Proximal Radio

The Return of
Infrastructure-free Radio

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Abstract

This research brief summarizes our current work on the general theme of "proximal networking." We emphasize two things:

(1) The importance of physically close connections that are accessed by intention rather than address; *and*

(2) The importance of a point-to-point radio system to support such interactions.

Taken together, they form an agenda for considering an approach to networking that takes the word "public" in "public safety" seriously. It is a viral radio system in the truest sense of the words in that it simplifies grassroots networking applications (ranging from home control to electric dog collars) and includes social parameters.

We also consider these radio systems in the context of our "Third Cloud" principle—where services are distributed between cooperative sets of mobile devices spread throughout the environment. We also make note that these Third-Cloud principles and proximal networks can be used to realize an "Internet in a box" that can serve where the infrastructure is absent or disabled.

Finally, this brief is designed to further seed some of your thinking with respect to a technology we are working with—QUALCOMM's *FlashLinq*[1].

[1] http://www.telecomseurope.net/content/qualcomm-bids-p2p-glory

Introduction

The Viral Communications Group began by addressing asymmetries in radio communications. We believe that all radios (AM or FM radio, or television sets for that matter) should at least radiate or signify their presence and therefore no one would waste airwaves broadcasting to a device that potentially was not there. Such early research concepts are the antecedents of the radio analogy used throughout this discussion.

In 2003, radio systems were dominated by a centralized approach to system design, which concentrated the intelligence and power in towers that communicated with relatively unsophisticated mobile and fixed user terminals. Cell phones, for example, could not communicate with each other directly by dint of the radio implementation; television receivers wasted more than 35% of the information capacity of the channel on synchronization signaling that carried no picture data.

The question before us in 2003 was whether this system design was the result of the underlying physics of radio or an artifact of design and economics. More important, could another approach result in a better, more easily scalable, use of the spectrum? In other words, is the spectrum really a scarce resource? Or is it held artificially scarce due to considerations other than efficiency?

More recent concerns have been driven by two speculations. The first is that there will be a pendulum swing "back to reality." That is to say, after having spent the past 15 years exploring and creating the virtual, we anticipate a shift back to an interaction with actual spaces—the physical spaces around us in particular. Put another way, rather than using devices predominantly to bring the distant near (i.e., long distance phone calls and messaging), technology is poised to enhance the immediate experience of the world around us.

Some of this is driven by the penetration of sensors (cameras, GPS, physical) throughout real places. Another part is driven by the (perhaps cyclical) re-emergence of the city as the dominant forum for society.[2] Once thought of as "the place for the nearly wed and the nearly dead" even people with school-age children are beginning to return to cities.[3] The implications for the sustainability of cities are also documented: apartment buildings and public transportation are more efficient ,[4] and the critical mass of creative and intellectual activity that leads to innovation can be achieved.[5]

The second speculation considers the evolution of mobile devices. In a few years, it is likely that everyone (literally, all 6 Billion of us) will have a mobile device as powerful as our current smartphones, *but not much more so*. The devices may well plateau in terms of processing power, and become instead a nexus for the communications and sensing that we carry with us. In other words, they will evolve from being portable computers to become portable sensors and communicators. This is a new form of thin client.

The rationale for this prediction is that as the device becomes more powerful, so does its energy consumption and the concomitant need for more battery power. Unless there is a breakthrough in computing power—which is always possible but not always foreseeable—these devices will be limited by the size of the battery. And battery power cannot get more efficient without becoming more dangerous—extreme power density can be unstable (witness gasoline and lithium batteries). In other words, if the battery gets too good, you won't be able to carry it on an airplane (a comment made by Joe Markowitz in the late 1990s).

It is therefore desirable to concentrate the processing capabilities of the mobile device on the user interface rather than on computing tasks that can be off-loaded. There is no real limit to the richness required of an interface—better sound, pictures, cameras, and other

[2] *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier* by Edward L. Glaeser

[3] SEE: Richard Florida's recent blog post (http://www.theatlantic.com/business/archive/2011/07/how-the-great-reset-has-already-changed-america/241200/), a follow up to his 2010 book *The Great Reset: How the Post-Crash Economy Will Change the Way We Live and Work.* His 2008 Book, *Who's Your City?: How the Creative Economy Is Making Where to Live the Most Important Decision of Your Life* is also about the return to the city.

