VoiceCon SPRING 2007
The Forum for Business IP Telephony

Survey of Wireless Technologies

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Program Outline

- Overview of the Wireless Market
- Cellular Network Services
- Wi-Fi and Muni Wi-Fi
- WiMAX Network Technology and Services
- Developing Areas in Wireless
  - New Spectrum Options
  - Fixed Mobile Convergence
  - Smart Antenna Systems

My background…

- Independent consultant, writer, and industry analyst
- Over 30-years experience in telecommunications
- Management and engineering positions at ITT, AT&T, and MDS
- Presented over 2000 training programs in the US, Europe, Asia, Africa, and Latin America
- Published over 200 columns and articles in *Business Communications Review*, *Computerworld*, *ACUTA Journal*…
- Spoken at numerous industry conferences including InterOp, VoiceCon, Mobile Business Expo, ComNet, Wall Street Tech Assn.
- Currently writing a book to be titled *The Complete Guide to Voice over Wireless LANs*
- MBA in Marketing and MIS from Northwestern University and a member of IEEE

Wireless Overview

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General Advantages of a Wireless Network

- Mobility: Communications on the go
- Channel sharing: You are the only one who can use your home telephone line- wireless channels are shared over a whole area
- Speed of Deployment: Lesser-developed countries many never have a wired residential telephone service.
- Cost Savings in Low-Density Areas: WiMAX is now augmenting ADSL and cable modem services in hard-to-reach areas.

…however, radio transmission is still a difficult science to master

People Love Wireless!

- You don’t have to sell people on the convenience of wireless
- While they would prefer perfection, people realize radios don’t work 100% of the time
- Ever since we saw this guy, we knew how we wanted to communicate

Categories of Wireless Networks

- Transmission Range
  - Personal Area (10 m): Bluetooth, Zigbee, UltraWideband (UWB)
  - Local Area (100 m): Wi-Fi (IEEE 802.11)
  - Metro Area (10 Km): Cellular, Wi-MAX, Point-to-Point Microwave
  - Wide Area (>10 Km): Broadcast Radio/TV, Satellite

- Mobility:

Fixed Location:

Fixed points

- Point-to-Point Microwave
- Satellite (Typically)

Nomadic:

Stationary anywhere within the coverage area

- Bluetooth
- Wi-Fi
- Fixed WiMAX

Mobile:

Mobile with handoffs as the user moves through the area

- Cellular
- Mobile WiMAX
- Wi-Fi (Eventually)

Major Frequency Bands and Applications

Application	Frequency Range	Bandwidth
AM Radio Broadcast	535 K – 1705 KHz	1.17 MHz
FM Radio Broadcast	88 M – 108 MHz	20 MHz
VHF TV Broadcast (Channels 2 to 13)	54 MHz – 216 MHz (Non-contiguous)	72 MHz
UHF TV Broadcast (Channels 14 to 69)	470 MHz- 806 MHz	336 MHz
Cell Phones **- AMPS Band** **- PCS Band**	 824 MHz- 890 MHz 1.850 GHz – 1.990 GHz	 48 MHz 120 MHz
Satellite Radio	2.31 G – 2.36 GHz	5 MHz
Unlicensed Bands **- 900 MHz ISM** **- 2.4 GHz ISM** **- 5 GHz U-NII**	 900 MHz – 928 MHz 2.40 GHz – 2.4835 GHz 5.150 GHz – 5.850 GHz (Non-contiguous)	 28 MHz 83.5 MHz 555 MHz*
* Not all countries have allocated the full 555 MHz in the 5 GHz band		

Wireless Challenges

- Limited Radio Spectrum
  - Licensed
  - Unlicensed/License Exempt
- Interference and Reliability
  - Countless variables in signal propagation
    - Path loss
    - Multipath
    - Obstructions/Indoor coverage
  - Worse in unlicensed bands
- Bandwidth Efficiency
  - Radio spectrum allocation is fixed
  - Continuing developments in technologies to carry more information in the available bandwidth (i.e. bits/second/Hz)
- Operational Expertise
  - Building and supporting wide area radio networks is still challenging
  - Cellular carriers have amassed decades of experience and employ an army of expert engineers and field technicians
  - That difficulty will mean that “serious” competition may still take years to develop

Cellular Networks

Cellular Data Services

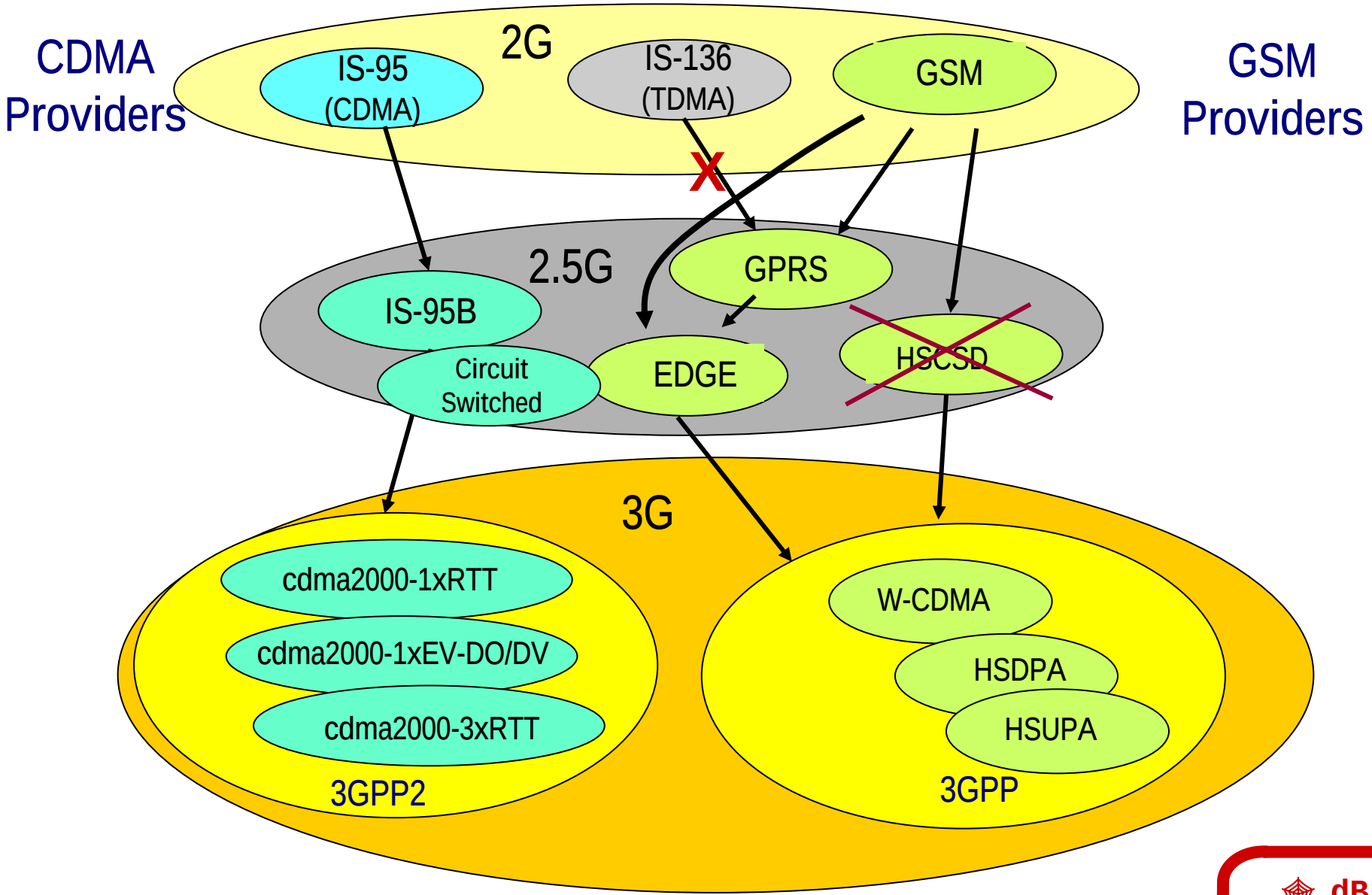
- Cellular voice market is maturing, and as a result data services are growing in importance
- Data rates are increasing, but still fall short of wired (e.g. ADSL or cable modem) services
- Engineers are making enormous strides in improving:
  - Data rate
  - Range
  - Reliability
- Different development tracks and different standards are being followed by GSM and CDMA carriers

