

Me and My Research

Victor Bahl

October 2, 2013

MobiCom 2013, Miami, Florida, USA

joined MSR on June 2, 1997

newly minted PhD with some industry experience

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newly minted PhD with some industry experience



rick

&



rich

brought me to start-up networking
research

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newly minted PhD with some industry experience



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rich

brought me to start-up networking research

MSR was intimidating (bell, thacker, lampson,, gray,...) & exciting

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Turner handed me the Hamming article



turner whitted

“You and Your Research”

Bell Communications Research Colloquium Seminar
7 March 1986



Richard Wesley Hamming

Feb. 11, 1915 – Jan. 7, 1998

“A characteristic of great scientist is that they have courage. They will go forward under incredible circumstances”

this talk is about a systems researcher's desire

- to be courageous

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- to be courageous
- to have positive impact &

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- to be courageous
- to have positive impact &
- to help others by sharing some lessons learned

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pardon me for dropping a bit of modesty

it's necessary for some points I want to make

enterprise Wireless →

chapter 1

research at scale

state of wireless in 1997

- IEEE 802.11 had not been standardized
- very few companies sold wireless APs
- dominant WNIC was WaveLAN and Orinoco



NCR WaveLAN



Lucent's Orinoco



Digital's RoamAbout

Cost \$297. 50

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Digital's RoamAbout

state of wireless community

- we had just formed SIGMOBILE

new guy in town.....wanted to make an
impression...what to do?

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bold idea: turn bldg. 31 (MSR's home) into a giant .11 lab and pursue research at scale

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how? where to get resources from?

find a forward looking individual in an influential position and convince him/her to support you

new guy in town.....wanted to make an impression...what to do?

bold idea: turn bldg. 31 (MSR's home) into a giant .11 lab and pursue research at scale

how? where to get resources from?

find a forward looking individual in an influential position and convince him/her to support you

for me that individual was Dan Ling



Dan Ling
Managing Director, MSR

settled on Aironet Wireless Inc.

the ability to program wireless NIC was critical for my research

Windows didn't understand wireless LANs

NDIS programming model was inadequate

Wireless is not Ethernet

Victor Bahl, Marvin Theimer, Pradeep Bahl
Microsoft Research

Abstract

Radical differences in channel characteristics and end-node mobility make wireless networking significantly different from wired networking. Unfortunately under current implementations of Windows operating systems, a local area wireless network is treated as “just another network” and is exposed to higher layer OS networking protocols and to applications as an Ethernet technology. This makes it difficult for higher layer OS networking protocols and applications to adapt to changing channel conditions and prevents software vendors from developing adaptive applications that not only handle mobility transparently but also benefit from it. In this paper we describe how the Windows network architecture can be enhanced to support wireless-aware and mobility-aware networking protocols and applications.

1 Introduction

Wireless networks are very different from traditional wired networks. When applications and the operating system's network protocol stacks ignore this fact, performance can suffer substantially and potential functionality may not be exposed for use.

NDIS programming model was inadequate

Wireless is not Ethernet

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*if you want people to spend their currency (time) on your ideas,
show them the money*

idea: implement a location determination system

- Roy Want & Andy Hopper (Olivetti Research Labs) had pioneered the concept

....but there was nothing in the RF space



Active Badge

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....but there was nothing in the RF space
- I had done some work before.....



Active Badge

Mobility Modeling, Location Tracking, and Trajectory Prediction in Wireless ATM Networks

Tong Liu, Paramvir Bahl, *Senior Member, IEEE*, and Imrich Chlamtac, *Fellow, IEEE*

Abstract—Wireless ATM networks require efficient mobility management to cope with frequent mobile handoff and rerouting of connections. Although much attention has been given in the

system can determine if there are enough resources available along the mobile's path for the lifetime of the connection. In this paper, the system can determine the satisfaction of

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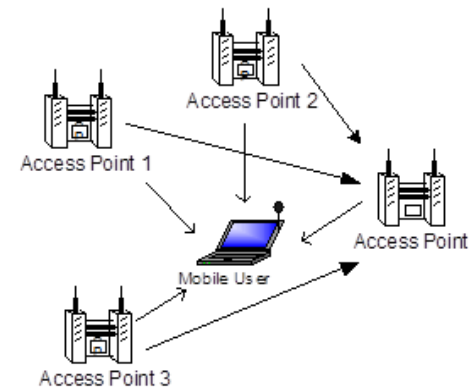
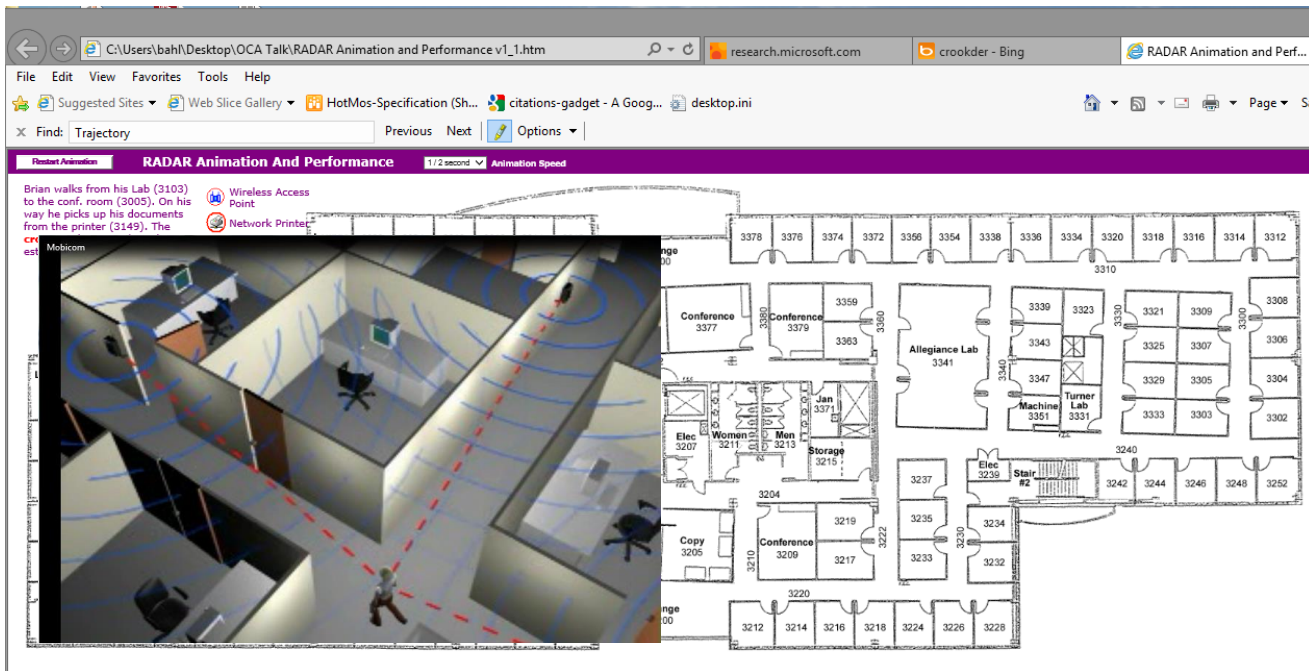
Abstract—Wireless ATM networks require efficient mobility management to cope with frequent mobile handoff and rerouting of connections. Although much attention has been given in the

system can determine if there are enough resources available along the mobile's path for the lifetime of the connection. In such a case, the system can plan in anticipation of

too complicated

had worked seven years in image processing
idea: apply pattern recognition techniques to wireless LAN
worked with a great new-hire (Venkat) & Radar was born.....

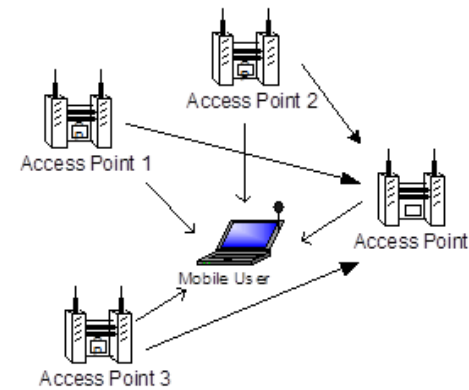
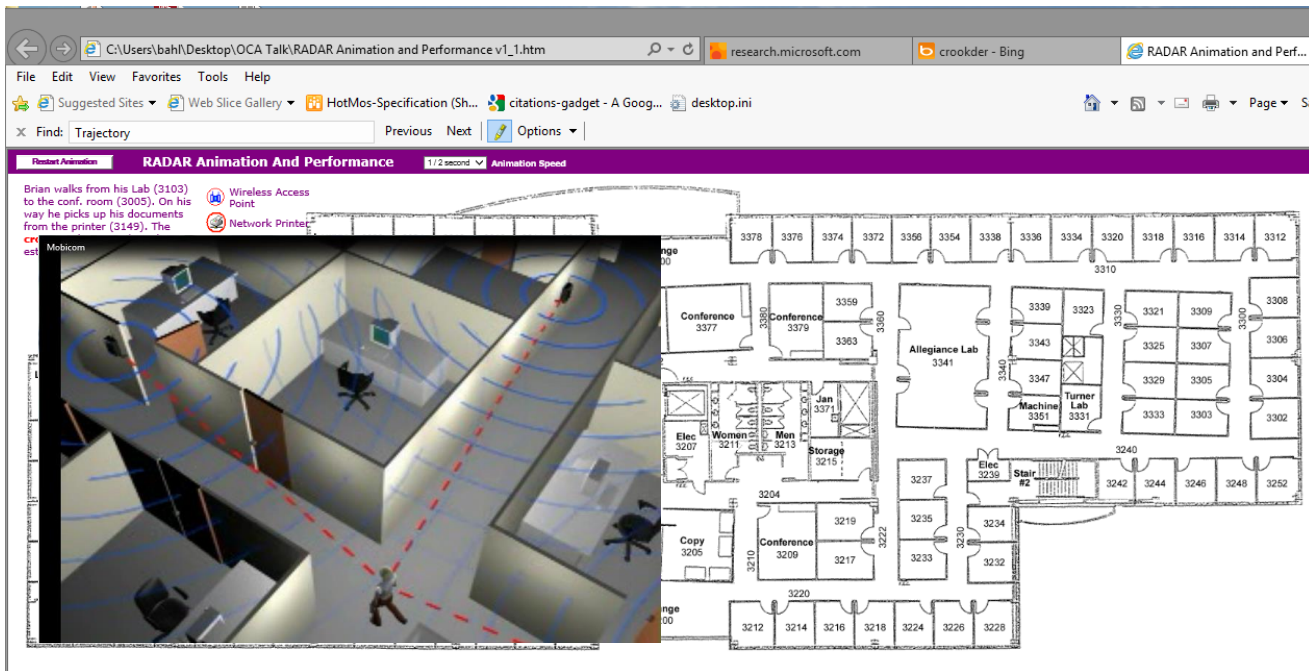
1998 – 99



