Social Distance Alert System to Control Virus Spread using UWB RTLS in Corporate Environments

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Abstract— **Recent pandemic situation of covid-19 which is caused due to the outbreak of highly dangerous and easily spreadable corona virus is an increasing concern throughout the entire world. The purpose of this study is to develop an alert system which alerts employees to maintain social distance in corporate working environments. A real-time location systems (RTLS) based on ultra wide band (UWB) wireless technology gives most accurate locations of approximately 10cm using methods like trilateration and TDOA (Time Difference of Arrival). Co-ordinates of the location can be obtained by installing RTLS in predefined area which are used to calculate the distance between Mobile UWB Devices (MUD's). An alert triggered by a system to maintain distance if distance between the employees is less than the prescribed social distance can keep the work premises safe and control the spread of corona virus. This study can be a great solution to control spread of virus in corporate working environments which are mostly of confined in size and indoor in nature.**

Keywords—covid-19, corona virus, social distance, real-time location systems (RTLS), ultra wide band (UWB) wireless technology, trilateration, TDOA (Time Difference of Arrival), Mobile UWB Devices.

I. INTRODUCTION

In the recent time, whole world is going through a pandemic of covid-19 which is dangerous and life taking viral disease caused by a virus called corona virus. Studies say that there are almost more than 3 crore people got affected all over the world and approximately 10 lakhs people died due to this virus and counting. Daily thousands of people are dying due to covid-19.

Since this virus can spread easily and with rapid speed, every country implemented lockdowns in their respective regions. Due to this, all the industries, factories and companies got shutdown and started to implement work from home in almost all the corporate companies.

But loss of economy all over the world is major concern in lockdown. So each and every country started unlocking procedure to boost their respective countries economy.

As part of unlocking procedure governments gave permissions to corporate companies to make their employees work from office but with less number of employees in the work area by passing a Standard Operating Procedure (SOP) to follow.

World Health Organization (WHO) issued a set of safety measures to protect people from getting affected. Some of the safety measures are listed below.

- Wearing a certified face mask
- Regular sanitization
- Avoid touching common touch points
- Maintaining a safe social distance

Wearing a proper certified face mask will protect person A from others and vice versa from getting affected. A mask should be wear such that mouth and nose areas should be covered properly. Regular sanitization of hands with a proper alcohol based sanitizer is necessary for people to protect themselves from getting affected. Touching common touch points like lift buttons can also increase chance of getting affected. So avoiding to touch common touch points is also important safety measure to follow.

Not only above mentioned safety measures but also maintaining the safe social distance can protect individuals. As per WHO, a social distance of minimum 6 feet or 2 meters is safe distance which can control the spread of virus.

After lockdown period, since the governments eased the restrictions on corporate companies, slowly companies are ramping up the process of bringing their respective employees to office to maintain their productivity by following standard operating procedures decided by the governments.

Even though employees are following safety measures like wearing face mask and regular sanitization, not maintaining social distance can increase chance of spread of virus especially in corporate environments.

So it is better have an alert system which can alert the employees depending on the distance between the individuals. This can be achieved by installing a Real Time Location System (RTLS) which can find location of employees.

Since almost each every corporate work environments are indoor in nature, it is efficient to install RTLS which is based on Ultra-Wide Band (UWB) technology.

In general, Global Positioning Systems (GPS) are used in finding location of an object or an individual. Even though GPS are good in tracking in outdoor environments where the line of sight is good, it lacks efficiency in indoor environments like corporate environments which are indoor in nature.

So, an ultra-wide band based real time location system can be a great solution in working areas like corporate environments to alert the employees to maintain social distance who are failing to do so.

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II. UWB OVERVIEW

Ultra-wideband (UWB) technology has achieved broad adoption in both science and industry since the Federal Communications Commission's consideration and approval of standardization in 1998 and 2002. In 2002, the Federal Communications Commission(FCC) opened the ultra-wideband (UWB) bands of 3.1-10.6 GHz and 22-29 GHz with a cumulative equivalent isotropically radiated power (EIRP) of -41.3 dBm / MHz in either band [1]. The original use and interest of UWB was attributed to the low potential for commercially involving radar identification and networking applications that started much later in 1998, when the FCC released its Notice of Inquiry, which culminated in the official decision to open the bands in 2002 [2].