Digital Cellular Standards

Four different digital cellular standards are used in the US and Canada

Technology	Frequency Band	Carriers
TDMA	824-894 MHz 1850-1990MHz	AT&T/Cingular (Phasing out)
GSM	824-894 MHz 1850-1990MHz	ATT/Cingular, T-Mobile
CDMA	824-894 MHz 1850-1990MHz	Verizon, Sprint/Nextel, US Cellular (Sprint 1.8-1.9 MHz Only)
iDEN	806- 866 MHz (For Now)	Sprint/Nextel

Migration Paths to 3G



3G Options- W-CDMA and cdma2000

GSM Evolution

- 2.5G: GPRS/EDGE
  - Uses time slots (2 or 4) in a 200 KHz GSM carrier
  - Better bandwidth efficiency and adaptive modulation account for higher EDGE rates
- 3G: Wideband CDMA/HSDPA
  - Uses 5 MHz channel pair
  - DSSS radio technology like CDMA
  - If 3G service not available, device reverts to EDGE

CDMA Evolution

- CDMA 2000
  - 1x Services use one 1.25 MHz carrier
  - 3x Services use 3-, 6-, 9-, or 12- 1.25 MHz carriers
  - No 3x services available
- Data Rates
  - 1xRTT: 50- 70-Kbps
  - 1xEV-DO: 300- 500-Kbps
  - 1xEV-DO Rev A: 300- 500-Kbps
  - If EV-DO service not available, device reverts to 1xRTT

- Major differentiator with highest speed services is availability
- Pricing as high as $60- $80/user/mo for “unlimited” use

Cellular Data Capacity

- Actual user capacity impacted by several variables
  - Network Loading:
    - One data channel is provided in each cell or sector
    - All active users share that channel
  - Adaptive Modulation:
    - Distance from the base station impacts raw data rate
    - With HSDPA, preference is given to users with a stronger signal
  - EDGE Time Slots:
    - HSDPA runs on a separate 5 MHz channel pair
    - EDGE users can be allocated a different number of GSM time slots in each cell
- User Impact
  - Ideal for low-volume applications like text messaging and email
  - Heavy laptop use possible but there are limits to “unlimited use”
  - Very high-volume applications like mobile video will likely migrate to other alternatives like DVB-H or MediaFLO

Summary of 2.5G/3G Data Services

	GSM-Based Networks				CDMA-Based Networks		
	GPRS	EDGE	WCDMA	HSDPA	1xRTT	1xEV-DO	1xEV-DO Rev A
Radio Access	TDMA	TDMA	CDMA	CDMA	CDMA	CDMA	CDMA
Theoretical Rate	170 K	473.6/384 K	2.4M/307K	14 Mbps	144 K	2.4M/153K	3.1M/1.8Ms
Actual Rate	20-40K	100-120 K	200- 250K	5-700 Kbps	50-70K	300- 500K	500- 700K

2.5G/3G Wireless Data Applications

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Enterprise Applications

- Wireless Email/Instant Messaging
- Web Surfing
- Remote LAN Access
- Government/Public Safety
- Specialized: Federal Express, UPS
- Location-based Services (In Trial)

2.5G/3G Wireless Data Applications

Consumer Applications

- Text Messaging
- Downloadable Ringers
- Music Downloads
- Digital Pictures
- Mobile Video
- Location-based (In trials)

Cellular Conclusion

- Since the inception of digital networks in the early 1990s, cellular technology has revolutionized voice communications
  - Analog networks were too expensive for widespread acceptance
  - Digital allowed for more channels and lower prices
  - Countries without a wired residential voice telephone network may never have one!
- Wireless data is universally recognized as the next major growth potential
  - Text messaging and email have been the biggest success stories
  - The goal is to expand beyond that base
- Cellular carriers have had an exclusive franchise in wide area wireless, but competition is imminent in both voice and data
  - Wi-Fi Hot Spots and Municipal Wi-Fi
  - WiMAX/Mobile WiMAX

"Wireless Carrier Services Update" Thursday, 11:45AM
"Merging Mobility and Unified Communications" Thurs 8:00AM

Wi-Fi and Municipal Wi-Fi

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Wi-Fi Definition

- Wireless LAN technology described in the IEEE 802.11 standards:
  - Maximum range: Around 100 m
  - Operates in unlicensed radio spectrum; no protection from interference from other users.
  - Maximum raw bit rate 11 M or 54 Mbps but declines with:
    - Distance
    - Obstructions in the radio path
    - Interference from other users
  - Shared Media:
    - All users vie for access to a shared channel
    - Protocol and channel contention reduce maximum throughput to 50% of raw data rate
  - QoS:
    - Initially no ability to prioritize voice traffic, but that is now available with 802.11e/Wi-Fi Multimedia (WMM)
  - Security:
    - Had been a major issue but has now been addressed with new options like WPA and WPA2 (802.11i)
  - Battery Life:
    - Unlike cellular, not designed for power optimization

Wi-Fi Developments

- WLAN Switching
  - Enterprise scale Wi-Fi networks using a central controller to assist in network layout, manage RF resources, and support roaming
- Improved Security
  - Security is still the most frequently cited reason for not deploying WLANs
  - New options have essentially addressed that:
    - Authentication: 802.1x Extensible Authentication Protocol
    - Privacy: WPA, WPA2/802.11i
- Quality of Service (QoS)
  - Critical for real time voice/video applications
  - IEEE 802.11e/Wi-Fi Multimedia provides prioritized access for voice
- Capacity
  - IEEE 802.1a standard for 5 GHz band (23 channels)
  - IEEE 802.11n standard (2.4 G and 5 GHZ Band) data rates to 600 Mbps
  - Pre-standard version being certified by the Wi-Fi Alliance

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"WLAN Security"- Thursday 8:00 AM

802.11 Radio Link Interfaces

IEEE 802.11 Radio Link Interfaces						
Standard	**Maximum Bit Rate**	**Fallback Rates**	**Channel Bandwidth**	**Non-Interfering Channels**	**Transmission Band**	**Licensed**
802.11	2 Mbps	1 Mbps	22 MHz	3	2.4 GHz	No
802.11b	11 Mbps	5.5 Mbps 2 Mbps 1 Mbps	22 MHz	3	2.4 GHz	No
802.11g	54 Mbps	Same as 802.11a plus 1 M 2 Mbps	20 MHz	3	2.4 GHz	No
802.11a	54 Mbps	48 M, 36 M, 24 M, 18 M, 12 M, 9 M, 6 Mbps	20 MHz	23	5 GHz	No
802.11n	289 Mbps (20 MHz) 600 Mbps (40 MHz)	Down to 6.5 Mbps (20 MHz)	20 MHz or 40 MHz	2 in 2.4 GHz 11 in 5 GHz	2.4 GHz or 5 GHz	No

