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Accurate TOA-Based UWB Localization System in Coal Mine Based on WSN

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Abstract

Over the last years, there has been a great deal of interest in Ultra Wideband (UWB) wireless communication and Wireless Sensor Networks(WSN), especially following the proposing of the internet of things by the MIT (Massachusetts Institute of Technology) in 1999, hich is also result in an increasing research on UWB and WSN applications. This article mainly introduced the accurate UWB Localization System based on WSN in coal mine. Firstly, we briefly introduced UWB and WSN Localization technology. Secondly, the advantages and disadvantages of the previous personnel localization technology in coal mine was analyzed and contrasted, and then the suitable personnel localization system in coal mine based on UWB signal and TOA estimate positioning scheme are presented. At last the rationality and feasibility of this scheme was proved through the simulation results.

Keywords:UWB; coal; mine; localization; TOA; WSN

1.Introduction

With the development of science and technology, in view of the present grim situation in mining, the importance of safety precautions in mining become apparent in front of the government and scientists. Although recently Chinese mining industry also was taken a lot of measures in terms of security, but are still lagging behind developed nations. According to document [1], There were 27416 accidents and 45162 persons who died in mining during 2000 to 2007 in China. There was an average of about 3427 accident and 5645.25 dead persons a year. mortality rates of per million tons was 3.04 persons. And there were 241 persons dead during 2000 to 2007 in USA, 30 persons dead a year,mortality rates of per million tons was 0.027 persons. It is obvious that how serious the safety situation for us is. Therefore, the development and application of personnel localization system in mine is very necessary, on one hand, it is helpful for rescuers to locate distress persons quickly and take effective measures in accidents, On the other hand, it is also helpful to the usual scientific and orderly production management.

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2.Introduction to UWB and Wireless Sensor Network Localization

Ultra Wideband (UWB) is a fast emerging technology used for future short range indoor radio communication. This system provides very high bit rates services, low power consumption and accuracy position capability. In 2002, the Federal Communication Commission(FCC) regulated the UWB technology utilization for commercial applications in the United States in the frequency range of 3.1–10.6 GHz [2].

WSN localization techniques are used to estimate the locations of the sensors with initially unknown positions in a network using the available a priori knowledge of positions of a few specific sensors in the network and inter-sensor measurements such as distance, time difference of arrival (TDOA), time of arrival (TOA), angle of arrival(AOA) and connectivity. Applications of WSN localization techniques are very widely, in military reconnaissance, such as enemy personnel and equipment monitoring, in environmental monitoring applications such as animal habitat monitoring, bush fire surveillance, water quality monitoring and precision agriculture and other applications such as inventory management intrusion detection, road traffic monitoring, health monitoring, reconnaissance and surveillance[3]. In this paper, we provide our localization method of monitoring and tracking the human or vehicle locations based on UWB and TOA in coal mine environments.

TOA based ranging technique using UWB radio has the potential to provide accuracy range measurement because of its broad bandwidth. For range measurements under LOS channel conditions or NLOS channel conditions, face a more difficult challenge, since the Direct Path(DP) is either detected but attenuated or completely blocked. In the former case, the ranging performance of UWB is slightly degraded since the DP is not the strongest path. In the latter situation the DP is severely attenuated and blocked due to harsh obstacles and the UWB ranging accuracy is degraded seriously.

3.Localizition System

At present, many underground positioning systems, commonly used in the Radio Frequency Identification(RFID), and ZigBee technology, RFID technology positioning accuracy is not as high, and gradually be eliminated, and high positioning accuracy using zigbee technology, but nevertheless, the underground environment, the complexity of the reliable transmission of signals facing great challenges, according to the literature [5], the actual positioning system underground zigbee technology has reached the error of about 1-5m, can be seen in order to obtain very high accuracy positioning system underground, must be applied with high anti-interference ability, low-power Ultra Wideband technology. Here we first introduce under the ZigBee-RSSI positioning technology, and then introduce wireless location technology based on UWB system model.

