

Abstract

In this paper, a hybrid multicast and opportunistic unicast transmission scheme is proposed with Amplify-and-Forward (AF) relaying in wireless cellular network and its performance over Rayleigh fading channel is analyzed and evaluated, and some distribution functions are derived such as the signal-to-noise ratio (SNR) distributions for the selected user in the multicast and unicast transmission. To the best of our knowledge, this is the first paper addressing the SNR distributions of the multicast and unicast transmission with AF relaying. Numerical results show that analytical results are well matched with computer simulation results over 20000 simulation runs, the overall performance of the scheduling-based system with DF relaying is better than that with AF relaying, and the multicast and unicast transmission with AF relaying can play their respective advantages under certain conditions. The relay may combine the signals if it received two signals correctly and forward it to destinations in the next half slot. The destinations, therefore, can recover signals either from direct transmission or the relay forwarding. The performance analysis on the developed NCBC multicast protocol is given in the viewpoint of physical layer, such as the outage probability and diversity order. It is demonstrated that the NCBC multicast scheme can work better than the source direct multicast in terms of outage probability. Meanwhile, the NCBC multicast scheme can achieve full diversity gain (diversity two for one relay case). Comparing with the known relay schemes, i.e., amplify-and forward (AF) and selection decode-and-forward cooperation schemes, it shows that the NCBC multicast scheme achieves almost the same outage performance

KEYWORDS; Multicast transmission; Amplify-and-Forward (AF); Multicast analysis; Ergodic capacity; Outage probability

Table of Contents

1.1 Current research on multicast network	1
1.2 System model.....	2
Chapter 2 Co-operative communication.....	4
2.1 cooperative wireless communication,.....	4
2.2 Historical Background	6
2.3 Detect and Forward Method	7
2.4 Multiple Access and Other Practical Issues	8
Chapter 3 System Model	17
4.1 System capacity	24
Chapter 5 Conclusions.....	34
Acknowledgements	37
Abbreviation table	Error! Bookmark not defined.

Chapter 1 Introduction

1.1 Current research on multicast network

Wireless multicast is a point-to-multipoint service in which data is transmitted from a single source to multiple destinations, while unicast is a point-to-point service in which data is transmitted from a single source to a single destination. Currently there are three kinds of networks which can support wireless multicast services, i.e., 1).

Multicast service is provided by a terrestrial digital broadcasting system, such as DVB-H (Digital Video Broadcasting-Handheld) DB-T (Terrestrial Integrated Services Digital Broadcasting) and CMMB (China Mobile Multimedia Broadcasting); 2) Multicast service is provided by a satellite network, such as S-DMB (Satellite-Digital Multimedia Broadcasting); 3). Multicast service is provided by a cellular system, such as MBMS (Multimedia Broadcast and Multicast Services), BCMCS (Broadcast and Multicast Services) and MBS (Multicast Broadcast Services). In this paper, we will study the case that both multicast and unicast services are carried over a cellular system. In a conventional wireless multicast system, the sender will select a data rate according to the worst channel user in the multicast group to ensure the reliable delivery of data to all the multicast users. However, as the system capacity of multicast transmission is affected by both the data rate and the number of users who can receive the data, if there are a large number of multicast users, the data rate which is selected according to the worst channel user will be very low, and hence the system capacity of the multicast transmission will be small.

To exploit multiuser diversity gain and multicast gain simultaneously, an opportunistic multicast scheduling (OMS) approach was proposed in [9], that is, instead of sending the packet to all the multicast users at the lowest supportable data rate, in each transmission, one copy of data is sent to a ratio (e.g., 50%) of users in the multicast group, the data rate will be much higher than that of the conventional multicast scheme, and the ratio of 50% users in the multicast group can receive the data [10]-[13]. In [14], a proportional fair scheduling scheme was proposed, aiming to maximize throughput while maintaining the fairness between multicast users and

multicast groups. In [15], the SNR distributions of the scheduling-based system are derived, and the performance of the scheduling-based systems is evaluated in terms of ergodic capacity and outage probability using the derived SNR distributions. And in [16], a hybrid scheduling scheme for the mixed multicast and unicast traffic services is proposed, in which the system adaptively selects a transmission scheme between the multicast and unicast transmission schemes according to varying channel conditions with SNR threshold values.

However, these works only studies the wireless multicast system without relaying, the performance of a hybrid multicast and unicast transmission system with relays still needs to be investigated. In this paper, a hybrid multicast and opportunistic unicast transmission scheme with DF and AF relaying is proposed, in which multicast signals are transmitted to a multicast group with a data rate depending on the worst channel user in the multicast group, whereas unicast signals are transmitted to the best channel user among unicast users.

To the best of our knowledge, this is the first paper addressing the SNR distributions of the multicast and unicast transmission with DF and AF relaying. In this paper, the performance of the multicast and opportunistic unicast transmission system with DF and AF relaying is evaluated in terms of ergodic capacity and outage probabilities using the derived SNR distributions. The rest of the paper is organized as follows. A system model is presented in section II. The SNR distributions of the scheduling-based system are derived in section III. The performance of the scheduling-based system is evaluated from the perspective of ergodic capacity and outage probability in section IV. Numerical results are shown in Section V. Finally, conclusion is given in Section VI.

1.2 System model

Consider a single-cell system as shown in Fig. 1 which is composed of a source (S), a relay (R), and L users denoted as D_1, D_2, \dots, D_L respectively. Among L users, there are L_m multicast users and L_u unicast users. Suppose that the transmissions from S to D_i ($i=1,2,\dots,L$), S to R , and R to D_i ($i=1,2,\dots,L$) suffer from quasi-static fading with independent Rayleigh distribution. Then the channel gains from S to D_i ($i=1,2,\dots,L$), S to R , and R to D_i ($i=1,2,\dots,L$), h_{SD_i} , h_{SR} , and h_{RD_i} can be modeled as zero-mean, independent, circularly symmetric complex Gaussian random variables with variances 1. As a result,

the power gains $|h_{SD_i}|^2$, $|h_{SR}|^2$, and $|h_{RD_i}|^2$ are exponentially distributed random variables with parameter 1, i.e., the small-scale fading component α is expressed as:

$$f_{\alpha^2}(x) = \exp(-x)$$

The quasi-static fading leads to constant fading for each transmission (two channel uses). The distance from each user to the source (e.g., a base station (BS)) is approximately equal to r_{sd} , the distance from each user to the relay is approximately equal to r_{rd} , and the distance from the relay to the BS is equal to r_{sr} . The additive noise is modeled as a complex Gaussian random variable with variance N_0 . The transmit power at the BS and the relay is assumed as P respectively, then the transmit SNR at the BS and the relay is $\rho = GP/N_0$ respectively (where G is a constant influenced by the carrier frequency, antenna gain and antenna height, etc.). Base station (BS) Relay(R)

