The Second Wave of Wireless Communications

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Wireless @ Virginia Tech ICTAS CRT Cognitive Radio Technologies

Thesis

- Increasingly ubiquitous wireless information availability will be augmented by autonomous intelligent agents that use that information (ideally) to the benefit of their users
  - Cognitive radio, Smart Grid, Precision Agriculture
- Significant impact on how we work, live, and play
  - Here and elsewhere

2

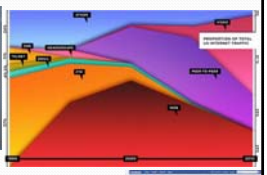
Presentation Material

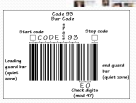
- First Wave: Information Ubiquity
  - Rising information demand
  - Femtocells vs WiGig
  - Smartphones
- Second Wave: Augmented Intelligence
  - CR
  - Self Organizing Networks
  - DSA in USA and around the world
  - Applications
    - Smart City, Smart AND cognitive phones, contextual awareness
- Impact

3

Information in our Lives

- Digital Information is everywhere in our lives
  - Online web content
  - Smart Phone apps
  - Kindle
  - Facebook
- Displacing (and augmenting!) traditional content delivery
  - Email for Mail
  - Blogs for Newspapers
  - Netflix for Blockbuster
    - NetFlix #1 source of Internet traffic (2x greater than YouTube)
  - Webmeetings for face-to-face
  - Telemedicine? Remote banking?
    - Afghans paid through their phones
- Wireless provides information access without tethers





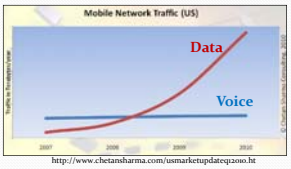
4

Delivering this information is a significant task

Owners of the iPhone 3GS, the newest model, "have probably increased their usage by about 100 percent," said Chetan Sharma, an independent wireless analyst. "It's faster so they are using it more on a daily basis.

J. Wortham, "Customers Angered as iPhones Overload AT&T" New York Times, September 2, 2009.

A. Gothard, "Managing Femtocells and the Evolved Packet Core"



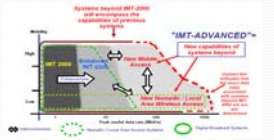
http://www.chetansharma.com/usmarketupdateq2010.htm

A. Gothard, "Managing Femtocells and the Evolved Packet Core"

5

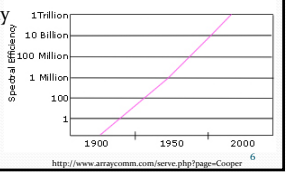
More bits per Hz / km² / sec

- Chetan Sharma 09
  - Mobile Data traffic > Mobile Voice Traffic
  - 1 Exabyte Data Traffic
  - 2010: more mobile broadband connections than fixed
- Further need due to ¼ of US households not having a landline
- Aiming for 10x increase in capacity for 4G
- Cooper's Law (Arraycom):
  - Spectral efficiency doubles every 18 months
  - > 112x since Marconi



http://3gamericas.com/PDFs/3G_Americas_Defining_4G_WP_July2007.pdf

Cooper's Law



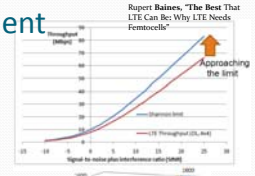
http://www.arraycomm.com/serve.php?page=Cooper

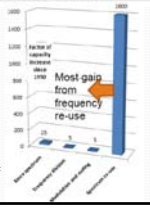
6

Need better frequency reuse and interference management

- Already close to limit of what modulation and coding can provide
- Historically capacity gains came from frequency re-use
  - Parallel communications
  - Sectorization, smaller cells, beamforming

Rupert **Baines**, "**The Best** That LTE Can Be: Why LTE Needs Femtocells"