Proposed 802.11n Data Rates

802.11n Data Rates in 20 MHz Channel									
		Data Rate (Mbps)							
Modulation	FEC	1 Stream		2 Streams		3 Streams		4 Streams	
		Guard Interval		Guard Interval		Guard Interval		Guard Interval	
		800ns	400ns	800ns	400ns	800ns	400ns	800ns	400ns
BPSK	1/2	6.5	7.2	13.0	14.44	19.5	21.7	26.0	28.9
QPSK	1/2	13.0	14.4	26.0	28.89	39.0	43.3	52.0	57.8
QPSK	3/4	19.5	21.7	39.0	43.33	58.5	65.0	78.0	86.7
16-QAM	1/2	26.0	28.9	52.0	57.78	78.0	86.7	104.0	115.6
16-QAM	3/4	39.0	43.3	78.0	86.67	117.0	130.0	156.0	173.3
64-QAM	2/3	52.0	57.8	104.0	115.56	156.0	173.3	208.0	231.1
64-QAM	3/4	58.5	65.0	117.0	130.00	175.5	195.0	234.0	260.0
64-QAM	5/6	65.0	72.2	130.0	144.44	195.0	216.7	260.0	288.9

802.11n Data Rates in 40 MHz Channel									
		Data Rate (Mbps)							
Modulation	FEC	1 Stream		2 Streams		3 Streams		4 Streams	
		Guard Interval		Guard Interval		Guard Interval		Guard Interval	
		800ns	400ns	800ns	400ns	800ns	400ns	800ns	400ns
BPSK	1/2	13.5	15.0	27.0	30.0	40.5	45.0	54.0	60.0
QPSK	1/2	27.0	30.0	54.0	60.0	81.0	90.0	108.0	120.0
QPSK	3/4	40.5	45.0	81.0	90.0	121.5	135.0	162.0	180.0
16-QAM	1/2	54.0	60.0	108.0	120.0	162.0	180.0	216.0	240.0
16-QAM	3/4	81.0	90.0	162.0	180.0	243.0	270.0	324.0	360.0
64-QAM	2/3	108.0	120.0	216.0	240.0	324.0	360.0	432.0	480.0
64-QAM	3/4	121.5	135.0	243.0	270.0	364.5	405.0	486.0	540.0
64-QAM	5/6	135.0	150.0	270.0	300.0	405.0	450.0	540.0	600.0

VoWLAN Challenges

- Network Capacity
- Quality of Service
- Call Access Control
- Load Balancing
- Handset Selection/Features
- Battery Life
- Security
- Management Systems

- Design Issues in VoWLAN- Tuesday 2:30 PM
- VoWLAN Market/Deployment Update- Wednesday 8:00 AM

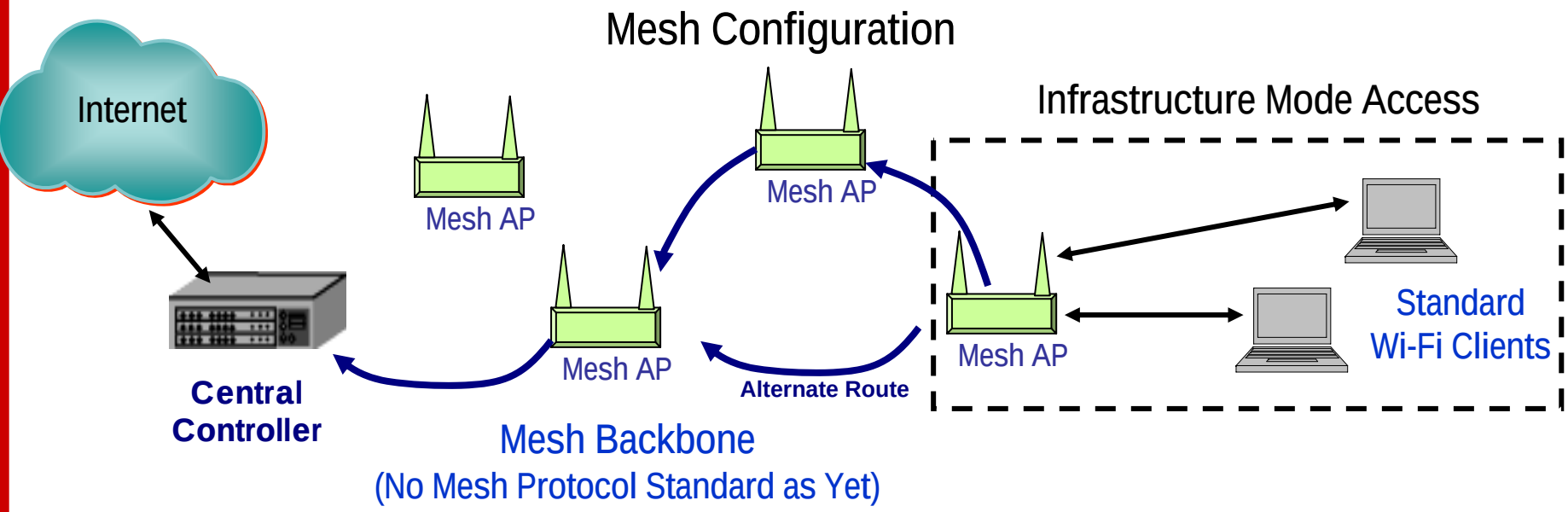
Beyond the LAN: Wi-Fi Mesh/Muni Wi-Fi

- A radical idea to expand broadband availability, eliminate the digital divide, and cure male pattern baldness?

Or

- An ill-conceived plan to take a LAN technology and try to use it to cover a whole metro area proposed by people without enough business sense to run a lemonade stand?

Wi-Fi Mesh Network



- Network constructed with Mesh-capable AP/Routers
  - Standard client device associates with the nearest Mesh-capable AP
  - Client transmissions are relayed router-to-router to a central controller that supports the Internet connection
- Coverage requires 7 to 30 access points per mile
- Client access is standard Wi-Fi, mesh relay is vendor proprietary (IEEE 802.11s Standard in development)

Mesh Technology Concerns

- Network capacity and transit delay impact
- Congestion increases as packets move closer to the network controller
- Indoor Operation
- Interference with existing home and office-based Wi-Fi Networks
- Generally lack hand-off capability (nomadic not "mobile")
- Security:
  - No standard implementation- check with the carrier
  - Authentication: Not an issue in free services; paid services use log-on routine like paid Hot Spot services
  - Privacy: May be included but encrypted VPN or SSL recommended for enterprise users
- Maintaining a network with thousands of distributed access points
- Ongoing viability of the Muni Wi-Fi business model is a real concern (Private Mesh Networks are a different case)

Municipal Wi-Fi Business Models

- Original Idea: Have local governments build Wi-Fi Mesh networks and provide free broadband access
  - Justification: Spur business development and eliminate the "digital divide"
  - Carriers went ballistic and lobbied for laws to prohibit it!
- Evolved Idea ("Philadelphia Plan"): Have the city license someone else to build the network and offer low-cost broadband access
  - Government would provide access to facilities (lampposts)
  - Government would also be the first customer (with discounted prices)
  - Government could also mandate free service in some areas
- Advertising Idea (“Google Plan"): Have the city license a carrier to build a the network
  - Offer low-cost broadband access
  - Provide lower speed “free” service with advertising
- Commercial Wi-Fi Mesh: Allow carriers or entrepreneurs to do this if they see a potential business
  - Very few takers thus far (Toronto Hydro)

WiMAX Broadband Wireless Access

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WiMAX versus Wi-Fi Market Overview

