Selective Relaying in OFDM Multihop Cooperative Networks

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Abstract—**There has been growing interest in the integration of multihop (or relaying) capability into conventional wireless networks. In this paper, we propose an OFDM-based selective relaying scheme, where the relay selection at each hop is performed on a per-subcarrier basis and joint selection is adopted at the last two hops. The outage analysis clearly shows that full spatial diversity gain can be achieved with this proposed Selective OFDMA Relaying. In contrast, no diversity gain can be obtained if the entire OFDM block chooses the same relay with the highest combined SNR. It is also demonstrated that with coding among the subcarriers, superior performance can be achieved by Selective OFDMA Relaying with only symbol detection at each relay. This is highly attractive as the processing complexity and decoding delay incurred are very small.**

Keywords- OFDM, Cooperative diversity, Multihop, Selective relaying.

I. INTRODUCTION

Future wireless networks, whether infrastructure-based or ad hoc, will be highly dynamic with extreme demands on performance, particularly in terms of energy and bandwidth. The use of multiple antennas, which has provided significant improvements in power and spectral efficiency for single-link wireless communications, however, might be impractical in many instances because of the limited size and power of the individual nodes. Fortunately by exploiting the broadcast nature of the wireless medium and the spatially dispersed arrangement of nodes, some of these advantages, such as diversity gain, can be realized through cooperation among the nodes in the network (for example, see [1-3]).

In the simplest embodiment of cooperative networking, a series of nodes may simply relay a message. This type of relaying is often a necessity in ad hoc wireless networks and has also been proposed to augment the performance of infrastructure-based networks, such as cellular and wireless LANs, as well as the metropolitan broadband networks proposed under IEEE802.16, popularly called WiMAX [4-5].

Orthogonal Frequency Division Multiplexing (OFDM), on the other hand, is one of the most popular physical-layer technology for wireless systems. By dividing the transmission channel into many narrow subchannels, OFDM can overcome the bit-rate limitation imposed by multipath [6]. It has been widely accepted by current wireless standards such as IEEE 802.11 (WiFi) and 802.16 (WiMax) and has also been proposed for the evolution of third-generation systems.

Although there has been growing interest in the integration of multihop (or relaying) capability into conventional wireless networks, little research has focused on OFDM-based relaying.

In most of the relevant work, OFDM is simply considered as the underlying transmission technology [7-9] or as a multiple access scheme aiming at optimal subcarrier allocation in a two-hop two-user cooperative network [10-11]. How to use OFDM to facilitate relaying in a multihop network is still an open issue.

In a decode-and-forward [1] multihop network with L relays at each hop, the maximum diversity gain provided by the cooperation among relays is L-fold regardless of the number of hops. To achieve the full spatial diversity order, selective relaying, i.e., only the best relay is selected for forwarding the signal at each hop, is a good candidate which requires minimum cooperation among the relays and which can be performed in a distributed way [12]. However, we will show that in an OFDM-based network, no diversity gain can be achieved by selective relaying if the entire OFDM block is transmitted over the same path, i.e., the relay with the highest combined SNR is selected at each hop. Instead, relay selection should be performed on a per-subcarrier basis. In particular, each subcarrier chooses the best relay independently at each hop; in this way, then, different subcarriers might traverse different paths. In addition, joint selection of the last two hops is necessary to guarantee that L-fold diversity gain can be achieved at the destination. The above two types of relaying are referred to in what follows as Selective OFDM Relaying and Selective OFDMA Relaying, respectively. [2]

In this paper, the end-to-end outage performance of the proposed Selective OFDMA Relaying approach will be evaluated and compared to that of Selective OFDM Relaying. It is proved that full diversity gain can only be achieved with Selective OFDMA Relaying. Coding among subcarriers is further considered, and it is shown that the performance of Selective OFDM Relaying can be significantly improved through the coding gain achieved at each hop. Nevertheless, Selective OFDMA Relaying still has much better performance and requires only symbol detection at each hop, which implies that much lower processing complexity and decoding delay are incurred than the Selective OFDM Relaying case. Simulation results validate the analysis very well. Practical issues, such as distributed implementation and complexity issues, are also briefly addressed.

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[1] Specifically, here "decode-and-forward" relaying means the relay nodes regenerate the signal by fully decoding and re-encoding.

