Understanding Spectrum Issues in the Deployment of Broadband Wireless Access Networks

Presented by Joanne C. Wilson

to the Meeting of the South Carolina Senate Broadband and Telecommunications Technology Study Committee

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Overview

- Introduction
- Defining “Broadband Wireless Access”
- Wireless 101
- The Economics of Deploying Broadband Wireless Access Networks
- Overview Commercial Spectrum for Broadband Wireless Access
- Summary

Mission and Objectives

- To provide the S.C. Broadband and Telecommunications Technology Study Committee with sufficient technical insight into the spectrum and technology issues that determine the economics of BWA deployment.
- This presentation will:
  - Describe key radio aspects of BWA systems
  - Present a high-level, simplified discussion of physics of radio propagation
  - Discuss the impact of spectrum and technology choice on the economics of broadband deployment
  - Provide a survey of spectrum bands available in the US that can be used by “an entity” for deployment of a BWA service.
- This presentation will not:
  - Make any policy recommendations on the State’s plans for its 2.5 GHz licenses.
  - Discuss any specific operators’ plans or activities, though publicly available industry information will be cited.

Some Definitions of Broadband

- FCC [1]:
  - 47 U.S.C. § 157 nt. [The FCC uses] the term *"broadband services"* to refer to those services that deliver an information carrying capacity in excess of **200 kbps** in at least one direction. These services are also described as "high-speed services" in Commission reports issued pursuant to section 706.
  - 47 U.S.C. § 157 nt. [The FCC has] used the term *"advanced services"* to refer to the subset of broadband or high-speed services that deliver an information carrying capacity in excess of **200 kbps** in both directions.
- Organization for Economic Cooperation and Development (OECD)[2]:
  - The OECD definition of broadband is at least **256 kbps** downstream and at least **64 kbps** upstream.

Some Definitions of Broadband (cont'd)

- International Telecommunications Union –Radiocommunications Sector (ITU-R) [3]
  - *Broadband wireless access (BWA)* is defined as wireless access in which the connection(s) capabilities are higher than the *primary rate*, which is defined as the transmission bit rate of **1.544 Mbit/s** (T1) or **2.048 Mbit/s** (E1). *Wireless access* is defined as end-user radio connection(s) to core networks.
- One industry view [4]
  - "Broadband Wireless" refers to services that offer (a) pure IP transport, (b) truly broadband end user data rates, with real-world speeds of **1 Mbps** and more even in fully-loaded networks, enabling use of the service as subscribers' *primary mode of access* to the Internet (c) ubiquitous wide-area coverage through macro-cellular deployments across large geographies (not a collection of small hotspots), (c) seamless handoff between cells and support for vehicular mobility, and (d) non-line-of-site operation.
- There is no commonly accepted definition of *broadband*, *broadband service* or *broadband wireless access*.

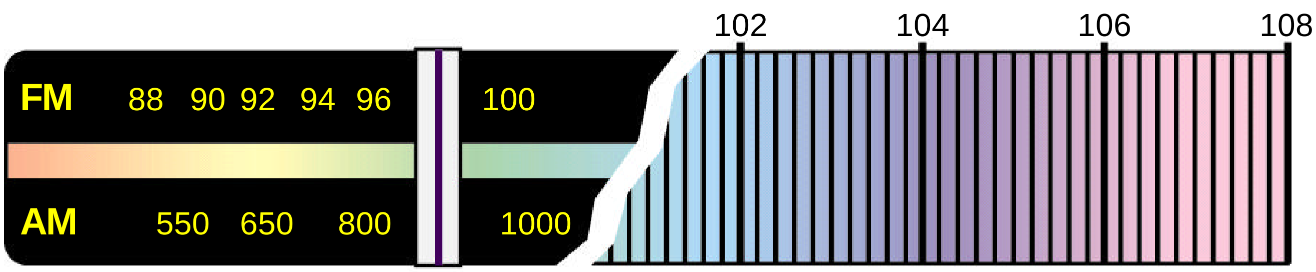
Wilson's definition of BWA

- *Broadband wireless access (BWA)* shall be defined as wireless access in which the connection(s) capabilities of a fully loaded system support applications and quality of service attributes that are comparable to or better than that provided by ADSL systems. *Wireless access* is defined as end-user radio connection(s) to core networks.
  - Establishes a relative performance benchmark that allows a BWA service to substitute for a wired broadband service.
  - Ensures support for streaming video and other applications typically expressed as requirements for public safety users.
  - Using "fully loaded system" attributes ensures that the quality of service provided does not deteriorate below acceptable levels as demand increases.
  - An application-based definition takes into account data rate, latency[5] and other technical requirements needed for achieving a broadband user experience.
  - More than fulfills the FCC and OECD requirements, though not as aggressive as that established by the ITU-R.

Wireless 101

Everything I ever needed to know about Wireless Systems …

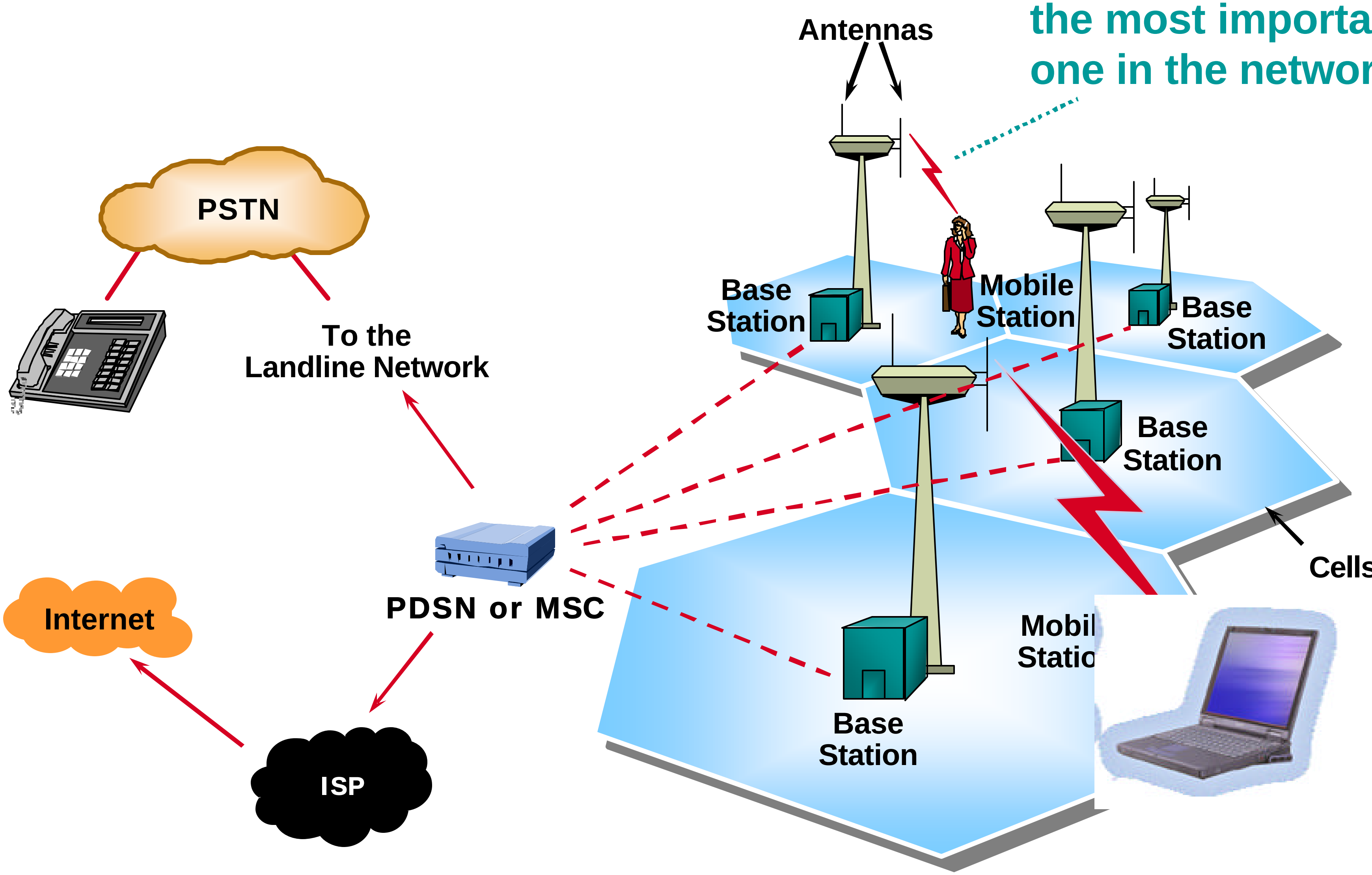
… I learned while driving to work!



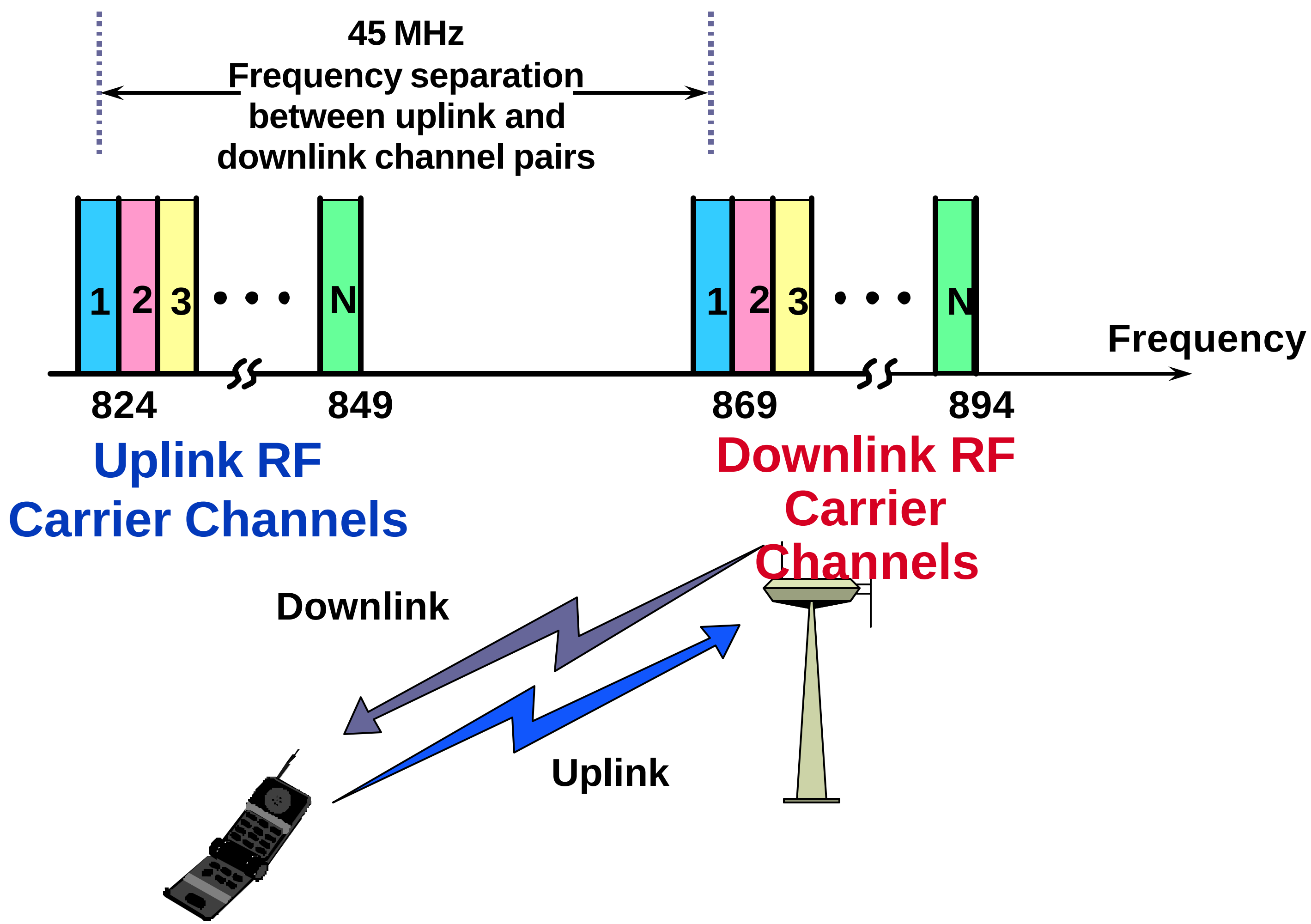
1. Spectrum Band Plans are just like my radio dial!
2. Radio waves fade with distance!
3. Radio signals can interfere with each other!
4. Poor reception stinks!
5. Different technical approaches (e.g. AM and FM) can influence the service provided!