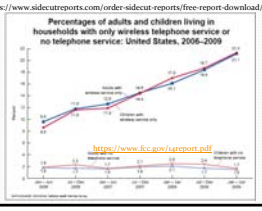
Rupert **Baines**, "**The Best** That LTE Can Be: Why LTE Needs Femtocells"

7

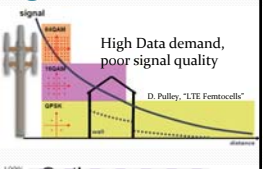
The action is moving indoors

According to Saw, early lessons Clearwire learned from active WiMAX networks shows customers "**using more bandwidth than I've ever seen in my years of working with wireless networks**" and that they are **using these mobile services primarily indoors**, where they work or or live. "No longer is mobile broadband limited to what you would call the road warriors," Saw said.

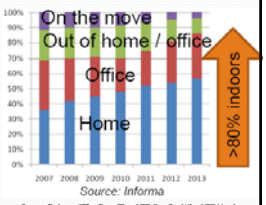
https://www.sidecutreports.com/order-sidecut-reports/free-report-download/?rid=6



https://www.fcc.gov/iareport.pdf



High Data demand, poor signal quality

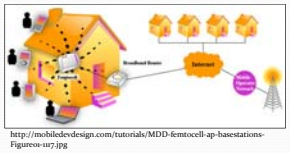


Rupert **Baines**, "**The Best** That LTE Can Be: Why LTE Needs Femtocells"

8

Femtocells

- WLAN in licensed spectrum
  - Operator management
  - Internet backhaul
    - Fiber-to-home
    - You pay
- Femtocell Forum
  - http://www.femtoforum.org/femto/
- 3GPP Rel 8/9
- Recent launches
  - AT&T http://www.lightreading.com/document.asp?doc_id=192708&f_src=lightreading_gnews
  - Vodafone Spain
    - http://lteworld.org/news/vodafone-spain-launches-femtocell-service
  - Femtocell based 3G service revenue $9bn per annum by 2014
    - D. Pulley



http://mobiledevdesign.com/tutorials/MDD-femtocell-ap-basestations-Figureo1-117.jpg

ftp://ftp.3gpp.org/Inbox/Marcoms/Conference_Presentations/2010_05_Moscow/Femto_Forum_Germano.pdf

Sprint

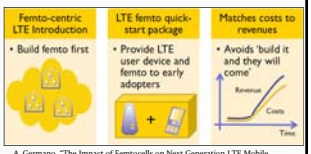
Verizon

AT&T

9

Why Femtocells? Data. Why not WiFi? Hmmm…

- Some think solution in search of problem
  - http://gigaom.com/2009/11/02/who-needs-femtocells-if-we-have-wi-fi/
- Versus offloaded WiFi data traffic?
  - Cheaper to both user and provider
  - WiFi already deployed
  - (My speculation) Only happens if provider covers cost of femtocell or incentivizes data plan
  - LTE vs WiFi faceoff or both in a box?
  - $150 box from AT&T? Free Time Square WiFi?



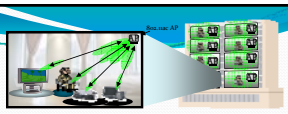
A. Germano, "The Impact of Femtocells on Next Generation LTE Mobile Networks"

- My best WAG
  - Joint WiFi / Femto
  - User on WiFi, other subscribers on Femto (hybrid CSG)
  - Options:
    - Free, discount on data plan, partnerships with ISPs

10

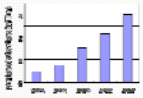
802.11ac

- Very High throughput < 6 GHz
- Target Application:
  - Streaming IPTV (and video in general)
  - VoIP, smart phones
- Requirements (IEEE 802.11-08/1285r):
  - 15 bps/Hz
  - 500 Mbps / 40 MHz – single link
  - 1 Gbps / 40 MHz – multi-station
- Key tech appears to be Spatial Division Multiple Access
  - And **A LOT** of antennas



802.11-09/0631r1

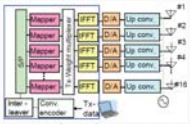
3 million IPTV subscribers in Japan in 3 years