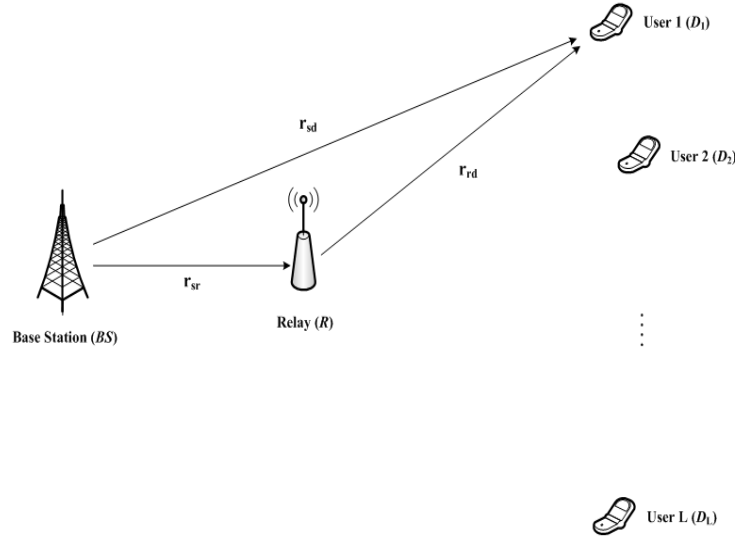


Fig. 1. Wireless cooperative multicast system.

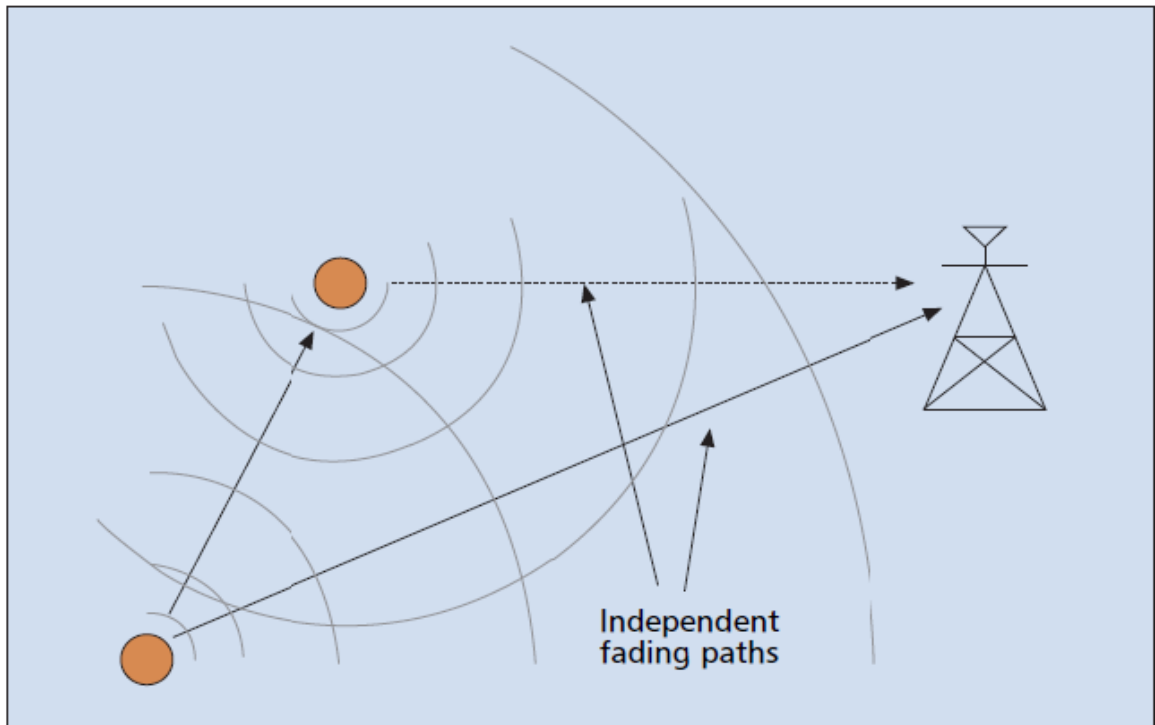
Wireless networks, signal fading arising from multipath propagation is a particularly severe channel impairment that can be mitigated through the use of diversity [1]. Space, or multiple-antenna, diversity techniques are particularly attractive as they can be readily combined with other forms of diversity, e.g. time and frequency diversity, and still offer dramatic performance gains when other forms of diversity are unavailable Multicast is a way to distribute information from a single transmitter to multiple intended receivers in a network. For instance, in a wireless sensor network, sensed information may be needed to multicast to neighboring nodes for information gathering.

