DISTRIBUTED COOPERATIVE MULTICAST IN WIRELESS NETWORKS: PERFORMANCE ANALYSIS AND OPTIMAL POWER ALLOCATION

H. Vicky Zhao
ECE Dept., Univ. of Alberta
Edmonton, AB T6G 2V4 Canada
Email: vzhao@ece.ualberta.ca

Weifeng Su
EE Dept., State Univ. of New York at Buffalo
Buffalo, NY 14260 USA
Email: weifeng@buffalo.edu

ABSTRACT

For wireless multicast applications where a group of users subscribe to the same service and receive the same data, a promising solution to combat channel fading is to explore the cooperative diversity and let users help each other forward packets. This paper investigates a distributed cooperative multicast scheme that uses a maximal ratio combiner to enhance the received signal-to-noise ratio (SNR), and provides a thorough performance analysis. We derive a close-form formulation of the average outage probability, examine its asymptotic behavior in the high SNR regime, and investigate the optimal power allocation. Our analytical and simulation results show that cooperative multicast performs better in denser networks with more relays helping, and user cooperation can significantly reduce the outage probability, especially in the high SNR region.

1. INTRODUCTION

In the past years, we witness the emergence of multimedia broadcast and multicast applications over wireless networks, where multimedia data are delivered to a group of users simultaneously. However, the error-prone and dynamically changing characteristics of wireless channels make wireless multimedia multicast very challenging, and it is of crucial importance to combat the inherent channel fading, path loss, and shadowing effects in wireless channels in order to provide a satisfactory level of service.

Various spatial/temporal/frequency diversity techniques provide effective solutions to enhance the reliability of wireless links, and cooperative communication is an emerging concept providing a new communication view, where users in a wireless network may help each other forward packets to improve the system performance [1]. Some recent works studied user cooperation in multicast applications, where users who correctly decode the message sent by the source serve as relays and forward the message to others [2]. The work in [3] assumed that the selected relays transmit in orthogonal channels, e.g., TDMA, FDMA or CDMA, and investigated the optimal relay scheduling and power allocation strategies to minimize the total power consumption. The authors in [4] studied the optimal rate adaptation and relay selection strategies for cooperative video multicast over wireless networks. In [4], a fixed number of relays take turns to forward packets, and layered video coding is used to provide users with different video quality depending on their channel conditions. The work in [5] adopted the distributed cooperation strategies in [6] and assumed that all users who correctly decode the message transmitted by the source act as relays. In [5], all relays forward packets simultaneously using the randomized distributed space-time code (RDSTC).

In this work, we incorporate the maximal ratio combiner (MRC) into the distributed cooperative wireless multicast schemes to further improve the system performance, and let an intended receiver jointly combine all received signals to decode the message. We provide a thorough performance analysis of the MRC-based cooperative multicast scheme, and derive a close-form formulation of its average outage probability. We also obtain an asymptotically tight approximation of the average outage probability to study the asymptotic behavior of the cooperative multicast schemes in the high SNR regime. We then analyze the optimal power allocation strategy to minimize the average outage probability. We also compare the performance of the cooperative multicast schemes with that of the direct multicast (without user cooperation), and examine when users should cooperate with each other to improve the system performance.

The rest of the paper is organized as follows. Section 2 reviews the system model for the distributed cooperative multicast scheme. Section 3 analyzes the average outage probability of the cooperative multicast, studies its asymptotic behavior in the high SNR region, and investigates the optimal power allocation scheme. Section 4 shows simulation results, and conclusions are drawn in Section 5.

2. SYSTEM MODEL

We consider a wireless network with a circular cell of radius $R_0$. The base station/access point (BS/AP) is located at the center of the cell, and multicasts data to $M$ users who are uniformly distributed in the cell. For user $i$ ($1 \leq i \leq M$), the joint probability density function of the user’s distance $r_i \in [0, R_0]$ from the BS/AP and the angle $\theta_i \in [0, 2\pi]$ is $f(r_i, \theta_i) = r_i/(\pi R_0^2)$. $\{r_i, \theta_i\}_{i=1}^M$ for different users are i.i.d.