- General Capabilities
  - WiMAX: A carrier-oriented wireless technology designed to support stationary or mobile voice and data services, using licensed or unlicensed spectrum, with the capability to support hundreds of simultaneous users
    - Data Rate: Up to 70 Mbps (20 MHz channel)
    - Range:Up to 70 Km though actual cells will be much smaller
    - Operates in licensed or unlicensed spectrum
    - Request/Grant Access with QoS capabilities
    - Integrated Security
  - Wi-Fi: A wireless local data network technology that operates on a shared channel using unlicensed spectrum, and designed to provide mobility in private networks
    - Data Rate: ≤11 M or ≤54 Mbps
    - Range: Around 100m (farther outdoors)
    - Operates in unlicensed frequency bands (2.4 G and 5 GHz)
    - Contention-based data service
    - Security Features Available

The Two WiMAXes

- Fixed/Nomadic: IEEE 802.16- 2004
  - The metro-area wireless service originally described in the 802.16 standards
  - Potential Markets:
    - Wireless DSL- Fixed location initially
    - Local Telephone Service in Developing Areas
  - Status: WiMAX-Certified products becoming available, though most current services use pre-WiMAX gear
- Mobile WiMAX: IEEE 802.16-2005
  - Standard for mobile WiMAX, formerly called IEEE 802.16e, supporting high-speed hand-offs that could potentially compete with cellular voice and data services
  - Status:
    - No products available or expected until mid-2007
    - Technical attributes of the service (data rate, reliability, latency, etc.) essentially unknown
    - Nationwide deployments promised by Sprint/Nextel and Clearwire Communications

WiMAX Applications and Timetables

Now

Phase 1: Pre-WiMAX Fixed-location Broadband Wireless Access
- Numerous suppliers including Clearwire Communications
- Data Rates from 512 K to 1.5 Mbps

2007

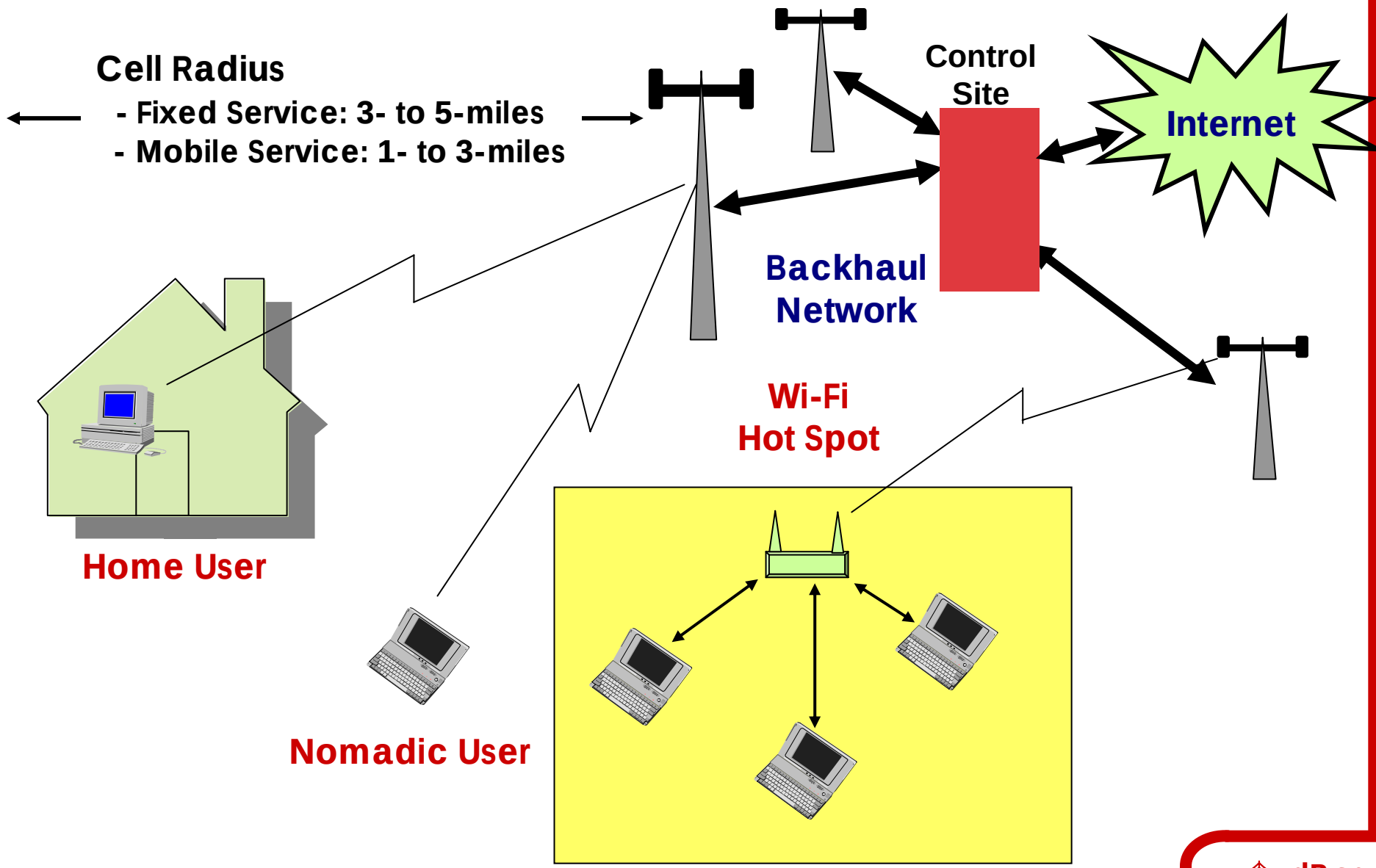
Phase 2: WiMAX-based, fixed-location Broadband Wireless Access
- Migration to standards-based solution
- WiMAX modems integrated in laptops and other devices
- No major US carriers have announced plans for fixed services

Phase 2.5: Nomadic Service
- Access to the network from a stationary position anywhere within the coverage area
- Can be supported with either fixed or Mobile WiMAX technology
- Could be introduced concurrently with fixed service

2008-9

Phase 3: Mobile WiMAX
- True mobile service with handoffs between cells
- Can support stationary and nomadic users as well
- Data Rates around 512 K to 1 Mbps
- No prices disclosed

Typical WiMAX Cell



Key WiMAX Radio Link Features

- Licensed (2.5 GHz BRS) or unlicensed (5GHz) implementations
- Adaptive Modulation
  - Adjusts Transmit Power, Signal Modulation, and Forward Error Correction (FEC) coding strength based on signal quality
- Channel Bandwidth
  - Adjustable from 1.25 M to 20 MHz
- Duplex Operation
  - FDD, TDD, and Mesh Implementations
- Bandwidth Efficiency
  - Up to 3.5 or 5 bits/second/hertz; 2.5 bits/second/Hertz initially
  - Bandwidth efficiency drops with range
  - Delivers up to 50 Mbps on a 20 MHz channel at 3 miles
  - Not sufficient capacity to support broadcast video
- Advanced Antenna Technologies
  - Designed to incorporate Space-Time Coding and MIMO systems

WiMAX Quality of Service (QoS)

- Carrier Scale
  - Protocol designed to support hundreds of simultaneous user connections
- Integrated Encryption
  - Can use public or private keys
  - Specific encryption algorithm not defined; can use 3DES or AES
- Request/Grant Access Protocol with QoS Capability
  - Unsolicited Grant-Real Time: Consistent delay (i.e. isochronous) TDM-like service for real-time voice and video (private line emulation)
  - Real Time Polling Service (rtPS): Another consistent delay service that operates like the 802.11e Hybrid Controlled Channel Access (HCCA).
  - Non-Real Time Polling Service (nrtPS): Variable-delay data service with capacity guarantees akin to frame relay's Committed Information Rate.
  - Best Effort: An IP-like best effort data service for residential Internet users.
- Shared channel configuration, so user capacity difficult to predict:
  - Capacity variables include:
    - The carrier's network configuration
    - User's signal strength (adaptive modulation, indoor/outdoor)
    - The number of active users in the cell or sector

