Bringing harmony to discord in the IoT world

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Credit: Carnegie Mellon University Electrical and Computer Engineering

Billions of devices are connected to wireless networks all over the globe, and because of the Internet of Things (IoT), they're starting to communicate with each other and the cloud now more than ever. Today, some of our devices can 'talk' with other applications to make our lives more manageable and stress-free: our smart phones can track our movements to help us navigate, and our Fitbits can count our steps to monitor our health, but what if *every* device in our homes, or in our

cities, could be connected to the Internet? The Internet of Things (IoT) is a growing platform that could make this possible.

Over the years, sensors and chips have been embedded in physical 'things' like coffee machines, thermostats, garage doors, and traffic cameras to communicate with and transmit information to the IoT platform, a platform that gathers and analyzes data before sharing it with other relevant applications and technologies around us. This data-sharing platform has been created to help us build better systems (like healthcare) while also making our lives more convenient. But can current technologies (such as Wi-Fi or the Internet) support the growing IoT platform? According to Carnegie Mellon Electrical and Computer Engineering Assistant Professor Swarun Kumar, the answer is no. To accommodate the vast number of devices we wish to enhance, or make 'smart,' he says we must upgrade our technology.

"We want all of our devices to be smart, everything around us, from the chairs we sit on, to the phones we use to communicate, to the bags we lug around everywhere," says Kumar. "To achieve this vision, the fundamental question that needs to be addressed is, 'How are we going to network these devices?' All of today's technologies, like cellular, Wi-Fi, and Internet don't make the cut. The last link between your handbag and the internet does not yet exist."

In a recent research paper, titled "Empowering Low-Power Wide Area Networks in Urban Settings," which will appear in ACM SIGCOMM'17, Kumar along with ECE Ph.D. students Rashad Eletreby and Diana Zhang, and ECE Faculty Proffesor Osman Yagan, explain how they tackle this fundamental question with their networking platform, Choir, a system that can potentially be used to connect IoT devices. Kumar and the team capitalize on the challenges that Low-Power Wide Area Networks (LP-WANs) face in urban environments to build the basis of their system.

The challenges of LP-WANs at City-Scale

LP-WANs help low-cost devices transmit information at low data rates (kilobits per second) over long distances, which make them ideal networks for low-cost, low-power IoT devices that have batteries with limited life spans. As such, this is an enabling technology for IoT. Although LP-WANs have been used successfully in open, rural settings, Kumar says that implementing LP-WANs on a city-scale comes with several challenges.

"What really changes the game is when these radios are brought from rural environments to cities because first, there are going to be millions of radios in a relatively small area," says Kumar.

With millions of radios trying to transmit data simultaneously, Kumar says that transmission collisions will inevitably occur, draining the power from IoT devices.

"A second challenge is that the range of these systems changes," he says. "In open, rural environments, there are no buildings to absorb and attenuate signals, which means that your signals could potentially reach towers several miles away. But the moment you step inside a city, because of all the concrete and other obstacles in the environment, your signal is going to be significantly weaker."

Density of deployment and range reduction are the two major obstacles that LP-WANs face in urban environments. But what's the root cause of these challenges? The LP-WAN hardware, says Kumar.

Because of the limited lifespan and inexpensive nature of many LP-WAN clients, or devices connected to the IoT platform, it's challenging for experts to deploy complex schemes that can prevent transmission collisions from occurring without draining the battery of these devices.

Taking advantage of hardware imperfections

But instead of repairing the LP-WAN hardware imperfections, Kumar and his team used them to their advantage. When building Choir, they exploited the imperfections of low-cost LP-WAN radio components to help disentangle collisions at the base station, which allowed devices to communicate with each other at greater distances. One of the important imperfections that Kumar exploited was the offset in frequency produced by devices when transmitting radio signals.

"You can think about it this way: an ideal radio should be able to transmit and receive signals at 900 megahertz," says Kumar. "But in practice, because these radios are imperfect, there will be small differences. If you ask five or six different radios to transmit at 900 megahertz, they will all transmit at slightly different sets of frequencies. Some might transmit at 900.01. Others might transmit at 900.05. Our system, Choir, exploits these differences and filters out the received signal to essentially disentangle the transmissions."

A bright future for the Internet of Things

With the ability to disentangle radio transmissions and the capacity to exploit other hardware imperfections, Choir improves the throughput, latency, and battery life of LP-WAN nodes while also increasing the range at which they can communicate. With this new technology, future LP-WAN towers could potentially gather sensor data from millions of low-power devices within a single city. These devices could then communicate with each other (from any location and without ever being charged) by simply exploiting the hardware imperfections of the LP-WAN platform.

Now, the Internet of *all* Things seems well within our reach.

But Kumar says his team is still searching for ways to build upon Choir because they want to answer even more fundamental questions related to today's networking technologies.

"How do you ensure that this new age of the Internet of Things doesn't collapse under its own weight?" he asks. "If everything in the world is attached to the Internet, what are the new applications that can be enabled? And how do we ensure security and privacy of our information in a world where every object is inter-connected?"

These are the questions that Kumar hopes to answer.

And optimistically, he says: "The technology is starting to emerge—first-generation radio chips have just been rolled out and LP-WAN standards are starting to be developed. As researchers at CMU, we really get to define the so-called Internet of Things. We get to define the future of the Internet that the public will use 10 years from now."

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