Opportunities in Last Mile Wireless Access

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The growth of the Internet has spurred a number of new business ventures in a drive to push the capabilities of the "Information Superhighway". Some of these ventures have been successful; many others have not. However, all agree that the ultimate success of the overall market proposition is bounded by the ability to bridge the elusive "last mile". As the need to solve this portion of the value chain economically becomes more crucial, a wider variety of access technologies are being considered. In fact, there is a tremendous amount of activity – and confusion – associated with opportunities in wireless last mile access. We look at some of the issues associated within this arena and provide some views on potential opportunities going forward.

1. The Last Mile Problem

Since the onset of the Internet revolution, a tremendous amount of energy and funding has gone toward moving more data around to end users more seamlessly. However, the last mile remains the most important bottleneck that has stifled the overall growth of the market. While there has been significant development in terms of long haul and metropolitan area networks (MAN), efficient last mile solutions have eluded providers. The question of how to support high bandwidth requirements at affordable costs has still not been resolved with a compelling solution that could enable the significant population of dial-up users to adopt broadband. While many last mile access solutions like cable modem, DSL and DBS Satellite series have been deployed, the take rate among consumers has been far from satisfactory. Some four years after the introduction of broadband services, the current residential penetration stands at below 10%[1], a figure much lower than the earlier projected 15-20%[2]. The penetration among small businesses is also a low 15%[3] compared to the initial expectations of 40-50%. The low adoption of high-speed Internet services among small and medium enterprises is especially alarming given that currently fiber penetration is limited to only 5% of the total enterprise buildings in the US. We believe that one of the key reasons for this lower than expected broadband penetration in both residential

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[1] FCC, The Shpigler Group analysis

[2] Morgan Stanley Dean Witter, *The Internet Data Services Report: Picks and Shovels for Prospectors*

[3] FCC, International Data Corporation, Infonetics Research, Access Media International, Cisco Marketing Research, The Shpigler Group analysis

and SME market is the absence of solutions with good value proposition (high bandwidth capabilities at low costs) for end users.

Most of the currently deployed high-speed access solutions such as DSL, cable modem, direct broadcast satellite services and fiber have some associated technology or economic drawbacks. DSL suffers from technology-related distance limitations that typically make it unavailable for areas that are more than 18,000 ft from the Central Office. Meanwhile, cable modem and broadcast satellite services require significant capital investment to deliver limited bandwidth and therefore have high cost per delivered bandwidth. On the other hand, fiber delivers high bandwidth connectivity, but features very intensive capital expense and involves difficulty in obtaining rights-of-way and building rights, resulting in very low deployment levels. Furthermore, prohibitive deployment costs have largely kept fiber access out of reach for the local access market.

None of these limitations are expected to change much in the very near future. The inability of these current solutions to support high-speed residential and enterprise access needs at affordable prices has resulted in significant frustration among end users. As a result, there is a strong latent desire among millions of dial-up users for a better value proposition. For a long time, fixed wireless has been projected as a solution for the "last mile" access problems. The basic premise behind deploying broadband wireless technologies is that it uses the over-the-air transmission and therefore removes the need to deploy an alternative wireline network infrastructure to connect to an end-user. Such end-user connections are typically very costly to install and maintain. Wireless connections, when used in appropriate situations, also have the added advantage of being scalable and are therefore more amenable to the addition of new customers. Additionally, there are fewer legal and legislative restrictions on the installations. However, it should be noted that wireless solutions suffer from significant drawbacks of their own – line of sight limitations, weather effects, the need to acquire spectrum for certain approaches, and others. Nevertheless, the development of solutions in the wireless access arena offers additional choice for service providers and end users alike. We look at some of the solutions currently available in the market and their respective value propositions.

