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1. Technology Review

There is a wide array of wireless technologies available today. Their suitability depends on the desired applications and the geographic conditions of the area. Today, WiFi and WiMax dominate the discussions at trade shows and in the media. However, not to be ignored is the Broadband Radio Service (BRS) and Educational Broadband Service (EBS); these licensed frequencies were previously known as the Multichannel Multipoint Distribution Service (MMDS) and the Instructional Television Fixed Service (ITFS), respectively. For rural areas 700 MHz is evolving into a cost effective alternative. In addition, availability and performance of Evolution Data Only (EvDO) from the cellular carriers is increasing while access costs are declining.

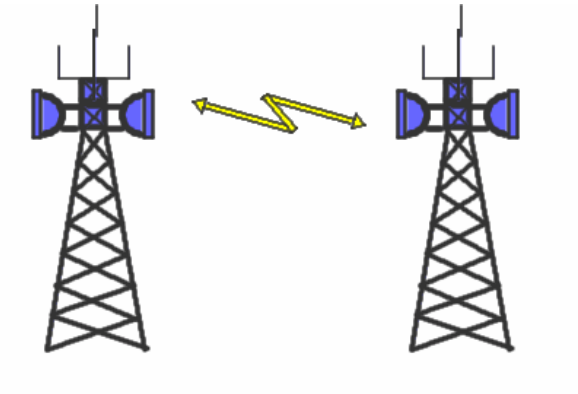
Topologies

There are three basic types of topologies used in wireless networks:

1. Point-to-point
2. Point-to-multipoint
3. Meshed

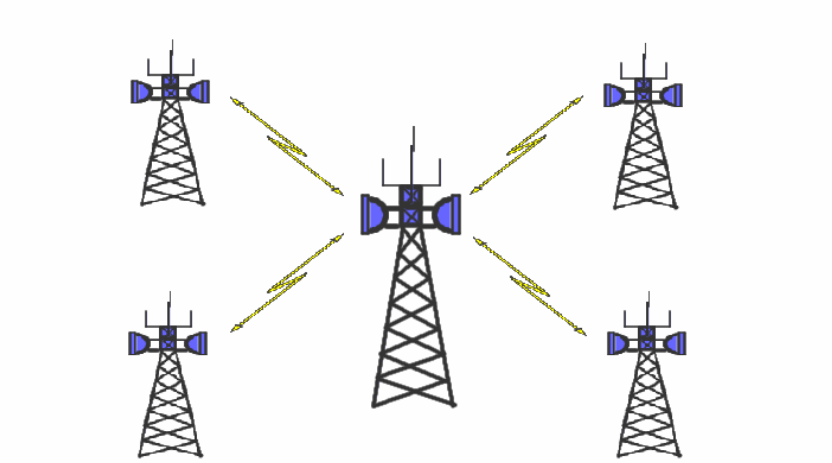
The point-to-point topology is shown in Figure 1. Point-to-point wireless topologies are used in microwave systems, and will support high bandwidth applications. Point-to-point technologies are not appropriate for applications such as residential Internet access. Point-to-point systems can be designed to support connections of 30 miles or greater.

Figure 1: Point-to-Point Topology



Point-to-multipoint topology is shown in Figure 2. Point-to-multipoint topologies support applications such as business Internet access, or backhaul transport for a meshed network. Point-to-multipoint connections can typically support connections up to 10 miles, depending upon terrain, foliage, and other conditions. Often, with a point-to-multipoint system, coverage gaps of 20% to 30% are experienced.

