Impact of Mobility on Ranging Estimation using UltraWideband

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1 Introduction

e-Health based on Wireless Body Area Networks (WBAN) is gaining more and more attention from researchers. The objective is to collect as much informations as possible on the person of interest to either detect or prevent a disease, coach the person when doing sport, or speed up the recovery when doing restoration of motor functions. In the last case, the posture is expected to be estimated with an Impulse Radio-Ultra Wideband (IR-UWB) system [1]. Thanks to the high time resolution of IR-UWB, the Time of Arrival (ToA, i.e., the propagation duration) can be accurately estimated for precise range measurements. The distance between two nodes is deduced with the Two-Way Ranging (2WR), (resp. Three-Way Ranging (3WR)) protocol by combining the typical timers obtained from 2 (resp. 3) transmissions [2].

In the literature, the considered challenges are mainly the clock synchronization, the NLOS case (Non Line of Sight), the interference, and multipath [3]. This is realistic when considering static network. However, when considering mobility, the actual distance changes at each transmission, thus introducing error in the estimation [4]. In [2], the authors have considered the mobility issue, for the localization of a pedestrian in a room. But, no rigorous analysis was provided. Besides, the considered speed is much lower than the one in a BAN. Thus, in this paper, we propose to study the impact of mobility on the distance estimation between 2 nodes of a BAN which represents our preliminary study for Individual Motion Capture with IR-UWB sensors.

2 System Model and Results

We consider a WBAN using IR-UWB technology. For the sake of simplicity, we assume two nodes, a sensor and an anchor, attached to a human body. The anchor has a known position with respect to a global 3D coordinate system while the sensor does not have any knowledge of its own position. We assume that the sensor follows a back-and-forth linear motion.

We adopt a simulation approach where the IEEE 802.15.6 physical layer is implemented in WSNet simulator [5] to insure the 3WR (resp. 2WR) transactions. We assume a TDMA-based Medium Access Control (MAC) protocol with a frame size of three slots (resp. two slots) corresponding to one request plus two responses packets (resp. one request plus a single response packet) [2]. In order to reduce the transaction time, we use a dynamic slotted TDMA approach where the size of each slot depends on the size of the transmitted packet. When several nodes are asking for localization, the transmission of the request and response packets may not be consecutive. We model these delays with $\Delta t1$ (resp. $\Delta t2$) as the time between the received request packet and the first transmission of packet response (resp. the time between the first and the second transmission of response packets), as shown in Figure 1.

In this paper, we quantify the impact of mobility by using the Root Mean Square Error (RMSE). There are generally several parameters that may affect the 2WR and 3WR based ranging errors. We focus on two types of parameters: (i) the speed of nodes; (ii) the values of $\Delta t1$ and $\Delta t2$. The RMSE compare the estimated distance d_{est} and the reference distance d_{ref} as follows: $RMSE = \sqrt{\frac{\sum^N |d_{ref} - d_{est}|^2}{N}}$. We consider three reference distances : d_{Ref1} is the actual distance at the beginning of the first request, d_{Ref2} is the actual distance at the reception of the last response, and d_{Avg} is the average of d_{Ref1} and d_{Ref2}.

