Bridging the Information Divide
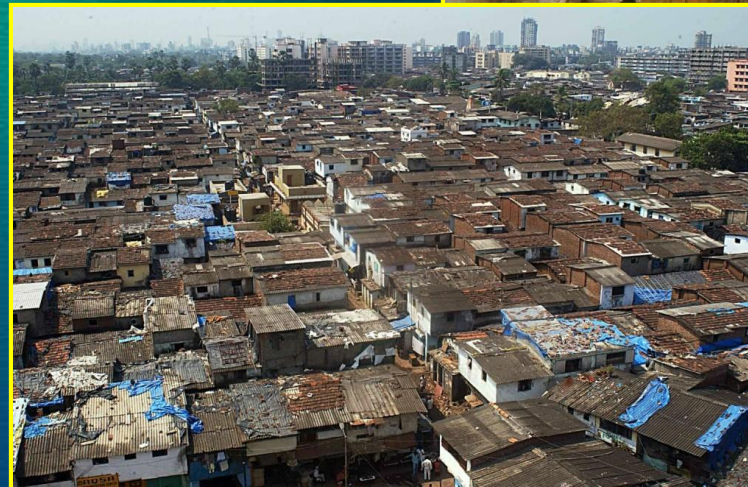
Victor Bahl
Senior Researcher
Manager, Networking Group
Microsoft Research

3+ billion people…

- Pay a "poverty premium" for basic goods and services

- Have little access to important amenities

- Make livelihood decisions with incomplete information

Technology alone is not the answer…

Deeper socio-economic issues have to be addressed

> Yet the debate over the digital divide is founded on a myth--that plugging poor countries into the internet will help them to become rich rapidly. This is highly unlikely, because the digital divide is not a problem in itself, but a symptom of deeper, more important divides: of income, development and literacy.

The Real Digital Divide
The Economist
Mar 10th 2005

However technology can help….

Victor Bahl

Remarks by Secretary General Kofi Annan
(Opening ceremony of the World Electronic Media Forum)
December 9, 2003

"The goal is an information society – open and inclusive – in which knowledge empowers all people, and serves the cause of improving human condition"

"All over the developing world, as antennas and satellite dishes sprout across the landscape - we can see the immense thirst for connection. Let us show that we are listening."

Thirst for Connection…
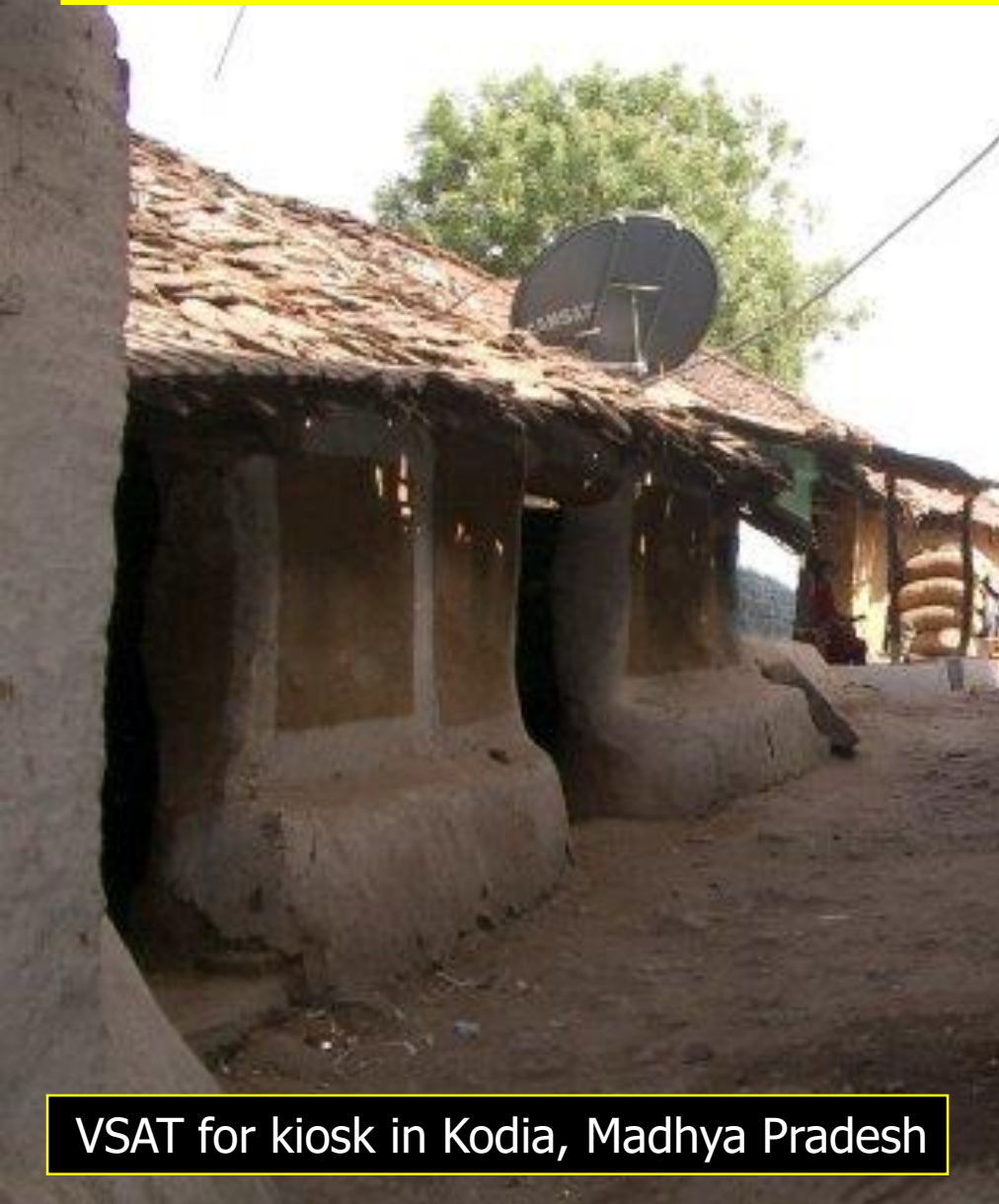
VSAT for kiosk in Kodia, Madhya Pradesh

n-Logue corDECT wireless tower

Thirst for Connection…

In developing countries……

AKSHAYA

Bhoomi
Computerisation of Land Records

Driven by
e-governance, telemedicine, e-learning,
LRIS (Land record Information System)

Projects, Business India, Jan. 3, 2005

- *Project Akshaya* in Kerala
- *Project Bhoomi* in Karnataka
- *Project Sarita* in Maharashtra
- *Project Bhu-Lekh* in Haryana
- *Project Apna Khata* in Rajastan
- *Project Tamil Nilan* in Tamil Nadu
- *Project Rajiv Internet Village Project*
    (Planned) 6000 centers up to 22,000 panchayat

तारहाट
Helping People Help Themselves

Victor Bahl

Thirst for Connection…

Victor Bahl
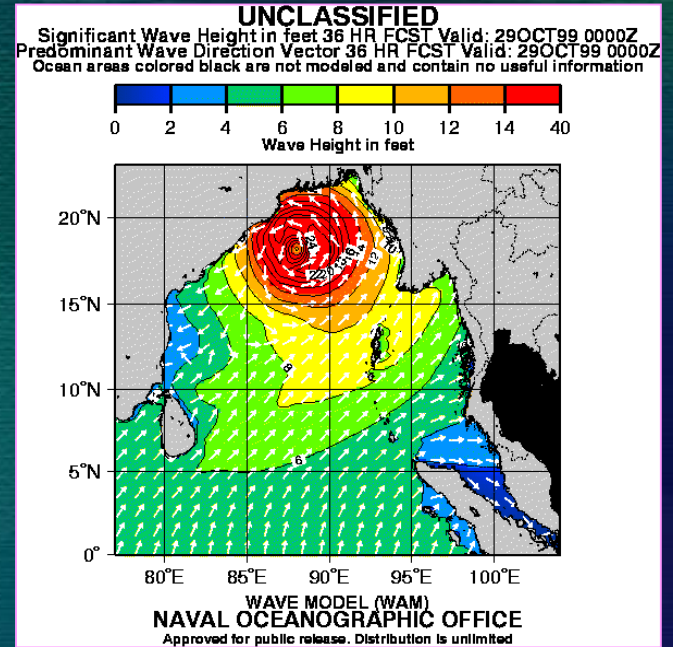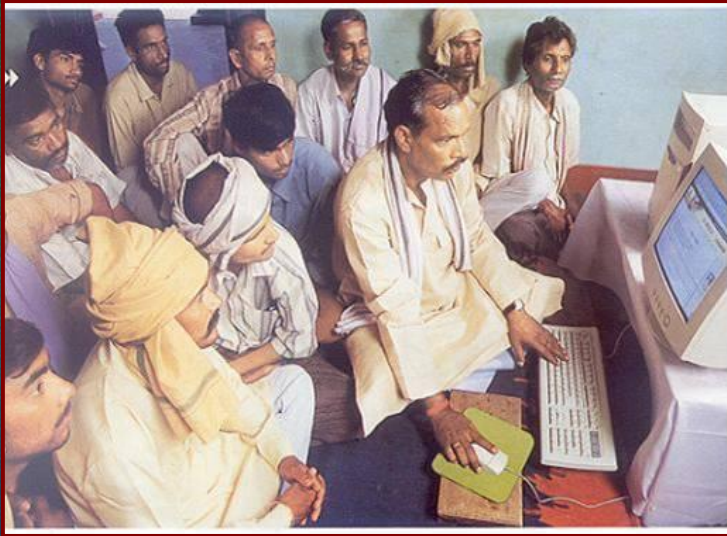
Thirst for Connection…

In United States……

- **New Orleans launches free Wi-Fi service,** Associated Press, November 30, 2005
  "Biggest such effort by a major city yet"

- **San Francisco Keeps Pushing City Wide WiFi,** CNET News.com, August 17, 2005
  "San Francisco Mayor Gavin Newsom wants to make Wi-Fi coverage in the city as ubiquitous as the fog that blankets its neighborhoods."

