

Towards Opportunistic Sensing of Precipitation Using 5G mmWave Commercial Cellular Equipment



AJ Cuddeback^{1,2} & Scott Palo¹

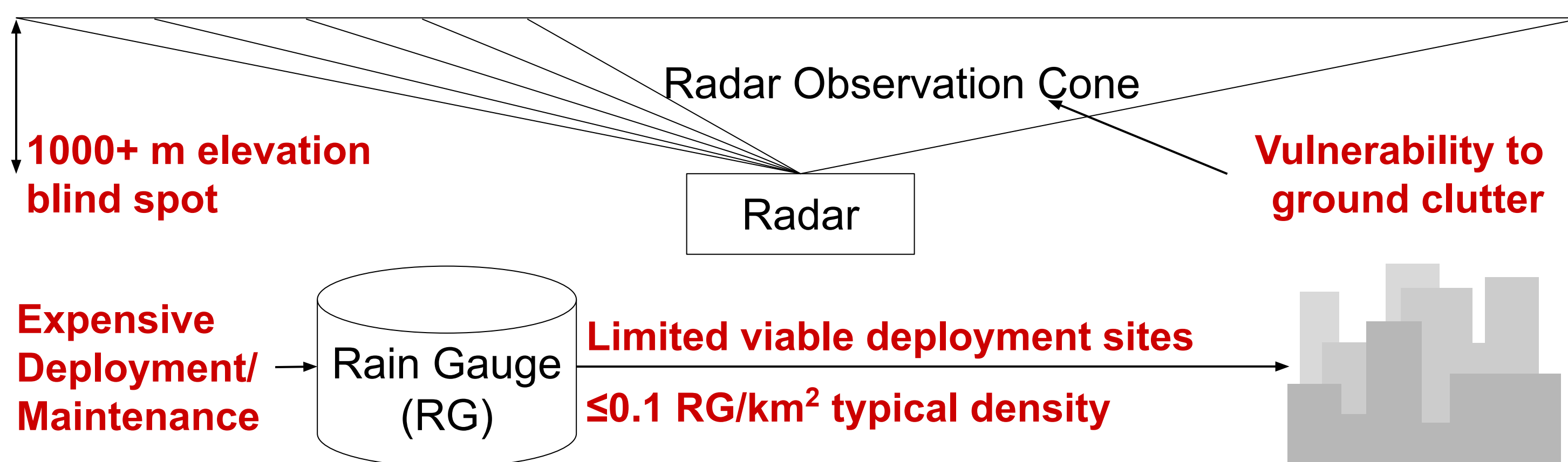
1. University of Colorado, Boulder; 2. NTIA Institute for Telecommunication Sciences

