Why Open Spectrum Matters

The End of the Broadcast Nation

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See also: The Open Spectrum FAQ

The End of the Broadcast Nation

We are not in the age of Information. We are not in the age of the Internet.

We are in the Age of Connection.

Being connected is at the heart of our democracy and our economy. The more and better those connections, the stronger are our government, businesses, science, culture, education…

Until now, our connectedness has depended on centralized control points that have been the gatekeepers of our economic and political networks. To *speak* to everyone, you had to be one of the few with access to a broadcast networks. To *sell* to everyone, you had to be one of the few with access to a global distribution channel. To *achieve office*, you had to be one of the few with access to corporate coffers and national media.

But we are on the verge of being able to connect to anyone and everyone, whenever and however we want. No gatekeepers. Ubiquitous connection. Connectedness that's always there and always on.

This isn't about getting more TV channels. Change the way we're connected and you've changed everything, from the economy to governance. This is how fundamental transformation occurs.

In this context, spectrum has nothing to do with electromagnetic waves and auctions. It is far more fundamental: Spectrum is connection.

We will connect. The human drive for connection is too strong to be stopped. The market and the electorate are clamoring for this. Consider just some of the more obvious changes:

When *consumers* are connected, we turn off the marketing messages and tell one another the truth about what we buy.

When *students* are connected, they teach each other and work

collaboratively…even if they are still being graded as if each assignment were done alone in a cell.

When *citizens* are connected, we put our money and our votes with politicians who join the fray. Safe, phony words and please-everyone positions sound more hollow than ever. We want our government to recognize and reflect the values connectedness brings.

When an *economy* is connected, goods and services move faster. Little players get a foothold against the giants. Innovation skyrockets. Risks are taken and investments are made. The old gatekeepers of connection find their treasure is now a commodity. But that commodity fuels an outbreak of economic growth that will last for decades.

When a *society* is connected, it becomes more fair. Broadcasting's lock on the channels of communication is broken, so more voices are heard and people are better able to determine their own individual and collected fates.

The Age of Connection will begin with a fundamental change in metaphors and a basic reframing of the issues.

Reframing the issues

The conversation about Open Spectrum needs to be re-framed. We cannot afford to talk about it in terms of interference, pipes, scarcity and property any more. Those metaphors are getting in our way.

Not how we can slice up the spectrum ham ... but what will bring the greatest connectedness?

Not spectrum as a thing ... but as an open standard.

Not who owns spectrum ... but whether we even need a handshaking "etiquette" to allow devices to communicate wirelessly.

Not how many bits can be carried by a particular slice ... but how do we move information from every A to every B most efficiently?

Not whether this megacorp should be allowed to own that particular station in some specific city ... but how can we turn an audience into a conversation?

Not how scarce is bandwidth ... but what can we best do with the abundance?

Not how can we tinker with the current policies ... but what policies would create the most freedom, wealth and value given the new

technological possibilities?

The old metaphors are broken. The new metaphors will change the way we connect with one another and thus will change the world.

How we got here: Technology and bad metaphors

Current spectrum policy is based on bad science enshrined in obsolete ways of thinking. The basic metaphors we've used are just plain wrong.

Pipes. The first metaphor treats spectrum as if it were a pipe. A pipe has a measurable capacity: a predictable volume of water can flow through a municipal water trunk. Of course, this analogy makes certain assumptions, such as that water can't be compressed effectively and you can only send one stream of water through a pipe at any one time. In the context of these assumptions, it made sense for the Federal Communications Commission to begin licensing spectrum as if it were a scarce resource under the framework established by the Communications Act of 1934.

Interference. The second metaphor thinks of the electromagnetic energy as waves that can be deformed by interference. In fact, electromagnetic waves can pass through one another without distortion. The policies set in 1934 by the FCC prohibiting two broadcasters from using the same frequency treat interference as a law of nature rather than as a limitation of the technology of that time.

Consumption. The third metaphor thinks of wireless communications devices as consumers of bandwidth. Every time a broadcaster receives a license, the amount of available spectrum goes down. Spectrum is not only a finite resource, it is a scarce resource, at least according to this metaphor. New technology, however, *increases* bandwidth with the number of users.

Property. The first three metaphors lead to a fourth. As a pipeline to an audience, a licensed slice of spectrum has had tremendous value. Because same-frequency waves would interfere with one another, the broadcaster had to be given exclusive access rights. Spectrum thus took on the practical characteristics of property: something of value to which someone, by legal right, has exclusive access.

Three advances past the old metaphors

These metaphors are misleading and outdated, reflecting the state of technology over 70 years ago. They came before information theory, the Internet, and Hedy Lamarr made obsolete any policy based on

interference and scarcity as if they were laws of nature.