- **Wi-Fi Hits the Hinterlands**, BusinessWeek Online, July 5, 2004
  "Who needs DSL or cable? New "mesh" technology is turning entire small towns into broadband hot spots"
  Rio Rancho N.M., population 60,000, 500 routers covering 103 miles^2

- **NYC wireless network will be unprecedented**, Computerworld, June 18, 2004
  "New York City plans to build a public safety wireless network of unprecedented scale and scope, with a capacity to provide tens of thousands of mobile users"

- **Rural Areas need Internet too!** Newsweek, June 7, 2004 Issue
  "EZ Wireless built the country's largest regional wireless broadband network, a 600-square-mile Wi-Fi blanket, and activated it this February"
  Hermiston, Oregon, population 13,200, 35 routers with 75 antennas covering 600 miles^2

- **Mesh Casts Its Net**, Unstrung, January 23, 2004
  "Providing 57 miles^2 of wireless coverage for public safety personnel in Garland Texas"

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Thirst for connection…

Around the world…

- PCCW takes Wireless Broadband to London, The Register, September 2, 2005
  "Prices for the service in UK start from £10 / month for 256 Kbps to £18 /month for 1 Mbps"
- Anacapa and Firetide Bring Free Wireless Internet to La Semaine Italienne in Paris, France , Business Wire, 24 May, 2005
- Bell Canada and Nortel Networks launch Project Chapleau, [designed to evaluate broadband in rural Canada], Optical Networks Daily, 18 July 2005
- Nationwide Wi-Fi for Macedonia, Wi-Fi Planet, 18 Nov. 18, 2005
- …

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"Residential broadband access is an under developed technology that has the potential for profound positive effect on people's lives and Nation's economy"

Residential Broadband Revisited, NSF Report, October 23, 2003

% of housholds with BWA as F (income)

Source: *Leitchman Research Group*

Victor Bahl

Services in Rural Areas
(Determined by repeated visits to villages)

- E-agriculture
- E-government
- Computer training
- Telemedicine
- VoIP, chat, e-mail
- Etc.

Services in Urban Areas
(Determined from focus group studies)

- Inexpensive broadband Internet
- Sharing info on goods, services, A/V,…
- Gaming
- Medical & emergency response
- VoIP, chat, email
- Security (e.g. neighborhood video surveillance)

Internet use increased social contact, public participation and size of social network.
(social capital - access to people, information and resources)
Prof. Keith N. Hampton, Sloan School, MIT (author of "Netville Neighborhood Study")
URL: http://www.asanet.org/media/neville.html

Design Constraints

Technology must be:

- inexpensive, possibly free for end-users
- easy to setup & deploy
- require minimal ramp up time & easy to use
- robust, handle failures (power-cuts, dust, heat, etc.)
- self-managing – require minimal human intervention

Ian Ferrell

Connectivity Option I – Wire the Last Mile

Internet   **Backbone**   **Middle Mile**   **Last / First Mile**

Scale & legacy make first mile expensive

~ 135 million housing units in the US (U.S. Census Bureau 2001)

- POTS (legacy) network designed for voice & built over 60 years
- Cable TV networks built over last 25 years

The Truck Roll Problem: Touching each home incurs cost: customer capital equipment; installation & servicing; central office equipment improvements; unfriendly terrain; political implications etc..

In our estimate building an alternate, physical last mile replacement to hit 80% of US homes will take 19 years and cost ~ US $60-120 billion

Victor Bahl

Connectivity Option 2 – Wireless Last Mile

- < $2 Billion for 80% of the homes in US
- Readily available & inexpensive
  - 802.11 hardware or some version of it
- Low deployment cost
  - Decentralized ownership & maintenance
- Trivial setup & small hardware
  - Integrates easily indoors & outdoors
- Flexible
 - Deployable In difficult terrain, both urban or remote

Victor Bahl

Connectivity option: Wireless Mesh

Mesh Network

Classic Hub & Spoke Network
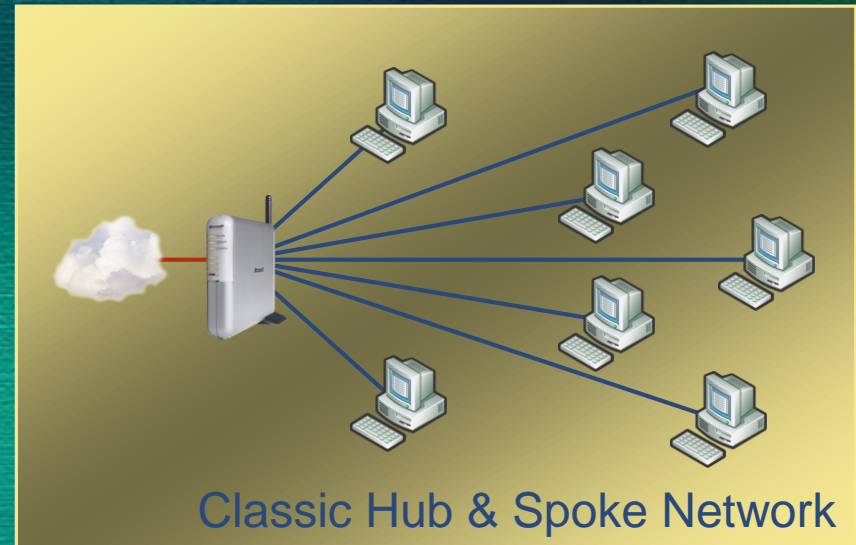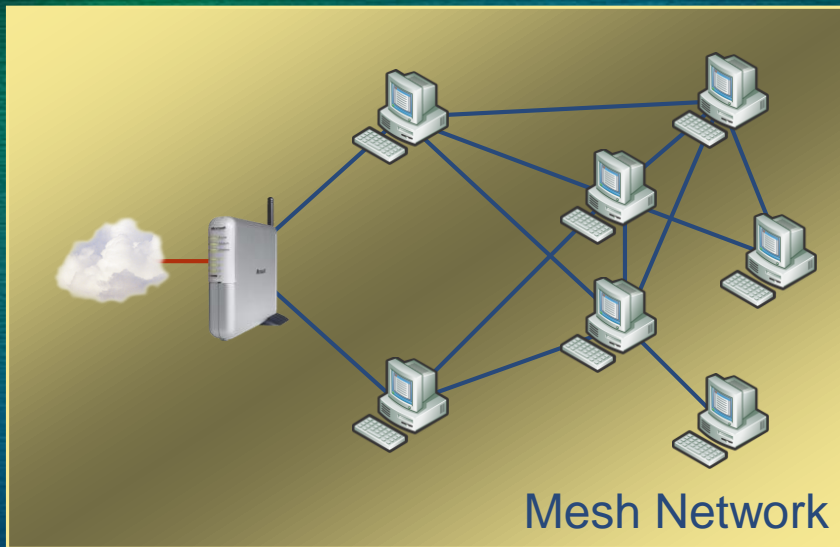
Ad hoc multi-hop wireless network (with static topology)

- Grows "organically"
- Does not require any infrastructure
- Provides high overall capacity
- Robust & Fault tolerant
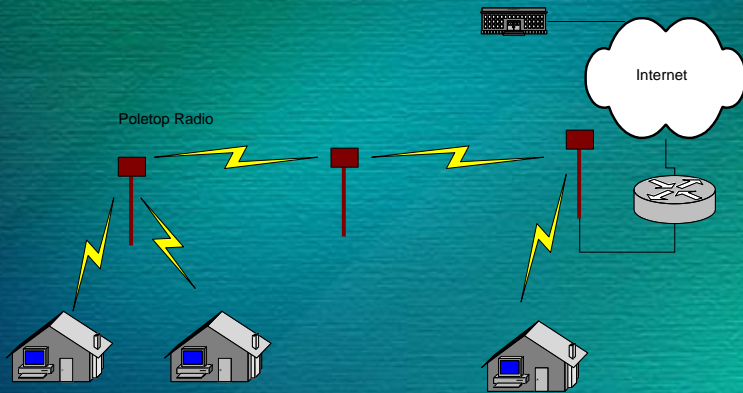- No centralized management, administration necessary
- Empowers the individual

