Poster Abstract: UWB Ranging with Scheduled Broken Packet Reception

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ABSTRACT

Ultra-wideband technology has the potential to provide precise real-world localization. However, due to Non-Line-of-Sight propagation, the transmitted packet can be incomplete or lost during the ranging, which may lead to communication failure. To minimize this, we propose the scheduled signal reception technique. The proposed approach is tested in a real-world environment with Qorvo DWM3001C modules. The experimental results verify its efficiency, offering a practical solution for UWB-based localization, particularly in dynamic circumstances.

KEYWORDS

Localization, Ultra-Wideband, Preamble detection

1 INTRODUCTION

Deploying UWB devices in practical, dynamic environments introduces a significant challenge: obstacles. In Non-Line-of-Sight (NLOS) propagation, no direct path is free of any obstruction between the transmitting and receiving antenna. This results in signal attenuation, when the signal decreases as it travels through obstacles obstructing the path. Dynamic NLOS conditions, encountered in densely populated areas where obstacles and movement can unpredictably affect signal propagation, further accentuate the challenge. Therefore, UWB NLOS propagation has garnered attention in both academia and industry.

Traditional localization methods rely on obtaining the entire packet embedded with the signal. However, in scenarios with NLOS, a packet may be interfered with after transmission, resulting in errors in the received packet or packet loss. In such contexts, *reliable signal reception* becomes essential for accurate localization and positioning. To minimize this problem, the receiver could only receive part of the packet which is shorter and carries less data, so that it will be less susceptible to errors caused by interference. We conducted a small experiment in the university hall, putting the two DW3000 modules [3], initiator and responder at a 30 m distance with a clear, direct path, and transmitted 150 messages. One responder received the whole signal, and the other received only the signal's preamble. When the person was in the middle of these devices, causing interference, as a sudden NLOS, the first one received only 6.7%, while the second one received 38.6% of the packets. Even though the receiver received a third of the transmitted messages, it was six times more than when the receiver was demodulating the whole signal. Nevertheless, why does this happen? Because the preamble does not need encoding and demodulation like the rest of the data, so in most cases, when there is high signal interference, the preamble reaches the destination [1].

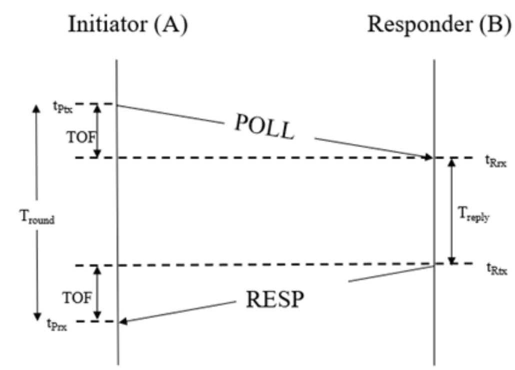

Figure 1: Single-sided two-way ranging

Ongoing research is focused on finding effective ways to deal with NLOS, but there are two main problems: reception of the signal and human occlusion. The latter problem was investigated in the impact of human body interference on localization. In work [2], the robust human body shadowing detection and mitigation algorithms for static positioning assisted by an Inertial Measurement Unit (IMU) were proposed. In a different approach, the work in [4] considered the Machine Learning (ML) algorithms in the classification of the channel condition in Line-of-Sight (LOS) and NLOS to the relative heading angle (RHA). They concluded that the ranging measurements are influenced by the human body shadowing effect, and that the error has a close relationship with RHA. Moreover, UWB radios use machine learning analysis of the channel impulse response (CIR) for distance estimation, imposing computational constraints that limit onboard exploitation on embedded devices.

To tackle both mentioned problems, we propose a signal reception technique using scheduled peak detection that divides the data symbol frame duration into smaller time windows. The threshold technique detects the signal's preamble in each window interval. Through a proposed algorithm, the preamble detection is limited explicitly to the forecasted time, ensuring the reception of the correct packet from the devices.

