WACNet(11b アドホック)におけるルートダイバーシティの実験

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あらまし　無線アドホックネットワークは、端末自身がルータの機能を有し、端末間の通信を基地局等のインフラストラクチャを用いることなく、端末間で直接通信が出来ることが特徴である。また、所謂、電波が届かないために、直接、通信が出来ない端末間の場合には、他の端末を中継局として、目的端末まで、マルチホップ通信を行うことにより、端末単体の伝送範囲以上の通信エリアを確保している。無線LAN(IE³802.11b)をベースとした無線アドホックネットワーク(WACNet: wireless Ad hoc Community Network)を ITS の車車間通信に応用するに当たり、従来、路面反射によるマルチパスの影響により、受信電力が低下した時に、PER(Packet Err Rate)等の通信特性が劣化するため、高さの異なるアンテナ×２個を用意して、受信電力の良い方を選択するｽﾍﾟｰｽﾀﾞｲﾊﾞｰｼﾃｨの方法が用いられているが、受信電力が低下した時、比較的、受信電力が良好な中継端末を見つけて、マルチホップ通信を行うことにより、従来とおりの装置１台に対してアンテナ×１個で目的端末へデータ通信を可能とするﾙｰﾄﾀﾞｲﾊﾞｰｼﾃｨの実験結果について報告する。

キーワード 無線アドホックネットワーク，指向性ビームＭＡＣ，ルートダイバーシティ，スペースダイバーシティ，マルチパス

Experiment result of route diversity in WACNet (Wireless Ad hoc Community Network, 11b Ad hoc)

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Abstract Wireless ad hoc networks offer the advantage of direct communication without the need for infrastructures such as base stations. Instead, each node is equipped with a router function which makes multihop communication, even if microwaves cannot reach the destination. In the application of ITS inter-vehicle communications, the influence of multipaths should be considered for due to the effect of reflection from the road surfaces. According to the traditional processing, which avoids the influence of multipaths, space diversity technique is often applied with two or more antennas of different height. By using ad hoc network technology to avoid the influence of multipaths, it is possible to apply the route diversity technique with the multihop communications. This paper describes fundamental measurement data of reflection characteristics on asphalt surfaces in the 2.4-GHz band and the experimental results of space diversity and route diversity on the road when using WACNet (Wireless Ad hoc Community Networks), which is based on the ESPAR antenna and 802.11b ad hoc system.

Key words Wireless ad hoc network, Directional beam MAC, Route diversity, Space diversity, multipath

1. Introduction

Wireless ad hoc networks offer the advantage of direct communication without the need for infrastructures such as base stations. Instead, each node is equipped with a router function which makes multihop communication, even if microwaves cannot reach the destination. It is important to determine the best relay nodes for routing in wireless ad hoc networks. However, GPS (Global Positioning System) information is not always useful, because microwaves are often shielded by buildings, bridges and other something materials. Therefore, each node itself should find the best relay nodes via periodic collected information on both neighbor nodes locations and microwave propagation conditions. Figure.1-1 shows the outline of the developed test system consists of ESPAR (Electronically Steerable Parastic Array Radiator) antenna [1], as a smart antenna, wireless module based on 802.11b ad hoc and notebook PC embedded routing protocol.

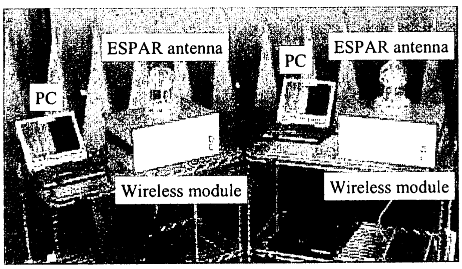

Figure 1-1 Outline of the test system

The protocol for searching the best relay nodes is that a setup signal is broadcast with an omni (non-directional) beam, and a search phase is transmitted, while a source node A senses carriers on the CSMA/CA. When the setup signal is received at a neighbor node (B, C, D), an RQ signal with a directional beam stirred at a set angle unit from source node A is received and the signal intensity is measured. A neighbor node (B, C, D) also follows in sensing the carriers and replies with RE signals carrying the measurement result (Figure.1-2). RE signals are received in order as a data packet, for which the communication procedure consists of the four-way handshake: RTS/CTS/DATA/ACK based on 802.11 MAC (Figure.1-3). In the meantime, the source node A creates the AST (Angle-SINR-Table) information on the related nodes after receiving the reply. Such repetition brings the AST information to all nodes (Table.1-1). [2]–[5] Based on this information, a relay node is searched for that offers the most suitable route for multihop communication.