[2] In this paper, no correlation is assumed among the subchannels, which serves as a performance bound. With a decrease of the delay spread, the performance gap between these two relaying strategies becomes smaller because more subcarriers will use the same relay at each hop. Selective OFDMA relaying has the same performance as Selective OFDM relaying where there is no delay spread.

The paper is organized as follows. In Section II, we provide the system model and propose the Selective OFDMA Relaying. Section III presents the outage analysis for Selective OFDMA Relaying and Selective OFDM Relaying. Simulation results are given in Section IV. We address some implementation issues in Section V. Finally, Section VI summarizes and concludes the paper.

II. SYSTEM MODEL AND SELECTIVE OFDMA RELAYING

We consider a clustered M-hop network with L relays at each hop; each node is equipped with only a single antenna. As shown in Fig. 1, L relays are clustered at each hop and each cluster is equally spaced. Assume that the distance between clusters is much larger than that between nodes in the same cluster. Therefore, only the effect of small-scale fading is taken into account. TDMA is adopted so that only one source/destination pair is active at each particular period. Selective decode-and-forward relaying is assumed. That is, at each hop, only one relay is selected for forwarding the packet.

In previous work, OFDM is the underlying transmission technology and is simply adopted as a physical layer technique to overcome the frequency-selective fading in the network [7-9]. As shown in Fig. 1 (a), one relay is selected at each hop to forward the entire OFDM block so that all the subcarriers traverse the same path. In particular, at hop i, $i=1,\dots, M$-1, the relay with the largest combined SNR, i.e., $\max_l \sum_{n=1}^{N} \gamma_{l,n,i}$, is selected, where $\gamma_{l,n,i}$ is the received SNR of the n-th subcarrier at the l-th relay, $n=1,\dots, N$ and $l=1,\dots, L$ (N is the total number of subcarriers). This type of relaying is referred to as *Selective OFDM Relaying* in the rest of the paper. Compared to the other relaying strategies, selective relaying requires the least amount of signaling and can be performed in a distributed way [12]. It also has the potential to achieve the full spatial diversity gain (L-fold in this case). However, it will be shown that no diversity gain can be obtained with Selective OFDM Relaying.

In this paper, we propose a new relaying scheme, which we call *Selective OFDMA Relaying*. In particular, the relay selection is performed in a per-subcarrier manner. For subcarrier n, $n=1,\dots, N$, the relay with the highest received SNR is selected, i.e., $\max_l \gamma_{l,n,i}$, $i=1,\dots, M$-1. Different relays might be selected for different subcarriers at each hop. As shown in Fig. 1 (b), subcarrier 1 may choose relays 1 and L at hops 1 and 2, respectively, while subcarrier 2 chooses relays 2 and 1. At the destination all the subcarriers are collected.

It can be expected that full spatial diversity gain would be achieved with Selective OFDMA Relaying at hops 1,…, M-1. However, the last hop is different because there is only one receiver – the destination node. In particular, at hop M-1, if relay R_n is selected for forwarding the symbol of subcarrier n based on the received SNR, i.e., $R_n = \arg \max_l \gamma_{l,n,M-1}$, clearly no diversity gain can be achieved at the last hop (considering that only one antenna is employed at the destination node). The last hop could be the bottleneck for the transmission.
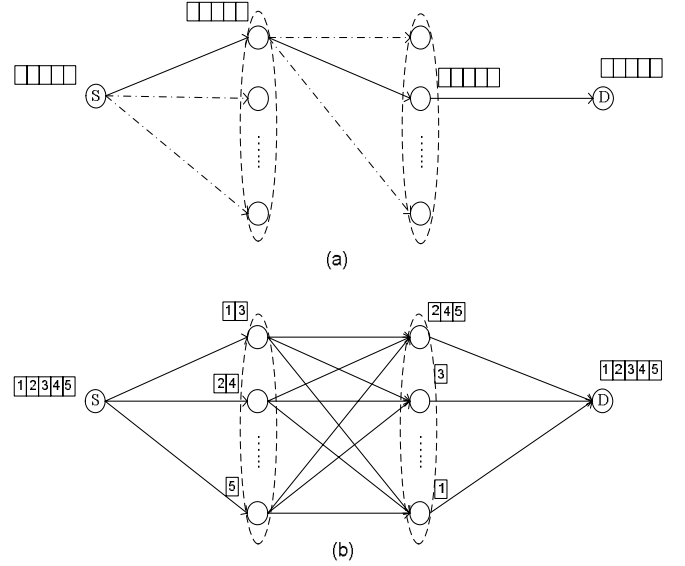
Fig. 1: (a) *Selective OFDM Relaying* in a 3-hop network, i.e., at each hop the relay with the largest combined SNR is selected out of L relays to forward the entire OFDM block; (b) *Selective OFDMA Relaying* in a 3-hop network, i.e., the best relay is selected for each subcarrier at each hop. Each subcarrier chooses the path independently.

