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User-Centric Propagation Models for Rural Wireless Communication Systems

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When employing propagation models to evaluate the future performance of a wireless communication system, the predominant considerations are typically technical. These include radio frequency parameters (such as frequency, bandwidth, and modulation) and geographical factors (such as distances, heights, and environmental typologies) [1]. Based on these factors, system availability can be assessed in terms of geography and time to ensure a minimum required quality of service. However, the influence of user social behavior is rarely taken into account. This omission can result in significant and unnecessary efforts to provide coverage in certain areas solely to meet a predetermined minimum coverage percentage, even in regions where users rarely, if ever, require connectivity. Similarly, it may lead to maintaining system operation during periods (e.g., nighttime) when the service is not needed in specific locations.

Deploying a network based solely on technical considerations is straightforward. However, placing the user at the center of network planning can help reduce excessive costs and avoid installations in challenging areas. By incorporating the social behavior of potential users, network designers can analyze user habits and integrate them into simulation models, thereby improving their real-world applicability.

To this end, we deployed LoRa networks in three small rural hamlets and provided volunteer residents with user equipment comprising nodes equipped with GPS receivers. These nodes transmitted the villagers' locations at five-minute intervals, offering a valuable service to elderly individuals by allowing them to maintain autonomy while walking in the surrounding fields and forests. As users moved naturally, without imposed constraints or directives, the devices they carried continuously transmitted both location data and connectivity parameters such as the Received Signal Strength Indicator (RSSI).

Using RSSI data in conjunction with precise localization, we developed a conventional propagation model capable of estimating received power (or, alternatively, attenuation) at varying distances from the transmitter. The accuracy of GPS data enabled the classification of locations into distinct environmental categories—built-up areas, agricultural fields, or forests—allowing for the refinement of propagation models to better account for geographical typologies. The integration of social behavior into these models arises from the nature of the data collection process. Rather than systematically sampling predefined points at uniform distances, we gathered data based on real-world user movement patterns. Consequently, data were naturally concentrated in areas where individuals spent more time, while regions with minimal user presence yielded fewer data points. In the extreme case, areas that were never visited remained unmeasured, allowing long-term observations to reveal locations where ensuring coverage is unnecessary due to a lack of demand.

The collected data facilitated not only the development of traditional propagation models tailored to specific geographical typologies but also the estimation of user mobility patterns. By analyzing the probability of users remaining in a given area or transitioning between different zones, we incorporated a temporal dimension into the model. This approach allowed us to estimate both the duration of user presence in specific areas (e.g., forests) and the likelihood of transitioning between different environments (e.g., from forests to fields or built-up zones). During the conference, we will present a model that integrates both technical parameters and social behavior, aiming to assist in optimizing network planning by mitigating unnecessary engineering complexities (e.g. providing coverage in remote areas with no human presence).

1. Recommendation ITU-R P.1411-6, "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz", International Telecommunication Union. Geneva, Switzerland, 2012.

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