Mobile BWA Networks

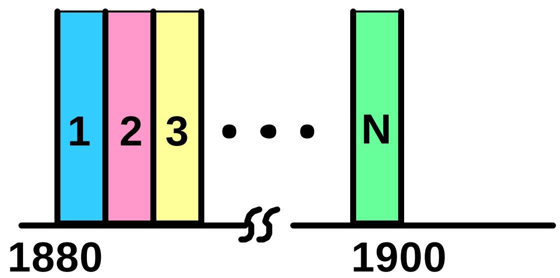
The air interface is the most important one in the network!!



Channels for Two-Way Communications Frequency Division Duplex (FDD)

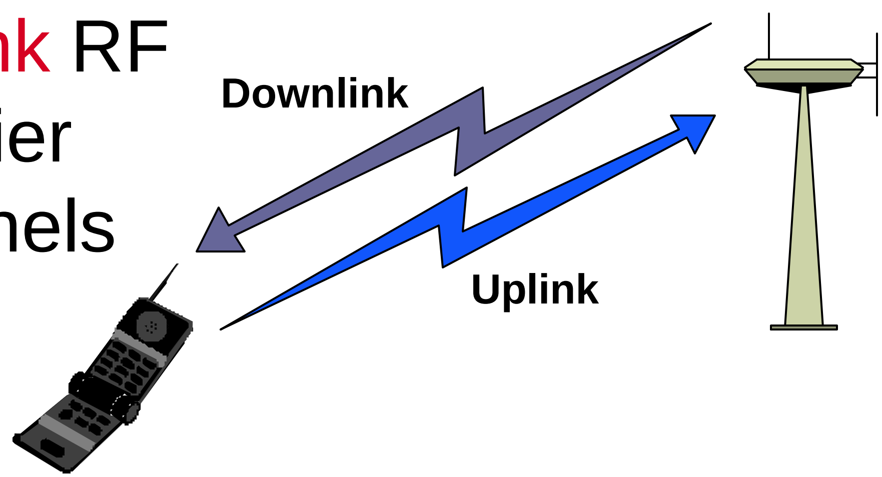


Channels for Two-Way Communications
Time Division Duplex (TDD)



Uplink and Downlink are done in the same channel, but different time slots!

Uplink and Downlink RF Carrier Channels



Bandwidth Requirements

- Bandwidth or Channel bandwidth - the spectrum required by one channel and contains the occupied bandwidth plus buffer spectrum [which may be] necessary to meet the radio performance specifications in same-technology, adjacent channels deployment. The concept is depicted in the following figure.[15, 16]

- Wireless systems are deployed using one or more channels within a block of licensed block.
- Different systems have different channel bandwidths that are capable of supporting different data rate capacity. The required data rate capacity for a deployment will have different bandwidth requirements for different technologies.
- As such, a particular technology may or may not be deployable within a given licensed block of spectrum and may or may not be able to support the data rate capacity needed. [17]

Key Message #1

- Two fundamental aspects of a radio interface of a BWA system will determine whether it can be deployed in a given block of spectrum:
  - Does the technology require paired (FDD) or unpaired (TDD) blocks of spectrum?
  - Is the bandwidth available within the block(s) of spectrum sufficient so that the technology can be deployed and can meet the service requirements?
- A spectrum band may be suitable for a BWA deployment even though only a subset of all available technology options may be deployable in that band.

Physics of Radio Propagation[6]

- Radio propagation modeling is hugely complicated stuff! The most simplified, idealized model provides a glimpse at the phenomena, while ignoring many factors that further reduce the range of a cell site.
- The line of sight (LOS) transmission loss across "free space" – an environment free of all objects that might reflect or absorb energy – is given by:

$$L_p = \left(\frac{4\pi}{c}\right)^2 f^2 d^2 \qquad (a)$$

or in decibels:

$$L_p = 36.6 + 20\log f + 20\log d \quad dB \qquad (b)$$

f = carrier frequency (MHz)
d = distance (miles)
L_p = Path loss

- Path loss between transmitting and receiving antennas increases with the square of the carrier frequency.

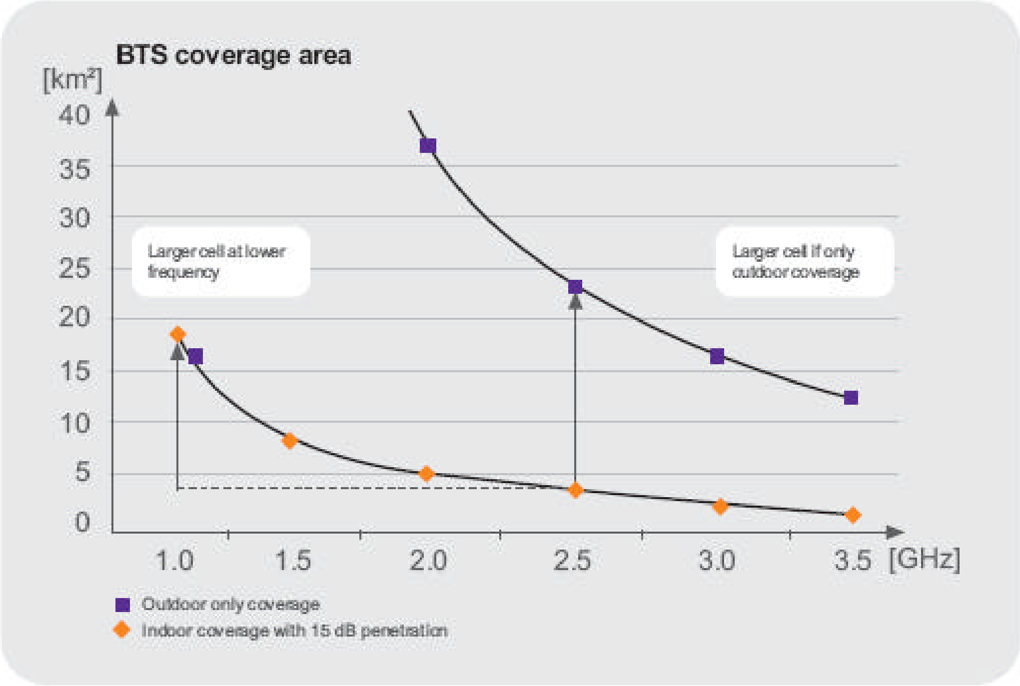
Physics of Radio Propagation (cont'd)

- Doubling the carrier frequency would reduce the power at the receiver by a factor of 4 over the same distance. In decibels, this is a 6dB increase in path loss, which results in a significant shrinkage in cell sizes.
- There are three mechanisms which may cause the path loss to differ from the free space case:
  - *refraction* in the earth's atmosphere, which alters the trajectory of radio waves, and which can change with time.
  - *diffraction* effects resulting from objects near the direct path.
  - *reflections* from objects, which may be either near or far from the direct path.
- Radio transmission and reception in cellular networks are modeled as occurring in a non-line-of-sight (NLOS) propagation environment.
  - When we have a path which is NLOS, it becomes even more difficult to predict how well signals will propagate over it.
  - Propagation models for NLOS are extremely complex. One crude, but useful, approximation of the loss on many NLOS paths in urban areas can be modeled quite well by assuming a square-law distance loss for distances up to 1 km (or 1 mile, for the non-metric version of the equation), and fourth-law loss thereafter. In other words, we substitute d^4 for d^2 in equation (a). In equation (b), we can substitute 40log(d) for the 20log(d) term, which corresponds to a more rapid reduction in signal strength.

Physics of Radio Propagation (cont'd)

- There are advantages to using higher in frequencies for LOS propagation environments, which are typical for indoor WiFi (IEEE 802.11) deployments, due to the higher antenna gains which can be achieved.
- Higher frequencies allow for tighter focusing of energy that may result in lower overall path loss on LOS paths, and less multipath.
- The main advantage of higher frequencies is that there is more bandwidth available for high-speed data, and less probability of interference. However, this advantage may be lost in non-LOS situations, since diffraction losses, and attenuation from natural objects such as trees, increase with frequency.
- Providing in-building coverage from outdoor cell site transmissions becomes more difficult at higher versus lower frequencies.
- The good news is that some of the most advanced radio systems are using spatial processing to exploit the NLOS propagation environments, dramatically increasing the range and capacity of cellular networks.