The distributed cooperative multicast scheme contains two stages. The BS/AP first broadcasts a unit-power signal $x$. For user $i$ located at $(r_i, \theta_i)$, his/her received signal is $y_i^{sd} = \sqrt{P_{s,d}} r_i^{-\eta} h_i x + n_i$, where $P_{s,d}$ is the transmission power used by the BS/AP, $h_i$ is the channel fading gain between the BS/AP and user $i$, and $\eta$ is the path loss parameter. $h_i$ is modeled as a zero-mean circularly symmetric complex Gaussian random variable with unit variance, and $n_i$ is additive white Gaussian noise with variance $N_0$. Given $r_i$, the received SNR is $\gamma_i^{sd} = P_{s,d} |h_i|^2 / r^{-\eta} / N_0$, which follows an exponential distribution with parameter $\lambda_i^{sd} = (N_0 r_i^{-\eta}) / P_{s,d}$.

We assume that $N (N \leq M)$ out of $M$ users decode the message correctly in stage 1, and $C_s = \{i_1, i_2, \ldots, i_N\}$ is the set including their indices. $C_f = \{1, 2, \ldots, M\} \setminus C_s$ contains the indices of those who decode incorrectly in stage 1. Same as in [5], in stage 2, all users in $C_s$ serve as relays and help forward the message. To simplify the analysis, we consider the repetition code and let all relays broadcast...
the message $x$ simultaneously, using the same power $P_{r,d}$. For a user $i_j \in C_f$, who decodes incorrectly in stage 1, in stage 2, his/her received signal $y_{i,d}^{r,d}$ is the superposition of all the $N$ signals broadcasted by the relays, subject to narrow-band Rayleigh channel fading, propagation path loss and additive white Gaussian noise. That is, $y_{i,d}^{r,d} = \sum_{r \in C_r} P_{d} |h_{r,i}^{r,d}|^2 + \sum_{s \in C_s} P_{d} |h_{s,d}^{r,d}|^2 + n_{i,j}$, where $r_{i,j} = \sqrt{r^2 + r^2_{o,i}}$ and $s_{i,j} = \cos(\theta_{r,i} - \theta_{o,i})$ is the distance between the relay $i \in C_s$ and the user $i_j \in C_f$. In this work, we assume that all channel gains $\{h_{r,i}^{r,d}\}$ are i.i.d. $CN(0,1)$, and $n_{i,j}$ are additive white Gaussian noise with zero mean and variance $N_0$. So $y_{i,d}^{r,d} = \sqrt{P_{r,d}} h_{r,i}^{r,d} x + n_{i,j}$, where $h_{r,i}^{r,d} = \sum_{r \in C_r} \sqrt{(r_{r,i})^{-n} h_{r,i}^{-n} x} \sim CN(0, [\sum_{r \in C_r} r_{r,i}^{-n}])$. Given $(r_{i,j}, \theta_{i,j})$ and $C_S = \{i_1, i_2, \cdots, i_N\}$, the received SNR of $y_{i,d}^{r,d}$ is $\gamma_{i,j}^{r,d} = \left(\frac{P_{r,d} |h_{r,i}^{r,d}|^2}{N_0}\right)$, and it is an exponential random variable with parameter $\lambda_{i,j}^{r,d} = N_0 (\sum_{r \in C_r} (r_{r,i})^{-n})^{-1} / P_{r,d}$.

We assume that the channel gains $h_{r,i}^{r,d}$ and $h_{s,d}^{r,d}$ are known to user $i_j \in C_f$, and user $i_j$ uses a maximal ratio combiner (MRC) to combine $y_{i,d}^{r,d}$ and $y_{i,j}^{s,d}$, and jointly decodes the message $x$. Given $(r_{i,j}, \theta_{i,j})$ and $C_s$, the SNR of the combined signal is $\gamma_{i,j}^{r,d} = \gamma_{i,j}^{r,d} + \gamma_{i,j}^{s,d} = \sum_{r \in C_r} \sum_{s \in C_s} |h_{r,i}^{r,d}||h_{s,d}^{s,d}|^2 / N_0$.

Let $P_{d}$ be the transmission power used by the BS/AP to broadcast a unit-power signal in the direct multicast scheme (without relays). For fair comparison, we assume that the average total transmission power used by the BS/AP and all relays in the cooperative multicast scheme is the same as the total power used in the direct multicast scheme. That is, we select $P_{r,d}$ and $P_{s,d}$ such that $P_{r,d} + E[N]P_{s,d} = 2P_{d}$ [7]. Here, $E[N]$ is the expected number of users who decode correctly in stage 1 and who serve as relays. In this work, we assume that all users are willing to cooperate, and there is no selfish free riding or malicious behavior.