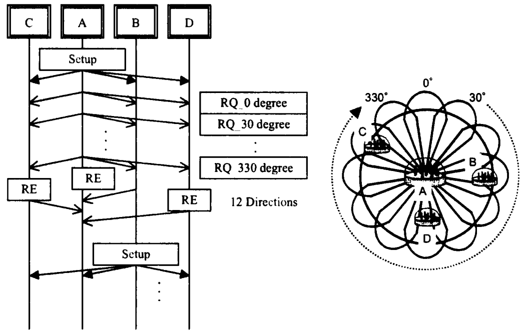

Figure.1-2: AST creation protocol

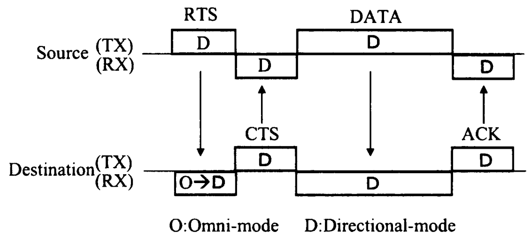

Figure.1-3: Data communication procedure

Table.1-1: AST information (Node-B)

Abgle(°)	Received Signal Level (RSSI)		
	Node A	Node C	Node D
0°	-18.5	-15.3	-21.6
......	......	......	......
240°	7.6	-0.8	7.6
270°	9.4	4.9	5.2
300°	8.7	6.4	2.1
330°	4.3	1.3	-6.8

At the data communication phase, a directional beam can suffer less interference on the same frequency channel than an omni beam, which contributes to better performance of total throughput than an omni beam on a network of same size (Figure.1-4). [6][7]

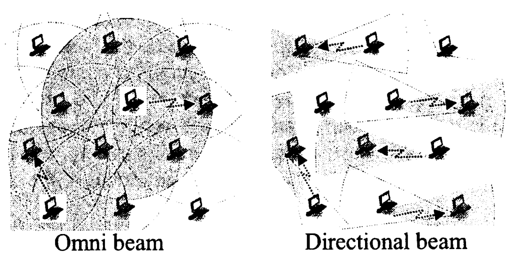

Figure.1-4: Difference of total throughput

2. Reflection characteristics of asphalt

Details data of the asphalt sample are as follows: 500 mm long (rectangular shape), 50 mm thick, 2.38 g/cm^2 density, used as a piece of road for about one month (Figure.2-1). The cutback method [8], which is used in the measurement of transmission characteristics (such as attenuation and the transmission bandwidth) of optical fibers, is applied with a modification for free-space instead of a coaxial line, to measure the dielectric properties; these are complex relative dielectric (εr=εr'-jεr") in the microwave band (Figure.2-2). The measurement principle for this method is that group delay is related to √εr', while attenuation is related to εr"/√εr'. With this measurement, the complex relative dielectric (εr) is to be εr'=5.70, εr"=0.56 at 2.484 GHz (IEEE802.11b_ch14) (Figure.2-3).

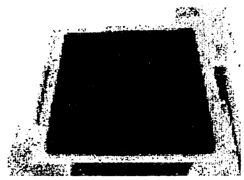

Figure2-1: outline of asphalt

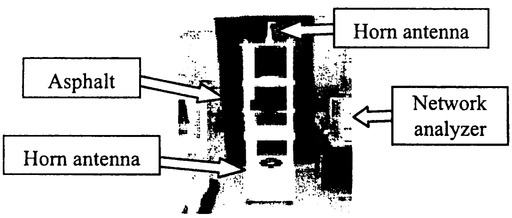

Figure.2-2: εr measurement scene

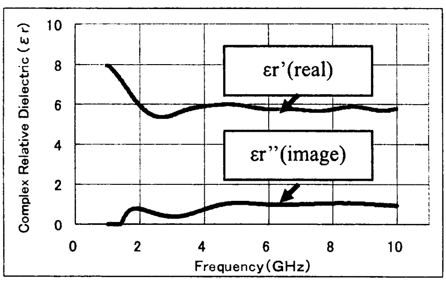

Figure. 2-3: characteristics of complex relative dielectric (εr=εr'-jεr")

Furthermore the complex refraction rate (n) is calculated to be n=2.39-j0.117 by formula (1),

$$n=\sqrt{(\mu_2/\mu_1)}*\sqrt{\{(\varepsilon r_2'-j\varepsilon r_2'')/(\varepsilon r_1'-j\varepsilon r_1'')\}} \quad ....(1)$$

The reflection characteristics are calculated for the case of vertical polarization (Γv) by formula (2), while the case of perpendicular polarization (ΓH) is calculated by formula (3),

$$\Gamma V=\{n^2\cos\theta i-\sqrt{(n^2-\sin^2\theta i)}\}/\{n^2\cos\theta i+\sqrt{(n^2-\sin^2\theta i)}\} \quad ....(2)$$

$$\Gamma H=\{\cos\theta i-\sqrt{(n^2-\sin^2\theta i)}\}/\{\cos\theta i+\sqrt{(n^2-\sin^2\theta i)}\} \quad ....(3)$$

Where μ is the permeability and ε 0=8.8542E-12[F/m] and θi is the incident angle (Figure.2-4).