2. Wireless Access Solutions

End customers are primarily made up of two large groups: residential accounts (also including SOHO customers and small businesses) and enterprise customers (typically medium and large businesses). While the needs of each individual customer is unique, we can broadly characterize the overall ranking of key broadband requirements of each customer set as follows:

Customer Requirements in Order of Priority

Residential Requirements for Broadband	*Business Requirements for Broadband*
• **Low Cost:** The most important criteria for most residential customers is affordable access to broadband • **Average Speeds (400Kbps-1Mbps):** Most residential customers still use the Internet for checking e-mails and web surfing. These requirements are met with average speeds of 400 kbps • **Ease of Installation:** In today's environment where most providers push solutions featuring self installation, ease of installation would help attract residential customers	• **High Speeds (1 Mbps to 45 Mbps):** One of the key requirements for businesses in need of moving increasing amounts of data • **High Reliability**: Availability of 24x7 service with no interruption from environmental or other physical factors • **High Security**: Ability to conduct secure transactions • **Relatively Lower Costs**: While costs are not the most important criteria, they need to be lower than the current ILEC-provided prices

Critical to any broadband data deployment is satisfying these needs for end customers. With this in mind, we can look to the various wireless solutions available in the marketplace.

Residential Solutions

There are a number of potential access solutions geared toward serving residential customers with wireless access; the selections below represent the most viable candidates today:

- *WLAN (802.11b)*: Service providers utilize unlicensed frequency spectrum in the 2.4GHz range to deliver broadband solutions. Typical solutions provide an outdoor range of 300 feet - 1 mile. A vast coverage range indicates significant variance in deliverable speeds that vary from a low of 500 kbps to a maximum of 11Mbps.

- *WLAN Meshed Networks*: These are typical WLAN solutions extended over longer distances through ground-based meshed amplification. Other than the improved coverage, the other characteristics resemble that of the WLAN solution.

- *MMDS*: Providers utilize MMDS licensed spectrum in the 2.5 GHz frequency range. However, unlike the WLAN solution, MMDS requires use of licensed spectrum auctioned by the FCC. Currently, three large providers (Sprint, WorldCom and Nucentrix) own more than 65% of all MMDS spectrum in the US. MMDS coverage typically varies from 5 to 15 miles.

- *Wireless Local Loop:* Typically operates in the 3.5 GHz international WLL spectrum. Unlike other countries, currently the U.S. does not allow the use of 3.5 GHz for broadband access. Coverage for WLL solution ranges from 5 - 10 miles and typically involves speeds ranging from 0.5 – 4 Mbps.

- *Rooftop Mesh Solutions*: Typically operates in the unlicensed frequencies and uses a "mesh" architecture where each rooftop receiver can route data to any other receiver in its range. This allows data to flow around obstructions that would otherwise block a line-of-sight signal. A receiver simply has to have a line-of-sight to the nearest receiver, not to the main antenna. Each rooftop system has a range of 1-2 miles and supports speeds in the range of 350 - 700Kbps.

Enterprise Solutions

Some of the solutions that cater to the residential market also offer promise for enterprises as well, including WLAN and MMDS. In addition, there are other wireless solutions that come into play specifically geared toward the enterprise segment. Looking at all of them yields the following list:

- *Local Multipoint Distribution Services (LMDS)*: Providers use high frequency LMDS spectrum (28 GHz to 39 GHz) to provide high-speed broadband solutions. Given the high frequency and low wavelengths associated with the solution, the typical coverage is around 0.1 - 0.3 mile and involves speeds delivered in the range of 20 – 100 Mbps.

- *Free Space Optics*: Also called "Fiberless Optics" solution. Providers utilize lasers to deliver fiber-like broadband speeds. Given the high frequencies of laser, the speeds delivered are in the range of 100 Mbps to 1 Gbps. However, the coverage is limited to only 0.1 - 0.2 mile and requires perfect line of sight.

- *WLAN (802.11b)*: Service providers utilize unlicensed frequency spectrum in the 2.4 GHz range to deliver broadband solutions. The solution is very similar to the solution described earlier in the residential section. However, the number of users served is significantly lower, thereby enabling high bandwidth capabilities to business users.

- *WLAN (802.11a)*: Service providers utilize unlicensed frequency spectrum in the 5.0 GHz range to deliver broadband solutions. Given the higher frequency, the coverage range is very limited but does not suffer from other problems such as overcrowded space and interference from other carriers and household equipment that are typically associated with 2.4 GHz spectrum.

- *MMDS:* Licensed frequency in the 2.5 GHz spectrum is also being utilized by service providers to offer high-speed Internet access to SME customers. Unlike the residential case, the range of these solutions is limited to offer higher capacity to business customers.