Chapter 2 Co-operative communication

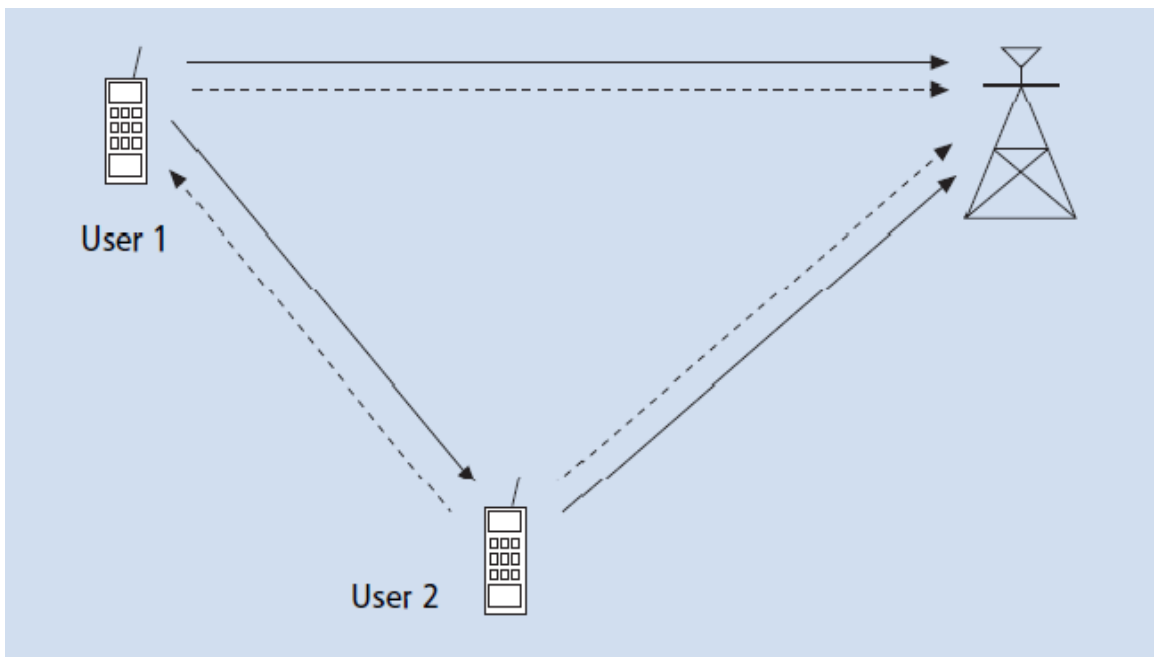
2.1 cooperative wireless communication,

In cooperative wireless communication, we are concerned with a wireless network, of the cellular or ad hoc variety, where the wireless agents, which we call *users*, may increase their effective quality of service (measured at the physical layer by bit error rates, block error rates, or outage probability) via cooperation. In a cooperative communication system, each wireless user is assumed to transmit data as well as act as a cooperative agent for another user (Fig. 2). Cooperation leads to interesting trade-offs in code rates and transmit power. In the case of power, one may argue on one hand that more power is needed because each user, when in cooperative mode, is transmitting for both users. On the other hand, the baseline transmits power for both users will be reduced because of diversity. In the face of this trade-off, one hopes for a net reduction of transmit power, given everything else being constant. Similar questions arise for the rate of the system.

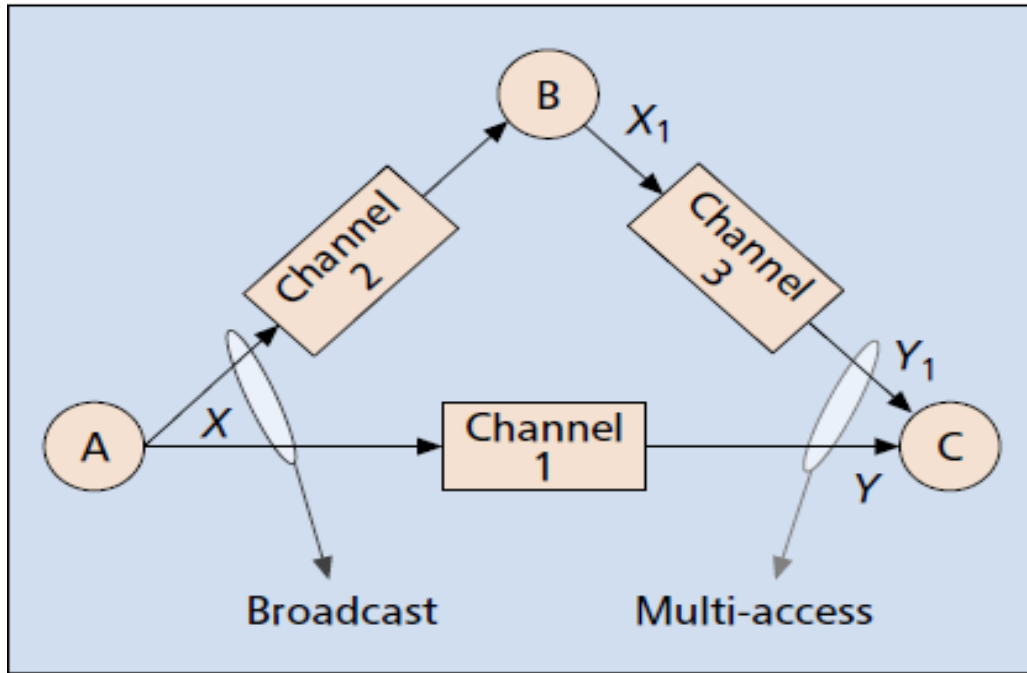
In cooperative communication each user transmits both his/her own bits as well as some information for his/her partner; one might think this causes loss of rate in the system. However, the spectral efficiency of each user improves because; due to cooperation diversity the channel code rates can be increased. Again a tradeoff is observed. The key question, whether cooperation is worth the incurred cost, has been answered positively by several studies, and is demonstrated by plots toward the end of this article. One may also describe cooperation as a zero sum game in terms of power and bandwidth of the mobiles in the network. The premise of cooperation is that certain (admittedly unconventional) allocation strategies for the power and bandwidth of mobiles lead to significant gains in system performance. In the cooperative allocation of resources, each mobile transmits for multiple mobiles.



■ Figure 1. *Cooperative communication.*



■ Figure 2. *In cooperative communication each mobile is both a user and a relay.*



■ Figure 3. *The relay channel.*

2.2 Historical Background

The basic ideas behind cooperative communication can be traced back to the groundbreaking work of Cover and El Gamal on the information theoretic properties of the relay channel [1]. This work analyzed the capacity of the three-node network consisting of a source, a destination, and a relay. It was assumed that all nodes operate in the same band, so the system can be decomposed into a broadcast channel from the viewpoint of the source and a multiple access channel from the viewpoint of the destination (Fig. 3). Many ideas that appeared later in the cooperation literature were first explicated in [1].

However, in many respects the cooperative communication we consider is different from the relay channel. First, recent developments are motivated by the concept of diversity in a fading channel, while Cover and El Gamal mostly analyze capacity in an additive white Gaussian noise (AWGN) channel. Second, in the relay channel, the relay's sole purpose is to help the main channel, whereas in cooperation the total system resources are fixed, and users act both as information sources as well as relays. Therefore, although the historical importance of [1] is indisputable, recent work in cooperation has taken a somewhat different emphasis.

