Enabling Future Consumer Radios to Interact Directly With Things

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Abstract

Many Things in the Internet of Things will likely interact directly with consumers, via the consumer's personal handheld device. That observation suggests that the radio(s) or other communications devices in the handheld need to be consistent with those communications devices in Things. This essay looks quickly at the likely evolution of radios in handhelds and asks us to consider whether that evolution is consistent with the Internet of Things and if not, what we might do to encourage interoperability in the future.

1 Introduction

Most proposals for the Internet of Things propose that each Thing will have a wireless network interface. The type of wireless interface will vary according to the Thing. A light bulb will presumably have a simple wireless interface. A more expensive Thing, such as an automobile or a refrigerator, may have a sophisticated multi-frequency capable wireless interface.

Now consider the position of the consumer. The consumer probably wants to interact with all these Things via her or his personal handheld device. For instance, the consumer may wish to poll the light bulbs in his home to decide if light bulbs are part of today's shopping trip, and then convey the resulting shopping plans to the car so that a route can be mapped.

What requirements might the wireless diversity of the Internet of Things place on the wireless capabilities of the consumer's handheld device? Can we build experimental devices that demonstrate these capabilities?

2 The Consumer Radio of 2030

What sort of radio might be in a consumer's handheld device when the Internet of Things begins to be become an established part of our infrastructure, say in 2030? Predicting the future is hard, but we can make some intelligent estimates.

First, the radio will be be a software radio. That is, many aspects of how the radio behaves will be determined by software, running in real-time on the radio. Radios are already including substantial amounts of software and this will continue. (Whether IoT radios will be software radios is an open question we'll return to at the end of this essay).

Second, the radio will be a mix (hybrid) of analog and digital components. That's important as analog logic improves slowly in terms of cost and performance: about 7% improvement in cost/performance per year vs. the 40% per year predicted improvement in digital logic. Reverse engineering those rates, if we think that the radio component of the handheld device will cost about $100 USD (which is approximately what it costs in today's devices), then if the device were entirely analog, the parts today would cost about $275. If the device were entirely digital, the parts would cost about $15,000.

One implication is that we'll see a continued push towards increased digitalization of the interior of the radio, as that puts manufacturers on the steeper price/performance improvement curve. A related implication is adding digital processing power to compensate for the use of cheaper and lower quality analog components will continue to make sense for the foreseeable future. Another implication is that the experimental radios that cost between $3,000 to $10,000 today are probably a good hint of what the consumer radio of 2030 might be able to do.

If we look at two of those radios, the Wireless Network-after-Next (WNAN) radio[2] and the USRP Radios[1], what do we see? We see a radio with a relatively large frequency range, from around 1MHz to about 6GHz, tunable in bands sized to 1MHz or so. The radio is frequency agile, has multiple antennas, power management, beam steering and MIMO.

The question I'd like to raise at the workshop is whether those capabilities are the right ones for interacting with the Internet of Things, or do we need to seek to inject other features into the radio of 2030?

3 Different Things/Different Radios

The consumer radio will interact with a wide range of Things.

Some Things will be small and have little or no power. These Things will rely on communications technology that

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is simple and extremely low power, such as RF ID-style technology to interact.

Other Things, such as light bulbs and many automotive parts, will be small but powered. So their communications capability will be constrained by size. Sometimes they will also be constrained by cost – for instance, a consumer LED light bulb that costs about $10 will probably only support a radio that costs under $1.

Things that interact with, and perhaps consolidate information from, other Things will likely have radios comparable in capabilities, if perhaps slightly less sophisticated, to the consumer radio. For instance, a refrigerator could can inventory its contents and send a suggested shopping list to the consumer's handheld device. That mix of activities requires the refrigerator to support the multiple communications standards that will inevitably arise across the food industry, and also support the necessary protocols to communicate with the consumer's handheld. Similarly, the computer in the automobile dashboard will collect data from sensors throughout the car and interact with the consumer and also the wireless system(s) used by automobile maintenance companies and perhaps, given the evolving practice of tracking driver behavior to adjust insurance rates, with insurance companies' wireless systems.

4 Other Forms of Communications

A focus of this workshop is to consider whether other communications media, such as thermal, infrared, laser, camera-based and acoustic communications might be fruitfully employed in the Internet of Things.

My guess is that some of these media will indeed prove useful. I would also suggest that they reinforce the need to think about how we provide a unified interface to the IoT from the consumer's handheld device.

What we do *not* want is a situation where the consumer has to shuffle their handheld device through different modes to find the Thing(s) they want. Imagine standing at a street corner and trying WiFi, then turning on the microphone, then holding the device above one's head to maximize optical reception, all to try to find the nearest bus shelter. The point is that the consumer, for the most part, does not care about how communications takes place and should not be forced to be aware.

We will need a unified architecture that blends all communications media into a single coherent service. The goal of this essay is to start some discussion at the workshop about how to achieve that coherence in the RF domain, with the hopes we might identify the key ways in which the consumer device will need to access the RF domain in support of the IoT.

5 Clarifications and Disagreement

In discussions with colleagues and in the workshop reviews, a few points of substantially varying opinions emerged.

One is whether "handheld" is the right word for the consumer's personal radio. There's general agreement that the consumers will have some personalized communications device, but whether it will be handheld or embedded in another object such as their wallet (or their person) is unclear. Observe that if the personal radio is embedded, we must have the image of a user swinging an object over their head to improve reception.

Another issue is where the dividing line is Things with sophisticated radios and Things with simple radios. A lightbulb is a good example. Several people observed that we consistently underpredict how much more powerful chipsets will be in the future. These folks (who include the largest manufacturer of embedded processors) assert that even lightbulbs will have substantial processing power. Some go farther and observe that lightbulbs would make excellent wireless hotspots and repeaters.

Finally, there is the question of whether the consumer's device will interact directly with Things, or via a cloud. There are powerful economic reasons to assume interaction via a cloud, as the cloud can collate and interpret the vast array of information about local Things. But the principle of fate sharing suggests direction interaction. Someone standing in front of a Thing will expect to communicate with the Thing, and be non-plussed by trouble reaching a cloud.

6 Where Are Things Headed?

This essay has raised the question of whether commercial handheld devices and their radio(s) are on a trajectory to be consistent with the communications trajectory for the Internet of Things. I will close this essay with a suggestion that in some ways they are consistent and some ways they are not and we need to look hard at where they are not.

Consider consistency first. I will suggest that any Thing which has reliable power and a price of a few $100 USD or more will contain a software radio. The radios will be designed to go into consumer handhelds and thus will be inexpensive, reasonably durable, and compatible with interfacing with the consumer. But they need a modest supply of power to support the processing requirements of a software radio. Examples of such Things are automobiles, refrigerators, and heating/cooling systems.

Where I would argue that the trajectories are not well understood is for inexpensive Things and Things that lack power. A consumer light bulb, while having a ready source of power, cannot include a radio that costs $10s or $100s USD. A label on a shipping pallet lacks reliable power. The shipping pallet is not consistent with software radio for the foreseeable future. As discussed above, the light bulb may or may not have a software radio. The radio(s) or other communications devices in the handhelds may have to adapt to interact with these less capable Things. We need to think about what requirements those less capable Things will place on their communications now, while there is time to nudge future software radios to support those needs.

7 References

[1] USRP X series. http://www.ettus.com/product/category/USRP-X-Series.

[2] J. Redi and R. Ramanathan. The DARPA WNaN network architecture. In *MILITARY COMMUNICATIONS CONFERENCE, 2011 - MILCOM 2011*, pages 2258–2263, Nov 2011.