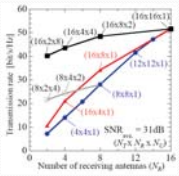
802.11-09/0631r1

Up to 42.8 bps/Hz with 16 antennas

802.11-09-0532-00-00ac



802.11-09/0303r1



802.11-09/0303r1

11

802.11ad (WiGig)

- Requirements
  - IEEE 802.11-08/1285r0
  - > 1 Gbps @ 10 m
  - Seamless handoffs between 2.4/5 GHz and 60 GHz
    - 3 Gbps ~ uncompressed 1080p
- Known Issues
  - Coexistence with 802.15.3c (60 GHz version)

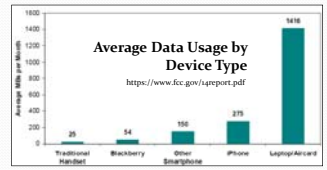
Req number	Parameter	Value	Description
Req04	Rate	3 Gbps	Uncompressed video,
Req05	Packet loss rate (8Kbyte payload)	1e-8	1080p (RGB): 1920x1080
Req06	Delay	2 ms	pixels, 24bits pixels,60frames/s

- "Done"
  - Published draft at wigig.org with adopter program
  - Alliance of all major players
  - Used as common draft in 802
    - https://mentor.ieee.org/802.11/dcn/10/11-10-0432-02-00ad-cp-presentation.ppt
    - https://mentor.ieee.org/802.11/dcn/10/11-10-0433-02-00ad-cp-specification.docx
  - Sept/10 session, approve creation of D1.0 and go into WG letter ballot
    - http://wirelessgigabitalliance.org/news/wigig-alliance-publishes-multi-gigabit-wireless-specification-and-launches-adopter-program/
  - Probably ends Amimon
  - SiBeam to do WiGig
    - http://www.eetasia.com/ART_8800606508_499488_NT_da2689da.HTM

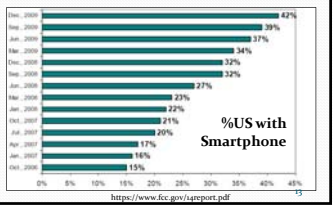
12

Apps and smartphones > networks

- Smartphone +67% yoy Q1 09 to Q1 10
- Well-known iPhone and Android App stores
  - **7 BILLION** app downloads 2009
- Kindle, Smart Grid, Android for GM
- AT&T may be strongest case that the apps and phones now matter more than the network



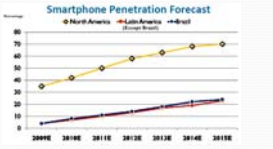
IMG: http://blog.jjhelp.com/?p=417



https://www.fcc.gov/14report.pdf

Smart Phone and Apps

- 67% Growth YoY Growth
  - http://www.fiercemobilecontent.com/press-releases/global-smart-phone-market-growth-rises-67
- World: iPhone > Android but US: Android > iPhone
  - http://digitaldaily.allthingsd.com/20100511/apple-on-npd-android-outselling-iphone-claim/
- 9->38 App stores in 2009
- iPhone Stats
  - 206,297 apps in iPhone store
  - >3 billion apps downloaded
  - Average approval delay < 7days
  - App store for jail broken iphones
    - http://cydia.saurik.com/
- Android Stats
  - 100,000 Android-based phones are activated every day.
  - On 60 devices from 21 OEM makers on 59 carriers in 48 countries.
  - >50,000 apps in the Android Market Place
  - http://gigaom.com/2010/05/24/android-vs-chrome-os/