[4] SEE: *Green Metropolis: Why Living Smaller, Living Closer, and Driving Less Are the Keys to Sustainability* (2009) by David Owen

[5] SEE: *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community, and Everyday Life* (2003) also by Richard Florida

sensors. But tasks that can be done elsewhere might be best outsourced. The result is that mobility is an evolving ecology comprised of the device and how that device functions in the world around it.

Third-Cloud principles and proximal networks

David Reed and I termed this ecology the "Third Cloud": a set of local resources that assists those who are nearby. That may mean integrating the cameras around you to let you "see around the next corner," or storing data and channels for remote information. Most important, the Third Cloud is an opportunity for a new style of communications that is based on intentions and relationships rather than destinations. For example, a question such as "*how do I get across town?"* would be based on a specific location rather than on a query of all taxicab, bus, bicycle, and hitchhiking opportunities.

The Third Cloud is not characterized by a destination (for example, the way phone calls are characterized by a phone number that you dial or e-mail is characterized by an address)—but rather is characterized by a relationship, a request, an advertisement or an offer. One could ask what the traffic conditions are two miles down the road; where have the croissants just come out of the oven; or who wants to share a cab? Work by Polychronis Ypodimatopoulos addresses the processing and distribution of such request-based interactions.

Proximal networks are thus a realization of the third could. Ypod's work envisions several dimensions of proximity including:

- Physical
- Social
- Temporal

We have thought about the network architectures that would facilitate these proximities and Third-Cloud principles. We do not necessarily need new network architectures—GPS and location solve much of the problem (at least for many of the positional attributes). But on the other hand, we have an opportunity to think about a network that offers us:

- Broadcasting, multicasting or outcasting abilities;
- Simultaneity and synchronization; and
- The ability to include agency or actions that are done on our behalf.

Implicit in the notion of proximal networks is that they are infrastructure-free. They are intended to require no registration, little setup, and no permanent structure. They are created by the users. Of course, they can be connected to the Internet.

Point-to-point radio: a proximal realization

There are many decentralized, point-to-point radio systems in use today and their application is instructive. Globally, there is the IMO-sanctioned VHF-FM[6] marine radio that is mandatory on ships and pervasive on smaller craft. It is a thriving industry that provides devices that range from inexpensive hand-held units for rowers to GMDSS[7] elements that are carried by international freighters. High frequency (HF), ham and Citizen's Band are other examples that have had a place in society.

One unifying characteristic of these systems is that they are unlicensed. The technology by which they operate is still defined for each radio band that they use, but entry to that band (generally) is unlimited. It is determined by convention more often than by law. Unlike Bluetooth and Wi-Fi, which operate in ISM bands[8], these radios are designed to interoperate collectively and collaboratively.

Another characteristic that has emerged is a convention related to hailing safety and establishing point-to-point links. In marine radios, there is a dedicated channel—channel 16 (158.6MHz, narrowband FM)—that is used for broadcast functions such as emergencies, establishing private communications, and for security messaging. By convention (and in some cases law) it is monitored and used by all, but only for notification, not for content. Since all stations and people hear it, there is a human filter that triggers actions and weeds out the irrelevant. The important bit is the combination of a filtered broadcast channel working in concert with private ones (as it turns out, there is a digital enhancement called DSC (digital selective calling) which is seldom used except where mandated. And

[6] International Maritime Organization (IMO); Very high frequency (VHF) frequency modulation (FM)
[7] Global Maritime Distress and Safety System (GMDSS)
[8] Industrial, scientific and medical (ISM) radio bands

there is a scrambling option on some radios for privacy on some channels, but this is likewise rare.)

Broadcast, multicast and outcast

We should be clear about what we mean by the term "broadcast." For the sake of discussion, broadcast is a one-to-many radiation of information that includes no requirement of reception. Traditional radio and television are examples: they blanket an area with a signal independent of whether that signal is received or if any receiver exists.