Coverage vs. Deployment Frequency for a Particular Technology



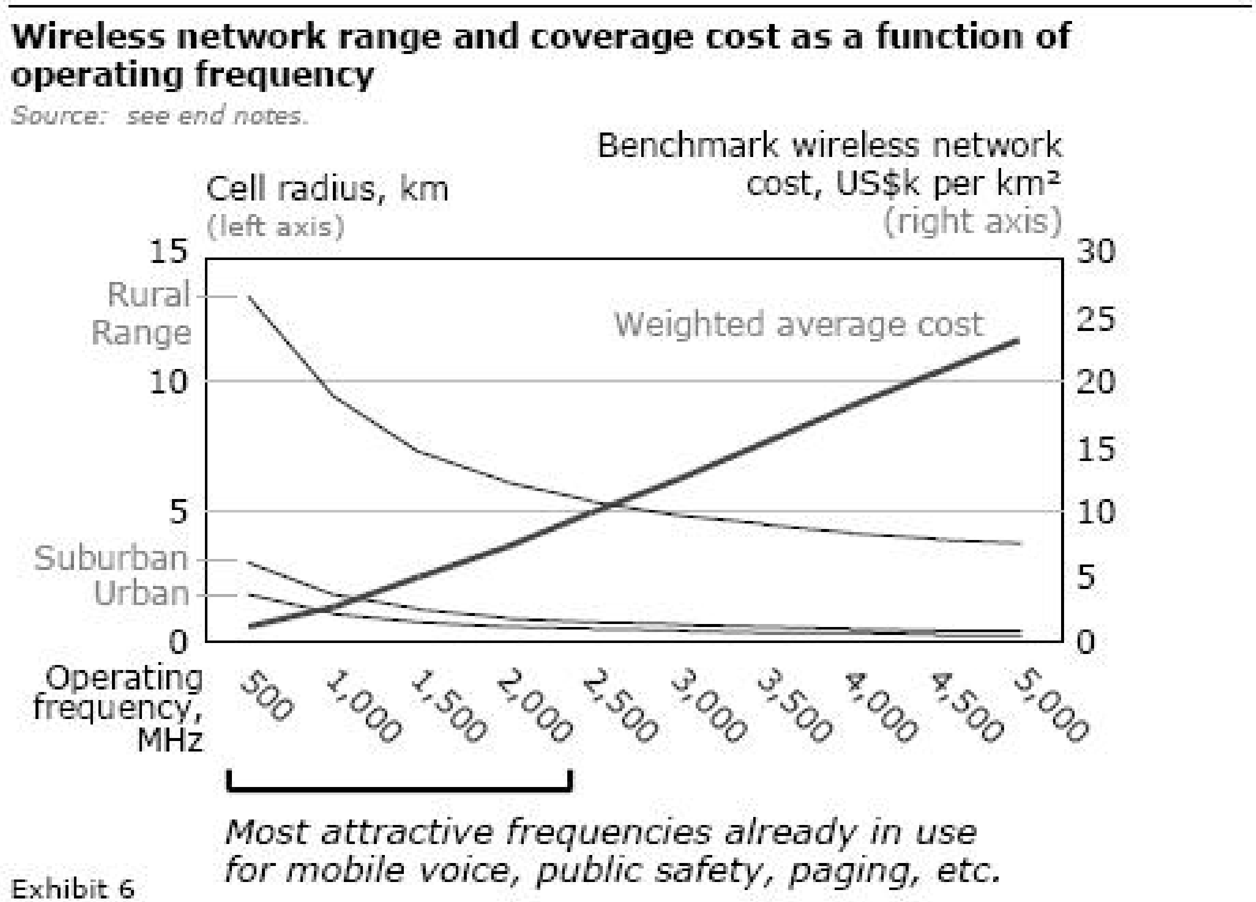
Relative impact of deployment frequency on base station coverage area. Actual coverage area depends on several factors, particularly technology choice, bit rate requirements, and environment.

Key Message #2

- Based solely on the physics of radio propagation, it is correct to assume that a given radio system can be deployed with fewer cells at a lower operating frequency.
  - Operation of **a given wireless system** in 700 MHz vs. 2.5 GHz
    - Cell radius 3.6 times larger at 700 MHz
    - Cell area 12.8 times larger at 700 MHz
    - In a coverage limited deployment, 12.8 times more cell sites at 2.5 GHz than at 700 MHz for same coverage area[9].
- However, it cannot be assumed that any radio system operating in a lower frequency band will require fewer cells or be more economical to deploy and operate than another radio system operating in a higher frequency band.
- In urban areas that are capacity-limited, there is likely to be little to no difference in the number of cells required at 700 MHz vs. 2.5 GHz
- In short, while spectrum matters, it is the combination of spectrum and technology that together makes a BWA deployment possible.

The Economics of Deploying Broadband Wireless Access Networks

Operating Frequency and Network Cost [7]



Factors affecting BWA Network Economics [8]

Variables and critical assumptions in typical broadband wireless deployment economics analysis, by category

Market	Deployment	Link Budgets, Capacity and Range	Customer Behavior by Segment	Financial and Operating Parameters
geographic size	sectors/cell	baseline hardware link budget	usage per average subscriber in busy hour by service segment and year, over time	site acquisition/installation cost
pop density	spectrum available	adjustments for technology	aggregate consumption as function of busy-hour usage	1x site cost per antenna
pops / HH ratio	spectrum re-use	service definition (data rate, cell edge coverage target)	retail ARPU by segment, over time	site op & maint cost
residential broadband penetration	configuration (intra- and inter-cell)	sector antenna incremental gain over omni	subscriber device price (paid by subscriber), over time	site wired backhaul recurring cost
total candidate SMEs in market	antennas/sector	smart antenna gains	subscriber adoption	base station cost / sector
PC penetration	spectrum operating point	laptop built-in antenna gain	modem type mix over time	modem costs (desktop, laptop, handset)
laptop share of PC installed base	capacity reserve	laptop adjustment for cell-edge data rate		indoor antenna + cable cost
mobile phone penetration	planned coverage for fixed service over time	desktop built-in antenna gain		outdoor antenna + cable cost
morphology mix	planned coverage for mobile service over time	desktop + window-mount antenna gain		outdoor antenna installation cost
	backhaul approach	desktop + prof'l-install antenna gain		NOC initial setup
		wall loss		NOC cost per data subscriber unit of capacity
		composite fading margin		NOC cost per line of VoIP capacity
		ranges by configuration and morphology		backbone connectivity per sub
		isolated cell spectral efficiency		tech support (wholesale, retail)
		interference-limited cell spectral efficiency		NOC opex, all else
				retail opex, all else (mbx, web space, etc.)
				subscriber acquisition expense
				service wholesale price by category
				wholesaler share of subscriber modem expense
				subscriber churn
				corporate overhead
				network amortization period
				spectrum unit cost
				spectrum depreciation period

Exhibit 7

Typical Cash Flow for New Network Deployments

Wireless operator cumulative cash position as a function of three critical radio-network variables

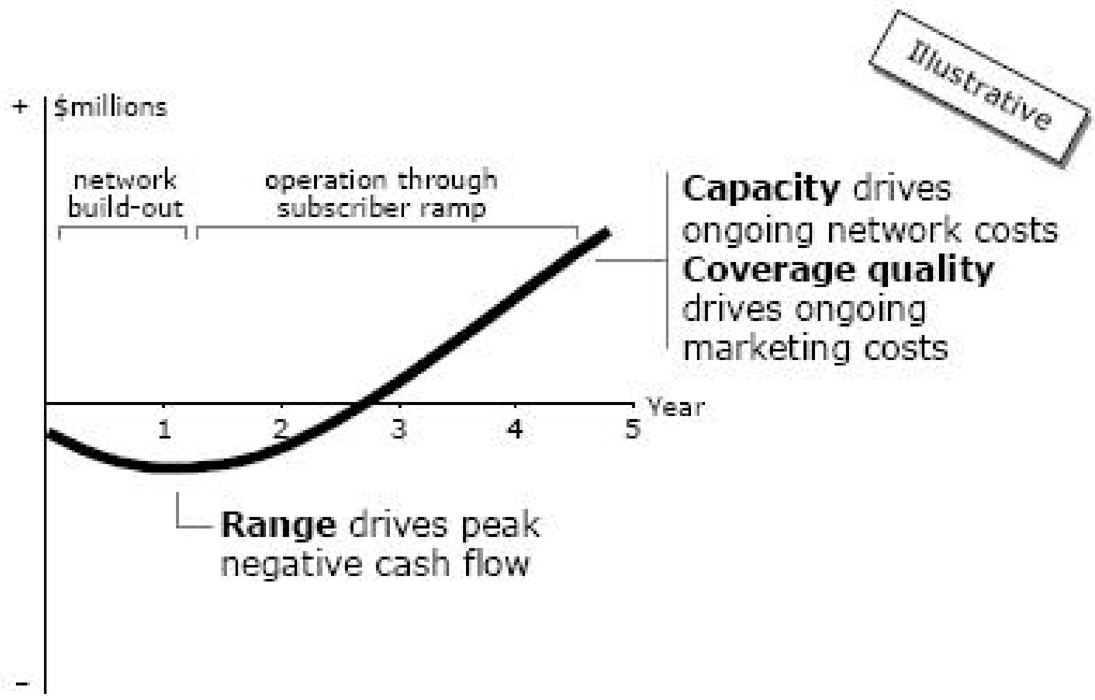


Exhibit 8

Some Observations on the Economics of Broadband Wireless Access

- Drivers for broadband wireless access business case
  - Spectrum and Site Acquisition costs
  - Capital Expenditures (CapEx)
  - Operational Expenditures (OpEx), including backhaul transmission
  - Performance and consumer pricing elasticities
  - Annual Revenues
- Costs can be driven down by reducing number of cell sites (access points) in the network
- Avoiding spectrum and site acquisition costs can significantly improve the ROI and move forward the break-even point in a BWA business case

Some Observations on Broadband Economics (cont'd)

- There is a wide choice of broadband wireless access (BWA) technologies
  - ITU-R recommends 8 mobile and 8 nomadic standards as suitable for BWA systems in the mobile service operating below 6 GHz.[10]
- There is a wide variance in the cost and performance of the various BWA systems
- BWA may or may not be a viable business depending on spectrum and technology choices

Spectral Efficiency is the Critical Metric!

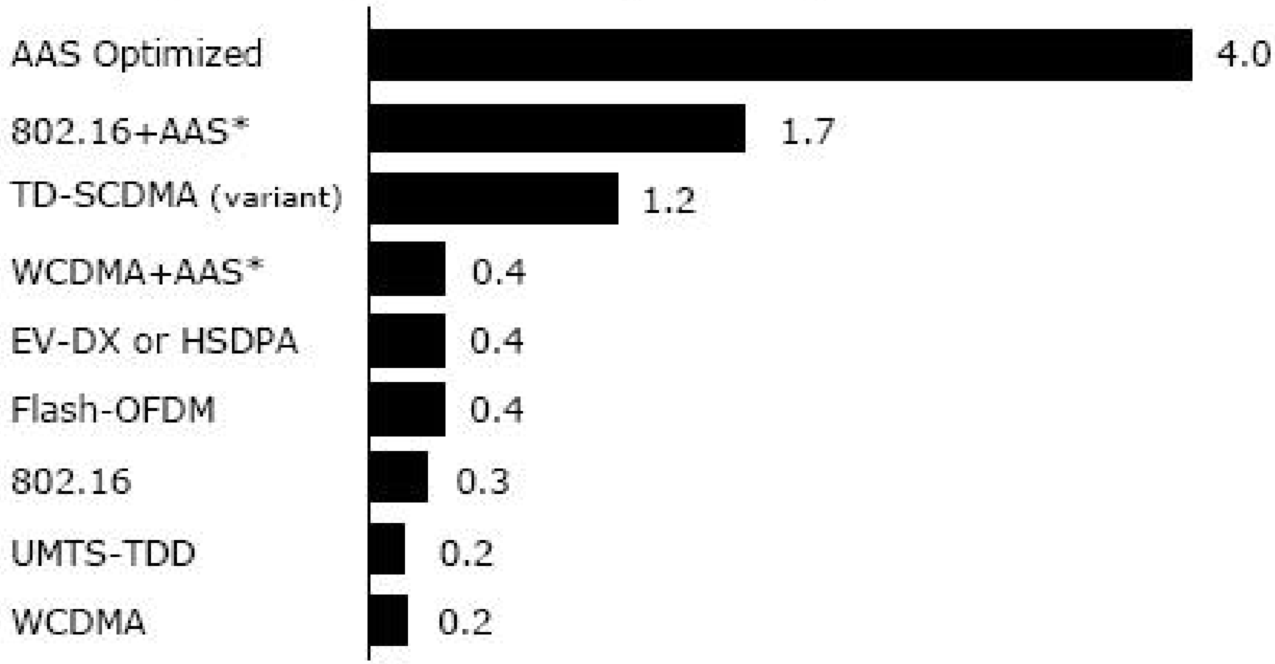
- Spectral Efficiency (SE):
  - Defined as “Bits per second/Hz/cell” or “bits per second/Hz/sq-km”
- SE is a unique measure of a technology’s data capacity within a fixed bandwidth
- More spectrally efficient systems can be deployed in narrower frequency bands and make effective use of lower frequency bands
- SE will determine the number of cell sites in a system and thereby drives key factors (CapEx and OpEx) in a broadband business case

