Wireless Options for Providing Internet Services to Rural America

Jessica Codr, jmc5@cec.wustl.edu, under guidance of Dr. Raj Jain (A survey paper written under guidance of Prof. Raj Jain)

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ABSTRACT:

An alternative to the high prices and inconvenience of extending wires to vastly spaced rural residents is wireless Internet service. Alternatives such as Wi-Fi, WiMAX, satellites, and balloons give hope to rural areas desperate for quality Internet access. Other alternatives such as distributed systems have been tried and failed while research stage options such as 802.22 and laser link technologies offer hope for even higher quality of service. In this paper, I examine all of these wireless alternatives and discuss the progress that has been made towards providing quality Internet service to rural communities as well as the work that remains to be done. I begin in section 1 with an introduction and examine the need for wireless access in rural areas, the obstacles to supplying this access, and the technologies discussed in this paper. In sections 2-5, I examine the wireless options of Wi-Fi, WiMAX, Satellites, and Balloons along with the strengths and weaknesses of each and how each technology has been implemented in rural communities. Section 6 presents brief information on distributed systems, 802.22, and laser link technologies, while section 7 wraps up with discussion of the progress made towards proving wireless internet to rural communities, the work that remains to be done, and the technologies addressed in the rest of the paper.

KEYWORDS:

wireless Internet, wireless network, farms, rural America, rural United States, digital divide, Wi-Fi, 802.11, WiMAX, 802.16, satellites, balloons, distributed systems, MMDS, 802.22, laser link, BridgeMAXX, Digital Bridge, Agristar, Intellicom, MyBlueDish, Space Data

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Introduction

Many residents of urban areas receive quality wired Internet services that they take for granted. However, the vast distances that wires must cover to make such services available to rural communities prevent Internet service providers from supplying the same services to these rural areas. An alternative to the high prices and inconvenience of extending wires to vastly spaced rural residents is wireless Internet service. The purpose of this paper is to discuss the wireless options available to residents of rural America. In this introduction section, we discuss the need for wireless services in section 1.1, the difficulties in providing these services in section 1.2, and the technologies discussed in the remainder of the paper in section 1.3.

1.1. Why We Need Wireless in Rural Areas

Rural America needs network and Internet access of some kind. Not only does network access give rural residents the basic web-browsing, online shopping, and information gathering privileges many of the rest of us enjoy, but networks could also be used within the farmlands of rural America. Farmers can use networked systems to monitor crops and animals or even operate certain equipment from a distance, saving farmers from the time and inconvenience it can take to monitor land in person or control all devices manually [Coo07]. People living in remote areas may also need connection to a network through which they can receive important weather and safety information, as Casey Perry of the Wisconsin Troopers Association points out [Per08].

Many of us who live in large cities or urban areas take these kinds of network accesses for granted, but for others, high-speed reliable Internet access is a luxury they can only dream of. In rural America, basic Internet access is often exceedingly slow and/or expensive at best and non-existent at worst [Zha04]. Difficulties in installing and maintaining long lengths of wire among the sparse populations of rural areas make wired connections unappealing. Wireless is a potentially great way to get rural America the high-speed Internet it craves.

1.2. Obstacles We Must Overcome to Get Wireless in Rural Areas

Despite all the possible advantages of wireless alternatives in rural America, many rural areas are still without wireless access. Sometimes this is due simply to limitations of technology. Residences can be tens of miles apart in rural areas, making it difficult to propagate a signal to many homes around a base station [Schl06].

The fact that homes are so sparse in rural areas also hinders companies from making the investments necessary to supply rural areas with quality Internet service, even when technology exists to make such service possible. As one can see from the illustration of Figure 1, with so few potential customers in rural areas and so many packed closely together in cities, it is usually much more profitable to supply service to the densely populated areas rather than the spread-out farmers who would love to have the service that others enjoy [Zha04][Fit06][Cti06]. Yet as we shall see, there are a few companies who recognize the technology needs of rural America and seek to fill them[Myb08][Agr08][Schm06][Blo05][Hig08][Car08]. Such companies may use any of the wireless alternatives discussed in this paper.

