Indoor Localization system using Time of Flight in UWB spectrum

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I. Motivation

Positioning systems based on GPS have become ubiquitous over the past few decades. Due to the attenuation of GPS signals by concrete walls, they cannot be used in an indoor setting for localization. In recent years, multiple attempts have been made to design a localization system for indoor applications. Indoor localization has the potential for trans-formative impact in a wide variety of applications like augmented reality, indoor navigation and advertising. Due to the inherent nature of the applications, high accuracy as well as energy efficiency is required.

Based on the application in target, various methods and system architectures have been proposed using broadcast-based technologies(RFID, BLE [**?**], WiFi, Ultrasound [**?**]) and motion based algorithms(Inertial based sensing). The choice of the algorithm and system architecture is an integral part of solving this problem as these choices directly impact both accuracy and energy consumption of the system.

II. Methodology

In our project, we propose and implement a system which is both accurate enough and energy efficient to be powered by batteries. The proposed method uses Time of Flight(TOF) algorithm to calculate the distance between two nodes. Although, TOF requires high time-synchronization and accurate time-stamping, we expect to achieve good results with this approach using the Decawave DW1000 sensors. The manufacturer claims a distance measurement accuracy within 10cm using these sensors. The block diagram of CC3200 and DW1000 are shown in figures **??** and **??**.

We can localize any node if we know the distance of the node from 3 or more fixed anchor points. In the TOF approach, every node that we are trying to localize, transmits packets to a set of anchored nodes whose locations are known. The anchor nodes reply with the appropriate timestamps. Using the time taken for roundtrip the distance between pairs of nodes can be calculated. Once the distance of the mobile node from each of the anchor nodes is determined, the co-ordinates of the mobile nodes can be triangulated in 3 dimensions.

To obtain the distance measurements, we having chosen to use time of flight of radio over UWB spectrum. UWB involves sending very short spikes of radio signals. This provides significant benefits like fine time resolution, energy efficiency and robustness to interference in harsh environments [**?**]. UWB is also particularly resistant to Multi-Path effects. In this project we plan to use DecaWave ScenSor DWM1000 Modules for UWB TOF measurements. We plan to have both our mobile and anchor nodes as DWM1000 modules. Using

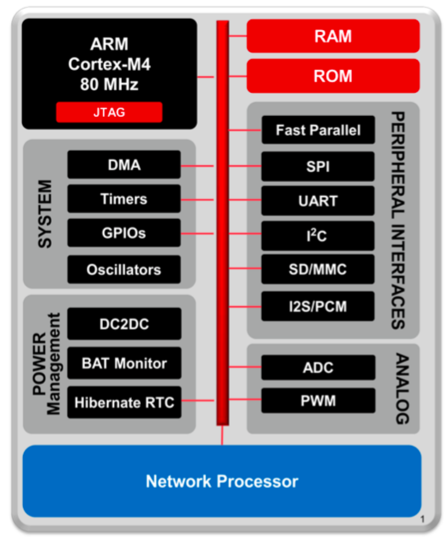

Fig. 1. Block Diagram of CC3200 SoC

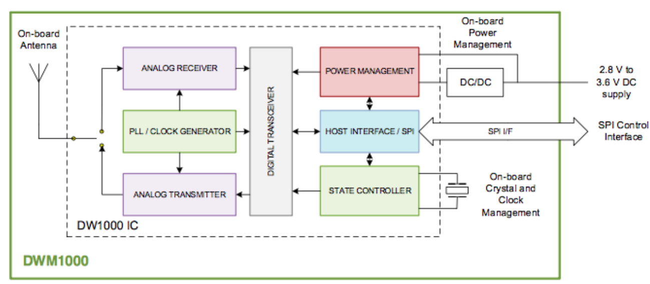

Fig. 2. Block Diagram of DW1000 UWB transceiver

these modules the distance of the mobile node from each of the anchor nodes can be determined. This information has to be accumulated at a gateway for the co-ordinate computation. For this we plan to interface DWM1000 with an appropriate MCU platform using the SPI interface supported by DWM1000.

A single chip Wireless MCU - CC3200 from Texas Instruments will be used to configure the sensor and run our application. The CC3200 SoC comes with a inbuilt WiFi module which can be used to interface with a PC to log the data and monitor all the nodes.