1998 – 99



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some of the best work gets done when you apply techniques from one field to another

lessons from RADAR

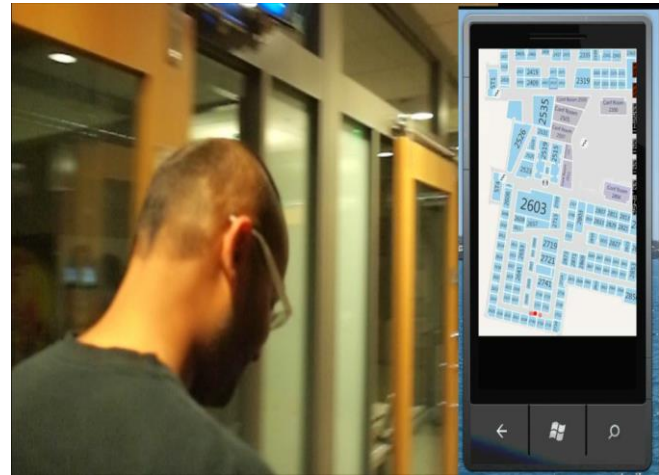
- research success does not always translate to commercial success
- for commercial success, be hard on yourself, have a convincing value proposition
 - didn't have it so didn't do additional research on this topic
- persevere market conditions may not be optimum for your technology
- market will adopt (intellectually) simpler solutions

Radar then and now

MobiCom 1999



14 years later, MobiCom 2013



....back to NDIS extensions

Enhancing the Windows Network Device Interface Specification for Wireless Networking

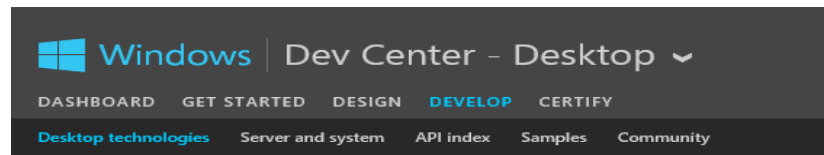
Victor Bahl
Gavin Holland

August 2000¹

Technical Report
MSR-TR-2000-84

Microsoft Research
One Microsoft Way
Redmond, WA 98052

accepted for
productization



- › Networking and Internet
- › Wireless Networking
 - Native Wifi
 - What's New in Native Wifi
 - › About Native Wifi
 - › Using Native Wifi
 - › Native Wifi Reference
 - › Wireless Ad Hoc Reference

Native Wifi

Purpose

The Native Wifi automatic configuration component can store profiles on the networks it connects to.

Developer audience

The Native Wifi API is designed for C/C++ developers and contains concepts and terminology.

success!

...about the bldg. 31 lab

MSR's Wireless Network - Message (Rich Text)

FILE MESSAGE INSERT OPTIONS FORMAT TEXT REVIEW

Ignore Delete Reply Reply All Forward Meeting IM More

Liesure Reading To Manager Done Create New

Team Email Reply & Delete


Rules OneNote Actions

Mark Unread Categorize Follow Up

Translate Find Related Select

Delete Respond Quick Steps Move Tags Editing Zoom

Wed 7/7/1999 8:54 PM

 Victor Bahl
MSR's Wireless Network

To Systems and Networking Research Group

Cc Dan Ling; Jim Kajiyu; Jack Breese; Kendall Martin; Stephen Dahl

I am pleased to announce that **MSR now has full wireless connectivity.**

We have installed 20 access points around the building and these provide complete coverage to our building (Bldg. 31) and in the Cafeteria. --- so no more excuses about not being able to respond to an urgent email since you were not at your desk :-)

I encourage you to start using this wireless network in your everyday lives -- this is the future. Take your laptops and notebooks with you to meetings, to the seminar room, to the library, etc Researchers who have been using this network swear by it and love the flexibility it provides.

We have gone through an extensive evaluation process and based on a well defined set of criterion, **we have settled on Aironet** (for now). **The cost of an Aironet adapter is \$297.50.** Device drivers for all our operating systems are available - Win2000, NT4, Win98 and WinCE (MIPS, SH-3 processor) so the network should be available on a wide variety of machines that support PC cards.

Currently we have 15 machines that are on the net and we expect to see more soon. I will be sending out a Redmond-research-wide announcement on this in about a week or so but before I do so, I would like you to test the network out first. Experience the difference of being connected while being mobile.

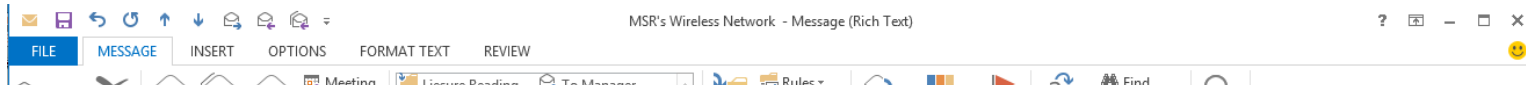
A note of caution, use the network wisely, you will be frustrated if you try to do large bulk data transfers (install large software packages like Win2000 or Office2000), or run netshow over this network. Also, **be aware that the wireless NIC will suck up your battery rather quickly**, so if you have a power outlet nearby -- use it. If you keep simple things like these in mind you will not be disappointed with the performance.

Finally, please be aware that placement of APs is an in-exact science and an ongoing process. Their placement will effect the throughput you see. If you observe problems in coverage and low data rates in particular sections of our building on more than one occasion, please let us know. Steven Dahl will be able to help you resolve any problems you encounter. He has been worked on this project from the very start and he is now the resident expert on it.

I am interested in hearing your feedback as you use this network.

-Victor

...about the bldg. 31 lab



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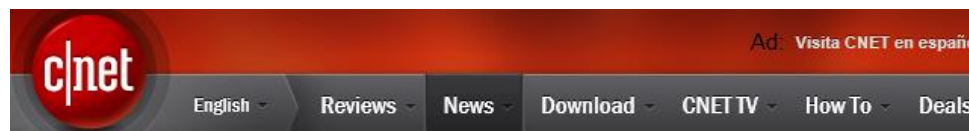
-Victor

more success ... building-wide deployment led to campus-wide deployment



Aug. 1999

Microsoft plans to "unwire" all 45 buildings on its campus within a year, linking the company's 16,000 workers wirelessly to the software giant's computer system. The announcement, to be made Wednesday by CEO Bill Gates, is aimed at spurring other companies to take steps to use technology to free what Gates calls "knowledge workers" to spend more time thinking and less time fumbling with wires.



CNET > News > News.com Miscellaneous

November 9, 1999 10:18 AM PST

Cisco buys Aironet for \$799 million

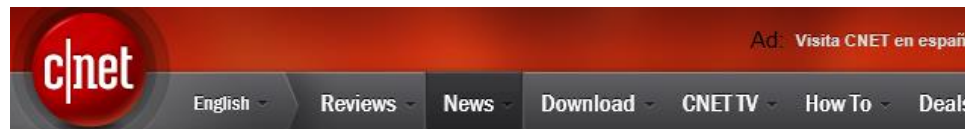
By Tiffany Kary
Staff Writer, CNET News

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CNET > News > News.com Miscellaneous

November 9, 1999 10:18 AM PST

Also buy Alenet for \$700

*it is difficult to predict what your small project will lead to, so go
with your instincts*

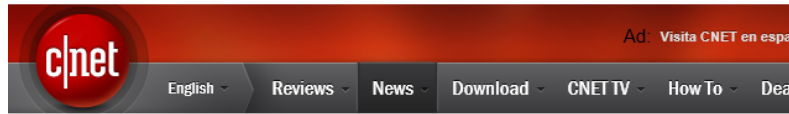
Staff Writer, CNET NEWS

enterprise wireless → public wireless

chapter 2

what works in the enterprise

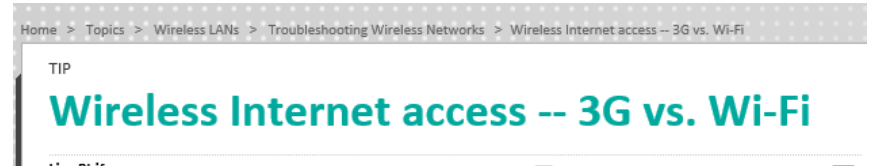
time of 3G networks...expected everywhere



