Poster Abstract: Combining Positioning & Communication Using Ultra Wideband Transceivers

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***Abstract*— A new generation of ultra wide band (UWB) communication transceivers are becoming available that supports both positioning and communication tasks. Transceiver manufacturers envision that communication and positioning features are used separately and asymmetrically. We believe that this is an unnecessary restriction of the available hardware and that positioning and communication tasks can be active concurrently. This paper presents and investigates a medium access control (MAC) protocol which combines communication and positioning functions. The presented MAC protocol extends an established protocol concept which is used, for example, in the standard TinyOS low power listening component. Our experiments show that the existing data communication of a network can be exploited to gather position information efficiently.**

I. Introduction

Many systems of positioning have been developed which use the existing communication transceiver of a sensor node. These currently used transceivers are however not well suited for positioning tasks due to the physical properties of the signal. Positioning systems relying on these conventional low-power communication transceivers typically make use of either the received signal strength indicator (RSSI) or the measured time-of-flight (TOF) of a signal as input for the positioning algorithm. Both methods can be used to determine the distance between transceivers and ultimately the position of all transceivers in relation to each other. These methods of distance measurements have been investigated at length and reports show that using current transceivers yield unreliable and inaccurate results. Patwari et al. [1] present an in-depth report of their findings of how multipath signals and shadowing obscure distance measurements.

The recent development of low-power, ultra wide band (UWB) transceivers for use in sensor nodes, overcomes the aforementioned ranging inaccuracies. The physical signal properties of UWB communication make it possible to accurately determine the time-of-arrival (TOA) of signals, by utilizing either clock synchronization or two-way-ranging it is therefore possible to accurately determine the time of flight (TOF) or the signal. Thus, the distance between communicating transceivers can be determined. The IEEE 802.15.4a physical layer specification [4], standardized in 2007, specifies the use of UWB transceivers for use in wireless personal area networks and the functionality of positioning. The Nanotron nanoLOC TRX [2] transceiver is one such transceiver which adheres to this standard.

UWB transceiver manufacturers envision that communication and positioning features are used separately and one at a time. Either the transceiver is used to transfer data packets between sender and receiver OR the transceiver is used to send ranging packets to determine the TOF between nodes. We argue that this leads to inefficient transceiver usage as excess packets might be generated unnecessarily. If an exchange of data packets is currently taking place between two nodes using a send and acknowledge scheme, the round-trip time can be used to determine the distance between nodes to avoid inter-node time synchronization. Therefore the distance can be estimated using the existing data packets, alleviating the need to transmit specialized ranging packets. If however there is currently not enough data communication taking place between nodes to accurately satisfy positioning needs, ranging packets may still need to be exchanged. Evidently the interplay of the transmission of data packets and ranging packets has to be organized to achieve the set communication AND positioning goals. Transceiver usage for communication purposes is defined by the MAC layer. The MAC layer determines when packets are transmitted and how their transmission shall be organized. Thus we propose to combine positioning and communication tasks within the MAC layer.

This paper describes how the existing FrameComm MAC layer [3] can be extended to support positioning tasks. The resulting system can be used with any transceivers adhering to the 802.15.4a IEEE standard.

II. Protocol Definition

FrameComm: FrameComm [3], like many wireless contention based MAC protocols, performs duty cycling of the node's transceiver. To ensure that rendezvous between transceivers occur, FrameComm deploys a method in which a trail of identical packets of data, called framelets, is transmitted by the sender with gaps between each. The receiver sends an acknowledgement to the sender after successfully receiving a framelet. Upon the reception of this acknowledgement, the sender may then cease sending and yield control of the channel (See Figure 1).