2 PROPOSED SCHEME

The devices performed Single-sided Two-Way Ranging (TWR) [1], as shown in Figure 1, with the initiator determining distance based on the timestamps obtained upon preamble reception with *RESP*.

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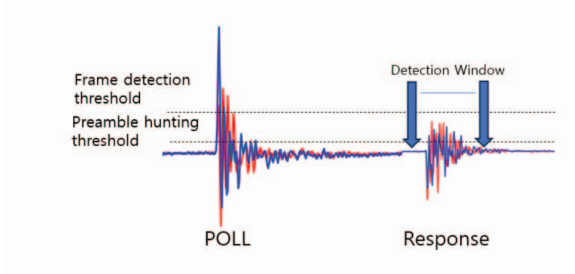

Figure 2: Preamble Detection within Window Frame

Our approach, as depicted in Figure 2, involves breaking down the received signal into discrete time windows, each representing a distinct signal reception period designed by a scheduling algorithm. The scheduling algorithm operates by calculating the approximate Rx time to start the next reception based on the time difference between two timestamps. Therefore, the distance estimate of the device will take the form of:

$$Distance = \frac{((t_{Prx} - t_{Ptx}) - T_{reply} * (1 + e_r)) \cdot c}{2} \tag{1}$$

The T_{Reply} is the time delay from the Rx reception and Tx transmission and is hardware-dependent, where the e_r is the calibration value, and c is the light of the speed. Within these time windows, we perform independent preamble detection, identifying peaks in the signal's preamble to obtain timestamps. By comparing peak amplitudes against a predefined threshold, we accumulate approximate timestamps, enabling precise signal arrival time estimation without explicit decoding. Peaks surpassing this threshold are deemed valid, while those falling below are disregarded.

3 PRELIMINARY EVALUATION

To demonstrate the performance of our approach, we conducted experiments using two Qorvo DWM3001C modules in a university corridor. The experiments involved positioning an initiator and a responder 45m apart, generating 300 ranging messages. The experiment imitated a real-world scenario: from time to time, people passed by, and the initiator was covered by a human body.

The reliability of these exchanges is shown in the Ranging Success Rate (RSR) at the initiator, the ratio of packets received to transmitted. Then, we assessed the Mean Absolute Error, the average difference of the predicted values with true values. Also, we report the Variance in results, which estimates the standard deviation of values from the mean.

Experimental results. Evaluation results, outlined in Table 1, demonstrate the effectiveness of the proposed approach. The Ranging Success Rate (RSR) improved nearly threefold, and calibration aided in mitigating bias, resulting in reduced overall performance error. The accuracy performed better despite being sensitive to *Rx* timestamping errors. Moreover, variations in ranging results were marginally higher compared to basic Two-Way Ranging (TWR). While this may lead to increased errors with larger sample sizes, the benefits of improved RSR and bias regulation suggest promising outcomes for the proposed approach.

Table 1: Overall Performance compared to TWR

Ranging Success Rate (%)	Proposed	75.6%
	TWR	28.3%
Absolute average error (m)	Proposed	0.35
	TWR	0.77
Variation (m)	Proposed	0.36
	TWR	0.19

Our study is experimental, so it is biased to the conditions in which it has been carried out. In our proposed method, reliability is sacrificed to ensure the success of the ranging. Despite this, in such critical situations, the preamble-based approach may be a valuable hybrid technique, showcasing its importance in maintaining communication under adverse circumstances. This also helps to enlarge the range, providing more connectivity. Furthermore, since there is no information about the sender of the data, once the number of devices increases, it may introduce a problem when ranging. However, this can be minimized by encoding the first of the message and proceeding with the preamble through the time frame.

4 CONCLUSION AND FUTURE WORK

This paper introduces an innovative packet reception technique centered on preamble detection. It offers high connectivity over a large distance and in an obstructive dynamic environment. In future work, our focus will be on enhancing the scalability and extending our research to develop the system further to overcome the identified trade-offs. We will explore new possibilities and applications in the field of indoor localization and extend the experiments to different environments to claim its benefits.

5 ACKNOWLEDGEMENT

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