On Performance Analysis of Position Based Routing Algorithms in Wireless Networks

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ABSTRACT

This paper presents an overview of position-based routing algorithms. We analyze performances of routing algorithms such as Hybrid Opportunistic Forwarding (HOF), Opportunistic multi-hop routing (ExOR), Location based Geocasting and Forwarding (LGF), and Greedy Forwarding in nearest with forward Progress (GFP) routing algorithms to find the best one in terms of packet error rate and throughput efficiency over effects of fading and noise variance in wireless networks. The analyses in closed form expressions are confirmed by the simulation results, which fully agree to analysis results. Additionally, the simulation results indicate significant differences among algorithms when varying the average SNR or the number of relays.

Key Words : Cooperative Communications, ARQ Protocol, Position-based Routing Algorithms, ExOR, HOF, LGF Algorithm

Ⅰ. Introduction

In wireless networks, finding the best way to transmit signals from a source to a destination is considered as one of the most important issues. Thus, many routing algorithms were proposed and analysed to find the optimal one[1-8]. In routing algorithms, the position-based routing algorithms achieve advantages compared to other algorithms [1,5,7] where the nodes in the network require the information about the physical position of participating nodes that are available. For example, in [5] the GOAFR geographic routing algorithm was presented, in which it combines from the greedy forwarding and face routing approaches. Based on simulation results, the authors proved that the GOAFR algorithm is an efficient and simple algorithm. In [8], the ExOR algorithm was proposed where the closest relay node is allowed to retransmit signals to the destination. It is also confirmed as an effective algorithm by performing simulation results, which achieve better performance than the traditional algorithms. In [9], Geographic Random Forwarding (GeRaF) algorithm was given in which the closest relays attempt to retransmit signals to the destination. The main difference between the GeRaF algorithm and the ExOR algorithm is that the GeRaF algorithm does not consider the case when the destination still incorrectly receives the signal from the chosen relay while the ExOR algorithm does. An alternative algorithm requiring the closest relay to retransmit the signal to the destination is HOF algorithm[4]. In the HOF algorithm, after the transmitter incorrectly sends the signal to the receiver, it picks a node, to which the last data signal was sent as the most preferred node to retransmit the signal. In [4], the authors gave the comparison results on byte error rate, throughput, and delay among four routing algorithms such as GeRaF, OSPF, HOF- Pre, and HOF-Post algorithms. Among them, both HOF algorithms can work well in wide range of channel conditionals as well as achieve better performances than the

※ 이 논문은 2007년도 정부(과학기술부)의 재원으로 한국과학재단의 지원을 받아 수행된 연구임 (No. R01-2007-000-20400-0).
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논문번호 : KICS2010-02-067, 접수일자 : 2010년 2월 9일, 최종논문접수일자 : 2010년 5월 28일

GeRaF algorithm. Similarly, in [3], an algorithm called Location based Geocasting and Forwarding (LGF) algorithm was analysed where the closest relay is chosen to repeat the erroneous signal at the destination. The major dissimilarity among the LGF algorithm with other algorithms such as the ExOR, GeRaF, and GOAFR is that the source does not care about the correctness of the received signal at the closest relay node. On the contrary to mentioned algorithms, in [7], the authors gave an algorithm (Greedy forwarding in nearest with forward progress (GFP)) where the closest relay to the source is firstly considered to retransmit the erroneous signal to the destination.

However, in all proposed algorithms as [4,7,8], there are some problems needed to be solved. First, all comparison results among algorithms are obtained by only simulation results not closed form expressions. Second, the performance is compared in terms of number of transmissions required to route, a packet versus the node pair or the packet delivery rate versus used distance[8], mean algorithm cost versus network density[5], or delay versus bit error rate or throughput versus speed of fading[4]. However, some parameters such as packet error rate, throughput efficiency versus variance of power are not considered. In [9], the upper bound and lower bound of average number of hops to reach a destination were analysed. However, like the mentioned problems, they are not impressive. Third, the authors did not give a total comparison of position-based algorithms to find which algorithm is the best one in a specific parameter.

