Feasibility of Fixed Wireless Access

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***Abstract*- Fixed wireless access has the unrealized potential to play a major role in the adoption of broadband in the U. S. We conduct a case study of the feasibility of business in a suburban U. S. community and conclude that with a preference for the use of licensed spectrum, such a small scale, grass roots business would be feasible. This opens the question of promoting the economic availability of licensed spectrum in areas smaller than a Basic Trading Area (BTA).**

I. INTRODUCTION

Fixed wireless access (FWA) has not been particularly visible or successful to date as an option for providing broadband Internet access; it contributes a very small fraction of such lines and most potential subscribers are simply unaware of it [1]. Notwithstanding some novel business and technology efforts in unlicensed spectrum, attempts to launch businesses in licensed spectrum have been subject to numerous setbacks and reconsiderations, and are under the constant threat that spectrum will be repurposed for other applications such as backhaul for mobile telephony networks or directly for mobile use [2,3]. Nonetheless, fixed wireless has the potential to play various important roles in the adoption of broadband and in fulfilling steadily increasing demand [1].

In this paper we attack in particular the question of business feasibility of fixed wireless access through a case study. We carefully examine the technology, market, and business drivers for fixed wireless access in a particular suburban Denver community. We demonstrate a preference for the use of licensed spectrum if available, and show that a successful small but scalable local business with limited capital requirements could be established by entrepreneurs in areas like the subject of our study. The possibility of encouraging grass roots bootstrapping of fixed wireless access businesses is an exciting one, but our choice of licensed spectrum presents a critical conundrum for spectrum policy: how to promote regulation or practice in spectrum licensing that allows the economic allocation of spectrum in areas geographically much smaller than Basic Trading Areas.

II. METHOD AND SCOPE

The method of this paper is to analyze the background information of the regulatory, technical, economic and interdependent factors pertinent to FWA. After creating a common understanding of the FWA environment, a feasibility study of each driving factor is provided. To generate additional insight for the project, a broadband market survey and technical (physical) site survey specific to a particular location were conducted. We supplemented our analysis with interviews with experts in the FWA sector.

We are interested in suburban residential U. S. markets and to for-profit businesses (rather than co-ops, government run networks, or other organizations). Superior, CO, a suburban town of about 9,000 located 20 miles Northeast of Denver, was used as the case study for the research project. Although this case study may be relevant to many other suburban areas in the United States, it is important to note that every market area will have its own nuances.

III. ANALYSIS OF THE FIXED WIRELESS ACCESS ENVIRONMENT

Regulatory Factors and Analysis

The Federal Communication Commission (FFC) allows FWA services to operate in three licensed frequency bands: Multipoint Multichannel Distribution Service (MMDS), Instructional Television Fixed Service (ITFS), and Local Multipoint Distribution Service (LMDS). Each of the service licenses are distributed throughout the U.S. in 493 Basic Trading Areas (BTA). Tables 1-3 briefly describe each of the licensed frequency bands.

Table 1. MMDS Services Information [4]

Multipoint Distribution Service	
MDS is a commercial service generally used to provide multichannel video entertainment programming and is often referred to as "wireless cable." Wireless cable is similar to land based cable television.	
Also Known As	MMDS (Multichannel) Wireless Cable
Established	1970
Service Rules	C.F.R., Part 21
Spectrum / Frequencies	
Band	2.1-2.2 GHz, 2.5-2.7 GHz
Channels	13
Auctions	
6 - Multipoint/Multichannel Distribution Services 11/13/1995 - 3/28/1996	

Table 2. ITFS Services Information [4]

Instructional Television Fixed Service	
ITFS is used to provide educational instruction and cultural and professional development in schools and other institutions. ITFS may be leased to companies offering subscriber-based services, provided usage requirements are met.	
Established	1963
Service Rules	C.F.R., Part 74
Spectrum / Frequencies	
Band	2.5-2.7 GHz
Channels	20

Table 3. LMDS Services Information [5]

