Laissez-Faire: Fully Asymmetric Backscatter Communication – Public Review

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Laissez-Faire is a novel design for backscatter communication that enables much higher data rates. The key idea is simple and elegant. The authors note that low-power backscatter systems, e.g., RFIDs, transmit their signal using ON-OFF keying –i.e., they convey bits by transitioning the signal between two levels, up and down. However, since their bit rate is low (tens of kbps), they have a small number of transitions in a unit of time. The RFID reader on the other hand is a powerful device, and can sample the signal very fast (e.g., at tens of MHz). Thus, it can detect many more transitions per unit of time than there are in an RFID signal. This yields an opportunity for increasing the data rate of RFIDs but without jeopardizing their low-power simple design. Specifically, we can have many RFIDs transmit concurrently so that we stack many transitions from different RFIDs in a unit of time. As long as the signals from different RFIDs do not experience a transition at exactly the same time, the reader can recover all transitions and hence all bits. The paper proposes this simple principle and builds on it to ensure the reader can tell which bits are from which RFID.

Past work on enabling concurrent transmissions typically strives to synchronize the transmitters so that their combined signals create a code over the air. In contrast, this paper leverages asynchrony as well as the natural asymmetry in a backscatter system to allow the reader to detect many more transitions from concurrently transmitting RFIDs by sampling the received signal faster. The simplicity and creativity of the idea has impressed the SIGCOMM reviewers and is a key strength of the paper.

Of course, in any communication system, there are tradeoffs. So, what did Laissez-Faire trade for its increased data rate? The first tradeoff involves its ability to operate the network at low SNRs. Specifically, detecting signal transitions is tricky since noise spikes can be confused as signal transitions. If transitions seldom occur, then the stability of the signal after a transition can be used to gain confidence at low SNRs. However, if transitions are stacked back to back, the reader may confuse a noise spike as a signal transition. Hence, the paper shows that such a design is suitable only for scenarios of moderate to high SNRs.

But there is a second trade-off that I find particularly intriguing: If RFIDs used their bandwidth efficiently, there would be no benefit from Laissez-Faire. Specifically, the key assumption underlying Laissez-Faire is that an RFID signal transitions quickly and stays stable at one level for an extended interval; this allows the authors to stack transitions from multiple asynchronous RFIDs to increase the overall data rate. But this behavior of an RFID signal means that the RFID is not using the bandwidth efficiently. Specifically, the total bandwidth occupied by an RFID signal is determined by how quickly it transitions –i.e., the sharpness of the transition – and is not affected by how long the signal stays at the same level after a transition. Thus, each RFID could transition more often leading to a higher data rate but without increasing its overall bandwidth usage. The fact that it doesn't means that an RFID does not use its bandwidth efficiently. Laissez-Faire capitalizes on this inefficiency to enable asynchronous RFIDs to stack their transitions without interference and hence increase the data rate.

The above argument begs a question: Why combine transitions across RFIDs? Why don't we make each RFID eliminate the still time and transition more often to increase its data rate? I believe such a design would increase the complexity of an RFID and hence current RFIDs (e.g., the MOOs) do not do it. Another reason could be that separating the transitions in time allows an RFID to accumulate more energy before the next transition. Either way, current RFIDs do not use the bandwidth in the best way. Laissez-Faire provides an elegant system that leverages this inefficiency, and effectively counters it by allowing higher data rates over the same spectrum.

This paper made me think carefully about the implicit tradeoffs between bandwidth bitrate and power in backscatter systems. I encourage the SIGCOMM community to read it and think whether our traditional designs fit the new generation of sensors, actuators, and RFID tags.