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Robust Evaluation for Indoor Channel Propagation Model Based on IA-RSSI algorithm

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Abstract

To improve the indoor positioning precision, there needs more details about channel propagating characteristics. As an indicator existing almost all wireless communication devices, Received Signal Strength Index (RSSI) has a feature that is susceptible to channel mutation. Aiming to alter empirical formula used for many indoor position methods that consider the related RSSI channels propagating mode as a 'black box', the fluctuated RSSI derived from the electromagnetic theory in inhomogeneous area can be utilized in reverse to evaluate ICPM(indoor channel propagating model). Following this idea, anew algorithm called IA-RSSI (RSSI-based Iteration Approach) is proposed, which is outstanding to adaptively and accurately estimate ICPMaffected by electromagnetic environment distribution with versatile RSSI. The simulation results demonstrated that it could not only rebuild an excellent ICPMwhich is close to the actual environment greatly, also increase the practical operability because of the devices to obtain RSSI is more cost-effective compared with other electromagnetic parameters.

Keywords: Indoor Positioning, ICPM, IA-RSSI

Introduction:

With the rapid increase forprecise and real-time needs of indoor targets tracking localization, indoor positioning has become the 'last kilometre' difficult problem because of global positioning system (GPS) can't meet high accuracy demand smothered byroom's variant propagating scenario [1].

Aiming to mitigate the unpredicted relationship between the wireless signals and the geometry position affected by the actual complex indoor conditions, the existing algorithms include mainly two schemes, fingerprint based or channel propagation model recovery based methods. The former can deal with the environment including Non-Light-Of-Sign (NLOS) and multipath transmission based on the prior measurement database [2]-[4], but hard to adaptenvironment changes, that is to sayfingerprint localization systems lack self-adaptability. The latter employs receiving Time of Flight (TOF) or phase difference between the Tx and Rx as the parameter to iteratively evaluate indoor electromagnetic propagating channel model for boosting position accuracy [3,4]. TOF is chosen as the working parameter due to the nature of the geometry distance and time transition. But the amount value of TOF is picosecond level for the indoor scale and general wireless devices have no ability to deal with such a short interval time extraction. Similarly, for phase difference parameter, some problems about phase ambiguity and measure accuracy still be there. For solving this shortcoming, RSSI entered our field of vision. Susceptible RSSI almost is a universal component in a wireless device to assist in adjusting the transmitting electromagnetic power, judging link quality or locating because of its cheaper facility. But unfortunately, the dynamic nature of RSSI is considered as harmful in ordinary wireless indoor positing which usually use many smooth techniques to suppress it[6]. This leads a misunderstanding about the fluctuation feature of RSSI derived from the change of electromagnetic propagating channels.

In this paper, a novel algorithm is presented in order to accurately predict wireless ICPM with an easily obtained RSSI. The relationship between the fluctuation of RSSI and the channel model are re-recognized based on the inhomogeneous electromagnetic propagating theory and this new algorithm. Namely, RSSI would be seen as an important evaluation parameter for indoor mediums distribution.

1. The Reason to Choose RSSI:

Generally, in a precisely given instant and place, RSSI values obtained by a device in a wireless network depend on a large number of unpredictable factors. Specifically, dramatic differences in RSSI can happen due to small changes in device positon or the presence of moving objects. These impacts can be incarnated popularly through simplified experience propagation model, from which it could be known that two important factors influencing RSSI are spreading distance and path loss exponent. In most pre-existing indoor position algorithms, loss exponent is seen as a known quantity whose range is 2~4 according to experience usually and it means indoor area would be handled as a rough space which could result in low locating accuracy because of the distance is the only corrected parameter to confirm the position of target. Consequently, an innovative algorithm is needed urgently to acquire the actual distribution of path loss factor for high positioning performance.

However, how could we estimate the real situation of path loss underan inhomogeneous condition? It can be demonstrated by indoor intrusion detection technology based on RSSI [2] that the change of path loss exponent may lead to the decrease or fluctuation in RSSI values due to the sudden emergence of one or more barriers may interfere in the station-to-station path propagating when the wireless devices remain static. Exactly, the variation of RSSI could be utilized in reverse to estimate the practical values of indoor path loss factor.