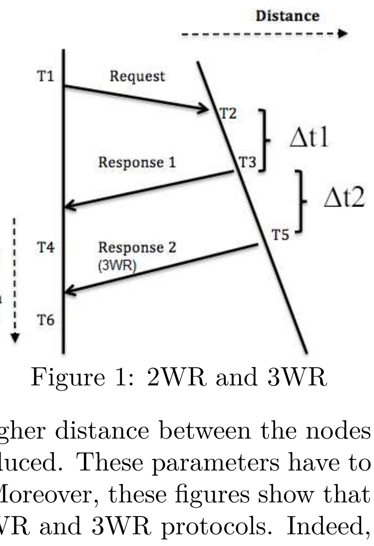


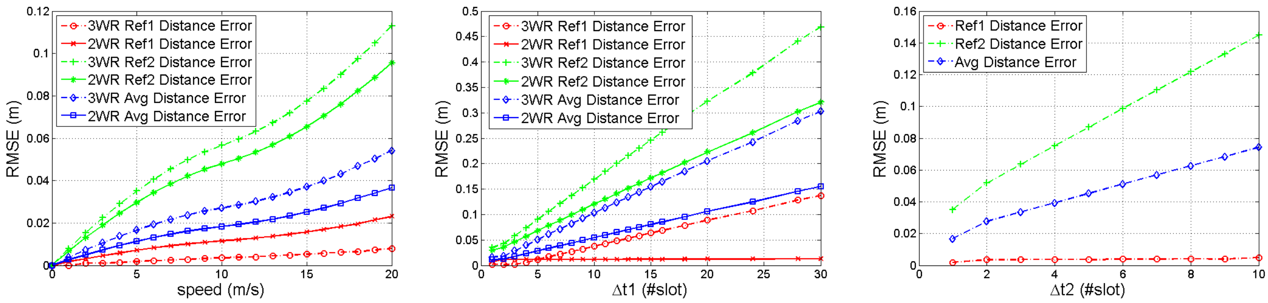
Figure 1: 2WR and 3WR

Figure 2a, 2b and 2c show that RMSE increases with the speed and the response time ($\Delta t1$ and $\Delta t2$). Increasing one of these parameters leads to a higher distance between the nodes due to the node mobility, and hence an error in the ranging estimation is introduced. These parameters have to be considered in the protocol design phase, i.e. scheduling at the MAC layer. Moreover, these figures show that the distance d_{Ref1} is the better estimated compared to the others for both 2WR and 3WR protocols. Indeed, due to the packets size, transmissions occurs much closer to the beginning time than the ending time. The intermediate distance leads to better results than d_{Ref2}, but is still worse than d_{Ref1}. Thus, when considering mobility, one can suppose that the estimated distance is the one at the beginning of the localization protocol.

Figure 2a shows that depending on the chosen reference distance, the 2WR can be better than 3WR and vice-versa. The 3WR gives a fine estimation of d_{Ref1} with a RMSE lower than 1 cm, while 2WR is more efficient to estimate d_{Avg} and d_{Ref2} thanks to lower transaction time.

If we consider a motion capture system looking a precision lower than 5cm, with d_{Ref1} as reference distance, the 2WR can be enough if the clock drift is not a problem, otherwise 3WR is a better choice. However, this precision could be degraded depending on the number of nodes in the network which leads an increasing of response time ($\Delta t1$ and $\Delta t2$).

Figure 2b shows that 3WR gives better d_{Ref1} estimation when $\Delta t1$ is lower than 5 slots while 2WR is better when $\Delta t1$ is higher. Moreover, Figure 2b and 2c shows that increasing $\Delta t1$ and $\Delta t2$ lead a different impact on the estimation of d_{Ref1} in 3WR.



(a) RMSE of estimated distance between 2WR/3WR as function of speed

(b) RMSE of estimated distance between 2WR/3WR as function of $\Delta t1$

(c) RMSE of estimated distance with 3WR as function of $\Delta t2$.

Figure 2: Impact of mobility on Ranging Error

Based on these results, $\Delta t1$ has more impact on the ranging estimation than the speed since the RMSE can reach 50cm while with 20m/s of speed not exceed 12cm. This leads us to investigate more in the optimization of the scheduling problem in order to reduce the response time.

3 Conclusion

This paper focused on the impact of mobility on ranging estimation between two nodes of a WBAN. The results show that depending on the speed and the chosen reference point, the 2WR can be better than 3WR if only mobility is taken into account. This would mean that the channel would be less used since sends a packet less. In further works, it could be interesting to analyse the case with joint mobility and clock drift to find the right compromise. Others mechanisms like the scheduling algorithm or the aggregation data can be adopted in order to reduce the TDMA frame size.

4 Acknowledgement

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References

[1] Z. Xiao, Y. Hei, Q. Yu, and K. Yi, "A survey on impulse-radio UWB localization," *Sci. China Inf. Sci.*, vol. 53, pp. 1322–1335, Jul 2010.

[2] J. Choliz, A. Hernandez, and A. Valdovinos, "A framework for UWB-based communication and location tracking systems for wireless sensor networks," *Sensors*, vol. 11, pp. 9045–9068, Sep 2011.

[3] H. Soganci, S. Gezici, and H. Poor, "Accurate positioning in ultra-wideband systems," *IEEE Wireless Communications*, vol. 18, no. 2, pp. 19–27, April 2011.

[4] J. Hamie, B. Denis, R. DErrico, and C. Richard, "On-body toa-based ranging error model for motion capture applications within wearable UWB networks," *Journal of Ambient Intelligence and Humanized Computing*, Dec 2013.

[5] G. Chelius, A. Fraboulet, and E. Ben Hamida, "http://wsnet.gforge.inria.fr/."