CNET > News > Communications
August 1, 2001 3:00 PM PDT

Verizon to launch 3G network by year's end

By Ben Charny
Staff Writer, CNET News

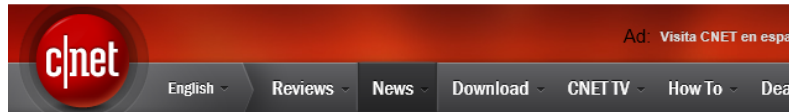


	Data-Control Extension to SCSI for Scalable Storage Area Networks <i>Yitzhak Birk, Nafea Bishara (Technion)</i>	Wi-Fi vs. GPRS vs. 3G
5:00 - 6:30 pm	Dinner	
6:30 - 8:00 pm	Panel Discussion Wireless Wars: Wi-Fi vs. GPRS vs. 3G <i>David Liddle (General Partner at U.S. Venture Partners)</i>	

- The links above reference the slides presented at the

telecoms feared public WLANs will eat into their existing business

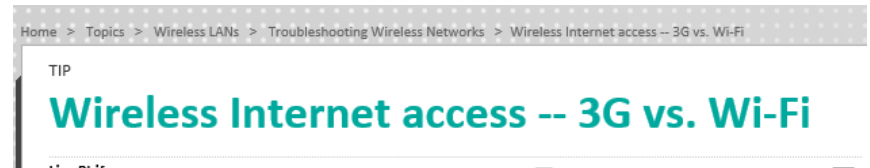
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August 1, 2001 3:00 PM PDT

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telecoms feared public WLANs will eat into their existing business

think independently, media often gets swayed by marketing

the world's first free public area Wi-Fi hotspot with location services



Eat, Drink and Be Connected

You can now access the corporate and Internet at Crossroads Shopping Center using the same wireless technology ITG has deployed in this building.

Enjoy a great meal, listen to live music, watch the passing parade – while doing your e-mail, collaborating with campus colleagues on a presentation or doing research on the Web.

Microsoft Research is testing a suite of wireless access protocols and applications in a trial at Crossroads. To participate you will need to provide your own hardware (e.g. a laptop and ITG-approved 802.11 wireless network card) and install some beta software. If you're interested, please email choice@microsoft.com, or check out <http://choice>.

CROWN
Crossroads
Wireless
Network

Sign up now!

Microsoft

Choice
Networks

CROSSROADS
SHOPPING CENTER



The CHOICE Network - Windows Internet Explorer
http://www.mschoice.com

Microsoft Research
The Choice Network Project

The CHOICE Network
High Speed Secure Wireless Internet Access
and Location Services in Public Places
The Choice Network is available at the Crossroads Mall in Bellevue, Washington.

Retired, June 14, 2002

To the best of our knowledge, the Crossroads Wireless Network (CROWN) was the first free public area wireless hot-spot network in the world. At a time when the community was touting 3G networks, CROWN showed how Wi-Fi could be used for ubiquitous Internet access. Our network supported global authentication, network discovery, user mobility, differentiated services, last hop security, and location / context services. The edge-server design and the accompanying protocols have been picked up by working groups within the Internet Engineering Task Force (IETF) and by many companies as part of their world-wide hot-spot deployment. The centralized switch architecture for enterprise-wide Access Point deployment can also be traced back to CHOICE/CROWN. The New York Times covered our project on public area Wi-Fi networks in Feb. 2000. CROWN provided Internet access and location services for a little over 2 years and was retired on June 14, 2002.

The Crossroads Shopping Center continues to use our equipment and provide free wireless access via the King County Library System. Check it out here

All you need to do when you enter a public place that offers the CHOICE network is to Configure your wireless LAN Card, get a passport account, check your proxy settings and point your web browser to <http://choice>.

<http://choice>

Lots of innovations

- ◆ (dumb AP) smart wireless switch arch.
- ◆ global authentication
- ◆ IP address management
- ◆ packet level accounting
- ◆ policy based differentiated services
- ◆ mobility between networks
- ◆ secure for both users and network operators
- ◆ improved battery/device lifetime
- ◆ location-aware services
- ◆ local content provider
- ◆ Hardware & OS agnostic

PAWNs: Satisfying the Need for Ubiquitous Secure Connectivity and Location Services

Paramvir Bahl¹, Anand Balachandran², Allen Miu³, Wilf Russell¹, Geoffrey M. Voelker², Yi-Min Wang¹

¹ Microsoft Research

² University of California, San Diego

³ MIT

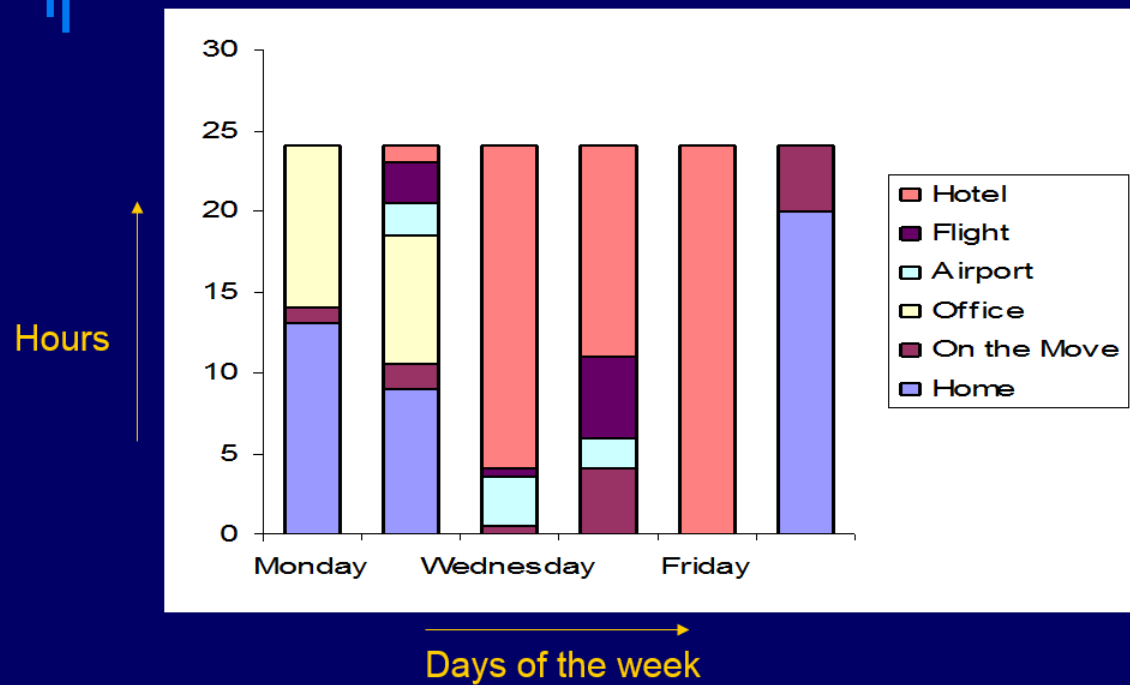
Abstract

The dawning of the 21st century has seen unprecedented growth in the number of wireless users, applications, and network access technologies. This trend is enabling the vision of pervasive, ubiquitous computing where users have network access anytime, anywhere, and applications are location sensitive and context

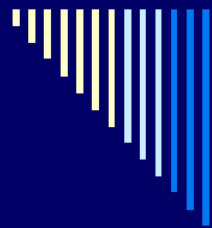
deployments increasingly common. Based upon the IEEE 802.11 standard [1], wireless LANs are emerging as the ideal solution for providing high-speed connectivity in private networks and, to a limited extent so far, public places. As a result, network connectivity at 11 Mb/sec is becoming commonplace, and this data rate is expected to

...and then made the case

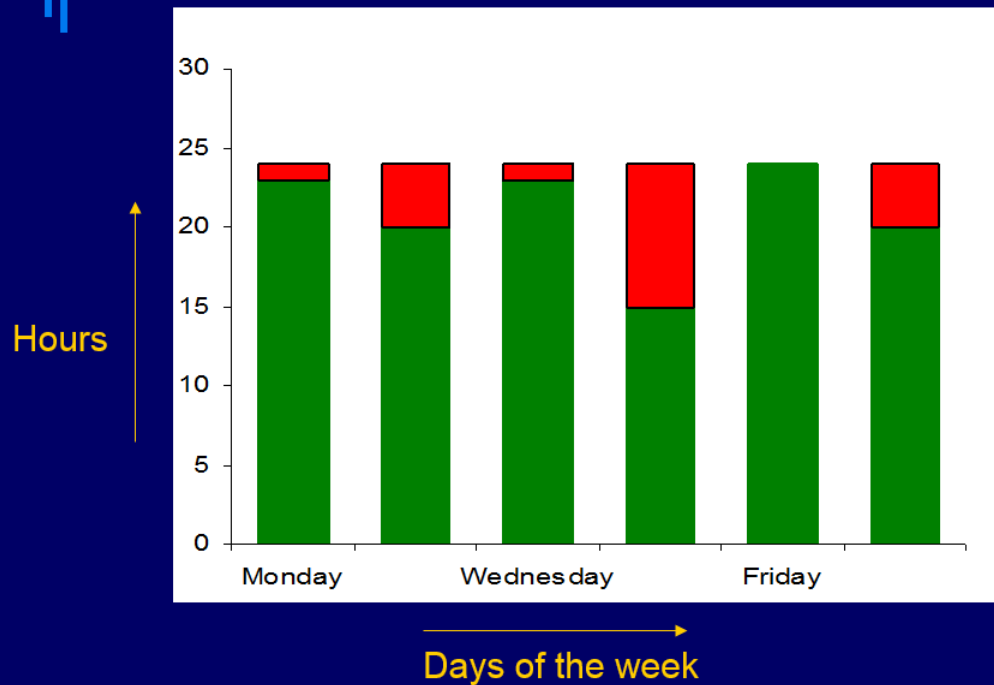
Sample of my activities last week



...and then made the case



Amount of time I spent indoors (green) versus outdoors (on the move) (red)



major uptake

- 100,000+ hotspots in the US alone
- telcos embraced hotspots for offloading traffic
- we expect them everywhere



me...not so successful

- product groups too busy to see the opportunity
- embraced fat AP architecture (IEEE 802.1X)

High Speed Wireless Internet Access In Public Places

Abstract

We have built a network, called the CHOICE network, which enables globally authenticated users to securely access the Internet using a high-speed local area wireless network. Our objective in designing this network is to enable easy-to-use, individual-centric, service-oriented, accountable wireless access to the Internet from places

modem or special communication line. In this situation her access is tied to her wired link provider, or to the ISP through which she has her account. Alternatively, she may access the Internet at work or elsewhere through a network that is provided and maintained by her employer. In this situation, her access is tied to her employer. Neither of

- dejected...decided to move on

me...not so successful

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if you believe in it...persevere

seven years later...