3. Comparing the Solutions

Having looked at the solutions, we now turn to evaluating the opportunities each carries to solving customer needs in the marketplace:

Residential Market

Earlier we looked at the requirements customers have regarding broadband access solutions. The performance and economics of these different solutions is highly dependent on the deployment environment. In order to compare "apples with apples" we have selected a single hypothetical environment for all residential deployments. For the purpose of this analysis, we have analyzed a residential environment with a household density of 800

households (HH) per square mile, a normal line of sight (LoS) environment of 60%, and a 10% market penetration. Given these assumptions, we see the following comparison for residential solutions:

Comparative Analysis of Last Mile Residential Wireless Solutions Across Customer Requirements

		Wireless LAN	***MMDS***	***Wireless LAN Meshed Network***	***Wireless Local Loop***	***Rooftop Mesh Solutions***
Increasing Importance to Customers ▲	***Capital Costs***	*CapEx Items* •Base Station/ Access Point •Hub •CPE *Costs per Sub* **•$630**	*CapEx Items* •License •Base Station •CPE *Costs per Sub* **•$900**	*CapEx Items* •Access Point •CPE *Costs per Sub* **•$450**	*CapEx Items* •Access Point •CPE *Costs per Sub* **•$1200**	*CapEx Items* •Access Point Costs •CPE *Costs per Sub* **•$930**
	Potential Speeds	•Current residential speeds (higher coverage and therefore lower speeds) are limited to 400-800 kbps	•Current speeds limited to 600-800kbps •Speeds to increase with better modulation techniques	•Current speeds are limited to 200 – 400 kbps due to sharing of capacity between access points •Speeds are expected to increase in course to 3 Mbps	•While WLL solutions can provide high data rates up to 4 Mbps, the more typical residential solutions provide speeds in the range of 600 kbps to 1 Mbps	•The actual throughput an end-user receives will depend on the number of hops they are from the main receiver. Typical data speeds range from 384 -768 kbps
	Ease of Installation	•Very easy to install •Occasional software related issues	•Difficult •Requires LoS and therefore antenna needs to be professionally installed on roof –top •2G systems do not require LoS	•Easy to install but require intelligent programming •Occasional software related issues	•Difficult •Requires LoS and therefore antenna needs to be professionally installed on roof –top	•Difficult •Requires LoS and therefore antenna needs to be professionally installed on roof –top

The above cost comparisons are limited to capital expenses. Also of concern would be operating expenses, which typically include backhaul, maintenance and tower expenses for installation of radios and antennas. While maintenance expenses are mostly similar across all of the wireless solutions, backhaul expenses and tower expenses show variance between different solutions. WLAN meshed solutions require minimum backhaul while LoS dependent solutions require significant tower expenses due to the greater height of MMDS towers and roof-top installations. Also, the above bandwidth estimates are largely for average environments only. The actual throughput received by an end-user will depend on the number of hops they are from the main receiver, how the network is statistically multiplexed, and the flow regulation settings.

Evaluating these different solutions side-by-side and comparing them against the needs of residential users enables us to pick the best last mile wireless solution for residential purposes. For users that place significant importance

on cost reduction, meshed WLAN solutions appear to be the optimal solution. On the other hand, the WLL solution appears to be more appropriate for residential users that require good speeds and are willing to pay a bit higher price for such access. Also, while MMDS solution attractiveness has increased significantly with the arrival of second generation of non-LoS equipment, the limited availability of MMDS licenses proves a major hurdle to widespread "last mile" deployment among service providers. Overall, there is more than one winner and the most optimal solution for a given environment can be established only after a rigorous demand and "need" analysis.