In this paper, algorithms are compared with each other in terms of packet error rate (PER) and throughput efficiency that are effective parameters to verify advantages of algorithms as well as to decide the best algorithm in wireless networks.

The goals of the paper consist of some attributions. First, we provide comparison results in terms of the PER and throughput efficiency among algorithms. Second, we drive the closed form expressions for PER, throughput efficiency of all algorithms. Third, an overview of position-based algorithm is presented.

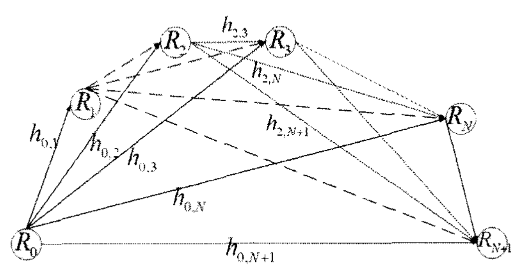
The remainder of the paper is performed as follows. Section II presents the system model, the different operations of algorithms, and the data link layer at the network layer. Closed form expressions for PER, throughput efficiency are derived in Section III. The numerical results and discussion are shown in Section IV to confirm the correctness of analyses. Section V concludes the paper

Ⅱ. System Model

2.1 System Model

Consider a network including a source R_0, a destination R_{N+1}, and N relays in communication range of the source and the destination as shown in Fig. 1. The relays are numbered according to their distance to the destination in which the R1 is the furthest and RN is shortest. As [5,7,9], we assume that each node can know its own position as well as that of the destination.

On the performance of all algorithms, the system follows the finite retransmission probability. It means that the number of retransmissions for a packet is limited in a predetermined value that is presented *m* $(0 < m < \infty)$. The retransmissions terminate when the destination correctly receives the signal or the number of used retransmissions exceeds the number of allowable retransmissions *m*. We also suppose that the destination may count this parameter. Therefore, after m times



R_0 : *Source*. R_{N+1} : *Destination*, R_i – *ith relay with* $i = 1,...,N$
$h_{i,j}$ *for* $i, j = 1,...,N$ *denotes the complex channel coefficients*

Fig. 1. The multi-hop relay network

receiving the erroneous packet, it sends an inform message to the source and all relay nodes to flush the packet out of memory and transmit a new one.

On the operation of all algorithms, firstly the source transmits a packet to the destination and all relays. After that, if the destination successfully receives the packet, it sends an Acknowledge (ACK) message to inform the source to send new one. Otherwise, it broadcasts a Negative-acknowledge (NAK) message to invoke a retransmission. In the retransmission phase, choosing the best relay differs from each algorithm. The detail performance of each algorithm and the method to access the common channel are shown clearly as follows.

2.1.1 The ExOR algorithm

As [8], after the destination incorrectly receives the packet from the source, a relay that satisfies two conditions is assigned to transmit the packet. Two conditions of the relay include: its received signal is fully decoded and other nodes having the shorter distance to the destination than it has may not correctly receive the packet. To avoid collisions, authors in [8] used transmitting the signalling among nodes. However, it may cause bandwidth inefficiency. In here, we propose a method to allow nodes access to the channel as following. Each node established a delay time based on the distance from it to the destination. After a node receives the NAK message from the destination, it starts a delay time determined. The first responding node is selected as a relay. For example, the node R_i $(0 < i < N+1)$ uses a delay time as $T_i = \lambda d_{i,N+1}$ where λ is a unit of time and $d_{i,N+1}$ is the distance from the node R_i to the destination node. After receiving the NAK message from the destination, the relay R_i starts its own timer. After the delay time, if the relay R_i does not receive any ACK messages from other nodes, it sends the ACK message to inform other nodes and retransmits the signal to the destination. Otherwise, whenever it receives an ACK message on the delay time, it flushes its memory and keeps silent. In the case the destination still incorrectly receives the packet from the chosen relay R_i, only relays from the relay node R_i to the relay R_N are considered. If any relay node R_j $(i < j < N+1)$ correctly receives the signal from the node R_i after the delay time, the node R_j sends an ACK message to inform other nodes and retransmit the signal. Otherwise, it keeps silent and the relay R_i repeats the erroneous packet.