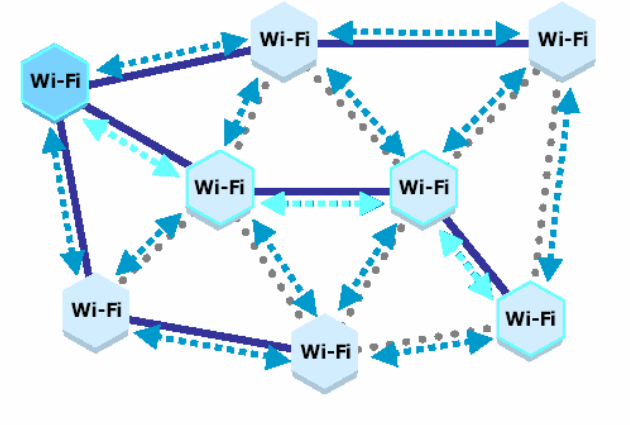
Figure 2: Point-to-Multipoint Topology



Meshed topologies consist of placing many overlapping cells that provide coverage throughout (95% plus) the service area. Each radio node is mounted 20 to 30 feet in height, typically on lampposts, with a 750 foot to 1,000 foot spacing[1]. Depending upon the vendor, for each 6 to 10 radio nodes, one node will be designated as a gateway which collects information from other nodes. This gateway then communicates via a fiber or a point-to-multipoint wireless backhaul to the network operations center. A typical meshed configuration is shown in Figure 3.

[1] Typical densities are 30 to 45 radio nodes per square mile, depending upon terrain, foliage, and other conditions.

Figure 3: Meshed Topology



1.2 EVDO

Evolution Data Optimized (EvDO) wireless access is an available data transport alternative for some municipalities. EvDO data service is offered by the Personal Communications Services (PCS) carriers (often referred to as cellular). In theory, EvDO will deliver 2.4 Mbps[2] to users; in reality, EvDO delivers 300 to 500 Kbps. EvDO advantages include:

- No infrastructure investment required;
- No operational expenses; and
- When available it provides coverage beyond the city boundaries.

EvDO disadvantages include:

- Monthly recurring fees; and
- Data rates may limit some public safety-service applications.

EvDO does have a niche in the market. It is not, however, the solution for a low-cost essential service. EvDO, when available, is quite appropriate for applications that require mobile data access.

1.3 Broadband Radio Service

Broadband Radio Service (BRS) offers a licensed frequency alternative for consideration. The BRS was created by refarming the ITFS frequencies reserved for education. If the local School District still controls the frequencies, it is possible to transfer the license to the City.

The BRS offers protection from interference since it is a licensed band. A summary of the differences between WiFi and BRS is presented in Table 1.

[2] In theory, 802.11b will deliver 11 Mbps. After overheads, the maximum throughput is approximately 5 Mbps.

Table 1: BRS vs. WiFi

Attribute	Technology	
	BRS	**WiFi**
Frequency Protection	Yes – licensed frequency.	Limited – no regulatory protection, but technology designed to operate in noisy environment.
CPE Cost	Non-standards-based. Cost around $350 to $500.	Standards-based. Cost $100 to $150.
Portability	No	Yes
Coverage	Few cells covering large area. Designed for 80% coverage.	Many cells covering small areas. Designed for 95% coverage.

If a provider was to target a $30 to $40 per month retail offering, without portability or ubiquitous coverage objectives, BRS is a viable alternative. This technology is being used by Clearwire in approximately 30 markets[3] in the United States. Recently, BRS has been promoted by Clearwire as a WiMax alternative.

1.4 700 MHz

The FCC has allocated 24 MHz of spectrum for public safety services at 764-776 MHz and 794-806 MHz (referred to as the 700 MHz band). Table 2 shows the proposed designated use of the spectrum.

[3] Please refer to Clearwire.com for a list of communities served.

Table 2: 700 MHz Frequency Database Module

Designated Purpose	Amount of Spectrum	Narrowband (6.25 kHz)	WideBand (50kHZ)
General Use	12.5 MHz (52.1%)	7.7 MHz (1232 Channels)	4.8 MHz (96 Channels)
Interoperability	2.6 MHz (10.8%)	0.8 MHz (128 Channels)	1.8 MHz (36 Channels)
Secondary Trunking	0.2 MHz (0.8%)	0.2 MHz (32 Channels)	-0-
State License	2.4 MHz (10.0%)	2.4 MHz (384 Channels)	-0-
Low Power	0.3 MHz (1.3%)	0.3 MHz (48 Channels)	-0-
Reserve	6.0 MHz (25.0%)	0.6 MHz (96 Channels)	5.4 MHz (108 Channels)
Total	24 MHz (100%)	12 MHz (1920 Channels)	12 MHz (240 Channels)

Spectrum Coalition for Public Safety

The Spectrum Coalition for Public Safety is a national coalition of cities, states, and public safety associations organized to secure additional spectrum in the 700 MHz range to support critical public safety wireless applications organized by the District of Columbia Office of the Chief Technology Officer. The District of Columbia has constructed an interoperable, city-wide, broadband public safety wireless network as a one year pilot project for potential 700 MHz deployments. This Wireless Accelerated Responder Network (WARN) uses an experimental license from the FCC to operate in the 700 MHz band. The objectives of the pilot are to demonstrate the applications and benefits of broadband wireless networks satisfy short-term critical unmet needs, and to further develop public safety's knowledge base on the networks and applications associated with broadband wireless deployments.

