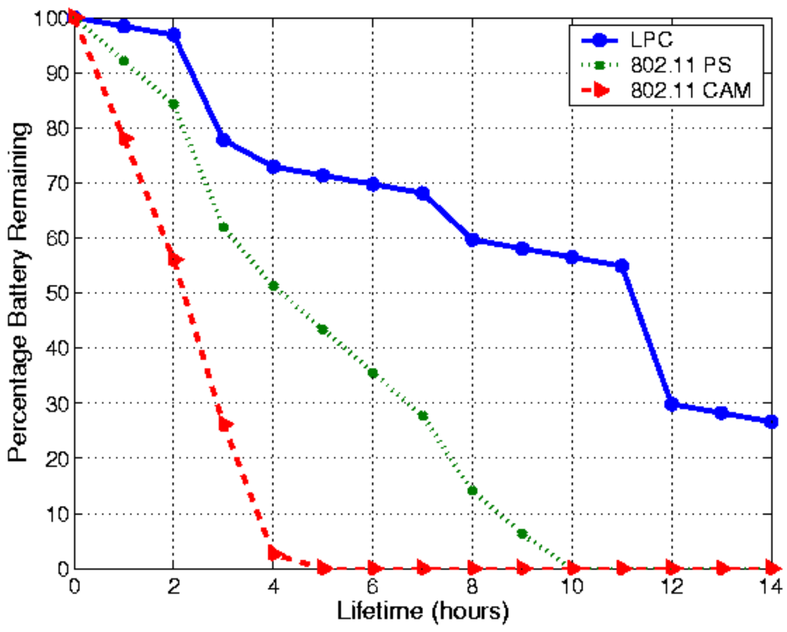
Bob

35 minutes talk time

(562 minutes / month)

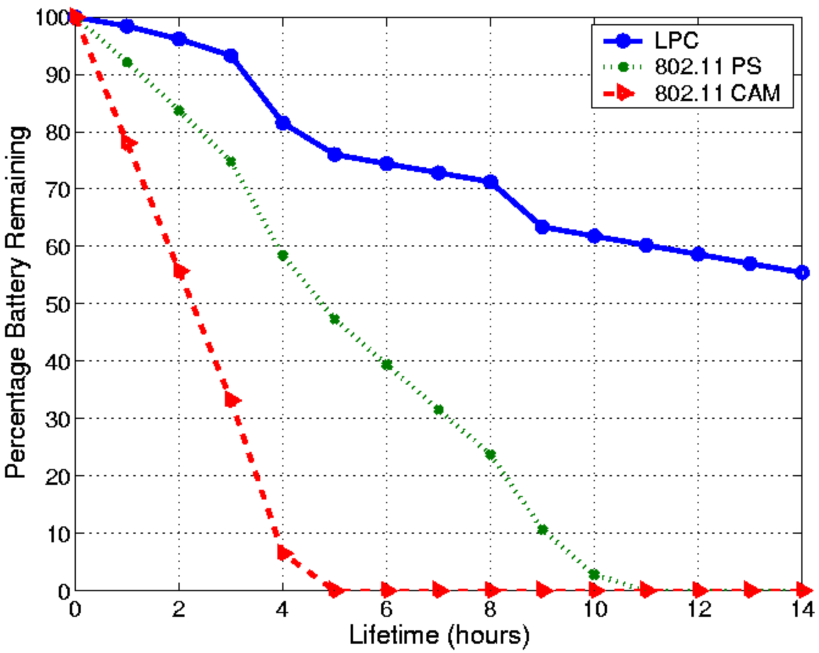
Battery Lifetime for real users

With .11 PS both Alice and Bob will have to perform midday recharge for all days profiled