3. PERFORMANCE ANALYSIS AND OPTIMAL POWER ALLOCATION

In this section, we analyze the outage probability of the distributed cooperative multicast scheme, and investigate the optimal power allocation strategy to minimize the average outage probability.

3.1. Outage Probability

The outage probability is the probability that the maximum mutual information between the message transmitted by the BS/AP and the signal received by a user is smaller than a predetermined threshold $R$, or equivalently, the probability that the received SNR is below a threshold $\gamma_0$ [7]. If the received SNR is higher than the threshold $\gamma_0$, the user is assumed to be able to decode the received message with a negligible probability of error.

3.1.1 The Decoding Results in Stage 1: In the distributed cooperative multicast scheme, for user $i$ located at $(r_i, \theta_i)$, the SNR of his/her received signal in stage 1, $\gamma_i^{r,d}$, is an exponential random variable with parameter $\lambda_i^{r,d}$. With i.i.d. circularly symmetric complex Gaussian input $x$, the maximum mutual information between the input $x$ and the output $y_i^{r,d}$ is $I_{r,d}^{r,d} = \frac{1}{2} \log_2 (1 + \gamma_i^{r,d})$, where the normalization factor $1/2$ is due to the fact that the cooperative multicast uses two time slots to transmit one symbol [8]. If $I_{r,d}^{r,d}$ is larger than the threshold $R$, we assume that user $i$ can decode the message with a negligible probability of error in stage 1. Otherwise, user $i$ decodes the message incorrectly in stage 1. Thus, given $r_i$, the probability that user $i$ decodes the message erroneously in stage 1 is

$$P_{o,i} = P[I_{r,d}^{r,d} < R | r_i] = 1 - \exp \left\{ -\frac{\gamma_0 N_0 \lambda_i^{r,d}}{P_{r,d}} \right\},$$

where $\gamma_0 \triangleq 2^{2R} - 1$. We assume that all channel gains $\{h_{r,i}^{r,d}\}$ are i.i.d. Therefore, given the locations of the $M$ users $\{(r_i, \theta_i)\}_{i=1}^M$, the probability that users in $C_s = \{i_1, i_2, \cdots, i_N\}$ decode correctly and users in $C_f$ decode incorrectly is

$$P_{i,d}(C_s, C_f | r_1, \cdots, r_M) = \prod_{i_j \in C_s} \left(1 - P_{o,i_j}^{r,d} \right) \prod_{i_j \in C_f} P_{o,i_j}^{r,d}.$$ 

3.1.2 Conditional Outage Probability: For user $i_j \in C_f$ who decodes incorrectly in stage 1, given its location $\{(r_i, \theta_i)\}$ and $C_s$, the SNR of the maximum-ratio combined signal is $\gamma_{i,j}^{r,d} = \gamma_{i,j}^{r,d} + \gamma_{i,j}^{s,d}$, where $\gamma_{i,j}^{r,d}$ and $\gamma_{i,j}^{s,d}$ are exponential random variables with parameters $\lambda_{i,j}^{r,d}$ and $\lambda_{i,j}^{s,d}$, respectively. For user $i_j$, the maximum mutual information with i.i.d. complex Gaussian inputs is $I_{i,j}^{r,d} = \frac{1}{2} \log_2 \left(1 + \gamma_{i,j}^{r,d}\right) = \frac{1}{2} \log_2 \left(1 + \gamma_{i,j}^{s,d} + \gamma_{i,j}^{s,d}\right)$ [8]. Thus, given $\{(r_i, \theta_i)\}$ and $C_s$, user $i_j$'s outage probability is

$$P_{o,i_j}^{r,d} = P[I_{i,j}^{r,d} < R | \{(r_i, \theta_i)\}, C_s] = 1 - \frac{\lambda_{i,j}^{s,d} + \lambda_{i,j}^{r,d}}{\lambda_{i,j}^{r,d} - \lambda_{i,j}^{r,d}} \exp \left(-\lambda_{i,j}^{r,d} \gamma_0 N_0 \right).$$

3.1.3 Average Outage Probability: Given the locations of the $M$ users $\{(r_i, \theta_i)\}$, we first average $P_{o,i}^{r,d}$ in (3) over all users $i_j \in C_f$ and all possible decoding results (C_s) in stage 1, and calculate

$$P_{o,c}^{r,d} = \frac{1}{M} \sum_{i_j \in C_f} P_{o,i}^{r,d} C_s, C_f | \{(r_i, \theta_i)\}.$$ 

Detailed derivation of (4) is omitted here.