Utah 700 MHz Regional Planning Committee

On February 7, 2006, Utah 700 MHz Regional Planning Committee (Region 41) submitted a proposed plan for the use of the 12.5 megahertz of spectrum in the 764-776 and 794-806 MHz band (700 MHz public safety band) designated for General Use. The plan for this region has been approved by the FCC. The region encompasses the entire state of Utah consisting 29 counties.

Rural Use

The 700 MHz band offers the opportunity for cost-effective solutions in rural areas today. To demonstrate this potential, we have outlined two uses, one for retail offerings, and the next for asset management.

Gardonville Cooperative Telephone Association, Brandon Minnesota[4]

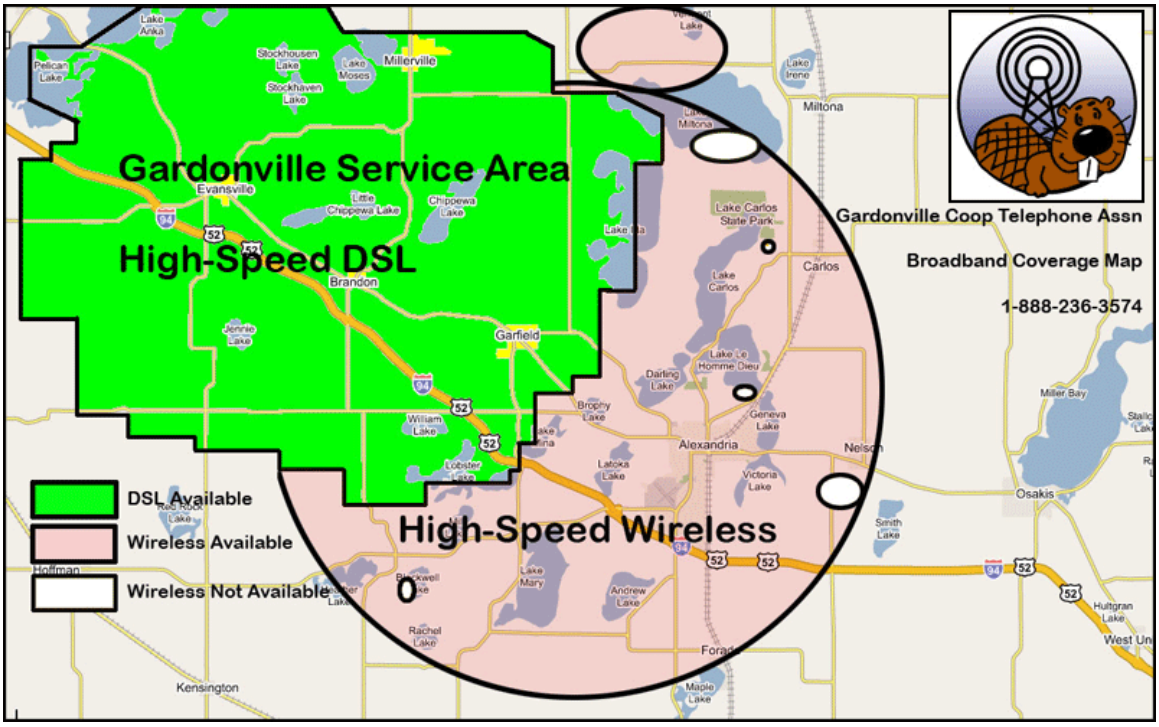
Gardonville Cooperative Telephone Association (GCTA) is an aggressive cooperative serving its consumer members throughout western Douglas County and eastern Grant County in Minnesota. GCTA provides service for 4 exchanges in west central Minnesota, serving the towns of Brandon, Erdahl, Evansville, Garfield, Leaf Valley, Melby and Millerville. GCTA also offers traditional landline telephone and DSL service in Garfield, Evansville, Brandon, Millerville, and the west side of Alexandria

GCTA is a cooperative telecommunication system that was formed in the early 1940's by a group with a desire and understanding of how important telecommunications would be in the future. GCTA was started primarily from the formation of consolidation of small farmer-owned rural line systems, which were consolidated at that time into offices in each town that it currently serves.