Comparison of Various Systems' Spectral Efficiency

Mobile wireless system capacity in mature networks

Mbps of net usable aggregate BTS throughput per MHz available

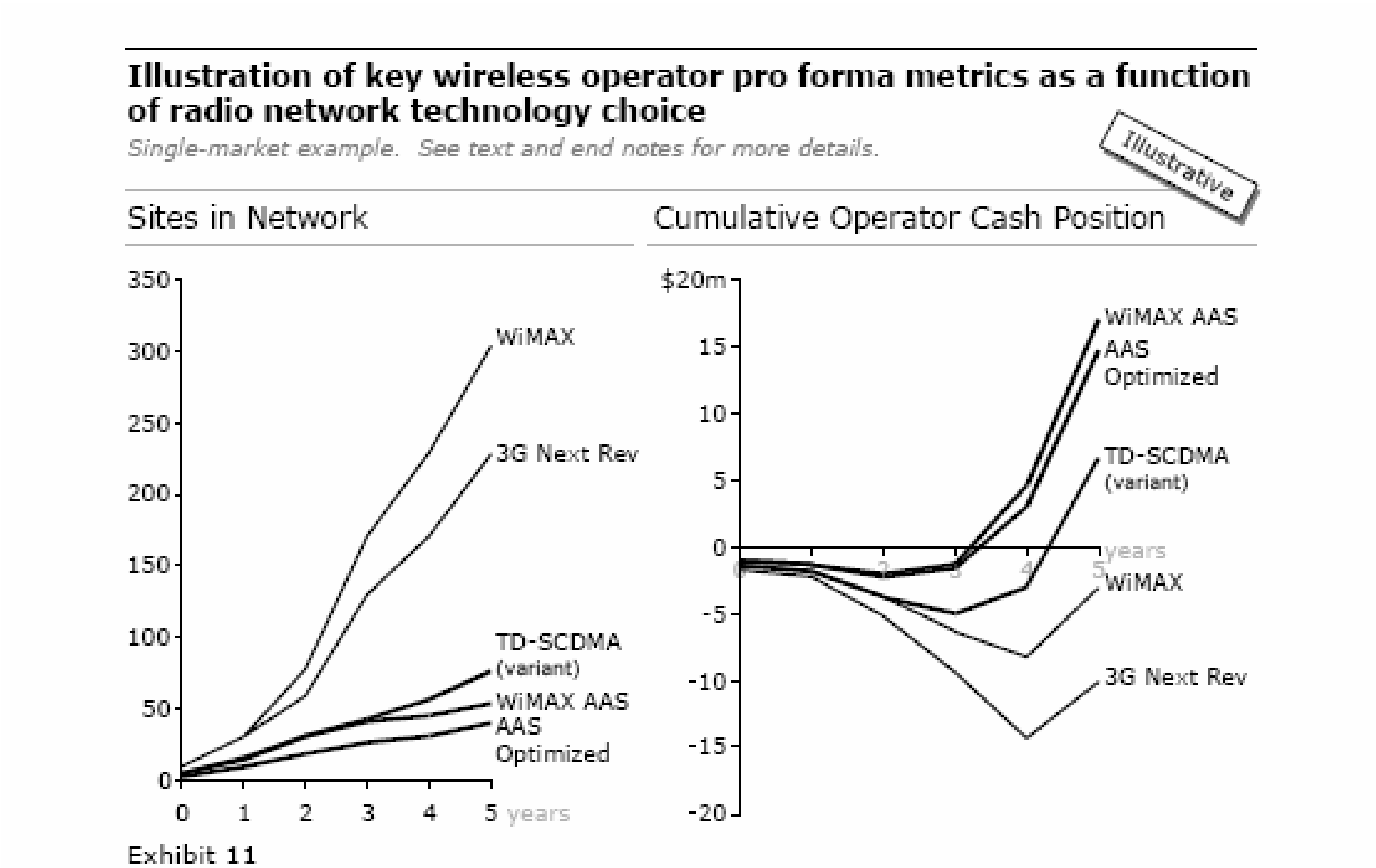
Sources: system vendors, AC field experience, various analysts. See also end notes.



*Standard protocol with base station enhanced by fully-adaptive antenna system

Exhibit 9

Spectral Efficiency Drives Business Case Fundamentals [11]



Caveat Emptor !

Lies, Damned Lies, and Spectral Efficiency

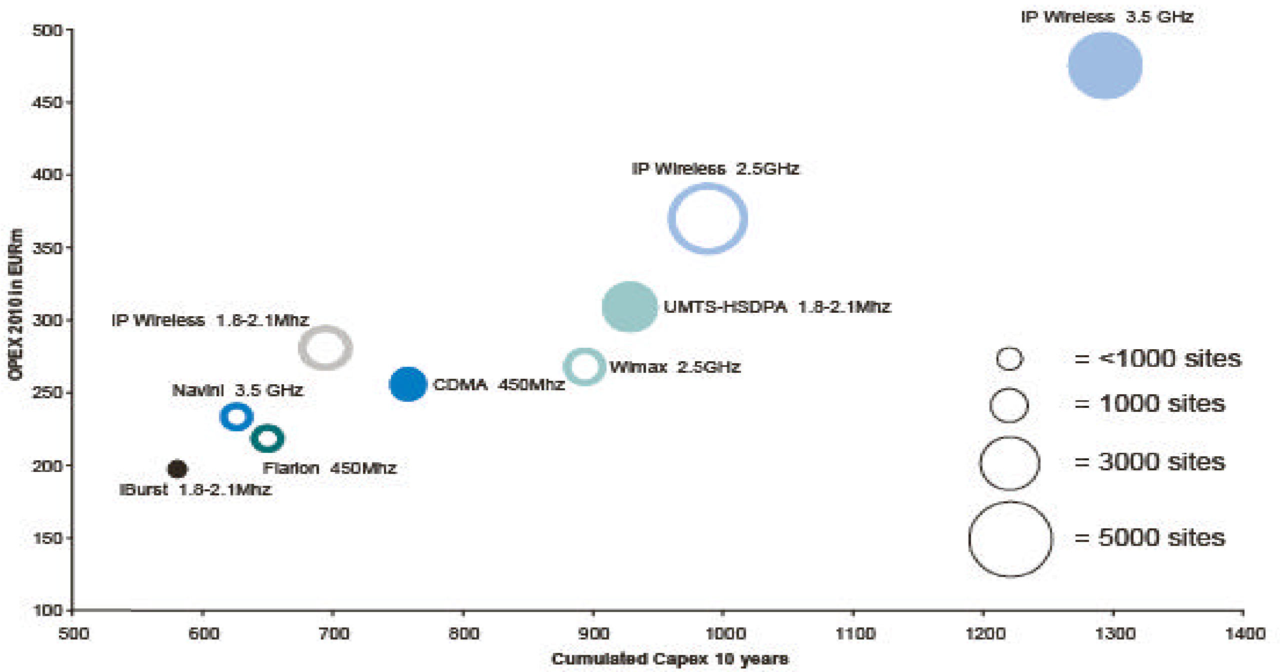
The starting point: a figure relevant to operator economics, i.e. field-proven aggregate net user throughput in a multi-cell, fully-loaded (interference-limited) network

From there, an enterprising vendor can...	**Overstatement Seen in Practice**
Measure a single sector in isolation	2–4x
Include 'system bits' and airlink overhead	30–40%
Measure with only one user active in the sector	30–40%
Exclude one half of an FDD (paired) allocation	2x
Exclude guard bands within the allocation	20%
Count only higher-efficiency downlink, not aggregate throughput	30–40%
Measure with subscriber device at zero base station range	30–40%
Discuss lab measurements that cannot be replicated in field conditions	20–30%
Allow marketing to improvise, since no hardware needs to back up the claim yet	very large

Exhibit 12

Some mobile broadband technology comparisons[12]

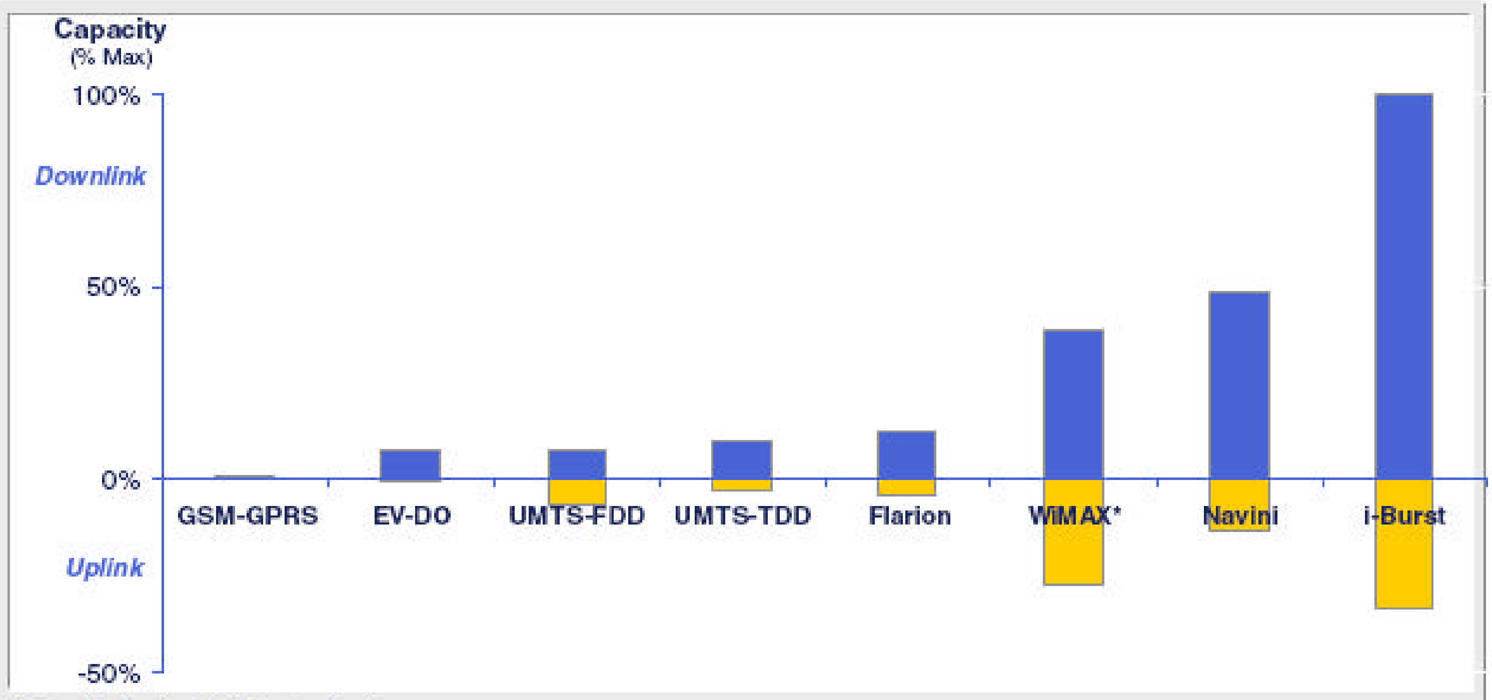
Chart 22: Comparison of the total Capex+Opex for the rollout of different MBWA technologies