Local Multipoint Distribution Service	
A local multipoint distribution system (LMDS) is capable of offering subscribers a variety of one and two-way broadband services, such as video programming distribution; video teleconferencing; wireless local loop telephony; and high speed data transmission, e.g. internet access. Because of its multi-purpose applications, LMDS has the potential to become a major competitor to local exchange and cable television services.	
Spectrum / Frequencies	
Band	Block A: 27,500-28,350 MHz; 29,100-29,250 MHz and 31,075-31,225 MHz Bands Block B: 31,000-31,075 MHz and 31,225-31,300 MHz Bands
Auctions	
17 – Local Multipoint Distribution Services February 18, 1998 - March 25, 1998	

Currently the two unlicensed frequency bands available are: Industrial, Scientific and Medical (ISM) and Unlicensed National Information Infrastructure (U-NII) "support spread spectrum operation on a non-interference unlicensed basis" [6].

The [FCC] has provided for the operation of low power unlicensed devices under part 15 of the rules. Devices operating under part 15 must meet technical standards that are designed to control harmful interference to radio communications services. Users must correct any harmful interference that may occur and must accept any interference that is received [7].

The U-NII spectrum is subdivided into three sections of which the "5.725 - 5.825 GHz portion of the band is intended for community networking communications devices operating over a range of several kilometers. The FCC permits fixed, point-to-point U-NII devices to operate with up to 1-W transmitter power and directional antennas with up to a 23-dBi gain" [6].

Policies that Supersede State and Local Policies

The Telecommunications Act of 1996 contains important provisions concerning the placement of antenna structures or towers that provide personal wireless services[1] and most local communities have worked closely with personal wireless service providers to place such facilities within their localities. Section 704 oversees federal, state, and local government issues regarding personal wireless service facilities. "It also prohibits any action that would ban altogether the construction, modification or placement of these kinds of facilities in a particular area and requires the federal government to take steps to help licensees in spectrum-based services …get access to preferred sites for their facilities" [8]. Section 704 of the Telecommunications Act of 1996, "also directs the [FCC] to offer assistance to state and local governments in resolving wireless facility sitting issues" [9]. Section 207 of the Telecommunications Act of 1996 pertains to the policy of attaching antennas to a residential property.

Technical Factors and Analysis

The technical factors involved in implementing a FWA solution must be examined to build a sound infrastructure. The predominant technologies available for a FWA solution are primarily based on the Institute of Electrical and Electronics Engineers (IEEE) standards 802.11a, 802.11b and 802.16. The essential assessment of characteristics such as: coverage, speed and capacity, reliability, and security can ultimately assist the determination of the effectiveness and efficiency of deployment.

Table 3 summaries the major technical characteristics of the four primary FWA solutions.

[1] "Personal wireless services" include commercial mobile services, unlicensed wireless services, and common carrier wireless exchange access services.

Table 3. Technical Characteristics of FWA Solutions [10][11]

Common Name	Wi-Fi	Wi-Fi5	MMDS	LMDS
IEEE Standard	802.11b	802.11a	802.16.3	802.16.1
Frequency Bands (US)	2.4 - 2.43825GHz	5.15 - 5.35GHz 5.725 - 5.835GHz	2.1 - 2.2GHz 2.5 - 2.7GHz	27.5 - 28.35GHz 31.0 - 31.30GHz
Speed and Capacity				
Data Rates (theoretical)	1-11Mbps	6-54Mbps	3Mbps-1Gbps	5Mbps-1.25Gbps
Channels and channel size	12 channel; 6Mhz 3 non-overlapping	8 non-overlapping 6Mhz	13 channels; 6Mhz 4 non-overlapping	up to 1.3GHz
Coverage				
Distance (max.)	10 miles	3-5 miles	35 miles	3-5 miles
Line-of-sight (LOS)	Near-LOS	Near-LOS	Non-LOS	LOS
Reliability				
Weather	Minimal Interference	Minimal Interference	Minimal Interference	Large Interference
Interference	Highly Congested	Minimal Congestion (new technology)	No Congestion; licensed spectrum	No Congestion; licensed spectrum