CC3200 is a WiFi Certified single chip Micro controller unit with built-in 2.4GHz PHY/MAC and TCP/IP networking engine. The controller provides a easy to use framework with wide variety of peripherals. Multiple Real-Time Operating systems like FreeRTOS and TIRTOS are supported for this platform. Although, we do not plan to use many of these

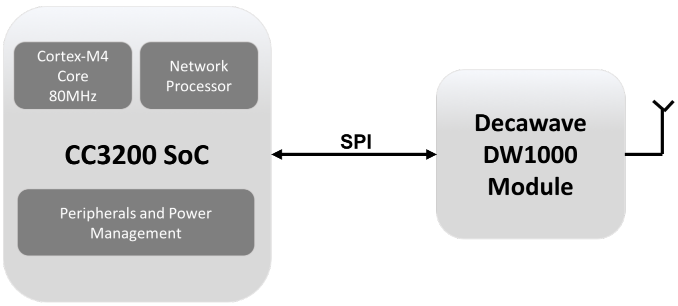

Fig. 3. System Block Diagram of Each Node

features, the platform/software can be scaled to implement complex algorithms and capabilities in the future. The network engine on this controller can be configured to behave as an access point or as a host. A mobile device or a personal computer can connect to the SoC when configured as an access point. We plan to use this capability to log data and monitor all the mobile nodes. In our architecture, the mobile node transfers all the data(time stamps from each anchor node) to a personal computer(gateway). This gateway then uses these pairwise distance measurements to compute the co-ordinates of the mobile node. A software application running on the computer, logs this data and displays the location of the mobile nodes on a GUI.

One disadvantage of using ToF algorithm is that it cannot be scaled. As the number of nodes increase, we expect each node to consume more energy. As an extended goal, we propose to use Time Difference of Arrival(TDOA) [**?**] to provide scalability. In this system architecture, anchor nodes will broadcast their location to all the nodes that are being localized in the vicinity. Using the anchor node's location and the difference in time of arrival of packets from each of the anchor nodes, triangulation can be performed. A detailed explanation of these algorithms are provided in the next section.

III. Goals

The Goals of the project are listed below:

- Goal : In our final project presentation, we plan to demonstrate the localization task performed by our system on a GUI. As the mobile node moves, the location of the node on the GUI will get updated in real-time.
- Stretch Goal 1 : Due to the inherent nature of the ToF algorithm, it will not be scalable when the number of mobile nodes are significantly high. With ToF, the anchor nodes have to send packets to all nodes with accurate time-stamps when the mobile nodes request for it. An efficient algorithm called Time Difference of Arrival(TDOA) can be used to overcome this problem.
- Stretch Goal 2 : The crystals used on the DWM1000 for generating the clock frequency will have different performance on each board, which may result in inaccurate time-stamps. Due to this variance, the distance calculated may be quite inaccurate. If the error is too high, the localization will be way off. If this problem arises, we plan to synchronize the clocks across all DWM1000 modules externally to improve the accuracy.

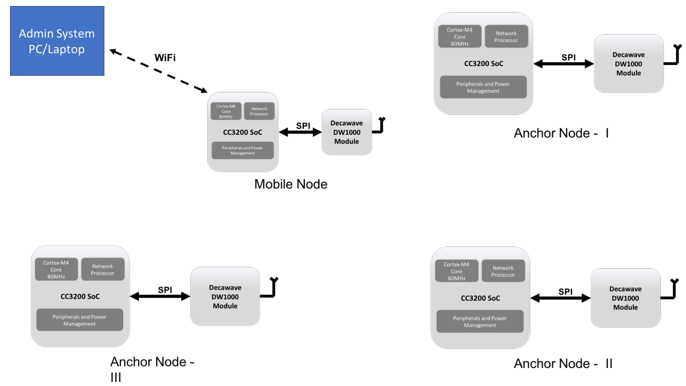

Fig. 4. Complete system architecture

IV. Milestones

The following are the milestones expected in course of the project:

- Interface of DWM1000 with CC3200, May 7, 2017: The DWM1000 modules have to be interfaced over the SPI interface with the CC3200 MCUs. This might require significant work in porting the SPI libraries from the reference STM32F105 board to TI CC3200 board.
- Distance measurement between two nodes (Mid-term Milestone) : The DWM1000 modules have to configured to work in the TOF mode. We plan to complete the distance measurement between two nodes with direct communication. In our demonstration during the mid-term project presentation, we plan to demonstrate the accuracy of distance measurement with the DWM1000 modules.
- Application Development for Localization (Final Project presentation) : Once the point-to-point communication is established and distance measurement between two nodes is done, we plan to build on this to implement our final application code. The final application code running on the mobile node will calculate the distance between itself and multiple anchor nodes. This data is sent to a PC to perform localization and compute the location of the mobile node.

V. Work Partitioning

We plan to divide the work amongst the three team members as follows:

- One team member will work on interfacing the CC3200 with the PC and get the GUI running.
- Second team member will work on porting the code required for DWM1000 from reference solution to CC3200
- Third team member will work on hardware interfacing of DWM1000 with CC3200.

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