Source: Exane BNP Paribas, Arthur D Little

Some mobile broadband technology comparisons (cont'd)[13]

Figure 6 Average Cell and Site Data Throughput Performance

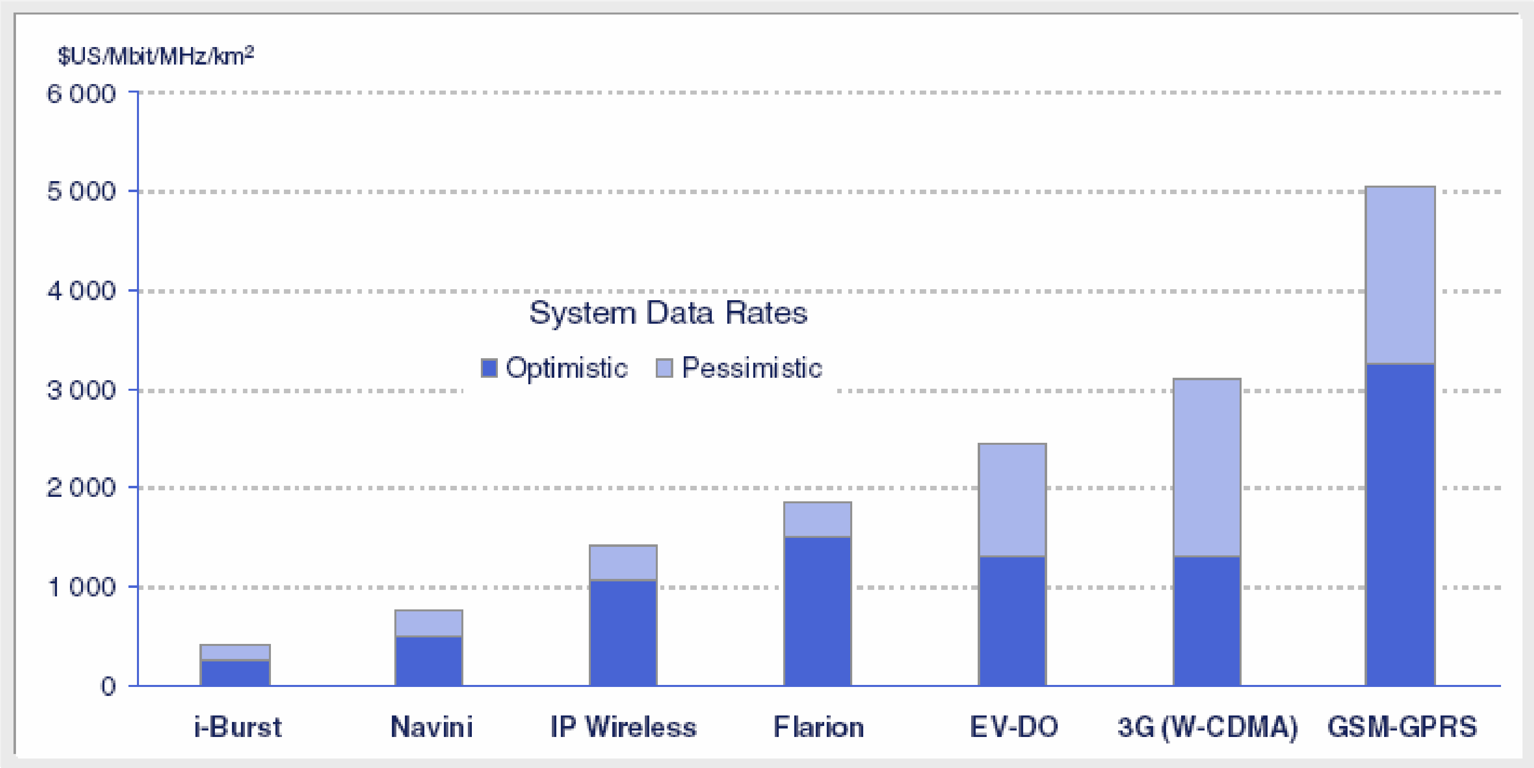


*) Considering the 802.16a standard

Source: Company specifications, Arthur D. Little analysis

Some mobile broadband technology comparisons (cont'd)[13]

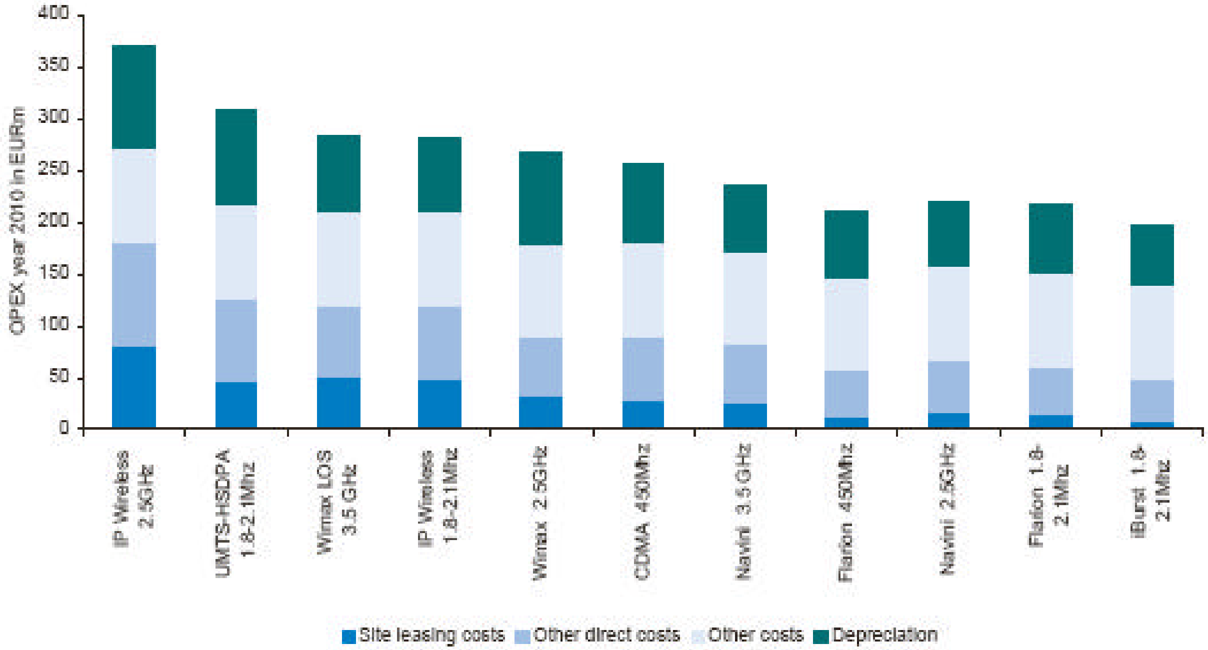
Figure 9 **Comparative Delivery Costs for Broadband Wireless Data**



Sources: Vendor specifications, Arthur D. Little analysis

Some mobile broadband technology comparisons (cont'd)[12, 14]

Chart 23: Cost breakdown for different MBWA technologies



Source: Exane BNP Paribas, Arthur D Little

Key Message #3

- Spectral efficiency is the key driver in the economics of deploying a BWA system.
- However, a commercial operator's choice of technology is typically driven by other factors, e.g. existing commercial relationships, or achieving a global or national footprint of a single technology in a common frequency range.
- What is economically attractive for one operator may not be attractive to another. As such, different companies will have different degrees of interest in deploying a system in a particular frequency band or in deploying a particular technology.

Overview Commercial Spectrum for Broadband Wireless Access

Commercial Spectrum for Broadband Wireless Access

- Previously Auctioned Bands
  - Cellular Service (800 MHz)
  - Broadband PCS (1900 MHz)
  - Wireless Communications Service (2300 MHz)
  - Broadband Radio Service and Educational Service (2600 MHz)
  - Advanced Wireless Service (1700/2100 MHz)
- Non-exclusively Licensed
  - 3650 – 3700 MHz
- Pending Auctions
  - 700 MHz
  - 2155-2175 MHz

800 MHz Band (Cellular)

- Cellular Services: Mobile radiotelephone service in which common carriers are authorized to offer and provide a mobile telecommunications service for hire to the general public using cellular systems.
- Established in1981
- Service Rules: CFR, Parts 1 and 22
- Related Services: Broadband PCS
- Band Plan
  - Band(s):824-849 MHz and 869-894 MHz Blocks: 2 Block
  - Size: 25 MHz
  - Market Areas: MSA and RSA
  - ULS Radio Service Code: CL

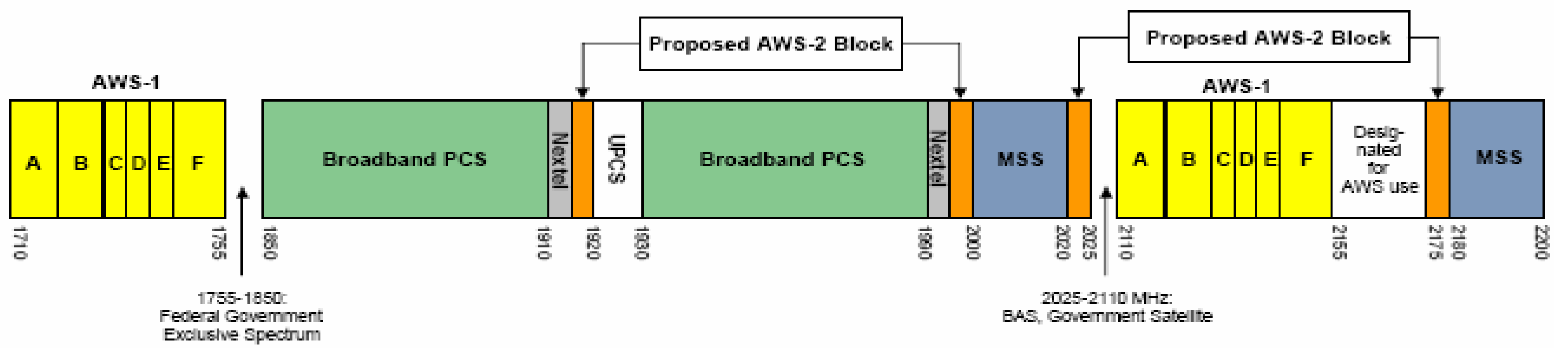
1850-1990 MHz (Broadband PCS)

