Experimental Study of DVB Multipath Behavior

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***Abstract*—Indoor positioning of first responders after disaster is of vital importance. Multipath mitigation is one of the main tasks for a wireless network based indoor positioning system. This paper presents an experimental study on behavior of Digital Video Broadcast (DVB) signal multipath in both outdoor and indoor environments. We find out that when test nodes are close enough, they share similar multipath and background. Relative range estimation among the nodes can greatly suppress large multipath errors. Time Difference of Arrival (TDOA) method may be used with Received Signal Strength (RSS) for improved for positioning estimation accuracy.**

I. INTRODUCTION

Indoor positioning system that utilizes signal of opportunity (SoOP) is a significant permissive technology since it can provide low power wireless localization of first responders (FR) after disaster when other wireless signals are out of service or ineffective. However indoor positioning techniques have to face challenges like none–line–of–sight (NLOS), the influence of obstacles, all weather condition, and other factors. One of the main problems is the multipath effect. If the multipath effect can be compensated, improved accuracy may be achieved [1-5].

II. EXPERIMENTAL BASED MULTIPATH STUDY

To study the behavior of DVB signal multipath, two different test setups have been used (Fig.1). Case 1: Each node has a dedicated antenna. Case 2: nodes share one antenna.

A. Case 1

Node A and node B are placed at different locations and connected with a cable as shown in Fig.1. (1). The range difference between node A and node B from the SoOP is defined as

$$R_A - R_B = \Delta, \quad (1)$$

The node range is defined as the range difference between the relay and direct SoOP LOS paths to the node:

$$Range_A = R_B + R_{Cable} - R_A = R_{cable} - \Delta, \quad (2)$$

$$Range_B = R_A + R_{Cable} - R_B = R_{cable} + \Delta. \quad (3)$$

The ambiguity functions for nodes A and B can be written as:

$$\int_{-\infty}^{+\infty} \left\{\sum A_i\, s\big(t-\delta_{A,i}\big)\right\}\left\{\sum B_j\, s\big(t-\delta_{B,j}-\tau_A\big)\right\} dt, \quad (4)$$

$$\int_{-\infty}^{+\infty} \left\{\sum B_j\, S\big(t-\delta_{B,j}\big)\right\}\left\{\sum A_i\, S(t-\delta_{A,i}-\tau_B)\right\} dt, \quad (5)$$

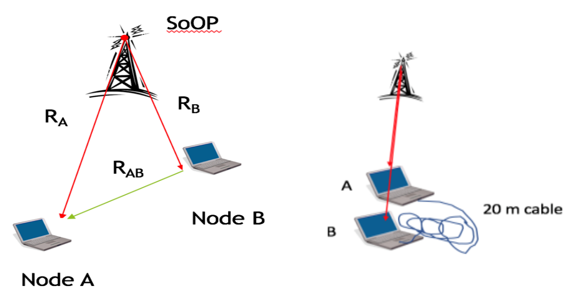
where $\tau_A = \frac{Range_A}{c}$, and $\tau_B = \frac{Range_B}{c}$. When test node A, node B signal is used as the reference signal. When test node B, node A signal is used as the reference signal.

B. Case 2

In this case Node A and node B are closely located and connected with a cable. Since the nodes share one antenna, the multipath and background clutter are canceled. Ambiguity functions for node A and node B are:

$$\int_{-\infty}^{+\infty} \left\{\sum A_i\, S\big(t-\delta_{A,i}\big)\right\}\left\{\sum A_j\, S\big(t-\delta_{B,j}-\tau_A\big)\right\} dt \quad (6)$$

$$\int_{-\infty}^{+\infty} \left\{\sum A_i\, S\big(t-\delta_{B,i}\big)\right\}\left\{\sum A_j\, S\big(t-\delta_{A,j}-\tau_B\big)\right\} dt \quad (7)$$



(1) (2)

Fig.1. (1) Case 1: Nodes with individual antennas.
(2) Case 2: Nodes with a shared antenna.