To achieve full diversity gain, joint selection should be employed at the last two hops. As shown in Fig. 2, assume relay R_n is selected for transmission of subcarrier n at hop M-2. At hop M-1, instead of selecting relays based on the received SNR, $\gamma_{l,n,M-1}$, $l=1,\dots, L$, both $\gamma_{l,n,M-1}$ and $\gamma_{l,n,M}$ are considered and the one with the largest $\min(\gamma_{l,n,M-1}, \gamma_{l,n,M})$ is selected for the transmission of subcarrier n. We will show that in this way L-fold diversity gain can be achieved with Selective OFDMA Relaying.
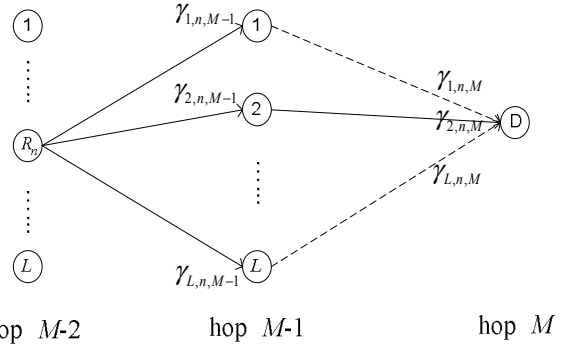
Fig. 2: Relay selection for subcarrier n at hop M-1. The relay with the largest $\min(\gamma_{l,n,M-1}, \gamma_{l,n,M})$, instead of $\gamma_{l,n,M-1}$, is selected.

III. OUTAGE ANALYSIS

In this section, we will evaluate the end-to-end outage performance of Selective OFDM Relaying and Selective OFDMA Relaying. Assume that each subchannel is independently and identically distributed (i.i.d) and the channel remains constant during an OFDM block interval, but varies from block to block. We first consider the case where no coding is adopted in an OFDM block.

A. Selective OFDMA Relaying

The end-to-end outage of Selective OFDMA Relaying is given by

$$p_{out}^{OFDMA} = 1 - \prod_{i=1}^{M}(1 - p_{out,i}^{OFDMA}) = 1 - (1 - p_{out,a}^{OFDMA})^{M-2}(1 - p_{out,b}^{OFDMA}) \quad (1)$$

where $p_{out,i}^{OFDMA}$ is the outage probability of hop i, $i=1,\ldots,M$.

The outage probability of hop i, $i=1,\ldots,M\text{-}2$, is given by

$$p_{out,a}^{OFDMA} = 1 - \int_0^{\infty}\cdots\int_0^{\infty}\prod_{n=1}^{N}(1 - p_s(\varepsilon\,|\,\gamma_n))\cdot f(\gamma_1,\gamma_2,\ldots,\gamma_N)d\gamma_1\cdots d\gamma_N \quad (2)$$

where $\gamma_n = \max_l \gamma_{l,n,i}$, $i=1,\ldots,M\text{-}2$, and $p_s(\varepsilon\,|\,\gamma_n)$ is the symbol error probability conditioned on γ_n, $n=1,\ldots,N$. Since the relay selection is performed independently for each subcarrier, the γ_n's are i.i.d. random variables and we have

$$p_{out,a}^{OFDMA} = 1 - \prod_{n=1}^{N}\int_0^{\infty}(1 - p_s(\varepsilon\,|\,\gamma_n))f(\gamma_n)d\gamma_n = 1 - (1-P_s)^N \quad (3)$$

where P_s is the average symbol error probability with L-branch selective reception. The expression for P_s with M-QAM in Rayleigh fading channel is given in [13] where full diversity order is shown to be achieved.