TopStories



Windows 8.1 now available
2013-10-17

Windows 8.1: The most powerful and
flexible OS for your business
2013-10-17

Nortel and Microsoft Form Strategic Alliance to Accelerate Transformation of Business Communications

July 18, 2006

Shared vision for unified communications to drive new growth opportunities for both companies.

From: John Mulgrew (LCA)
Sent: Friday, June 29, 2007 11:02 PM
To: Victor Bahl
Cc: Louis Carbonneau (LCA)
Subject: Microsoft, Nortel form alliance



Hi Victor,

We included one of your patents in a presentation we gave to Nortel on October 10, 2005 as part of a patent cross license negotiation. **These negotiations ultimately resulted in the signing of a landmark cross license deal with Nortel** that got a lot of press and keen attention by Nortel's peers. **The Nortel agreement was a momentum shifting event for the licensing team and I want to thank you for your contribution.**

The inclusion of your patent in these discussions is a remarkable achievement and speaks volumes to the value we get out of promoting research and innovations such as yours and seeking proper IP protection for it. Microsoft has nearly 7000 issued patents. Yours was among approximately 20 patents we selected. As you may know, we place a pretty high bar on what we choose, and then it gets subjected to scrutiny again by the people we present it to.

Thank you again for the great work you've done as an inventor.

All the best,
John

...one more thing about enterprise wireless applying the lessons

2002 - interviewed a charming young PhD candidate from Cornell

- loved him....took him on
- worked on *MultiNet* with my brother & I
- built the real thing
 - ignored by business groups
 - persevered & "shipped" it to the world



ranveer

2009 – victory! PGs shipped *MultiNet* as *VirtualWiFi* in Windows (the world's first wireless virtualization product)

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ranveer

2009 – victory! PGs shipped *MultiNet* as *VirtualWiFi* in Windows (the world's first wireless virtualization product)

lessons applied: (1) build the real thing (2) show them the money (3) persevere

enterprise wireless → public wireless → last-mile wireless

chapter 3

the last mile problem

it started with a chinese dinner



&



Craig Mundie

it started with a chinese dinner



&



Craig Mundie

-----Original Message-----

From: Pierre De Vries
Sent: Tuesday, March 26, 2002 2:33 PM
To: Alexis Chandler; Victor Bahl
Subject: craigmu/bahl/pierredv meeting

Victor, Craig would like to get your input on what would be a feasible MAC proposal for an ad hoc multi-hop network.

Perhaps the three of us can meet at the Chinese Restaurant in Redmond? Craig wants to meet with you before the big meeting at the end of April, so I think that means tomorrow night...

over dinner, I learned about

- lack of broadband internet access in rural areas
- the cable & DSL duopoly
- network neutrality
- why our field needs lobbyist in Washington DC

over dinner, I learned about

- lack of broadband internet access in rural areas
- the cable & DSL duopoly
- network neutrality
- why our field needs lobbyist in Washington DC

problem: how to get cable & DSL to speed up the spread of broadband Internet access?

constraint: don't break the bank

Thirst for Connection.....

"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."

Secretary General Kofi Annan (Dec 9, 2003)

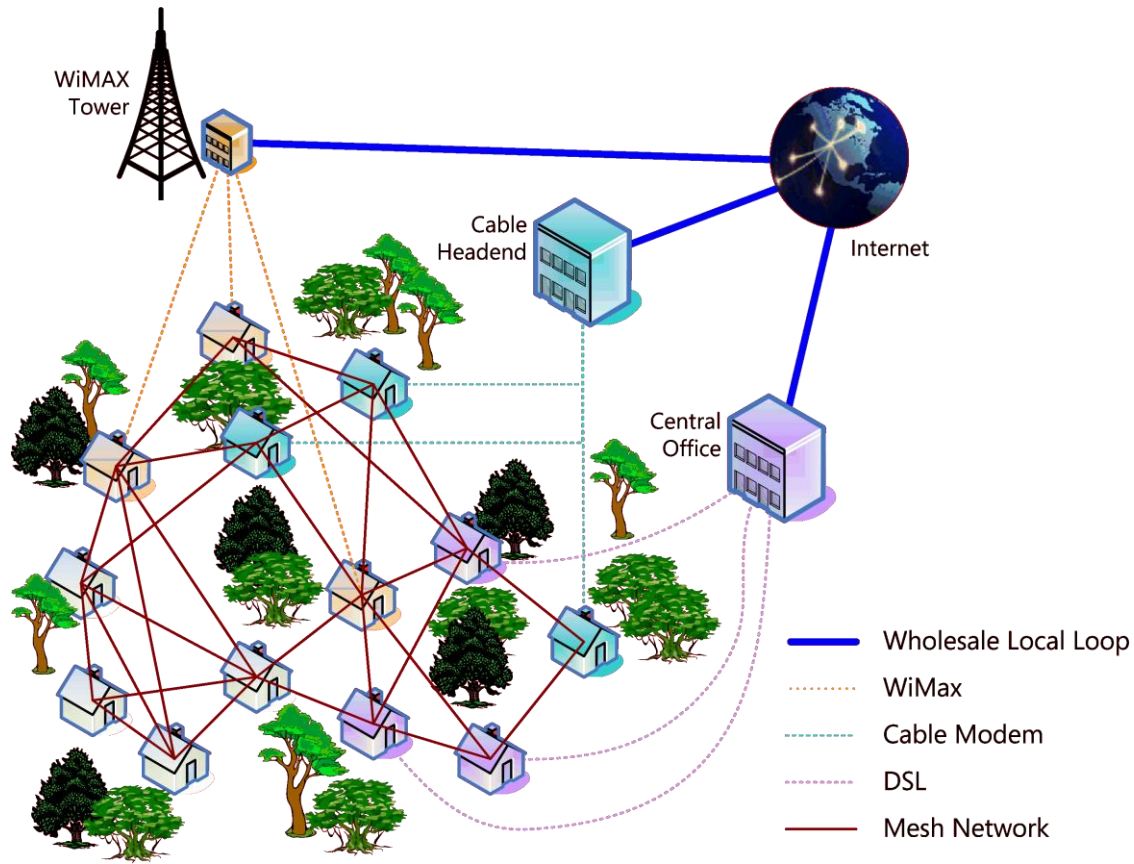
"The power of ideas and opportunities, fueled by local entrepreneurial energy, is the most important resource available in the resource-scarce part of our world."

Richard Newton, Dean UC Berkeley (Jul. 2005)

VSAT for kiosk in Kodia, Madhya Pradesh

corDECT wireless tower

idea: mesh networking



Organic – Participants own the equipment and the network

20 years of research on multi-hop ad hoc networks,
this should be an easy engineering job, right?.....

20 years of research on multi-hop ad hoc networks,
this should be an easy engineering job, right?.....

.....wrong!

many, many unicast multi-hop routing protocols

- [ABR](#) (Associativity-Based Routing Protocol)
- [AODV](#) (Ad Hoc On Demand Distance Vector)
- [ARA](#) (Ant-based Routing Algorithm)
- [BSR](#) (Backup Source Routing)
- [CBRP](#) (Cluster Based Routing Protocol)
- [CEDAR](#) (Core Extraction Distributed Ad hoc Routing)
- [CHAMP](#) (CacHing And MultiPath routing Protocol)
- [CSGR](#) (Cluster Gateway Switch Routing)
- [DART](#) (Dynamic Address Routing)
- [DBF](#) (Distributed Bellman-Ford)
- [DDR](#) (Distributed Dynamic Routing)
- [DNVR](#) (Dynamic Nix-Vector Routing)
- [DSDV](#) (Dynamic Destination-Seq. Dist. Vector)
- [DSR](#) (Dynamic Source Routing)
- [DSRFLOW](#) (Flow State in the DSR)
- [DYMO](#) (Dynamic Manet On-Demand)
- [FORP](#) (Flow Oriented Routing Protocol)
- [FSR](#) (Fisheye State Routing)
- [GB](#) (Gafni-Bertsekas)
- [GLS\(Grid\)](#) (Geographic Location Service)
- [GPSAL](#) (GPS Ant-Like)
- [GSR](#) (Global State Routing)
- [Guesswork](#)
- [HARP](#) (Hybrid Ad hoc Routing Protocol)
- [HSLs](#) (Hazy Sighted Link State)
- [HSR](#) (Hierarchical State Routing)
- [HSR](#) (Host Specific Routing)
- [IARP](#) (Intrazone Routing Protocol)
- [IERP](#) (Interzone Routing Protocol)
- [LANMAR](#) (LANdMARk Routing Protocol)
- [LAR](#) (Location-Aided Routing)
- [LBR](#) (Link life Based Routing)
- [LCA](#) (Linked Cluster Architecture)
- [LMR](#) (Lightweight Mobile Routing)
- [LQSR](#) (Link Quality Source Routing)
- [LUNAR](#) (Lightweight Underlay Network Ad hoc Routing)
- [MMRP](#) (Mobile Mesh Routing Protocol)
- [MOR](#) (Multipoint On-demand Routing)
- [MPRDV](#) (Multi Point Relay Distance Vector)
- [OLSR](#) (Optimized Link State Routing)
- [OORP](#) (OrderOne Routing Protocol)
- [DREAM](#) (Distance Routing Effect Algorithm for Mobility)
- [PLBR](#) (Preferred Link Based Routing)
- [RDMAR](#) (Relative-Distance Micro-discover Ad hoc Routing)
- [Scar](#) (DSR and ETX based)
- [SSR](#) (Signal Stability Routing)
- [STAR](#) (Source Tree Adaptive Routing)
- [TBRPF](#) (Topology dissemination Based on Reverse-Path Forwarding)
- [TORA](#) (Temporally-Ordered Routing Algorithm)
- [WRP](#) (Wireless Routing Protocol)
- [ZHLS](#) (Zone-Based Hierarchical Link State)
- [ZRP](#) (Zone Routing Protocol)
-