aj.cuddeback@colorado.edu

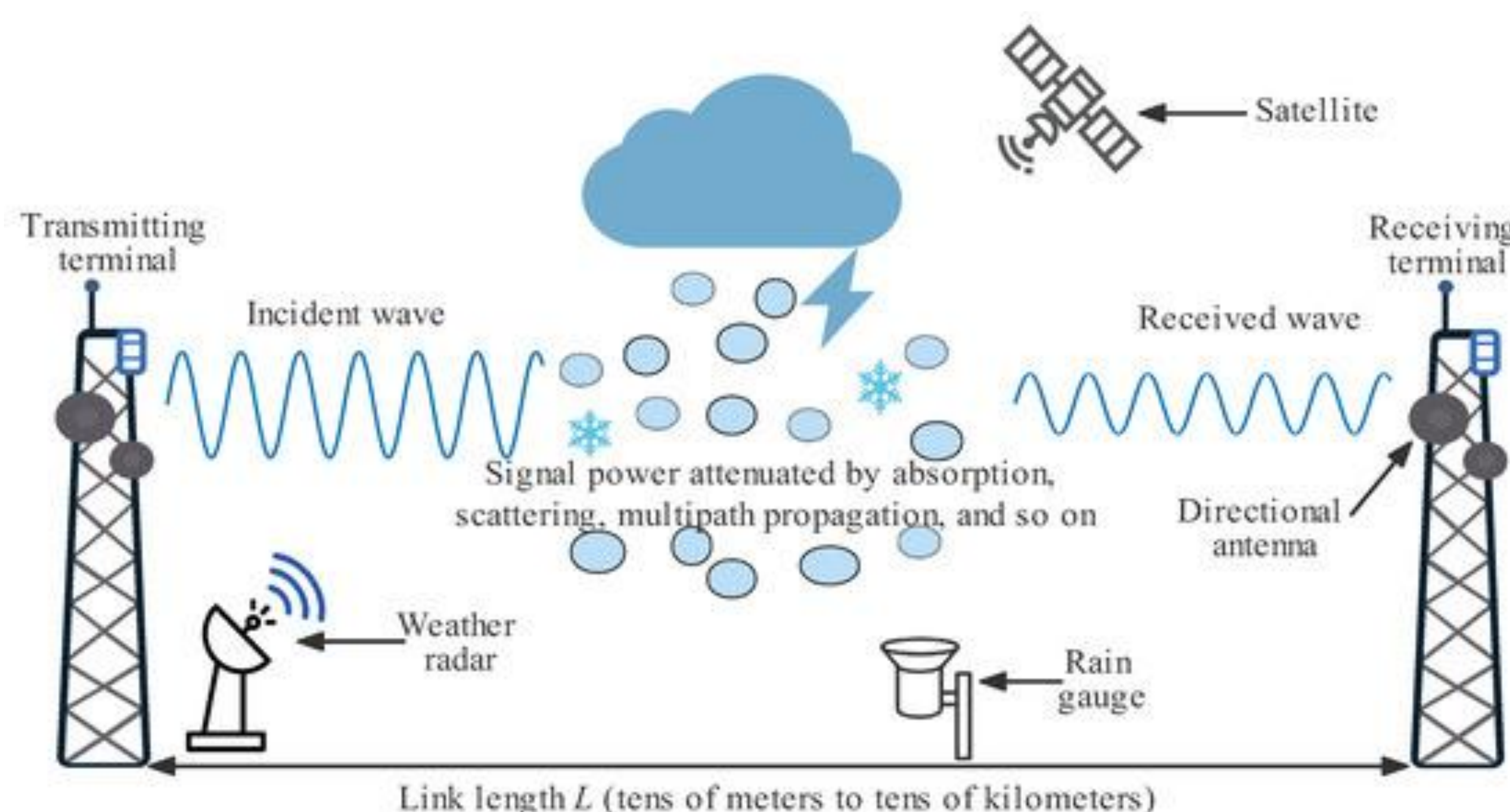


BACKGROUND

As a primary driving force of the water cycle, rainfall impacts virtually every terrestrial process and ecosystem. Precipitation is a highly dynamic process in both space and time, and **conventional precipitation measurement methods such as rain gauges and satellites struggle to accurately estimate precipitation fields on the ground** [1]



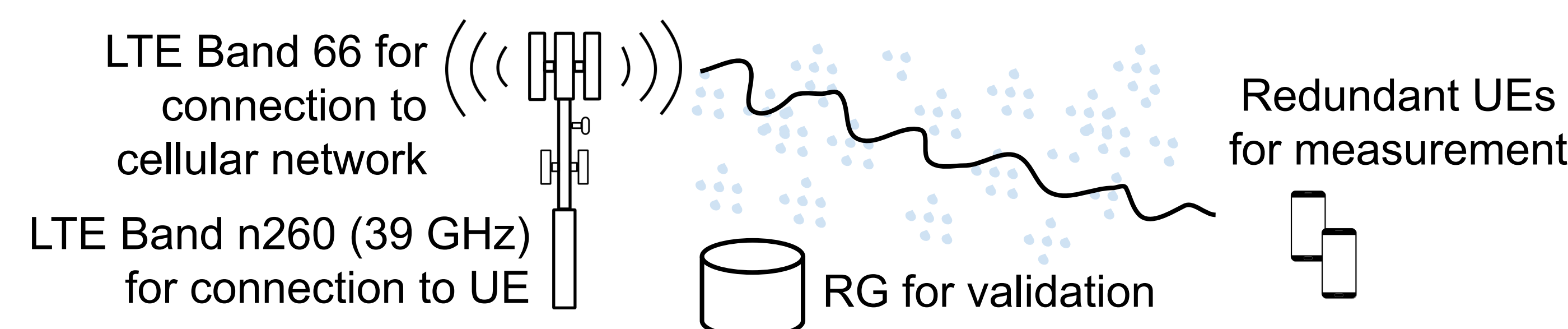
Rain-rate retrieval from Commercial Microwave Links (CMLs) used in cellular network backhaul has emerged as a solution for low-elevation precipitation measurements, as depicted below in the figure from [2]. However, data availability issues hinder widespread adoption [2].