3.1.ZigBee

The location algorithm used in the CC2431 Location Engine is based on Received Signal Strength Indicator (RSSI) values. The RSSI value will decrease when the distance increases like figure 1. The received signal strength is a function of the transmitted power and the distance between the sender and the receiver.

Path loss model in ZigBee [4]:

$$PL(d) = PL(d_0) - 10n(\frac{d}{d_0}) + X_\sigma \qquad (1)$$

In the equation (1), $PL(d)$ is the pass loss at d in dB, $PL(d_0)$ is the pass loss at d_0 in dB, d_0 is the reference distance, d is the distance from transmitter to receiver.

X_σ is random variables of Gaussian distribution whose average is zero.

n is refers to the path loss exponent which depends on channel and environment.

So we can obtain the equations(2):

$$d = d_0 \times 10^{\frac{PL(d_0)-PL(d)+X_\sigma}{10n}} \tag{2}$$

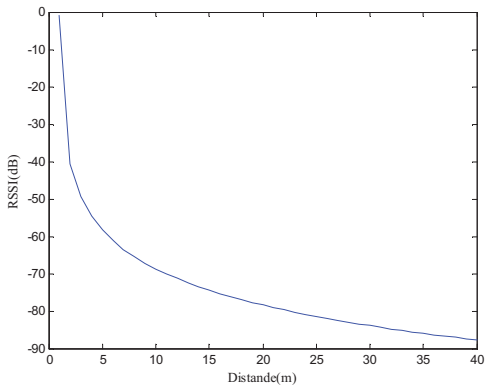

Figure 1. Relation between RSSI value and the distance

Figure1 show the relation between RSSI value and the distance.

3.2.UWB model

Transmitted signal:

$$s(t) = \sum_{i=0}^{N-1} p(t - i \cdot T_{\text{int}}) \tag{3}$$

In the equation (3), *p(t)* is Gaussian monopulse, T_{int} is the sum of guard time and pulse width, N is the number of identical pulses.

Received signal:

$$r(t) = h(t) * s(t) + n(t) \tag{4}$$

In the equation (4), h(t) is the channel impulse response and n(t) is the AWGN noise. Since AWGN has statistically zero mean.

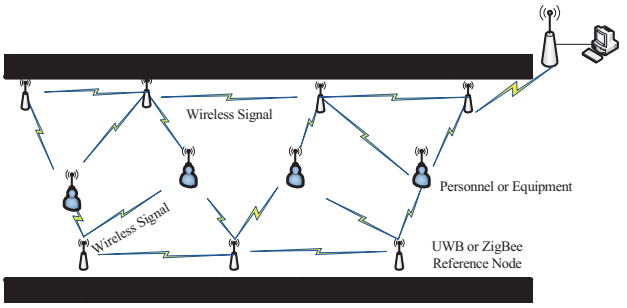

Figure 2. UWB or ZigBee localization system in mine

Figure2 shows UWB or ZigBee Localization System in coal mine.

4.Measurement Technology and Localization Algorithms

4.1.Trilateration

Suppose that we have three reference node with coordinates A(x_1 , y_1), B(x_2 , y_2) and C(x_3 , y_3),target node is T(x, y), shows in figure3

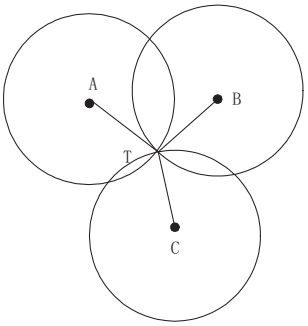

Figure 3. Trilateration

d_i (i =1, 2, 3)is the distance from the i_{th} reference node to the target node. The value of d_i can be obtained by UWB-TOA localization or ZigBee-RSSI localization.