Multiple Access Techniques

At this time the two primary techniques that are used in non-line-of-sight (non-LOS) FWA solutions are Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). CDMA is highly dependent on "bandwidth spreading for both multiple access, as well as, coverage gains - the higher the spreading factor, the larger the cell area that can be covered" [10]. With CDMA, in order to deliver users with the same data rates throughout a cell, it must "claim spectrum reuse of one" [10]. By setting the spectrum reuse to one, CDMA effective coordinates all cells to use the same RF frequency. The underlying problem with CDMA is that as the number of users increase, the more the cell coverage (radius) decreases.

OFDM is an efficient modulation technique as it "takes a broadband data pipe and distributes it among many parallel bins, the exact number being a function of the Fast Fourier Transform (FFT) size [10]. OFDM is less susceptible to multi-path interference because this technique uses the parallel bins which allow the symbol duration to be longer, thus making it less susceptible to multi-path interference [10]. Table 4 summaries the major characteristics of OFDM and CDMA.

Table 4. Characteristics of Media Access Techniques [12]

	OFDM	CDMA
Spectral Efficiency	More efficient	Less efficient
Multipath	Handles larger number of paths	Some diversity benefit; performance sensitivity to number of paths coherently combined
Multiple Modulation Support	Downlink and uplink	Downlink only
Resistance to Narrowband Interference	Not as robust as CDMA	Spread spectrum provides protection
Network Planning	Cell overlays simple to do; frequency planning	Difficult for cell overlays; PN offset planning; cell-breathing complications
Power Control	Usually employed but not a fundamental requirement	Required function
Peak-to-Average Ratio	10-12 dB	Varies; can be as high as 11 dB
Standards Adoption	WLAN, IEEE, 802.16, 4G	WLAN, 3G

Economic Factors and Analysis

Broadband Industry Overview

The recent downturn of the US economy and more specifically the technology sector may perhaps lead one to the conclusion that the adoption of broadband adoption is also slowing. As for the first six months of year 2002 this conclusion appears to be false. Between January and June of 2002 the number of broadband subscribers has increased by 25 percent to nearly 24 million households [13]. Over the last two years, even with the economic slow down, broadband access has increased by four times the number of subscribers in 2000 [13]. This rapid growth rivals the CD player and PC while surpassing the growth rate of VCRs and color televisions [13].

The price for broadband access remains an important issue. Studies have shown that demand for broadband is very price elastic [1]. Recent price reduction by British Telecommunication (BT) caused demand for ADSL to double [14]. With current prices of cable and DSL access increasing in the US, this fact could be detrimental to broadband adoption. Most of these increases are small, 1.4 percent to 5 percent increase, so the effect might not be as drastic as in the BT scenario, 14 percent decrease [15]. With wireless Internet service providers (ISP) just entering the market, there is inconclusive data about its pricing. Generally broadband costs range from $45 to $55, regardless of transmission media.

Predicaments with Previous FWA Service Providers

While most of the recent efforts to provide a viable FWA solution were started by small, competitive companies, Sprint was one of the first to enter the market. The primary obstacles encountered were: scalability, LOS issues, expensive CPE costs, and the need for professional installation. These issues made the viability of the business model next to impractical with then current technology [16].

Interdependent Factors and Analysis

A principle argument for providing FWA service is whether to operate in the licensed or unlicensed spectrum. By analyzing the regulatory, technical, economic and interdependent factors, we make a subjective determination of preferred frequency band in Table 5 based on currently available equipment.