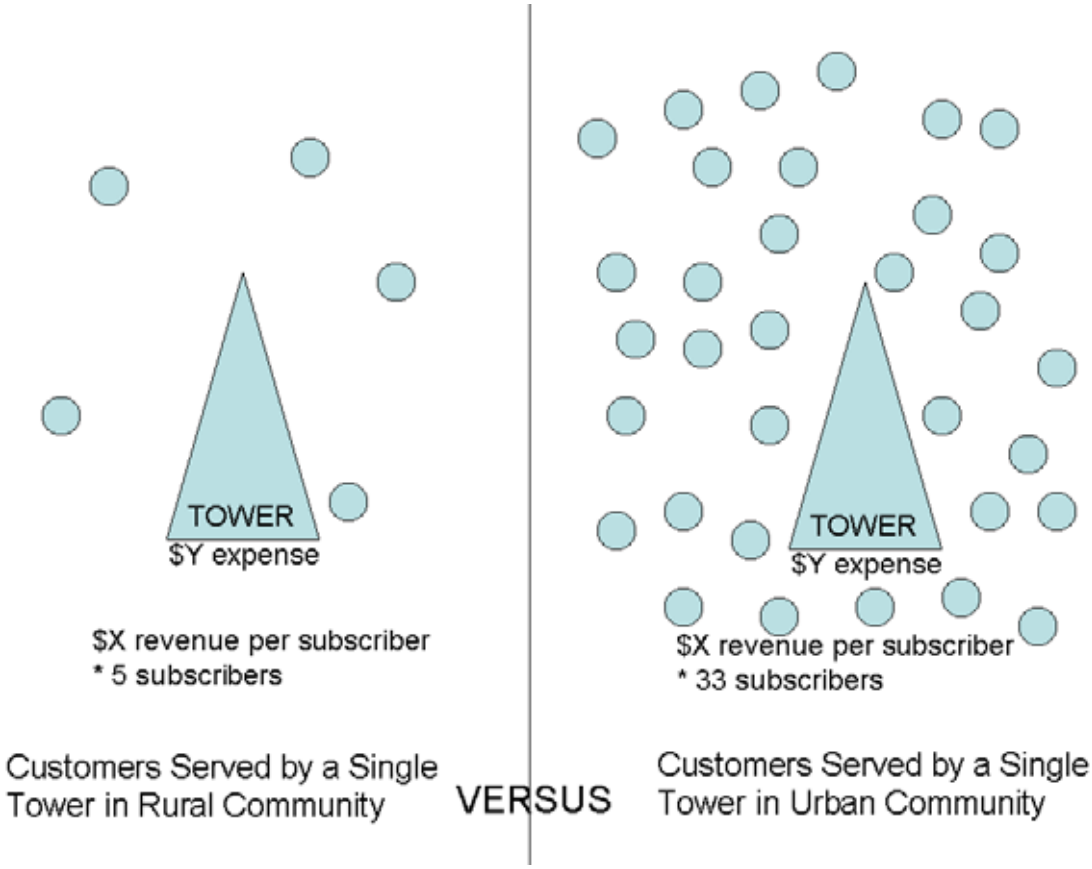

Figure 1 The urban appeal

1.3. Summary of Technologies to be Discussed

Each alternative has its own unique approach to serving the rural communities, each of which comes with its own advantages and disadvantages. Different service providers may choose different alternatives, and over the past few years, the use of certain alternatives has increased or declined as technology has changed. Some alternatives are old news while others are still in development. In this paper, I will define and discuss four major wireless alternatives that are used or have been used in rural America, namely Wi-Fi (Wireless Fidelity), WiMAX (Worldwide Interoperability for Microwave Access)-like services, satellites, and balloons. I will also briefly discuss other wireless technologies used or currently under development including 802.22, Laser Link, and Distributed Systems. Discussion will focus on the advantages and disadvantages of each approach as well as past, present, and/or future uses of the approach in rural America. I begin the discussion with a look at Wi-Fi, the oldest

of the primary technologies I discuss.

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2. Wi-Fi

Perhaps the starting point of efforts to bring Internet access to rural America, Wi-Fi is an alliance that certifies wireless devices based on the IEEE (Institute of Electrical and Electronics Engineers) 802.11 standard. The standard was first introduced in 1997, but this initial standard allowed for capacities of 1 or 2 Mbps and is no longer used by the wireless community. In 1999, IEEE 802.11a and 802.11b were introduced, allowing for 54 Mbps in a 5 GHz band and 11 Mbps in a 2.4 GHz band respectively [Jai08a]. 802.11a has a range of about 100 feet and 802.11b can cover up to 350 feet outdoors and 150 feet indoors [Hay07].

It was at the time that 802.11a and 802.11b were introduced that the Wi-Fi alliance formed and started its work certifying wireless devices [Wif08]. Since that time, 802.11 has been expanded further to include standards such as 802.11g, added in 2003 to allow for 54 Mbps transmissions in the 2.4 GHz band at ranges of 350 ft outdoors and 150 feet indoors [Hay07]; 802.11e, added in 2005 for quality of service requirements; 802.11i, added in 2004 or enhanced security; 802.11n, added or higher throughput of up to 200 Mbps; and 802.11s, added for Mesh Networks [Jai08a].

Wi-Fi itself has its own set of certification requirements based on the 802.11 standards. All Wi-Fi approved single mode devices must be compliant with standards 802.11a, 802.11b, and 802.11g. Dual mode products must comply with 802.11b and 802.11g, and multi-band devices must use the 2.4 GHz or 5 GHz spectrums. Devices must have WPA (Wi-Fi Protected Access) or WPA2 security and use EAP (Extensible Authentication Protocol). Other option services for Wi-Fi devices include support for 802.11n, security feature set-up, multimedia transfer, power save modes for multimedia, and details about performance in a converged handset and interaction with other Wi-Fi devices [Wif08].

In the remainder of this section, I discuss the strengths of Wi-Fi in rural areas (2.1), the weaknesses of Wi-Fi in rural areas (2.2), and the actual implementations of Wi-Fi technologies in rural America (2.3).

2.1. Strengths of Wi-Fi in Rural Areas

Perhaps the most important thing about Wi-Fi is that it is wireless. Citizens of rural towns and areas might not initially care if their Internet access is wired or wireless as long as they get access. Before Wi-Fi came along, wired was the only option, but it was not a very cost effective option for rural communities due to the remote areas to which wires would need to be extended and the long distances to be covered. When Wi-Fi came along, it presented a relatively cheap alternative for rural America to access the Internet.

Wi-Fi can also be used without licensing if, for example, spread spectrum is used [Man01]. This allows providers to avoid red tape and provide the service more easily to their rural customers.

2.2. Weaknesses of Wi-Fi in Rural Areas

Although Wi-Fi was an exciting improvement over wired technologies when it came to connecting rural America to the Internet, it still lacked the range and power needed to make it ideal for serving the rural community.

Some people were also concerned with the security features of Wi-Fi. Researchers at the North Carolina A&T State University School of Technology found that Wi-Fi networks could be at risk when they were first introduced

simply because there weren't as many widely used security protocols for protecting the data, but as long as proper security measures were taken, users could be assured that their data was as safe as possible [Hay07].

