Frequency-Hopped Chirp Spread Spectrum for Collision Resolution in LoRa Network

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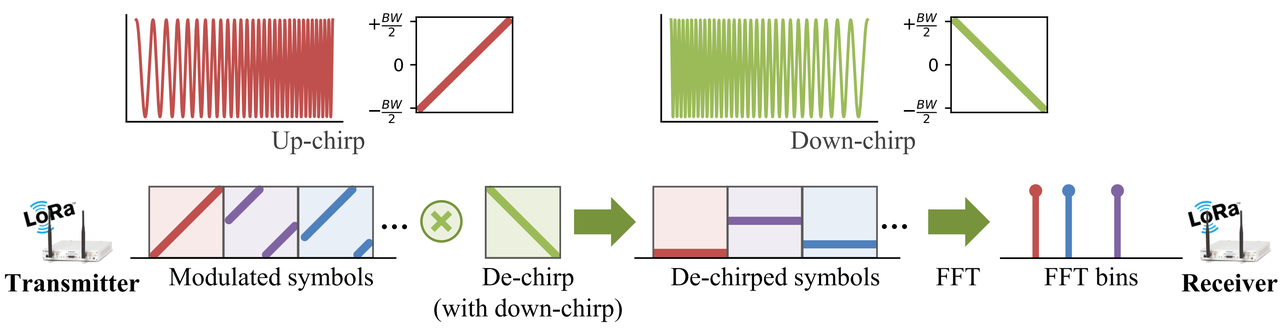
Introduction of LoRa & Challenges

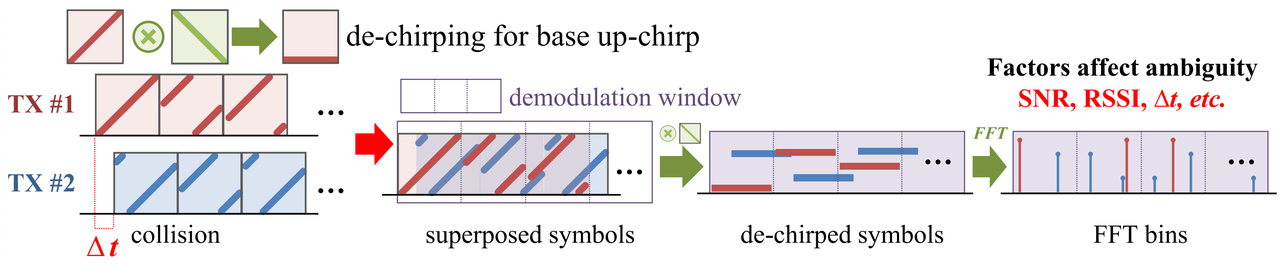
LoRa & Chirp Spread Spectrum

- LoRa attracts attention as one of the key wireless technology for IoT owing to its capability to **cover a wide area with low power consumption**.
- LoRa uses **'Chirp Spread Spectrum (CSS)'** for low-power and long-range communication.
- CSS embeds data into an **up-chirp with frequency shift**, and extracts using **a down-chirp**. (de-chirp)
  - Up-chirp: a chunk of frequency that linearly **increases** over time
  - Down-chirp: a chunk of frequency that linearly **decreases** over time



Decoding Failure in Collision

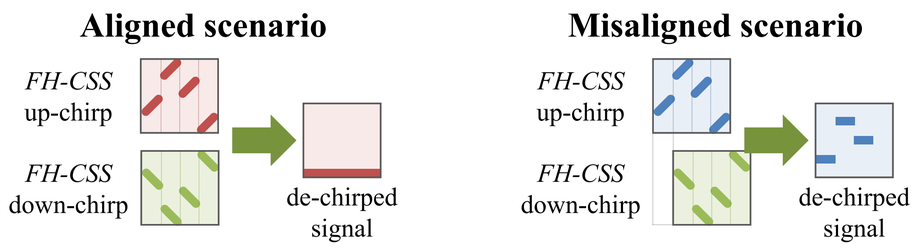
- CSS's modulation and demodulation includes the following step.
  1) Start frequency index of an upchirp represents a data symbol.
  2) Transmitter sets the start frequency according to the data and transmits.
  3) Receiver multiplies received signal with a downchirp. (*de-chirp*)
  4) Fast Fourier Transform (FFT) is applied to the de-chirped signal.
  5) Index of FFT bin peak represents a demodulated data symbol.
- Since a chirp *consecutively increases frequency*, a collision of two chirps leads to less distinction in FFT bin height between superposed symbols.
- Ambiguity will be more severe as the collision offset (Δt) gets narrower.



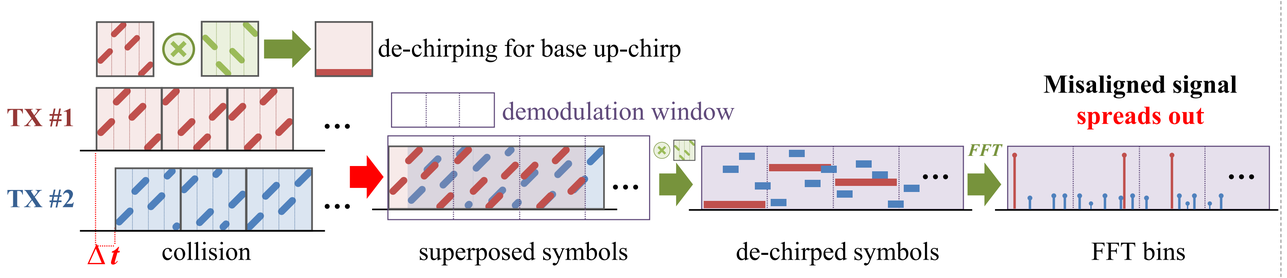
FH-CSS: Frequency Hopped Chirp Spread Spectrum

Energy Scattering Effect

- Proposed Scheme, *FH-CSS*, leverages the observation that the **energy of de-chirped signal spreads out** if chirps are not a counter part of each other.