$p_{out,b}^{OFDMA}$ is the outage probability of the last two hops, which can be obtained as

$$p_{out,b}^{OFDMA} = 1 - (1 - p_{out,n}^{OFDMA})^N \quad (4)$$

where $p_{out,n}^{OFDMA}$ is the outage probability of each subcarrier at the last two hops. If the relay selection at hop M-1 is only based on the values of $\gamma_{l,n,M-1}$, $l=1,\ldots,L$, we then have $l^* = \arg\max_l \gamma_{l,n,M-1}$ and obviously $\gamma_{l^*,n,M-1}$ is independent of $\gamma_{l^*,n,M}$. Therefore,

$$p_{out,n}^{OFDMA} = 1 - \prod_{i=M-1}^{M}\int_0^{\infty}(1 - p_s(\varepsilon\,|\,\gamma_{l^*,n,i}))f(\gamma_{l^*,n,i})d\gamma_{l^*,n,i} \approx p_{out,n,M-1}^{OFDMA} + p_{out,n,M}^{OFDMA} \quad (5)$$

It can be clearly seen that despite the L-fold diversity gain at hop M-1, the end-to-end performance is restricted by the last hop where no diversity gain can be achieved.

If joint selection at the last two hops can be performed, i.e., $l^* = \arg\max_l \min(\gamma_{l,n,M-1},\gamma_{l,n,M})$, we get

$$p_{out,n}^{OFDMA} \leq 1 - \int_0^{\infty}(1 - p_s(\varepsilon\,|\,\gamma^*))^2 f_{\gamma^*}d\gamma^* \quad (6)$$

where $\gamma^* = \min(\gamma_{l^*,n,M-1},\gamma_{l^*,n,M})$. According to [14], the probability density function (pdf) of γ^* can be derived as

$$f_{\gamma^*} = 2L\cdot f(\gamma)(1 - F(\gamma))(2F(\gamma) - F(\gamma)^2)^{L-1} \quad (7)$$

where $f(\gamma)$ and $F(\gamma)$ are the pdf and cumulative density function (cdf) of a Rayleigh distributed variable, respectively. Therefore, (7) becomes

$$f_{\gamma^*} = \sum_{k=1}^{L}\binom{L}{k}(-1)^{k-1}\frac{k}{\overline{\gamma}/2}e^{-\frac{k\gamma}{\overline{\gamma}/2}} \quad (8)$$

Substituting (8) into (6), the upperbound can then be derived (refer to [13] for detailed expressions) where full diversity gain is achieved.

B. Selective OFDM Relaying

So far we have shown that full spatial diversity gain can be achieved by Selective OFDMA Relaying. In this subsection we provide the outage analysis for Selective OFDM Relaying.

The end-to-end outage of Selective OFDM Relaying is given by

$$p_{out}^{OFDM} = 1 - \prod_{i=1}^{M}(1 - p_{out,i}^{OFDM}) = 1 - (1 - p_{out,a}^{OFDM})^{M-1}(1 - p_{out,M}^{OFDM}) \quad (9)$$

where $p_{out,a}^{OFDM}$ is the outage probability of hop $1,\ldots,M$-1, given by

$$p_{out,a}^{OFDM} = 1 - \int_0^{\infty}\cdots\int_0^{\infty}\prod_{n=1}^{N}(1 - p_s(\varepsilon\,|\,\gamma_n'))\cdot f(\gamma_1',\gamma_2',\ldots,\gamma_N')d\gamma_1'\cdots d\gamma_N' \quad (10)$$

where $\gamma_n' = \gamma_{l^*,n,i}$, $l^* = \arg\max_l \sum_{n=1}^{N}\gamma_{l,n,i}$, $i=1,\ldots,M$-1, $n=1,\ldots,N$. Let $\mu = \max_l \sum_{n=1}^{N}\gamma_{l,n,i}$; $f(\gamma_1',\gamma_2',\ldots,\gamma_N')$ is then a convolution based on the distribution of μ. This is very complex to solve analytically; so, we resort to a lower bound.