Potential WiMAX Providers

1. Incumbent LECs:
   - Intend to use WiMAX to increase their broadband coverage in areas where it is not economical to deploy ADSL
   - May support other business services as well
   - Plans unknown- no announcements have been made
2. Cellular Carriers
   - Sprint/Nextel: Made a major announcement in August 2006 to invest $3 billion to deploy WiMAX by YE 2008 using their significant holdings in the licensed 2.5 GHz band
   - The FCC had told them: "Use 'em or lose 'em"
   - Other cellular carriers are pursuing strategies based on 3G cellular technologies (WCDMA, 1xEV-DO)
3. Independent BWA Carriers
   - Clearwire: 47% owned by Craig McCaw with significant 2.5 GHz holdings
   - TowerStream: Enterprise oriented start-up using a mix of wireless access technologies
   - Mobilepro Corp. (Bethesda, MD): Claims 20,000 subscribers
   - "Other": Lots of no-name regional operators
   - Could potentially partner with CATV MSOs, Hot Spot operators or others

WiMAX Conclusion

- WiMAX looks great on paper and has major support from Intel, Motorola, Samsung, and others
- The standards are carrier-scale and cover virtually every conceivable option:
  - Fixed and Mobile
  - Voice or Data
  - Licensed or Unlicensed Spectrum- 2 G to 66 GHz
  - Can incorporate next-gen MIMO technology
- However, the technology is essentially untested and its competitive posture to other wireless technologies is unknown:
  - Cost/performance
  - User device availability- laptop cards, handsets, etc.
  - Ability to share cellular infrastructure (e.g. indoor antenna systems)
  - Scalability and expansion
  - Indoor operation
  - Battery life
  - Support requirements

Developing Areas in Wireless

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Three Areas to Watch

- New Spectrum Options
- Fixed Mobile Convergence
- MIMO and Smart Antenna Systems

Radio Spectrum

- Radio spectrum is the essential “raw material” for any wireless service
- Major dividing line:
  - Licensed: Provides exclusive use of a band of frequencies in a given area and typically involves a significant investment
    - Licenses covering more populous areas are generally more expensive (“cost/MHz Pop” = $ for 1 MHz covering 1MM population)
    - Used for: Broadcast Radio/TV, Cellular, most WiMAX services
  - Unlicensed/License Exempt: Radio “free for all”
    - Spectrum allocated for general use (within defined regulations), but no protection from interference
    - Used for: Wi-Fi, Bluetooth, Baby Monitors, Garage Door Openers, Cordless Phones, Microwave Ovens, and dozens of other things
- Not all frequencies offer equal utility
  - Higher frequencies lose more power over distance and more adversely impacted by weather
  - Non line-of-sight operation generally requires frequencies below 6 GHz

Major Developments in Spectrum Availability

- Unlicensed: Expanding the 5 GHz Band
  - Varies widely around the world, but the goal is to standardize on 555 MHz
  - November 2003, FCC added 255 MHz (5.47 G - 5.725 GHz) so 555 MHz available
- Unlicensed “TV-Whitespace” Initiative
  - Proposal being circulated in the US Congress to allow unlicensed operation on unused TV broadcast channels
  - No approval and no regulations as yet
- Advanced Wireless Service: 1.7 GHz and 2.1 GHz Bands
  - Additional cellular bands for 3G and possibly other applications
  - Total 90 MHz (1.71 G - 1.755 GHz, and 2.11 G - 2.155 GHz)
  - US auctions in mid-2006 raised $13.6 Billion- T-Mobile was the biggest buyer
- Digital TV Migration: 700 MHz Band (698 M - 806 MHz)
  - Plan to end all over-the-air analog broadcast TV and mandate digital transmission
  - Will free up 108 MHz of prime spectrum (UHF Channels 52 to 69)
    - 24 MHz allocated to Public Safety
    - 84 MHz to be auctioned (some have already been auctioned)
  - US mandated conversion for early-2009 After *March Madness*)

US 700 MHz Allocation Plan

Lower 700 MHz Band (48 MHz)						
Name	**Licenses**	**TV Channel**	**Band (MHz)**	**TV Channel**	**Band (MHz)**	**Total Bandwidth**
A	6	52	698-704	57	728-734	12
B	6	53	704-710	58	734-740	12
C	734	54	710-716	59	740-746	12
D	6	55	716-722	One-way channels		6
E	6	56	722-728			6

Upper 700 MHz Band (36 MHz)						
Name	**Licenses**	**TV Channel**	**Band (MHz)**	**TV Channel**	**Band (MHz)**	**Total B/W**
A	52	60*	746-747	65*	728-734	2
C	6	60*	747-752	65*	734-740	10
D	6	61/62*	752-762	66/67*	740-746	20
B	52	62*	762-764	67*	792-794	4
* Split Channels						

Channels 63 & 64 and 68 & 69 (24 MHz Total) Allocated for Public Safety

Fixed Mobile Convergence

Fixed Mobile Convergence (FMC)

- A network service that would allow calls to be handed off between public cellular and private wired or wireless networks

- Step 1: VoWi-Fi and VoWiMAX
  - VoWi-Fi is a small specialized market today (<1% of existing WLAN stations)
  - VoWiMAX does not exist, though handset manufacturers like Nokia have announced plans for WiMAX handsets

- Step 2: Dual Mode Handsets
  - Once VoWi-Fi/WiMAX is established, the next step is to build cellular capability into the same handset
  - At this stage there is no integration between the network services
  - The user (or the handset) selects the network on which to place the call, and the call is disconnected if they move out of range of that network

- Step 3: Fixed Mobile Convergence
  - Dual mode handset with the capability to transparently hand off calls
  - Several public and private options exist, and services are beginning to appear in Japan, the UK, and the US

Voice over Wi-Fi (a.k.a. “VoWLAN” or “VoFi”)

- Two major implementations today:
  - Consumer
  - Enterprise
- Consumer- Wi-Fi Cordless Phones
  - VoIP Service providers Vonage and Skype offer low-cost ($129) Wi-Fi compatible handsets that operate over the customer’s home WLAN
  - Voice quality is excellent (as long as the user stays within range) and the phones will also work through any free public Hot Spot
- Enterprise- Wireless PBX Stations
  - Generally implemented in conjunction with an IP PBX, mobile stations can be used anywhere within the WLAN coverage area
  - Service availability and voice quality highly dependent on WLAN design, and calls can be handed off between access points with a centrally-controlled WLAN switching system
  - Expensive handsets ($500) available from SpectraLink, Cisco, Vocera, and others
  - Very popular in health care and materials handling (i.e. warehouse) applications

Fixed Mobile Convergence

- A highly contentious topic among cellular carriers
- Advantages:
  - WLANs can provide better indoor coverage than cellular networks
  - WLANs could eliminate the need to deploy radio repeaters, distributed antenna systems, and other indoor coverage solutions
  - Shifting calls to unlicensed WLAN channels would increase the call handling capacity of the cellular network
  - Pre-emptive strike: Do it before the customers are screaming for it
  - Competition: If one carrier does it, everyone else will all have to follow suit (Note: Watch the “weak” players)
- Concerns:
  - Customer Control: Cellular carriers have enjoyed a unique franchise in mobile voice service that commands a premium price
  - Revenue Impact: Will the cellular carrier get any revenue for WLAN calls?
  - Quality Control: Is the cellular carrier responsible for WLAN screw-ups?
  - Security Control: Will WLAN security flaws open security vulnerabilities in the cellular network?