Fontana gives an impressive description of the history of UWB from the creation of the time domain Electromagnetics in 1960's [6]. As Fontana discusses, the original use and interest in UWB was poor in the possibility of Radar and contact tracking software for Commercial interest started much later in 1998, when the FCC was formed. Fontana's Notice of Inquiry was issued, resulting in the official Decision to open the groups in 2002 [6].

Fontana offers an impressive description of evolution seen in the generation of UWB pulses, beginning with the use of phase to generate high slew rate recovery diodes (SRDs) in MICs Pulses that can achieve a width of 300ps [6]. Latest techniques include both time-gated and time-gated oscillators and Time-gated power amplifiers and more power amplifiers mixed Conventional ways to up conversion [6].

Extensive scientific study of UWB localization systems for a diverse array of uses began around the year 2000, involving indoor short-range, outdoor locations, industrial inventory tracking, monitoring in biomedical applications, telemetry, hospital personnel, UWB based High Data Rate (HDR) and Low Data Rate (LDR) wireless networking solutions, etc. [2]. In turn, in tandem with the advancement of RF frontends, the development of new digital signal processing (DSP) systems, including the significant emergence of field programmable gate arrays (FPGAs) which can be converted into an application-specific integrated circuits (ASICs), has driven UWB localization systems with drastically improved efficiency [2].

In consumer and industrial applications as well as in research works, UWB is already commonly used. Also with rise of technology used to develop microwave circuitry, the landscape of UWB location tracking may well have transitioned. The energy consumption, scalability and increased efficiency of even the Ultra wide-band RF front end systems have increased substantially, starting with MICs, followed by MMICs and much more recently CMOS based RF components [2].

Ultra Wideband (UWB) uses a broader spectrum than those such as GPS, WIFI , Bluetooth and RFID, enabling it to interact with a very small pulse range. Generally, the short pulse distance allows for high precision calculation of TOA (Time of Arrival) or TDOA (Time Difference of Arrival). Therefore, when building RTLS that requires high precision and accuracy, UWB is more suitable than other communication methods.

In busy indoor settings and even NLOS conditions, a look at the evolution of RF front-end systems as well as the advancement of automatic UWB monitoring approaches and final positioning algorithms (e.g. TDOA or time-of-arrival (TOA)) helps understand the drastic improvements observed in the performance of these instruments. Aligning other RTLS technologies (e.g. WLAN, W-Fi, GPS, and RFID) with UWB, will play a broader role in determining how to use these key technologies in the future [2].

Various techniques for indoor locating devices have been developed that rely on radio frequency (RF) signals to identify objects and have gradually improved their performance over the years. Recently, centimeter-accurate real-time positioning systems (RTLS) have also been made usable for consumer products and the use of localization technology for the transmission of RF signals. [2].

Such high precision has been made possible by the use of ultra-wide band (UWB) ranging technologies [3]. The emergence of this new technology means that the evolution of localization systems has entered the micro-location era that produces a reliable position up to the level of the entity. The RTLS could change traditional market methods in many sectors when combined with the vision of the Internet of Things (IoT) [3]. For example, this new locating device might satisfy the demand of corporate businesses who need their workers to be notified inside a predefined workplace or location to monitor the spread of viruses.

III. REAL TIME LOCATING SYSTEM

The discipline of monitoring of building progress has shifted from compilation and review of paper-based data, Time-consuming and vulnerable to mistakes. The bar code strategy was first used, but its poor acceptance standard for automatic data collection and poor capacity for storage resulted in its Substitution by Radio Frequency Recognition Technique (RFID) [5]. However for portal-based identification purposes, RFID is limited: there is therefore a need for a more sophisticated form of RFID [5].

