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A design of NB-IoT random access preamble receiver for large frequency offset

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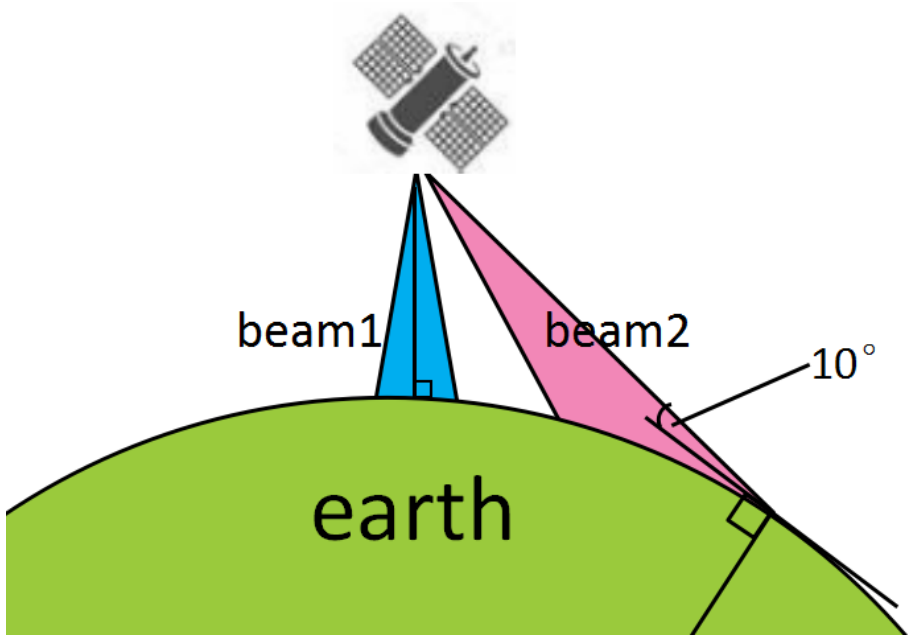
Paper S1.3: A design of NB-IoT random access preamble receiver for large frequency offset