ftp://ftp.3gpp.org/workshop/2010_04_Rio_LTEseminar/Marketplace_update.pdf

Smart Phone Trends / Predictions

- Android will "win" out over iPhone
- Not like how LTE is winning over WiMAX
  - Apple is still going to make its money and may even be the single largest smart phone manufacturer; definitely most profitable
- Why:
  - More types of devices
  - Increasing trend to offdeck
  - Increasing importance of ads
  - Open OS leads to unexpected applications
    - DARPA Android BAA
      - https://www.fbo.gov/download/35b/35bdddd6bb5d6a8f8f6c16317ea261cb5/TA_BAA_10-41_FINAL.pdf
    - Android for GM
      - http://earth2tech.com/2010/05/23/why-googles-android-could-rule-connected-cars/
  - Foreign Market growth, e.g., Japan (DoCoMo, KDDI)
    - http://www.mobile-ent.biz/features/272/Android-rising-in-Japan
  - MS Kin: Too Little, too late
    - http://paidcontent.org/article/419-microsofts-kin-too-little-too-late-/

Smart Phone OS Share

Company	2009 Market 2009 Units	Share (%)	2008 Market 2008 Units	Share (%)
Symbian	80,878.6	46.9	72,933.5	52.4
Research In Motion	34,346.6	19.9	23,149.0	16.6
iPhone OS	24,889.8	14.4	11,417.5	8.2
Microsoft Windows Mobile	15,027.6	8.7	16,498.1	11.8
Linux	8,126.5	4.7	10,622.4	7.6
Android	6,798.4	3.9	840.5	0.5
WebOS	1,193.2	0.7	NA	NA
Other OSs	1,112.4	0.6	4,028.9	2.9
Total	172,373.1	100.0	139,287.9	100.0

http://www.gartner.com/it/page.jsp?id=1356513

Global Mobile Apps Market Revenue by Type

Global Stats: Or Why the US Matters

- 26% 2009 Revenues Data
  - Recall equal voice, data traffic
- India subscribers catching China
- US talks the most (per user)
- Japan has greatest %Data of ARPU

Rank	By Subs	By Data Revenue	By Service Revenue
1	China	US	US
2	India	Japan	China
3	US	China	Japan
4	Russia	UK	France
5	Brazil	Italy	Italy
6	Indonesia	Germany	UK
7	Japan	France	Germany
8	Germany	Australia	Brazil
9	Pakistan	Spain	Spain
10	Italy	Korea	India

http://www.chetansharma.com/

Table 40
Mobile Market Performance in Selected Countries[567]

Country	Penetration (% of Pops)	Prepaid (% of Subs)	MOUs	Revenue per Minute ($)	ARPU ($)	Data (% of ARPU)
Receiving Party Pays						
USA	88.9	17.1	829	0.05	41.54	25.5
Canada	64.8	23.2	444	0.09	49.24	17.8
Hong Kong	147.6	44.9	447	0.04	20.40	26.7
Singapore	135.8	48.6	377	0.06	32.08	27.3
Calling Party Pays						
UK	125.5	62.0	192	0.12	35.35	27.8
Germany	130.6	56.6	102	0.16	20.59	25.3
Italy	152.7	88.3	131	0.16	26.87	24.7
Sweden	123.6	35.0	296	0.10	28.05	20.9
France	91.9	34.2	246	0.14	44.37	18.3
Finland	127.5	12.7	244	0.12	33.91	18.9
Japan	85.7	1.4	139	0.26	56.82	41.0
South Korea	95.9	3.0	320	0.08	30.34	17.0
Australia	109.9	44.9	218	0.11	34.57	32.4

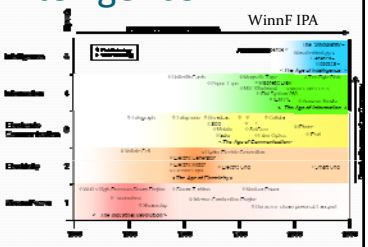
https://www.fcc.gov/mb/report.pdf

http://www.chetansharma.com/

16

New Trend: Intelligence

- Intelligent agents will assist our activities, adjust the behavior of the world, and better sort and present information from sea of data
- Recognize context – individuals, intent, objects, situation
- Augments and accelerates information trends
  - Makes use of universal connectivity
- Mix of local and remote intelligence



