Broadband Alliance of Mendocino County
FIXED WIRELESS TUTORIAL
Brian Churm

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Presented at the April Public Outreach Meeting

Technology Chair Brian Churm offered to do this tutorial because of questions that arose about wireless technology, such as, "Can fixed wireless support the new FCC definition of broadband at 25 Mbps down and 3 Mbps up?" Brian has a good ability to explain broadband technologies in a way that the lay person can understand.

PRESENTATION

In the next 10 years in rural communities, wireless will be a critical component for last mile access. Fiber may make it out to pockets, but in areas with few households per linear mile, only wireless will be an economical solution for connecting to the internet. We have 2 experts with us today from SeaKay, Jacob Turner and Kim Remick – your input is welcome. This technology is complicated, but we'll try to cover enough to give an idea of what we are dealing with in wireless. The wireless technology that provides you cellular, WiFi, radio and even satellite TV is all based on the same basic fundamental radio principles. Radio waves have been with us for a very long time providing communications. Today, advanced wireless technology is present in just about every home. Examples of wireless devices in the home are cordless phones, microwave ovens, and Wi-Fi routers. ***Purpose of Talk****: Ongoing discussions about:*

- *Discussion of "fixed wireless" deployments on the coast and what is feasible vs. advertised*
- *Discussion of new FCC broadband requirements of 25/3 and can wireless support the new standard*

To effectively discuss the above issues everyone needs to understand the basics on how wireless works, its advantages and its shortcomings.

Ten Wireless Terms*:*

1. ***Radio wave*** *– an electromagnetic wave within a specific range of frequencies*
2. ***Frequency*** *– the amount of full cycles (hertz) that a radio wave crosses the zero point (origin)*
3. ***Phase*** *– fraction of the wave cycle that has elapsed to the zero point (origin)*
4. ***Transmitters & Receivers*** *- devices which generate or receive radio waves*
5. ***Interference*** *– radio waves which overlap thereby affecting the end result*
6. ***Antennas*** *– a device which transmits or receives radio waves (types: omni directional, directional, parabolic, …)*

7. ***MIMO*** *– A specific type of antenna technology (multi-in, multi-out) which allows for triangulation and focusing of radio signals.*
8. ***WiMax, WiFi, 802.11a,b,c,g,n,ac*** *– evolving standards for fixed data communications over radio waves*
9. ***UMTS, HSPA+, LTE*** *– evolving standards for mobile data communications over radio waves*

10. 2G, 3G, 4G+, 4G, 4GMax, 5G *– Marketing terms; so diluted that they are now meaningless.*

DISCUSSION

Radio wave: Wireless technology is provided using radio waves. Today's wireless technology is just a different way of using the existing radio spectrum.

Frequency: Brian held up a copper wire in wave form to represent a radio wave, which is what the communication is carried on. If you draw a line through center, the time it takes to cross the center line = one full wave = a hertz cycle per second. Frequency is when you compress a wave, it gets shorter. The more crossing of the center line, the higher the hertz. 1,000 hertz means the center line was crossed 1,000 times per second.

Phase: In the past there was just one wave, one frequency and much less capacity for carrying conversations/information. When you take multiple radio waves in an interlocked form, in phase, if the waves shift a bit, one before other, then it's out of phase. If you rotate one, you can put different conversations on different waves/ frequency. With changes in antennas creating more rotations of waves, there's an almost infinite number of conversations/streams of information that can be carried.

Transmitters and receivers: Transmitters send, receivers receive - and a transceiver does both. Phones and home WiFi are transceivers.

Interference: When radio waves overlap, it interferes with sending the messages clearly, as antennas hear only one thing.

Mimo: Stands for Multi-in, Multi-out. It is a new configuration of antenna which allows you to tune the signal to the device for better reception.

WiMax, WiFi, 802.11a,b,c,g,n,ac: New generations keep coming out, become standardized until the next generation.

UMTS, HSPA+, LTE: LTE= long term evolution is a standard for wireless communication of high-speed data for mobile phones and data terminals. **White space**: This represents a certain segment of the radio spectrum that was allocated to old television transmission, it is now vacated. There is a move to make it public vs sell it to private carrier enterprises.

For the purpose of this talk – fixed wireless will be defined as a service in which both ends of the radio connection are static*. Fixed wireless can use any of the below:*

- *Open standards: WiMax, WiFi, etc*

- *Proprietary standards (e.g. Motorola)*
- *Mobile standards (LTE, etc.)*

If you nail a phone on top of a house it becomes fixed wireless. This is what WISPS provide. LTE is too expensive for WISPS, but is coming down in price. It is just a fixed antenna. How they market it has nothing to do with the technology, or how much you get etc.

***The Link Between Bandwidth and Speed**: Speed is defined as how much information can you pass through a connection over time.*

- *Amount of information (e.g. data) is measured in bits.*
- *Amount of time is measured in seconds.*
- *Examples: 10 Megabits per second*

In wireless, Bandwidth is the range, or width, of the frequencies over which a connection is transmitted.