2.3. Use of Wi-Fi in Rural Areas

Because Wi-Fi lacked power and range, yet was the first available wireless Internet service, it had limited use and acceptance in rural America [Coo07][Zha04][Hay07]. Some companies jumped at the chance to use this new wireless technology, and some even decided it was economical enough to use in rural areas. Wi-Fi was their first real opportunity to make quality Internet available to rural America. A real example of such a company is Columbia Energy of the Columbia Rural Electric Association. Columbia Energy provides Internet services to homes and businesses and gives farmers access to a network they can use to monitor irrigation, all through use of Wi-Fi technology. The service is centered in Walla Walla County, Washington, where a series of towers each with a 30 mile range were set up to cover 1500 square miles. Subscribers can receive service ranging from 256 kbps to 1.5 Mbps at costs ranging from $39.95 to $259.95 per month [Coo07].

To help encourage those who weren't as anxious to use Wi-Fi as Columbia Energy was, Mingliu Zhang and Richard S. Wolff from Montana State University conducted research showing that Wi-Fi could be "financially viable" in the rural area they studied [Zha04]. Their paper focuses on a model of using Wi-Fi through beam forming antennas in Gallatin County, a rural area of Montana and shows that although there is a much larger economical benefit to companies that provide Wi-Fi service to large cities, providing Wi-Fi in rural areas can still be worth it. The previously mentioned research at North Carolina's A&T State University also showed that Wi-Fi had a lot of potential for use as a secure and reliable option for rural communities [Hay07]. Haywood, Brown, and Dunn's research paper also discussed the work of PlaceLab to make it easy for users to connect to secure Wi-Fi networks and to raise awareness about where these networks are needed.

Despite the fact that Wi-Fi seemed better suited for densely populated communities, many people were excited about its prospects for rural America and saw a lot of promise in using Wi-Fi to connect rural areas when it first appeared on the market. However, once more powerful technologies such as WiMAX and satellites came along, Wi-Fi was replaced in rural America.

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3. WiMAX and BridgeMAXX

After Wi-Fi came WiMAX, a farther reaching wireless technology based on the IEEE 802.16 standard presented in 2004 and 2005 [Jai08b]. Like Wi-Fi, WiMAX technology is openly available and is actually a group that approves devices as supporting WiMAX technology. WiMAX reduces the 802.16 standard to a smaller set of requirements. WiMAX has data rates as high as 70 Mbps and can reach up to 50 kms or just over 30 miles. WiMAX is also highly mobile whereas Wi-Fi has almost no mobility, and provides excellent security and non-line-of-site services [Wim08]. Also, WiMAX can operate on any of many different bands [Jai08b]. As Paul Davidson of USA Today states, "WiMAX is like Wi-Fi… on steroids" [Dav04]. WiMAX is also compatible with European standards of its same nature, something that Wi-Fi cannot claim [Cur05].

From WiMAX spawned many WiMAX-like services, including BridgeMAXX, a wireless service provided by the company Digital Bridge. BridgeMAXX uses towers that cover only a 5 mile radius, but focuses on providing WiMAX services to rural areas in the USA [Digi08].

In the remainder of this section, I discuss the strengths of WiMAX (3.1), weakness of WiMAX (3.2), the initial response of ISPs (Internet service providers) to WiMAX (3.3), and the implementation of WiMAX-like technology of BridgeMAXX by Digital Bridge (3.4).

3.1. Strengths in of WiMAX in Rural Areas

WiMAX shares Wi-Fi's strength of not requiring expensive wires and cables and of allowing for even cheaper use of unlicensed spectrum. Plus, WiMAX provides additional range. Wi-Fi provides coverage of kms, but WiMAX offers a range of tens of kms [Jai08b]. An increase in range is particularly important in the densely populated areas of rural America since the number of people covered by a single tower is rather small compared to an urban area no matter what the range of the tower and having a tower that increases the number of households serves cuts down dramatically on costs and encourages service providers to establish themselves in rural communities. Just like Wi-Fi, WiMAX is an economically feasible option for rural America even if it doesn't yield the profits in rural areas that it yields in urban areas. WiMAX also offers data rates higher than 802.11a, 802.11b, and 802.11 g, though not as high as the fastest Wi-Fi services of 802.11n [Wim08][Jai08b]. Table 1 below summarizes the differences in speed and range between Wi-Fi and WiMAX, as well as the differences from the satellite and balloon technologies yet to be discussed.

3.2. Weaknesses of WiMAX in Rural Areas

Even though WiMAX is economically feasible, it is still potentially expensive enough to install and maintain with little enough payback in rural areas to keep many service providers from using it in rural America. Even though WiMAX is better equipped to serve rural America than Wi-Fi, WiMAX is also more expensive to install [San05]. Thus, even companies that were willing to provide wireless service to rural America were not necessary willing to pay the extra money for the improvement of WiMAX when they felt that Wi-Fi service was sufficient [San05].

Because of the costs of WiMAX, companies that own licensed spectrum aren't very likely to make the investment in rural areas. Even though some unlicensed spectrum was still available for use in rural areas, much of the spectrum goes unused, causing more limited service for rural areas. Use of unlicensed spectrum causes problems with collision responses and data lose that are not as prevalent with licensed spectrum [San05].

Table 1 Comparison of wireless options by range and power

Comparison of Four Major Rural Wireless Options

Technology	Data Rate	Coverage**
Wi-Fi	11 or 54 Mbps; <= 200 Mbps*	100-1000 ft; < 10 km
WiMAX	<= 70 Mbps	<= 50 km
Satellites	256 kbps – 1.5 Mbps	40% of earth
Balloons	(unsure)	40 cell towers

*Wi-Fi typically has a rate of 11 or 54 Mbps (802.11a,b,g), but rates can get as high as 200 Mbps for 802.11n.

**Coverage range of a single tower or device; For Wi-Fi, one source cites ranges only up to 1000ft, while another gives a range of kms.