2.1.2 The HOF algorithm

In this algorithm, the operation is proposed as [4]. Different from ExOR algorithm, the HOF algorithm uses a MPN (most preferred node) field to choose a node to retransmit the signal to the destination. The performance of the HOF algorithm will be similar with the ExOR algorithm if the transmitter does not have any information about the MNP node. The MPN is defined as the node is lastly sending the packet. If the transmitter has information about the MPN, this node is assigned in the first time slot to retransmit the erroneous signal. The other nodes still calculate their time slot by weighted shift distribution plus one time slot.

2.1.3 The GPF algorithm

The performance of this algorithm is analysed in [7] where a chosen node is located closer to the destination that the broadcaster in the previous time slot. For example, as the network in Fig.1, after the destination incorrectly receives the packet from the source, the source firstly waits for a message from the relay R_1 to know the status of the signal that is received by R_1. If the received signal at the relay R_1 is fully decoded, the relay R_1 will retransmit the signal to the destination. After that, if the R_1 incorrectly transmits the packet to the destination, the node R_2 is firstly considered. On the contrary, if the relay R_1 can not correctly receive the packet, the source repeats the packet. The above sequence is continued until the retransmission finishes.

2.1.4 The LGF algorithm

In this algorithm, the source just cares about the distance from the nodes to the destination, it does not consider about the correctness of the received signal at the closest node. The source decides a chosen node based on the shortest distance from a node to the destination[3]. Thus, the closest relay R_N always retransmits the packet whenever the destination incorrectly receives from the source.

2.2.Data Link Layer Model

We assume that the packet are formed and processed as [10]. Each packet includes the serial number; pay load and cyclic redundancy check (CRC) bits. By using CRC, the destination can judge whenever it receives an erroneous packet with assumption that the serial number and CRC bits are error free.

The received packet from a transmitter R_i to a receiver R_j is given by

$$y_{i,j}=h_{i,j}\sqrt{P_x}\,x+n_{i,j}\quad i,j=R_0,R_1,...,R_{N+1}\ (i\neq j) \tag{1}$$

where $y_{i,j}$ is the received packet at node R_i. x is sent packet which is an uncoded modulation with a predetermined packet size. $n_{i,j}$ is the noise at node R_j and modelled as mutually independent complex Gausisan r.v's with zero mean and unit variance N_1. $h_{i,j}$ captures the effect of the fading from the node R_i to the node R_j and are assumed to be i.i.d zero mean complex Gaussian r.v's with variance $V_{i,j}$. The $V_{i,j}$ expresses the signal energy decay which are modelled as $V_{i,j}=(d_0/d_{i,j})^{\mu}$ where d_0 is reference distance, $d_{i,j}$is the distance between two nodes $R_i$and R_j, and μ is the path loss coefficient with the values typically in the range $1\leq\mu\leq 4$. P_x is the transmitted power. $P_x=P_S$ if the transmitter is the source, otherwise, $P_x=P_R$

We suppose channels in the system be fading channels so the instantaneous SNR for channel between $R_i$and R_j, is

$$\gamma_{i,j}=\frac{|h_{i,j}^2|P_S}{N_1} \tag{2}$$

For Rayleigh fading channel, the instantaneous received SNRhas an exponential distribution with a probability distribution function (pdf):

$$f_{\gamma_{i,j}}=\frac{1}{\sigma_{i,j}}exp\left(-\frac{\gamma}{\sigma_{i,j}}\right) \tag{3}$$

where $\sigma_{i,j}$ is the average SNR.