A device that can be used to map an object's location within a coverage area with the least time delay is a real time locating system. The tracked object is usually equipped with several embedded electronic devices that can contact or transmit a signal to neighboring embedded devices. The position of the target can be determined by various methods that measure different RF signal characteristics between the transmitter and the receiver, such as the obtained signal strength (RSS), the arrival angle (AoA) method and the arrival time (ToA)/flight time (ToF) method [3].

A RTLS typically consists of nodes, mobile UWB devices and local server as database and for other operations. The node is typically an integrated device installed within the machine as a reference location. To allow geometry-based position measurement, at least three anchors are required. The mobile UWB is an integrated device that is connected to a tracked object that can roam across the RTLS coverage area. Typically, the location calculation uses one of the distance estimating algorithms that can be used on a server computer, such as trilateration, triangulation and multilateration. In this analysis, we concentrate on an RTLS that uses TDoA to approximate the position of the tag along with a multilateration algorithm.

A. Multilateration technique

Multilateration is widely used in civil and military applications to either a) locate a vehicle (aircraft, ship, car/truck/bus or person) by measuring the vehicle signal TOAs at multiple stations with known coordinates and synchronized 'clocks' (surveillance application) or (b) cause the vehicle to be positioned at known locations and synchronized 'clocks' in relation to multiple stations.

Multilateration is a navigation and tracking methodology based on the measurement of energy wave arrival times (TOAs) with a known propagation speed (radio, acoustic, seismic, etc.) [4]. A tracking system provides an individual with location (and possibly other) information about the 'vehicle' subject (e.g. any GPS client, whether stationary or moving); a control device provides a person with 'vehicle' location information not on the 'vehicle' (e.g. air traffic controller or mobile phone service provider).

Every system that can be used for navigation can also be used for surveillance under the reciprocity rule and vice versa. A consumer transmits synchronized 'clocks' for monitoring many receiving stations.

For navigation, several synchronized stations transmit to a user's receiver that may (but must not) determine the transmission time (TOT). At least d+1 TOA's must be calculated to locate user co-ordinates in d dimensions [4].

Using the measured TOA's, the user uses an equation that either: (a) measures the transmission time (TOT) for the same clock and 'd' user coordinates; or (b) ignores the TOT and forms a minimal d arrival time distance (TDOAs) used to classify the 'd' user coordinates [4].

B. Time Difference Of Arrival (TDoA)

TDOA multilateration, known as hyperbolic navigation, has become a common technique in earth-fixed radio navigation systems. The difference between the distance of the user and pairs of stations at known fixed positions is determined by TDOA method. The distance difference for one station pair results in an infinite number of potential subject positions that satisfy the TDOA. Multilateration depends on several TDOA's to find the exact subject's location in the curve. A second TDOA may create a second curve for two dimensions which intersects with the first, involving a separate pair of stations (typically one station is a part of both pairs, such that only one station is new).A minimal number of potential consumer positions (typically two) are discovered as the two curves are compared. Multilateration monitoring may be carried out without the consent or even knowledge of the subject being tracked.

C. Time of Flight (TOF)

Time of Flight (TOF) is nothing but the time taken for a signal to reach the receiver from transmitter. This is used to calculate the distance between the transmitter and receiver.

In any RTLS, time synchronization plays an important role in calculating the location of an object. As shown in Fig. 1, transmitter and receiver should be in sync with respect to time since this time is used in estimating the time of flight i.e. the time taken for a signal to reach the receiver from transmitter. In the Fig. 1, synchronized time is represented as Ts. The difference between the sent time of message from transmitter and received time of message at the receiver is used to calculate the distance between transmitter and receiver.