3.3. Initial Responses to WiMAX

Because WiMAX is more expensive than Wi-Fi, some companies felt older technologies worked fine and didn't want to switch to WiMAX, for example, Prairie iNet. However, many other companies were very excited when WiMAX came out and anxious to use it in rural areas [San05]. Thus, when WiMAX first emerged, providers serving rural America were split between embracing and rejecting it. It is mostly the smaller companies already devoted to providing wireless service specifically to rural America that embraced WiMAX [Cur05].

In response to the lack of willingness of many service providers to provide any sort of acceptable Internet service to rural America, Phillip J. Curtiss and Kelson L. Colbo of InfoMine of the Rockies, Inc. wrote a report presenting the real world plight of businesses in the small farming community of Galen, Montana [Cur05]. Companies desire fast, reliable Internet access, but due to the sparse population of the area, they are caught on the wrong side of the "digital divide" as ISPs choose to service larger communities over them. Although this rural Montanan town has some form of Internet access, it is outdated, slow, and over-used. Curtiss and Colbo suggest that if the many different types of organizations and people, including universities, hospitals, and banks, who desire Internet access throughout the area could rally together and demand better Internet service, providers could be motivated to use technology such as WiMAX to meet the rural demands for wireless access.

By carefully placing WiMAX towers to maximize the number of people serviced, companies can find use of WiMAX in rural areas quite feasible. In their study, Curtiss and Colbo estimated that a company could establish WiMAX to service three relatively sparsely populated communities at an overall initial cost of $321,132 and monthly recurring cost of $16,650 for things such as space rental, engineering, and marketing. The recurring monthly revenue for the company from the service would be $403,813.60 according to the researchers' calculations. Thus, Curtiss and Colbo would argue, it is economically feasible for an ISP to use WiMAX in sparsely populated areas when the proper planning is done [Cur05].

3.4. Digital Bridge and the use of BridgeMAXX in Rural America

Some companies choose to heed such pleas for use of WiMAX in rural areas and devote themselves fully to serving the rural community through use of WiMAX-like services. One such company is Digital Bridge, which uses its WiMAX based BridgeMAXX service in rural towns such as Rexburg, Idaho and Missoula, Montana and just recently launched its technology in the tiny town of Appomattox, VA in late January 2008 [Digi08][Gen08]. Before BridgeMAXX came along, Appomattox was without DSL or cable Internet access. The service costs Appomattox residents only $28.99 per month. Digitalbridge.com advertises speed of up to 3 MBps, and assures customers that BridgeMAXX is reliable and mobile and has security advantages over Wi-Fi [Digi08].

The populations of Rexburg and Missoula are about 27,000 and 57,000 [Epo08], giving BridgeMAXX a decent number of households to serve in these communities. However, Appomattox has a population of just over 1700 [Epo08], making the service provided there a perfect example of how WiMAX-based technology can serve particularly small communities. Yet as exciting as this type of WiMAX can be for rural areas, there are still more exciting possibilities for providing wireless services to rural communities.