1. Spread spectrum. Before Hollywood made Hedy Lamarr "the world's most beautiful woman" she was an Austrian aristocrat married to an arms merchant who was so possessive that she had to drug his maid in order to escape. In Hollywood, she became friends with George Antheil, an avant garde composer. One day, while playing four-handed piano with him, she realized how to defeat the jamming devices used to keep radio-controlled torpedoes from hitting their target: rather than staying on a single frequency, the transmitter and receiver could be synchronized to switch bands like four hands moving around a piano keyboard. She and Antheil were awarded a U.S. patent on the invention in 1942, and in 1958 electronics were sophisticated enough to enable the U.S. Navy to begin using frequency hopping as the basis of its communications. [2]

Spectrum-as-pipe does not make sense in a frequency-hopping world. In fact, Lamarr's invention directly contradicts the essence of the pipe metaphor: that there is a single medium, contained by hard walls, from A to B. [3]

2. Information Theory. The next blow to the old metaphors came from Claude Shannon and Warren Weaver in 1949 with their development of Information Theory. The carrying capacity of a water pipe can be known with near certainty. Likewise, how many beer bottles can be filled per hour can be predicted based on the speed of the conveyor belt. But spectrum is carrying neither water nor bottles. It's carrying information. And information is not a hard-edged good: It can be compressed, in many circumstances it survives some loss, and it is independent of the medium carrying it. A system optimized for carrying information, rather than for preserving the integrity of waves, would look much different than what we have today. And it would be much more efficient. In fact, current research indicates that the amount of information a frequency can carry increases with the number of users. The only question is *how much* it increases.[4]

3. The Internet. The Internet teaches us three lessons loud and clear.

(a) Open standards work. Rather than building a network that connects A to B to C by touching copper to copper, the creators of the Internet built a network by establishing standards for how information is to be moved. It is because the Internet was not built as a *thing* that it has been able to bring the world many orders of magnitude more bandwidth than any previous network. Our current policy, however, treats spectrum as if it were a physical thing to be carved up. By

focusing on open standards rather than on spectrum-as-thing, the medium can become far more efficient and offer far greater capacity.

(b) Decentralization works. Keep the architecture clean and simple. Put the "smarts" in the devices communicating across the network rather than in centralized computers. In fact, central control and regulation would have kept the Internet from becoming the force that it has.

(c) Lowering the cost of access and connection unleashes innovation beyond any reasonable expectation.

Open spectrum will do for wireless communications what the Internet has done for networking computers.

Today's technology

As a result of decisions based on the science of the early 1900s, we built a system that works around technological limitations that 21st century technology has overcome. Advances over the past ten years knock into a cocked hat our most important assumptions about wireless communications:

"To get good reception, lock onto a signal." Not any more. Just as a highway that allows cars to change lanes will have greater capacity than one that locks them into single-lane tunnels, bandwidth increases with adaptive radios that can change their frequencies, modulation, and information routing to compensate for and exploit the current conditions.

"A radio is a receiver." Until recently, a radio was a hard-wired device that could do one thing only: play music, receive voice data, etc. But software-defined radios are computers, capable of being reprogrammed on the fly. They can be upgraded after they are sold, and that they can dynamically be put to a wide variety of uses, enabling innovation far beyond simply providing more "stations" to listen to.

"The more you put into a network, the better it is." The Internet – an end-to-end network – has proven this idea to be backwards. It's precisely because the Internet wasn't optimized for any particular application that it's useful to the broadest range of innovations. Spectrum can be architected the same way: as an information transport utilized by "smart devices" such as adaptive and software-defined radios.

"*The more users, the less bandwidth*." Shannon and Weaver's Information Theory that guided the development of broadcast and

point-to-point networks did not consider the implications of the way our cellular networks currently enable multiple simultaneous users. In the past decade, a variety of research teams have begun to explore this unknown corner of the theory, and have shown a variety of counterintuitive results that show that our assumptions about capacity and interference are just wrong. [5]

"*It's all about the waves*." No, it's all about information. Digital communications techniques such as error detection and correction, maximum likelihood estimation, Rake receivers, and other techniques developed based on Shannon's information theory and Digital Signal Processing provide a rich set of techniques that have not been used in radio systems deployed before 1990 (the bulk of commercial systems), i.e. before digital cellular telephones.

"Interference is a law of nature." Very wideband modulation techniques such as DSSS (802.11b – AKA WiFi), OFDM (802.11a/g), UWB and many others use new technologies to spread information across many frequency bands, creating very high transmission rates at low cost with very little degradation even in noisy environments. They do not require "exclusive" use of those frequency bands, especially in a network that uses modern adaptive error-correction techniques, and they do not interfere with older technologies (such as TV) that uses the same frequencies. [6]

What could be

Imagine a world in which we've changed policy to adapt to the new metaphors. There will be changes in three dimensions: short term, long term and deep term.