It can be proved that

$$p_{out,a}^{OFDM} \geq 1 - \int_0^{\infty}(1 - p_s(\varepsilon\,|\,(\mu/N)))^N f(\mu)d\mu \quad (11)$$

The "$\geq$" comes from the fact that when $\gamma_1' = \cdots = \gamma_N'$, $\prod_{n=1}^{N}(1 - p_s(\varepsilon\,|\,\gamma_n'))$ is maximized. Further, notice that $\mu/N \to \mathrm{E}(\mu) = 2L$ for large N. Therefore, from (11) we can see that only an L-fold power gain (but no diversity gain) can be achieved at hops $1,\ldots,M$-1.

The outage probability of the last hop is given by

$$p_{out,M}^{OFDM} = 1 - \prod_{n=1}^{N}\int_0^{\infty}(1 - p_s(\varepsilon\,|\,\gamma_{l^*,n,M}))f(\gamma_{l^*,n,M})d\gamma_{l^*,n,M} \quad (12)$$

Clearly no diversity gain can be achieved at the last hop. Therefore, we conclude that Selective OFDM Relaying can provide no diversity gain at all.

C. Outage with Coded OFDM

In the above analysis, no coding is assumed among the subcarriers. In this subsection, an (N, k) linear code is assumed to be adopted at the source node, where N is the number of subcarriers as well as the size of the codeword. With Selective OFDM Relaying, since the whole OFDM block is forwarded by the selected relay, decoding[3] can be performed at each hop. With Selective OFDMA Relaying, however, subcarriers may choose different paths, i.e., different relays are selected at each hop for different subcarriers. Therefore, decoding is adopted only at the destination, and symbol detection is performed at each intermediate hop.

With coding, the outage probability per hop with Selective OFDM Relaying is given by

$$p_{cout,a}^{OFDM} \geq 1 - \mathrm{E}_\mu\left[\sum_{x=1}^{(N-k)/2}C_N^x p_s(\varepsilon\,|\,(\mu/N))^x(1 - p_s(\varepsilon\,|\,(\mu/N)))^{N-x}\right] \quad (13)$$

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[3] In this paper, "decoding" refers to hard decision decoding.

Clearly coding gain is achieved at each hop. The end-to-end outage can be approximately obtained as

$$p_{cout}^{OFDM} = 1 - (1 - p_{cout,a}^{OFDM})^{M-1}(1 - p_{cout,M}^{OFDM}) \approx M p_{cout,a}^{OFDM} \qquad (14)$$

The end-to-end outage with Selective OFDMA Relaying, with coding, is given by

$$p_{cout}^{OFDMA} = 1 - \sum_{x=1}^{(N-k)/2} C_N^x \left(p_{cout,n}^{OFDMA}\right)^x \left(1 - p_{cout,n}^{OFDMA}\right)^{N-x} \qquad (15)$$

where $p_{cout,n}^{OFDMA}$ is the outage probability of each subcarrier over M hops, and is given by

$$p_{cout,n}^{OFDMA} = 1 - (1 - p_{cout,an}^{OFDMA})^{M-2}(1 - p_{cout,bn}^{OFDMA}) \leq M E_{\gamma^*} p_s(\varepsilon \mid \gamma^*) \quad (16)$$

In Section III.A we showed that $E_{\gamma^*} p_s(\varepsilon \mid \gamma^*)$ can be improved by an L-fold diversity gain. However, no coding gain can be achieved except at the last hop. Substituting (16) into (15), it can be observed that the effect of error propagation is more serious, which is indicated by a factor of M^N, compared to a factor of M in the Selective OFDM Relaying case in (14). Nevertheless, it will be shown that the L-fold diversity gain is significant enough for Selective OFDMA Relaying to outperform Selective OFDM Relaying even without coding gain at intermediate hops. Also note that only symbol detection is performed at each relay with Selective OFDMA Relaying; this requires much less complexity and incurs a lower delay than Selective OFDM Relaying.

IV. SIMULATION RESULTS

In this section, we present simulation results that validate the previous analysis. Consider a multihop network with M hops and L relays at each hop. The number of subcarriers N is fixed to be 16.