Table 5. Comparison of Licensed versus Unlicensed Spectrum

Metric	Weight	Licensed Spectrum		Unlicensed Spectrum	
		MMDS	LMDS	ISM	UNII
Regulatory Factors	**0.10**				
Acquiring Spectrum	0.05	**4** ±1	**4** ±1	**6** ±2	**6** ±2
Legal Protection from Interference	0.05	**9** ±1	**9** ±1	**2** ±1	**2** ±1
Technical Factors	**0.40**				
Performance (Speed and Capacity)	0.1	**5** ±2	**9** ±1	**5** ±1	**6** ±2
Line-of-Sight (LOS)	0.1	**7** ±2	**4** ±1	**5** ±2	**5** ±2
Coverage	0.05	**7** ±2	**3** ±1	**6** ±1	**5** ±1
Interference	0.05	**8** ±1	**8** ±1	**2** ±2	**4** ±2
Reliability	0.05	**7** ±2	**7** ±2	**7** ±1	**7** ±1
Security	0.05	**5** ±1	**5** ±1	**3** ±1	**3** ±1
Economic Factors	**0.20**				
CPE Cost (Variable)	0.10	**5** ±2	**2** ±1	**8** ±1	**6** ±2
Infrastructure Cost (Fixed)	0.05	**5** ±2	**3** ±1	**7** ±1	**6** ±1
Cost for Spectrum	0.05	**4** ±2	**4** ±2	**9** ±1	**9** ±1
Interdependent Factors	**0.30**				
Ease of Infrastructure Deployment	0.05	**5** ±2	**2** ±1	**5** ±2	**5** ±2
CPE Installation Ease	0.15	**8** ±2	**3** ±1	**7** ±1	**7** ±1
Scalability	0.05	**7** ±1	**3** ±2	**4** ±1	**4** ±1
Total (Range)	**1.00**	**(4.75 - 7.85)**	**(3.30 - 5.70)**	**(4.05 – 6.55)**	**(3.75 – 6.65)**
Total (Uncertainty)	**1.00**	6.30 ± 0.52	4.50 ± 0.40	5.30 ± 0.59	5.20 ± 0.64
Key: Quantitative Score: Poor – 0 ... Excellent – 10 (Uncertainty)					

After analyzing the different factors when providing a FWA solution, at this time it is evident the best overall approach is to operate in a licensed MMDS spectrum.

IV. FEASIBILITY STUDY OF FIXED WIRELESS ACCESS

Regulatory Feasibility

Interviews with Experts

After conducting interviews with expert faculty members such as: Dr. Ray Nettleton, Professor Dale Hatfield, and Dr. Douglas Sicker at the University of Colorado at Boulder Interdisciplinary Telecommunications Department, one can conclude that there are no regulatory issues that are restraining FWA in the U.S. market.

As Professor Hatfield stated there are no regulatory issues because "all regulatory winds are on [our] back …[he] wouldn't worry about the regulatory" issues when considering the feasibility of entering the FWA market [17]. Dr. Nettleton agrees with this point of view and he also adds that from the regulatory point of view, one can do whatever is necessary to enter the market as long as the FCC guidelines are followed. All three interviewees also agree that FCC has done everything possible to try to bring small businesses into this market in order to promote competition. As Dr. Sicker mentioned in the interview, the FCC is still putting a lot of effort into promoting the entrance of small businesses into this market arena [18].

Local Policy Implications

The town of Superior, CO authorities were well aware that they do not have jurisdiction over the CPEs including antennas due to the FCC allocating authority to Home Owners Associations (HOA) across the US [19]. At this time there are three HOAs located in the Superior, each having distinctive policies regarding attaching CPEs or antennas to residential properties. In the Saddle Brooke community, any and all external antennas are prohibited [20]. In the Horizons community, external antennas are permitted as long as they are not attached to any part of the building and the antenna itself cannot extend beyond the balcony area [21]. As for the other residential properties within the Rock Creek area, there are no restrictions for putting up any kind of external antennas within the homeowner's property. The matters surrounding HOA policies and guidelines need to be considered when deploying a FWA solution that requires attaching a CPE or antenna to the residential property.

Technical Feasibility

To better determine the technical feasibility of a FWA solution, the software application PlaNET was used to model the LOS and propagation in the Superior, CO area. The model predictions illustrates that it is technically feasible as more than a majority of the Superior area would be covered with LOS transmission. In addition, a wireless site survey was conducted within the Superior area using unlicensed wireless transmission analysis tools Grasshopper, and AEROPEAK software, a wireless packet sniffer to determine a spectrum use and analysis.