FrameComm with Positioning: The basic principle of FrameComm is ideally suited for the integration of positioning functions. The method of exchanging packets and acknowledgements mirrors that of the two-way-ranging method of determining the round-trip-time, and ultimately the TOF of signals. If the sender records the time of transmission of its last

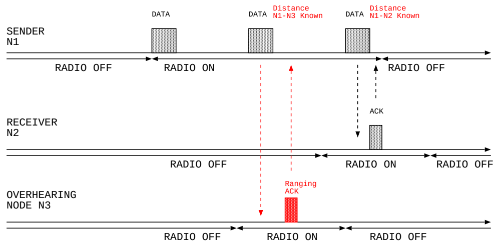

Fig. 1. FrameComm and FrameComm with Positioning

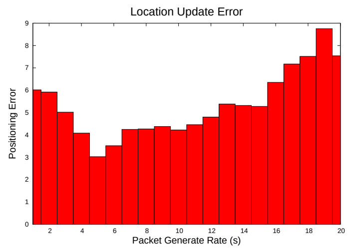

Fig. 2. Experiment 2 : Positioning error while tracking node movement.

framelet, and the time upon receiving its acknowledgement, the distance between nodes can be determined.

We propose extending this positioning enhancement further, in such a manner that the sender may derive not only the distance to its intended recipient, but potentially the location of any node within transmission range. During the exchange of framelets between the sender and receiver, a third node may enter its listening period and overhear a framelet. Before discarding the framelet and returning to sleep, the node exploits this overhearing and sends what we call a ranging acknowledgement. This ranging acknowledgement is offset to allow the communication acknowledgement from the intended receiver, to be processed without collision. Upon receiving the ranging acknowledgement the sender knows the distance to this third node (See Figure 1).

The described method allows us to implement positioning functionality without reducing the available bandwidth for communication. Minimal additional energy in form of ranging acknowledgements is consumed using positioning features.

III. Evaluation

Application Scenario: A warehouse (size $20m \cdot 30m$) is used to store crates which are equipped with a sensor node (12 nodes). Additional static nodes (14 nodes) are deployed such that a sensor node in a crate has always connectivity to at least one static sensor node. The sensor nodes in the crates transmit periodic sensor readings (packet generation rate of λ packets per second) through the network to a central sink. Collected distance measures are transported with these sensor readings in the same message to the sink. The sink employs a central location algorithm to calculate locations of all crates.

Experiment Setup: The evaluation consists of two simulation experiments. The first is designed to compare the original FrameComm protocol with our implementation including positioning, and is designed to measure differences in communication overheads. The second experiment evaluates the ability for our implementation to track mobile nodes (moving crates) within the network.

Results of Experiment 1: Table I shows data collected from one node in the deployment. The results show that the additional positioning mechanisms do not significantly decrease the nodes throughput or increase the nodes energy consumption. Only under a heavy traffic load ($\lambda = 1$) the achievable throughput drops as ranging acknowledgements are interpreted as a busy channel when nodes probe a channel before transmission.

Results of Experiment 2: Fig. 2 presents the findings of our second experiment where one node is mobile within the network (random waypoint movement, 1 m/s). The graph displays the distance (positioning error) between the true position of the node and the position estimated by the positioning algorithm on the sink for different traffic loads λ. For high traffics rates the positioning error is relatively high as packets carrying TOF measurements are lost in the network. For low traffic rates, the error is high as well as fewer packets containing TOF measurements reach the sink. For high traffic rates the problem could be corrected by ensuring that each node obtains a fair share of the available bandwidth. For low traffic rates, the problem could be corrected by sending TOF measurements to the sink even if no data has to be transported.

Traffic	FrameComm			FrameComm + Positioning		
λ (packets/s)	Transceiver On Time (s)	Throughput (packets/s)	Latency (s)	Transceiver On Time (s)	Throughput (packets/s)	Latency (s)
1	128.74	0.17	23.64	134.15	0.15	24.45
0.2	61.92	0.17	1.81	65.68	0.17	2.09
0.1	52.41	0.09	1.01	51.49	0.09	0.98
0.05	34.64	0.05	1.32	36.83	0.05	1.43

TABLE I
Experiment 1 Results : Communication overheads.

IV. Conclusion

In this paper we have presented a Medium Access Control Protocol which combines communication and positioning tasks. We have shown by simulation the general feasibility of the design. In further developments we plan to implement the protocol on real nodes that are equipped with 802.15.4a compliment UWB transceivers to evaluate the proposed protocol in a real-world deployment.

References

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