We first check the uncoded case. In Fig. 3 the outage is presented as a function of the average SNR per subcarrier per hop for Selective OFDM Relaying and Selective OFDMA Relaying with different values of L when $M=2$. It can be seen that with the increase in L, only a slight gain can be achieved by Selective OFDM Relaying. In contrast, an L-fold diversity gain is observed in the OFDMA case. When $L=4$, a 12-dB gain can be achieved by Selective OFDMA Relaying over Selective OFDM Relaying at an outage of 10^{-1}.

In Fig. 3, joint selection is performed with Selective OFDMA Relaying. As explained in Section III, if the relay selection is only based on the received SNR at hop M-1, there would be no diversity gain at the last hop and so the last hop would limit the overall performance. This is clearly shown in Fig. 4. With $M=2$ hops, the performance of Selective OFDMA Relaying significantly deteriorates if selection is only performed at hop 1. As the dashed-dotted curve indicates, no diversity gain can be achieved compared to Selective OFDM Relaying, despite some improvement at hop 1. Also notice that here joint selection at the last two hops is applied to both Selective OFDM Relaying and Selective OFDMA Relaying. Nevertheless, no performance gain can be observed in the case of Selective OFDM Relaying. It can be also seen that with an increase in the number of hops M, the performance of both Selective OFDM Relaying and Selective OFDMA Relaying degrades.
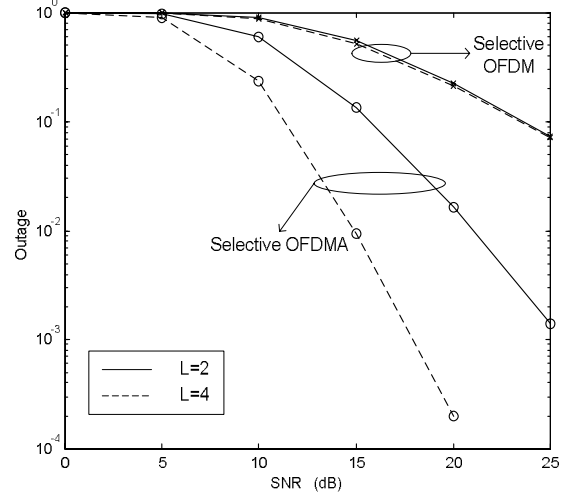

Fig. 3: Outage performance of Selective OFDMA Relaying and Selective OFDM Relaying for different values of L (M=2 hops).
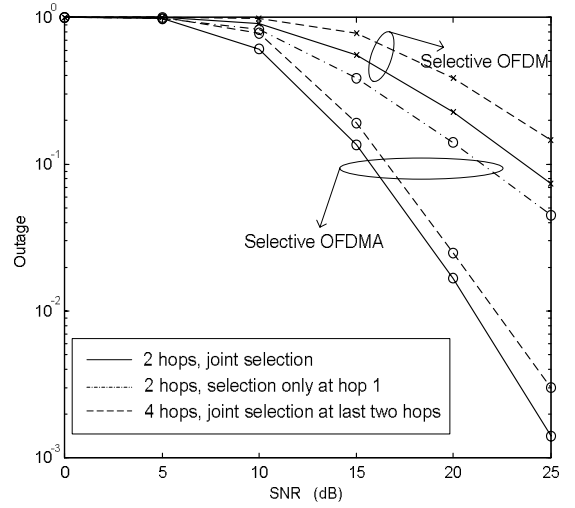

Fig. 4: Outage performance of Selective OFDMA Relaying and Selective OFDM Relaying for different values of M (L=2 relays).

No coding is assumed in an OFDM block in Figs. 3 and 4. Fig. 5 presents the performance comparison when an (N, k) linear code is used among the subcarriers with $k=3N/4$. The number of hops M is assumed to be 4. As shown in Fig. 5, tremendous gains can be achieved by coding compared to the uncoded case with both Selective OFDM Relaying and Selective OFDMA Relaying. However, a significant gap is still observed between coded Selective OFDMA Relaying and coded Selective OFDM Relaying. Note that Selective OFDMA Relaying only requires symbol detection at each hop. Compared to Selective OFDM Relaying, where decoding is performed at each relay, Selective OFDMA Relaying requires much lower processing complexity and delay. Moreover, with an increase in L, the performance of Selective OFDMA Relaying can be further improved, while only a slight gain can be achieved with Selective OFDM Relaying. Based on these

results, we conclude that Selective OFDMA Relaying is a very promising approach for multihop cooperative networks.