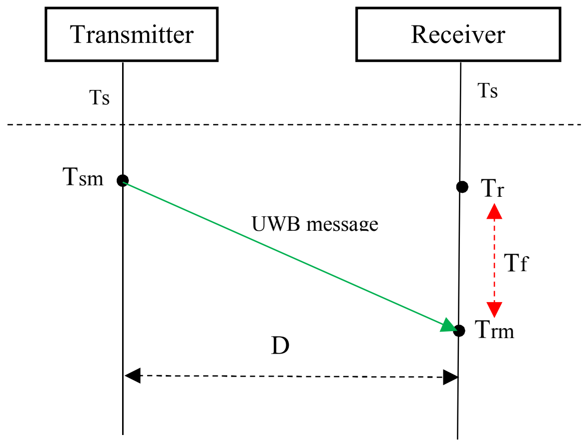

Fig. 1. Sequence diagram of Time of Flight for distance calculation

After the time synchronization between transmitter and receiver is established, transmitter will send a message with timestamp which is the sent time of message i.e. Tsm from transmitter and the same message is received at the receiver end at Trm which is the received time of message. The difference between both times i.e. Trm and Tsm is estimated and when this time difference multiplied with propagation speed of energy wave which is speed of light will give the distance (D) between the transmitter and the receiver. Equation (1) can be used to calculate distance between transmitter and receiver (in this case between fixed UWB node and mobile UWB device).

$$D = (Trm - Tsm) * speed\ of\ light \qquad (1)$$

Where D is distance between transmitter i.e. mobile UWB device and receiver i.e. fixed UWB node. Trm is received time of message at receiver. Tsm is sent time message from transmitter. Speed of light is $3 * 10^8$ m/s.

Since both transmitter and receiver are in sync with respect to time, message sent time (Tsm) on the transmitter side is taken as receiver time Tr on the receiver side.

To calculate the time of flight Tf the below mathematical equation (2) is used.

$$Time\ of\ Flight\ (Tf) = (Trm - Tsm) \qquad (2)$$

The whole above discussion of TDOA multilateration can be discussed with a simple figure as shown in below Fig. 2.

Consider there is only one transmitter (mobile UWB device) and one receiver (UWB node). This pair will form a circle with fixed UWB node as center i.e. A in the above figure and distance between mobile UWB device and fixed UWB node as radius i.e. Da in the above Fig. 2. This can create infinite number of possibilities (i.e. infinite number of points) of location of mobile UWB device.

The introduction of second fixed UWB node i.e. B in Fig. 2, will be the center of circle that is formed with distance between B (i.e. second fixed UWB node) and same mobile UWB device as radius i.e. Db in Fig. 2 will reduce the number of possibilities of location of mobile UWB tag from infinite to two possibilities, since there are only two intersection points between the first and second circles.

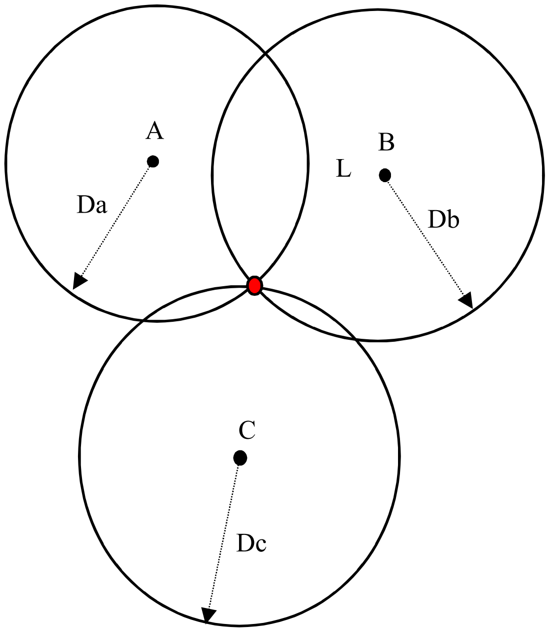

Fig. 2. Multilateration technique for location calculation

Finally by introducing the third fixed UWB node i.e. C in the above Fig. 2, will be the center of circle that is formed with distance between C (i.e. third fixed UWB node) and same mobile UWB device as radius i.e. Dc in the above Fig. 2, will reduce the possibilities of location of mobile UB device from two to only one possibility which is the intersection of all three circles which is represented in red colour point in the above Fig. 2.