Multicast is a one-to-many distribution of information where the recipients subscribe to the signal. Often that subscription is through an intermediary such as a group, so that, for example, an Internet router will maintain the group information and replicate packets for transmission to members of the group. The source may not know the actual identities of the recipients. Further, the system will not transmit information if there is no recipient.

We also consider a case we call "outcasting" which is the inverse of multicast. We are concentrating some of our experiments on this reverse-casting so that we can determine the utility of proximal networks for cases where large amounts of data originate in the leaves of the network rather than at fixed and known servers, for example, a number of parents creating real-time video of their kids' soccer game. We treat "outcasting" as multicasting and give it a separate name to indicate the intent.

Three rationales

The purpose of this exposition is to anchor an approach that updates the ideas and capitalizes on the social and technical benefits of such point-to-point systems. This anchors a design for a "computational" societal radio system that is inherently digital and designed not only for human listeners, but for computers that are listening as well. They communicate *data* that is interpreted and presented by processing, and their digital nature enables new ways to scale and utilize a radio channel. This is potentially far more significant than digital overlays such as DSC.

Here are three reasons for generalizing and rationalizing point-to-point radio:

1. Catastrophic events (natural and man-made). The denser an infrastructure, the more fragile it is, both from an operation perspective and from the point of view of the population. One need not look too far for infrastructure failures. The successes are few—we don't seem to learn quickly enough. Some even view the Internet as being designed to avoid concentrated points of failure.

In the last year alone, there have been communications failures due to earthquakes, tornadoes, tsunamis, hurricanes, floods and government blunders. A hundred years ago, when people were not accustomed to having instant, portable communications, other social systems were in place to organize the population when central failures occurred. Often the military played a role (1906 San Francisco earthquake, 1917 Halifax explosion). However, now that people expect instant communications at all times., a loss of communication renders bystanders more a part of the problem than a part of the solution. In the 1965 blackout in New York City, I helped direct traffic by acting as a human stoplight. In 2011, more people might wait to text their family to make sure they are well and fail to physically organize themselves effectively.

2. Natural logic. There are many cases where point-to-point is a logical choice: garage door openers, walkie-talkies, car keys, remote controls, NFC[9], etc. It makes some sense that a transmission intended for local use travel locally. This may or may not be the best way to do it. **OnStar**, for example, can unlock your car remotely. Maybe that generalizes; it might be a reasonable service to let the carrier unlock your house on command. However, there is an option value in having it technically possible to do it both ways. This allows the most economic and useful solution to emerge.

3. Scalability. It is clear from theoretical work that the radio spectrum scales better when all radios send a signal no farther than it needs to go. If all the radios in an area wanted to communicate with a neighbor, then more of them could do so if they were all operating at lower power. Initially, with some spectrum models, the scaling goes as the square root of the count, but the vagaries of transmission increases that scalability. When there are real barriers, such as walls, then ironically, the throughput of a space scales faster.

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[9] Near field communication (NFC)

The viral reason

It is generally true that most applications can work with a wide variety of architectures and realizations. To date, we have not invented or concocted any applications that would work in a point-to-point environment but could not be realized with existing or foreseeable networks. For example, sharing a cab ride can indeed be a central service of a city equipped with carrier-based or Wi-Fi networks and GPS. Carried to an extreme, location can even tell us how many people are waiting for a stoplight to change or are looking at a store window display.

However, their scaling characteristics may differ, and that can have practical impact. Carrier systems get overloaded when the concentration of users exceeds their immediate capacity. They cannot exploit commonalities of intent in the communications (this is a double edged sword in that local devices cannot make global optimizations).

Innovation and risk

There is another reason why a point-to-point system may be a welcome addition to the range of options for application development: it can be a viral turf that allows ideas to start small and then later be "rationalized" as economic services, even central ones.

We formalized the notion of viral systems as those systems that could start small, grow without limit and evolve through their diffusion and use. Radio was the instant example, but the general principles apply to all sorts of technical innovations including an economic environment that allows for easy startups that later become assimilated into larger industries.

Often, a large enterprise cannot launch small-scale ideas because the internal costs are too high or they are not well positioned to experiment with them. It also may not be efficient for them.