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Community Mesh Networks
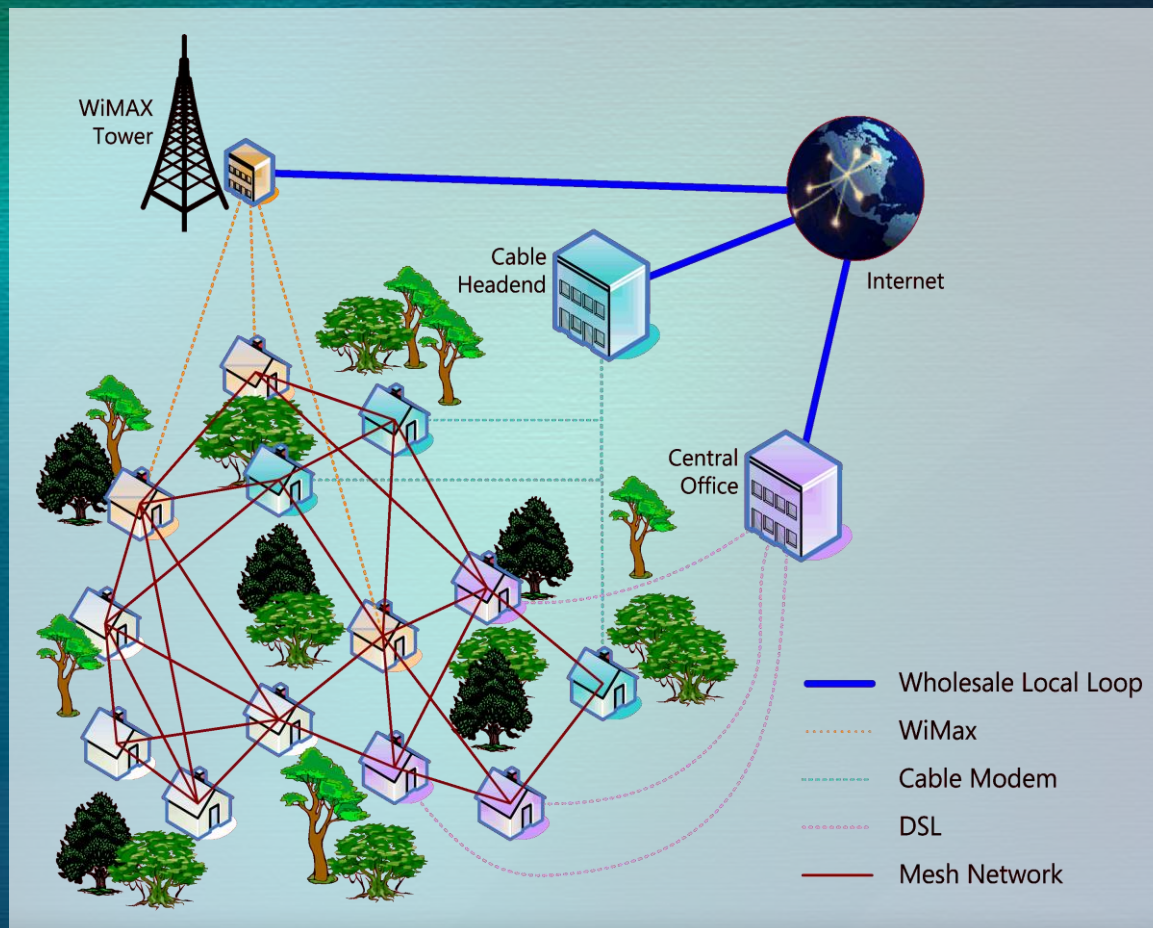
Organic – Participants own the equipment and the Network
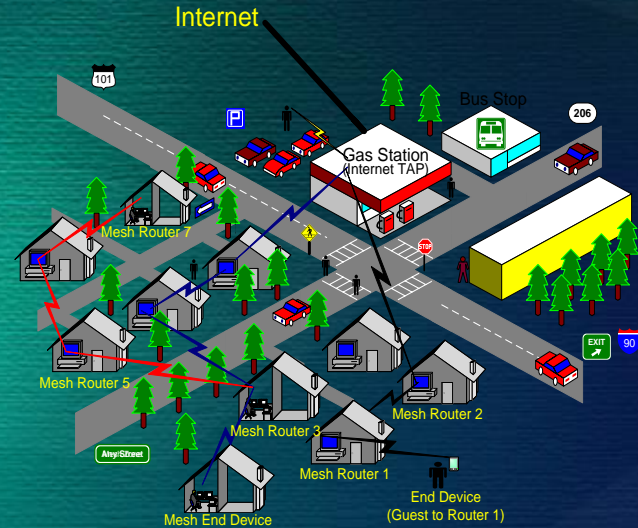
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Architectural Options

Infrastructure Based

SkyPilot, Flarion, Motorola (Canopy) Invisible Networks, RoamAD, Vivato, Arraycomm, Malibu Networks, BeamReach Networks, NextNet Wireless, Navini Networks, etc.

Infrastructure-less

Motorola (Meshnetworks Inc).,Radiant Networks, Invisible Networks, FHP, Green Packet Inc., LocustWorld, etc.

Architecture effects design decisions on
Capacity management, fairness, addressing & routing, mobility management, energy management, service levels, integration with the Internet, etc.

Victor Bahl

Deployment Scenarios

Target Wireless Mesh Markets by Vendor

Vendor	Metro Mesh	Public Safety	Enterprise	Digital Divide	Mobile Mesh
BelAir	1	2	3	3	4
Firetide	3	3	1	4	4
Hopling	1	4	4	4	4
Locust World	4	4	4	1	4
CUWiN	4	4	4	1	4
MeshDynamics	1	3	3	3	4
Motorola	2	1	4	3	1
Nortel	1	2	3	4	2
PacketHop	4	1	4	4	1
RoamAD	1	4	4	2	4
Strix	2	3	1	4	4
Tropos	1	2	3	3	4

Source: Unstrung Insider

Key:

1	Primary target: The major target market or application for this vendor
2	Secondary target: An important target market for this vendor
3	Tertiary target: Nice-to-have-business
4	Not targeted: The vendor has not developed a product for this application

March 2005, Source: Unstrung Insider

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Related Work

The CITRIS TIER Project (UC Berkeley, USA)
Technology and Infrastructure for emerging regions
Richard Newton, Drew Issacs, Eric Brewer, Tom Kalil
http://tier.cs.berkeley.edu/

The Digital Gangetic Plains Project (IIT Kanpur, India)
802.11-based low-cost Networking for Rural India
Bhaskaran Raman, Dheeraj Sanghi, A.R. Harish, Mohan K. Mishra, Anish Bhatia, A.K. Singh, Ram Chandra Prajapati
http://www.iitk.ac.in/mladgp

The Roofnet Project (MIT, USA)
802.11 mesh network for broadband IA in cities
Dan Aguayo, John Bicket, Sanjit Biswas, Robert Morris
http://pdos.csail.mit.edu/roofnet/doku.php

The TAPs Project (Rice University, USA)
Wireless broadband to residential and public places
Edward Knightly, Behnaam Aazhang, J. Patrick Frantz, David Johnson, Ashu Sabarwal
http://taps.rice.edu/index.html

