

## RESEARCH OUTPUTS / RÉSULTATS DE RECHERCHE

### **A Consideration on the Spatial Diversity Effect on Multi-Hop Ad Hoc Networks under Rayleigh Fading Environments**

François, Nicolas; Kamiya, Yukihiro; Schumacher, Laurent

*Published in:*  
Proceedings of 2006 General Conference of IEICE

*Publication date:*  
2006

*Document Version*  
Early version, also known as pre-print

[Link to publication](#)

*Citation for published version (HARVARD):*  
François, N, Kamiya, Y & Schumacher, L 2006, A Consideration on the Spatial Diversity Effect on Multi-Hop Ad Hoc Networks under Rayleigh Fading Environments. in *Proceedings of 2006 General Conference of IEICE*.

#### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

#### **Take down policy**

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# レイリーフェージング環境下のマルチホップ無線アドホックネットワークにおける空間ダイバーシティ効果に関する一検討

A consideration on the spatial diversity effect on multi-hop ad hoc networks under Rayleigh fading environments

ニコラ フランソワ<sup>1</sup>

Nicolas François

ナミュール大学<sup>1</sup>

University of Namur, Belgium

神谷 幸宏<sup>2</sup>

Yukihiro Kamiya

東京農工大学大学院共生科学技術研究部<sup>2</sup>

Tokyo University of Agriculture and Technology

ローレン シューマッハ<sup>1</sup>

Laurent Schumacher

## 1 Introduction

Although applications of diversity antennas to wireless ad hoc networks have been paid attention, the performance of multi-hop networks under Rayleigh fading has not been very well examined. In this short paper, the performance improvement brought by the diversity antenna will be clarified through computer simulations.

## 2 Formulations

The received signal consisting of  $M$  element waves received by  $N$  antennas are expressed as a vector of size  $(N \times 1)$  as follows:

$$\mathbf{x}(t) = \sum_{m=1}^M \frac{\sqrt{P_S}}{M} \mathbf{a}(\theta_m) s(t) e^{j\phi_m} + \sqrt{\frac{P_N}{2}} \boldsymbol{\eta}(t) \quad (1)$$

where  $\mathbf{a}(\theta_m) \in \mathcal{C}^{N \times 1}$  is the steering vector as a function of the direction of arrival (DOA)  $\theta_m$  while  $\phi_m$  is the initial phase. The subscript  $\cdot_m$  denotes the  $m$ -th element wave. The noise vector with the unit power is denoted by  $\boldsymbol{\eta}(t) \in \mathcal{C}^{N \times 1}$ . Then, the signal-to-noise power ratio (SNR) of the received signal  $\Gamma_{in}$  is defined as  $P_S/P_N$ .

Then, the correlation matrix  $\mathbf{R}_{xx} \in \mathcal{C}^{N \times N} = \mathcal{E}[\mathbf{x}\mathbf{x}^H]$  is decomposed by the eigenvalue decomposition (EVD) to obtain the weight vector  $\mathbf{w} \in \mathcal{C}^{N \times 1}$  by the eigenvector corresponding to the maximum eigenvalue. Here,  $\mathcal{E}[\cdot]$  denotes the ensemble average. Note that  $\|\mathbf{w}\| = 1$ . Then, the antenna output is obtained by  $y(t) = \mathbf{w}^H \mathbf{x}(t)$  with the antenna output SNR  $\Gamma_{out}$  as:

$$\Gamma_{out} = \frac{|\sum_{m=1}^M \frac{\sqrt{P_S}}{M} \mathbf{w}^H \mathbf{a}(\theta_m)|^2}{P_N} \quad (2)$$

## 3 Computer simulations

Table 1 lists simulation conditions. We assume an on-demand type wireless ad hoc network with AODV [1] for the route finding. Also, it is assumed that the media access control employs CSMA/CA. All nodes are under Rayleigh fading consisting of 10 element waves. Then, we compare the performance in terms of the number of the necessary hops till the arrival of Route Request (RREQ) packets to the destination

with and without the antenna diversity. In this simulation, it is considered that the channel is unavailable if  $\Gamma_{out} < 8.5[\text{dB}]$ . Figure 1 shows the success rate of RREQ versus the number of nodes. It is seen that the antenna diversity contributes to the improvement of the RREQ success rate due to the compensation of fading. Figure 2 shows Cumulative probability Distribution Function (CDF) for the number of hop only when RREQs are successful. It is clearly found that the antenna diversity reduces the number of hops also drastically.

表 1 Simulation conditions

Antenna	6-element circular
Path loss	Free space (square-law)
Receiving SNR $\Gamma_{in}$	10[ $\text{dB}$ ] @ 10m
Num. of element waves $M$	10
DOA $\theta_m$	Uniformly random within $[0, 360][\text{deg}]$
Phase $\phi_m$	Uniformly random within $[0, 2\pi][\text{rad}]$

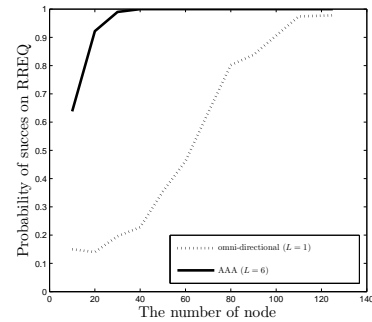


図 1 The number of nodes versus RREQ success rate

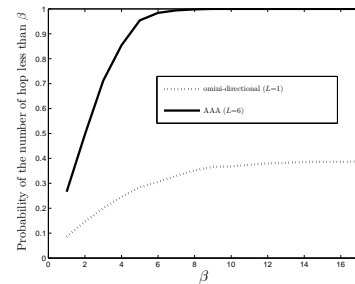


図 2 CDF of the number of hop

#### 4 Concluding remarks

In this short paper, we clarify the effect of the antenna diversity under Rayleigh fading to the performance of the wireless ad hoc networks with AODV in terms of the number of hops. More realistic scenario will be reflected in the simulations as a further consideration.

#### 参考文献

- [1] C-K.Toh, "Ad Hoc Mobile Wireless Networks: Protocols and Systems," Prentice Hall, 2001.