Researchers have begun to investigate using signals from cellular user equipment (UE), i.e. mobile phones, to estimate rain rate at LTE frequencies and below [3]. These studies have shown correlation between cellular signals and precipitation, **but have been unable to perform extraction of rain rate because of the weak, exponential nature of the relationship between rainfall and attenuation at these frequencies.**

OBJECTIVE

To address challenges in precipitation estimation at low frequencies, we will simultaneously measure rainfall and cellular signal attenuation at 39 GHz to estimate precipitation using data from commercial cellular user equipment.



THEORY

Attenuation-based estimates of precipitation are generally done using the relationship described in ITU-R Rec P.838-1 [4]. While this equation describes an exponential relationship, α is about 0.85 for 39 GHz, so the relationship between rain rate and attenuation is nearly linear. This is in contrast to previous studies in the 4-7 GHz range where $\alpha \geq 1.4$. Further, as k increases monotonically with frequency, the relationship is stronger at higher frequencies.

$$\gamma_R = kR^\alpha$$

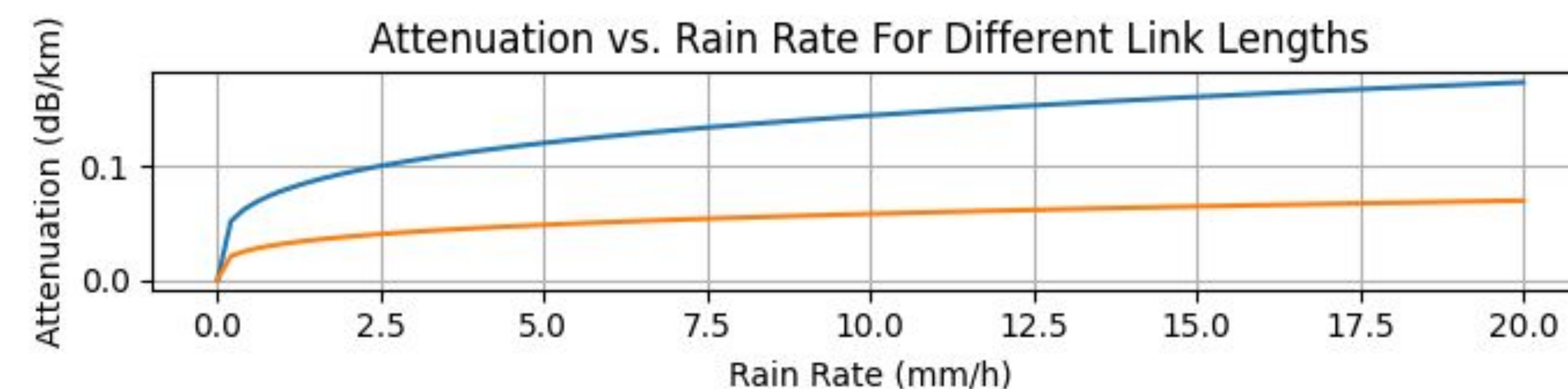
Function of frequency and antenna characteristics

Specific Attenuation (dB/km)

Rain rate

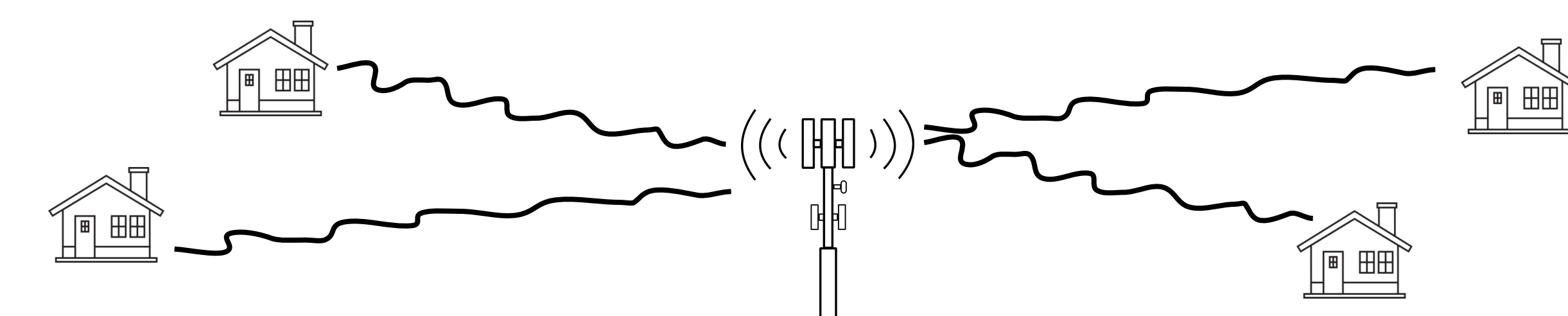
CHALLENGES

The data from cellular user equipment are low resolution, generally reported with 1dB discretization. This is larger than the fluctuations in signal strength we expect to see over the length of a typical FR2 5G link.



