A system for stable simultaneous communication among thousands of IoT devices

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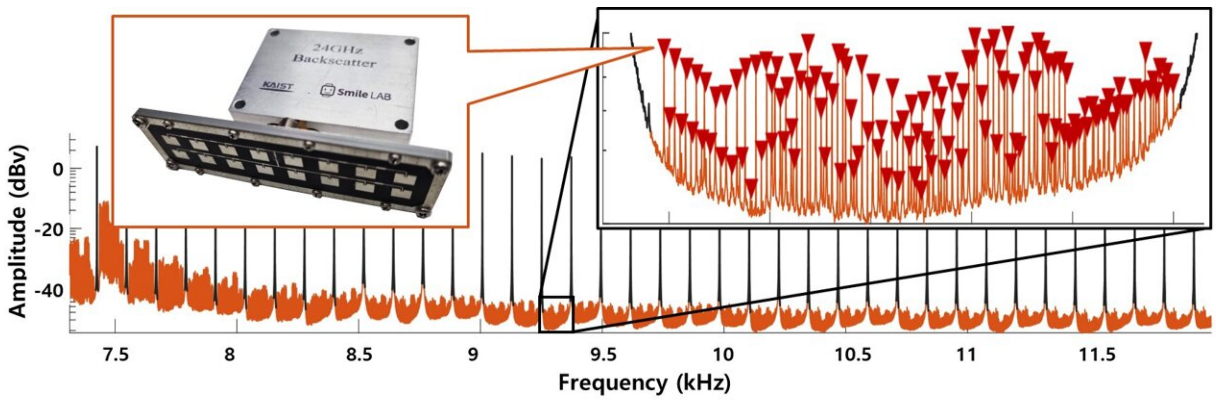

To demonstrate the massive connectivity of the system, a trace-driven evaluation of 1100 concurrent tag transmissions are made. Figure shows the demodulation result of each and every tag as red triangles, where they successfully communicate without collision. Credit: KAIST SMILE Lab

A research team led by Professor Song Min Kim of the KAIST School of Electrical Engineering developed a system that can support concurrent communications for tens of millions of IoT devices using backscattering millimeter-level waves (mmWave).

With their mmWave backscatter method, the research team built a design enabling simultaneous signal demodulation in a complex environment for communication where tens of thousands of IoT devices are arranged indoors. The wide frequency range of mmWave exceeds 10GHz, which provides great scalability. In addition, backscattering reflects radiated signals instead of wirelessly creating its own, which allows operation at ultralow power. Therefore, the mmWave backscatter system offers internet connectivity on a mass scale to IoT devices at a low installation cost.

This research by Kangmin Bae et al. was presented at ACM MobiSys 2022. At this world-renowned conference for mobile systems, the research won the Best Paper Award under the title "OmniScatter: Sensitivity mmWave Backscattering Using Commodity FMCW Radar." It is meaningful that members of the KAIST School of Electrical Engineering have won the Best Paper Award at ACM MobiSys for two consecutive years, as last year was the first time the award was presented to an institute from Asia.

IoT, as a core component of 5G/6G network, is showing exponential growth, and is expected to be part of a trillion devices by 2035. To support the connection of IoT devices on a mass scale, 5G and 6G each aim to support ten times and 100 times the network density of 4G, respectively. As a result, the importance of practical systems for large-scale communication has been raised.

The mmWave is a next-generation communication technology that can be incorporated in 5G/6G standards, as it utilizes carrier waves at frequencies between 30 to 300GHz. However, due to signal reduction at high frequencies and reflection loss, the current mmWave backscatter system enables communication in limited environments. In other words, it cannot operate in complex environments where various obstacles and reflectors are present. As a result, it is limited to the large-scale connection of IoT devices that require a relatively free arrangement.

The research team found the solution in the high coding gain of an FMCW radar. The team developed a signal processing method that can fundamentally separate backscatter signals from ambient noise while maintaining the coding gain of the radar. They achieved a receiver sensitivity of over 100 thousand times that of previously reported FMCW radars, which can support communication in practical environments. Additionally, given the radar's property where the frequency of the demodulated signal changes depending on the physical location of the tag, the team designed a system that passively assigns them channels. This lets the ultralow-power backscatter communication system to take full advantage of the frequency range at 10 GHz or higher.

The developed system can use the radar of existing commercial products as gateway, making it easily compatible. In addition, since the backscatter system works at ultralow power levels of 10uW or below, it can operate for over 40 years with a single button cell and drastically reduce installation and maintenance costs.

The research team confirmed that mmWave backscatter devices arranged randomly in an office with various obstacles and reflectors could communicate effectively. The team then took things one step further and conducted a successful trace-driven evaluation where they simultaneously received information sent by 1,100 devices.

Their research presents connectivity that greatly exceeds network density required by next-generation communication like 5G and 6G. The system is expected to become a stepping stone for the hyper-connected future to come.

Professor Kim says that "mmWave backscatter is the technology we've dreamt of. The mass scalability and ultralow power at which it can operate IoT devices is unmatched by any existing technology."

He added that they look "forward to this system being actively utilized to enable the wide availability of IoT in the hyper-connected generation to come."

The research was published in *Proceedings of the 20th Annual International Conference on Mobile Systems, Applications and Services*.

More information: Kang Min Bae et al, OmniScatter, *Proceedings of the 20th Annual International Conference on Mobile Systems, Applications and Services* (2022). DOI: 10.1145/3498361.3538924

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