In Fig. 6 the performance with different values of M is presented. Clearly with an increase in the number of hops, the performance of both OFDMA and OFDM degrades. The performance degradation of OFDMA is slightly larger than OFDM due to error propagation; however, significant gains are still observed.
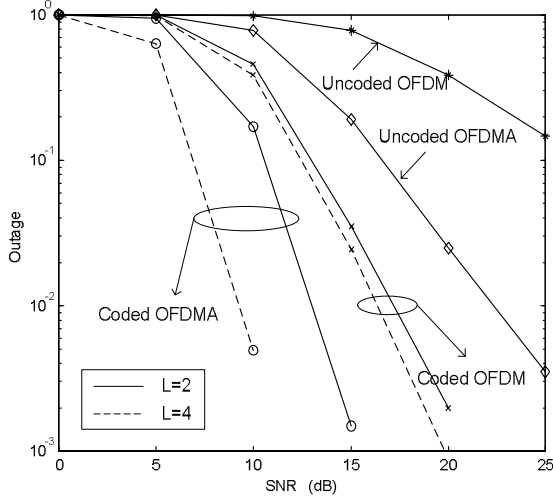

Fig. 5: Outage performance of Selective OFDMA Relaying and Selective OFDM Relaying with and without coding (M=4 hops).
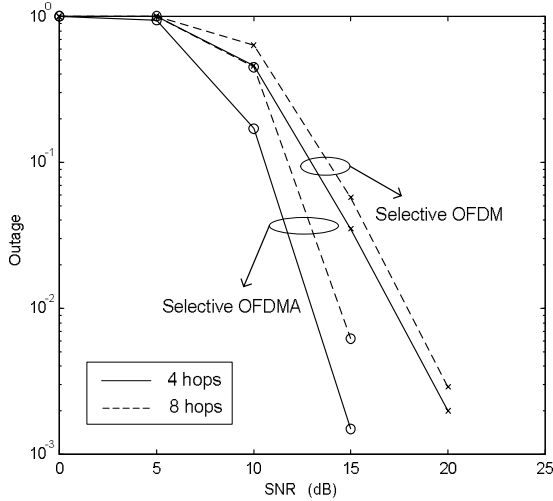

Fig. 6: Outage performance of coded Selective OFDMA Relaying and Selective OFDM Relaying with different values of M. A 3/4-rate linear block code is used among the subcarriers (L=2 relays).

V. IMPLEMENTATION ISSUES

We have provided analytical and simulation results which show that Selective OFDMA Relaying significantly outperforms Selective OFDM Relaying. In this section, we will address some important implementation issues, including the delay incurred in the relay selection process.

A. Distributed Relay Selection

With selective relaying, at each hop, the best relay(s) should be selected based on the received SNRs, or equivalently, the measured channel gains. If a central control node is available (such as a base station in a cellular network or an access point in a mesh network), it can collect all the channel information and then assign the transmission. This selection, however, can also be performed in a distributed way. In [12] a distributed relay selection was proposed, where each relay sets a timer based on its measured channel gain. The larger the channel gain is, the shorter the timer should be. In this way, the timer of the relay with the best channel will expire first. That relay then sends a flag signal. All other relays, while waiting for their timer to reduce to zero, are in listening mode. As soon as they hear the flag signal, they back off. This method requires that all the relays in a cluster can hear each other.

With Selective OFDM Relaying, each relay can set the timer according to the sum gain of all the subchannels. The one with the highest sum gain is selected. In the case of Selective OFDMA Relaying, however, the relay selection needs to be performed in a per-subcarrier manner, i.e., the best relay is selected for each subcarrier, which would significantly increase the delay, i.e., N-fold compared to Selective OFDM Relaying.

