TDOA Source Localization Using OFDM Signal

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Abstract

In this paper, we studied algorithm and bounds for distributed Time Difference Of Arrival based source localization using OFDM signal. Source localization using TDOA requires centralization of multiple copies of a signal,so it requires large amount of bandwidth and power .This paper considers blindly estimating the location of a cyclic prefix (CP) in an orthogonal frequency division multiplexing (OFDM) signal for positioning.To overcome the drawbacks of centralization TDOA we used OFDM signal

Key Words - Orthogonal Frequency Division multiplexing (OFDM), Time Difference Of Arrival (TDOA), Cramer-Rao lower bound (CRLB), Source Localization, cyclic prefix (CP).

1. Introduction

Source localization is important in variety of application. Source localization and navigation are two positioning problem. Range and angle measurements used for localization are measured in a physical medium that introduces errors. Accurate position measurement is important for many source localization and navigation problems[1][8]. The global positioning system (GPS) usually provides worldwide high-accuracy position measurements, but it requires lines of sight to multiple satellites. Hence, it is ill-suited for use in indoors, underground. Also, in the presence of radio frequency interference or jamming, GPS may be unavailable []. That's why, alternative methods of navigation and positioning are of interest. So we can use distributed TDOA based positioning as a backup for GPS or for use in areas unreachable by satellites. Radio frequency based positioning is completed through different method such as received signal strength (RSS), angle of arrival (AOA), time of arrival(TOA) and time difference of arrival(TDOA) measurements. TDOA measurements are very accurate, but the main drawback of using TDOA methods is that they require centralization of multiple copies of a signal in order to perform cross-correlation. Centralization wastes bandwidth and power. The amount of centralization of data can be reduced using OFDM signal by only comparing the temporal locations of the CPs rather than comparing the entire signals. But there is having some limits of each measurement.

1.1. RSS

This method uses a known mathematical model that depicts the path loss attenuation over distance between a mobile receiver and a transmitter. It is the voltage measured by a receiver's received signal strength indicator (RSSI) circuit. Often, RSS is equivalent to the measured as power.

Measured power is squared magnitude of strength. RSS is frequently used, but it generally requires assuming that the transmitted power and the path loss exponent are known or are included as additional parameters to be estimated, that there is no multipath, this assumptions which are generally not valid.

1.2. AOA

It provides information about the direction of neighbouring sensor rather than the distance to neighbouring sensors. It does this by comparing either the carrier-phase or signal amplitude across multiple antennas. But AOA calculations are very susceptible to range. As the distance from the source increases, the position accuracy decreases.

1.3. TOA

TOA is the measured time at which a signal first arrives at a receiver. The measured TOA is the time of transmission plus a propagation-induced time delay. TOA estimation that maximizes the cross-correlation between the received signal and the known transmitted signal. Errors are estimated in TOA by two problems. First, Many multipath signals arrive very soon after the LOS signal, and their contributions to the cross-correlation obscure the location of the peak from the LOS signal. Second, The LOS signal can be severely attenuated compared to the late-arriving multipath components and loss completely.

1.4. TDOA

It is very accurate. but the main drawback of using TDOA methods is that they require centralization of multiple copies of a signal in order to perform cross-correlation. Centralization wastes bandwidth and power. The amount of centralization of data can be reduced using OFDM signal , by only comparing the temporal locations of the CPs rather than comparing the entire signals.

2 . System overview

2.1. OFDM signal generation

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. Here we study the performance of cyclic prefix correlation based single timing acquisition algorithms for non-

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contiguous OFDM transmission. CP detection can be done blindly, without a priori knowledge of the data contained in each CP . Thus, the TDOA computation can be distributed, and the data-sharing burden will be greatly reduced.