GCTA continues to strive to meet its mission to provide state of the art telecommunication services to its members. GCTA has gone beyond traditional telephone services. GCTA offers a complete line of affordable Internet services including dial-up, DSL, and web & e-mail hosting to its consumer members. In February of 2006, GCTA expanded its Internet service – adding wireless. The wireless addition allowed GCTA to expand its high-speed Internet services beyond DSL footprint. The expanded service area is shown in Figure 4.

[4] Information for this summary are from interviews with Andy Erickson of Technical Support and Kathleen of Customer Service, GCTA, March 16, 2007 and GCTA's web sit - www.gctel.com.

Figure 4: DSL and 700 MHz Coverage Area



Wireless Internet system operates in the 700 MHz licensed spectrum and is encrypted. The system tower is located in Garfield (7 miles Northwest of Alexandria) and pointed at the Alexandria area. A new tower will be going up in Nelson (5 miles east of Alexandria) soon. This flexibility offers GCTA to offer Internet and VoIP services GCTA is presently testing VoIP telephony on the wireless system, and plans for system rollout at a later time.

System uses Vyyo headend equipment, wireless access points (WAPs), and customer premises equipment (CPEs) or modems. The system has a Vyyo CMTS and customers are provided with a Vyyo 280 Plus modem. Customers are provided with GCTA-owned modem, transceiver, and a mounted antenna at no extra charge as part of the service.

As shown in Table 3, multiple speed and packages available for Internet service. Prior to an installation, technicians test the location to determine if service is available. Foliage and other factors can prevent signal from being available.

Table 3: 700MHz Internet Service Offering

Speeds – Download/Upload	Price	Equipment	Installation Fee
256 kbps/256 kbps	$29.95/mo.	Vyyo 280 modem, external 700 MHz transceiver and house-mounted antenna	$40 install fee for one computer.
512 kbps/512 kbps	$34.95/mo.	Vyyo 280 modem, external 700 MHz transceiver and house-mounted antenna	$40 install fee for one computer.
1 Mbps/1 Mbps	$49.95/mo.	Vyyo 280 modem, external 700 MHz transceiver and house-mounted antenna	$40 install fee for one computer.

The above pricing is lower than satellite, for a service that does not have latency issues.

Arcadian Networks[5]

Another use of 700 MHz is for monitor and control of dispersed assets. In November of 2006, Arcadian Networks announced an agreement for deployment of a 700MHz network with Great River Energy (GRE) - a wholesale power cooperative which serves 28 distribution cooperatives in Minnesota. Arcadians' 700MHz solution will be primarily used for ongoing Supervisory Control and Data Acquisition (SCADA), security surveillance, Voice over Internet Protocol (VOIP), control area operations, automatic meter reading (AMR) and workforce management.

Arcadians' plan is based upon aggregating needs for companies with dispersed assets such as electric utilities in rural areas. Arcadian Networks approach is to provide a secure two-way private licensed broadband radio spectrum to substations, feeders and meter sites, allowing utilities and other dispersed assets industries to monitor mission-critical assets in real-time, detect problems proactively and respond to the growing security requirements of their facilities and assets.

It appears that Arcadian Networks is not looking to offer retail services over the 700 MHz network. Arcadian feels that industries that will use the network include electric, gas and water utilities, oil producers, public safety, mining, transportation, and other business or government agencies with dispersed critical infrastructure and assets.

[5] Information in this section is from the Vyyo Wireless website, www.vyyo.com and Arcadian Networks website, www.arcadiannetworks.com.