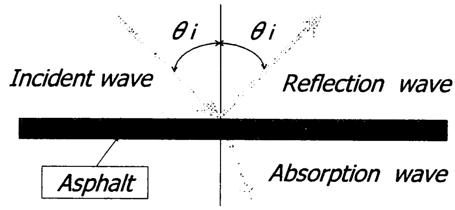

Figure.2-4: reflection image

In act, reflection characteristics are actually measured with a network analyzer (Figure.2-5), and it is clear from Figure.2-6 that both the experimental and calculated values of the reflection correspond closely. [9]

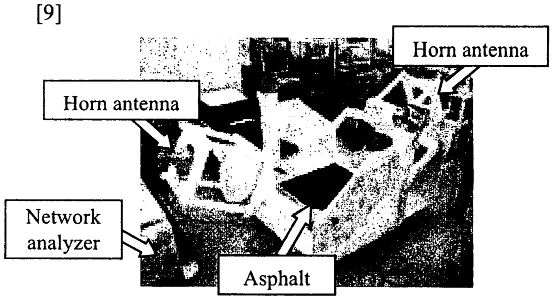

Figure.2-5: Γv &ΓH measurement scene

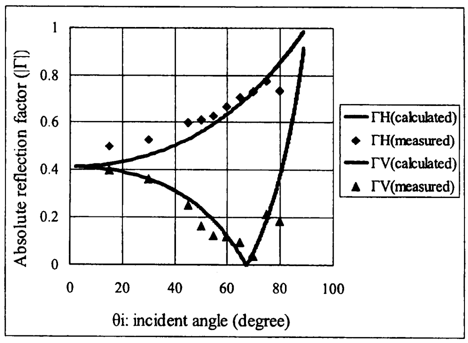

Figure.2-6: calculated and measured (Γv &ΓH)

3. Space diversity experiment

We measured the characteristics of both propagation and communication between the two WACNets. The instantaneous propagation characteristics could be estimated with a two-way propagation model (Figure. 3-1), (Figure.3-2), and they agree well with the measured results for each case of antenna of different height (Figure.3-3), (Figure.3-4). Multipaths have the effect of degrading the received signal level at a phase difference to one half of wavelength between a direct wave and a reflection wave, which contradicts each other. The received signal level in the two-way propagation model between a direct wave and a reflection wave from the road is expressed as formula (4), [10]

$$Pr=PtGtGr[Dd(\lambda/4\pi r_d)+Dr(\lambda/4\pi r_r)\Gamma\, e^{-j\{k(rr-rd)+\Phi\}}]^2 \quad ...(4)$$

Where Pr is the received signal level, Pt is the transmitter power, Gt and Gr are the Tx and Rx boresight antenna gains, Dd and Dr are the direct wave and reflection wave directivities with respect to the Tx and Rx antennas, r_d and r_r are the optical path lengths of the direct wave and reflection wave from the road, k is $2\pi/\lambda$, and Φ is the phase delay of reflection factor on the asphalt road.

The r_r is expressed as formula (5),

$$r_r=\sqrt{(r_d{}^2+(h_t+h_r)^2)} \quad ....(5)$$

Where h_t and h_r are height of the transmitter and the receiver

The PER (Packet Err Rate), which is one of the communication characteristics, increases at lower received signal levels. The instantaneous PER will increase at a specific range due to the multipath relation to the antenna height. The space diversity technique selects which received signal is strongest among the antennas, thus reducing the PER due to the continuous acquisition of stronger signals (Figure.3-5).

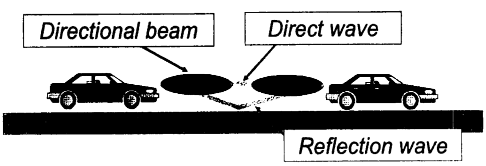

Figure 3-1: two-way propagation model

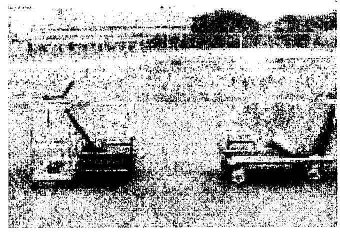

Figure 3-2: measurement scene

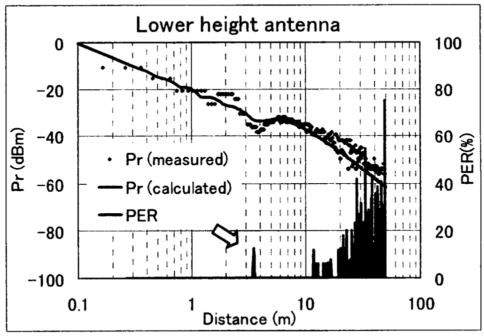

Figure 3-3: Pr vs PER at antenna height (450mm)