Alice

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



Bob

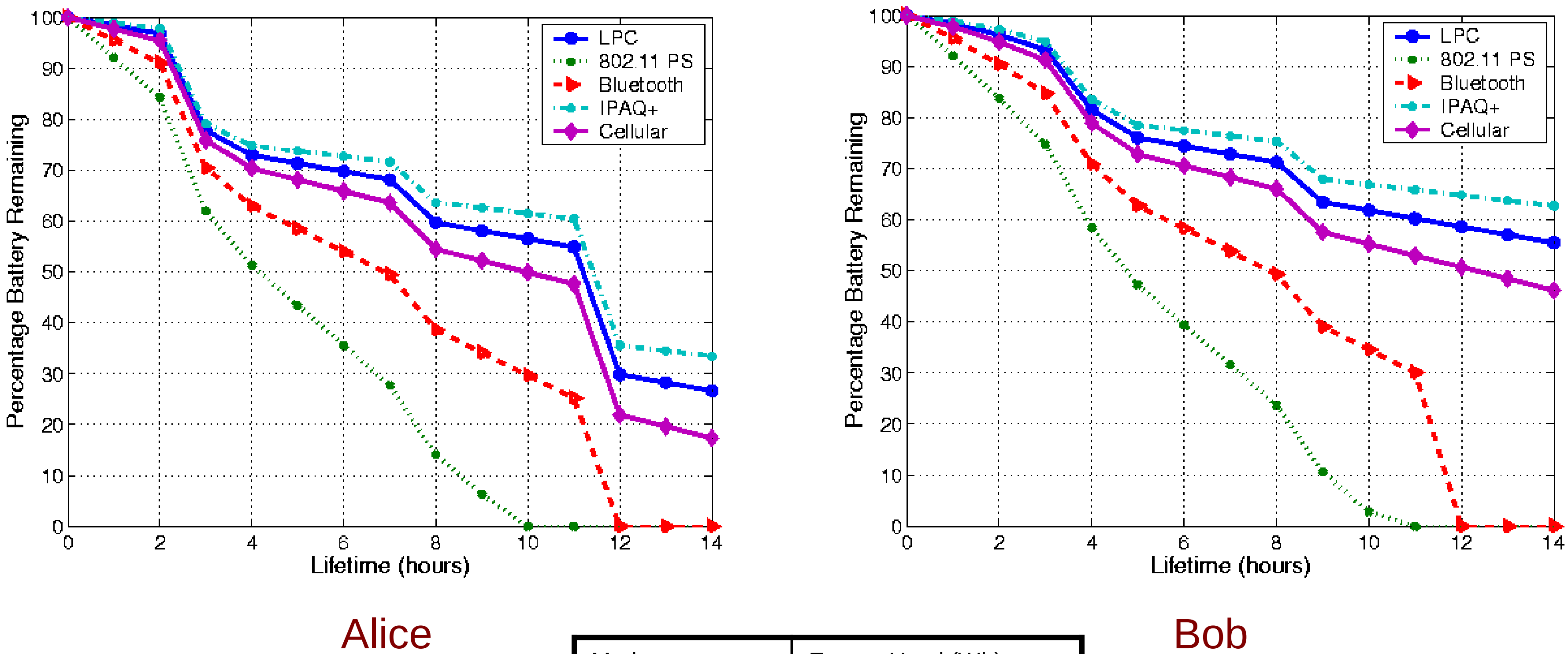
Gain over 802.11b PS > 27%
Gain over 802.11b CAM > 180%

A comparison with alternative strategies

Power Consumption Measurement: Methodology and Results – Cell Phones

Mode	High (mW)	Low (mW)	Average (mW)
Standby (weak signal)	156	84	125
Standby (strong signal)	26	17	20
Ringing	1676	1440	1582
Talking	1612	1032	1254
Call Attempt	704	884	696

Lifetime with various technologies



Mode	Energy Used (Wh)
802.11b CAM	**7600**
802.11b PSP	**7600**
Bluetooth	**6340**
With LPC	**3390**
IPAQ+ with LPC	**2830**
Cell Phone	**1720**

Summarizing

What did we achieve?

Started with

- iPAQ H3650 that consumes 112 mW even when it is “off”
  - Total standby lifetime: **35 hours**
- iPAQ H3650 with Cisco AIR-PCM340 802.11b in PS mode
  - Total standby lifetime: **14.5 hours**
    - Compare with Motorola v60t cell phone with **44.5 hours** standby time

Accomplished

- Standby life-time of a unmodified iPAQ with 802.11b and LPC went to **over 30 hours** -- an **improvement of 115%** (in addition to lower latency wake-on-wireless capability)
- For a typical user with 82 min./day use – we see an **improvement of over 40%** or a battery lifetime of **over 20 hour**

Important note

- Technique is not limited to iPAQ
- Technique is not limited to LPR, can use BT or GPRS as trigger network