III. EXPERIMENTAL RESULTS

Experimental tests have been carried out in urban, suburban, indoor, and outdoor. To prove of concept, two nodes are used for testing. Each node is equipped with an SDR Ettus N210. RX port is split to two ports. One RX port is for receiving SoOP signal; another RX port is interconnected to the TX port of the other node for synchronization and relay purpose. Table I lists the range estimation results. Comparing the results for node A and node B in case 1 and in case 2, they appear to have similar range errors. Based on these experimental observations, we may conclude that large range estimation error above range resolution due to multipath effect can be removed.

TABLE I. EXPERIMENTAL TEST RESULTS

Test Case		Case 1		Case 2	
		Range(m)	***error(m)***	***Range(m)***	***error(m)***
Urban	Node A	45	3	27	0.5
	Node B	10	5	28	3
Suburban	Node A	40	3	27	2
	Node B	11	0.5	28	3

IV. TDOA BASED POSITIONING

Hugh Transform is used for position estimation [6]. The distance from a reference site i at $(x_{R_i}, y_{R_i}, z_{R_i})$ to the location (x, y, z) is found to be,

$$R_i = \sqrt{\left(x_{R_i} - x\right)^2 + \left(y_{R_i} - y\right)^2 + \left(z_{R_i} - z\right)^2} \quad (8)$$

where the SoOP is the origin of the ordinate system. Range difference between a location on the grid, node i, and the reference site 1 is then:

$$c\tau_{i,A} = R_i - R_A$$
$$= \sqrt{\left(x_{R_i} - x\right)^2 + \left(y_{R_i} - y\right)^2 + \left(z_{R_i} - z\right)^2} \quad (9)$$
$$- \sqrt{\left(x_{R_A} - x\right)^2 + \left(y_{R_B} - y\right)^2 + \left(z_{R_C} - z\right)^2}$$

The TDOA estimation pdf function is:

$$p\left(x, y, z \middle| \tau_{i,A}\right) = \frac{\exp\left(\frac{R_{i,A}^2 - c^2\tau_{i,A}^2}{2\sigma_R^2}\right)}{\sqrt{2\pi}\sigma_l} \quad (10)$$

where σ is the "range error". The voting function for the system with L sensors is then:

$$A_{TDOA}(x, y, z) = \frac{1}{L}\sum_{l=1}^{L} p\left(x, y, z \middle| \tau_{l,A}\right) \quad (11)$$

The TDOA based measurements are shown in Fig. 2. The FR has a body wear device, such as a reflector, or a repeater that relays the DVB signal to base nodes (BNs). Three BNs A, B, and C are close by, with known locations. Since location of SoOP is known too, we can estimate relay ranges $R_A + R_{TA}$, $R_B + R_{TB}$, and $R_C + R_{TC}$ with TDOA measurements. The overlapped zone of the three ellipses will be the estimated FR location, which follows Gaussian distribution as shown in (10). RSS and fingerprinting methods may also be used for improved accuracy.

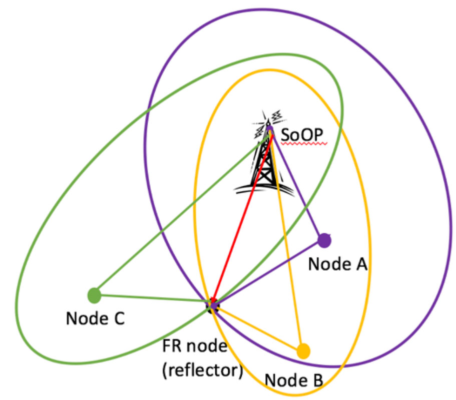


Fig.2 TDOC based positioning system.

IV. CONCLUSION

We have presented our experimental study on behavior of DVB signal multipath in both indoor and outdoor environments. We have found out that multipath and background clutters from DVB signals may be shared by many nodes in a closely located area (in our case ~< 50 m for outdoor, and 1-2 m in indoor), and can be greatly suppressed if TDOA measurements are used among the nodes.

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