We then integrate $P_{o,c}^{r,d}$ in (4) with respect to user locations $\{(r_i, \theta_i)\}$, and the average outage probability of the distributed cooperative multicast scheme is

$$P_o = \prod_{i} \prod_{i} P_{o,i}^{r,d} f(r_i, \theta_i) \cdots f(r_M, \theta_M) dr_1 d\theta_1 \cdots dr_M d\theta_M = \frac{1}{M} \sum_{N=0}^{M-1} \sum_{C_s} \binom{M-1}{N} B_N(C_s, i_j).$$

In (5),

$$A(P_{r,d}) = \frac{1}{N_0 \lambda_i^{r,d}} \Gamma \left( \frac{2}{\eta R_2^2} P_{r,d} N_0 \gamma_0 \right).$$

where $\Gamma(a, x)$ is the incomplete Gamma function, and

$$B_N(C_s, i_j) = \prod_{i_j \in C_s} \left(1 - P_{o,i_j}^{r,d} \right) \prod_{i_j \in C_f} P_{o,i_j}^{r,d}.$$
\[
\prod_{i_j \in C_s} \left[ 1 - P_{a_{i_j}}^{sd} \right] f(r_{i_j, \theta_{i_j}}) dr_{i_j} d\theta_{i_j}. \tag{7}
\]

In (6), \( A(P_{s,d}) \) depends only on the BS/AP’s transmission power \( P_{s,d} \). It is the same for all possible decoding results \( C_s \) in stage 1 and for all \( i_j \in C_f \). From (7), for a given \( C_s \), if we consider two different users \( i_j \) and \( i_k \) who decode incorrectly in stage 1, we have \( B_{N}(C_s, i_j) = B_{N}(C_s, i_k) \) and \( \sum_{i_j \in C_f} B_{N}(C_s, i_j) = (M - N) B_{N}(C_s, i_{N+1}) \) where \( N = |C_s| \). In addition, if we fix the number of users who decode correctly in stage 1 as \( N \), for two different decoding results \( (C_s^1, C_f^1) \) and \( (C_s^2, C_f^2) \) where \( |C_s^1| = |C_s^2| = N \), we can show that \( \sum_{i_j \in C_f^1} B_{N}(C_s^1, i_k) = \sum_{i_j \in C_f^2} B_{N}(C_s^2, i_j) \). Given the total number of users \( M \), for a fixed number of users who serve as relays \( N \), there are a total of \( \binom{M}{N} \) possible decoding results in stage 1 with \( |C_s| = N \). Without loss of generality, we use \( C_f(N) = \{1, 2, \cdots, N\} \) and \( i_j = N + 1 \in C_f(N) \) as an example, and define \( B_{N}(\bar{N}) = B_{N}(C_f(N) = \{1, 2, \cdots, N\}, N = N + 1 \).

Based on the above analysis, \( P_{o}^{sd} \) in (5) becomes

\[
P_{o}^{sd} = [A(P_{s,d})]M + \sum_{N=1}^{M-1} \left( \frac{M-N}{M} \right) [A(P_{s,d})]^{M-N-1} B_{N} = [A(P_{s,d})]M + \sum_{N=1}^{M-1} \left( \frac{M-N}{M} \right) [A(P_{s,d})]^{M-N-1} B_{N}. \tag{8}
\]

The first term in (8), \( A^{sd} \), corresponds to the scenario where all users decode incorrectly in stage 1, and thus the conditional outage probability \( P_{o}^{sd} \) is 1 for all users. The second term in (8) calculates the average outage probability when \( N \) users decode correctly in stage 1 for \( 1 \leq N \leq M - 1 \). Note that when \( N = M \), that is, all users decode correctly in stage 1, the conditional outage probability is 0. Thus, (8) does not include the term corresponding to \( N = M \).

3.1.4 Power Constraint: In the distributed cooperative multicast scheme, the average transmission power used by the BS/AP and by all relays is \( P_{s,d} + E[N] P_{r,d} \), where \( E[N] \) is the average number of users who decode correctly in stage 1 and who serve as relays in stage 2. With i.i.d. channel gains, we have \( E[N] = M[1 - A(P_{s,d})] \). Therefore, under the power constraint, given the BS/AP’s transmission power \( P_{s,d} \) and the total number of users \( M \), the transmission power used by each relay is

\[
P_{r,d} = \frac{2 P_{d} - P_{s,d}}{M \cdot [1 - A(P_{s,d})]} \tag{9}.\]

To summarize, in the distributed cooperative multicast scheme, given the total number of users \( M \) and the base station’s transmission power \( P_{s,d} \), the transmission power used by each relay should be calculated using (9), and the average outage probability is in (8).