According to the view of Electromagnetics, in the inhomogeneous environment, ε (permittivity) and μ (permeability) of medium could chiefly influence the velocity of propagating signal, then influence the time arriving in antennas but the existence of σ (conductivity) would mainly affects the signal amplitude. This relationship could be shown in following spherical wave equation to simulate electromagnetic wave propagation in a room.

$$\nabla^2 E(r,t) - \omega^2 \sigma\mu \frac{\partial E(r,t)}{\partial t} - \omega^2 \varepsilon\mu \frac{\partial^2 E(r,t)}{\partial t^2} = 0 \quad (1)$$

Where E is electric field, r denotes the propagating radius of spherical wave. Owing to spherical wave can be seen as the superposition of multiple plane waves, so in the every r direction it can be achieved a solution that

$$E(r,t) = \frac{1}{f(r)} E_{r0} e^{-\omega\sqrt{\frac{\mu\varepsilon}{2}\left(\sqrt{1+(\frac{\sigma}{\omega\varepsilon})^2}-1\right)}r} e^{-j\omega\sqrt{\frac{\mu\varepsilon}{2}\left(\sqrt{1+(\frac{\sigma}{\omega\varepsilon})^2}+1\right)}r} \quad (2)$$

Here E_{r0} means the initial field intensity [5]. From (2), it can be seen that RSSI in propagating process actually can be expressed as $\mathrm{RSSI} = \frac{1}{f(r)} E_{r0} e^{-\omega\sqrt{\frac{\mu\varepsilon}{2}\left(\sqrt{1+(\frac{\sigma}{\omega\varepsilon})^2}-1\right)}r}$, which demonstrated the presence of σ along r direction could result in decrease in RSSI compared with lossless medium when ε and μ remain the same at equipotential surface.

In general, if the actual RSSI is below RSSI values in homogeneous environment when the antennas remain static, it could be obviously known that this room exists for eigninhomogeneous mediums to cause the signal loss. In other words, RSSI can be used to predict whether this room has the objects with σ, even their locations or sizes.

2. Proposed Algorithm:

In this research, IA-RSSI algorithm is presented to estimate accurately ICPM based on the loss difference of

RSSI. It mainly involves the following steps:

(a) Fix receiving antennas around the known room and collect the practical RSSI ($\mathrm{RSSI_c}$).

(b) Calculate the simulated RSSI ($\mathrm{RSSI_s}$) at all detectors based on the assumed field. Under an indoor environment without changing ε, the wave always propagates along a straight line. We assume the signals transmit in a vacuum space firstly and calculate the propagating paths. According to (2) before, the initiative $\mathrm{RSSI_s}$ can be speculated as

$$\mathrm{RSSI_s} = \frac{1}{f(L)} E_{r0} \quad (3)$$

Here, L denotes the length of each path between emitters and receivers.

(c) Calculate the loss difference between the above $\mathrm{RSSI_c}$ and $\mathrm{RSSI_s}$, then divide it equally into the propagating path. The correction factors as

$$\Delta\,\mathrm{RSSI}_i = \frac{1}{L}(\mathrm{RSSI_c} - \mathrm{RSSI_s}) \quad (4)$$

Where $\Delta\,\mathrm{RSSI}_i$ represents the loss difference of RSSI in the i th sensor.

(d) The loss difference of RSSI has the following relationship with the conductivity difference value $\Delta\sigma$ between this grid point and prior grid pointas

$$\Delta\,\mathrm{RSSI}_i = L\int_0^{d_x} e^{-\omega\sqrt{\frac{1}{2}\left(\sqrt{1+(\frac{\Delta\sigma_i}{\omega})^2}-1\right)}r} dr \quad (5)$$

Here ω denotes the angular frequency of electromagnetic wave from transmitting antenna and dx is the size of one grid.

(e) Judge whether described in step (c) is smaller than a threshold or not. If it is, then enter into step (f). If not, return to the step (b) to repeat latter processes using other active sources at different points, new $\mathrm{RSSI_s}$ could be updated through the latest conductivity distribution.