Some Relevant Standards

IETF MANET

- Layer 3 protocols for Mobile Ad Hoc Networks

IEEE 802.11s

- Extended Service Set for Mesh Networking

IEEE 802.16

- Broadband Wireless Metropolitan Area Networks

IEEE 802.20

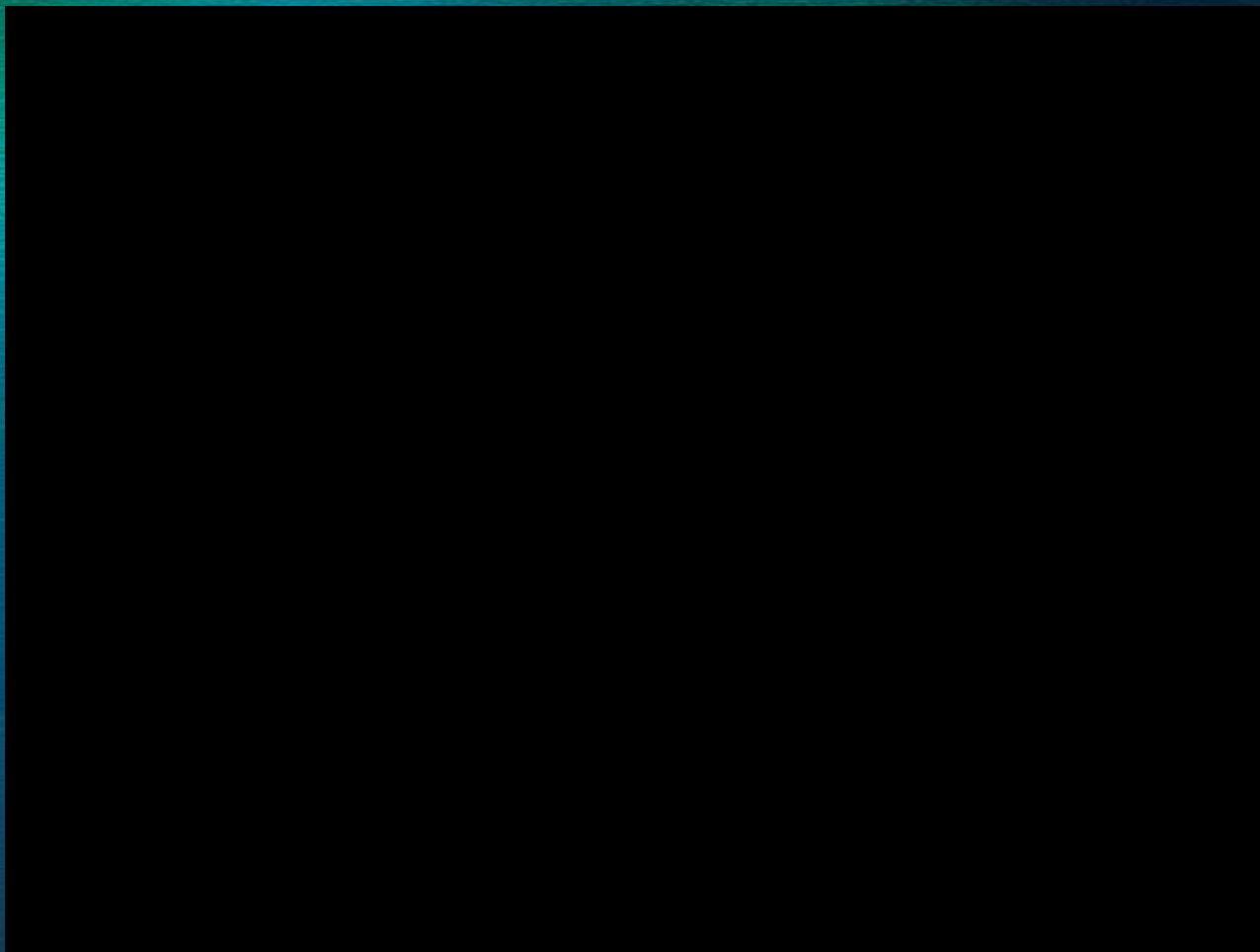- Mobile Broadband Wireless Access for business & residential markets

IEEE 802.22

- Wireless Regional Area Networks (WRANs)

OBAN

- Broadband Coverage in Urban Area (European effort)

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Wireless Meshes

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Many Challenges

Deployment

- "Real-world" study with real traffic traces, usage patterns and failure /performance logs

Self Healing & Management

- Minimal human intervention - avoid network operator
- Mechanisms for data cleaning, anomaly detection & liar detection
- Automatic tools for what-if analysis for optimal operation
- Pleasant, hassle-free user experience (zero-configuration setup)

Smart Spectrum Utilization

- Spectrum Policy - etiquettes and/or rules with technical input
- Spectrum Leasing
- Cognitive software & applications
- Agile radios, cognitive radios, 60 GHz radio, underlay technologies

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Many Challenges (cont.)

Power

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

Security, Privacy, and Fairness

- Guarding against malicious users
- Priority for VoIP and time-sensitive data

Connectivity, Range, Scale, and Capacity

- Inexpensive electronically steerable directional antenna and/or MIMO
- Multi-frequency meshes & multi-radio / multi-channel hardware
- Data channel MAC with Interference management for higher throughput

Analytical Tools

- Information theoretic tools that predict network viability & performance with practical constraints, based on experimental data

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Research Community Assets

Mesh Networking Summit 2004
Making Meshes Real

Mesh

Networking

- Technical Program
- Program Notes
- Abstracts & Bios
- Posters & Demos
- Hotel & Travel

June 23-24, 2004
Salish Lodge & Spa
Snoqualmie, Washington
http://www.salishlodge.com

Sponsored by Microsoft Research & Microsoft's Advanced Strategy Group

Videos, Presentations, Notes etc.
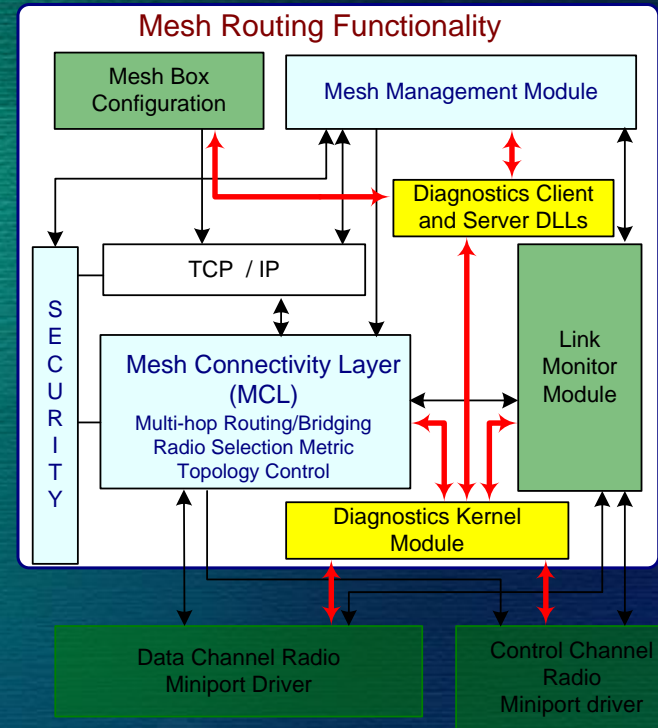*http://research.microsoft.com/meshsummit/*

Self-Managing Networks
Summit 2005
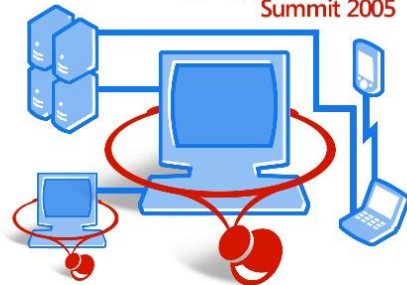
Making Networks Self-Aware

June 1-2, 2005
Woodmark Hotel on Lake Washington
Kirkland, Washington
http://www.thewoodmark.com

Sponsored by Microsoft Research

Mesh Routing Functionality

| Mesh Box Configuration | Mesh Management Module |

Diagnostics Client and Server DLLs

TCP / IP

SECURITY

Mesh Connectivity Layer (MCL)
Multi-hop Routing/Bridging
Radio Selection Metric
Topology Control

Link Monitor Module

Diagnostics Kernel Module

Data Channel Radio Miniport Driver

Control Channel Radio Miniport driver

Software, Papers, Presentations
http://research.microsoft.com/mesh/

http://research.microsoft.com/events/smnsummit/

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Academic Resource Kit 2005

http://research.microsoft.com/netres/kit/

Microsoft Research
Wireless Networking Research Program

Mesh Networking
Academic Resource
Toolkit 2005

A research and teaching resource for exploring core technologies in wireless networks.

THIS TOOLKIT INCLUDES:

Software for Mesh Networking, Including:
- Full source code and binaries for Mesh Connectivity Layer along with build tools
- Full source code and binaries for mesh performance measurement tools & utilities
- Binaries for Venice software along with setup utility
- 10 hours of video talks on multi-hop wireless networking
- 14 papers and technical presentations

Software for Virtualizing WiFi cards, Including:
- Full source code and binaries for Virtual WiFi along with build tools, and documentation
- 5 hours of video talks on Virtual WiFi architecture and applications
- 5 papers and technical presentations

Supporting software, Including
- Windows® XP Professional Service Pack 2 Edition
- Microsoft® Driver Development Kit (DDK)
- MSDN Subscription http://msdn.microsoft.com/subscriptions/

Microsoft .net   Microsoft Research

This toolkit contains Microsoft's Mesh Connectivity Layer (MCL) and MultiNet software. Microsoft Research (MSR) is providing MCL and MultiNet to the public in both source and binary forms to support research and teaching in the areas of ad-hoc multi-hop wireless networks.

This kit Includes:
- Source code and binaries for Mesh Connectivity Layer (MCL)
- Source code and binaries for mesh performance measurement tools and utilities (ttcp, sink, LQSR Parser for NetMon)
- Source code and binaries for virtualizing wireless cards (Virtual WiFi, MeshSvcs, MDS, Setup)
- Binaries for Venice software (MeshConfig, MeshMonitor, MeshSvcs, MDS, Setup)
- 19 papers and technical presentations
- Over 15 hours of video talks
- Windows® XP Professional Service Pack 2 Edition
- Microsoft® Driver Development Kit (DDK)
- MSDN Subscription

If you are interested in learning the details of implementing Layer 2.5 multi-hop routing and understanding the virtualization architecture for wireless cards, or if you are interested in simply getting a mesh network up and running so you can do additional research or writing if you want to write multi-radio applications using only one radio IEEE 802.11 radio then this kit is for you.

Many important research challenges remain and it is our hope that MCL and Virtual WiFi will provide you a solid start as you get on with the task of finding developing solutions to problems over operational testbeds.

Thanks and enjoy!