- Broadband PCS is primarily used to provide a variety of services, such as digital mobile phones and wireless internet access. These services are also called mobile telephone services and mobile data services.
- Established1994
- Service Rules: C.F.R., Part 24
- Related Services: Cellular, Narrowband PCS
- Band Plan:
  - Band(s)1850-1990 MHz
  - Blocks: A-F, C1-C5
  - Block Size10 to 30 MHz
  - Market Areas MTAs, BTAs
  - ULS Radio Service Codes: CW - PCS Broadband

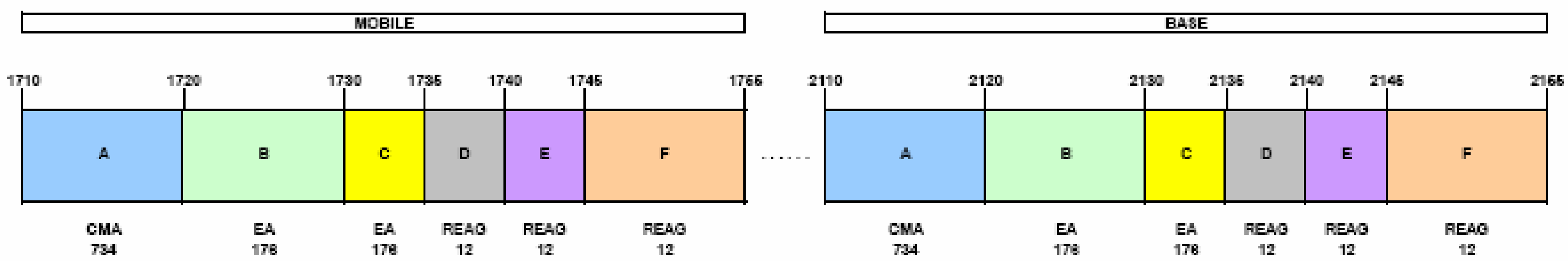
1710-1755/2110-2155 MHz (Advanced Wireless Service)

- The Commission allocated, auctioned, and licensed additional spectrum that can be used to offer a variety of wireless services, including Third Generation (“3G”) mobile broadband and advanced wireless services.
- Also Known As AWS
- Service Rules: Spectrum licensed on a flexible use basis under 47 C.F.R., Part 27
- Related Services: Cellular, Broadband PCS, BRS & EBS
- Band Plan: Band(s)1710-1755 MHz and 2110-2155 MHz; additional F and G blocks
- Proceedings:
  - Docket No. 00-258 allocates spectrum below 3 GHz for Advanced Wireless Services, including Third Generation ("3G") systems.
  - Docket No. 02-353 establishes services rules for the 90 MHz of AWS spectrum in the 1.7 and 2.1 GHz bands.
  - Docket No. 04-356 focuses on establishing service rules for the 20 MHz of AWS spectrum at 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz, and 2175-2180 MHz.
- Auctions: #66: AWS-1 8/9/2006 - 9/18/2006

Advanced Wireless Services (AWS) Band Plan



Advanced Wireless Services (AWS-1) Band Plan Detail



Block	Frequencies	Pairing	Bandwidth	Area	Licenses
A	1710-1720 and 2110-2120 MHz	2 x 10 MHz	20 MHz	CMA	734
B	1720-1730 and 2120-2130 MHz	2 x 10 MHz	20 MHz	EA	176
C	1730-1735 and 2130-2135 MHz	2 x 5 MHz	10 MHz	EA	176
D	1735-1740 and 2135-2140 MHz	2 x 5 MHz	10 MHz	REAG	12
E	1740-1745 and 2140-2145 MHz	2 x 5 MHz	10 MHz	REAG	12
F	1745-1755 and 2145-2155 MHz	2 x 10 MHz	20 MHz	REAG	12

2300 – 2400 MHz (Wireless Communications Service)

- The Wireless Communications Service (WCS) is primarily used to provide fixed, mobile, radiolocation or satellite communication services to individuals and businesses.
- Also Known As WCS
- Established 1997
- Service Rules: C.F.R., Part 27
- Band Plan
  - Band(s): 2305-2320 MHz and 2345-2360 MHz
  - Blocks: A-D
  - Block Size: 5 and 10 MHz
  - Market Areas MEAs, REAGs
  - ULS Radio Service Codes: WS - Wireless Communications Service
- Auctions: #14: WCS 4/15/1997 - 4/25/1997
- NOTE: The ULS yielded no WCS licenses in South Carolina.

2495 – 2690 MHz (BRS and EBS)

- **Broadband Radio Service:** Flexible use service that can be used to accommodate a variety of fixed, portable, and mobile services, including high-speed broadband services (including internet access), video programming, and cellularized communications services.
  - Also Known As BRS
  - Established 2005 (formerly known as the Multipoint Distribution Service)
  - Market Areas: Combination of Basic Trading Areas (BTAs) and 35-mile radius geographic service areas
  - ULS Radio Service Codes: BR - Broadband Radio Service
- **Educational Broadband Service:** Flexible use service licensed to educational institutions or non-profit educational organizations designed to accommodate a variety of fixed, portable, and mobile services relating to education and instruction. Licensees can also lease excess capacity to other entities so long as they meet educational programming requirements.
  - Also Known As EBS
  - Established 2005 (formerly known as the Instructional Television Fixed Service)
  - Band(s)2495-2690 MHz (shared with the Broadband Radio Service)
  - Market Areas: 35-mile radius geographic service areas
  - ULS Radio Service Codes: ED - Educational Broadband Service (EBS)
- Service Rules: 47 C.F.R., Part 27
- Band Plan
  - Band(s): 2495-2690 MHz (shared by Broadband Radio and Educational Broadband Service)

2495 – 2690 MHz (BRS and EBS)

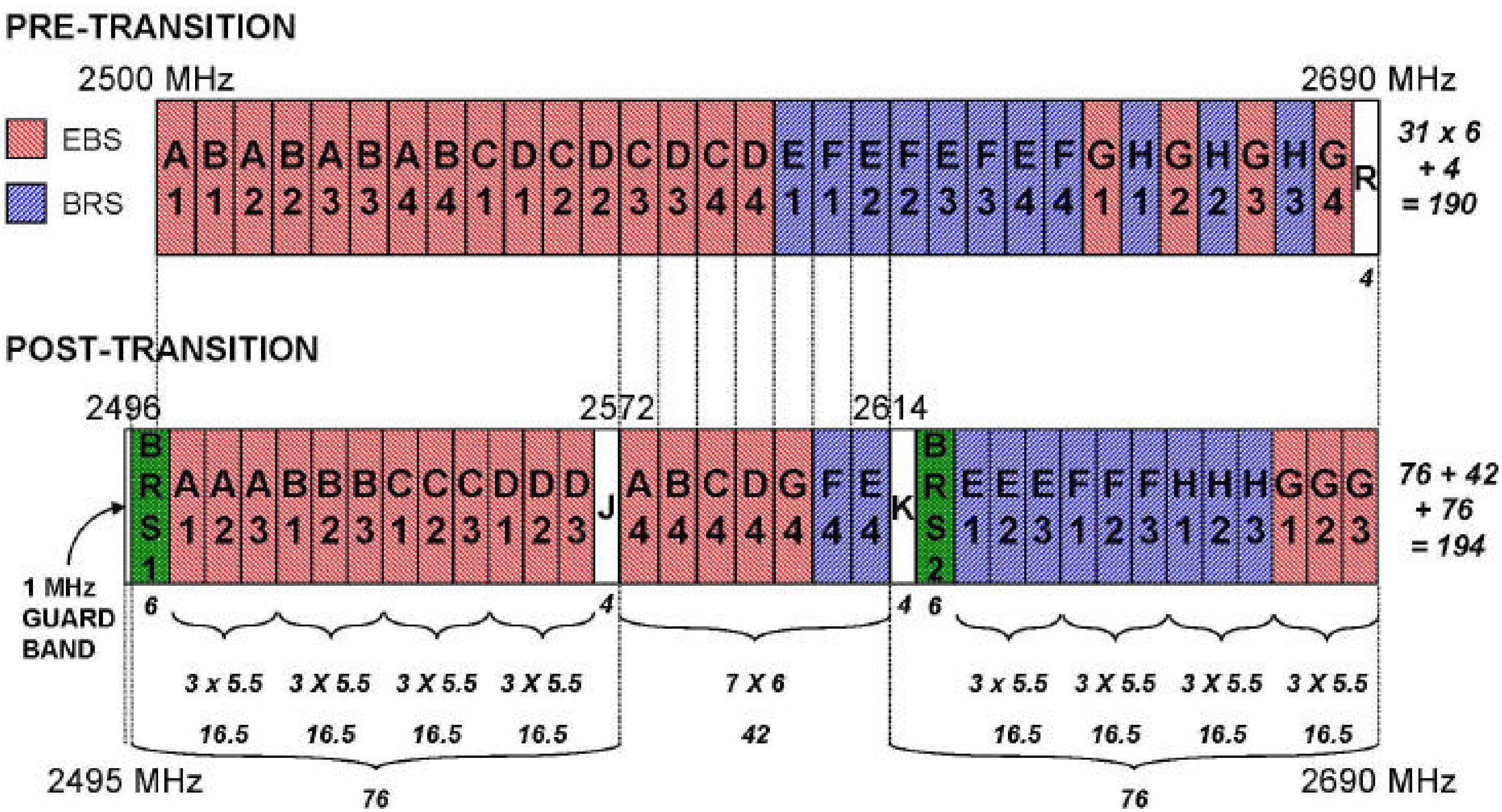
Operations

- Under the new rules, licensees will have the flexibility to use the technology of their choice for a wide variety of purposes. Until a market is transitioned, licensees may continue to operate in accordance with their currently licensed operations.

Geographic Service Area

- The new rules provide each licensee with a geographic service area. For EBS and site-based BRS authorizations, the geographic service area generally consists of the station's 35-mile protected service area (PSA). In those instances where two stations have overlapping PSAs, the rules use a "splitting a football" approach to divide the overlap area between the licensees. For BRS BTA authorization holders, the geographic service area consists of those portions of the BTA not occupied by the GSAs of other stations. Licensees may, in most cases, modify their facilities, consistent with the new technical rules, without prior Commission approval. With geographic area licensing, licensees may also add additional facilities (such as hubs and boosters) within their GSA without prior Commission approval, so long as the facilities comply with the technical rules.
- Licensees must file applications and be granted specific licenses for individual facilities within their GSAs if: (1) international agreements require coordination; (2) submission of an environmental assessment is required; or (3) the station would affect the radio quiet zones.