Enterprise Market

Similarly, we have looked at the differences associated with solutions targeted at the enterprise market. To compare across wireless platforms, we assume an urban setting with a density of 50 buildings per square mile, 1,500 businesses per square mile, a normal LoS environment of 45%, and a market penetration of 20%. Given these assumptions, we see the following comparison for enterprise solutions:

Comparative Analysis of Last Mile Enterprise Wireless Solutions Across Customer Requirements

		LMDS	***Free Space Optics***	***Wireless LAN (802.11a)***	***Wireless LAN (802.11b)***	***MMDS***
Increasing Importance to Customers ▲	***Potential Speeds***	•Provides speeds as high as 455 Mbps. More common speeds in the range of 45 – 155 Mbps	•Current speeds in the range of 10 Mbps - 0.5 Gbps •New 1 Gbps systems to be deployed by 2003	•Peak speeds in the range of 54 Mbps for enterprise users with average throughput close to 28 Mbps	•Peak speeds in the range of 11 Mbps but average throughput around 2 - 5 Mbps	•Peak speeds in the range of 20 Mbps but average throughput around 5 - 10 Mbps
	Network Reliability	•Low Reliability •Significantly affected by rain and weather conditions	•Medium to High Reliability •Not heavily affected by rain •Fog significantly affects performance	•Low Reliability •Performance significantly affected by weather conditions, rain and LoS	•Medium Reliability •Not heavily affected by LoS and weather conditions •Interference is a major issue	•Low to Medium Reliability •Affected by LoS, weather conditions and foliage
	Security	•Security issues have been well addressed	•Most security issues have been well addressed	•Security remains a big concern •Less of a concern than 802.11b solutions	•Security is a major concern	•Most security issues have been well addressed but remains a concern
	Capital Costs	*CapEx Items* •License •Base Station •Bldg Receiver •CPE *Costs per Business Sub* **•$4,560**	*CapEx Items* •Optics •EDFA •WDM/Filters •CPE *Costs per Business Sub* **•$11,050**	*CapEx Items* •Access Point •CPE *Costs per Business Sub* **•$2,840**	*CapEx Items* •Access Point •CPE *Costs per Business Sub* **•$1,310**	*CapEx Items* •License •Access Point •CPE *Costs per Business Sub* **• $2,285**

As in the residential case, the analysis focuses on the capital costs of different solutions. While the operating costs are similar, there are some differences due to the rooftop rights associated with LMDS solutions. Typically, rooftop rights in urban environments range from $25,000 to $50,000 per year.

Different solutions offer differing opportunities and challenges. While Free Space Optics provides very high speeds, fog can affect overall reliability. Similarly, while MMDS and WLAN 802.11b solutions provide moderate reliability, low speeds and security issues associated with the technology have prevented widespread adoption. The best solution could well be a hybrid of more than one solution. Some providers have tried to install a hybrid LMDS and Free Space Optics solution and the initial feedback appears to be positive. Similarly, some other providers are looking at an MMDS and LMDS hybrid solution, the former being used for coverage while the latter for addressing capacity issues. Overall, as in the residential case, the best solution depends upon the customer's needs. Free Space Optics potentially is the optimal wireless solution for customers with stringent security, reliability (except for markets with high fog) and fiber-like high-speed requirements. On the other hand, WLAN 802.11b is a good solution for customers looking for reasonable bandwidths (1-11Mbps) at low price points.

4. Conclusion

In addition to the solutions discussed here, there are a number of other solutions that hold significant potential and meet the key requirements of both the enterprise and residential users. These include the 802.16 spectrum-related solutions and the ultra wideband technology solutions operating in the 3.1-10 GHz spectrum. However, most of these solutions are either in developmental or trial stages and commercial deployment is highly dependent on successful trial results. As time progresses and more is known about these applications, these issues will need to be rechecked.

Customization is the key for wireless residential and enterprise solutions. The performance of these solutions is significantly affected by native environmental factors such as available LoS, weather conditions, fog and topology. As a result, each technology needs to be evaluated in detail for every deployment environment. In this white paper we have analyzed deployments only in one environment - suburban for residential and urban for enterprise users. Any change in this deployment environment has the potential to significantly change the economics associated with each solution.

As discussed previously, hybrid solutions offer much appeal in the market and should be considered. As the competitive marketplace becomes more demanding, we are seeing more attention being paid to solutions involving more than one application, like Free Space Optics/LMDS as well as LMDS/MMDS deployments. Furthermore, creative mesh solutions involving "daisy-chain" 802.11 deployments are beginning to gain momentum. The moral of the story is centered on being flexible in approach when considering a deployment strategy.

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