Networking Research Group, Microsoft Research
http:// research.microsoft.com/netres/

IMPORTANT: You must accept the enclosed License Agreements before you use this product. If you do not accept the terms of the License Agreements, you should promptly return the product

INSTALL INSTRUCTIONS AND SYSTEM REQUIREMENTS: Please refer to the Readme files and Release Notes on each CD and DVD-ROM for install instructions and system requirements

PRODUCT ACTIVATION: The commercial products included hereinafter technological measures for copy protection – you will not be able to use the products if you do not fully comply with the product activation procedures. Product activation is required for continued use of these products. This can be done online or by telephone within 14 days of installation. Detailed instructions and Microsoft's privacy statemtn are given during the installation of the products.

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meshkit@microsoft.com

Prof. Sivaram Murthy, **IIT, Chennai, India**
Hybrid wireless mesh for rural communities

Prof. Sanjiva Prasad, **IIT, New Delhi, India**
Async. messaging in Wireless network

Prof. Lili Qiu, **University of Texas Austin**
Resilience in wireless mesh Networks

Prof. William Arbaugh, **University of Maryland**
Security and Privacy in wireless meshes

Prof. Suman Banerjee, **University of Wisconsin**
Quality of service in wireless meshes

Prof. Dan Rubenstein, **Columbia University**
Channelization and routing

Prof. Richard Newton, **UC Berkeley**
The TIER Project

MS ERP has budgeted $1.2 million for research funding in FY06 under their Digital Inclusion Initiative

Victor Bahl

Requests for Academic Resource Kit (as of 8/12)

http://research.microsoft.com/netres/kit/

- Anna University, Chennai, India
- Arizona State University,AZ
- Auburn University, AL
- Columbia University, NY
- Dartmouth College , NH
- DeVry University, Kansas City
- Florida State University, FL
- Gdansk University of Technology, Poland
- Gwangju Institute of Sci&Tech, Korea
- Hogschool Gent, Belgium
- Huazhong University, China
- Indian Institute of Science Bangalore, India
- Institute of Compute Technology, China
- Iowa State University Ames, IA
- Iqra University, Pakistan
- Katholieke Universiteit Leuven. Netherlands
- National Chung Hsing University, Taiwan
- National Institute of Technology Karnataka, India
- National University of Singapore
- New Mexico State University, NM
- Ohio State University, OH
- Rice University, TX
- Rutgers University, NJ
- Ryerson University Toronto, Canada
- Saint-Hyacinthe College, Quebec, Canada
- Sogang University, Korea
- Stanford University, CA

- Syracuse University, NY
- Technology University of Tswane, South Africa
- Tsinghua University, Beijing, China
- Univ. of Applied Sciences of Southern Switzerland
- University of Victoria, Canada
- University of Texas at San Antonio, TX
- University of Louisiana at Lafayette
- University of California Berkeley, CA
- University of California San Diego, CA
- University of California Irvine, CA
- University of Cincinnati, OH
- University of Concordia, Canada
- Universidade Federal Fluminente, Brazil
- Univ. Federal Fluminense Rio de Janeiro, Brazil
- University of Hawaii, HI
- University of Maryland, MD
- University of Massachusetts Amherst, MA
- University of New South Wales Sydney, Australia
- University of North Carolina Chapel Hill, NC
- University of South Florida, FL
- University of Southern California, CA
- University of Texas Austin, TX
- University of Utah, UT
- University of Waterloo, Canada
- University of Wisconsin-Madison, WI
- Virginia Tech, VA
- Wyzsza Szkola Informatyki w Lodzi, Poland

Victor Bahl

Broadband WiFi Debate

Phone Giants Are Lobbying Hard To Block Towns' Wireless Plans
    Wall Street Journal, June 23, 2005

Two sides to the coin….

Proponents

- Local and state government should provide WiFi access free everywhere

- Propel the country into yhr broadband age
    - Lower cost, faster deployment (specially in rural areas)
    - Stimulate competition by raising service standards

Detractors

- Unfair to ask private sector to compete with local government who have tax dollars

- Not a utility, highly competitive enterprise

- Continuously changing due to innovation

Victor Bahl

> **"The digital divide is really diminishing, and it's the mobile phones doing it, not the PC"**
>
> Len Waverman, London Business School

- Common consumer electronic device

- Inexpensive; Value is clear;

- First waves of practical devices that integrate cameras, processor, network, & display are in the market

Victor Bahl

The Mobile Phone

Tracey Lovejoy

Gartner forecasts sales will approach 780 million units this year and more than 1 billion worldwide in 2009

Cellular Users

Legend:
- Rest of World
- Asia-Pac
- CALA
- N America
- C/E Europe
- W Europe
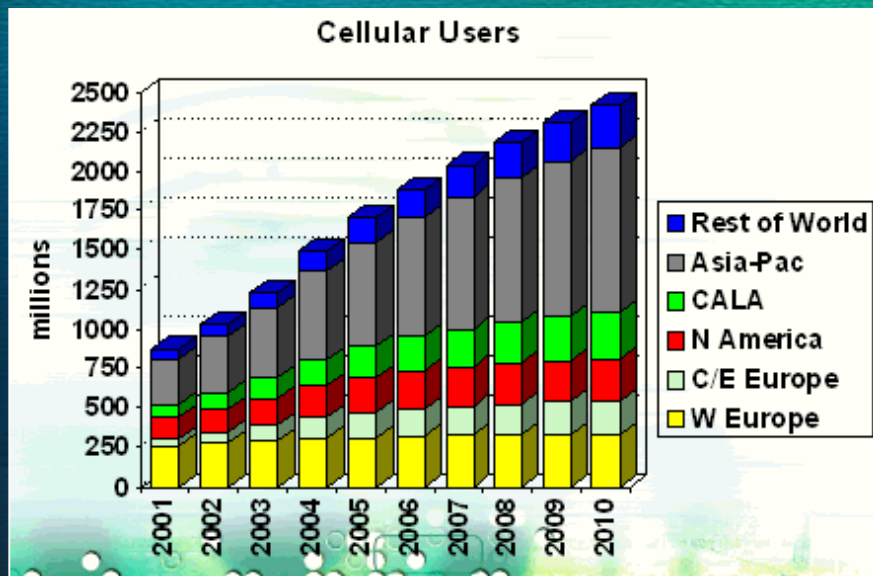
China (as of May 2004)
25 million PCs
300 million cell phones

India (as of May 2004)
15 million PCs
40 million cell phones
+ 2 million added / month

Source: Strategy Analytics
http://www.strategyanalytics.net/

Source: Forrester Research, December 10, 2004

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What are people doing with mobile phones today?