MIT: 6th Sense

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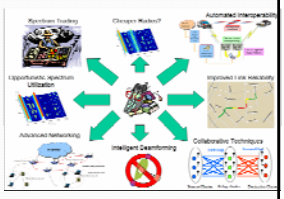
Cognitive Radio: Basic Idea

- Software radios permit network or user to control the operation of a software radio
- Cognitive radios enhance the control process by adding
  - Intelligent, autonomous control of the radio (link, network…)
  - An ability to sense the environment
    - Other information sources too
  - Goal driven operation
  - Processes for learning about environmental parameters
  - Awareness of its environment
    - Signals
    - Channels
  - Awareness of capabilities of the radio
  - An ability to negotiate waveforms with other radios



- Facilitate public / private spectrum sharing
- Improved link reliability
- Reduce setup time and cost
  - Self organizing networks
  - Mitigate environment
- Cheaper radios?

18

3GPP: Self Organizing Networks

[Brown_08]

- The belief among operators is that 3G represents a missed opportunity to automate network processes, and that much of the ongoing cost to configure and manage Node Bs, radio network controllers, and core network elements is accounted for by the need to allocate expensive technicians to mundane, yet cumbersome, tasks.

- Organizing Groups
  - 3GPP
  - Next Generation Mobile Networks
- Many cellular vendors focusing on reducing OPEX
  - See Motorola_09b], [NEC_09], and [Nokia Siemens_09]

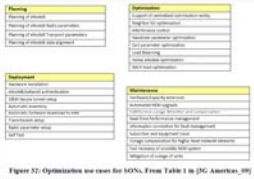


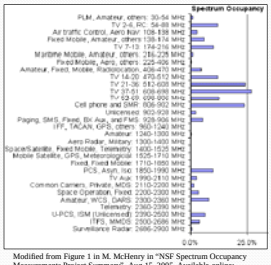
Figure 32: Optimization use cases for SONs. From Table 1 in [3G Americas_09]

- **3GPP Release 8**
  - automatic inventory, automatic software download, Automatic Neighbor Relation, Automatic Physical Cell ID (PCI) assignment
- **3GPP Release 9**
  - Coverage & Capacity Optimization, Mobility optimization, RACH optimization, and Load Balancing Optimization

19

Dynamic Spectrum Access (DSA)

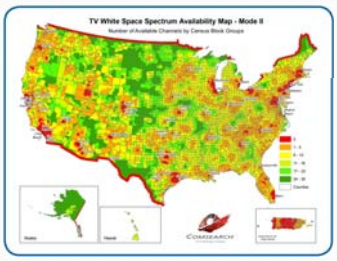
- Spectrum scarcity is purely a management phenomenon (for now)
- Primary Concept:
  - Let other applications / devices reuse underutilized spectrum
  - Autonomous intelligence empowered to make spectrum allocation decisions based on local conditions and rules
- Additional uses
  - Flexible, autonomous spectrum management
  - Spectrum Markets
- Simplified deployment in



Modified from Figure 1 in M. McHenry in "NSF Spectrum Occupancy Measurements Project Summary", Aug 15, 2005. Available online: http://www.sharedspectrum.com/?section=nsf_measurements

20

TV White Space & the Population Paradox



From M. Gibson, "TV White Space Geolocation Database Issues & Opportunities", CommSearch, TVWS Workshop Sep 16, 2010

- $100 billion over the next 15 years.
- Rural doesn't win unless urban wins
  - No spectrum for large urban portables
- Later squeeze from broadband (120 MHz)
  - **Regulatory Issue:** Technology can handle this, but will significantly impact business proposition

21

White Space Standards

- 802.22 – WRAN, fixed
- 802.16h – Unlicensed WiMAX
- 802.11af – TVWS WiFi
- CogNeA – Industry standard
- 802.19.1 - Interoperability
- Long term expectations:
  - 802.11af wins the WiFi on Steroids market
  - LTE "wins" the WRAN market
    - Used for fallback channels
  - Niche in fixed backhaul
    - 802.16h / 802.22
  - What of sensor nets?