We can calculate the approximation physical packet error rate if FEC is not used as

$$PER(\gamma)=\begin{cases}1 & \text{if } 0<\gamma<\gamma_t\\ aexp(-g\gamma) & \text{if } \gamma\geq\gamma_t\end{cases} \tag{4}$$

where (a,g,γ_t) are found by least squares fitting method. The switching threshold γ_t is set such that

$$aexp(-g\gamma_t)=1 \tag{5}$$

The average packet error rate of the packet over the slow fading channel from the transmitter node R_i to the receiver R_j with *(a+b)* transmissions where there are *a* incorrect retransmissions and *b* correct transmissions is calculated as

$$\begin{aligned}P_{i,j}^{a,b}&=\int_0^{\infty}PER^a(\gamma)\,[1-PER(\gamma)]^b f_{\gamma_{i,j}}(\gamma)d\gamma\\&=\sum_{l=0}^{b}(-1)^l C_b^l\int_0^{\infty}PER^{a+l}(\gamma)f_{\gamma_{i,j}}(\gamma)d\gamma\\&=\sum_{l=0}^{b}(-1)^l C_b^l\left[1-\frac{(a+l)\sigma_{i,j}g}{1+(a+l)\sigma_{i,j}g}exp\left(-\frac{\gamma_t}{\sigma_{i,j}}\right)\right]\end{aligned} \tag{6}$$

Ⅲ. Performance Analysis

In this part, the expression of packet error rate and throughput efficiency for each routing algorithm are derived and explained clearly.

3.1 Packet Error Rate

3.1.1 The ExOR algorithm

Based on the performance of the ExOR algorithm, the packet error rate can be calculated as an exclusive equation with the beginning of the transmission following

$$P_{ErOR} = P_1\left(R_0^{m,0}\right) \quad (7)$$

Where

$$P_j^m = PER(\gamma_{j,N+1}) \times \left[\Pr_{Icorr}(j) P_j^{m-1} + \sum_{h=j+1}^{N} \Pr_{Cor}(h) P_h^m \right] \quad (8)$$

where

- P_j^m denotes the average PER of the transmission from node R_j to the destination with the maximum allowed number of retransmission *m*.
- $\Pr_{Cor}(h)$ is the probability of the event that the relay R_h is the successfully decoded and is the closest to the destination, given by:

$$\Pr_{Cor}(h) = \left[1 - PER(\gamma_{j,h})\right] \prod_{t=h+1}^{N} PER(\gamma_{j,t}) \quad (9)$$

- $\Pr_{Icorr}(j)$ is the probability of the event that no relay between the current transmitting relay R_j and the destination can decode correctly, given by

$$\Pr_{Icorr}(j) = \prod_{t=j+1}^{N} PER(\gamma_{j,t}) \quad (10)$$

After multiplying the equations (8), (9) and applying characteristics of the slow fading as (6), we integrate the equation following different channels. Finally, we can get equation in slow fading as

$$\begin{aligned} P_1\left(R_i^{t,0}\right) &= P_{i,N+1}^{t+1,0} \prod_{l=i+1}^{N} P_{i,N-l}^{t,0} \\ &+ \sum_{l=1}^{t} P_{i,N+1}^{l,0} \sum_{b=i+1}^{N} \prod_{e=i+1}^{N} P_{i,e}^{l-s(b),s(b)} P_1\left(R_e^{t-l,0}\right) \end{aligned} \quad (11)$$

where

$$P_{0,e}^{l-s(b),0} = \begin{cases} P_{0,e}^{l,0} & \text{if } e > b \\ P_{0,e}^{l-1,1} & \text{if } e = b \\ P_{0,e}^{l-1,0} & \text{if } e < b \end{cases} \quad (12)$$

$$P_1\left(R_N^{t,0}\right) = P_{N,N+1}^{t+1,0}$$

3.1.2 The HOF algorithm

As mentioned above, the average packet error rate of the HOF algorithm can be calculated by recursive expression as:

$$\begin{aligned} P_j^m &= PER(\gamma_{0,j}) \times P_{j-1}^m + \\ &\left[1 - PER(\gamma_{0,j})\right] PER^m(\gamma_{j,N+1}) \\ P_0^m &= PER(\gamma_{0,N+1}) P_N^{m-1} \end{aligned} \quad (13)$$

where P_j^m refers to the PER when the transmitter R_j transmits the packet to the destination with the allowable retransmissions *m*.