BRS-EBS Band Plans: Pre-Transition at 2500-2690 MHz and Post-Transition at 2495-2690 MHz



3650-3700 MHz

- Available for use in a broad range of new products and services, including high-speed, wireless local area networks and broadband Internet access operating equipment that must use “contention-based protocols.” All licensees have the mutual obligation to cooperate to avoid harmful interference.
- Established in 2007
- Service Rules CFR, Part 90
- Related Services: AWS, BRS/EBS
- Band Plan
  - Band(s):
    - 3650-3675 MHz for Restricted Protocol
    - 3650-3700 MHz for Unrestricted Protocol
  - Block Size: 25 MHz and 50 MHz, Protocol Dependent
  - Licensing: Non-exclusive Nationwide with fixed and base station registration via ULS
  - ULS Radio Service Codes: NN - 3650-3700 MHz
  - Grandfathered FSS Incumbents

3650 – 3700 MHz

- *Nationwide, non-exclusive licenses*. New terrestrial operations in the band will be licensed on a nationwide, non-exclusive, *i.e.*, shared, basis with other licensees of the band. However, a licensee is not authorized to operate a fixed or base station until that station is registered with the FCC. All terrestrial licensees will have the mutual obligation to cooperate and avoid harmful interference to one another as well as to protect grandfathered operations, as further described below.[1] There are no eligibility restrictions for licenses (other than the statutory foreign ownership restrictions) and no in-band or out-of-band spectrum aggregation limits.[2] Licenses will have a 10-year license term and licensees will have a right to a renewal expectancy.[3] Licensees will be free to assign and transfer their nationwide non-exclusive licenses[4] and to "assign" or share fixed and base stations that are registered. [5] Applicant qualifications for nationwide non-exclusive licenses in the 3650 MHz band will be assessed in accordance with the requirements of FCC Form 601 and the Commission's rules.[6]
  - [1] 47 C.F.R. § 90.1319(d).
  - [2] Certain equipment, based on its FCC certification and as described below, will be restricted to operating only in the lower 25 megahertz of the 3650 MHz band.
  - [3] 47 C.F.R. § 90.1311; *2005 Order*, 20 FCC Rcd at 6516 ¶ 39.
  - [4] 47 C.F.R. § 90.1312.
  - [5] *See* discussion in Section IV, *infra*.
  - [6] 47 C.F.R. §§ 1.913-1.917. FCC Form 601 - *Application for Radio Service Authorization.*

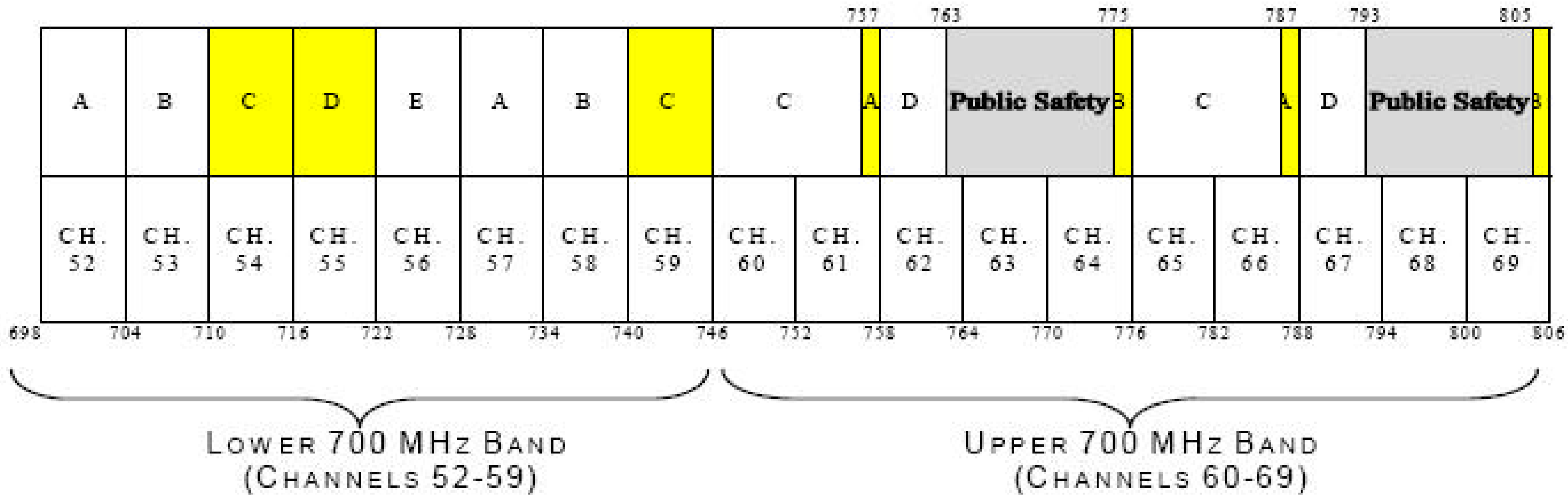
3650-3700 MHz (cont'd)

- *FCC-certified equipment:* Licensees should determine, by checking the equipment manual or asking their equipment vendor or manufacturer, whether the equipment they are planning to use is certified by the FCC as "unrestricted" or "restricted." Fixed, base, mobile, and portable equipment in the 3650 MHz band must use "contention-based protocols" and will be certified as either "unrestricted" or "restricted." Contention-based protocols will allow multiple users to share the same spectrum by defining the events that must occur when two or more devices attempt to simultaneously access the same channel and establishing rules by which each device is provided a reasonable opportunity to operate.
- Unrestricted contention protocols are broadly compatible and function to prevent interference even with other, dissimilar contention technologies on the market. Equipment using an unrestricted protocol can operate on all 50 megahertz (3650-3700 MHz).[1]
- Restricted contention protocols can prevent interference only with other devices incorporating the same or similar protocols. Equipment using a restricted protocol can operate only on the lower 25 megahertz (3650-3675 MHz).[2]
- [1] 47 C.F.R. §§ 90.7, 90.1319(c). For unrestricted devices, the FCC's Equipment Authorization Database and the grant of equipment certification will include note code "UR" and the following text: "This device incorporates an unrestricted contention based protocol. It is capable of avoiding co-frequency interference with devices using other types of contention-based protocols.
- [2] 47 C.F.R. § 90.1319(c). For restricted devices, the FCC's Equipment Authorization Database and the grant of equipment certification will include note code "RS" and the following text: "This device incorporates a restricted contention based protocol. It may not be capable of avoiding co-frequency interference with devices using other types of contention-based protocols. Operation is restricted to the 3650-3675 MHz band."

700 MHz (Commercial Service)

- Auction(s) of licenses for services in the 698-806 MHz band (herein, the “700 MHz Band”) scheduled to begin on January 24, 2008 (Auctions 73 and 76).
  - A and B Blocks: 2 x 6 MHz each; (24 MHz total)
  - E Block: unpaired 6 MHz; (6 MHz total)
  - C Block: 2 x 11 MHz (22 MHz total)
  - D Block: 2 x 5 MHz (10 MHz total); single, nationwide license; This license is established to be part of a public/private partnership between a commercial licensee and a single public safety licensee with respect to developing a nationwide, shared interoperable broadband network for use by public safety users.

Revised 700 MHz Band Plan For Commercial Services



Block	Frequencies	Bandwidth	Pairing	Area Type	Licenses
A	698-704, 728-734	12 MHz	2 x 6 MHz	EA	176
B	704-710, 734-740	12 MHz	2 x 6 MHz	CMA	734
C	710-716, 740-746	12 MHz	2 x 6 MHz	CMA	734*
D	716-722	6 MHz	unpaired	EAG	6*
E	722-728	6 MHz	unpaired	EA	176
C	746-757, 776-787	22 MHz	2 x 11 MHz	REAG	12
D	758-763, 788-793	10 MHz	2 x 5 MHz	Nationwide	1***
A	757-758, 787-788	2 MHz	2 x 1 MHz	MEA	52**
B	775-776, 805-806	2 MHz	2 x 1 MHz	MEA	52**

* These Blocks have been auctioned.

** These Guard Band Blocks have been auctioned, but are being relocated.

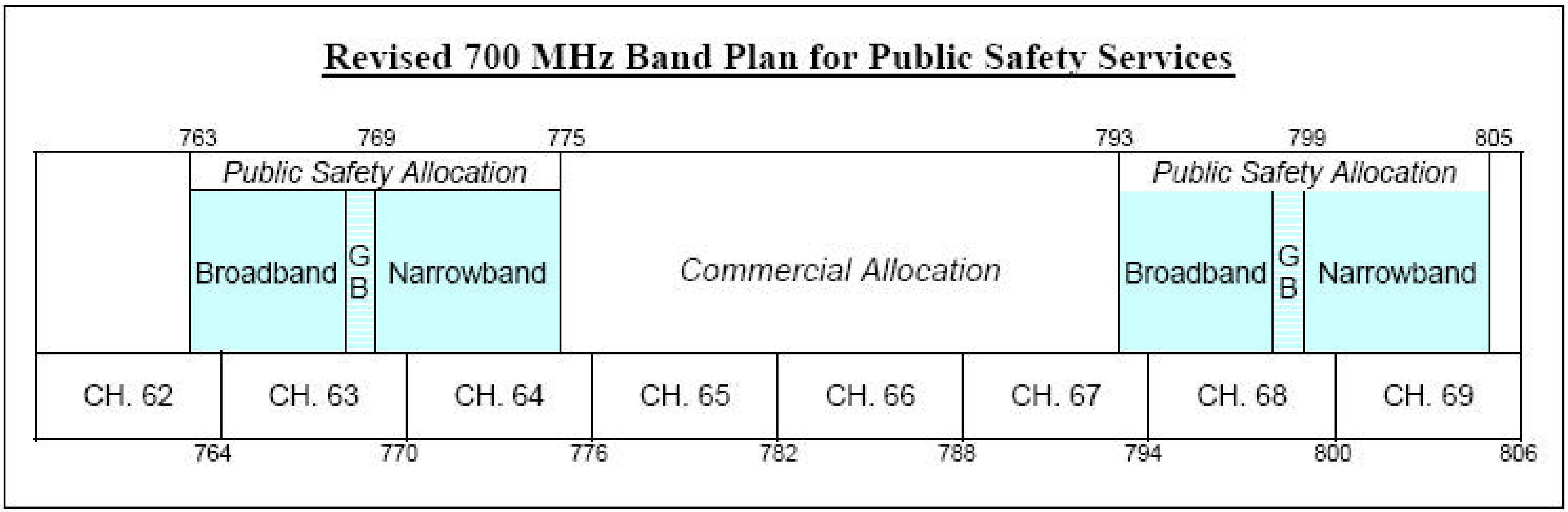
*** This Block is associated with the 700 MHz Public/Private Partnership.