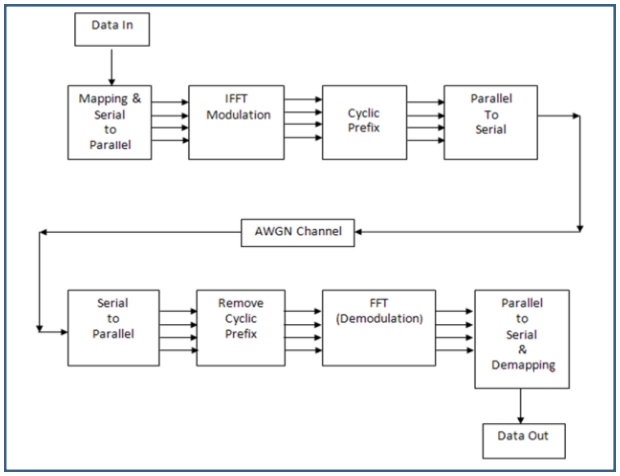


Figure 1. OFDM signal generation

The OFDM transmitter uses a fast Fourier transform (FFT) size of N, a CP length of v samples, and a bandwidth 1/Tof Hz[1].

In the presence of multipath, with resolvable paths separated by T_s and a line-of-sight (LOS) path present, the received signal to be sampled is

$$y(t)=\sum_k x[k]\sum_{j=0}^{j} h[j]p(t-\delta_0 T_s-kT-jT_s)+n(t) \quad (1)$$

2.2. System model and notation

First, consider the geographical layout, as in Figures 2 and 3 for the two similar problems of "navigation via signals of opportunity" and "source localization," respectively. In the navigation problem, [1] is shown in Figure 2, there are *k*th transmitters at known locations and two receivers at unknown locations. The *k*th TDOA corresponds to transmitter , and is determined by the two receivers.

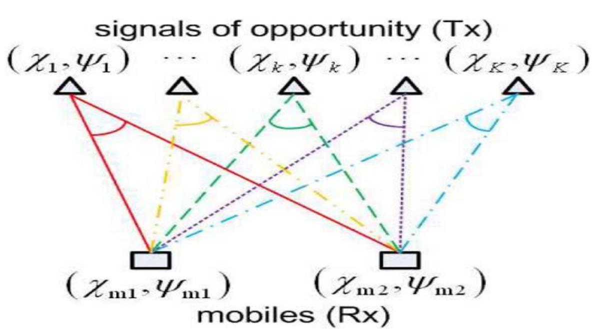


Figure 2. Geographical layout for navigation via signals of opportunity [1]

Also, source localization involves K receivers at known locations and one transmitter at an unknown location[1], and the K-1 TDOAs are jointly determined by the receivers. The n receiver locations are denoted as $\chi_k = (\chi_k, \psi_k)$, k=1………K and the source is at location $\chi_s = (\chi_s, \psi_s)$, The receivers are assumed to coordinate to remove any clock offsets between them.

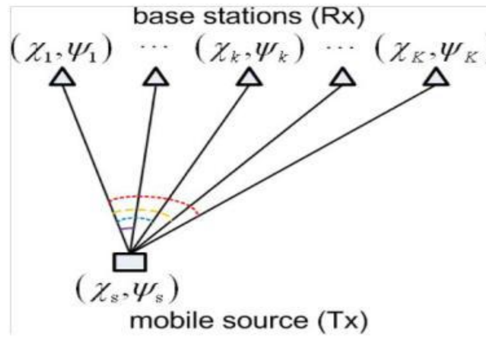


Figure 3. Geographical layout for source localization [1].

3. Proposed system

The block diagram consist of Distributed TDOA using OFDM signal is introduced as shown in Fig.4. For proposed system we will show how TDOA estimation and positioning can be performed for OFDM signals without any cross correlation of received signals.