After multiplying the equation (13), applying characteristics of the slow fading as (6), finally, we can get equation in slow fading as

$$\begin{aligned} P_{HOF} &= P_{0,N+1}^{m+1,0} \prod_{h=1}^{N} P_{0,N-h}^{h,0} + \\ &\sum_{l=1}^{m} P_{0,N+1}^{l,0} \sum_{b=1}^{N} \prod_{e=1}^{N} P_{0,e}^{l-s(b),s(b)} R_e^{t-l+1,0} \end{aligned} \quad (14)$$

3.1.3 The GFP algorithm

As the performance is explained, the packet error rate of the algorithm is written by an exclusive equation as following

$$P_j^m = PER(\gamma_{j,N+1}) \left[\begin{aligned} &PER(\gamma_{j,j+1}) P_j^{m-1} + \\ &\left[1 - PER(\gamma_{j,j+1})\right] P_{j+1}^{m-1} \end{aligned} \right] \quad (15)$$

where P_j^m denotes the average PER of the transmission from the node R_j to the destination with the maximum allowed number of retransmission *m*.

After performing the integral as (6) following different channels, we may have the final equation.

3.1.4 The LGF algorithm

Without checking the correctness of the signal, on the operation of the LGF algorithm, the chosen relay has the closest distance to the destination.

For an indirect link from the source to the relay R_i to the destination, when the signal is transmitted through the relay without be checked by threshold SNR or amplified by an amplifier, the packet error rate is calculated as:

$$PER(\gamma_{0,i,N+1}) = PER(\gamma_{0,i}) + PER(\gamma_{i,N+1})\left[1 - PER(\gamma_{0,i})\right] \quad (16)$$

After performing the integral as (6), we can write the packet error rate of the indirect link as

$$P_{0,i,N+1} = P_{0,i}^{1,0} + \left(1 - P_{0,i}^{1,0}\right)P_{i,N+1}^{1,0} \quad (17)$$

where $P_{0,i,N+1}$ presents for the average PER of the indirect link from the source, relay R_i, and the destination.

In this algorithm, based on the performance of the system, we have

$$P_{LGF} = P_{0,N+1}^{1,0}\left[PER(\gamma_{0,N,N+1})\right]^m \quad (18)$$

where $\left[PER(\gamma_{0,N,N+1})\right]^m$ is the packet error rate when we performs m retransmissions from the closest relays R_N. After replaying the equation (17) into (18) and performing the integral as (6), we have the closed form expression of the average packet error rate of LGF protocol as

$$P_{LGF} = P_{0,N+1}^{1,0}\left[\sum_{t=0}^{m} P_{0,N}^{t,s(t)} P_{N,N+1}^{t,0}\right] \quad (19)$$
$$s(t) = \begin{cases} 0 \text{ if } t = m \\ 1 \ otherwise \end{cases}$$

3.2 Throughput Efficiency

Throughput efficiency is a metric, which is defined as the number of correct packets received at the destination over total number of consumed time slots. As the result, the throughput efficiency of routing algorithms is written as

$$Th_R = \frac{1 - P_R}{T_R} = \frac{1 - P_R}{1 + PER(\gamma_{0,N+1})\left(1 + Ti_0^m\right)} \quad (20)$$

Where P_R, T_R presents for the packet error rate and total time slots consumed of the system. For each algorithm as ExOR, HOF, GFP, and LGF algorithms, the equation of P_R in (18) follows (11), (12), (13), and (15), respectively. Similarly, Ti_k^m refers to the total time slots used to retransmit the packet in which the transmitter is the node R_k and available retransmissions equals $M (M \le m)$.