VoiceCon SPRING 2007
The Forum for Business IP Telephony

“Fixed Mobile Convergence- What’s Real/What’s Needed”
Wednesday, 2:45 PM

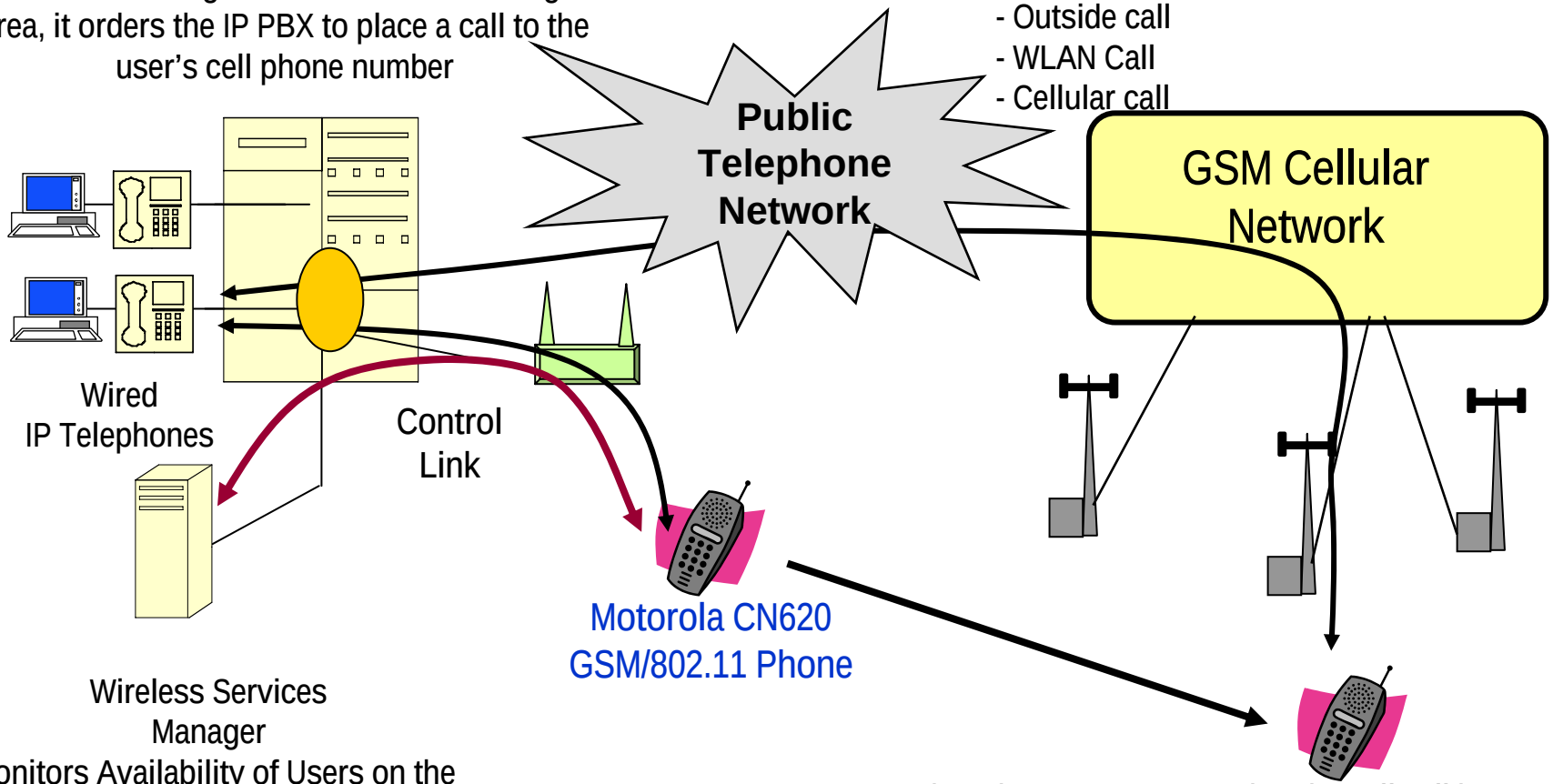
WLAN/Cellular Integration Options

- Non-Integrated Solutions
  - Dual Mode WLAN/Cellular Phones
- PBX Controlled Solutions
  - Extension to Cellular
  - Seamless Convergence/DiVitas Networks
- Carrier Controlled Solution
  - Network Add-ons
  - IP Multimedia Subsystem (IMS)

PBX Controlled “Handoff”

1. When the Wireless Services Manager sees the device is moving out of the WLAN coverage area, it orders the IP PBX to place a call to the user’s cell phone number