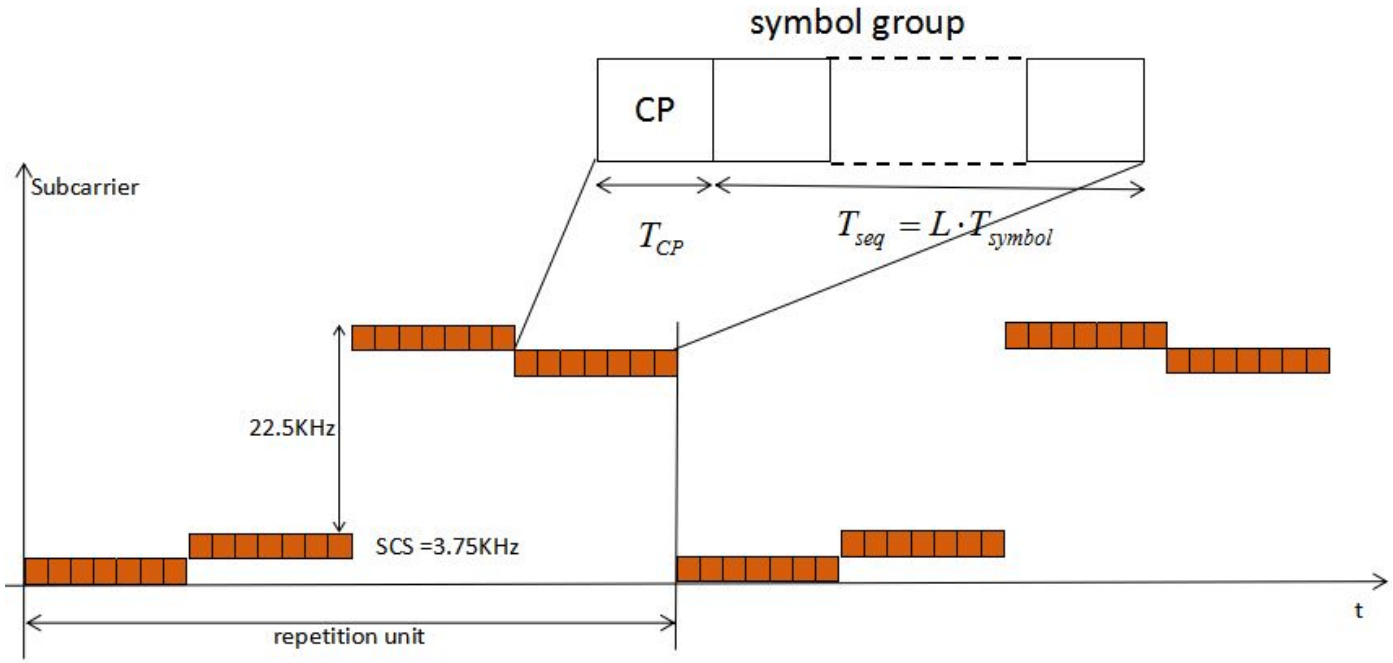
Background

- In non-terrestrial network, the wireless link has large Doppler offset and timing offset, which beyond the capability of terrestrial initial access technique.
- The 3GPP NTN WI supposes the UE knows the states of the satellite and itself. Then the UE can estimate the TA and doppler, and pre-compensates them in uplink transmission.
- However, the pre-compensation maybe not so accurate, and the residual Doppler and timing offset are still too large for terrestrial techniques.



Motivation

- NTN is supposed to support NB-IoT
- An NPRACH preamble is a single-tone signal with hopping
- NPRACH preamble has small subcarrier, so the residual Doppler may has large impact on the performance.
- This papre aims to mathematically analyze the influence of Doppler, and find solutions for receiver to alleviate the performance degradation.

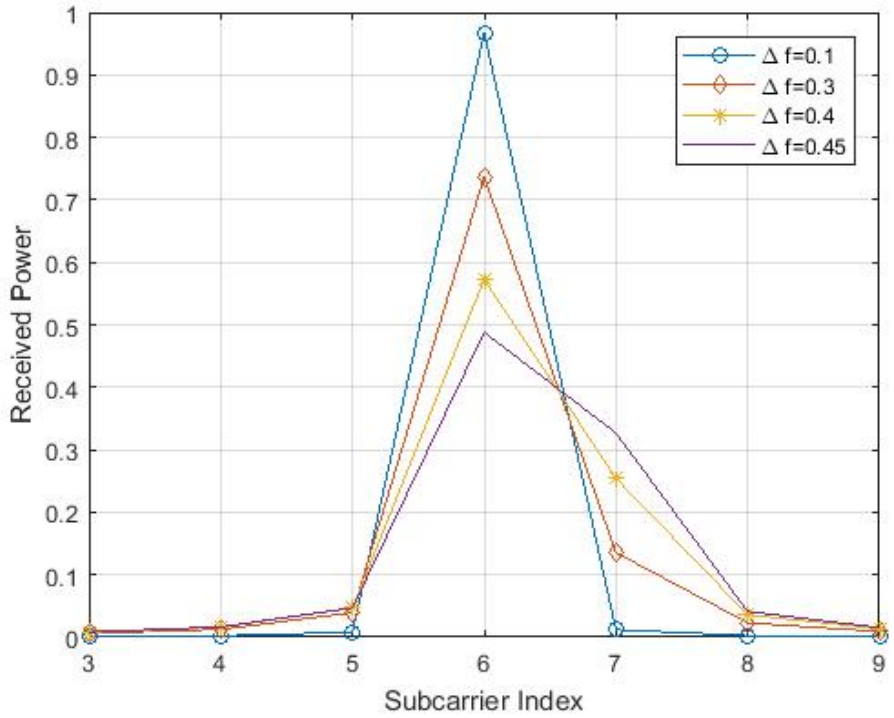


Influence of Large Doppler

- Suppose 1 is transmitted in the m-th subcarrier, without considering the power attenuation and phase shift caused by large scale path, the the received signal in the (m+k)-th subcarrier is

$$Y(k) = \frac{e^{j\theta(N-1)}\sin(\theta N)}{N\sin(\theta)} + noise(k)$$

where $\theta = (\Delta f - k)/N$, and Δf is the normalized residual frequency offset, i.e., Doppler/SCS.