3.2. Approximation of the Average Outage Probability

Due to the complexity of the exact average outage probability in (8), it is difficult to gain insights about the performance of cooperative multicast. In this subsection, we analyze the asymptotic behavior of the distributed cooperative multicast scheme, and find an approximation of \( P_{o}^{sd} \) that matches the exact average outage probability very well in the high SNR region. Such analysis is crucial to the investigation of optimal power allocation, which will be discussed in the next subsection.

We first approximate the term \( A(\cdot) \) in (8) as

\[
A(P_{s,d}) \approx \int_{0}^{R_{2}} \frac{N_{0} \tau_{0}^{2}}{P_{s,d}} r_{1}^{2} \frac{dr_{1} r_{2}^{2}}{2 R_{2}^{2}} \frac{N_{0} \tau_{0}^{2}}{P_{s,d}} = \frac{2 R_{2}^{2}}{\eta + 2} = b \frac{P_{s,d}}, \tag{10}
\]

where \( \frac{b}{2}N_{0} \gamma_{0} \lambda_{0}^{2} \approx \gamma_{0}^{2} \). Here, we use the first order Taylor series approximation \( \exp(x) \approx 1 + x \) for \( x \) close to 0, which is tight at high SNR when the ratio \( P_{s,d}/N_{0} \) is large. Similarly, to simplify the term \( B_{N} \) in (8), with high SNR and large values of \( P_{s,d}/N_{0} \) and \( P_{r,d}/N_{0} \), we use the following approximations:

\[
P_{o,N+1}^{sd} = 1 - \lambda_{o,N+1}^{sd} \exp \left( -\lambda_{o,N+1}^{sd} \gamma_{0,m} \right) + \lambda_{o,N+1}^{sd} \lambda_{N+1}^{o} \lambda_{N+1}^{sd} \exp \left( -\lambda_{N+1}^{sd} \gamma_{0,m} \right) \approx \frac{1}{2} \lambda_{o,N+1}^{sd} \lambda_{N+1}^{sd} \gamma_{0,m}^{2}, \text{ and} \]

\[
1 - P_{o,i_{N+1}}^{sd} = \exp \left( -\gamma_{0,m} \eta \frac{r_{i}^{N+1}}{P_{s,d}} \right) \approx 1 - \frac{\gamma_{0,m} \eta r_{i}^{N+1}}{P_{s,d}} \approx 1 \text{ for } 1 \leq i \leq N. \tag{11}
\]

Therefore, we have

\[
B_{N} \approx \int \cdots \int \frac{2 N_{0}^{2} \tau_{0}^{2} \lambda_{N+1}^{o} \lambda_{N+1}^{sd} \gamma_{0,m}^{2}}{2P_{s,d} P_{r,d}} \prod_{i=1}^{N+1} \left( \frac{r_{i}}{(\pi R_{2}^{2})} \right) dr_{1} \cdots dr_{N+1} d\theta_{1} \cdots d\theta_{N+1}. \tag{12}
\]

Here, \( r_{i,N+1} \) is the distance between user \( i \) and user \( N + 1 \). From (12), \( D_{N} \) depends only on \( N \) and \( R_{2} \) but not other parameters. Substituting (10) and (12) into (8), we have

\[
P_{o}^{sd} \approx \frac{b N_{0}^{2} \gamma_{0,m}^{2}}{2P_{s,d} P_{r,d}} D_{N} \frac{b^{M-N-1}}{P_{s,d}} \tag{13}
\]

Note that in (13), the lowest order of \( (N_{0}/P_{s,d} \text{ and } N_{0}/P_{r,d}) \) is 2 when \( N = M - 1 \). Therefore, for high SNR with large values of \( P_{s,d}/N_{0} \) and \( P_{r,d}/N_{0} \), we can ignore the third and all other higher order terms and further simplify \( P_{o}^{sd} \) as

\[
P_{o}^{sd} \approx \frac{b^{M}}{2P_{s,d} P_{r,d}} D_{N} \frac{b^{M-N-1}}{P_{s,d}} \tag{14}
\]

where \( D_{M-1} \) is a constant and depends only on the total number of user \( M \) and the cell radius \( R_{2} \).