To measure the physical location of a target node, the trilateration-based positioning algorithm uses three fixed non-collinear reference nodes (in 2D). The following equations (3) can be derived based on the co-ordinates of three reference nodes: A(x1, y1), B(x2, y2), C(x3, y3), and the corresponding distances from each reference node to the target node: Da, Db and Dc:

$$\begin{cases} ((x1-x)^2+(y1-y)^2)=(Da)^2 \\ ((x2-x)^2+(y2-y)^2)=(Db)^2 \\ ((x3-x)^2+(y2-y)^2)=(Dc)^2 \end{cases} \tag{3}$$

Where (x, y) denotes the (unknown) coordinates of the target.

Localization efficiency is further enhanced on the basis of the trilateration algorithm by taking into account the configuration of the three reference nodes. The study accepted that when the three reference nodes are deployed in the vertices of equilateral triangles, the trilateration algorithm would better show its advantages. In order to ensure the consistency of trilateration, Yang and Liu consider the influence of noisy environments and use various confidence coefficients for three nodes [7].

IV. SYSTEM OVERVIEW

This section will discuss about the block diagram of the system, initial hardware setup of real time location system (RTLS) and working of social distance alert system.

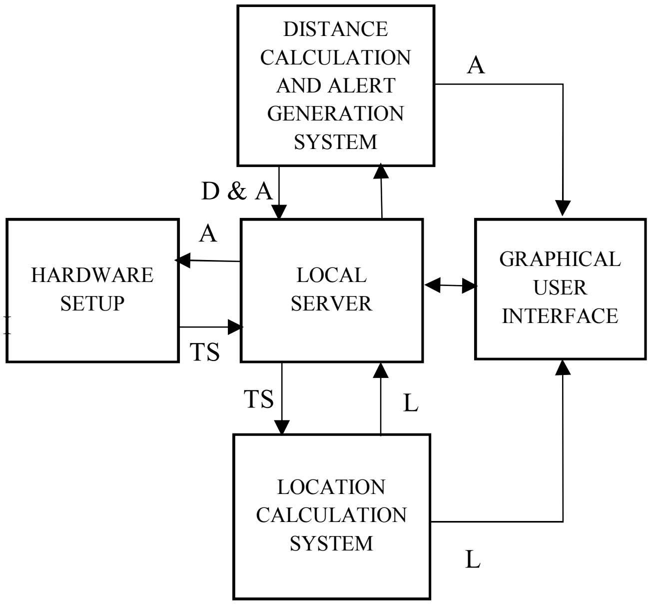

Fig. 3. Block diagram of social distance alert system

The block diagram of the social distance alert system consists of four blocks as shown in the above Fig. 3. Social distance alert system has hardware setup which is installed in the work area of corporate environment. The information from the hardware setup is sent to another block named local server which is the data base for the time stamps (TS) that are sent from mobile UWB devices which are used to calculate the location and locations of mobile UWB devices.

There are another two dedicated blocks which will collect the required information from local server and will calculate the co-ordinates of the location and calculate the distance between two mobile UWB devices to generate an alert. Location calculation system will collect the time stamps (TS) which are received mobile UWB devices from local server and calculate the co-ordinates of the location (L) of respective mobile UWB device. The calculated location (L) in the location calculation system will be stored in the local server. Distance calculation and alert generation system will collect the locations of respective mobile UWB devices (MUD's) and will calculate the distance (D) between the mobile UWB devices and generates an alert (A) for maintaining the social distance depending on the social distancing rules set by the programmer. Graphical User Interface will show the information of mobile UWB devices due which alert is triggered which is received from distance calculation and alert generation system and location of mobile UWB devices to supervisor who is monitoring the work area.

A. Hardware setup

The hardware setup will be installed in the work area as shown in the figure Fig. 4. Four UWB nodes will be installed at four corners of the work area where the employees nothing but mobile UWB devices will be moving.

Among the four fixed UWB nodes, one of the UWB node will be configured as master (M) as shown in the above Fig. 4, which is represented in red colour at the origin with co-ordinates (0,0). The other three UWB nodes will be configured as slaves which are represented as S1, S2 and S3 as shown in the above Fig. 4, in green colour at the co-ordinates (x,0), (0,y) and (x,y) respectively.