2.3 Detect and Forward Method

This method is perhaps closest to the idea of a traditional relay. In this method a user attempts to detect the partner's bits and then retransmits the detected bits (Fig. 4). The partners may be assigned mutually by the base station, or via some other technique. For the purposes of this tutorial we consider two users partnering with each other, but in reality the only important factor is that each user has a partner that provides a second (diversity) data path.

The easiest way to visualize this is via pairs, but it is also possible to achieve the same effect via other partnership topologies that remove the strict constraint of pairing. Partner assignment is a rich topic whose details are beyond the scope of this introductory article. An example of decode-and-forward signaling can be found in the work of Sendonaris et al. [2], which has inspired much of the recent activity in this area. This work presents analysis and a simple code-division multiple access (CDMA) implementation of decode-and-forward cooperative signaling.

In this scheme, two users are paired to cooperate with each other. Each user has its own spreading code, denoted $c_1(t)$ and $c_2(t)$. The two user's data bits are denoted $b_i(n)$ where $i = 1, 2$ are the user indices and n denotes the time index of information bits. Factors a_j denote signal amplitudes, and hence represent power allocation to various parts of the signaling. Each signaling period consists of three bit intervals. Denoting the signal of user 1 $X_1(t)$ and the signal of user 2 $X_2(t)$,

$$X_1(t) = [a_{11}b_1^{(1)}c_1(t), a_{12}b_1^{(2)}c_1(t), \\ a_{13}b_1^{(2)}c_1(t) + a_{14}b_2^{(2)}c_2(t)]$$

$$X_2(t) = [a_{21}b_2^{(1)}c_2(t), \\ a_{22}b_2^{(2)}c_2(t) + a_{23}\hat{b}_1^{(2)}c_1(t) + a_{24}b_2^{(2)}c_2(t)]$$

In other words, in the first and second intervals, each user transmits its own bits. Each user then detects the other user's second bit (each user's estimate of the other's bit is denoted \hat{b}^i). In the third interval, both users transmit a linear combination of their own second bit and the partner's second bit, each multiplied by the appropriate spreading code. The transmit powers for the first, second, and third intervals are variable, and by optimizing the relative transmit powers according to the conditions of

the uplink and interuser channels, this method provides adaptability to channel conditions. The powers are allocated through the factors $a_{i,j}$ such that an average power constraint is maintained. Roughly speaking, whenever the interuser channel is favorable, more power will be allocated to cooperation, whereas whenever the interuser channel is not favorable, cooperation is reduced.

This signaling has the advantage of simplicity and adaptability to channel conditions. Several notes must be made in reference to this method. First, it is possible that detection by the partner is unsuccessful, in which case cooperation can be detrimental to the eventual detection of the bits at the base station.

Also, the base station needs to know the error characteristics of the interuser channel for optimal decoding. To avoid the problem of error propagation, Laneman *et al.* [3] proposed a hybrid decode-and-forward method where, at times when the fading channel has high instantaneous signal-to noise ratio (SNR), users detect and forward their partners' data, but when the channel has low SNR, users revert to a noncooperative mode. This is not unlike the adaptability of coefficients $a_{i,j}$ provided by the method of Sendonaris *et al.*, and has been shown to perform very well.

2.4 Multiple Access and Other Practical Issues

Cooperative communication, as described previously, assumes that the base station can separately receive the original and relayed transmissions. This is accomplished by transmitting the two parts orthogonally so that they can be separated. The most straightforward method is separation in time, that is, the user's data and relayed data are transmitted in no overlapping time intervals. In the example of Sendonaris ET, orthogonality was achieved via spreading codes. In principle, it is also possible to achieve separation in frequency. Separation of signals is closely related to the issue of hardware requirements on the mobiles.

In cellular systems, even time-division multiple access (TDMA) ones, the uplink and downlink transmissions are performed on separate frequency bands. Ordinary mobiles receive only in the downlink band, but cooperative mobiles need to also receive in the uplink band, thus requiring additional input filters and frequency conversion. In ad hoc wireless networks where users may transmit and receive on the same frequency band, this is less of an issue. Another technological issue is transmitted and receives requirements on the mobiles. In TDMA systems this is generally not a problem, since the uplink transmissions by definition are nonoverlapping in time. However, in other

multiple access systems, such as CDMA, the mobiles may be required to transmit and receive at the same time. Transmit signals can be up to 100 dB above the level of receive signals, which is beyond the isolation achievable by existing directional couplers. Two preliminary solutions to this problem come to mind. First, cooperating users may agree to “timeshare” their transmission, so between the two they will create a mini-TDMA scenario where each transmits for 50 percent of the time at twice the power. A second solution is arrived at by realizing that most CDMA systems are actually hybrid, with more than one frequency band allocated to the uplink channel. Then the base station may require that cooperating mobiles reside on separate bands. It is also important to consider the knowledge required by the base station to handle cooperative communication. The amount of additional information varies for the various schemes introduced previously. In the simple detect-and-forward method, the base station needs to know the error probability of the interuser channel for optimal detection. In amplify-and-forward this is required, since conventional channel estimation methods can be used to extract the necessary information from the direct and relayed signals. For coded cooperation, as well as the hybrid detect-and-forward scheme, no knowledge of the interuser channel is needed in the base station. However, since cooperation is conditional, the base station needs to know whether the users have cooperated or not. More precisely, the base station needs to know whose bits each user is transmitting in the second frame. A simple solution is that the base station simply decodes according to each of the possibilities in succession (based on their relative likelihood) until successful decoding results. This strategy maintains the overall system performance and rate at the cost of some added complexity at the base station. One may ask what the tangible benefits of cooperation are at the network level. To answer this, we point to the multi-antenna technologies that motivated cooperation in the first place. Studies have shown that the diversity provided by MIMO space-time codes can improve performance at the medium access control (MAC), network, and transport layers

Extension and Continuing Work

While many key results for cooperative communication have already been obtained, there are many more issues that remain to be addressed. An important question is how partners are assigned and managed in multi-user networks. In other words, how is it determined which users cooperate with each other, and how often are partners reassigned? Systems such as cellular, in which the users communicate with a central base station, offer the possibility of a centralized mechanism. Assuming that the base station has some knowledge of the all the channels between users, partners could be assigned to optimize a given performance criterion, such as the average block error rate

for all users in the network. In contrast, systems such as ad hoc networks and sensor networks typically do not have any centralized control. Such systems therefore require a distributed cooperative protocol, in which users are able to independently decide with whom to cooperate at any given time. A related issue is the extension of the proposed cooperative methods to allow a user to have multiple partners.