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4. Satellites

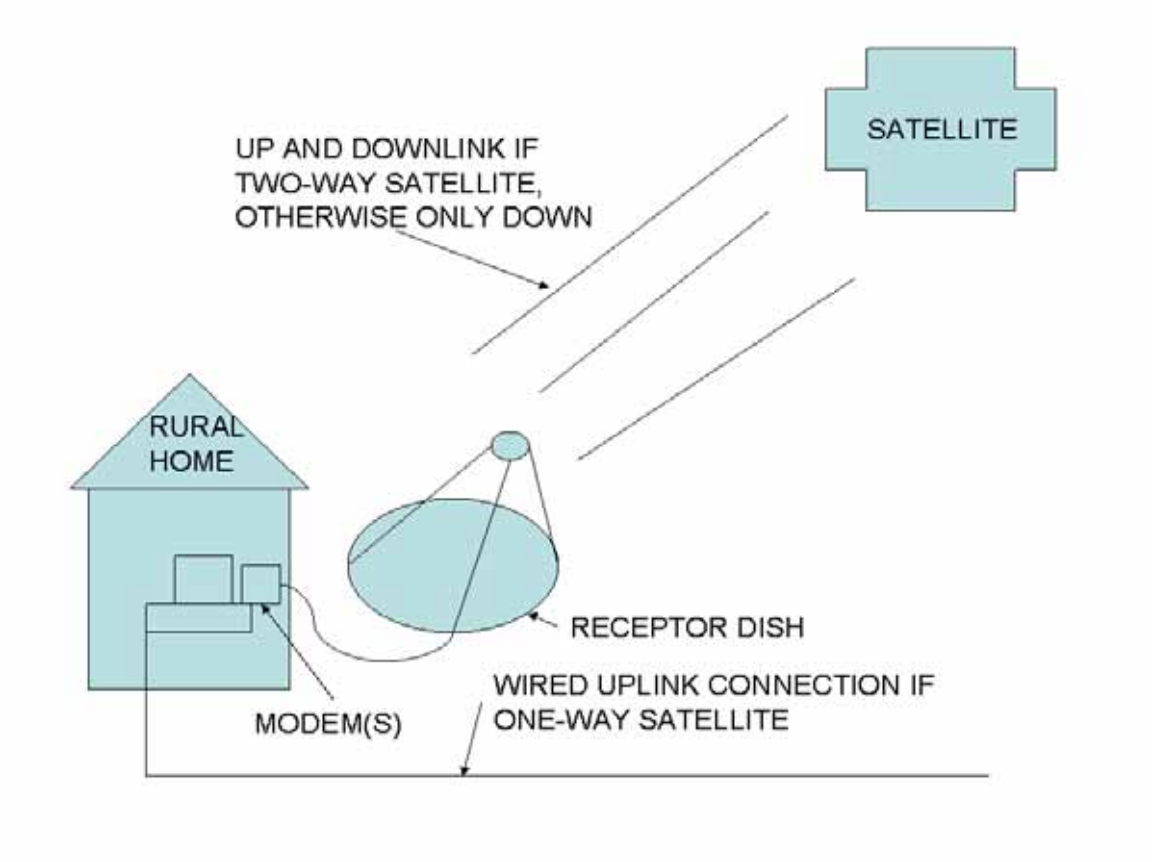

Figure 2 Satellite service

One such possibility is the use of satellites to carry wireless signals through rural areas. In this technological break-through, satellites orbiting above serve as wireless transmitters and possibly also receivers. As seen in Figure 2, signals propagate from the satellites to receptor dishes approximately two by three feet in size mounted by users [Man01]. Coaxial cable then connects the dish to a modem used to get the data to the user's computer. In a two way system, signals also propagate from a second modem, to the receptor dishes, and back to satellites. In a one way system, a different medium such as wired dial-up is used when the user needs to transmit data [Man01][How08]. Thus, in a one-way system, the uplink speed is slower, but it is usually the downlink speed that needs to be particularly fast. In general, one way satellite access provides faster, more reliable download access, making it potentially preferable despite the fact that the uplink may tie up phone lines. One way satellite access also lacks Federal Communications Commission regulation [Lon05]. Two-way access typically has about 5000 channels on which data can be transmitted [How08].

In addition to the choice between one-way and two-way satellite communication, there are options about the type of satellites used in the communication. The two main types of satellites are GEOs and LEOs. GEOs, or geosynchronous earth orbit satellites, maintain the same location relative to earth. About 40% of earth can be covered by a single GEO and receptor dishes must have clear line of sight to the location of the satellite. LEOs, or low earth orbit satellites, orbit the earth at an altitude of 450-700 miles. A set of LEOs offers coverage to the entire surface of earth at any given time, though since the satellites constantly change their position relative to earth, the satellite covering a particular location can change by the second [Man01].

The remainder of this section presents the strengths of satellite use (4.1), the weaknesses of satellite use (4.2), general companies that provide satellite-based internet access (4.3), and the specific efforts of Agristar to provide satellite access to rural America (4.4).

4.1. Strengths of Satellites in Rural Areas

The greatest strength of using satellites to access the Internet in rural America is that satellites can be used to

access the Internet from anywhere without having to build or set up additional base stations or access points to serve sparsely populated areas. A single satellite network can service many different communities in rural and urban areas. Service providers can service much larger populations with a single satellite than they could with a single base station. Service providers don't have to pay the cost of establishing base stations for each rural area and so service providers require no additional costs of adding stations that will serve a relatively low number of customers, meaning the financial gain for providing Internet to rural areas via satellite are greater than those of providing Wi-Fi or WiMAX service to rural areas [Man01][How08].

4.2. Weaknesses of Satellites in Rural Areas

Despite the great financial advantage to using satellites to provide Internet to rural areas, there are potential technical difficulties to using satellites in rural areas. For example, reception dishes require a clear line of sight to the sky without obstructions from things such as trees or bad weather [Man01][How08]. Stationary obstacles like trees are usually avoidable, but can still make dish placement difficult. Weather factors like rain and snow can also interrupt service and are unavoidable.

Getting the satellites into space and keeping them in orbit is also difficult [Man01]. This can require a fair amount of planning and additional money. It can also be difficult to maintain the satellites; they are not as easily accessible for repairs as are towers on the ground.

Finally, even though satellites are a great speed-up over dial-up, they still aren't as fast as DSL or cable; some users might want even faster access than the 256 kbps to 1.5 Mbps download rates that satellites can provide [Lon05].

4.3. Companies Providing Satellite Internet Service

Several Internet service providers use and advertise satellite service, some specifically for rural areas. Well known providers of two-way satellite service include Tachyon, Teledesic, Intellicom, Pegasus Express, and Starband [Lon05][Man01][How08]. Tachyon uses a satellite technology called VSAT that uses an antenna with a diameter of 1.8 to 2.4 meters and modem-like device the size of a desktop computer [Man01]. Tachyon also uses Tachyon Access Points (TAPs) to relay signals to its satellites. The ISP A+Net uses the Tachyon satellite network to provide service at a set-up cost of $995 for establishing a TAP with the A+Net Setup [Man01].

The Fremont, CA-based Intellicom company primarily services schools and companies in Illinois including University of Illinois at Urbana-Champaign ad the Marshall Community Unit School District. Intellicom can set up its system for $33,000 with a $1700 monthly fee for download speeds of 2 Mbps and 66 Kbps for upload. These Intellicom systems also service the rural town of Marshall, IL, with receiver dishes installed at the town's high school and elementary school [Man01].

There are also companies that aim specifically at serving individuals, for example MyBlueDish, which provides 1.5 Mbps download speeds almost anywhere in the U.S. for $49.95 per month [Myb08]. MyBlueDish claims to use smaller dishes than other satellite providers and specifically points out that their service is great for rural America.

4.4. Agristar and the Targeting of Rural America with Satellite Technology

MyBlueDish and other companies such as Agristar Global Networks also specifically target rural America for their satellite-based Internet service [Agr08]. As one can tell by their name, Agristar specifically focuses on serving rural America. They claim on their website that "Only Agristar Global Networks is dedicated to connecting leading agricultural operations worldwide. And only Agristar Global Networks provides a high-speed communications system specifically designed to deliver the types innovative business programs and services that farmers, ranchers, and agribusinesses need to excel in today's agricultural industry" [Agr08]. Agristar offers service to homes and small farm offices at an initial installation cost of $299 and a monthly fee of $59.95 for 1

simultaneous user with a 169 MB load limit, 22 TCP/IP (Transmission Control Protocol/ Internet Protocol) connections, and 50kbps recovery rate or a monthly fee $69.95 for up to two simultaneous users with a 350 MB load limit, 30 TCP/IP connections, and 56 kbps recovery rate. Agristar also offers many options for large farms and businesses, with their most expensive offering serving up to 10 simultaneous users with downloads of up to 2 Mbps and uploads up to 1 Mbps. This service costs $399.95 per month, plus the initial $1,875 set-up fee [Agr08].