Tracey Lovejoy

SMS Text-messaging

Purchasing

Web Surfing & email

Watching & Sharing Video

Taking & Sharing Pictures

Expression of Identity

Victor Bahl

The SmartPhone Platform
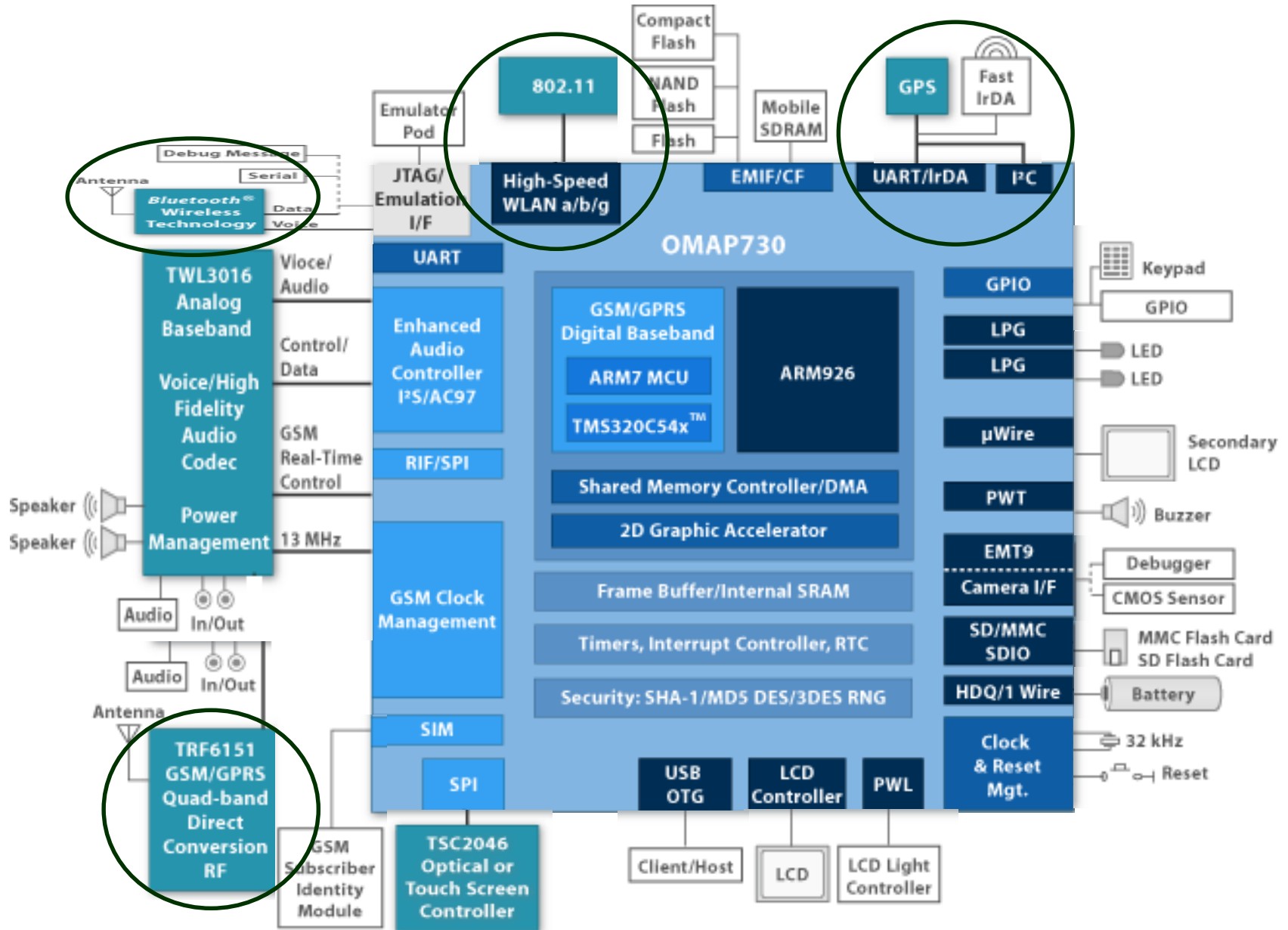
SmartPhone Ecosystem
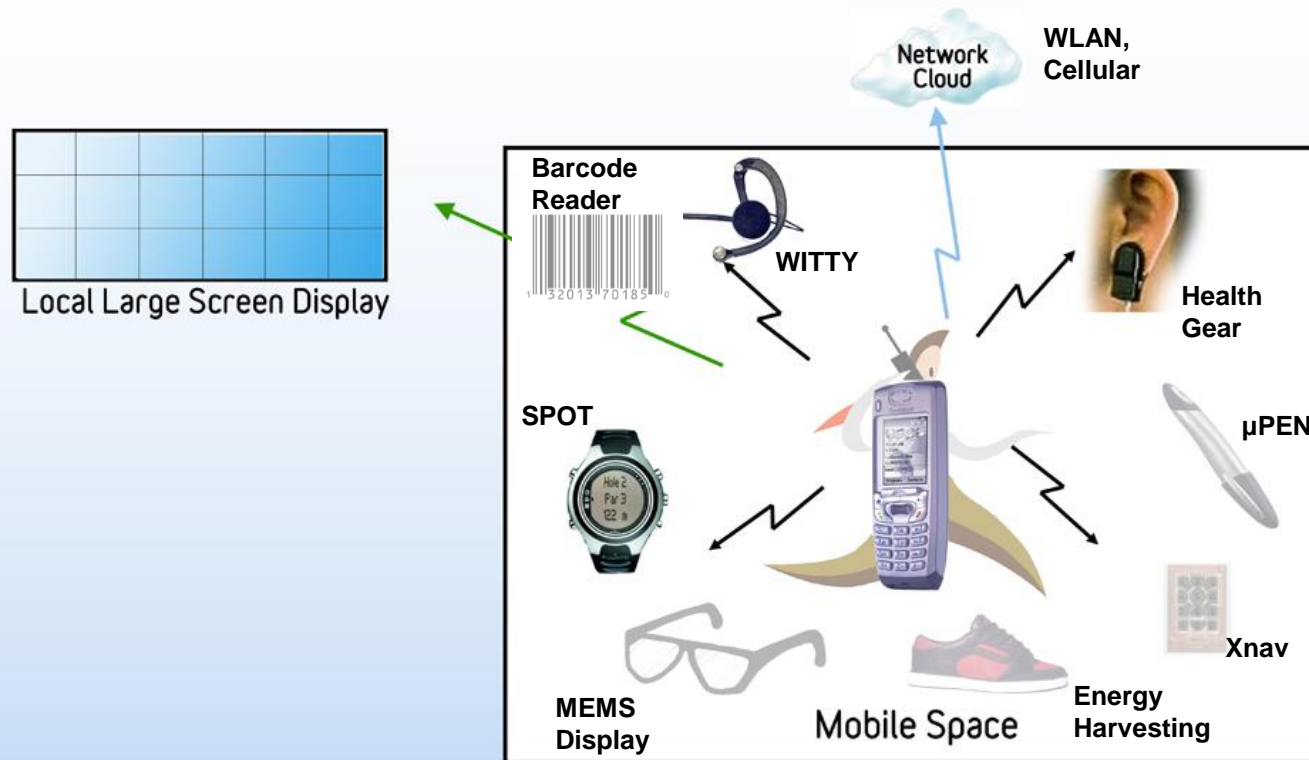
Talk to people
Access information on the Internet
Monitor personal health & diagnose problems
Improve social interactions
Share experiences via AirBlogs

Victor Bahl

What could people be doing with mobile phones tomorrow?

WiTTY

Health Monitoring

Social Grouping

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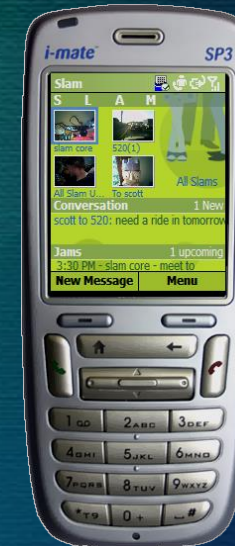
Mike Sinclair :: Zhengyou Zhang
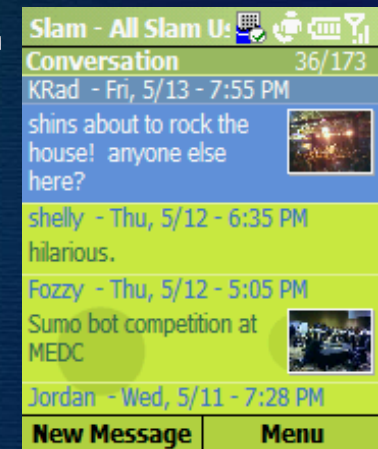
WITTY
<u>W</u>ho <u>I</u>s <u>T</u>alking <u>T</u>o <u>Y</u>ou?

Array microphone

+

Bone vibration sensor

=

Speaker gating

Lower noise

Longer battery life

Reduces effects of ambient noise

Mic 1   Mic 2   Mic 3

Bone sensor

Victor Bahl

WITTY Microphone

Mike Sinclair :: Zhengyou Zhang
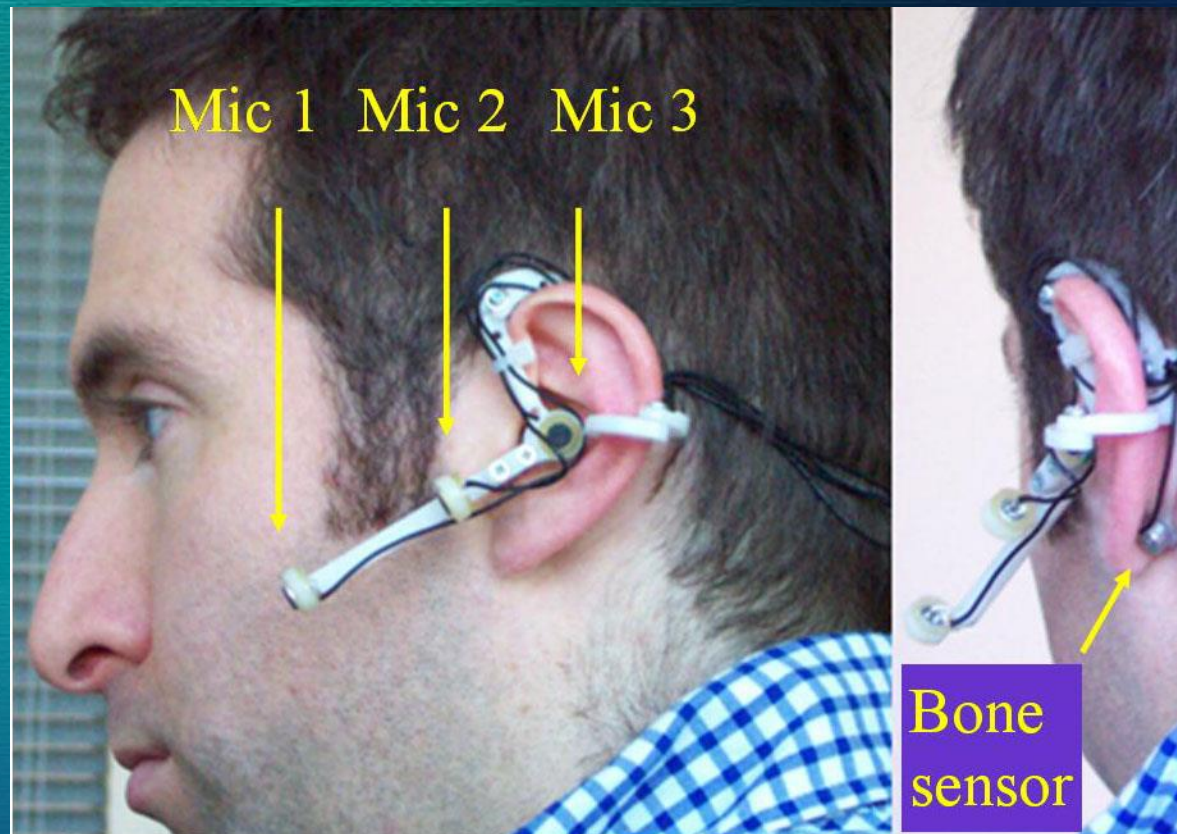
Conventional microphone
- √ High-quality audio
- x Sensitive to external noise or speech

Bone microphone
- √ Very resistant to external noise or speech
- x Low-quality audio (less than 3KHz, distorted)

Fusion of complementary information:
- Enhance user's voice & eliminate noise

Air mic.   Bone mic.