Reliability

In order to effectively provide a reliable architecture, a site survey was conducted to determine the quality of service (QoS) at the receiver. QoS is determined by the signal-to-noise ratio (SNR), bit error rate (BER), and available bandwidth. The site survey concluded that the noise levels in the Superior region were extremely high, resulting in a low SNR. Furthermore, Superior has mass deployment of wireless Access Points causing tremendous amount of interference in the 802.11b bands. This in turn, increases the BER and decreases the available bandwidth.

Line-of-Sight Considerations

The PlaNET propagation model indicated that 90 percent of Superior is covered by LOS. This is acceptable for utilizing technologies such as MMDS, because it has the ability to offer near-LOS, wireless coverage. Near-LOS can only be obtained in lower frequencies, less than 10GHz, because the wavelength becomes greater as frequency is decreased; furthermore, near-LOS utilizes modulation techniques, OFDM or CDMA, that allow for enhanced signal propagation to overcome environmental and man made obstacles.

Weather and Climate Considerations

The geological positioning of Superior demonstrates some consideration resulting from the semi-arid mountainous region in which it resides. However, the yearly average precipitation rate for Colorado is 17 inches, resulting in minimal distortion of wireless signals throughout the year. The higher the frequency, the greater the distortion from rain fade and snow have on wireless signal [11]. The amount of attenuation from climate conditions dramatically decreases with decreasing frequency; therefore, the 10GHz range will have minimal attenuation from climate conditions; to illustrate, Rob Flickenger, author of "Wireless Community Networks", concluded that a one percent attenuation factor from rain must be applied to frequencies less than 10GHz [11].

Interference Considerations

Interference considerations have an enormous impact on the ability to provide a reliable connection. A site survey for the area of Superior was conducted to map the wireless concentrations with a "Grasshopper WLAN IEEE 802.11 Tester", and AEROPEAK software. The results from the grasshopper demonstrated that there was a large amount of noise interference being projected over the entire area. As noise levels increase, the signal degrades exponentially, as observed by the SNR. There are five reasons why the SNR would have such a dramatic effect on the signal quality: the transmitter input gain maybe too low, the transmitter distance maybe too far away to obtain a quality signal, environmental RF noise maybe centered near the receiver, multi-path phase cancellation is occurring at the receiver; and obstructions that reside between the transmitter and receiver [22].

In addition to PlaNET, we conducted an assessment by sniffing throughout the region for wireless AP's and traffic watches using "AEROPEAK Software". After conducting this survey, it was obviously apparent that the 802.11b spectrum was completely saturated; to illustrate, the tests indicated that there were over 100 Access Points being used causing high bit error rates and low signal to noise ratios. This is an early indication that the market price for 802.11 devices has reached the saturation point, and the situation will only get more congested from this point forward. Since QoS is highly diminished due to congestion, licensed spectrum is a more viable solution for the Superior area.

Economic Feasibility

Market Analysis

In order the accurately gauge the demand and willingness to pay for broadband in Superior we conducted a door-to-door survey. The survey focused on the customer's willingness to pay for monthly and startup costs. With 68 percent of the people surveyed willing to pay at least $30 for monthly service and 27 percent willing to pay over $50 a month for service, our survey findings show that there is a large market demand for broadband in this area. Even though incumbent DSL and cable broadband is not offered in this area, alternative forms of broadband are available. Currently 56 percent of people surveyed do not have broadband access. Of this group, 59 percent are willing to pay more than $30 for broadband access.

Besides the monthly cost of broadband, another important issue when starting an ISP is the customer startup cost. The startup cost includes equipment and installation charges. Our results show that 76 percent of the people surveyed are willing to pay more than $50 for installation. More importantly, 67 percent responded that they would rather purchase startup equipment for $200 than rent equipment for $10 a month. This helps to reduce the acquisition cost of a customer.