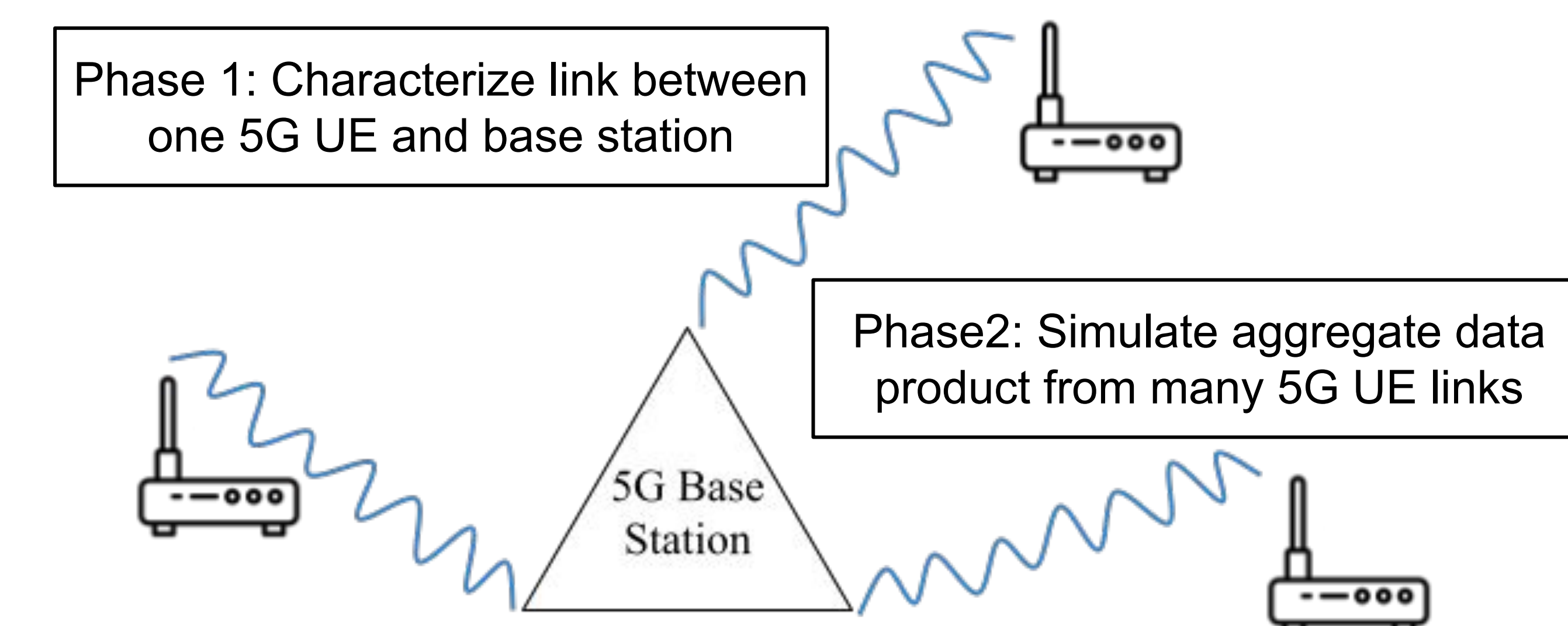
OPPORTUNITIES

Commercial 5G mmWave home internet is already available in select locations across the U.S. and will only continue to become more prevalent. As the technology spreads, it will create the opportunity to leverage these signals within neighborhoods to make precipitation measurement networks even more dense than those made with CMLs. Additionally, as these frequencies are only beginning to be used for commercial purposes, we anticipate that there will eventually be use-cases for opportunistic sensing that we have not yet envisioned.



PATH FORWARD

We will work towards 5G mmWave precipitation measurement networks in two phases: individual link characterization and analysis of how to network these links to produce high-resolution precipitation data.



ACKNOWLEDGEMENTS

This work was supported in part through SpectrumX, the National Science Foundation (NSF) Spectrum Innovation Center, funded via Award AST 21-32700 and operated under Cooperative Agreement with NSF by the University of Notre Dame.

References