So we can obtain the equations(5):

$$\begin{cases} (x_1 - x)^2 + (y_1 - y)^2 = d_1^2 \\ (x_2 - x)^2 + (y_2 - y)^2 = d_2^2 \\ (x_3 - x)^2 + (y_3 - y)^2 = d_3^2 \end{cases} \tag{5}$$

Suppose

$$A=\begin{bmatrix} 2(x_1-x_3) & 2(y_1-y_3) \\ 2(x_2-x_3) & 2(y_1-y_3) \end{bmatrix} \tag{6}$$

$$b=\begin{bmatrix} x_1^2-x_3^2+y_1^2-y_3^2+d_3^2-d_1^2 \\ x_2^2-x_3^2+y_2^2-y_3^2+d_3^2-d_2^2 \end{bmatrix} \tag{7}$$

$$T=\begin{bmatrix} x \\ y \end{bmatrix} \tag{8}$$

By Minimum Mean Squared Error (MMSE) estimators we can obtain the estimation value of the T node:

$$\hat{T}=\left(A^T A\right)^{-1} A^T b \tag{9}$$

4.2.Improvement Algorithm of TOA Estimation

To achieve accurate position estimation, we must first acquire accurate measurements of TOA firstly. There are many algorithms of TOA estimation in previous articles. In this paper, we performance improvement of UWB position location algorithm using multiple pulse transmission based on TOA [6].

5.Simulation Result

The step of simulation is as follows:

First, we obtain three node using matlab. These three nodes are A (0, 0), B (8, 5. 6603) and C (10, 0). They are the reference node which are used in the methods of ZigBee and UWB.

Second, we locate the 10 blind nodes through trilateration technique. Involved in the localization process to the measurement of the distance d, we can obtain them using ZigBee and UWB communication. And we use RSSI positioning technology in ZigBee communication, use TOA positioning technology in UWB communications.

Third, analyze and compare simulation data.

In our simulation, the RSSI-ZigBee simulation condition is：

n=2， d_0 =20m.

The result of simulation shows in the figures 4 and figure 5.

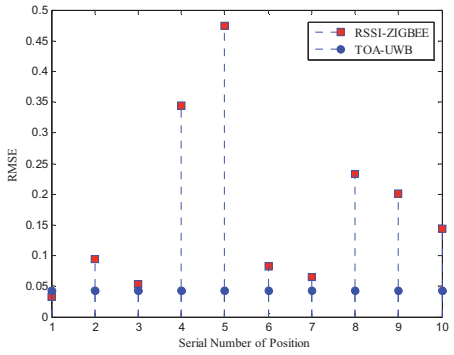

Figure 4. RMSE of the estimation values of the 10 blind nodes

Figure 4 shows the RMSE of the estimation values of the 10 blind nodes using RSSI-ZigBee localization and TOA-UWB localization.

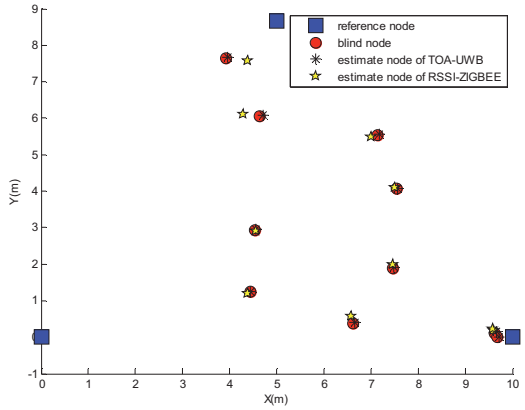

Figure 5. simulation scene

Figure 5 shows the simulation scene. In the scene,there are three reference nodes. The actual position of the ten blind nodes and their estimation position using UWB-TOA and ZigBee –RSSI are shown in the scene.

6.Conclusion

In this paper, accurate TOA-Based UWB localization system in coal mine based on WSN is proposed. By using matlab simulation and review some published literatures we can make a conclusion that accuracy of TOA-Based UWB localization system is higher than RSSI-ZigBee in coal mine. Importance of life, from the point of view, we should adopt such a high precision UWB system, this will give Chinese security environment in the mining industry a great deal of difference.

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