To achieve a tradeoff between performance and selection delay, subcarrier grouping can be further performed. In particular, divide the N subcarriers into G groups. For each subcarrier group, choose the relay with the best sum gain. Considering that correlation usually exists among the adjacent subchannels, an appropriate number of groups G could be decided according to the delay spread, i.e., the larger the delay spread is, the larger G should be (G=1 with a zero delay spread). In this way, a flexible performance-delay tradeoff can be achieved. As shown in Fig. 7, with a delay spread of $0.01T$ (T is the block length), relay selection can be performed based on G=2 groups, which achieves almost the same performance as the one using per-subcarrier selection, while incurring much less delay at each hop.
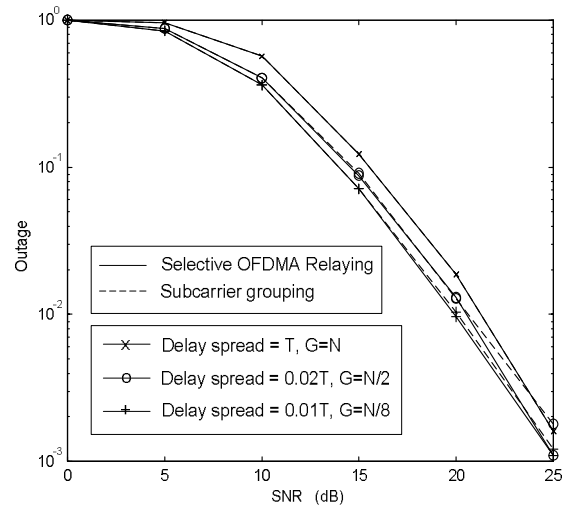

Fig. 7: Outage performance of Selective OFDMA Relaying with subcarrier grouping for different values of delay spread (M=2, L=2, and N=16).

B. Decoding per Hop with Selective OFDMA Relaying

We have shown that Selective OFDMA Relaying outperforms Selective OFDM Relaying with only symbol detection performed at each relay. Clearly this requires a much lower level of processing complexity and decoding delay, compared to Selective OFDM Relaying where decoding is performed at each hop.

If decoding, however, is performed at each relay in the Selective OFDMA Relaying case, additional performance gain can be achieved. As shown in Fig. 8, a 2-dB gain is observed at an outage of 10^{-2}. It should be noticed that for each relay, if decoding of the OFDM block is unsuccessful, it forwards the detection results anyway. Here a failed decoding does not mean a failure of the whole transmission (which is the case for Selective OFDM Relaying), since each relay only forwards a subset of the subcarriers.
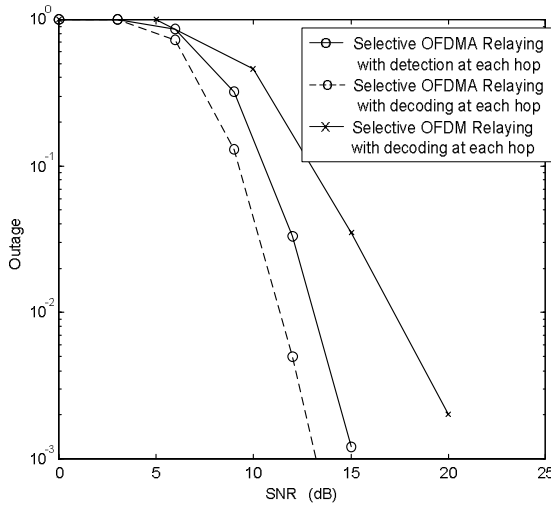

Fig. 8: Outage performance of Selective OFDMA Relaying and Selective OFDM Relaying with decoding or detection at each hop (M=4 and L=2). A 3/4 rate linear code is used among the subcarriers.

VI.   CONCLUSIONS

In this paper, we proposed an OFDM-based selective relaying scheme, where the relay selection at each hop is performed on a per-subcarrier basis and joint selection is used at the last two hops. We analyzed the outage performance of the proposed Selective OFDMA Relaying and showed that full spatial diversity gain can be achieved. In comparison, no diversity gain can be obtained with Selective OFDM Relaying where the entire OFDM block is forwarded by the relay with the highest combined SNR at each hop. Simulation results validated our analysis and showed that superior performance can always be achieved by Selective OFDMA Relaying with only symbol detection at each relay. This approach incurs much lower processing complexity and decoding delay

compared to Selective OFDM Relaying where decoding of the whole OFDM block is required at each hop.

Future work may include the performance analysis in a more practical environment; in particular, the effects of path loss and shadow fading will be taken into consideration. In addition, synchronization for the Selective OFDMA Relaying scheme is an important issue and requires more investigation.

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