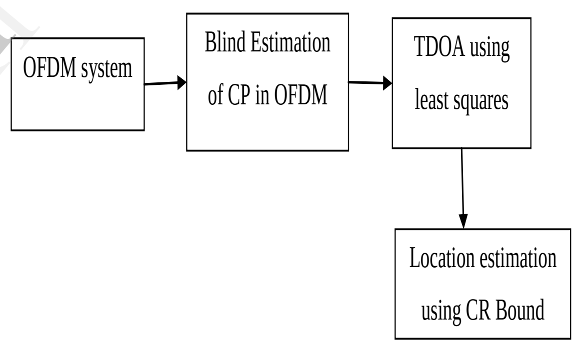


Figure 4. Distributed TDOA using OFDM signal

3.1. TDOA estimation

Time difference of arrival (TDOA) is commonly used in civil and military surveillance applications to accurately locate an aircraft, vehicle or stationary emitter by measuring the time difference of arrival (TDOA) of a signal from the emitter at three or more receiver sites.

A ML algorithm was derived to jointly estimate the temporal location of the CP and the carrier frequency offset (CFO), but no CRLB was derived. The ML algorithm of assumed no oversampling, i.e., q=1, hence it is not necessarily ML for q>1[1][9]. Accordingly, we will refer generalization as the van de Beek (vdB) algorithm. The vdB synchronization algorithm, is given by

$$\hat{\delta}_{vdB} = \text{ARG MAX}_{\frac{Mq}{2} \le \delta_Q < \frac{Mq}{2}} \left\{\gamma(\delta_0) - \frac{\rho}{2}\emptyset(\delta_0)\right\} \quad (2)$$

$$\gamma(\delta_0) = \sum_{t=1}^{L}\sum_{k=Ml}^{Ml+v-1} y(kT+\delta_0 T_s)y *\times((k+N)T+\delta_0 T_s) \quad (3)$$

$\emptyset(\delta_0) = \sum_{t=1}^{L}\sum_{k=Ml}^{Ml+v-1} y(kT+\delta_0 T_s)^2 + ((k+N)T + y((k+N)T +$
$\delta 0Ts)2$ (4)

$$\rho = \frac{SNR}{SNR+1} \quad (5)$$

We will consider that this algorithm only uses the autocorrelation of the received signal.This is motivated by the fact that $\emptyset$ (δ_0) is approximately constant over δ_0, especially if the amount of averaging (L)is large; and the $\rho\emptyset$ (δ_0)term vanishes at low SNR. Then we get,

$$\hat{\delta}_{acrr} = arg\max_{\frac{Mq}{2}\leq\delta_0<\frac{Mq}{2}}\{\gamma(\delta_0)\} \quad (6)$$

3.2. CRLB derivation

1. First, we derive the CRLB on estimating the delay of the CP in OFDM. Next, we consider the CRLB on estimators that only use the autocorrelation function to locate the CP This bound is derived both in the absence of and in the presence of multipath. Finally, we discuss how these bounds on the TDOA estimates affect the bounds on the position estimates, in positioning problems[1].
The TDOA is a subtraction of two delay estimates

$$VAR[TDOA_{cp}] \geq \frac{T^2}{LSNR}\left[\sum_{d=1}^{\infty} d\left(p_0'(d)\right)^2\right]^{-1} \quad (7)$$

$$\left[\sum_{d=1}^{\infty} d\left(p_0'(d)\right)^2\right]^{-1} = \eta \quad (8)$$

For raised cosine pulse shapes with excess bandwidths of 0, 0.25, and 0.5, the factor is 0.63, 0.82, and 1.49, respectively.

2. Bound for Autocorrelation-Based Methods
The bound for the TDOA using autocorrelation is doubled,

$$VAR[\widehat{TDOA}_{acorr}] \geq \frac{(1+SNR^{-1})^2 T^2}{2L} \quad (9)$$

The limiting cases are,

$$VAR[\widehat{TDOA}_{acorr}] \geq \begin{cases} \frac{T^2}{L} & \text{high SNR} \\ \frac{T^2}{LSN\,R^2} & \text{low SNR} \end{cases} \quad (10)$$

both (44) and (64) are independent of the fraction of each block consisting of the CP, i.e., the fraction v⁄M . Thus, a short CP is as good as a long CP for purposes of blind delay estimation.