700 MHz (Public Safety)

- The FCC re-designated ten megahertz of public safety 700 MHz spectrum (763-768/793-798 MHz) for the purpose of establishing a nationwide, interoperable broadband public safety communications network.
- It created a single nationwide license for this spectrum – the Public Safety Broadband License.[A]
- This license has been assigned to a single entity – the Public Safety Broadband Licensee (PSBL).
- The Public Safety Broadband License and the PSBL were created for the purpose of partnering with a commercial entity – the auction winner of the immediately adjacent ten megahertz of commercial "D Block" spectrum – in order to facilitate a public/private partnership (the 700 MHz Public/Private Partnership) that would result in the build out of this nationwide public safety network.
  - [A] The license area of the Public Safety Broadband License encompasses the contiguous 48 states, Alaska, Hawaii, the Gulf of Mexico, and the U.S. territories. *Id*. at 15427 ¶ 385 n.825.

700 MHz Public Safety Band

- The FCC also specified the following baseline criteria that the PSBL must satisfy:
  - no commercial interest may be held in or participate in the management of the PSBL;
  - the PSBL must be a non-profit organization;
  - the PSBL must be as broadly representative of the public safety community as possible; and
  - the PSBL must submit written certifications from at least ten geographically diverse state and local government entities in support of its candidacy.
- To further ensure that the PSBL focuses exclusively on the broadband needs of public safety entities, the Commission specified the composition of the PSBL's board of directors and identified specific minimum elements of its Articles of Incorporation and Bylaws.
- On November 19, 2007 the FCC granted the application of the Public Safety Spectrum Trust Corporation (PSSTC) to be the PSBL.
  - The license granted to the PSSTC includes ten megahertz of broadband spectrum (763-768/793-798 MHz) and two megahertz of guard band spectrum between the public safety broadband and public safety narrowband allocations (768-769/798-799 MHz).


Revised 700 MHz Band Plan for Public Safety Services
763
769
775
793
799
805
Public Safety Allocation
Public Safety Allocation
Broadband
G
B
Narrowband
Commercial Allocation
Broadband
G
B
Narrowband
CH. 62
CH. 63
CH. 64
CH. 65
CH. 66
CH. 67
CH. 68
CH. 69
764
770
776
782
788
794
800
806

2155 – 2175 MHz Band

- The 2155-2175 MHz band is currently occupied by over 1,800 active, incumbent Fixed Service (FS) and Broadband Radio Service (BRS) licenses, which are subject to relocation by AWS entrants.
- This spectrum consists of a single, unpaired, 20-megahertz block, rather than two, separate paired blocks. Therefore, a symmetrical pairing approach cannot be adopted in the rules for this spectrum.
- The FCC's Notice of Proposed Rulemaking is seeking comment on the following:
  - several different technological approaches to use in the 2155-2175 MHz band in light of this characteristic of the spectrum.
  - ways to address interference concerns if both mobile and base transmissions are to be allowed in the band, including the use of power limits and out-of-band emissions requirements.
  - any other technological approaches that could be employed in this band.
  - whether to auction the spectrum, authorize unlicensed use of the spectrum, or adopt some other alternative licensing approach.
  - licensing and operational rules for this spectrum, including: a) the appropriate block size; b) geographic area size to be used for licensing the spectrum; c) whether to license the spectrum under the FCC's flexible, market-oriented Part 27 rules; d) whether to auction the licenses in a simplified subset of alternative band plans.
- Comments must be filed on or before December 14, 2007, and reply comments must be filed on or before January 14, 2008.

Key Messages #4

- There are a variety of blocks of spectrum that have been or are being licensed for the provision of commercial mobile services.
- The FCC's policies are technology and service neutral, such that there are no regulatory requirement to provide a broadband service consistent with any of the definitions presented in this paper.
- South Carolina's 2.5 GHz licenses contain more than enough spectrum for a BWA deployment and/or leasing spectrum to one or more entities. The actual amount of spectrum required for a deployment depends on technology choice.
- Coverage of rural areas using 2.5 GHz spectrum would require substantially more investment than what would be required for urban and suburban areas. The amount of spectrum required and the actual costs depends on the spectral efficiency of the technology chosen.
- A BWA service could be deployed in other spectrum that is allocated for a commercial mobile service, including the 700 MHz spectrum that will be auctioned in January 2008.
- In all cases the economics of BWA deployment in any band will be driven by the spectral efficiency of the technology chosen. The 700 MHz licenses are relatively narrow and would require a highly spectrally efficient system to achieve a broadband service offering.

Recap and Summary

- While spectrum choice matters, it is the combination of spectrum and technology that together makes a BWA deployment possible.
- The spectral efficiency of the technology is a more important factor in the economics of deploying a BWA system than the frequency band of operation.
- There are numerous bands available for commercial deployment of BWA systems. However, there is no regulatory requirement that operators of those systems provide a truly broadband wireless access service.
- South Carolina's 2.5 GHz licenses contain more than enough spectrum for a BWA deployment and/or leasing spectrum to one or more entities. The actual amount of spectrum required for a deployment depends on technology choice.
- Coverage of rural areas using 2.5 GHz spectrum would require substantially greater investment than what would be required for urban and suburban areas. The amount of spectrum required and the actual costs depends on the spectral efficiency of the technology chosen.

Notes and Bibliography

1. Notice of Proposed Rulemaking in the Matter of Development of Nationwide Broadband Data to Evaluate Reasonable and Timely Deployment of Advanced Services to All Americans, Improvement of Wireless Broadband Subscribership Data, and Development of Data on Interconnected Voice over Internet Protocol (VoIP) Subscribership. WC Docket No. 07-38, Adopted February 26, 2007.
2. "Broadband Internet Access in OECD Countries: A Comparative Analysis." October 2003. Note: The OECD consists of 30 of the world's industrialized countries, including the United States.
3. The ITU is the leading United Nations agency for information and communication technologies. As the global focal point for governments and the private sector, the ITU's role in helping the world communicate spans 3 core sectors: radiocommunication, standardization and development. "Wireless access" and "BWA" are defined in Recommendation ITU-R F.1399, which also provides definitions of the terms "fixed", "mobile" and "nomadic" wireless access.

Notes and Bibliography (cont'd)

4. "Navigating the Harsh Realities of Broadband Wireless Network Economics," ArrayComm,Inc. 2004. (Note that many services being marketed as "broadband wireless" today — in particular those under the 3G umbrella, as well as approaches to fixed wireless service that have no path to mobility — do not conform to this definition.) <http://www.arraycomm.com/docs/ArrayCommonMBWAecons.pdf>
5. Latency: 1. The time it takes for a packet to cross a network connection, from sender to receiver; 2. The period of time that a frame is held by a network device before it is forwarded. Two of the most important parameters of a communications channel are its latency, which should be low, and its bandwidth, which should be high. Latency is particularly important for a synchronous protocol where each packet must be acknowledged before the next can be transmitted. *The Free On-line Dictionary of Computing*. Denis Howe. 06 Dec. 2007. <Dictionary.com: <http://dictionary.reference.com/browse/latency>.
6. "VHF/UHF/Microwave Radio Propagation: A Primer for Digital Experimenters," A workshop given at the 1997 TAPR/ARRL Digital Communications Conference, Barry McLarnon, http://www.tapr.org/ve3jf.dcc97.html
7. The range curves in Exhibit 6 use the industry-standard Okumura-Hata model for signal propagation, given the assumption of a 23 dBm mobile transmitter (which in common broadband wireless systems will be the limiting factor in the link budget analysis) and one-wall penetration losses of 16 dB. The coverage-cost curve assumes US$100k for total costs per site as a reference point, and a morphology mix of 25% urban, 50% suburban, and 25% rural. This chart is taken from [4].

Notes and Bibliography (cont'd)

8. The slides on pages 12, 13, 19, 20-21 are from [4].
9. Initially, cellular networks are deployed with the fewest cells and the largest possible cell sizes to cover the area of service. As capacity demand grows, more cells are added and cell sizes are reduced to increase overall network capacity. The total number of cells required in a fully loaded network depends on many factors including the total data rate requirements (capacity), frequency of operation, total bandwidth available to each cell, etc. Radio systems with greater spectral efficiency require fewer cells to achieve the coverage and capacity requirements of the network.
10. ITU-R Rec. M.1801, "Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz"
11. As this chart shows, the number of sites required by the less spectrally-efficient technologies grows dramatically after the first two years as the subscriber count and usage rise. These site count differences in turn drive fundamentally different cost structures for this hypothetical operator. Clarity about real-world spectral efficiency can spell the difference between a financially attractive operation and a very poor investment.

Notes and Bibliography (cont'd)

12. "*Telecom Operators – Facing off on convergence."* Arthur D. Little and Xane BNP Paribas. February 2006.
13. "*WiMAX vs. WiWAIT: Will Mobile Also Dominate Broadband?"* Arthur D. Little Mobile Broadband Wireless Report 2004.
14. This cost model includes: a) network capex, over a period of 10 years (including IMS but not HLR equipment). The calculation is based on a coverage target limited to large, high-density cities in a big European country corresponding to coverage of 60% of the population; b) handsets: this is a key question mark. In this model, they are included in CapEx based on a fixed handset/modem; c) OpEx: the main cost items are interconnection, network maintenance, backhaul, site rental, marketing and billing costs. This model does not include content costs.
15. "System Requirements for IEEE 802.20 Mobile Broadband Wireless Access Systems", 802.20-PD-06r1. http://www.ieee802.org/20/Documents.htm
16. *Occupied bandwidth* - The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage B /2 of the total mean power of a given emission. Unless otherwise specified in an ITU-R Recommendation for the appropriate class of emission, the value of B /2 should be taken as 0.5%.

Notes and Bibliography (cont'd)

17. For example, the WiMAX Forum states that, "The WiMAX Forum believes that if a wide range of personal broadband services are to be offered to subscribers, a minimum of 30 MHz of TDD spectrum is required per operator to realize the full potential of Mobile WiMAX. … There may be special circumstances where a viable business case could perhaps be established to roll-out WiMAX technology using spectrum allocations less than 30 MHz per operator. In such circumstances a Service Provider may not be able to offer a full suite of broadband services or may only be able to support a smaller number of subscribers. These factors depend on prevailing local conditions…." <http://www.wimaxforum.org/technology/downloads/Spectrum_Requirements_for_Mobile_WiMAX_Sept2007.pdf>

About the Presenter

Joanne C. Wilson
Email: joanne.wilson@ieee.org

- Telecommunications consultant with more than 20 years of professional experience in the telecommunications industry, specializing in wireless standards, regulatory and market access issues.
- Senior Advisor to CompassRose Int'l, which advises and assists companies, governments, and NGOs in strategic management, business development and operations, policy and regulatory issues, *etc*.
- Former VP, Standards for ArrayComm, where she developed and successfully executed strategies leading to the adoption of their technology by ANSI, the IEEE and the ITU-R.
- 15 year career with AT&T and Lucent Technologies.
- Brookings Institution Congressional Fellow in 1995.
- BS and MS degrees in EE from Southern University and A&M College, and Stanford University, respectively.