many, many unicast multi-hop routing protocols

- ABR (Associativity-Based Routing Protocol)
- AODV (Ad Hoc On Demand Distance Vector)
- ARA (Ant-based Routing Algorithm)
- BSR (Backup Source Routing)
- CBRP (Cluster Based Routing Protocol)
- CEDAR (Core Extraction Distributed Ad hoc Routing)
- CHAMP (CacHing And MultiPath routing Protocol)
- CSGR (Cluster Gateway Switch Routing)
- DART (Dynamic Address Routing)
- DBF (Distributed Bellman-Ford)
- DDR (Distributed Dynamic Routing)
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- ZHLS (Zone-Based Hierarchical Link State)
- ZRP (Zone Routing Protocol)
-

which one to use?
different performance for different setting

- didn't get a good sense of what works ... had to take care of it ourselves
- lost some faith in the academic networking research community
- MobiCom was becoming too academic
 - needed a home for systems researchers

founded MobiSys



The banner for MobiSys 2003 features a dark blue background with a white skyline of San Francisco. The text 'MobiSys2003' is prominently displayed in white, with the subtitle 'THE FIRST INTERNATIONAL CONFERENCE ON MOBILE SYSTEMS, APPLICATIONS, AND SERVICES' below it. To the right, it says 'SAN FRANCISCO, CA, USA' and 'MAY 5-8, 2003'. Below the main text, it states 'JOINTLY SPONSORED BY ACM SIGMOBILE AND THE USENIX ASSOCIATION, IN COOPERATION WITH ACM SIGOPS'. At the bottom, there is a navigation menu with five buttons: 'MobiSys Home', 'Invitation', 'Organizers', 'At a Glance', and 'Students' in the first row; and 'Register/Hotel', 'Tutorials', 'Technical Sessions', 'Activities/BoFs', and 'Call for Papers' in the second row.

JUST UP:
[Panel Session on Ubiquitous Computing](#)
[Press Release: Leading Computer Science Professional Organizations to Present MobiSys '03](#)

Jointly sponsored by ACM
SIGMOBILE and The
USENIX Association, in
cooperation with ACM
SIGOPS

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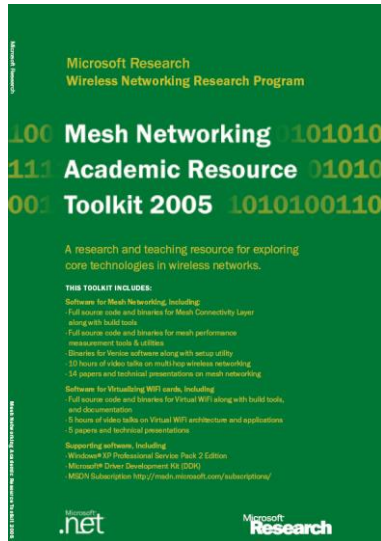
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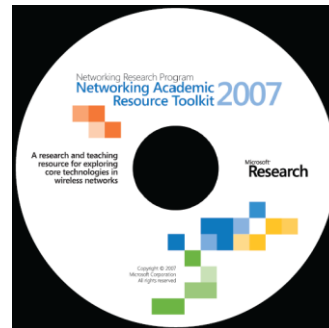
as systems researchers it is our responsibility to take our ideas to the point of irrefutability

for us project was successful...

- published software



Networking Research Program
**Networking Academic
Resource Toolkit** 2007
A research and teaching resource for exploring
core technologies in wireless networks

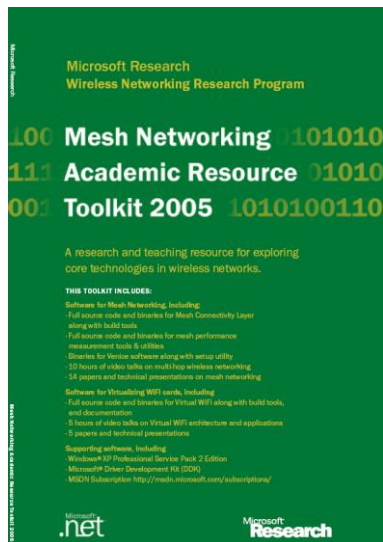


Over 1200 schools world-wide used our kits

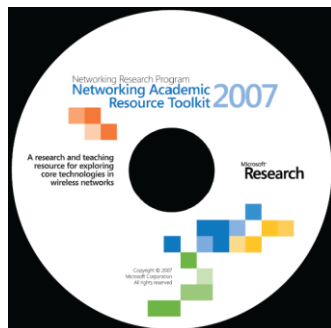
- organized summits & workshops
- invigorated the academic community, 100s of papers published

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Networking Research Program
Networking Academic Resource Toolkit 2007
A research and teaching resource for exploring core technologies in wireless networks



- VC \$\$ flowed into startups

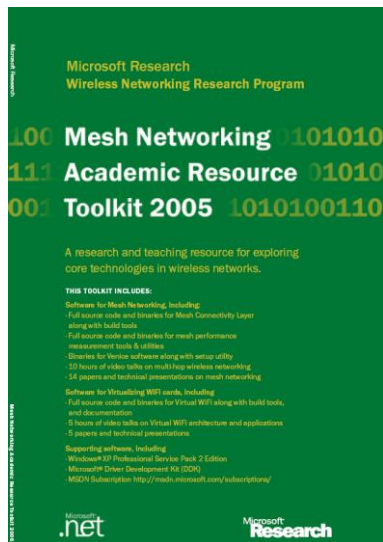


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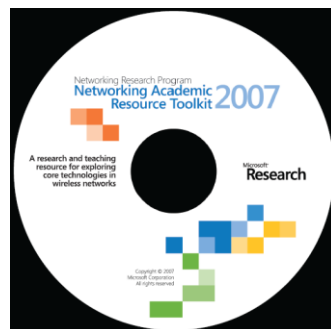
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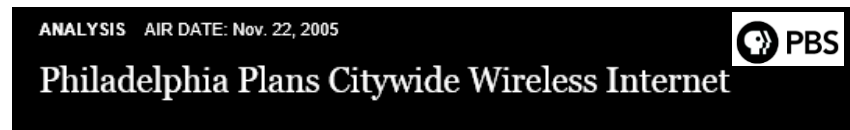
- published software



Networking Research Program
Networking Academic Resource Toolkit 2007
A research and teaching resource for exploring core technologies in wireless networks



- VC \$\$ flowed into startups



COMPUTERWORLD

Michigan city turns on citywide Wi-Fi
The Grand Haven Wi-Fi network went live yesterday

By Bob Brewin
July 30, 2004 12:00 PM ET [Add a comment](#)

Over 1200 schools world-wide used our kits

- organized summits & workshops
- invigorated the academic community, 100s of papers published

we lighted a fire under the duopoly

technically: introduced multi-radio wireless networks to the community

... but not so successful for others

Sept. 12, 2007, 9:38 p.m. EDT

San Francisco formally ends citywide Wi-Fi effort

AT&T kills St.Louis' citywide Wi-Fi plan

By [Layer 8](#) on Sat, 10/27/07 - 10:05pm.

[NEWS](#) → The Problems with Citywide wireless

The Problems with Citywide Wireless

By [Eric Griffith](#)
April 14, 2006

- VC's got it wrong
- saw quick money, jumped on the bandwagon
- spent lots of \$\$ on hearsay

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- VC's got it wrong
- saw quick money, jumped on the bandwagon
- spent lots of \$\$ on hearsay

business models based on incorrect understanding of the technology will lead to disaster.

enterprise wireless → public wireless → last-mile wireless → rural wireless

chapter 4

licensed versus unlicensed

in 2003, I had got first exposure to the breadth & complexity of the issues involved

everyone wanted more spectrum

debate was licensed or unlicensed

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everyone wanted more spectrum

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I learned about:

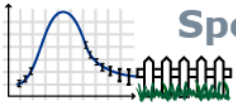
Ronald Harry Coase

29 Dec. 1910 – 2 Sept. 2013



noble laureate & "father" of reform in spectrum allocation policies

STANFORD UNIVERSITY



Spectrum Policy: Property or Commons?

Location & Travel	Schedule	Speakers	Sponsors & Organizers	Resources/Blogs
---------------------------------------	--------------------------	--------------------------	---	---------------------------------

WHO

Stanford Law School Center for Internet and Society and the Manhattan Institute

WHAT

Should spectrum be treated as property or a commons?

WHEN

Saturday, March 1 and Sunday, March 2, 2003

WHERE

Stanford Law School, Stanford, CA, USA
[\[directions\]](#)

Video and audio archives of [Spectrum Allocation: Property or Commons](#) are now available in the [Schedule](#) section of the site.