Figure 1 compares the exact and the approximated average outage probabilities of the distributed cooperative multicast scheme. We consider two networks with different user densities, and let \( P_{d}/N_{0} \) vary from 75dB to 95dB in Figure 1. We consider \( P_{d} = P_{d} \), that is, half of the total transmission power is used by the BS/AP. We use 20,000 Monte Carlo simulations to find \( B_{N} \) in \( P_{o}^{sd} \) for \( 1 \leq N \leq M - 1 \) and \( D_{M-1} \) in \( P_{o}^{sd} \). From Figure 1, we can see that \( P_{o}^{sd} \) matches \( P_{o}^{sd} \) very well for networks with different user densities, especially when \( P_{d}/N_{0} \) is large. We observe similar trends for other values of the system parameters.

3.3. Optimal Power Allocation

Given the tight approximation of \( P_{o}^{sd} \), we can analyze the optimal power allocation between the BS/AP and the relays. From (14), minimization of \( P_{o}^{sd} \) is equivalent to maximization of the product \( P_{s,d} P_{r,d} \) under the constraint that \( P_{s,d} \) and \( P_{r,d} \) satisfy (9).
To simplify the power constraint (9), we need to simplify the denominator in (9). From (10), with high SNR and large values of $P_{s,d}/N_0$, we have $A(P_{s,d}) \approx b/P_{s,d}$ and

$$P_{r,d} \approx \frac{2P_d - P_{s,d}}{M - (1 - b)} = \frac{P_{s,d}(2P_d - P_{s,d})}{M(P_{s,d} - b)}.$$  

(15)

To minimize the outage probability, we should select $P_{s,d}$ to maximize the function $G^*(P) = \frac{P^2(2P_d - P)}{M(P - b)}$. We let $\frac{\partial G^*(P)}{\partial P}|_{P=P^*_{s,d}} = 0$, which gives

$$P_{s,d}^* = \frac{2P_d + 3b \pm \sqrt{(2P_d + 3b)^2 - 32bP_d}}{4}.$$  

(16)

With high SNR and $P_{s,d} \gg b$, the optimal solution in (16) can be approximated as $P_{s,d}^* \approx P_d$, that is, the BS/AP should use half of the total transmission power and the relays use the other half.

4. SIMULATION RESULTS

In our simulations, we consider a coverage area of a circle with radius $R_2 = 100$, and randomly generate $M$ user locations inside the circle. All channel gains are generated independently following the complex Gaussian distribution $CN(0, 1)$, and the path loss parameter is set to $\eta = 2.6$. Half of the total transmission power is allocated to the BS/AP, that is, $P_{s,d} = P_d$.

Figure 2 compares the simulation results based on $10^7$ simulation runs with $P_n$ in (5). It can be seen that the simulation results match our analytical results very well. In addition, from Figure 2, the distributed cooperative multicast scheme achieves a smaller outage probability when the total number of users $M$ is larger and when more users help relay the message in stage 2. For example, there is a 3dB gain if $M$ is increased from 10 to 100, and another 1dB gain if $M$ is further increased to 250. Thus, the distributed cooperative multicast performs better in denser networks with more users.

We then compare the performance of the distributed cooperative multicast with that of the direct multicast. In the high SNR region, user cooperation can significantly help reduce the outage probability. For example, with $P_d/N_0 = 95dB$ and hundreds of users in the network, distributed cooperative multicast helps reduce the average outage probability from $O(10^{-4})$ to $O(10^{-6})$. Also, the distributed cooperative multicast helps increase the diversity order from 1 to 2 in the outage probability performance. However, cooperation does not always offer the best performance. With the system setup as in Figure 2, with $M = 10$, the direct multicast is beneficial when $P_d/N_0 < 81dB$; and with $M = 100$ users, user cooperation gives a smaller outage probability only if $P_d/N_0 \geq 76dB$.

5. CONCLUSIONS

This paper studies the MRC-based distributed cooperation scheme for wireless multicast applications. We derive the close-form formulation of its outage probability, and provide approximations to show the asymptotic performance of the cooperative multicast scheme. We then analyze the optimal power allocation strategy, and show that allocating half of the total transmission power to the BS/AP helps minimize the outage probability. Our results indicate that the cooperative multicast scheme achieves a smaller outage probability when there are more users in the networks. Compared with the direct multicast, the cooperative multicast scheme achieves diversity order 2 and user cooperation helps significantly improve the performance, especially in the high SNR region.

6. REFERENCES