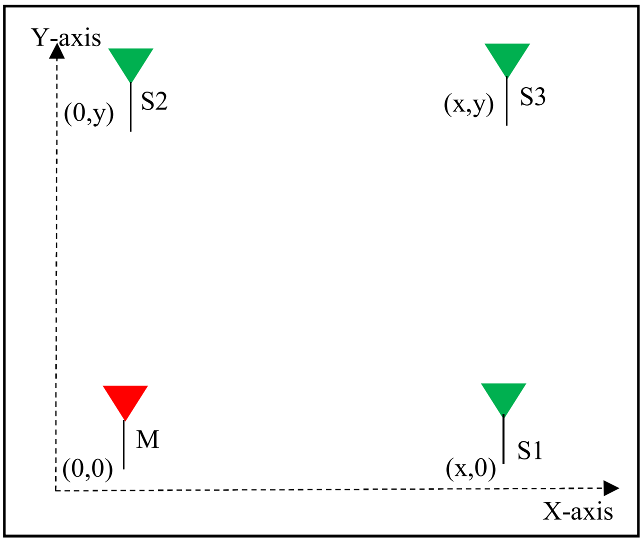

Fig. 4. UWB nodes arrangement in work area of employees

UWB nodes will be installed at some height from the ground for better line of sight. After the installation of UWB nodes, there is a need of synchronization with respect to time between master and slave UWB nodes. For this time synchronization, master UWB node will send synchronization messages to all the remaining UWB nodes and mobile UWB devices. This time synchronization will improve the accuracy of the location of mobile UWB devices.

Mobile UWB devices will send messages to fixed UWB nodes with times stamps. The timestamps (TS) will be sent to the local server from access point which is the master anchor. This communication will happen with the help of Ethernet (i.e. wired connection) or Wi-Fi (i.e. wireless connection). The wired Ethernet connection will have Ethernet cables from each fixed UWB nodes to the access point. In wireless connection, each UWB node will have Wi-Fi antennas to send and access point will have Wi-Fi receiver which will receive the timestamps from UWB nodes.

B. *Local server*

Local server is nothing but a Central Processing Unit (CPU). The time stamps information from the access point will be stored in the local server.

Location calculation system will take timestamps (TS) and calculate the location (L) and will store back in to the local server. Distance calculation and alert generation system will take location information from local server and calculate the distance and store back into the local server.

C. *Location Calculation System*

Location calculation system will calculate the location of the mobile UWB devices. Time stamps that are received from the local server will be used to calculate the location of mobile UWB devices. The location of mobile UWB devices will be calculated using techniques namely multilateration and TDoA as previously discussed. The calculated location will be stored in local server.

D. *Distance calculation and alert generation system*

Distance calculation and alert generation system will calculate the location (L) between two mobile UWB devices by taking location co-ordinates that are stored in the local server after getting calculated in location calculation system using TDoA and multilateration methods.

The distance between two mobile UWB devices is calculated using the mathematical equation (4).

$$D = \sqrt{((X2 - X1)^2 + (Y2 - Y1)^2)} \quad (4)$$

Where D is the distance between two mobile UWB devices and (x1, y1), (x2, y2) are the co-ordinates (i.e. calculated locations of mobile UWB devices.

Depending on the distance (D) between mobile UWB devices, the alert will be generated by the distance calculation and alert generation system according to conditions shown in the below Fig. 5.