Spectrum policy is undergoing a fundamental reorientation in the United States and elsewhere. An emerging consensus holds that the traditional system of governmentally-allocated spectrum rights inhibits innovation and competition. The central question now facing policy makers is what form of spectrum management should replace the existing system. These issues will be discussed and debated at:

Spectrum Policy: Property or Commons? Stanford Law School

Stanford, California
Saturday, March 1 and Sunday, March 2, 2003

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Lawrence Lessig of the Stanford Law School Center for Internet and Society



Lawrence Lessig



Thomas Hazlett



David Farber



Judge Alex Kozinski



Gerald R. Faulhaber



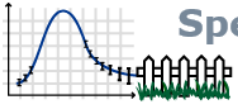
Stuart Benjamin



Tom Freeburg

.....

STANFORD UNIVERSITY



Spectrum Policy: Property or Commons?

Location & Travel

Schedule

Speakers

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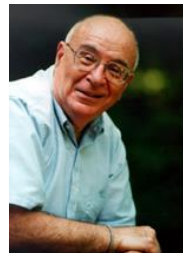
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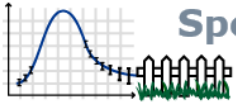
Stuart Benjamin



Tom Freeburg

.....

If you want a seat on the table, bring a proposal



Spectrum Policy: Property or Commons?

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Work-in-Progress
Version 1.1

Draft Proposal for Comment Etiquette Rules and Procedures for Unlicensed Bands

Victor Bahl
Microsoft Research

I. Abstract

This document is a draft for discussion of etiquette rules for short range wireless devices operating in the unlicensed frequency band. Regulators like the Federal Communications Commission (FCC) can be invited to apply these rules to the operation of 'unlicensed' wireless devices. The wireless devices may support asynchronous and/or isochronous digital communications. The proposed set of rules builds on rules that govern operation of wireless devices in Europe [11] and Japan and enhances them for adoption in the United States. It is our belief that these rules will enable the regulators of our spectrum to set an etiquette that enforces fair sharing of our precious national resource, while still allowing people to innovate at all levels of the protocol stack.



Lawrence Lessig



Thomas Hazlett



David Farber



Judge Alex Kozinski



Gerald R. Faulhaber



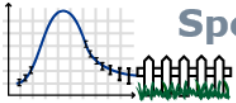
Stuart Benjamin



Tom Freeburg

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Spectrum Policy: Property or Commons?

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spectrum etiquette is not enough!



Lawrence Lessig



Thomas Hazlett



David Farber



Judge Alex Kozinski



Gerald R. Faulhaber



Stuart Benjamin



Tom Freeburg

.....

If you want a seat on the table, bring a proposal

... at stake were TV white spaces

in 1996, US Congress had set June 12, 2009 as the deadline for full power television stations to stop broadcasting analog signal

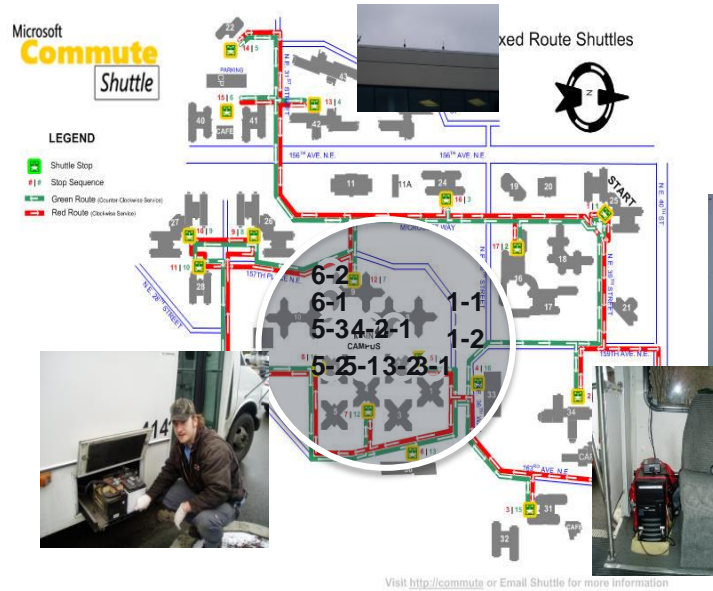
the idea of dynamic spectrum access was in the air but someone needed to step up and prove that the DSA concept works

the first urban white space network in the world

Oct. 16, 2009



White Space Network Setup in Bldg. 99



Campus-Wide Deployment



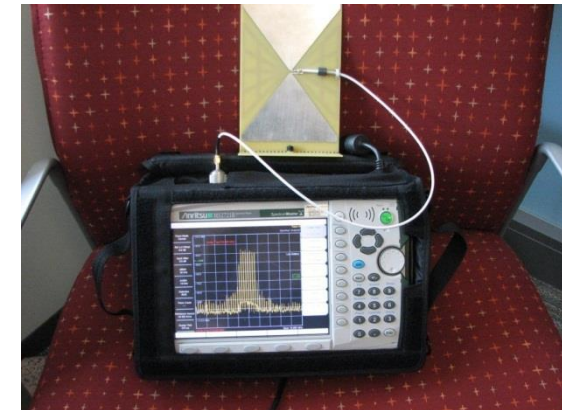
WS Antenna on Bldg 42



WS Antenna on MS Shuttle



Shuttle Setup



Data packets over UHF

success!

Aug 14, 2010

THE WALL STREET JOURNAL
Digital Network

MAY 11, 2010, 6:59 P.M. ET

FCC Officials Visit Microsoft To Examine Experimental Network



Chairman Genachowski & Microsoft's CTO Craig Mundie, August 14, 2010



Chairman Genachowski and FCC Managing Director Steven VanRoekel Climb aboard the MS Shuttle to look at our WhiteFi Network

The New York Times

F.C.C. Opens Unused TV Airwaves to Broadband

By EDWARD WYATT

Published: September 23, 2010

world-wide influence on spectrum policy



India
October 22, 2009



Federal Communications Commission
April 28, 2010



Office of Communications (UK)
June 10, 2010



Singapore
Apr. 8, 2010



China
January 11, 2010



Brazil
Feb. 2, 2010



**NSF Workshop on
Future Wireless
Communication Networks**

US Research Funding
November 9 2009



Standards



Fisher Communications Inc.
January 14, 2010

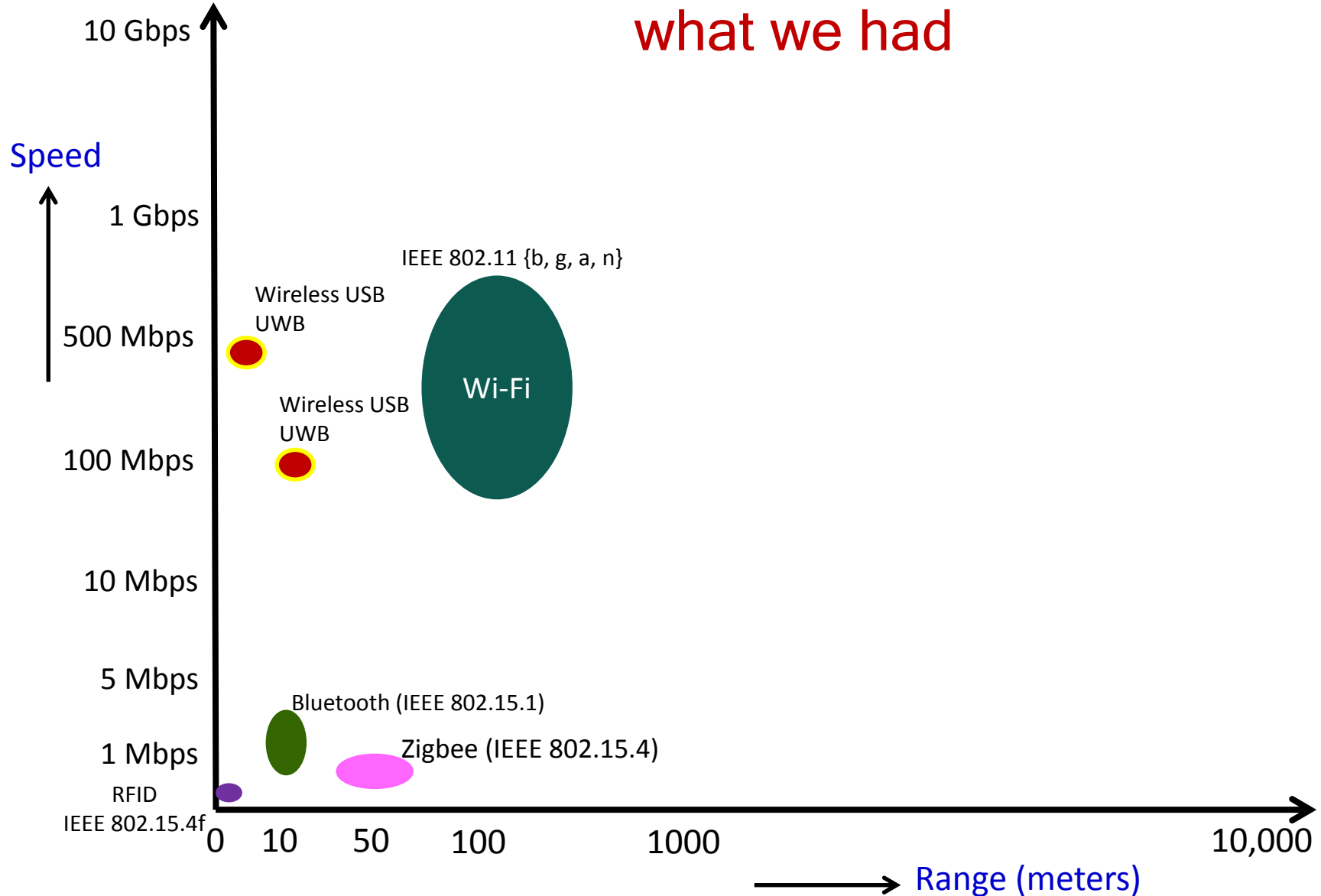
Workshop: Research Recommendations for the Broadband Task Force