2. The IP PBX establishes a three-way conference call:
- Outside call
- WLAN Call
- Cellular call

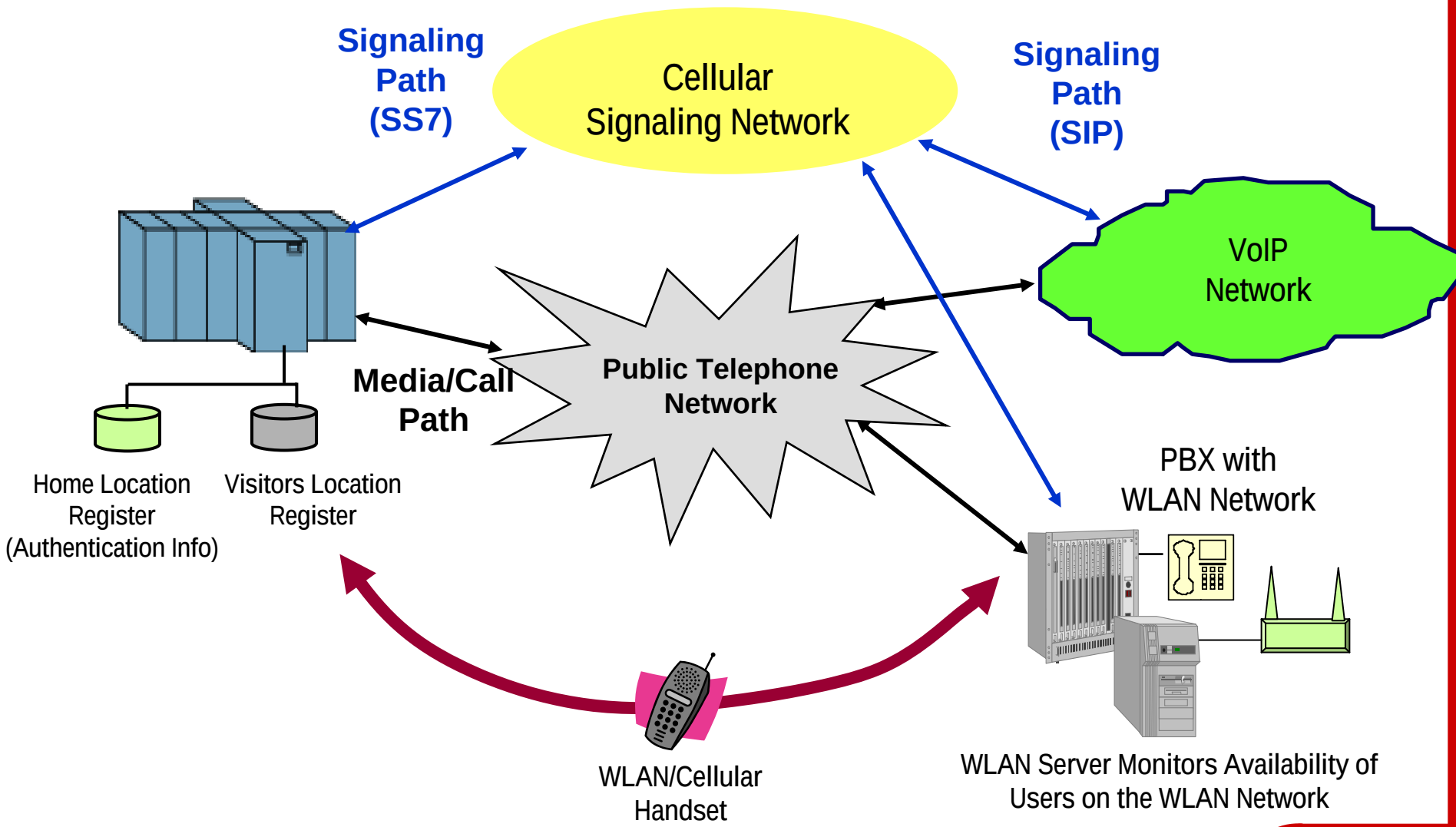


3. When the IP PBX senses that the cell call has been answered, it drops the WLAN call from the conference (“Make Before Break”)

Carrier Controlled Convergence

- True Fixed Mobile Convergence
  - The only truly integrated WLAN/cellular solution would be one where a call could be handed off in either direction!
  - The decision to deploy that solution is solely in the hands of the cellular carriers
- FMC Options:
  - Short Term: Several available products/architectures
    - Kineto Wireless: Unlicensed Mobile Access (UMA)
    - BridgePort Networks: MobileIGNITE
  - Longer Term: IP Multimedia Subsystem (IMS)
    - A ITU-endorsed plan to merge public and private networks for both media and signaling and transparently hand-off calls between the two environments
    - Standards for full functionality are still in development

Carrier Controlled Convergence



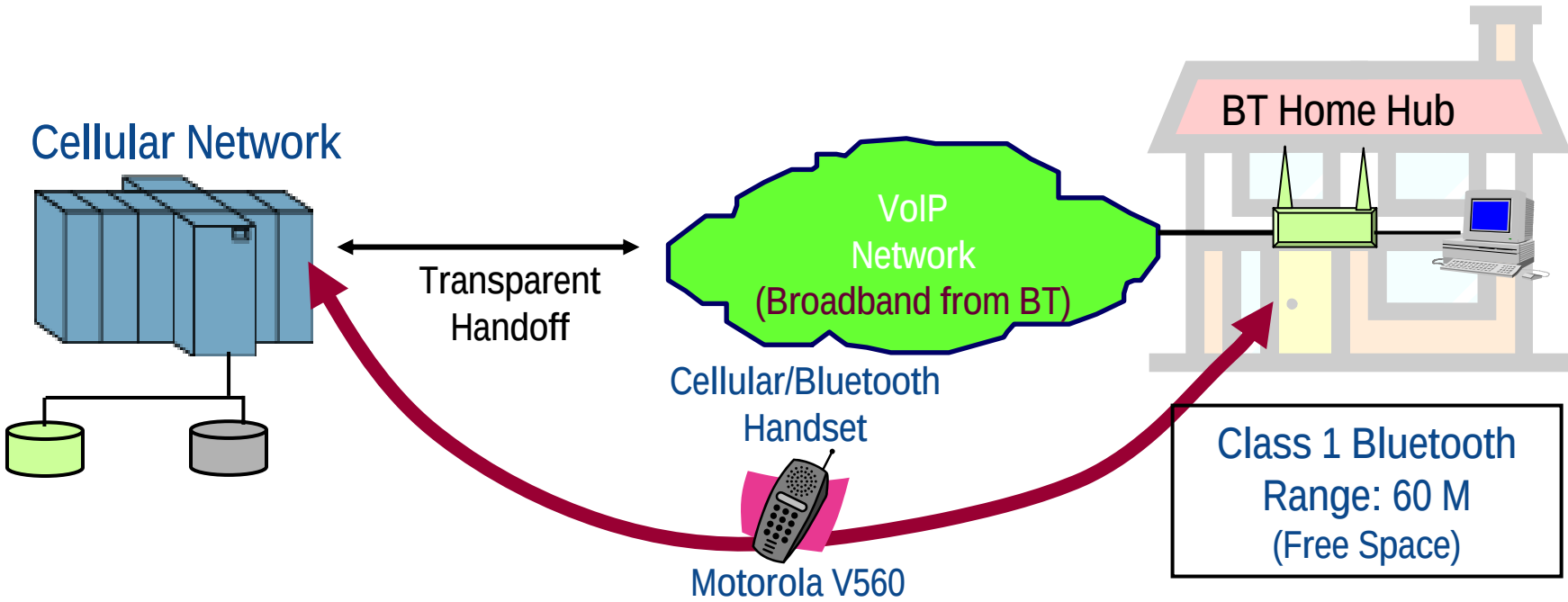
FMC Around the World

- Enterprise:
  - NTT DoCoMo Passage Duple™
    - Uses N900iL handset from NEC/Panasonic
      - Cellular Capability
      - 802.11b WLAN with SIP Signaling
  - KDDI is also testing in Japan

- Consumer:
  - BT Fusion (UK)
    - Cellular/Bluetooth Initially
    - Cellular/Wi-Fi now in testing
  - T-Mobile (US)
    - Trial commencing in Seattle, WA (*Hot Spot@ Home*)
    - Works with home Wi-Fi networks and T-Mobile Hot Spots
    - Additional $20/month with any T-Mobile calling plan