For ExOR algorithm, the total time slots that the system uses to transmit packets are calculated as:

$$Ti_k^M = \prod_{a=k+1}^{N} PER(\gamma_{k,a}) PER(\gamma_{k,N+1})\left(1 + Ti_k^{M-1}\right) + \sum_{b=k+1}^{N}\prod_{a=1}^{N-b}\left[\begin{matrix} PER(\gamma_{k,N-a})\left[1 - PER(\gamma_{k,b})\right] \\ PER(\gamma_{b,N+1})\left(1 + Ti_k^{M-1}\right)\end{matrix}\right] \quad (21)$$

For the HOF algorithm, the total time slots that the system uses to transmit packets are calculated as:

$$Ti_k^M = \begin{cases} \prod_{a=k+1}^{N}\left[\begin{matrix} PER(\gamma_{k,a}) PER(\gamma_{k,N+1}) \\ \left(1 + Ti_k^{M-1}\right)\end{matrix}\right] + \\ \sum_{b=k+1}^{N}\prod_{a=k+1}^{N}\left\{\begin{matrix} PER(\gamma_{k,N-a}) \\ \left[1 - PER(\gamma_{k,b})\right] \\ PER(\gamma_{b,N+1}) \\ \left(1 + Ti_k^{M-1}\right)\end{matrix}\right\} & \text{if } k = 0 \\ PER(\gamma_{k,N+1})\left(1 + Ti_k^{M-1}\right) & otherwise \end{cases} \quad (22)$$

Similarly, the total time slots in GPF algorithm are written as:

$$Ti_k^M = PER(\gamma_{k,k+1})\left(1 + Ti_k^{M-1}\right) + \left[1 - PER(\gamma_{k,k+1})\right]\left(1 + Ti_{k+1}^{M-1}\right) \quad (23)$$

In the same way, the total time slots in the LGF algorithm are:

$$Ti_N^M = PER(\gamma_{0,N,N+1})\, Ti_N^{M-1} \quad (24)$$

Where $PER(\gamma_{0,N,N+1})$ is calculated in equation (14).

Ⅳ. Simulation Results

In the simulation, we use BPSK modulation without FEC (Forward Error Code) to simulate performance of all algorithms. The length of a packet is set to be 1080 bits and the (α, g, γ_t) parameters in (4) are (67.7328, 0.9819, 6.3281dB) ([10], Table. 1).

In all simulations, the definition of the SNR in the following figures is the ratio of the transmitted power over the noise variance at the receiving node which is assumed to be 1 ($N_i=1$). Furthermore, variance of the channel links between the source and the relay also equals 1. The position of relays is put in a line from the source to the destination in which the distance from the source to the first relay equals distance from the first relay to second relay. It is applied for all distances. In addition, the distance from the source to the destination is sum of all distances. The reference distance d_0 in the channel gain equals 1, and the path lost equals 3.

In the simulation results, firstly, we simulate the detail of algorithms with different number of relays. From the figures Fig.1-Fig.5, we can easily observe that the simulation results match exactly with the theoretical results. It means that the closed form expressions that we have given in Section III are correct.

From Fig.2 and Fig.5, it is so easy to see that when

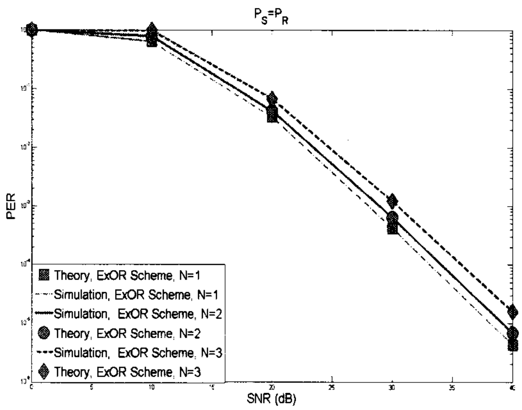


Fig. 2. PER performance vs average SNR of the ExOR algorithm with different number of relays and variance of the SNR at the source and the relays.