+

WITTY (Enhanced)

8 KHz sampling

Jabra EarWrap

Witty EarWrap

Victor Bahl
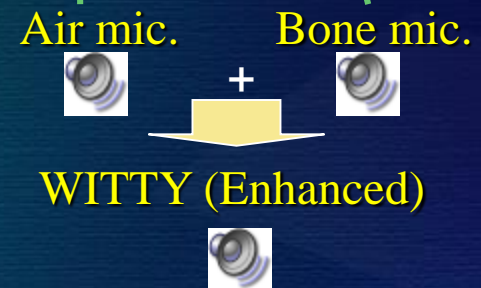
Health Monitoring

Aging population in developed countries

Rural areas in developing countries

SmartPhone technology will transforming health care
- Early detection of health deterioration
- Notifying health care providers in critical situations
- Enhancing sense of connectedness with loved ones
- Find correlations between lifestyle and health
- Sports conditioning

Victor Bahl

Nuria Oliver :: Fernando-Flores Mangas :: Mike Sinclair

Sleep Apnea

A common undiagnosed condition

- Affects children and adults
- 4% in men and 2% in women (higher for elderly)
- Untreated causes $3.4 billion of medical costs
- 40 million undiagnosed Americans

Periods of interrupted breathing (apnea) & reduced breathing (hypoapnea)

Leads to

- Hypoxia, asphyxia and awakenings
- Increased heart-rate, high blood pressure
- Extreme fatigue, poor concentration
- Compromised immune system
- Cardio/cerebrovascular problems

Nuria Oliver :: Fernando-Flores Mangas :: Mike Sinclair

HealthGear

- Real-time, wearable health monitoring system

- Mobile phone as central processing unit

- Continuous recording of blood oximetry, heart-rate & plethysmographic signal

- Real-time analysis and presentation of data to the user

Test Results

Nuria Oliver :: Fernando-Flores Mangas :: Mike Sinclair
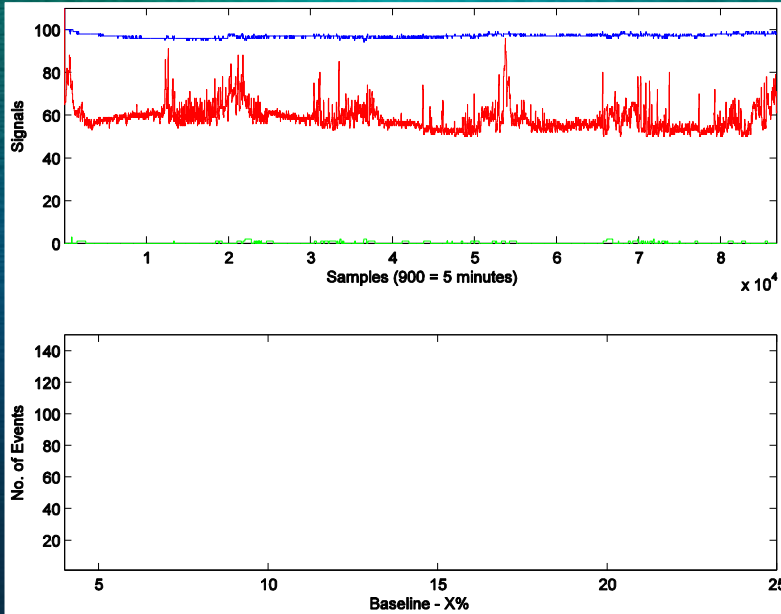
Mild-Severe Apnea

No Apnea

Severe Apnea

Bahl
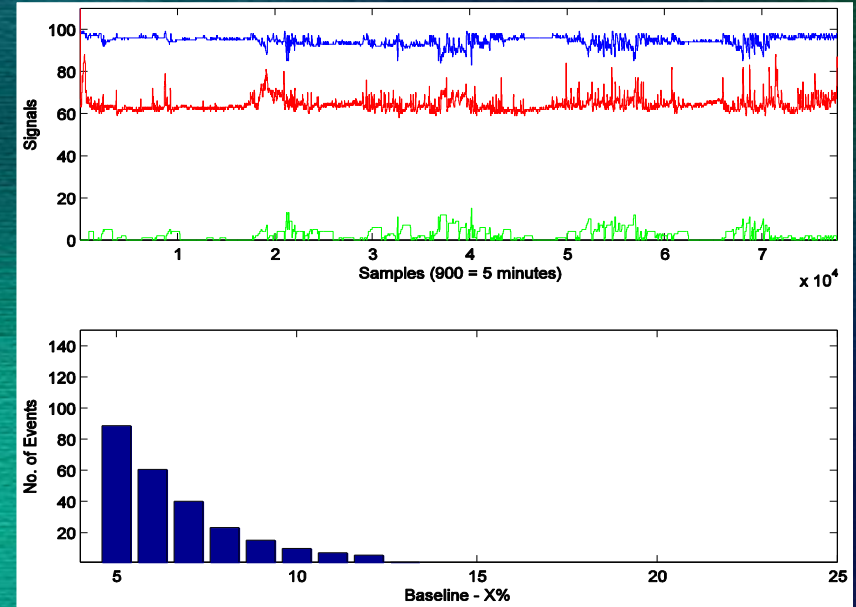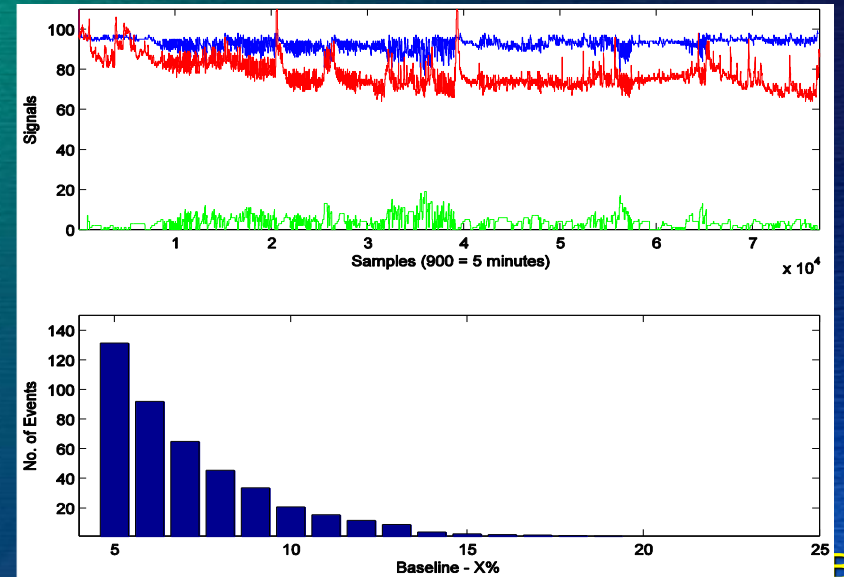
Related Work

MDKeeper, Tadiran Spectralink

– Launching in 2006

– For cardiac and circulatory disease

– Measures pulse rate, cardiac rhythm (ECG or EKG) and blood oxygen levels.