4. Simulation Results

This section explains the performance analysis using simulations. The transmitter uses an FFT [1] size of N=64, a cyclic prefix (CP) length of v=16, and a block size of M=80, the Nyquist sampling period is T=50ns. Simulated offset in meters of RMSE and CRLB versus SNR The simulation results finds estimation of cyclic prefix delay. The RMSE of the vdB estimator of [7] are compared to square root
of the CRLBs derivation from (7) and (9).
The difference between the figures is only number of blocks is changed.

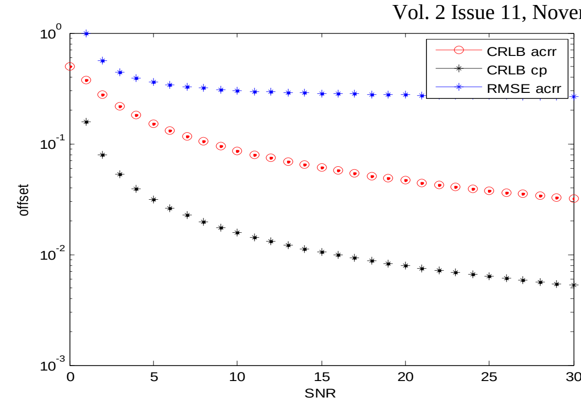


Figure 5(a). The CRLB and the RMSE versus SNR, for v=16 N=64, and L=4

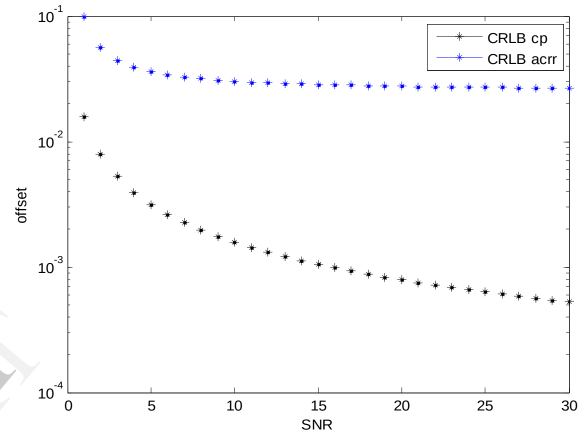
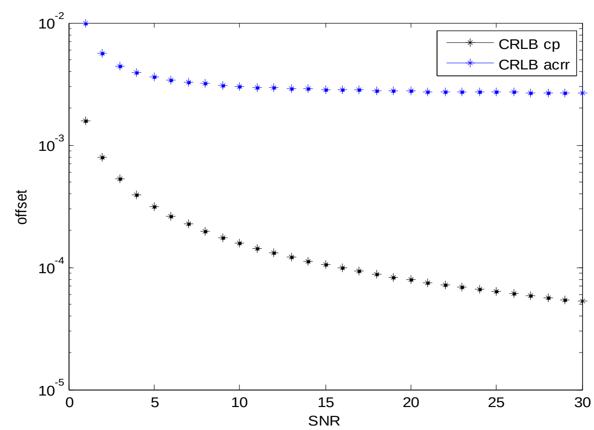


Figure 5(b). The CRLB and the RMSE versus SNR, for v=16 N=64,and L=40.

5. Conclusion

In this paper, we discussed different source localization



techniques such as AOA, RSS, TOA and TDOA and showed that TDOA is best suited for source localization.

Figure 5(c). The CRLB and the RMSE versus SNR, for v=16 N=64, and L=400.

A new method for the estimation of the source localization, by using cyclic prefix using OFDM signal is proposed in this paper. The requirement of large amount of bandwidth and power by TDOA-based method of source localization is overcome by the proposed system.

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