- Suppose m=6, then the received power in different subcarriers is shown in right figure. With the increase of Doppler, more powe leaking into adjacent subcarriers.

Combination of the leaked power

- Because of the large Doppler, the power of the transmitted NPRACH preamble is leaked into adjacent subcarriers, one solution is to combine the adjacent subcarriers in receiver to make use of the leaked power.

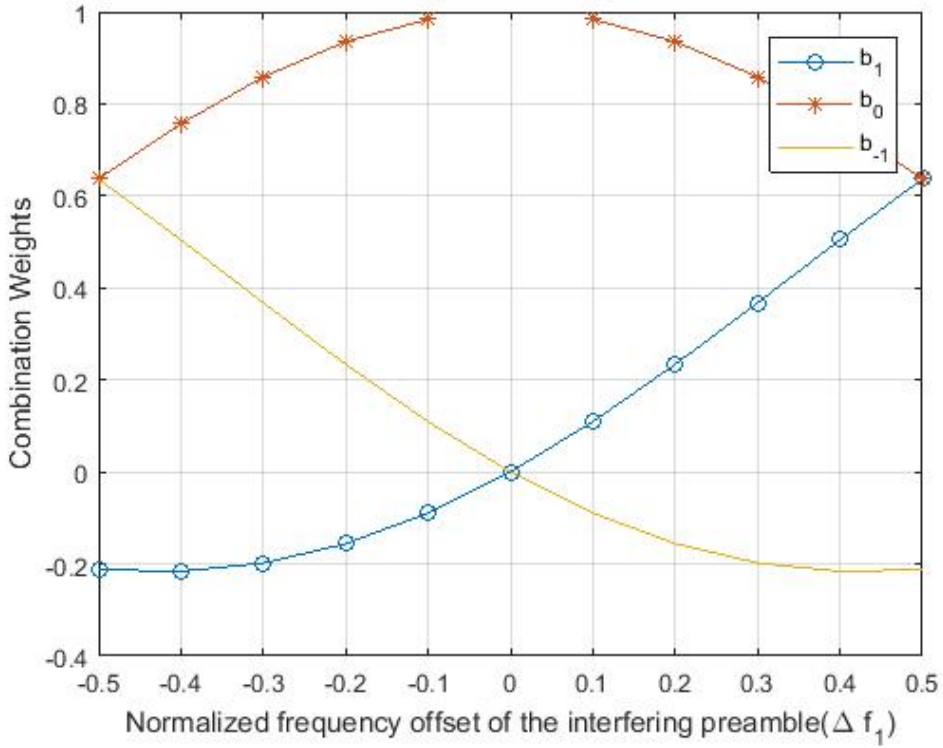
- With Doppler, the received signals in adjacent subcarriers has constant phase difference. The combination is to rotate the phase to align and weighted summarize the signals.

- To detect a preamble in the m-th subcarrier, we combine the received signals in {m-1, m, m+1}-th subcarriers with the weights

$$\left\{ e^{-j\pi(N-1)/N} \frac{\sin(\pi(\Delta f+1))}{N\sin(\pi(\Delta f+1)/N)}, \quad \frac{\sin(\pi\Delta f)}{N\sin(\pi\Delta f/N)}, \quad e^{j\pi(N-1)/N} \frac{\sin(\pi(\Delta f-1))}{N\sin(\pi(\Delta f-1)/N)} \right\}$$