WIRELESS INNOVATION FORUM

CALL FOR PARTICIPATION:

TD-LTE WHITE SPACE PROJECT

PROJECT GOALS:

QUESTIONS TO BE EXPLORED:

TO GET INVOLVED:

www.WirelessInnovation.org

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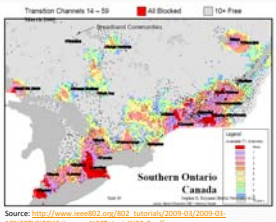
White Space Canada

- Canada
  - Interim Guidelines (06)
    - *http://www.ic.gc.ca/epic/site/smt-gst.nsf/en/sf08739e.html*
  - High power, licensed, intended for fixed (point to multipoint) systems, up to 500 W, Vertically polarized (TV services are horizontally polarised)
  - Not CR
    - *"Sites and services including spectrum are individually planned and coordinated around TV services"*
  - 3/09 licenses issued, no services yet
- Channel Availability in Ontario



Source: http://www.ieee802.org/802_tutorials/2009-03/2009-03-10%20TV%20Whitespace%20Tutorial%20r0.pdf

VERY Limited in Urban areas

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White Space UK (OFCOM)

- http://www.ofcom.org.uk/consult/condocs/cognitive/statement/

- Considering Geolocation / database requirements / processes
  - Responses by Feb 9, 2010
  - http://www.ofcom.org.uk/consult/condocs/cogaccess/

Outdoor Availability

VERY Limited in Urban areas
(not as bad indoor)

Source: http://www.ieee802.org/802_tutorials/2009-03/2009-03-10%20TV%20Whitespace%20Tutorial%20r0.pdf

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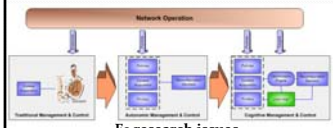
Major EU Initiatives

- COST ICO902 –Technical multi-country collaboration on CR impact on all layers of the protocol stack (algorithms and protocols)
- COST –TERRA (ICO 905) – deployment scenarios, business analysis, regulatory impact
- E2R / E3 (complete)
  - CR system for heterogenous networks; integration into cellular
  - Cognitive Pilot Channel



E3 research issues

- COGEU - secondary spectrum trading and the creation of new spectrum commons regime
- CREW – testbed of CR with heterogenous systems
- QoSMOS – managed QoS in mobile broadband in mixed licensed spectrum
- FARAMIR – Radio environment mapping and spectral awareness
- ARAGORN – collaborative intelligence for ISM band
- SAMURAI – multi-user MIMO + spectrum aggregation
- QUASAR

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CR Activities in China

- 863 Project (started 2005)
  - Spectrum sensing, Spectrum allocation, etc
  - Hierarchical spectrum sharing network (HSSN): HSSN architecture, Cooperative spectrum sensing, Spectrum management, Spectrum allocation, Routing, Power control, etc
  - Dynamic spectrum sharing network (DyS2)
    - Support cooperative spectrum sensing and dynamic spectrum management
    - SDR-based nodes for dynamic spectrum sharing
    - Network and nodes with reconfigurability
      - Node: access point, gateway or terminal
      - Network: centralized, decentralized or hybrid architecture
  - Demonstration of DyS2 in 694-806MHz TV band
- 973 project
  - Important National Science & Technology Specific Project
    - Researches and verification on key techniques for efficient spectrum utilization to WRC-11
      - Task 1: researches on special scenarios
      - Task 2: platform
      - Task 3: exploratory researches
      - Task 4: standardization
  - Several CR projects funded from National Natural Science Fund

Info from L. Pucker, J. Neel, P. Kolodzy, V. Kovarik, "State of the Art in Spectrum Sharing," NIST Workshop on Spectrum Sharing July 2010.

