Programmable Radio Environments for Smart Spaces

HotNets-XVI Dialogue

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RC: This is a really cool vision—having antennas everywhere, that can be programmed to create custom RF environments!

KW: Agreed—it seems like exactly the kind of wacky paper that will provoke a healthy discussion at HotNets. I think people who build radios are used to thinking of environmental reflections as a sort of adversary, so I'm intrigued to see what happens when a room might tune those reflections to help radios in the space. Maybe crazy or maybe genius—it seems too soon to tell. Ranveer, you're much more of an expert in this space than I am: what kinds of questions do you see being raised at the workshop? And what kind of evaluation will be required to see if the houses of 2032 will be full of smart radio walls?

RC: I am excited about a discussion that focuses on how one could use these smart RF spaces, what kind of applications can they enable, that were previously not possible, e.g., gaming, AR/VR headsets. The other interesting question is how will the multipath be customized when there are multiple devices, some of which would be mobile. Helpful multipath for one could hurt another device. But these are all open research problems, and will need to be solved to make this vision a reality. Keith, I think this system would work even better if it knew the applications that were running on the end devices. A Skype call on one device could get higher priority than a background download on another. Do you think such a system can be practically implemented?

KW: Naively I would say, probably. We're talking about tweaking low-level parameters of the MIMO multiagent radio channel (with only partial and fuzzy visibility), in order to achieve a pretty high-level goal (network QoS for different applications). But I think if you can predict the effect of any particular radio channel on the eventual data rates between every pair of endpoints (which this scheme sort of needs anyway), you probably could tune QoS in this way.
Let me ask a dumb question: The paper posits putting passive switchable reflectors/attenuators in the walls of a smart space, in order to help wireless radios within the space communicate better among themselves. By "passive," it wasn't quite clear to me if the switching itself is powered by incoming radio waves, or if there is a power feed to each of these switches. Do you know what they envision?

RC: From what I could gather, the passive refers to antenna elements that are not actively transmitting. And also, not amplifying the incoming signal. If powered, they would be plugged into the wall, although theoretically you can imagine an RF-powered system with a battery pack, although that is probably not an elegant design.

KW: Okay, fair enough. So we think there would be a (small?) power source at each smart reflector/attenuator site, but maybe not nearly as much power as you'd need to actually power a real radio. It seems to me, then, that the logical competitors for this kind of approach in future evaluations would be: (a) systems where the power is used to power the radio, not simply an occasional actuation of a switch, and (b) systems where the in-wall elements actually have network connectivity (e.g., an 802.11 access point connected to wired Ethernet). If a mobile device can just talk directly to the nearest in-wall element, that might be a challenging baseline to compete against. And if you're already going to be installing these things in the walls and getting power to each one somehow, running an Ethernet cable might not be so difficult.

RC: I agree. These could potentially be enabled by the active elements in PRESS. And as you mention in

(b), I would imagine these systems to be connected to either the mobile devices, or the wireless Access Point to learn about the channel, so that it can be improved using the passive + active antennas.
Another interesting discussion I would love to see happen is around the various applications of such a distributed active + passive antenna system. For example, could they enable new forms of backscatter communication? Can they be used to transmit RF power, where these antennas beamform to transmit power to a location in the room? For example, this could potentially enable a future where rooms equipped with PRESS could have devices communicating with each other without any batteries! AR/VR systems that can last much longer when used in a PRESS-enabled room!

KW: I love it. Seems reminiscent of past work on long-distance wireless charging (WiTricity, WattUp, MIT's Pi).

RC: Something like what Ossia does (http://www.ossia.com/cota/), but data transmissions as well?

KW: An all-purpose data-and-power RoomZapper().

RC: Keith, if you were to define a smart wireless space, what features would you want from it? Like a smart home learns your habits, adjusts the thermostat, and other parameters, what would you want a smart wireless space to do for you?

KW: Hmm, that's a good question. I think one area where I could envision these techniques helping might not be in improving performance or new use cases at all—what would be nice would be to just have a little more debuggability and understandability about what's going on in my wireless network. Why did that YouTube video stall? Was it bad SNR? Is it somebody else using Facebook at the same time? If you can monitor the wireless medium from 1,000 vantage points, then even if you don't have that much power to actuate the situation, I can imagine all kinds of cool debugging and failure-provenance opportunities.

RC: That's interesting. So instantaneous throughput or latency are not your biggest concerns.

KW: Not really, but imagine if Verizon (or any wireless network) could commit to a certain level of minimum performance, no matter where your mobile device travels within a 3D space. You could actually hold the network accountable for once! And they might feel comfortable making that kind of guarantee if they have the monitoring in place.

RC: That could potentially be an interesting direction for PRESS, where the antenna array can be used to recover from faults, and also to provide more insights to help you debug the fault. Lots of interesting applications of this wacky idea!

KW: Excited to see where this goes—and where the conversation goes later this month at HotNets. Thanks, Ranveer.

RC: Thank you Keith!