- A misaligned chirp has less FFT bin height while the aligned chirp peaks.
  → *FH-CSS* can resolve collisions without additional signal processing technique.



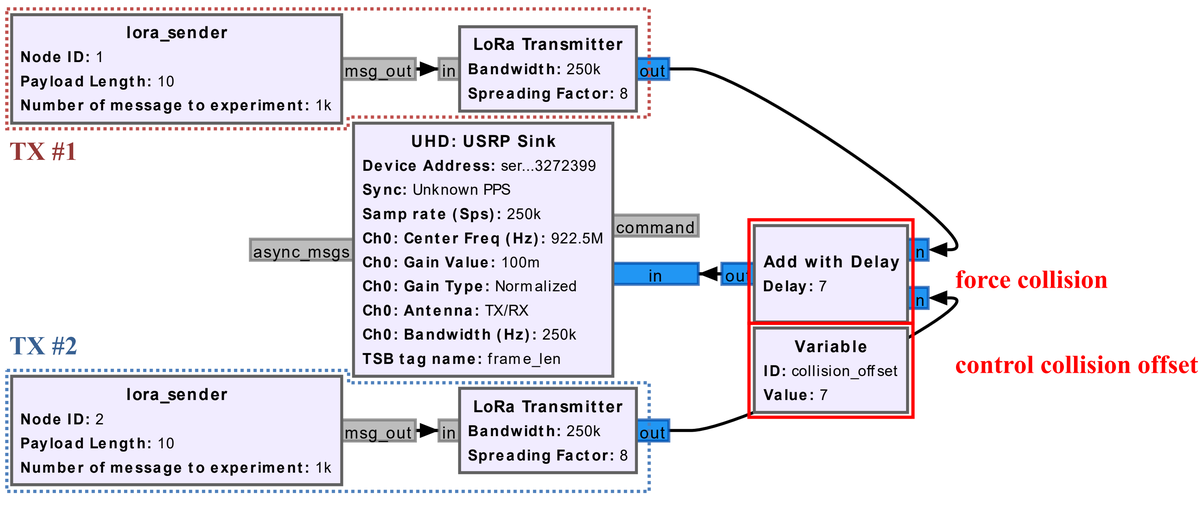
Design Issues

- To support real-time PHY-rate decoding with high reliability, *FH-CSS* has several challenges.
- **Synchronization/Alignment**
  - *FH-CSS* receiver can decode only if the demodulation window aligns with a frequency-hopped chirp.
  - Initial proof-of-concept implementation uses a brute-force linear search.
- **Number of sub-chirps**
  - Higher number of sub-chirps provide better robustness to collisions, but it is more susceptible to noise.
- **Frequency hopping pattern**
  - It should ensure that *FH-CSS* has 'different level of changes' between adjacent hopping patterns so that they are better distinguishable.

Evaluation

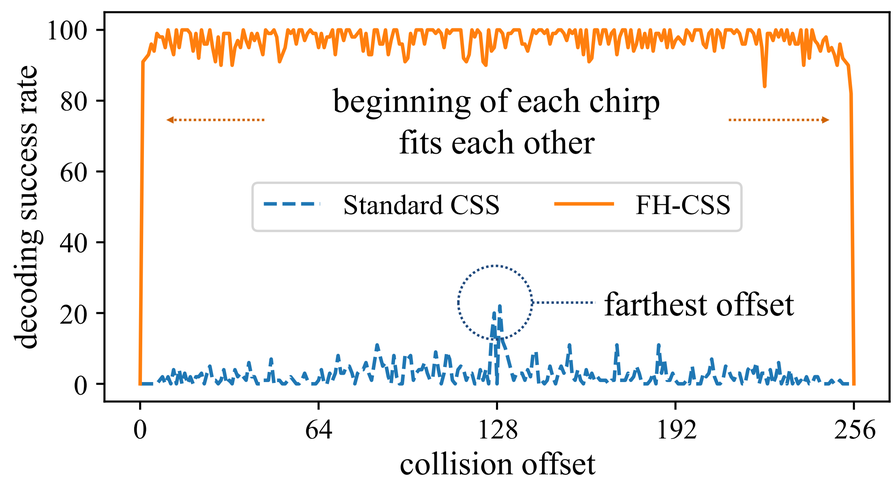
Implementation

- We implement *FH-CSS* and *standard CSS* in GNU Radio using an open source LoRa library, and conduct experiments on USRP B200 SDR.
- To conduct packet collision experiments with *precisely controlled collision offsets*, we built a LoRa transmitter to mix two modulated signals with deterministic delay in software.



Preliminary Results

- SF:8 / Packet Interval: 100ms / # of Packets: 100 / # of Freq.hop: 16 / Collision Offset Range: [0, 256] (= 2^{SF}, within a chirp)



- *Standard CSS* has **less than 10% decoding rate** on average.
- *FH-CSS* maintains **~90% decoding success rate** for almost collision offsets.