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Programs in Japan

- The MIC Program

- Objectives
  Research and develop technologies to increase frequency utilization efficiency for next generation mobile communication system
- Period: 2006-2012
- Current Status
  May 2008: Call for proposals for research topics provided from MIC
  Aug. 2008: Decided proposers

Research topic	Selected proposers
(1) R&D on joint control technology between multiple base stations for various cellular zone	Softbank Mobile, Softbank telecom, Univ. of electro Communication
(2) R&D on reliability improvement technology by dynamic use of multiple radio communication system	NTT Docomo, ATR
(3) R&D on radio resource control technology between multiple radio access technologies on common frequency band	KDDI, ATR
(4)R&D on dynamic spectrum access networking technology in multiple wireless access networks	NICT, NTT Personal Communications
(5)R&D on dynamic spectrum access equipment in multiple wireless access networks	NICT

- White space communication (spectrum sharing type cognitive radio)
  - 2009/11/25: Task force to consider usage of white space were launched
  - 2009/12/02: First task force meeting
  - 2009/12/11-2010/01/12: Public comments on usage model in white space band was received and 102 usages from 53 entities
  - 2010/03/01: International symposium was held in Tokyo managed by MIC
  - 2010/04: Public hearing on public comments
  - Still under discussion

Info from L. Pucker, J. Neel, P. Kolodzy, V. Kovarik, "State of the Art in Spectrum Sharing," NIST Workshop on Spectrum Sharing July 2010.

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Elsewhere

- iDA (**Singapore**)
  - I²R submitted device for US TVWS testing
  - April 7, 2010 "White Space Technology Information Package and Test Plan"
  - July 31, 2010 White Space trials (Cognitive Radio Venues)
- MiniComm + Anatel (**Brazil**) – setting up pilot White Fi network
- **Korea**
  - CR Systems Project at ETRI (08-10)
    - Research on cognitive radio technologies for providing best connectivity in multi-RAT (Radio Access Technology) environments
      - Universal Access based on CR/SDR technology
        - RAT discovery and RAT selection based on cognitive engine
        - Reconfiguration for adaptation
- Netherland Antilles
  - Exploring adopting secondary access in TVWS

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LOW COST TELECOMMUNICATIONS INFRASTRUCTURE

- It is hard to provide communication services in developing nations and remote communities
  - Fixed wire-line infrastructure is too expensive
  - Wireless deployments require:
    - Backhaul infrastructure
    - High energy costs of base stations, and
    - Skilled engineers
  - Development is impeded because of the
    - large geographic area
    - lower population density
    - and economically depressed customer base

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LOW COST TELECOMMUNICATIONS INFRASTRUCTURE

- A Femtocell, is a very low cost base station that is currently used to supplement coverage
- Unoccupied TV spectrum (whitespace communications) provides long range high-bandwidth backhaul
- Benefits:
  - economies of scale of cellular based products
  - long range
  - unlicensed
  - self managing capabilities of whitespace technology
  - Solar power reduces energy costs and the energy infrastructure needs
- This technology also has applications worldwide as a rapidly deployable communications infrastructure to support disaster events.
- New business models:
  - Women in rural villages in Bangladesh are selling airtime to other villagers
  - When demand is sufficiently high, a full scale infrastructure can be built with reduced business risk

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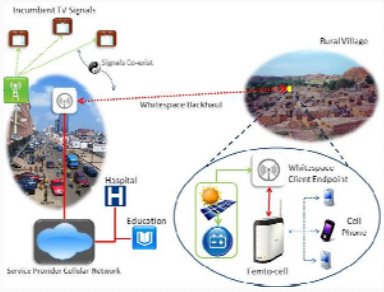
LOW COST TELECOMMUNICATIONS INFRASTRUCTURE



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Smart City Trials in Wilmington, NC (SCADA for the rest of us)

- **Downbanded WiMAX TVWS equipment for telemetry data**
  - **Impractical to run wires**
  - **Not 802.16h**
- **View as part of eventual transition to telemetry data for everyone**
- **TV Band Service, LLC**
- ***In Partnership With:***
  –New Hanover County, NC
  –Wilmington, NC
  –Spectrum Bridge, Inc
- More info:
  - John Chapin jchapin@mit.edu