– Can store or transmit using GPRS

:
:
:

Scott Counts :: Shelly Farnham :: Jordan Schwartz

SLAM

Lightweight Grouping for Mobile Communication, Coordination, & Sharing

Smartphone application for:

- Real-time communication and media sharing

- Continuous access to social circles

- Social networking across events
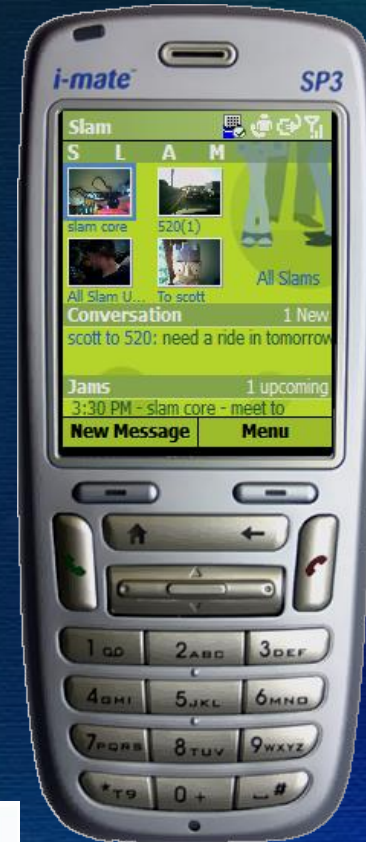
social computing

SLAM

Scott Counts :: Shelly Farnham :: Jordan Schwartz

Lightweight Grouping for Mobile Communication, Coordination, & Sharing

The Mobile Advantage

- The social computer you take everywhere
- Support natural social interactions
- Hyperawareness
- Hypercoordination
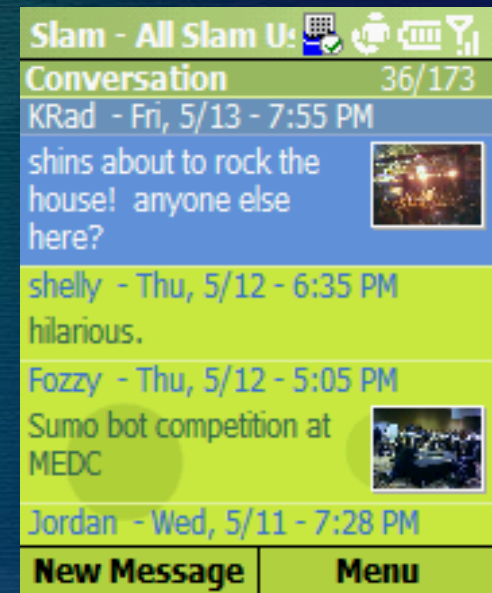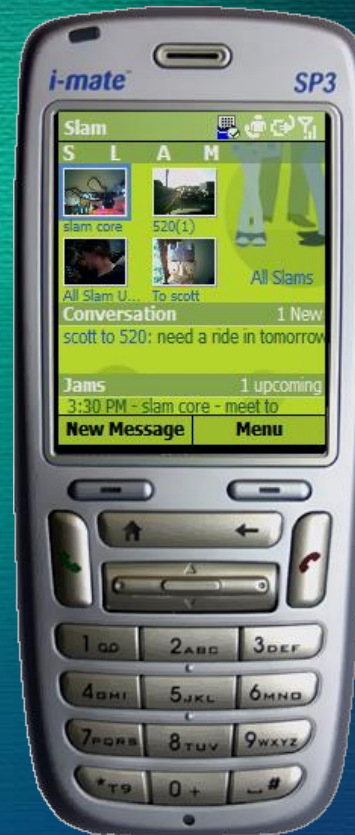
SLAM

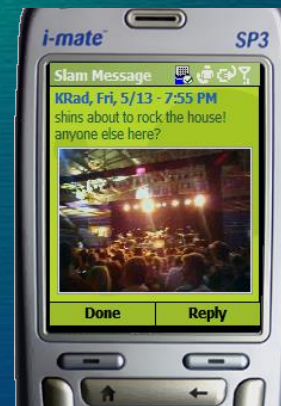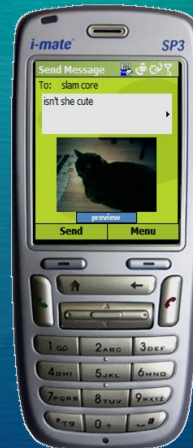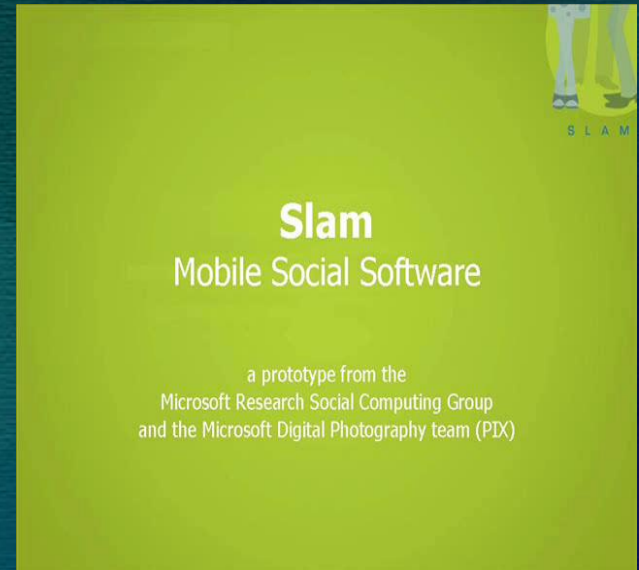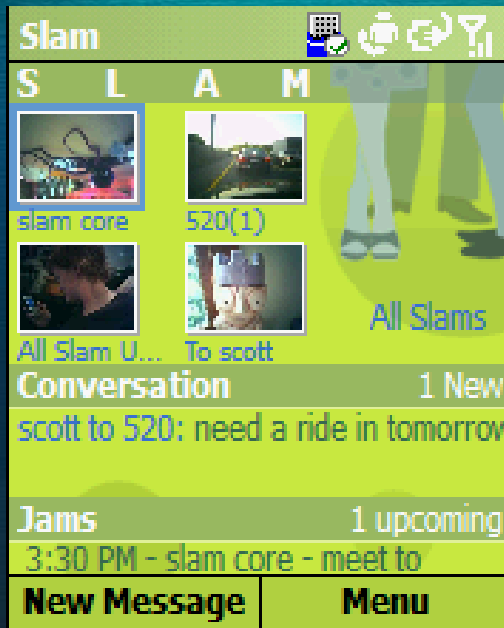## Lightweight Grouping for Mobile Communication, Coordination, & Sharing

Groups & Events

- Easily make new groups on the fly
- Minimal click event creation

Communication & Sharing

- Group-wide distribution
- Conversation + blog + profile
- Photo-rich social presence

Slam
Mobile Social Software

a prototype from the
Microsoft Research Social Computing Group
and the Microsoft Digital Photography team (PIX)

Victor Bahl

Bridging the Information Divide

The power of ideas and opportunities, fueled by local entrepreneurial energy, is the most important resource available in this resource-scarce part of our world.

- Richard Newton, Dean UC Berkeley

Technology can help

Connectivity Options

- Organically growing wireless meshes that require minimal human intervention

Services Platform

- SmartPhone for deploying compelling services

but we have to work together…….

Call To Action

Together academia, government, and industry must develop common vision

Perform scenario & systems based research tackling hard problems

Partner in building and deploying real-world test beds

Victor Bahl

Thanks!

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

Backup Material

Nuria Oliver :: Fernando-Flores Mangas :: Mike Sinclair

Automatic Detection of Sleep Apnea

Multithreshold Time Analysis:

- Defines multiple levels of desaturation (drop gap) and resaturation (return gap)

- Desaturation starts when oxygen level falls below a baseline by a certain amount
  - continues until the signal recovers to a level, which is lower than the baseline by 25% of the specified amount

Spectral Analysis:

- Periodogram of the mean-subtracted oximetry signal

- Sleep apnea events are detected as a peak in the range 0.015-0.04Hz

- This frequency has a fisiological explanation corresponding to the typical lenghts of apnea events

SLAM

Scott Counts :: Shelly Farnham :: Jordan Schwartz

Lightweight Grouping for Mobile Communication, Coordination, & Sharing
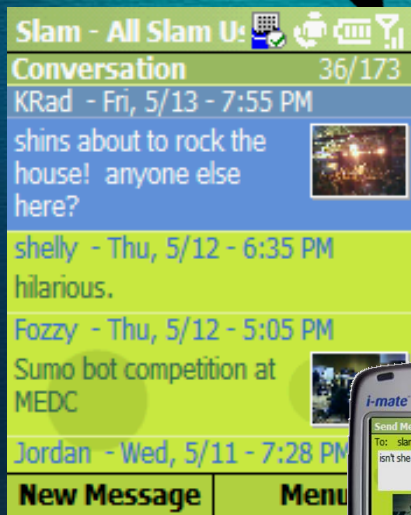
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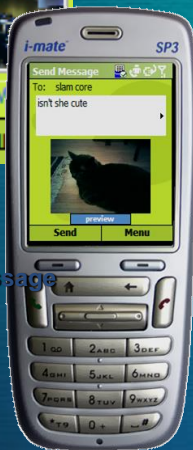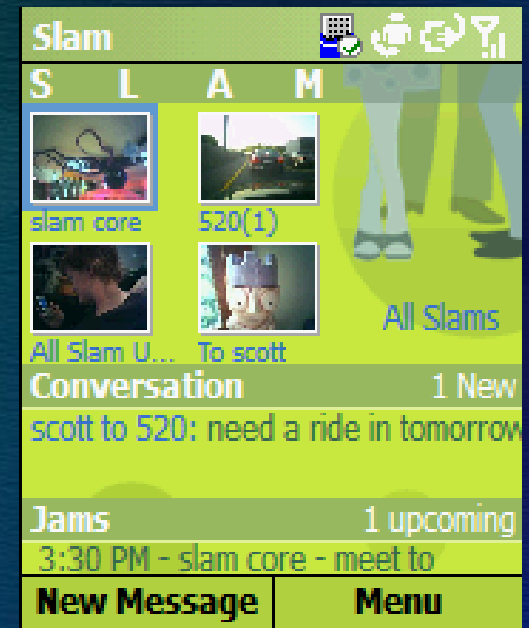- Conversation + blog + profile
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