This implies that a parallel system *optimized for invention* can be a feeding ground for established operators and service providers to allow ideas to develop rapidly, cheaply and independently. Dominant ones can then be developed or culled based on real-world experience and results. The risk is thus diffused through the entire field rather than concentrated among the few, larger elements. To some measure, this is a radio parallel to the entrepreneurial condition uniquely extant in the US—it benefits the large industries as well as the risk capitalists.

We think it is intuitively clear that inventions and innovations thrive in a viral environment. The barrier to experiment is low, and small ideas can start and grow. They may later become central services, but they less frequently start that way. Therefore, it is an advantage for a service provider to have a field of dreams and a migration path. This is especially true if large companies prefer to innovate through acquisition, which is more common now that finance is a more fluid means to conduct almost any transaction. Just as they outsource invention to universities, they can outsource ideas and buy them later. It will likely cost more, but with correspondingly reduced risk.

I have asked our new students to validate these claims with some numerical research. What seems obvious is often wrong or incomplete or biased. For example, we used spreadsheets as an example of a viral invention yet we could just as well have used cellular telephony as an example of an innovation that sprung from a large company.

Tim Wu, in his *The Master Switch: The Rise and Fall of Information Empires*, argues that innovation is reduced in a monopoly environment. After the Carterfone decision, we got large-scale facsimile penetration, answering machines, modems, wireless phones, and loads of designs. He further argues that some inventions are suppressed because they potentially intrude on a business model—tape recording is his exemplar.

Notwithstanding the obviousness of Wu's arguments, their factual basis gives them force. We want to forcefully make a strong point as well: that a parallel, viral invention arena *enhances* a large company's ability to innovate. This point is less obvious and may not be true. What is undoubtedly true is that *we* ought to be central node for knowledge about this.

Current research and directions

We are exploring proximal networking and point-to-point radio in part via a research grant from Qualcomm Corporation that includes an implementation of such a digital radio system. Called *FlashLinq*, this radio has a digital broadcast channel, the opportunities for computational filtering of requests and offers for services and side channels for private communications. We expect that this is but one of many examples of the potential use of the services and side channels capabilities of *FlashLinq*, but it is certainly a good start.

The most compelling features of *FlashLinq* are:

- A few years ago, more effectively utilizing the "two-way radio" capabilities of smartphones was impossible. Now it is merely difficult. *FlashLinq* is designed to optimally facilitate such usage.
- By being infrastructure free, it has the ability to work in adverse circumstances–like a Katrina or World Trade Center disaster—where the infrastructure isn't there.
- It has a heartbeat. That is to say, the radios all operate in a synchronous fashion and once every couple of seconds—they all advertise their presence to up to 5,000 other radios in about a 1-kilometer range. They do that in a way that seems to work and seems to scale in a reasonable way. The rest of the time is used to establish private channels.
- *Flashlinq* was not optimized for a known and restrictive application set, as was the case with Bluetooth and Wi-Fi. It is a general and efficient use of modern radio techniques.

The Viral Communications Group is going to add agency and some dimensionality to how these features work. Work focuses on several areas:

- We are exploring the possibilities of that particular technology. Often the real thing can prompt idea development on its own, and it can certainly expose missing elements.
- Most important, we are building the software environment for the propagation of services and requests through an area.
- Finally, we are working towards making an "Internet in a box" that will be a rapid deployment local communications system that is robust, scalable, and can organize a community and provide outside communications.

Conclusions and directions

We stress the symbiotic nature of viral radio shown through research in point-to-point systems. We see it as a way to enable a fertile area of invention of socially responsive systems that can function in a locality such as a city but scale to work throughout the world. We see the focus being on applications that can migrate to other architectures as well as those for which local connectivity is optimal. Finally, we think that the notion of a radio system that is inherently digital and "computational" is timely and important.

We also think that mobile systems will evolve to a thin-client based highly distributed set of services for the reasons outlined—power and interface demands. Therefore this work will also inform the evolution of such mobile devices and help answer questions about whether they will be an ever-increasing platform for new hardware augmentations or whether they will converge on becoming a wireless and sensing nexus carried on the body. That will be important for the development of better systems for health, wellness, social safety, economics, and energy conservation.