Short term, we will see a sudden breaking free from wireless gridlock. This will not only bring new, smaller players into a broadcast industry that has been locked up by media mega-giants. More important, it will enable consumers and citizens to communicate with one another. We will create our own content, but we'll also be in constant conversation. From these connections will emerge new social groupings, just as simple text messaging on telephones has created "flocking" behavior in Japan and Scandinavia. We will see innovations wherever action at a distance or ubiquitous access makes sense – including, incidentally, object-to-object communications as our household and office devices start to "talk" to one another.

Long term, we cannot predict the sort of innovation that will happen, any more than Marconi could have predicted WiFi 100 years ago.

Predictions range from ubiquitous access to "personal knowledge avatars" to even Star Trek-style transporters "beaming us" across space. The only certainty is that our current predictions are inadequate to the reality that we will invent for ourselves.

Deep term, the unleashing of wireless connectivity will eat away at one of our last remaining social dependencies on broadcast media.

"Broadcast" isn't simply an industry. It is a network topology, an economic model, and a social structure with direct consequences for the political process as well. As a *network* topology, broadcast assumes that the messages are sent one to many. As an *economic* model, it assumes the "channel" is an expense and revenues come from the content that is broadcast (via subscription or advertising). As a *social* structure, broadcast assumes that the ability to communicate is unequally – and unfairly – distributed.

The result of these assumptions is a population that by and large is presumed to be sitting quietly, facing forward, consuming content developed by commercial interests. The effects of having become a "Broadcast Nation" are profound. Our freedom is defined by the channel changer nearby. We expect power to be concentrated in the hands of those who have access to media. We expect politicians to be talking at us more than listening to us. We expect consumer goods to be "broadcast" the way messages are: identical goods flowing from a single source. We even experience The Famous as a special class of person whose lives are played out over the broadcast network.

We can get a taste of the effect of breaking free of the broadcast metaphor by looking at what the Internet is doing. The Net enables people to connect with one another, circumventing the broadcast chokepoints and the organizational chart formalities. We are at the beginning of a generational phase of innovation not only in technology but in ways we human beings are organizing ourselves. We're inventing new types of groups, new ways of writing, new rhythms of social intercourse.

To gauge the effect of opening up spectrum, take the energy of the Internet and multiply it, for all of that Net's passion and commitment comes from a medium that until now is overwhelmingly used to transmit text. It is a *typed* medium. Imagine when our connectedness is no long constrained to the speed of typing and the limits of a text-based presentation of ideas.

Certainly new businesses will arise commercializing the new inventions. More important, however, is the great democratizing effect this will

have on our culture. We will get up off the couch and face one another. We will expect — demand — direct responses. Cant and marketing messages will be worse than insulting; they will be boring. We will be able to organize ourselves not just around ideas that can be typed but richer expressions of thought and attitude. Mood, emotion, and art — hard to convey in ASCII — will re-enter the global connection. A bottom-up conversation can begin over the ether, helping to make participatory democracy real.

We are not in the Information Age. We are not in the Age of the Internet. We are in the Age of Connection. To achieve the ideals this country was built on — equality, freedom of speech and thought, the basic fairness that let's people determine their own destinies — we need everyone connected to everyone else.

Spectrum is ubiquity. Open spectrum is equality and freedom.

Endnotes

[1] Jock Gill, Dewayne Hendricks and David Reed contributed ideas, information, links and words to this paper. All errors and infelicities are mine, however.

[2] Dave Hughes, as told to Howard Rheingold, *Smart Mobs*, p. 157-8. See also http://www.ncafe.com/chris/pat2/index.html.

[3] The story of the invention of spread spectrum is actually far more complex. In fact, Lamarr's invention wasn't developed and used by the military until after direct sequence spread spectrum (DSSS aka CDMA) was put into practice in the early 1950s. Lamarr's contribution was real, but the story is so appealing that it has been over-played…as in the body of this very paper. For more information about the history of these inventions, see "Spread Spectrum Communications" by Charles E. Cook, Laurence B. Milstein (Editors), IEEE, December, 1983.

[4] http://www.its.bldrdoc.gov/meetings/art/art02/slides02/ree/ree_slides.pdf

[5] David Reed, "The Sky's No Longer the Limit," *Context Magazine*, http://www.contextmag.com/archives/200212/Insight2TheSkysNoLonger.asp

[6] David Reed provided the content for the "Today's Technology" section of this paper. Many of the phrases are his.

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