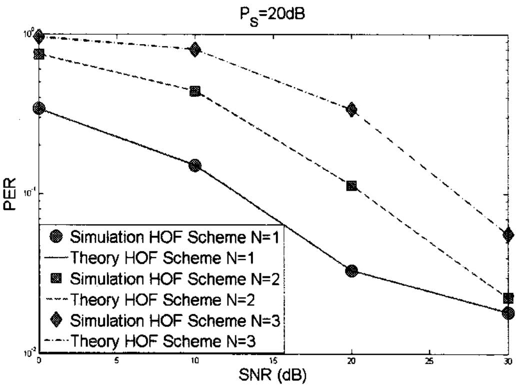


Fig. 3. PER performance vs average SNR of the HOF algorithm with different number of relays and the transmitted power at the source is fixed at 20dB.

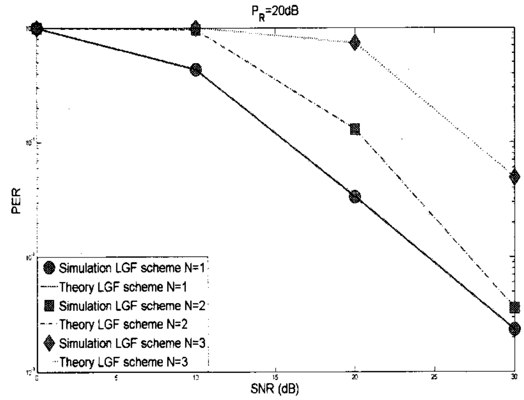


Fig. 4. PER performance vs average SNR of the LGF algorithm with different number of relays and the transmitted power at the relays is fixed at 20dB.

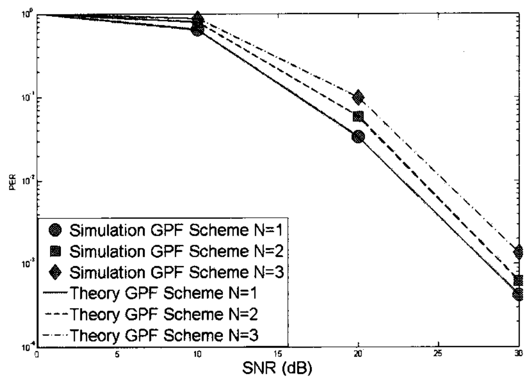


Fig. 5. PER performance vs average SNR of the GFP algorithm with different number of relays and the transmitted power at the source is varying from 0 to 30dB.

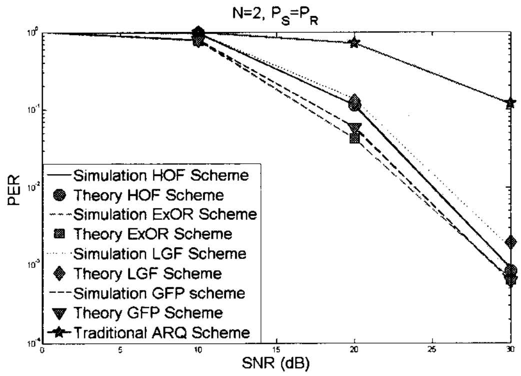


Fig. 6. PER comparison among algorithms when the transmitted power at the source is fixed at 20dB.

the number of relays increases, the performance of algorithms decreases. The reason can explain as the simulations are performed when nodes are located in a line network. Thus, as the number of relay increases, the distance from the source to the destination or to the closest relay also increases. As the result of this, over long distance, the probability that the receiver or even the chosen relay in algorithms can correctly receive the signal from the transmitter decreases. Hence, the performance of algorithms decreases as the number of relays increases as shown from Fig.2 to Fig. 6.