Acquisition Costs

For a wireless ISP, the cost of acquiring a customer will be lower than that of DSL and cable providers. This is caused by the reduced cost of network infrastructure when obtaining new customers [23]. Current acquisition costs for ISPs average about $400 [24]. This price can be reduced with customer's willingness to purchase startup equipment and self installs. Recently Bell South had a 90 percent success rate with DSL self installs [25].

Feasibility of Interdependent Factors

Scalability

One of the interdependent factors Professor Hatfield stated that must be overcome is the issue of scalability [17]. Scalability is predominately a technical and economic issue, but one cannot overlook the regulatory aspects as well. To overcome the technical issues of scalability, a microcell or cellular approach can be used. The mobile wireless communication industry is a proven model for applying the cellular concept because it can utilizes the spectrum efficiently with frequency reuse patterns and increase user capacity by employing sectoring and repeater techniques.

Backhaul is both a technical and economic issue when considering operating a FWA service. By utilizing LDMS for the backhaul from the base stations (microcells) to a Tier 1 ISP using the national transport infrastructure from Level3, both the technical and economic constraints can be overcome. LMDS has high data rates (155 Mbps) that could provide adequate speeds for backhaul and can be relatively easily deployed for a backhaul network infrastructure. More importantly it provides better cost savings compared to other backhaul access solutions such as T1, T3, fiber and satellite.

Franchise Business Model

When considering the feasibility of providing a FWA service the unsound business model is the primary economic issue that must be overcome. "This technology would seem the perfect choice for all WISPs. However, unless a service provider has a long line of investors behind them, there is very little opportunity to make a business case out of the MMDS proposition" [26]. This economic barrier can be overcome by using a franchise concept to provide FWA service. After establishing a sustainable business model, a franchise can share the startup costs and risks while expanding into different service or market areas. A prime example of a predominant service provider that effectively demonstrates the service franchise concept is McDonalds.

Multi-mode CPE

Another approach to solving the business case problem is the proposition of starting up the FWA service in the unlicensed spectrum. After establishing financial stability one could then switch to the licensed spectrum for potentially better long-term success. The key to making a successful migration from the unlicensed to the licensed spectrum is no end-user (CPE) intervention. The mobile wireless communication industry is another prime example that supports this theory, a mobile service providers requested equipment provider to develop and manufacture dual-mode and tri-mode mobile (cellular) phones.

Spectrum Availability

Having reviewed many technical, regulatory, and economic issues, and determined a preference for licensed spectrum, we come to the critical question of spectrum availability. MMDS and ITFS bands are currently underutilized in most urban areas and should nominally be available in almost any BTA at a discounted rate. Greg D. Widroe at Media Venture Partners states, "it is difficult to determine the price of buying or leasing spectrum in a service area, but a good estimate would be 25-50 cents per household" [27]. Dr. Nettleton noted the price two years ago was $3-5 per household [28], indicating the relative absence of other high value economic uses having emerged to sustain valuations of the technology bubble of the late '90s. Critically important, though, is that licensed spectrum trades in relatively large BTA's; the BTA relevant to Superior, CO, for instance, covers the entire Denver metro region and beyond. There is no evidence that current BTA license holders are willing to geographically sub-license spectrum. FCC spectrum reform policy is moving towards more aggressive sharing geographically and temporally of spectrum [29] and success in this activity and its application to MMDS frequencies is likely a pre-requisite for the success of grass-roots small fixed wireless access businesses within licensed spectrum such as the one envisioned in this paper.

V. CONCLUSION

To conclude, after analyzing the FWA environment and conducting a feasibility study on the regulatory, technical, economic and interdependent factors it, appears that a FWA solution for residential suburban areas is feasible and scalable if licensed spectrum is economically available in limited geographic areas. This report provides a definitive franchisable business solution using the MMDS licensed spectrum in a microcell approach with LMDS backhaul and multi-mode consumer premises equipment.

While we are encouraged by the evolution of technical solutions and market demand for broadband, we see this as calling for efforts on the part of policy makers and interested industry parties to foster the availability of licensable spectrum in more limited geographic areas than current BTA's.

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