See paper

- Compares iPAQ+.11b+LPR with Cell Phone
- Compares iPAQ + .11b+LPR to iPAQ + .11b+BT
- Analyzes a optimized iPAQ for power saving

Idea: Use Cellular network (low power control channel) in WiFi enabled (Hot Spot) Business

Today

Tension between cellular 2.5G / 3G providers and WiFi hot-spot owners

Instead of competing - collaborate

When inside a WiFi enabled building

- use GPRS or cellular tech. as low-power radio and a PIC to wake-up the multi-modal phone, then
- Make the VoIP call over the WiFi network

Share Revenues

- 2.5G / 3G providers get paid for routing call.
- WiFi providers gets paid for Internet access

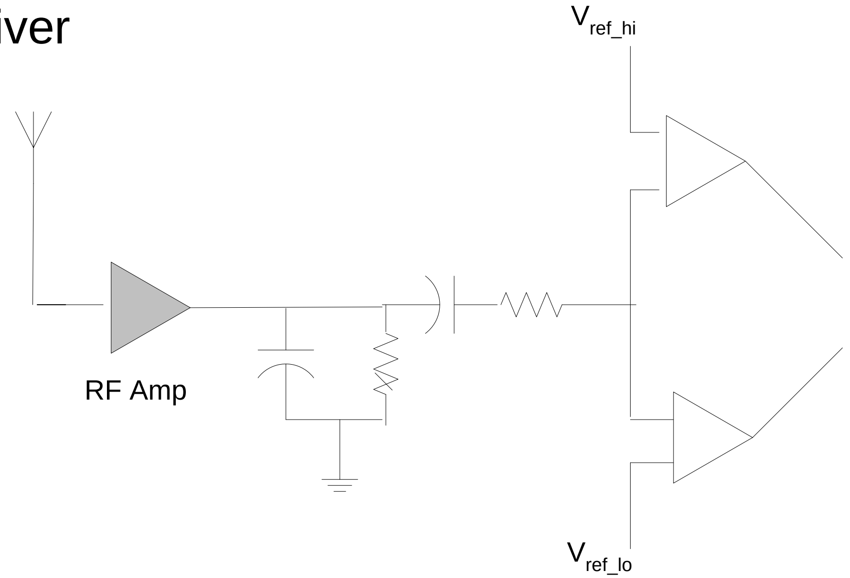
Add value for the customer

- Per minute calling cost (to China) is reduced
- Single phone number where-ever he/she roams
- Battery lifetime is increased
- Voice quality is great (better audio codecs, more bandwidth)

Note: can do wake on wireless using a low power one way radio….

Reactive Radio (Otis et. al)

Implement Wake on Wireless using a a simple low bias current (< 10 mA) RF receiver



PicoRadio design

But our design includes a two-way low power radio…..

We add a second Low Data Rate Low Power Radio to High Data Rate High Power Radio

Can do wake on wireless….

and more…

Revisiting some classical problems with a 2nd channel?

Increase battery lifetime with Wake-on-Wireless

Provide wireless QoS and increase battery lifetime with managed channel access

Increase battery lifetime with application transparent power aware communications

Fast Authentication with Context Migration

Improve performance of ad hoc networks….

Feasibility of Multi-Radio Wireless LAN

We are agnostic of the underlying low power RF technology

Are devices going to have a second radio?

Available today

- RFM TR1100 ASH Transceiver
  - 1 Mbps, PHY-only, low cost, very low power < $10 (OEM)
- Mobilian TrueRadio™ MN12100 chip
  - Integrated 802.11b + Bluetooth
- Nokia D211
  - Integrated 802.11b + GPRS + HCSD
- iPAQ Pocket PC H3870
  - Integrated Bluetooth + expansion pack 802.11

Coming shortly

- IEEE 802.15.4 Standard (sponsor ballot: July 2002)
  - 200 kbps, MAC and PHY defined– low cost, low power
- Symbol Technologies, Voice Stream etc.
- UWB (Intel, Sony have prototypes, Time Domain.com)

Bottom Line: Build Multi-Radio WLANs

Multi-Radio Wireless LANs can solve many “classical” problems in wireless networking

Thanks!

Details available in
ACM MobiCom 2002 Paper

download from http://research.microsoft.com/~bahl