PhD Thesis

- Rohan Narayan Murty, *Opportunistic Wireless Network Architectures*, Harvard University (June 2011)
- Yuan Yuan, *Enabling Dynamic Spectrum Allocation in Cognitive Radio Networks*, University of Maryland College Park (Sept. 2007)

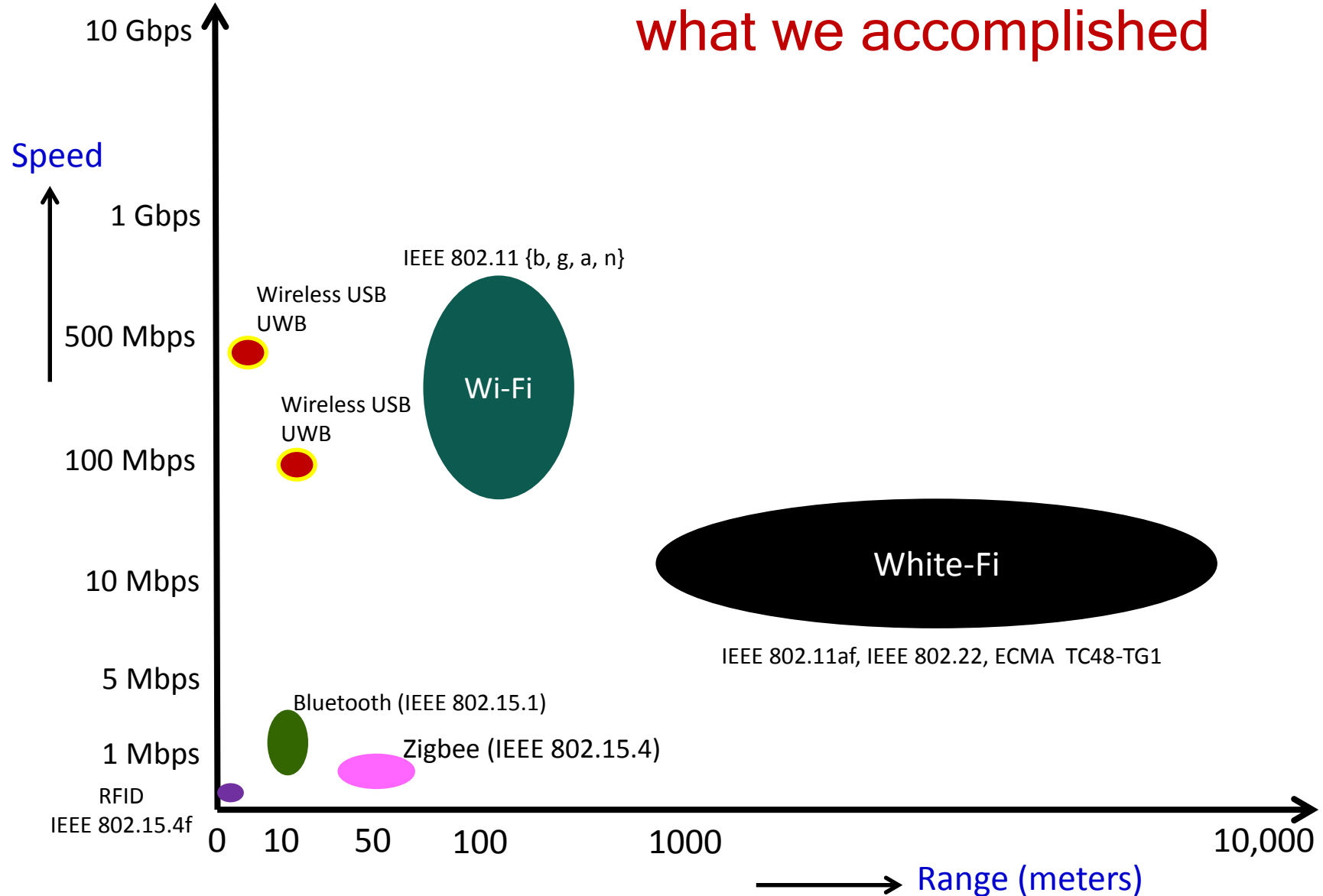
connectivity options over unlicensed frequencies

what we had

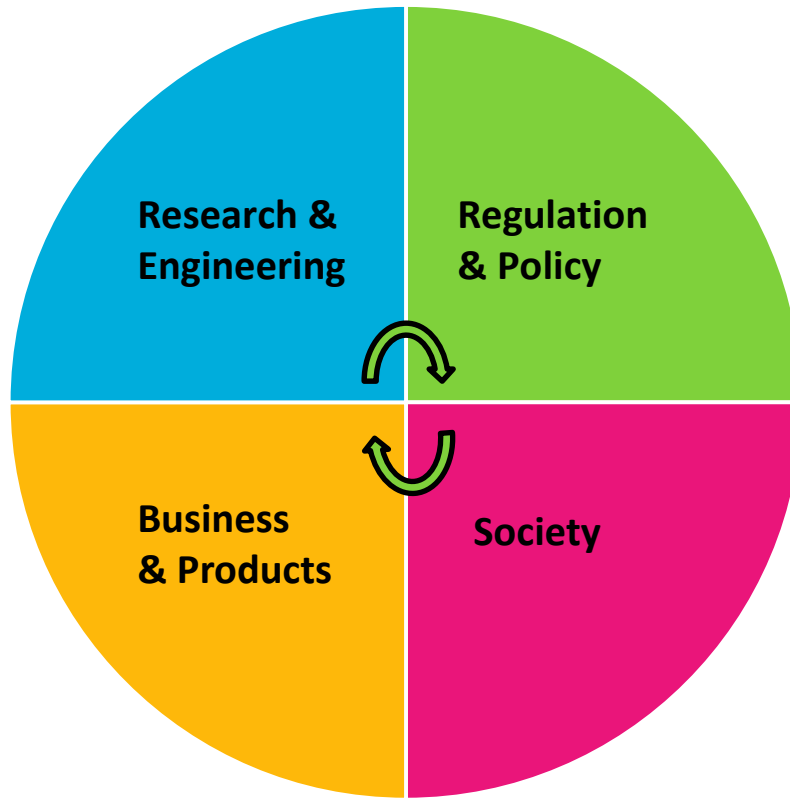


connectivity options over unlicensed frequencies

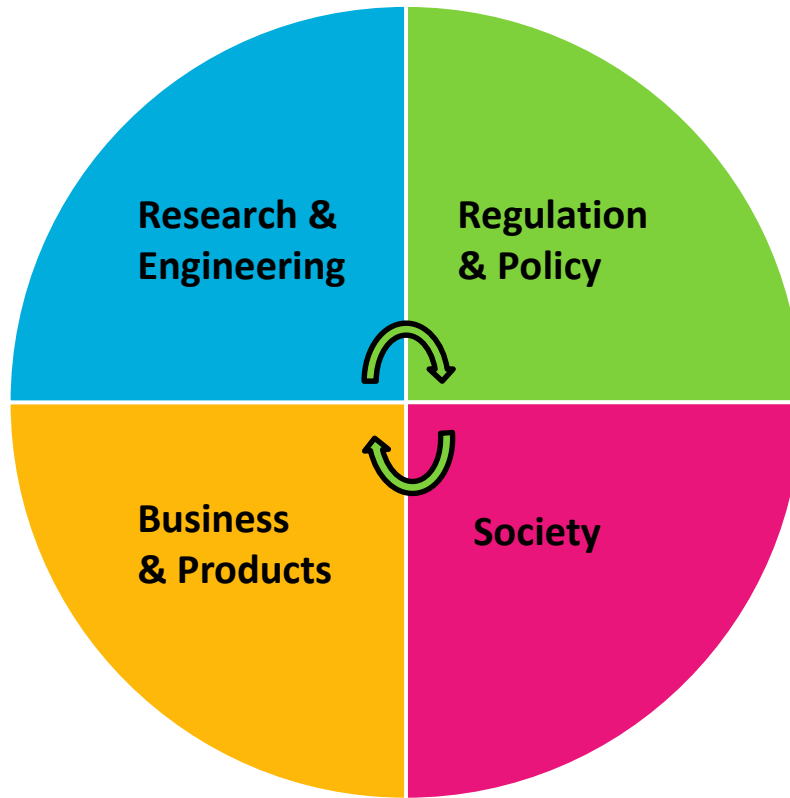
what we accomplished



lessons learnt



lessons learnt



research is only one part of the story, understand what it takes, get involved, and make it happen

impact!



The Mawingu Project (in Kenya)



Steven Mwaniki. - 6 hours ago

As one of the lucky student of Gakawa secondary school am so humbled by the kind of Noble project that you guys have brought to our school. That is so kind of you. We promise to take great care of precious project. We are so grateful of you and may our Mighty Lord Bless you Forever.

^ | x Reply Share >

chapter 5

looking ahead

in progress ...