As one can see, there are many companies providing and using satellite service for rural areas, but there are still issues with satellites, such as launching the satellites, that can be overcome with the use of another rural wireless alternative: balloons.

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5. Balloons

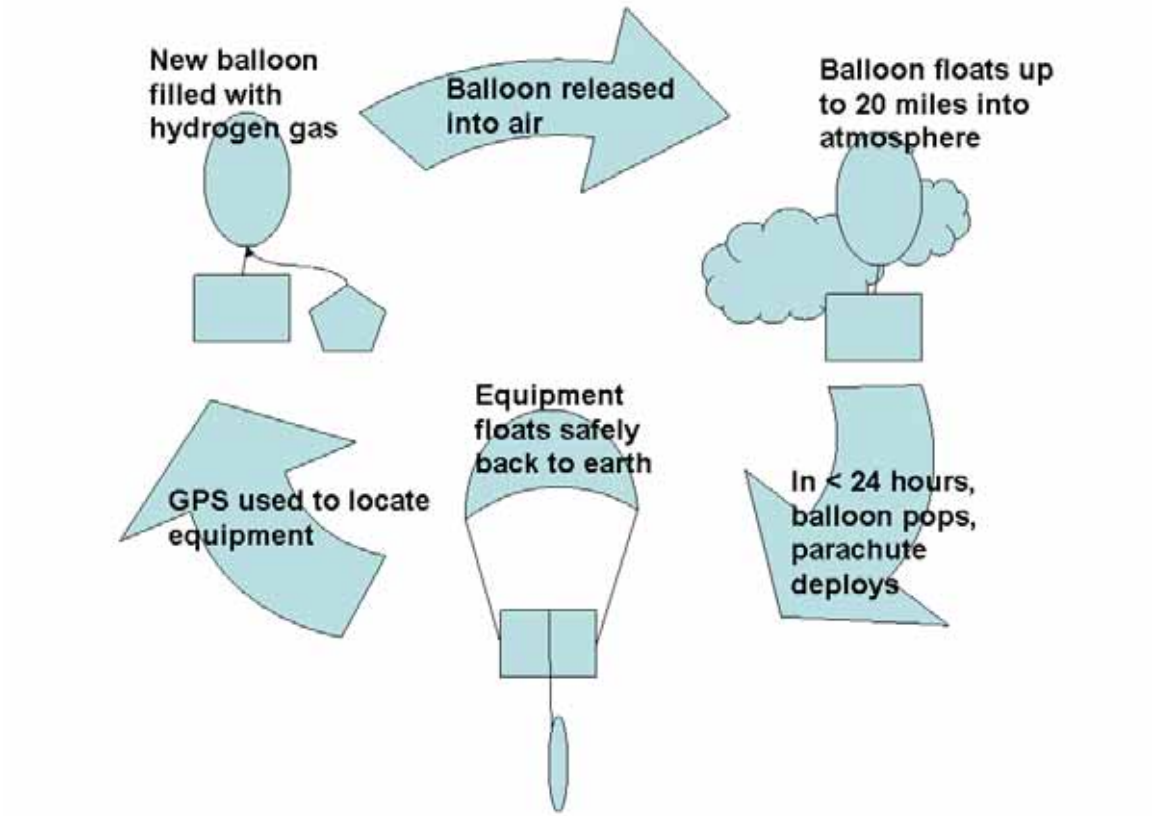

Figure 3 The balloon cycle

Another wireless service method in the spirit of the use of satellites launched into space is to use balloons lifted above the earth. Instead of using satellites in space to send and receive signals, balloons would float up to the edge of space carrying equipment to send and receive wireless Internet or cell phone signals [Amo08][Saf08]. The equipment could be Wi-Fi based, but would reach customers in a much larger area than traditional Wi-Fi towers [Digg08]. In the most well-known use of balloons to provide wireless Internet, a balloon carries up the equipment and then once a day, the balloon pops due to the thinner air where it hovers. The equipment drifts back to the ground carried by a parachute. Balloons must be refilled and released again once the equipment reaches the ground. Companies may hire people in rural areas where the balloons come down the refill them with hydrogen

and release them back into space every evening [Amo08][Saf08]. This cycle of equipment release and recovery is illustrated in Figure 3.

In the remainder of this section, I discuss the strengths of using balloons for wireless access (5.1), the weakness of balloon usage (5.2), and the details of the use of balloons by service provider Space Data (5.3).

5.1. Strengths of Balloons in Rural Areas

Balloons share satellites' advantage of being able to service a much larger area than wireless towers and thus not suffering as much lose from providing service to sparsely populated. In fact, balloon Internet company Space Data states that one balloon can cover the same area that 40 cell towers can [Amo08][Saf08]. These balloons then also do not require the construction of any sort of towers and thus are relatively non-obtrusive [Amo08].

An additional advantage of balloons over satellites is that balloons they do not require as carefully calculated or technical launches: the balloons are simply filled with hydrogen and released into the air [Amo08]. The equipment carried by the balloons is also easier to maintain and repair than satellites since the balloons come down daily and thus the equipment can be examined and repaired as necessary at any time.

5.2. Weaknesses of Balloons in Rural Areas

As with satellites, there is the potential for weather to cause interference with the equipment carried by balloons. Some also fear that balloons could be damaged by aircraft or could damage birds that might accidentally run into them. However, balloon proponents point out that the balloons lifting the wireless equipment are essentially the same as weather balloons which are launched regularly without taking damage from aircraft or giving damage to wildlife [Amo08]. The concerns about the safety of birds is also countered by pointing out that balloons take the place of tall satellite towers that cause even more problems with birds running into them [Amo08].