- *Analogy: the size of the pipe through which wireless information flows*
- *Examples: a 22 Mhz bandwidth, WiFi channel 1, represents the frequencies 2.401 Ghz through 2.423 Ghz*
- *Examples: 10 Megabits per second*

Simple rule of thumb:

- *Current technology provides around 5 to 5.5 Mbps of data per Ghz.*
- *A 22 Mhz WiFi bandwidth would theoretically support 110 Mbps (802.1g)*
- *Larger speeds are obtained by gluing consecutive channels together*
- *WiFi Problems: Only 11 channels and they overlap*

DISCUSSION

We measure in bits of 1s and 0s. It's how computers think and picture. Everything is a conversation of 1s and 0s put together at the other end. That information divided by time is your effective speed.

Bandwidth: The width of the "pipe" changes the amount of information that can get through – the wider, the more information.

If you put a radio wave in a band and another a little closer and another a little closer, all these waves can be in one pipe. The US standards have 11 channels that aren't separated completely and have some overlap. Out of 11 channels, only 3 are non-overlapping. They are 22 megahertz wide. Most devices off the shelf are on channel 11. If you have problems, you are probably getting overlap with a neighbor. Just change the channel and it will probably clear up. The more neighbors there are using the same channel, decreases the performance. The same thing happens to WISPS (wireless internet service providers). They have to sort out their airspace. If more than 3 channels are being used, they start overlapping. At some point the FCC will open more bandwidth to create more channels.

The cellular carriers are fighting over the spectrum as it becomes available. Legacy providers have old networks that they bought in little chunks, that can't go over 10

megahertz. Newer wireless providers bought wider chunks of spectrum and can get more data through than the large companies.

Another issue is the radio spectrum US frequency allocations. Radio spectrum covers from 3 kilohertz to 3 gigahertz, from little radios to satellites. As technology evolves, the sweet spot is around 1 – 10 gigahertz range. If the frequency is lower meaning a longer wave, information carrying capacity is less. The higher the frequency the more compressed the wave, and the more information it can carry. The White Space radio spectrum is borderline for this reason. It penetrates long distances, but doesn't carry a lot of information fast. Shorter radio waves (higher frequencies) are more sensitive to interference. They need a clean line of sight because interference affects it (trees etc.) Lots of things produce radio frequency, such as microwave ovens, which can interfere with the waves bringing your information in. Lots of things knock out radio waves, which give WISPS nightmares. If there are trees, or a number of homes between you and the transmitter, they will interfere with your reception.

The FCC grants the right to broadcast in an area. If you get a license, no one else can use that frequency. That gives some control, but you can still have interference. Things like electric motors, microwave ovens, cordless phones and even shop tools interfere. The wireless spectrum is one big giant party-line!

The way things are being done now, the effort is to get fiber infrastructure to the last mile; that is the gold standard. But in our rural areas, that last mile mostly needs to be wireless. Cellular technology is addressing some of this. The backbone to city center on the coast will be wireless.

Question – are receivers adjustable? Yes, for a range. Wi-Fi in home has 11 channels. It's just a small change in the frequency.

For example, AT&T has 5 bands they operate. Your phone pings the tower, the tower checks frequencies and says "this band is clear and changes the antenna to that frequency for your call.

How do we manage to share one pipe without getting congested? The answer is antennas.. More antennas with smaller coverage areas increase the amount you can send out and receive. But these antennas have to be connected to the internet – and that usually means fiber is required at least to the antenna node.

Antennas *are the primary means which providers use to share bandwidth across the wireless spectrum.*

Types of antennas are:

- *Omnidirectional – broadcasts in all directions (e.g. FM Radio)*

- *Directional – broadcasts in a single direction or cone*
- *Parabolic – focuses a signal broadcast on a single point*
- *MIMO – an antenna array which adapts the signal broadcast to the location of the source using triangulation*

Traditional Cellular Antenna

DISCUSSION

Parabolic antennas, shaped like a parabola, can take a faraway weak signal and bring it to a single point where the antenna is to pick it up. It strengthens the signal. It's important to focus it just a degree at a time. The flip side of parabolic antennas is that they pull in everything and focus it all to a point, including stray signals coming in. So depending on what radio waves are around, they may not work well in a particular situation. **Collisions:** When 2 pieces of information collide, the device can't decipher it and it gets thrown out, which triggers a re-transmittal of the same information. But every time that happens, say on a computer, it slows down – it's called degradation. If 6 – 10 of your neighbors are downloading Netflix, suddenly everyone is transmitting the same information. It is conflicting and it collides. But the movie can't be re-transmitted as the information is already gone and moved on. Then you start seeing white spots on the screen, little pixels, that got tossed, because you can't get it back and it moves on. This happens in all technology, but is more frequent in parabolic antennas.