J. Chapin, TV Band White Spaces "Smart City Trial Wilmington, NC, TV Band Devices Workshop, June 15 2010

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CR + iPhone (MIS/2000)

- COTS for coordinating disaster response with non first-responders (SAHANA)
- Communicate over civilian infrastructure when available, set up TVWS network when not available

- In same vein as Mitola / Fette "Radar O'Reilly on your phone"
- Other apps:
  - Logistics management w/ interface to Zigbee
  - Maintenance and Intel apps
- More info:
  - Bob Wiebe: bwiebe@geltd.net

Plug in HW supports ad-hoc TVWS network

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MIT Media Lab's Sixth Sense Device

- Allows interaction between the physical and digital world
  - Camera detects hand motion and other information
  - Mini projector displays information on any surface
- Affordable, current cost $350 using COTS
- Countless applications

Source: http://www.pranavmistry.com/projects/sixthsense

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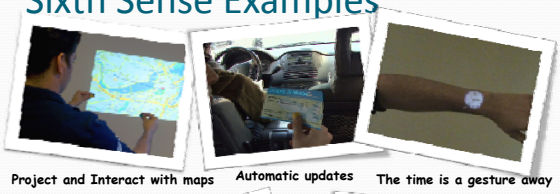
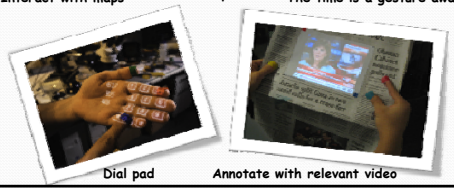
Sixth Sense Examples



Project and Interact with maps | Automatic updates | The time is a gesture away



Dial pad | Annotate with relevant video

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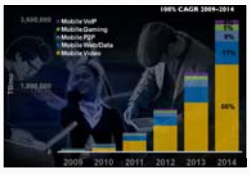
Tech. Summary

- Information is playing an increasingly important part of our lives today
  - Wireless + IP cloud provide ubiquity, smart phones for access
  - Struggle to keep up with bandwidth demands
- Intelligent software processes will assist us (more) in the future
  - Automate spectrum management and network set up
  - Many apps far removed from wireless domain (but using wireless)
  - Continued confluence of successful technologies



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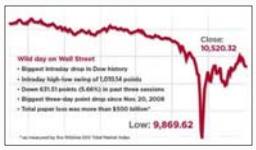
Intelligence: Impact

Precision Agriculture

IBM: Smarter Planet

Smart Grid



Flash Crash of May 6, 2010

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Aker and Mbiti: Mobile Phones and Economic Development in Africa

- http://www.cgdev.org/content/publications/detail/1424175/
- There are ten times as many mobile phones as landlines in sub-Saharan Africa (ITU, 2009),and 60 percent of the population has mobile phone coverage.
- An emerging body of research shows that the reduction in communication costs associated with mobile phones has tangible economic benefits, improving agricultural and labor market efficiency and producer and consumer welfare in specific circumstances and countries (Jensen, 2007; Aker, 2008; Aker, 2010; Klonner and Nolen, 2008).
- "A device that was a yuppie toy not so long ago has now become a potent force for economic development in the world's poorest countries.
- "It's really great for a farmer to find out the price of beans in the market," says Mbiti, who has seen the impact of the cell phone boom firsthand while conducting research in his native Kenya. "But if a farmer can't get the beans to market because there is no road, the information doesn't really help. Cell phones can't replace things you need from development, like roads and running water."

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Discussion items

- 3rd world benefit even with focus on "yuppie toys"?
  - Will they address the pressing problems?
  - Appropriate cost point?
- Will augmented intelligence increase economic activity in the 3rd world?
- Should we expect similar deflation in the cost of intelligence as in the cost of gates?
- Are there hidden dangers that need to be addressed?

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