The challenge here is to develop a scheme that treats all users fairly, does not require significant additional system resources, and can be implemented feasibly in conjunction with the system's multiple access protocol. Laneman and Wornell [7] have done some initial work related to distributed partner assignment and multiple partners, and additional work by others is ongoing. Another important issue is the development of power control mechanisms for cooperative transmission. Work thus far generally assumes that the users transmit with equal power. It may be possible to improve performance even further by varying transmit power for each user based on the instantaneous uplink and interuser channel conditions.

Furthermore, power control is critical in CDMA-based systems to manage the near-far effect and minimize interference. Therefore, power control schemes that work effectively in the context of cooperative communications have great practical importance. For the coded cooperation method, a natural issue is the possibility of designing a better coding scheme. In this tutorial article as well as [5], Examples are given using RCPC codes, while in [8], turbo codes are applied to the coded cooperation framework. Both of these coding schemes were originally developed for noncooperative system. An interesting open problem is the development of design criteria specifically for codes that optimize the performance of coded cooperation.

Multicast

In computer networking multicast is the delivery of a message or informaton to a group of destination computers simultaneously in a single transmission from the source. Copies are automatically created in other network elements, such as routers, but only when the topology of the network requires it.

Multicast is most commonly implemented in IP multicast which is often employed in Internet Protocol (IP) applications of streaming media and internet television. In IP multicast the implementation of the multicast concept occurs at the IP routing level, where routers create optimal distribution paths for datagrams sent to a multicast destination address.

At the Data Link Layer, multicast describes one-to-many distribution such as Ethernet multicast addressing, Asynchronous Transfer Mode (ATM) point-to-multipoint virtual circuits (P2MP) or Infiniband multicast. In an optical mesh network protecting multicast light paths is one of the key concerns. The most straight forward approach to protect a multicast tree is to establish a link-disjoint backup tree which establishes dedicated protection. It is much easier to find an arc-disjoint path for each leaf node in a light tree. The essence of protecting a multicast session is to find a backup path for each destination node when a link on the working path to that node fails.

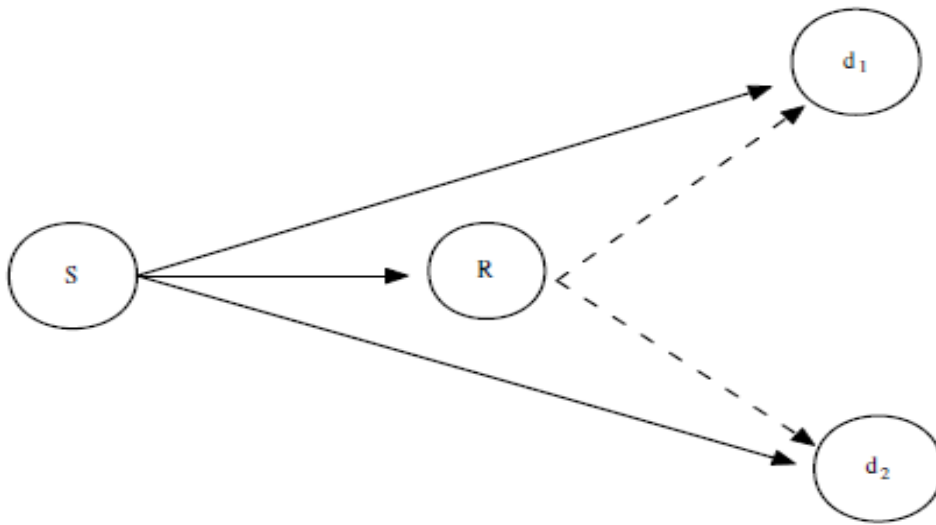


Figure 1. Illustration of the cooperative multicast network.

Multicast Transmission

In a conventional multicast transmission, in each transmission the multicast signals are transmitted to a multicast group with a data rate depending on the worst channel user. The worst channel user i is the one with the lowest received SNR among L_m multicast users, and note that in a multicast transmission the user selection should be based on both small-scale fading and path-loss. The subscript of the selected user is

$$i = \arg \min_{k=1, \dots, L_m} \{z_k\}$$

Where z_k is the received SNR value of user k in each transmission (two channel uses). In a conventional multicast transmission, if user i is selected as the worst channel user, it means that in the multicast group, user i has a received SNR value z_m while all the other users in the group have higher received SNR values. Therefore, the joint pdf of z_m and i is expressed as

$$\begin{aligned}
 f_{z_m, i}(z, i) &= f_{z_m, i}(z) \prod_{\substack{j=1 \\ j \neq i}}^{L_m} [1 - F_{z_m, j}(z)] \\
 &= \frac{r_{sd}^n r_{rd}^n (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z})}{\rho(r_{sd}^n - r_{rd}^n)} \left(e^{-\frac{r_{sd}^n}{\rho} z} + (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z}) \frac{r_{sd}^n}{r_{sd}^n - r_{rd}^n} \right)^{L_m - 1} \\
 &= \frac{r_{sd}^n r_{rd}^n (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z})}{\rho(r_{sd}^n - r_{rd}^n)} \left(\frac{r_{sd}^n e^{-\frac{r_{rd}^n}{\rho} z} - r_{rd}^n e^{-\frac{r_{sd}^n}{\rho} z}}{r_{sd}^n - r_{rd}^n} \right)^{L_m - 1}
 \end{aligned}$$

Since L_m multicast users are peer parties to each other, therefore, from a view of statistics, all the users in the multicast group have an equal opportunity to be selected, thus the selection probability of user i is given by

$$P_i^m(i) = \frac{1}{L_m}$$

Unicast

The term unicast is contrasted with the term broadcast which means transmitting the same data to all possible destinations. Another multi-destination distribution method, multicasting, sends data only to interested destinations by using special address assignments. Unicast messaging is used for all network processes in which a private or unique resource is requested. Certain network applications which are mass-distributed are too costly to be conducted with unicast transmission since each network connection consumes computing resources on the sending host and requires

its own separate network bandwidth for transmission.