QUESTIONS AND ANSWERS

1. Can fixed wireless support the new FCC standards (25 Mbps down / 3 Mbps up)?
Answer: Yes; if you have the entire spectrum to yourself (no other companies), you could have 25 Megabits
2. How many 25 Mbps customers can one fixed wireless antenna support?
Answer:
a) Under WiFi 2.4 Ghz (b,g) standards - 3 non-overlapping 22 Mhz channels
3 x 22 x 5 Mbps = 330 Mbps total throughput.

330 Mbps / 25 Mbps = 13.2 simultaneous customer streams

b) Under 5 Ghz protocols: Example: 5.470-5.725 Ghz is 255 Mhz. One could fit 3 x 80 Mhz channels providing 1.2 Gbps throughput serving 48 customers

THE REAL WORLD IS MUCH DIFFERENT

- *Shared spectrum (competitors, private networks, etc.)*
- *Interference from trees, electric motors, cordless phones, even microwave ovens*

3. How do we use fixed wireless to deliver broadband?

Answer: Multi-part

a) Smaller more vari-directional antenna nodes

b) Meshed networks to increase coverage

4. Can all places be reached with fixed wireless broadband?

Answer: NO

a) Dense foliage requires lower frequencies and narrower bandwidth which results in a lower speed

b) Some areas prohibit multiple (if any at all) antennas

DISCUSSION

There is a new term – "the internet of many" meaning <u>everything</u> being connected to the internet. The projection is that eventually your refrigerator will tell you when you need more milk and order it. Amazon just introduced the "dash button", paid for by brand name companies. You put it on your washing machine and when you run out of Tide, you press it, and it sends a message to Amazon through your Wi-Fi. A few days later, that programmed order shows up at your door.

QUESTIONS FROM GROUP

Q: Is the system scalable?

A: Yes, you can continue to add to it. Verizon is coming to cities and going to smaller antennas - micro antennas in buildings. The big antennas can't handle it all. But they will have to get copper or fiber out to the new antenna. For AT&T, this is their broadband solution – to run fixed wireless off cell sites and put up more and more cell sites. They will have to deal with architecture and local issues because cities don't want towers and antennas everywhere. They will be asking building owners to put panels on buildings and owners will be coming to counties for permits. Comcast's solution is to light up Wi-Fi on all local routers, creating a cloud of radio waves that will be hard to penetrate. Wireless can support the new FCC standard, but the middle mile becomes the key. (**middle mile:** the segment of a telecommunications network linking a network operator's core network to the local network plant. When bought from the incumbent operator, it is often very expensive and often forms the major expense of non-incumbent broadband ISPs). Micro antennas don't get out of tight spots.

Q: Is there a mesh network wireless solution?

A: You can use fixed wireless mesh and ricochet. The mesh is all connected and talks to each other, which has the best hop out of the room. It is constantly talking with the weakest, talking to the next, and the next, to get out. You can use it for expanding coverage in areas where you can't put a giant antenna. If someone is off line, your signal hops to another. But at the top where it goes out, it gets hot because everyone is using it to get out. That point must be robust to bounce off the many other signals.

In rural areas we don't always have enough buildings close together to create a mesh and end up with ricochet which is like a bullet bouncing off walls, one to one. It is not as survivable as mesh.

There is good infrastructure along Hwy 1, but to get off into outlying areas you need these wireless systems. It is too expensive to put in a big antenna to serve several houses. In those situations you will have to ricochet up roads to get to houses.

Mesh is appropriate technology for businesses, hospitals etc. But it does not have good security. As the information keeps getting passed around, hacking is very possible. Good encryption in the system is the best way to be secure.

It's important to start getting neutral fiber into the ground, not locked to a particular vendor. Fiber is the best and large institutions especially need it. Cities can sell access to a variety of companies. If we don't do it when trenching is being done for other purposes, the cost later will be very high.

Q: How can areas further than 3 miles from a central office have DSL?

A: They do have DSL out in the hills further than 3 miles by using wireless to provide the middle-mile back to the internet backbone. It depends on the terrain.

Q: Is it that common around here to set-up DLS like that - wireless to the copper and then back to a wireless router in the home?

A: Not at the moment because of regulations which only allow CLECs can touch the copper (competitive telephone companies that provide their own network and switching). The incumbents typically will not let WISPs interconnect to serve unserved areas. It doesn't seem like good business.

Q: Should we caution realtors about advertising that a particular house on the market has high speed?

A: The available speed is not necessarily what a particular household is paying for and receiving. Sometimes a much higher speed is throttled down at the house antenna, due to the level of service that the existing resident has chosen and is paying for.

Q: Using microwave backhaul, what is distance they can use for point to point transmission?

A: It depends on the size of parabola in the antenna. An FCC license allows only so much power to overlap another license area.

FINAL THOUGHTS

Wireless is our only solution for now for various areas. What we need is to get creative and work from the grassroots. We can't make wireless work without our neighbors, which in this area is how people typically think. Meet with your neighbors, and solve this. Comcast and others can help with the middle mile.

Many times there is no clear answer!

Advertising rarely matches real world performance.

Every location must be evaluated on its own merits.

Some technologies work better than others depending on the environment.