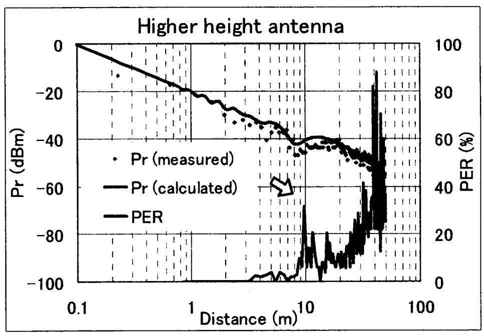

Figure 3-4: Pr vs PER at antenna height (688mm)

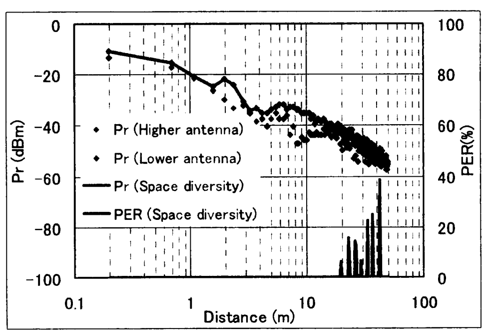

Figure 3-5: Pr vs PER with Space diversity

4. Route diversity

We measured the characteristics of propagation, communication and routing dynamics among the three WACNets (Figure.4-1), (Figure.4-2). Results show that when the received signal level decreases or PER increases between node A and node C due to multipath occurrence or the behavior of moving far away, node A and node C communicate with node B under better propagation conditions using multihop communication owing to the periodic collected information of neighbor nodes locations and propagation conditions (Figure.4-3). First, in the routing table of node A, the metric numbers for node B and C are equals to one. In the multihop communication phase, the metric number for node B equals one, but for node C it changes to two, and next hop is shown to be node B, which means that B is rely node (Fig. 4-4). [11]

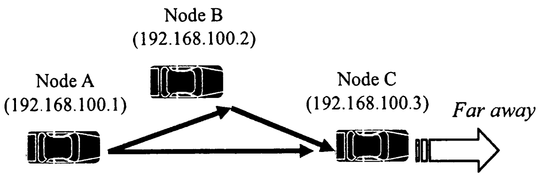

Figure.4-1: experiment image for route diversity

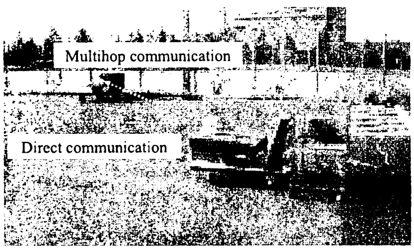

Figure.4-2: measurement scene

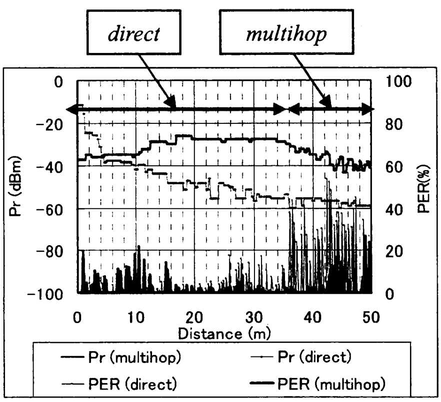

Figure.5-2: Pr vs PER with Route diversity

Direct

[## Route Table ##]

Destination	NextHop	Metric
192.168.100.2	192.168.100.2	1
192.168.100.3	192.168.100.3	1

Multihop

[## Route Table ##]

Destination	NextHop	Metric
192.168.100.2	192.168.100.2	1
192.168.100.3	192.168.100.2	2

Figure 4-4: Routing table (node A)

We measured and collected the data of received signal level, PER and routing table among the three WACNets continuously. We embedded FSR (Fish eye State Routing) of the routing protocol to the WACNet test bed of which trigger up date time for refreshing the routing table is set to be 5sec.

5. Conclusion

We measured fundamental data of reflection characteristics on asphalt surfaces in the 2.4-GHz band, and multipath characteristics of the relation between received signal level and PER in several situations. We confirmed the performance of space diversity which is the current technique to avoid the influence of multipath, and validity of route diversity which is the advantages of ad hoc network technology. In our future work, We plan to measure the communication characteristics; throughput, delay time and convergence time for routing table, et al in the several situations in order to evaluate the effects of dynamic changing networks which major parameters are node numbers, relative velocity and density of the networks.

6. Acknowlegement

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