However, there are many different performances among schemes when we changes the initial conditions. In Fig.1 and Fig.5, we perform simulation for both ExOR scheme and GPF scheme when the transmitted power at all the source and relays is similar. From this, the graph among performance of the system with a relay, two relays, and three relays is so small. For example, in order to achieve PER of ExOR scheme at 10^{-3}, the transmitted power is required for the system with a relay, two relays, and three relays are 27, 28, 30 dB, respectively.

However, when the transmitted power at the source or at the relay is fixed, the graph when the system increases the number of relays are so large. As Fig.3, the transmitted power at the relay has to be equal 8, 20, and 28dB while the transmitted power at the source is 20dB in order to get PER to be 10^{-1}. On the same way, when the transmitted power at the relay is 20dB, the system with a relay, two relays, and three relays has PER values as 0.07, 0.006, and 0.004.

The comparison of algorithms is clearly shown in the Fig. 6 in which four position-based routing algorithms are compared with each other and with the direct transmission (or traditional ARQ algorithm). From the figure, we can easily recognize that the when SNR is small enough ($SNR < 25\ dB$), the performance of the ExOR algorithm outperforms other algorithms. The SNR gain equals *2dB, 4dB, 6dB, 7dB* and *10dB* compared to the HOF algorithm, LGF algorithm, GFP algorithm and traditional ARQ algorithm, respectively. However, when the SNR is high enough ($SNR > 30$), the performance of the LGF algorithm reach to equal to the ExOR algorithm.

In terms of throughput efficiency, we also gave a comparison for different schemes in Fig. 7. As seen, while the ExOR achieves the highest performance, the traditional ARQ scheme gets the worst performance among schemes. These results are totally suitable with the results on packet error rate where the ExOR algorithm reaches the smaller PER and the traditional ARQ meets higher PER. The most special operation in terms of throughput efficiency of schemes is the operation of the LGF scheme. Its throughput increases so fast when the SNR value of the system increases. It is because when the SNR is high, the probability that the node having the closest distance to the destination receives the signal correctly increases. From this, the node transmits the correct signal to the destination in a short distance. Hence, the probability that the destination receives the correct signal after retransmissions also increases. As the result, the performance of the LGF scheme in terms of throughput efficiency gets better when the SNR is high enough ($SNR \geq 20$dB).

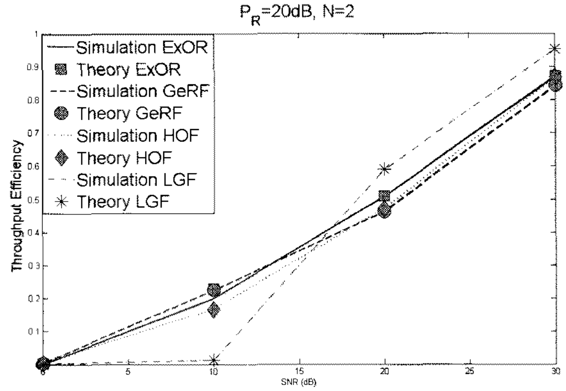


Fig. 7. Throughputcomparison among algorithms when the transmitted power at the relays is fixed and the number of relays N=2.

From these results, we can conclude that the ExOR has the best performance in terms of packet error rate and throughput efficiency when SNRs is small. If the SNR is high enough, the GFG is better choice for selection relaying schemes.

V. Conclusion

In this paper, the number of position-based algorithms is considered in terms packet error rate and throughput efficiency. After that, the best algorithm over the slow fading environment also is suggested. The closed form expressions of algorithms are derived and analysed. The simulations matched with the theory are clearly proved the correctness of the analyses.

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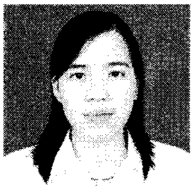

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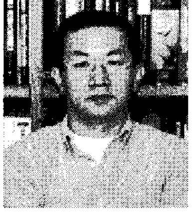

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