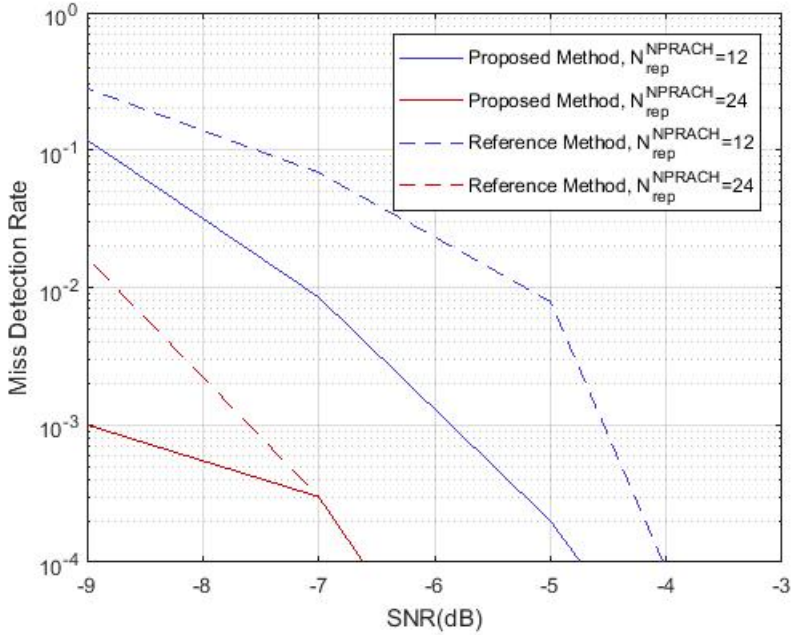
Interference from Other UE

- Other UE's preamble may be transmitted in adjacent subcarriers. We need to evaluate its effect on the combination.
- A preamble in the (m+1)-th subcarrier will affect signals in the m-th and (m+1)-th subcarriers, which will affect the detection of preamble in m-th subcarrier.
- Because of the combination weights, the interference signals in the two subcarriers will contouract each other.
- Intutively, as shown in right figure, $b_0 b_1$ always have opposite sign with $b_{-1} b_0$.

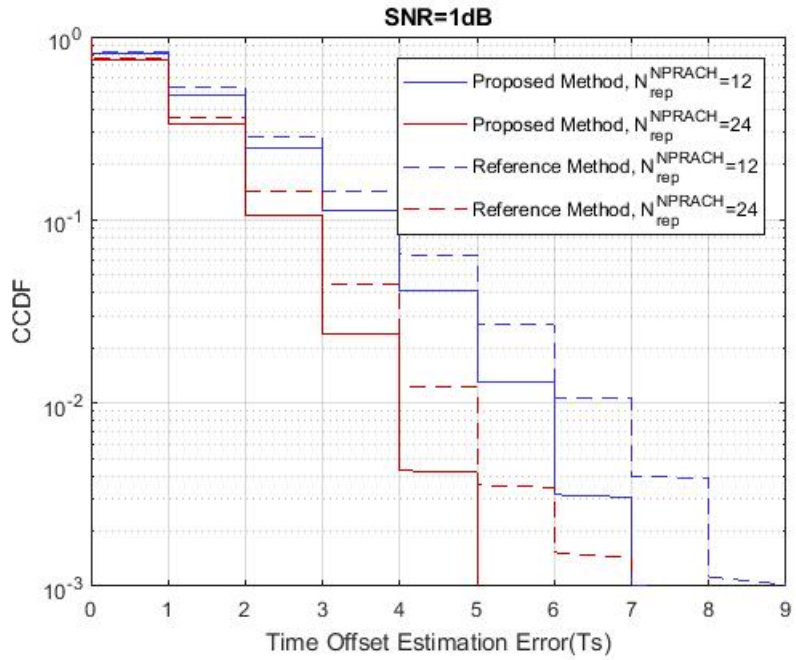


Simulation

- In simulation, the NPRACH preambles follow the format 1 in frame structure type 1. 3GPP TDL channel is used.