1.5 WiFi or WiMax

WiFi and WiMAX are complementary technologies, not competing ones. The most fundamental difference is that they are designed for entirely different applications. A blend of WiFi (IEEE 802.11) and WiMax (IEEE 802.16) technologies may offer a flexible and accessible wireless broadband approach for businesses, residents, municipal, and school organizations.

WiFi is a Local Area Network (LAN) technology designed to support user portability. Many vendors have taken advantage of the standards and have developed Wide Area Networks (WAN's) to support community-wide applications.

- Several vendors have developed proprietary Mesh Networks using WiFi technology. Mesh Networks will blanket an area so that virtually all of the community will have coverage. Other vendors deploy WiFi using sectored antennas, time-slotting, and other methods to increase coverage area.

- WiFi, as specified in the standards, is appropriate for hot-spots or other LAN applications.

- WiFi, as developed by meshed network vendors, is appropriate for community-wide applications and support of low cost residential and small business Internet access.

WiMax is designed for Metropolitan Area Network (MAN) fixed and vehicle-based wireless access.

- Initial WiMax Customer Premises Equipment (CPE) is much more expensive than WiFi and requires an external antenna installation. WiMax CPE devices are projected to cost in the $650 to $1,000 range.

- Initial WiMax applications include wireless T1 services, hotspot back-haul, and other transport services.

- WiMax standards are still under development to address the needs of mobile applications (802.16e); however, there are vendors that offer a pre-WiMax product that supports mobile data terminal applications.

Unfortunately, trade journals often portray WiFi and WiMax as an either/or selection; in reality WiFi and WiMax are complimentary. The confusion between WiFi and WiMax results from some basic misconceptions, including:

- WiFi is often stated as having a 300 foot coverage limit. This is not necessarily true.

- The WiFi LAN standard, as specified, will have difficulty covering more than 300 feet.
- Meshed network vendors leverage the WiFi standards to take advantage of manufacturing economies of scale, while enhancing the effective coverage area.
  - Coverage limits are constrained by the CPE to radio node link, not the radio node to CPE link.
  - Meshed network vendors increase the coverage limit by increasing CPE transmit power (how loud the CPE speaks) and increasing the base station receiver sensitivity (how well it listens). These modifications allow the effective coverage to approach 800 to 1,000 feet, while maintaining a "standards-based" CPE.

- WiMax is touted as a technology which will support coverage ranges of 20 or more miles under non line-of-site conditions. This is not true.
  - WiMax, in theory, will cover a radius of 20 or more miles, under the right conditions (i.e., line-of-site, no trees, and no other obstacles), and depending upon the specific frequencies used. WiMax has standards for use in the non-licensed (5GHz) and licensed (2.5 GHz and 3.5 GHz) frequencies; in addition the standards can be applied to a range of frequencies.
  - WiMax could be used to support non line-of-site connections, particularly at frequencies below typical WiFi transmissions (such as the 700 MHz bands being recaptured from television broadcasters); however, the effective coverage radius will likely be less than 3 miles.

Given the above characteristics, WiMax and WiFi are suited for different applications. We present sample applications supported by WiMax and WiFi technologies in Table 2.

Table 4: Application Types by Wireless Technology

Application	WiMax	WiFi
Fixed Transport Services (Fractional T1 to 100 Mbps)	✓	
Business Internet (DSL and T1 replacement)	✓	
Back-haul from WiFi Hot Spots	✓	
Moderate Cost Internet Access for Rural Residences	✓	
Low-cost Internet Access for Residents and Small Business		✓
Portable Connectivity Access		✓
Public Safety and Other Vehicle-Based Application	✓	✓
User Mobility/Portability Applications	✓	✓
Campus Networks		✓
Wireless Hot Spots		✓
Apartment or Dorm Networks		✓

This examination shows that WiMax and WiFi are not competing technologies, but are actually complementary technologies. The difference comes down to the fact that WiMax

and WiFi have a different fit depending upon the application. Selection of a WiMax or WiFi technology should be based upon which applications you want to enable.

1.6 WiFi

There are a variety of wireless configurations available, or expected to be released by vendors. Today, the WiFi options nearly always use 802.11b/g (2.4 GHz) for the consumer market. This leaves us with three key questions: 1) should a community implement 802.11b, or 2) deploy 802.11b/g, or 3) wait for WiMax or another alternative?