Such applications include streaming media of many forms. Internet radio stations using unicast connections may have high bandwidth costs. These terms are also used by streaming content providers' services. Unicast-based media servers open and provide a stream for each unique user. Multicast-based servers can support a larger audience by serving content simultaneously to multiple users.

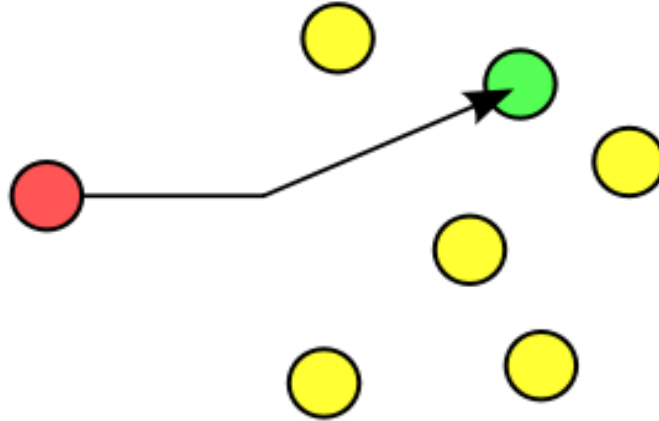


Fig. 1 Illustration of unicast network

Unicast Transmission

In an opportunistic unicast transmission, in each transmission the unicast signals are transmitted to a user with the best channel conditions. The best channel user i is the one with the highest received SNR among L_u unicast users, and note that as all the users have the same distance to the BS and the relay, hence in an opportunistic unicast transmission the user selection which is based on both small-scale fading and path-loss can guarantee the fairness among users. The subscript of the selected user is

$$i = \arg \max_{k=1, \dots, L_u} \{z_k\}$$

where z_k is the received SNR value of user k in each transmission (two channel uses). In an opportunistic unicast transmission, if user i is selected as the best channel user, it means that among L_u unicast users, user i has a received SNR value z_u while all the other unicast users have lower received SNR values. Therefore, the joint pdf of z_u and i is expressed as

$$\begin{aligned}
 f_{z_u,i}(z,i) &= f_{z_u,i}(z) \prod_{\substack{j=1 \\ j \neq i}}^{L_u} F_{z_u,j}(z) \\
 &= \frac{r_{sd}^n r_{rd}^n (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z})}{\rho (r_{sd}^n - r_{rd}^n)} \left(1 - e^{-\frac{r_{sd}^n}{\rho} z} + (e^{-\frac{r_{sd}^n}{\rho} z} - e^{-\frac{r_{rd}^n}{\rho} z}) \frac{r_{sd}^n}{r_{sd}^n - r_{rd}^n} \right)^{L_u - 1} \\
 &= \frac{r_{sd}^n r_{rd}^n (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z})}{\rho (r_{sd}^n - r_{rd}^n)} \left(1 - \frac{r_{sd}^n e^{-\frac{r_{rd}^n}{\rho} z} - r_{rd}^n e^{-\frac{r_{sd}^n}{\rho} z}}{r_{sd}^n - r_{rd}^n} \right)^{L_u - 1}
 \end{aligned}$$

Since L_u unicast users are peer parties to each other, therefore, from a view of statistics, all the L_u unicast users have an equal opportunity to be selected, thus the selection probability of user i is given by

$$P_i^u(i) = \frac{1}{L_u}$$

Combining the received SNR value z_u is given by

$$\begin{aligned}
 f_{z_u|i}(z,i) &= f_{z_u,i}(z,i) / P_i^u(i) \\
 &= \frac{r_{sd}^n r_{rd}^n (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z})}{\rho (r_{sd}^n - r_{rd}^n)} \left(1 - \frac{r_{sd}^n e^{-\frac{r_{rd}^n}{\rho} z} - r_{rd}^n e^{-\frac{r_{sd}^n}{\rho} z}}{r_{sd}^n - r_{rd}^n} \right)^{L_u - 1} \bigg/ \left(\frac{1}{L_u} \right) \\
 &= \frac{L_u r_{sd}^n r_{rd}^n (e^{-\frac{r_{rd}^n}{\rho} z} - e^{-\frac{r_{sd}^n}{\rho} z})}{\rho (r_{sd}^n - r_{rd}^n)} \left(1 - \frac{r_{sd}^n e^{-\frac{r_{rd}^n}{\rho} z} - r_{rd}^n e^{-\frac{r_{sd}^n}{\rho} z}}{r_{sd}^n - r_{rd}^n} \right)^{L_u - 1}
 \end{aligned}$$

Broadcasting

Broadcasting is the distribution of audio and video content to a dispersed audience via any audio or visual mass communications medium, but usually one using electromagnetic radiation (radio waves).

The receiving parties may include the general public or a relatively large subset thereof. Broadcasting has been used for purposes of private recreation, non-commercial exchange of messages, experimentation, self-training, and emergency communication such as amateur (ham) radio and amateur television (ATV) in addition to commercial purposes like popular radio or TV stations with advertisements.

The term broadcasting was first adopted by early radio engineers from the Midwestern United States treating broadcast sowing as a metaphor for the dispersal inherent in Omni directional radio signals. Broadcasting is a very large and significant segment of the mass media. Originally all broadcasting was composed of analog signals using analog transmission techniques and more recently broadcasters have switched to digital signals using digital transmission.

Types of Broadcasting

Historically, there have been several types of electronic media broadcasting:

- Telephone broadcasting (1881–1932): the earliest form of electronic broadcasting (not counting data services offered by stock telegraph companies from 1867, if ticker-tapes are excluded from the definition). Telephone broadcasting began with the advent of Théâtrophone ("Theatre Phone") systems, which were telephone-based distribution systems allowing subscribers to listen to live opera and theatre performances over telephone lines, created by French inventor Clément Ader in 1881. Telephone broadcasting also grew to include telephone newspaper services for news and entertainment programming which were introduced in the 1890s, primarily located in large European cities. These telephone-based subscription services were the first examples of electrical/electronic broadcasting and offered a wide variety of programming.
- Radio broadcasting (experimentally from 1906, commercially from 1920):

radio broadcasting is an audio (sound) broadcasting service, broadcast through the air as radio waves from a transmitter to a radio antenna and, thus, to a receiver. Stations can be linked in radio networks to broadcast common radio programs, either in broadcast syndication simulcast or subchannels. History of television broadcasting (telecast), experimentally from 1925, commercial television from the 1930s: this television programming medium was long-awaited by the general public and rapidly rose to compete with its older radio-broadcasting sibling. Cable radio (also called "cable FM", from 1928) and cable television (from 1932): both via coaxial cable, serving principally as transmission mediums for programming produced at either radio or television stations, with limited production of cable-dedicated programming.

