Empowering Low-Power Wide Area Networks in Urban Settings

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Recent years many Low-Power Wide Area Network Technologies (LP-WANs) were proposed to connect the Internet-of-things, including NB-IoT, LTEM, LORA and SigFox. Though LP-WANs are promising with the advantage of long-range communication and low power consumption, deploying LPWANs in large urban environments is challenging, due to the sheer density of nodes that causes interference and blockage of buildings that limits signal range. However, before Choir, state-of-the-art techniques to address these limitations demand significantly increasing the hardware complexity, including both size and cost. This paper suggests Choir, a system that addresses the aforementioned challenges, density and range of urban LP-WANs. First, Choir proposes to disentangle and decode large numbers of interfering transmissions at a simple, single-antenna LP-WAN base station by making use of hardware imperfections. The rationale behind is that hardware imperfections bring different nodes different carrier frequency offset (CFO), and the CFO itself can be used to distinguish different transmissions. Second, Choir exploits the correlation of sensed data collected by LP-WAN nodes to collaboratively reach a faraway base station, even if individual clients are beyond its range. The authors implement and evaluate Choir on USRP N210 base stations serving a 10 square kilometer area surrounding Carnegie Mellon University campus. The results show that Choir improves LORA's network throughput by 6.84 times and expands communication range by 2.65 times.

Some discussions during the class are summarized below.

1. Trade-offs between the base setation's coverage and its ability of handling requests. It was mentioned choir can increase transmission distance from 1 km to 2.6 km. However, when the coverage increases, there would be more and more nodes connecting to this same base station. Thus, it brings about a new challenge of handling more and more concurrent transmissions at the base stations side. For this question, Choir relies on two LPWAN properties to avoid being overwhelmed by transmissions. First, the uplink transmissions are sporadic, generally once per hour. Second, Choir expects that all LP-WAN sensors were initially deployed in the vicinity of an LP-WAN base station (and thus should be reachable), their transmissions may not reach the base station because of the randomness of the wireless channel, or a change in the surrounding urban environment itself. With this assumption, Choir base stations should be able to handle the increased number of nodes.

2. Strong time and frequency offset assumption: to make sure this is a safe assumption, the authors need to first show the evidence that (1) every radio has distinct offsets, (2) probabilistically how many nodes can have a distinct offset, and (3) stability of the offset, and (4) what is workable offset difference. From the evaluation, we can see that (1) and (2) are extensively experimented. For (3), only show low and high SNR cases seems not sufficient enough. A detailed result with more scenarios considered would be better, like temperature varying scenario. (4) is missing in the evaluation.

3. The separating collisions algorithm in Section 5.1 and 5.2 are really hard to follow. The authors only use texts to illustrate their complex design, it would be much easier to follow if there are some small figures describing the relationships of the involved signals. Actually, we did it in the class, only some annotations make it much more clear to the audience.

4. It is unclear how Choir identify the nodes that need to coordinate. There is no specific explanation in section 7, only a vague solution "a scheduling algorithm can estimate the signal-to-noise ratio of clients to schedule larger groups of sensors". There are some strategies mentioned in evaluation, including randomly, by floor and by relative distance. But the coordination method only makes sense when the coordinated nodes are close geographically. Coordinating all users with similar SNR without considering their geographical locations, though the signals can then be decoded, only gives the base station a measured value without any physical meanings.