I can't see that far but as far as I can see there are lots of problems to solve

PCAST report [July 2012]

“Traditional practice of clearing and reallocating portions of the spectrum used by Federal agencies is not a sustainable model for spectrum policy”

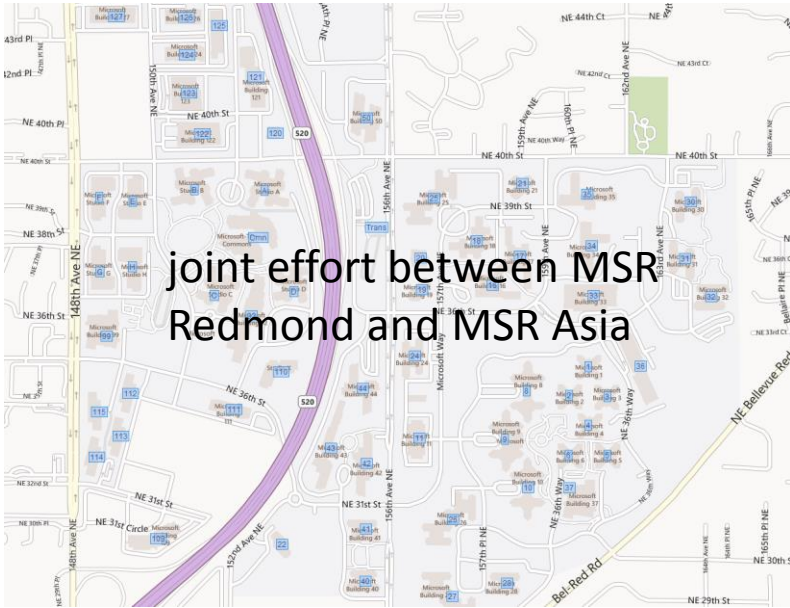
“The norm for spectrum use should be sharing, not exclusivity”.

If we get this done then *“[we] could multiply the effective capacity of the spectrum by a factor of 1,000.”*

few projects I continue to work on:

- a campus-wide DSA network
- platform to encourage DSA research in academia
- data to change spectrum regulations world-wide
- DSA in all licensed bands

project Istanbul: a campus-wide wsn



spectrum crisis - can it be managed?

THE HILL NEWS ALERTS
SIGN UP NOW
Enter Email **GO**

- Home
- Senate
- House
- Administration
- Campaign
- Polls
- Business &

THE HILL'S Congress Blog

Where lawmakers come to blog

InformationWeek
Government

The spectrum crisis is upon us

By Brent Skorup - 06/20/13 12:00 PM ET

Tweet 14 Like 32 Send

COMMENT
 EMAIL
 PRINT
 SHARE

NEWS

FCC Chair Cites 'Spectrum Crisis'

HOME PAGE TODAY'S PAPER VIDEO MOST POPULAR U.S. Edition ▼

The New York Times **Business Day**
Technology

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION

Carriers Warn of Crisis in Mobile Spectrum

CTIA Blog The Wireless Association*
CTIA is an international nonprofit trade association that has represented the wireless communications industry since 1984.

CYBERSECURITY ENVIRONMENT SPECTRUM & TOWERS STATS & FACTS TAXES & FEES

[Home](#) > [Public Policy](#) > It is No Trick – There is a Spectrum Crisis

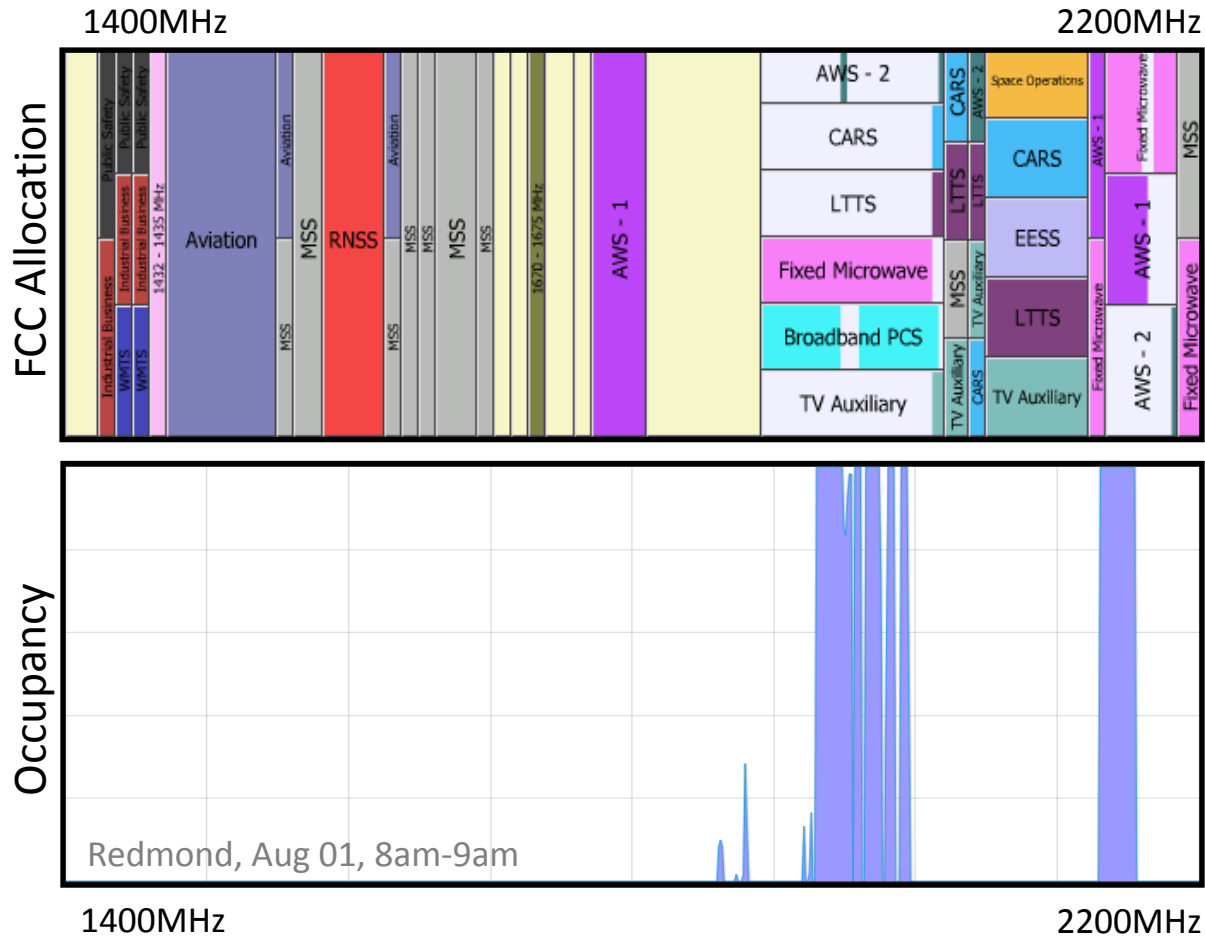
OCTOBER 23, 2012 [Print Preview](#)

It is No Trick – There is a Spectrum Crisis


Like Send 36 people like this. Be the first of your friends.

Yes, I'm the cybersecurity guy, but I'm also an engineer by trade, a Bell Labs alumnus and a patent holder who has worked on

early (inconclusive) results




let's find out if it's being used

 Microsoft
Spectrum Observatory

[Home](#) [Stations](#) [Charts](#) [About](#)

[Home](#) ▶




Browse Spectrum Stations
Discover all the spectrum observatory stations and measurements (eg., Frequency Bands)™

Create New Charts
Create charts of your choice, save them and browse through built-in charts.

About
Learn more about Spectrum Observatory, User Manual, FAQs etc.

Technology Policy Group
The Microsoft Technology Policy Group is currently collecting frequency usage data from a number of sensor base stations. Select a sensor location to view more detailed reports and graphs about the spectrum usage.

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call to action: let's scale it up

replace speculation with hard data



consider this as a national service

once we show spectrum is not being used, we can build DSA systems in the infrequently used frequency band and eliminate the spectrum crisis problem forever

parting thoughts

- question the assumptions

parting thoughts

- question the assumptions
- pursue your research to the point of irrefutability

parting thoughts

- question the assumptions
- pursue your research to the point of irrefutability
- publish only when you are done

parting thoughts

- question the assumptions
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- publish only when you are done
- persevere

parting thoughts

- question the assumptions
- pursue your research to the point of irrefutability
- publish only when you are done
- persevere
- don't be afraid of failing

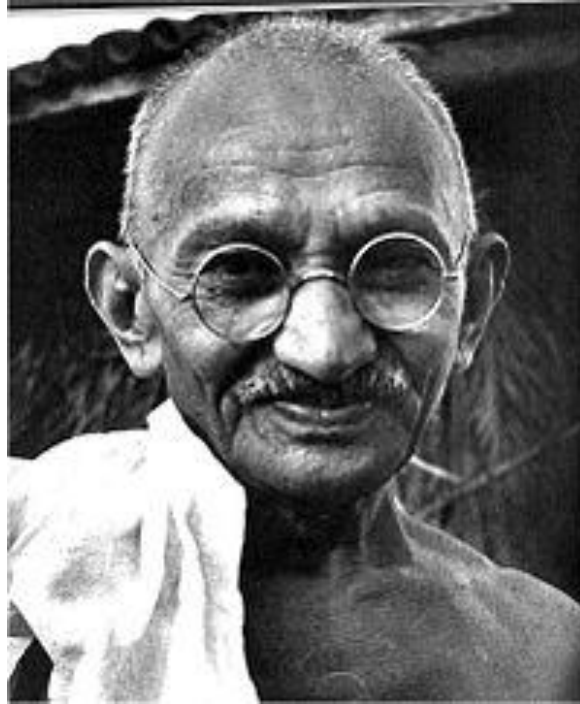
parting thoughts

- question the assumptions
- pursue your research to the point of irrefutability
- publish only when you are done
- persevere
- don't be afraid of failing

.....and go change the world for the better

Mohandas K. Gandhi

(2 October 1869)



“One needs to be slow to form convictions, but once formed they must be defended against the heaviest odds.”

Thanks