- Direct-broadcast satellite (DBS) (from circa 1974) and satellite radio (from circa 1990): meant for direct-to-home broadcast programming (as opposed to studio network uplinks and downlinks), provides a mix of traditional radio or television broadcast programming, or both, with dedicated satellite radio programming. (See also: Satellite television) Webcasting of video/television (from circa 1993) and audio/radio (from circa 1994) streams: offers a mix of traditional radio vision station broadcast programming with dedicated internet radio-webcast programming. The sequencing of content in a broadcast is called a schedule. As with all technological endeavors, a number of technical terms and slang have developed. A list of these terms can be found at List of broadcasting terms. Television and radio programs are distributed through radio broadcasting or cable, often both simultaneously. By coding signals and having a cable converter box with decoding equipment in homes, the latter also enables subscription-based channels, pay-tv and pay-per-view services.

Chapter 3 System Model

Consider a single-cell system as shown in Fig. 1 which is composed of a source (S), a relay (R), and L users denoted as $D_1; D_2; \dots; D_L$, respectively. Among L users, there are L_m multicast users and L_u unicast users. Suppose that transmissions from S to D_i ($i = 1; 2; \dots; L$), S to R , and R to D_i ($i = 1; 2; \dots; L$) suffer from quasi-static fading with independent Rayleigh distribution. Then the channel gains from S to D_i ($i = 1; 2; \dots; L$), S to R , and R to D_i ($i = 1; 2; \dots; L$), h_{SDi} , h_{SR} and h_{RD_i} can be modeled as zero mean, independent, circularly symmetric complex Gaussian random variables with variances 1. As a result, the power gains $|h_{SDi}|^2$, $|h_{SR}|^2$ and $|h_{RD_i}|^2$ are exponentially distributed random variables with parameter 1, i.e., the small-scale fading component is expressed as:

$f_2(x) = \exp(-x)$ (1) the quasi-static fading leads to constant fading for each transmission (two channel uses). The distance from each user to the source (e.g., a base station (BS)) is approximately equal to r_{sd} , the distance from each user to the relay is approximately equal to r_{rd} , and the distance from the relay to the BS is equal to r_{sr} . The additive noise is modeled as a complex Gaussian random variable with variance N_0 . The transmit power at the BS and the relay is assumed as P respectively, then the transmit SNR at the BS and the relay is $\gamma = GP/N_0$ respectively (where G is a constant influenced by the carrier frequency, antenna gain and antenna height, etc.). Besides, it is assumed that the relay can always correctly decode the data from the BS.

3.1 Received SNR Distribution

In this section, the received SNR for a transmission and AF relaying is derived. The received SNR is a measured one at each user terminal in a transmission.

In the opportunistic unicast transmission, in each transmission, the unicast signals are transmitted to the user with the best channel conditions. The best channel user i is the one with the highest received SNR among L_u unicast users, and note that as all the users have the same distance to the BS and the relay, hence in the opportunistic unicast transmission the user selection which is based on both small-scale fading and path-loss can guarantee the fairness among users. The subscript of the selected user is:

$$i = \arg \max_{k=1, \dots, L_u} \{z_k\}$$

AF relaying

The maximum mutual information for AF relaying can be expressed as:

$$\begin{aligned} I_{AF} &= \frac{1}{2} \log_2 \left(1 + \left(\rho \frac{\alpha_{sd}^2}{r_{sd}^n} + \rho^2 \frac{\frac{\alpha_{sr}^2}{r_{sr}^n} \cdot \frac{\alpha_{rd}^2}{r_{rd}^n}}{\rho \frac{\alpha_{sr}^2}{r_{sr}^n} + \rho \frac{\alpha_{rd}^2}{r_{rd}^n} + 1} \right) \right) \\ &= \frac{1}{2} \log_2 \left(1 + \rho \left(\frac{\alpha_{sd}^2}{r_{sd}^n} + \frac{\frac{\alpha_{sr}^2}{r_{sr}^n} \cdot \frac{\alpha_{rd}^2}{r_{rd}^n}}{\frac{\alpha_{sr}^2}{r_{sr}^n} + \frac{\alpha_{rd}^2}{r_{rd}^n} + \frac{1}{\rho}} \right) \right) \\ &= \frac{1}{2} \log_2 \left(1 + \rho \left(\frac{\alpha_{sd}^2}{r_{sd}^n} + \frac{\alpha_{sr}^2 \alpha_{rd}^2}{r_{rd}^n \alpha_{sr}^2 + r_{sr}^n \alpha_{rd}^2 + \frac{1}{\rho} r_{sr}^n r_{rd}^n} \right) \right) \end{aligned}$$

Where α_{sr}^2 denotes the small-scale fading gain between the BS and the relay.

The received SNR for AF relaying can be given as:

$$Z_{AF} = \rho \left(\frac{\alpha_{sd}^2}{r_{sd}^n} + \frac{\alpha_{sr}^2 \alpha_{rd}^2}{r_{rd}^n \alpha_{sr}^2 + r_{sr}^n \alpha_{rd}^2 + \frac{1}{\rho} r_{sr}^n r_{rd}^n} \right)$$

Let $X = \frac{\alpha_{sd}^2}{r_{sd}^n}$, $Y = \frac{\alpha_{sr}^2 \alpha_{rd}^2}{r_{rd}^n \alpha_{sr}^2 + r_{sr}^n \alpha_{rd}^2 + \frac{1}{\rho} r_{sr}^n r_{rd}^n}$ then

$$Z_{AF} = \rho(X + Y)$$

Let $Y_1 = \alpha_{sr}^2$, $Y_2 = \alpha_{rd}^2$ then

$$Y = \frac{Y_1 Y_2}{r_{rd}^n Y_1 + r_{sr}^n Y_2 + \frac{1}{\rho} r_{sr}^n r_{rd}^n}$$