(f) Acquire the last indoor inhomogeneous conductivity distribution as

$$\sigma_i^k(x,y) = \sigma_i^{k-1}(x,y) + \Delta\sigma_i(x,y) \quad (6)$$

Here, σ_i^k is the conductivity of pixel (x, y) in the k th iteration at i th path.

3. Simulation Model setting:

In the simulation, the assumed ICMP is shown in Fig.2. Table 1 lists the detailed parameter setting about indoor environment. From the picture it can be seen that the coordinates of four active sources are, separately, (300, 300) (145, 200) (300, 450) and (445, 200) in a 600*600 room, which could launch persistently pulse signals with the frequency of 6GHz by turns. Furthermore, there are 280 receiving antennas to constitute a big round whose radius is 250cm in the picture and the channel characteristic except the three barriers is hypothesized as vacuum environment in this room.

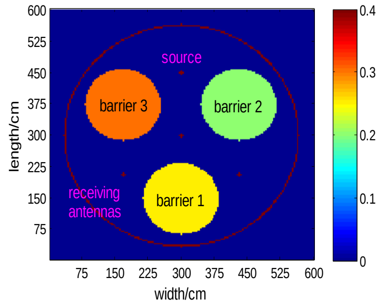

Fig. 1*Assumed indoor channel model*

Table 1: Parameter setting of indoor environment

name	Centre coordinate	Radius(cm)	conductivity	Relative permittivity
Barrier 1	(300, 150)	75	0.25	1.0
Barrier 2	(445, 375)	75	0.2	1.0
Barrier 3	(145, 375)	75	0.3	1.0

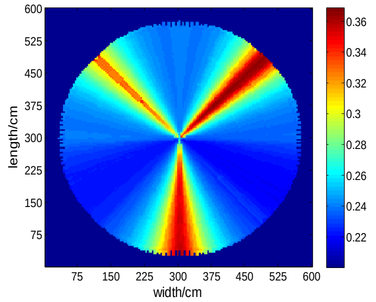

Fig. 2*The distribution of conductivity obtained by the centre source (300, 300)*

4. Simulation Results:

The simulation results about accurate estimation of indoor channel characteristics based on IA-RSSI algorithm are shown in following pictures. Fig. 3 reveals a rough distribution of conductivity obtained by the centre source (300, 300), three obvious bright fan-shaped areas indicate this room exists foreign matters and their probable positons, but just one source can't get the perfect shape or size about barriers. So in Fig. 4, through the iteration of four active sources in turn, the last distribution of conductivity in this complex room condition could be obtained which can be seen that there are three obvious rounds proximate to Fig. 1 not only in shape but also on their position. So this new algorithm can rebuild an accurate ICMP which is close to the actual environment ideally through the continuous updating of multiple sources.

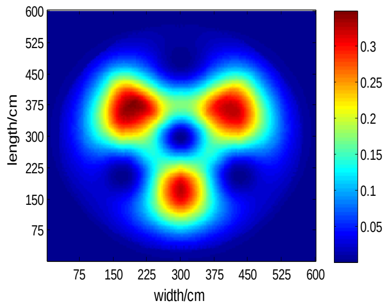

Fig. 3 *The perfect Evaluation of indoor channel model after 4 iterations*
Three bright rounds mean three barriers

5. Conclusion:

A creative algorithm is proposed in this letter for the precise recovery of ICPM which could help positioning methods to more accurately locate small mobile communication terminals under indoor complex and inhomogeneous environment. The above simulations demonstrated the presented IA-RSSI algorithm could reconstruct perfectly the interior model distribution as the actual room. Here, estimated results is proportional to the number of receiving antennas, more antennas have better results but higher cost, so a balance point must be found between cost and accuracy according to demand. Furthermore, actual fading is extremely complex due to the probable factors like reflections, diffractions or scattering and it is impossible to confirm which factor cause this fading or calculate specific decrease. So this paper achieved evaluating target based on the simplified transmission attenuation caused by conductivity when signals pass through unknown barriers and the FDTD (finite-different time-domain)has been used to reduce the impact from other element. Compared with traditional technology of channels recovery, the presented algorithm has same superior performance but better practicability for establish of real system. It will be a very useful technology to greatly improve the precision of wireless indoor position system in the future.

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