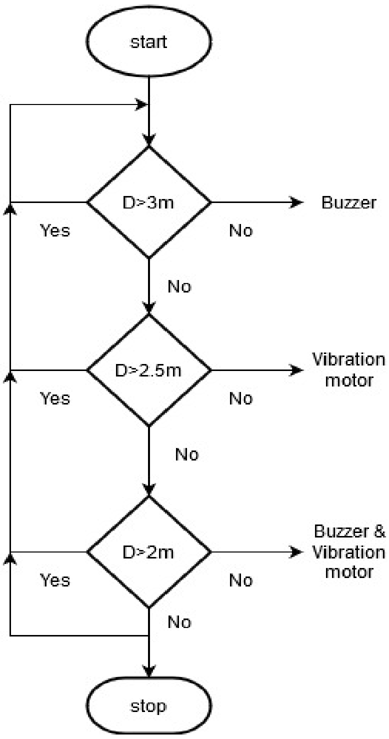

Fig. 5. Flowchart of Distance Calculation and Alert Generation System

There will be two alert indication systems in mobile UWB devices namely buzzer and vibration motor. After calculating the distance (D) between two mobile UWB devices, if D is less than 3 meters then alert will be sent to the buzzer in mobile UWB device to give beep sound. If D is less than 2.5 meters then the alert will be sent to the vibration motor in mobile UWB device to vibrate for small period of time. If D is less than 2 meters which is less than the recommended social distance then the alert will be sent to buzzer to make beep sound and vibration motor to vibrate which are in mobile UWB device.

V. PROCESS OVERVIEW

The flow of social distance alert system is shown in the Fig. 6, below with the help of flow chart.

As shown in the flowchart in Fig. 6, the process starts from mobile UWB device. MUD will send short UWB messages with timestamps. The fixed UWB node will receive the UWB messages sent from mobile UWB devices and the timestamps (TS) of UWB messages will be stored in the local server which is acting as a database. From the local server, location calculation system (LCS) will collect the timestamps (TS) and calculate the location (L) of mobile UWB devices using multilateration technique.

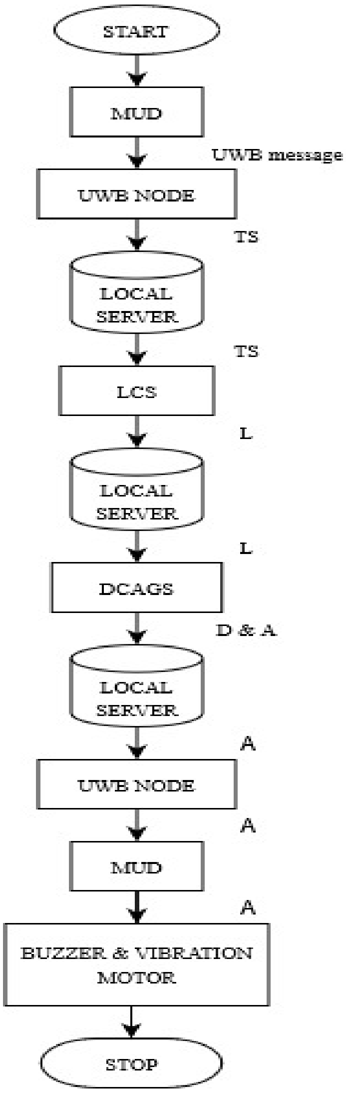

Fig. 6. Flowchart of social distance alert system process

The calculated location (L) of MUD will be stored in the local server. The distance calculation and alert generation system (DCAGS) will collect the locations (L) of mobile UWB devices and calculates the distance (D) between two mobile UWB devices and will generate the alert depending on the social distance conditions set by the programmer. The generated alert (A) will be sent to the local server from where alert will be sent to fixed UWB nodes and finally transmitted to the mobile UWB device alert systems. After receiving the alert (A), the alert systems in mobile UWB device namely buzzer and vibration motor will give alert to the employees to maintain social distance according to the alert generated by DCAGS.

VI. CONCLUSION

In this paper, a social distance alert system based on Real Time Location System which works on UWB technology is discussed which can be installed at any predefined work places in corporate environments. Since few months, corporate companies resumed work from office for their employees based on the guidelines given by the government. So it is important to control the spread of virus in work areas between the employees. Maintaining social distance is one of the important prescribed and recommended safety measure. This discussed alert system can alert the employees, when the distance between one employee and other employee is less than the prescribed distance. Since Social Distance Alert System mainly works on distance between two mobile UWB devices, the used technology for locating should work with great accuracy. The main reason for UWB based Real Time Location System to alert the employees is ultra-wide band has been already proved that it works with great accuracy approximately in centimeters and with less power consumption.

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