It is also troublesome to re-release the balloons every day, even though this adds the advantage of being able to check on the equipment as regularly as desired. Re-releasing the balloons first requires finding people who are willing to track down the balloons via GPS (Global Positioning System) and refill and release them and second, requires these people to actually make the time and effort to find the balloons. Even with GPS to track down the equipment, it can be very difficult to track them down or get to them since the balloons can drift while in the air and then the parachutes could potentially bring equipment down across streams or in mountains or miles away from where the people retrieving the equipment live. These people also require access to enough hydrogen to continue to fill the balloons for many days, and companies have to pay them for the retrieval and re-launch services; typical payment is $50-$100 per day [Amo08][Saf08].

5.3. Space Data's Use of Balloons in Rural Areas

The main company making use of this new balloon technology is Phoenix based Space Data Corporation, owned by Jerry Knoblach. The company provides service to the American southwest by launching 10 balloons per day and has attracted attention from google, which may be interested in investing in Space Data and the services they provide. The balloons Space Data are about 6 feet in diameter and float about 20 miles above the earth's surface. Space Data uses hydrogen instead of helium to fill the balloons because hydrogen is cheaper. The balloons themselves cost only $50, and the $1500 equipment they carry is protected by Styrofoam casing and the parachutes that carry them back to earth. The equipment weights about six pounds [Amo08].

Though Space Data is a US-based and operated company, it has caught the attention of other countries as well, particularly the UK, and could expand to serving not only rural America, but rural areas across the world [Tuk08]. The company started out providing wireless communications services to oil companies and truckers and is now expanding to serve rural areas in general [Amo08].

Balloons seem like the most novel recent idea for providing wireless service to rural areas. However, there are other innovative technologies still in research and development phases that could hold even more promise for the

future of providing reliable Internet service to the rural community.

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6. Other rural wireless options and technologies

IEEE 802.22, Laser Link technology, and distributed systems are a few other wireless ideas that serve rural America. 802.22 and Laser Link, discussed in subsections 6.1 and 6.2, respectively, are cutting-edge technologies still in research phases and not yet released for public use. Distributed systems, which I discuss in subsection 6.3, is an older technology that gave way to WiMAX, but it is still worth discussing due to its positive contribution towards efforts to supply rural America with internet service. We continue now by looking at the new 802.22 standard.

6.1. 802.22

This IEEE standard is still in its development stages and has not been released to the public, but the basic idea behind the standard is to use unused television channels to transmit wireless data. The standard started as 10 different proposals that were combined into a single standard in 2006 [Mic06]. 802.22 provides the potential for long-reaching wireless service, making it ideal for use in the rural community where customers greatly spaced out. Signals from transmitters could extend 40 km or more [Lin08] Of 802.22, Carl R. Stevenson, the man chairing the working group for the new standard, said "It will be especially applicable to sparsely populated areas where wireline service is economically infeasible due to the distance between potential users." [Lin08]. Since this technology is still under development, further details of the protocol cannot be given here.

6.2. Laser Link

Research into this technology, performed by Penn State University, reveals that it provides transmission through cloud cover, which may have applications in airplanes as well as in rural areas [Jon07]. Laser link technology could help overcome weather-based interference that satellite and balloon technologies face and offers added power to wireless connections spanning the vast distances separating consumers in rural areas. This technology is primarily being developed for the air force as a means of communicating efficiently and quickly from ground to airplanes and satellites through cloud cover, but applications could easily expand to bridging the distances separating rural customers desiring Internet access.

6.3. Distributed Systems

Distributed systems are an older idea when it comes to providing Internet access to rural communities, and though they could have been useful, they have been replaced with the newer technologies discussed in this paper. One main distributed system used to provide Internet access to rural communities was the Multichannel Multipoint Distributed System, or MMDS. MMDS used microwave frequencies in the range of 2.5GHz to 2.686 GHz and offered a maximum bandwidth of 10 Mb over a range of up to 70 miles [Tec04]. Signals were received via a receive dish placed on the top of a user's home. MMDS was divided into 11 bands within its bandwidth range. When it was newer, MMDS seemed ideal for rural America due to its long range, but line of sight and other issues caused MMDS to become obsolete when the new and improved WiMAX standards were introduced.

When it was used, MMDS provided service through companies such as MCI/WorldCom and Sprint. These companies served about 50 million people in both urban and rural areas with MMDS and were able to service over 3000 square miles with one transmitter. MMDS made its way to towns with populations of 6000 or more and to rural areas near larger towns or clusters of towns. As of the release of 802.16in 2004, however, MMDS was

pushed aside, and in 2006, frequencies previously allocated to MMDS were reassigned to Advanced Wireless Services through bidding to the FFC [Ans06].

Other distributed systems like LMDS (Local Multipoint Distributed Systems) and the DOCSIS+ (Data Over Cable Service Interface Specifications Plus) enhancement to MMDS were also briefly used to provide Internet to many communities, including rural areas, but were eclipsed by the release of 802.16 and WiMAX, and later by the even newer technologies discussed throughout this paper [Ans06][Tec04]. Still, distributed systems had their brief moment in the spotlight to help provide rural America with the wireless service it so desperately needs.

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7. Conclusions

Those of us who use the Internet regularly know the value of a fast, reliable Internet connection, and those who live in rural areas greatly desire access to fast, reliable Internet connections. Through use of wireless alternatives in rural America, many rural workers and families may receive the connection they so desperately desire. In this conclusion section, we take a look in 7.1 at efforts made towards supplying rural areas with wireless Internet, discuss in 7.2 the work that remains to be done, and sum-up in 7.3 the technologies discussed in this paper. We begin now with the optimistic view of the positive steps towards connecting rural America to the world wide web.