We believe the selection of 802.11b/g is appropriate. The 802.11b/g technology is proven, tested, and reliable. In addition, 802.11b/g is in a position to meet the needs of Internet users in models, and is well suited to meet the low-cost access objective. This belief is based on the following justification:

- Any technology, when purchased, has reached technical obsolescence. The question to address is functional obsolescence.

- The data rates/throughputs[6] supported by 802.11b are competitive with DSL and cable modem offerings.
  - Adding more gateways can increase effective throughput.
  - 802.11b throughput is symmetric[7] vs. cable modems asymmetric[8] service.
  - Having 802.11g support is a built-in migration path for increased capacity, effectively providing more than 20 Mbps (54 Mbps advertised) when used in an 802.11g-only configuration.

- The data rates/throughput supported by 802.11g should support customer requirements for the next three to five years. Video applications will drive the throughput needs.

- LAN products using 802.11g are available at retail outlets. The 802.11b products have been discounted and discontinued. One of these standards is supported in nearly all new laptops and PDA's, either in a standard configuration or as an upgrade option.
  - The 802.11g is less susceptible to multipath than 802.11b.
  - For mesh network WiFi, we recommend use of at least a 200 mW CPE with a 9 dBi gain antenna.

- Implementation of 802.11g will likely cost only marginally more, and 802.11g is backwards compatible with 802.11b (802.11g devices can connect to other 802.11b or 802.11g devices) and could potentially increase the throughput by two

[6] Data rate is the advertised transfer rate. For 802.11b it is 11Mbps. Throughput is the actual rate the user will see.

[7] Upload and download data transfer rates are equal. A 1 Mbps symmetrical service provides 1 Mbps upload and 1 Mbps download

[8] Upload and download data transfer rates are different. Often cable nodes advertised at 3 Mbps – provides 3 Mbps download however uploads are often constrained to 256 Kbps.

to four times that of 802.11b (though not with both 802.11b and 802.11g devices connected to the network simultaneously).

- WiMax, despite the claims made in trade journals, is a complementary technology to WiFi. The initial WiMax products are for point-to-multipoint applications and the CPE is projected at $650 to $1,000 plus installation (outdoor antenna required).

2. Vendor Selection Criteria

Technology vendor selection is often a daunting challenge. Purchasers of equipment are faced with a variety of questions, including:

- Which technology will stand the test of time?
- Will the vendor be around in five years? Ten years?
- How can we minimize the use of proprietary equipment and software?
- What standards are incorporated into the new network?
- Will the technology support migration?
- How reliable is the network?
- Will the technology evolve to meet changing consumer needs?

The list of wireless vendors continues to grow. Each offers a wide range of products, services, and capabilities. The selection of the vendor is dependent upon a variety of factors including:

1. Broadband network requirements
2. Fit to goals and objectives
3. Hardware specifications
4. Network architecture
5. Network coverage and reliability
6. Network installation cost
7. Network management and security
8. Network operation cost
9. Use of standards
10. Vendor financial stability

We recommend that vendor selection be facilitated by issuing a Request for Bid (RFB). The RFB can be structured to allow a comparison and assess the fit to your goals and objectives.

2.1 WiFi Meshed Network Vendors

The WiFi meshed network vendors include:

- BelAir
- Cisco Systems
- DigitalPath
- Firetide
- Motorola
- Nortel
- Proxim
- RoamAD

- Sky Pilot
- Strix
- Tropos

Since WiFi meshed networks are relatively new, the number of vendors is increasing. It is likely that if NORWICH pursues implementation of a network, additional vendors will emerge.

The key differences between the vendors include:

- Use of proprietary vs. standards-based CPE's
- Support of public safety and public service traffic
  - Separate frequencies, or
  - Virtual Private Networks (VPN)
- Mix of topologies for backhaul
  - Point-to-point wireless
  - Point-to-multipoint wireless
  - Fiber
- Use of unlicensed and licensed frequencies
- Mitigation of potential interference

It is important to remember that vendor and technology selection is a strategy, not a goal. The goals and objectives unique to your community need to drive the business model, technology, and vendor selection.

These and other characteristics need to be examined during the vendor selection process.