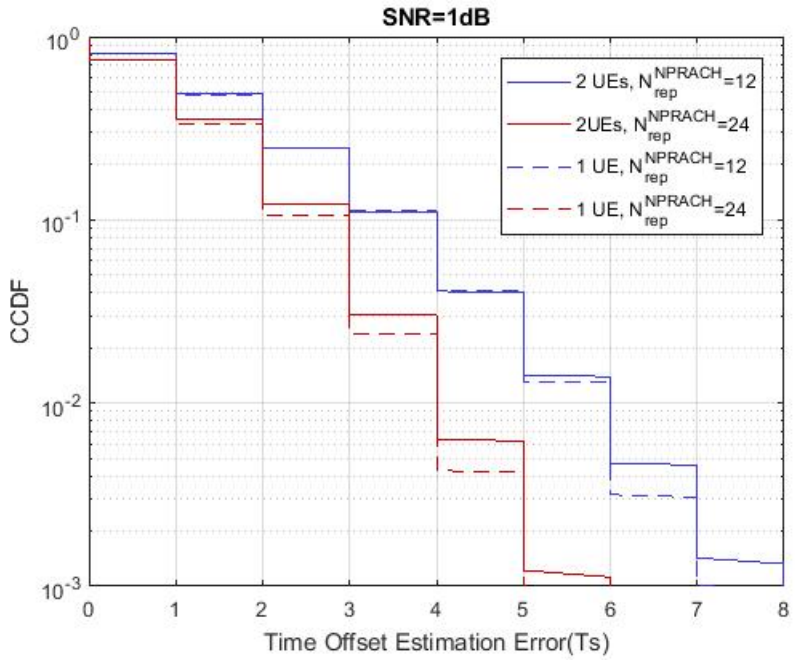


- Comparing with the traditional receiver method, the proposed method makes use of the leaked power, and gets better performance.

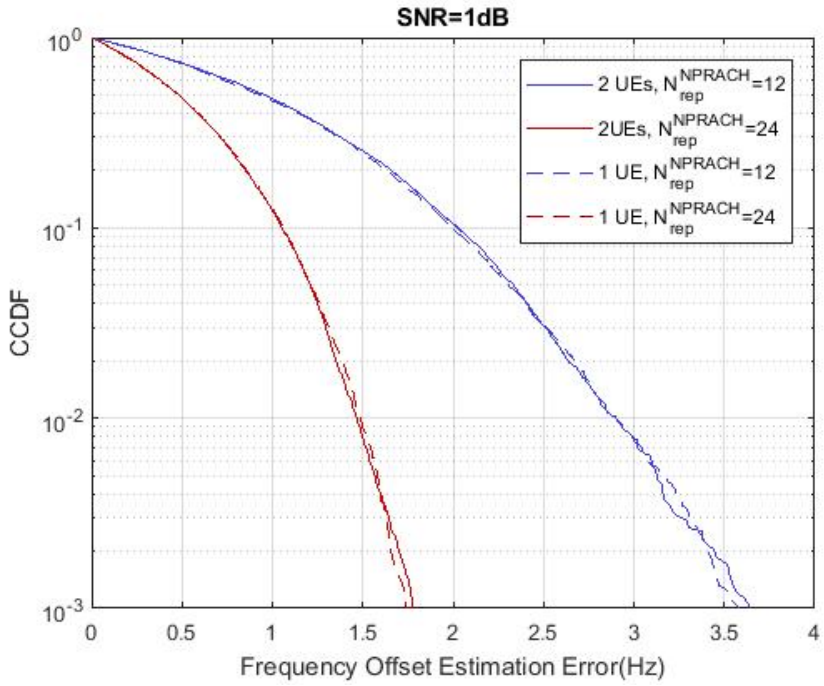


Simulation

- Suppose 2 UEs are simultaneously transmitting their preambles, and their first symbols are adjacent.



- It can be seen that the interference only causes negligible performance degradation.



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Thank you!