7.1. Work Done for Rural Wireless Internet

Many companies embrace the technologies discussed here and their strengths in serving rural communities [Myb08][Agr08][Schm06][Blo05][Hig08][Car08]. Companies like High Speed Networks and the previously discussed Agristar Global Networks focus exclusively on serving the rural community while other companies like Digital Bridge are starting in larger cities and expanding their services to smaller communities as well. As seen in Table 2 below, these companies are providing affordable wireless services at reasonable download speeds [Coo07][Agr08][Digi08]. Other companies like High Speed Networks, who advertise themselves as "Rural America's Wireless Broadband Provider," are also helping to serve rural communities[Hig08]. High Speed Network is not a service provider itself, but focuses on recruiting businesses in rural areas to serve as wireless ISPs to others in the community.

Table 2 Comparison of pricing of wireless options

Pricing Comparison of Rural Wireless Options*

Technology	Location	Monthly Fee**	Speed
Wi-Fi	Walla Walla County, WA	$39.95 - $259.95	256 kbps -1.5 Mbps
BridgeMAXX	Appomattox, VA (from Digital Bridge)	$28.99	3 MBps
Satellites	Anywhere (from Agristar)	$59.95 - $399.95***	50 kbps – 2 Mbps
Balloons	Southwest US (from Space Data)	unspecified	unspecified

*These prices are for individuals/homes, NOT entire communities.

**Service speed increases with price when prices vary.

***This service also has a set-up cost of $299 - $1,875.

High Speed Networks follows a philosophy that people must get involved and work to make wireless Internet available to rural communities. Many people and companies speak out in favor of providing Internet services to rural America. Some politicians even make it their special goal to help bring wireless services to rural community. One prominent example is Illinois Senator Dick Durbin who spoke out in August of 2006 about his view that the US needs a policy to speed to development of Internet services that reach rural America [Sas06]. The senator introduced the Broadband for Rural America Act of 2006 and voiced, in his words, the "need to close the digital divide, ensuring that rural American are not left behind in the 21st Century's digital economy" [Sas06].

Coalitions of "regular" people are a powerful means of making the voice of the rural community heard. "Connecting Rural America is a grassroots coalition of advocacy groups, community leaders and elected officials working or equality in wireless communications" [Con08]. U.S. Cellular supports the coalition, which encourages rural residents to be vocal about their demands for quality Internet service and speak out against legislation that could make it even more difficult for citizens to get the service they deserve. Coalitions such as Connecting Rural America are making large steps towards conquering the work that remains undone towards providing rural America with wireless Internet service.

7.2. Work Remaining for Rural Wireless Internet

Despite positive steps in the right direction, much remains to be done when it comes to bringing wireless Internet to rural communities. Among people living in rural America, about 36% still do not have Internet access [Amo08]. Many of these people want access to the Internet, but just do not have it available to them. These people need to speak out and find others who will speak out for them [Cur05].

The most powerful voices come from individuals and coalitions such as those mentioned above. These groups and people must continue to push for wireless service and encourage larger companies to get involved in rural communities. The research community is also a vital part of the push of wireless services into rural America as this community continues to look into new technologies and ideas like 802.22, laser link, and balloon usage. By embracing the technologies presented in this paper, and being willing to take some risks or suffer a slight decrease in profits, Internet service providers can make it possible for rural communities to receive the same quality of

service that the rest of America takes for granted.

7.3. Summary of Technologies Discussed

This paper examined several new and not so new wireless alternatives for serving rural America. The oldest technology of Wi-Fi was very exciting and promising in its time, but lacked the full power needed to provide highly reliable and cost effective service to rural America. Then WiMAX came along, promising additional range to better serve sparsely populated rural areas, but still some companies were reluctant to embrace WiMAX due to its increased cost, or to provide service to rural America at all due to the fact that building towers for densely populated areas offers much greater profit than building towers for sparse populations.

The financial woes of building a tower only to serve a few people in a rural community were countered by the introduction of satellite technology to provide wireless signals. Satellite networks offered service anywhere in the U.S., and a single network could serve both urban and rural communities so that providers didn't have to do much additional work or extra investing to serve rural America in addition to urban America. The novel new idea of using balloons rather than satellites to suspect wireless equipment in space built off of this idea of anywhere service and made the "launch" of equipment easier and improved accessibility for maintenance.

More exciting new technologies, including 802.22 and laser link, are still in development and hope to overcome the range and line of sight issues that currently used technologies suffer from in rural areas. Older technologies such as distributed systems also had their moment in the sun, but were quickly replaced entirely by technologies better suited to serve rural communities, including WiMAX, satellites, and balloons. These technologies give rural communities the hope of receiving the quality Internet and network access they crave. Perhaps one day, there will be no gap in service between rural and urban communities, and all Americans will receive the high-quality Internet access they need.

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LIST OF ACRONYMS

- **DOCSIS+:** Data Over Cable Service Interface Specifications Plus
- **EAP:** Extensible Authentication Protocol
- **GEO:** Geosynchronous Earth Orbit Satellite
- **GPS:** Global Positioning System
- **IEEE:** Institute of Electrical and Electronics Engineers
- **ISP:** Internet Service Provider

- **LEO:** Low Earth Orbit Satellite
- **LMDS:** Local Multipoint Distributed Systems
- **MMDS:** Multichannel Multipoint Distributed System
- **TAP:** Tachyon Access Point
- **TCP/IP:** Transmission Control Protocol/Internet Protocol
- **Wi-Fi:** Wireless Fidelity
- **WiMAX:** Worldwide Interoperability for Microwave Access
- **WPA:** Wi-Fi Protected Access

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APPENDIX: ADDITIONAL SOURCES

These sources were not directly cited in this paper, but may provide additional information about the use of wireless services in rural America.

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