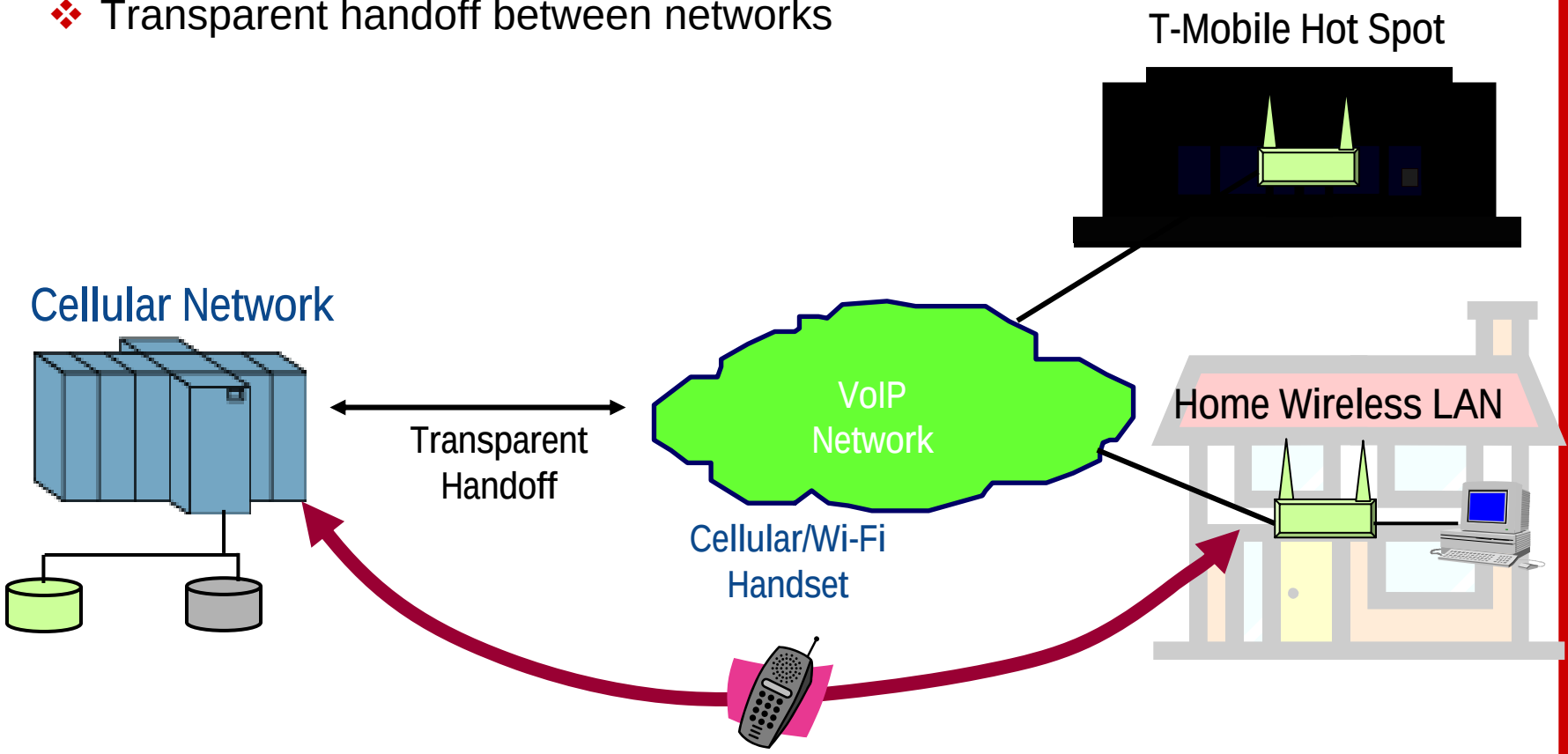
BT Fusion or *Bluephone*

- Introduced in mid-2005, the BT Fusion is the first consumer-oriented, carrier-supported fixed/mobile service
  - Uses an integrated GSM cellular/Bluetooth handset (Motorola V560) with a home base station ("BT Home Hub")
  - Inside the home, it transforms to a Class 1 Bluetooth interface that connects through BT's VoIP service
  - Transparent handoff between networks



T-Mobile Hot Spot @ Home (UMA)

- Trial planned for early-2007 in the Seattle, WA area
  - Uses an integrated GSM cellular/Wi-Fi handset (Samsung and others)
  - Works through both home Wi-Fi Networks and T-Mobile Hot Spots
  - Hot Spot @ Home plan cost $20 additional with any T-Mobile plan
  - Transparent handoff between networks



Advanced Antenna Systems

- Antenna: *Any structure or device used to collect or radiate electromagnetic waves. Antennas are passive devices in that they do not generate radio power but simply focus it in a particular direction. The resulting power increase is called antenna gain*

- More than a “Stick”
  - Antennas are engineered to enhance the performance of the radio system
  - A well-designed antenna system will result in better receive signal strength which has a positive effect on signal-to-noise ratio

- Bottom Line:Better receive signal strength impacts the “Three-R’s” of radio:
  - Rate (or Bandwidth Efficiency): The number of bits per second that can be carried in the available radio spectrum or bandwidth
  - Range: The distance over which that transmission rate can be sustained
  - Reliability: The effective bit error rate achieved

Major Categories of Antenna Systems

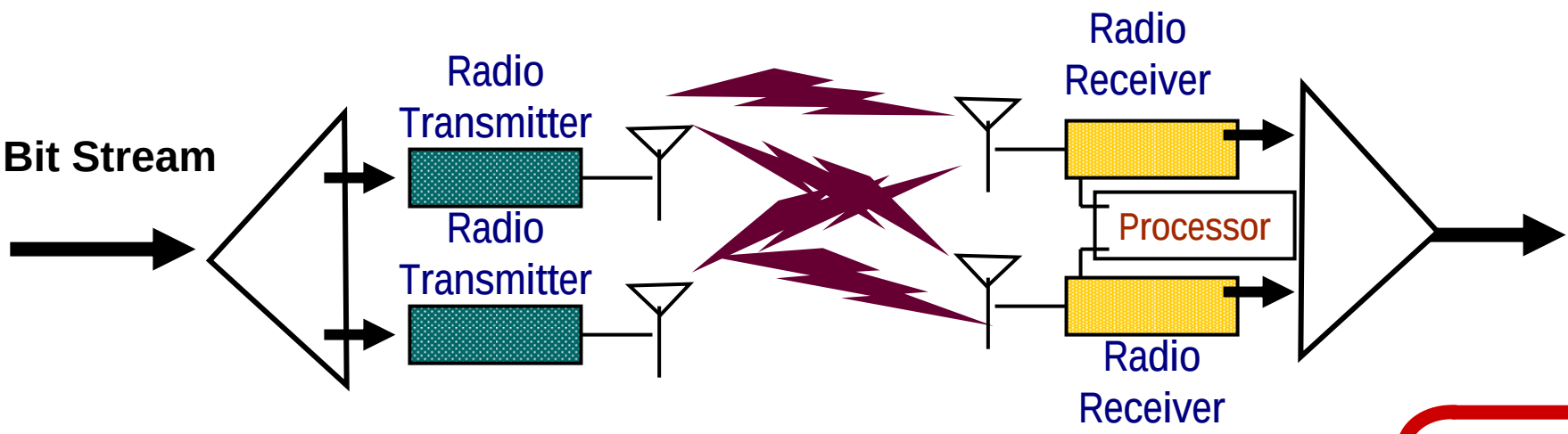
- Onmidirectional:
  - Transmits energy in all directions in the horizontal plane
  - Most typical structure for mobile devices
- Antenna Diversity:
  - The idea of providing two antennas and choosing the the one that receives the strongest signal from each user
  - Widely used in WLAN access points and cellular base station antennas
- Directional Antennas (e.g. Patch, Panel, Yagi):
  - Concentrates energy in a particular direction in the horizontal plane to increase signal strength
  - Used to provide coverage in hard to reach areas, to sectorize cell sites, and in point-to-point systems
- Steerable Antennas (e.g. Beamforming, Phased Array):
  - A directional antenna comprised of multiple electronically-controlled transit elements, that can form and steer a directional beam by altering the delay on each element.
  - Now being used in some WiMAX base station equipment
- Multiple Input-Multiple Output (MIMO):
  - An antenna system that transmits multiple independent signal images (i.e. transmit chains) in the same frequency band through antenna elements spaced some distance apart. Multiple receiver elements can distinguish the different transmit signals by the unique multipath signature each displays as a result of their different locations (i.e. spatial diversity). The receiver elements then combine all of the received signal power from each transmit chain, regardless of which antenna it is received on to increase the effective receive signal strength.
  - First used in 802.11n Wi-Fi radio link but also appearing in WiMAX products

Multiple Input-Multiple Output (MIMO)

MIMO Concept

- Divide bit stream into multiple "transmit chains" and encode them on separate radio carriers ALL IN THE SAME FREQUENCY BAND!
- Use Multiple Transmit Antennas spaced some distance apart ("Spatial Diversity")
- Multiple Receive Antennas can identify each transmit chain by its unique multipath radio fingerprint and combine the total received power
- Receive signal processing now becoming cost effective!

MIMO System



Conclusion

- People love wireless, and that convenience factor will cause demand to increase indefinitely
- The only real concern is the potential health risk, and that might never be fully resolved
- Cellular has had an exclusive franchise, but that is about to end
  - Competition will force innovation
  - Lower prices are a certain outcome
- Building and supporting wide area radio networks is still challenging
  - The new entrants will have to recreate that expertise or raid the cellular companies' "brain trust"
  - That difficulty will mean that "serious" competition may still take years to develop