As X and Y are independent, the cumulative distribution function (CDF) of the received SNR Z can be expressed as:

$$\begin{aligned} F_z(z) &= P(\rho(X+Y) \leq z) \\ F_z(z) &= P(\rho(X+Y) \leq z) \\ &= \int_0^{z/\rho} f(x, y) dx \int_0^{z/\rho - x} dy \\ &= \int_0^{z/\rho} f_x(x) dx \int_0^{z/\rho - x} f_y(y) dy \\ &= \int_0^{z/\rho} f_x(x) P\left(Y \leq \frac{z}{\rho} - x\right) dx \\ &= \int_0^{z/\rho} r_{sd}^n e^{-r_{sd}^n x} \left[1 - g\left(\frac{z}{\rho} - x\right) e^{-(r_{sr}^n + r_{rd}^n)\left(\frac{z}{\rho} - x\right)} K_{-1}\left(g\left(\frac{z}{\rho} - x\right)\right) \right] dx \\ &= \int_0^{z/\rho} r_{sd}^n e^{-r_{sd}^n\left(\frac{z}{\rho} - x\right)} \left[1 - g(x) e^{-(r_{sr}^n + r_{rd}^n)x} K_{-1}(g(x)) \right] dx \\ &= \int_0^{z/\rho} r_{sd}^n e^{-r_{sd}^n\left(\frac{z}{\rho} - x\right)} dx - r_{sd}^n e^{-r_{sd}^n z/\rho} \int_0^{z/\rho} e^{-(r_{sr}^n + r_{rd}^n - r_{sd}^n)x} g(x) K_{-1}(g(x)) dx \\ &= 1 - e^{-\frac{r_{sd}^n z}{\rho}} - r_{sd}^n e^{-r_{sd}^n z/\rho} \int_0^{z/\rho} e^{-(r_{sr}^n + r_{rd}^n - r_{sd}^n)x} g(x) K_{-1}(g(x)) dx \\ &= 1 - e^{-\frac{r_{sd}^n z}{\rho}} - \frac{r_{sd}^n}{\rho} e^{-r_{sd}^n z/\rho} \int_0^z e^{-(r_{sr}^n + r_{rd}^n - r_{sd}^n)\frac{x}{\rho}} g\left(\frac{x}{\rho}\right) K_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \end{aligned}$$

Then the probability density function (PDF) of the received SNR Z can be written as

$$\begin{aligned}
 f_z(z) &= \frac{dF_z(z)}{dz} \\
 &= \frac{d \left(1 - e^{-\frac{r_{sd}^n z}{\rho}} - \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \right)}{dz} \\
 &= \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} + \frac{r_{sd}^{2n}}{\rho^2} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \\
 &\quad - \frac{r_{sd}^n}{\rho} e^{-(r_s^n + r_d^n) \frac{z}{\rho}} g\left(\frac{z}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{z}{\rho}\right)\right) \\
 &= \frac{r_{sd}^n}{\rho} \left(e^{-\frac{r_{sd}^n z}{\rho}} + \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \right. \\
 &\quad \left. - e^{-(r_s^n + r_d^n) \frac{z}{\rho}} g\left(\frac{z}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{z}{\rho}\right)\right) \right)
 \end{aligned}$$

3.2 Multicast transmission with AF relaying

As described above, in the multicast transmission with AF relaying, the joint PDF of z_m and i is expressed as:

$$\begin{aligned}
 f_{z_m, i}(z, i) &= f_{z_m, i}(z) \prod_{j=1, j \neq i}^{L_m} [1 - F_{z_m, j}(z)] \\
 &= \frac{r_{sd}^n}{\rho} \left(e^{-\frac{r_{sd}^n z}{\rho}} + \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \right. \\
 &\quad \left. - e^{-(r_s^n + r_d^n) \frac{z}{\rho}} g\left(\frac{z}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{z}{\rho}\right)\right) \right) \\
 &\quad * \left(1 - \left(1 - e^{-\frac{r_{sd}^n z}{\rho}} - \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \right) \right)^{L_m - 1} \\
 &= \frac{r_{sd}^n}{\rho} \left(e^{-\frac{r_{sd}^n z}{\rho}} + \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \right. \\
 &\quad \left. - e^{-(r_s^n + r_d^n) \frac{z}{\rho}} g\left(\frac{z}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{z}{\rho}\right)\right) \right) \\
 &\quad * \left(e^{-\frac{r_{sd}^n z}{\rho}} + \frac{r_{sd}^n}{\rho} e^{-\frac{r_{sd}^n z}{\rho}} \int_0^z e^{-(r_s^n + r_d^n - r_{sd}^n) \frac{x}{\rho}} g\left(\frac{x}{\rho}\right) \mathbf{K}_{-1}\left(g\left(\frac{x}{\rho}\right)\right) dx \right)^{L_m - 1}
 \end{aligned}$$

As described above, all the users in the multicast group have an equal opportunity to be

selected, thus the selection probability of user i is given by

In this section, the performance of the scheduling-based systems is evaluated in terms of ergodic capacity and outage probability using the derived SNR distributions. According to the ergodic capacity of the selected user i of the conventional multicast and opportunistic unicast transmission is expressed as

$$C_i = \frac{1}{2} \int_0^{+\infty} \log_2(1+z) f_{z|i}(z|i) dz$$

The system capacity of a conventional multicast transmission is given by

$$C_m^{\text{sys}} = L_m C_i$$

The system capacity of an opportunistic unicast transmission is given by

$$C_u^{\text{sys}} = C_i$$

Outage probability represents the probability that the affordable SNR value for data transmission is less than a threshold value of Γ . According to the outage probability of a conventional multicast and an opportunistic unicast transmission is given by:

$$\begin{aligned} P^{\text{out}} &= P(Z \leq \Gamma) \\ &= \int_0^{\Gamma} f_{z|i}(z|i) dz \end{aligned}$$

3.3 Performance analysis

In this section, the performance of the scheduling-based systems is evaluated in terms of ergodic capacity and outage probability using the derived SNR distributions. According to (9), (13), (25) and (28), the ergodic capacity of the selected user i of the conventional multicast and opportunistic unicast transmission is expressed as.

$$C_i = \frac{1}{2} \int_0^{+\infty} \log_2(1+z) f_{z|i}(z|i) dz$$

The system capacity of a conventional multicast transmission is given by

$$C_m^{\text{sys}} = L_m C_i$$

The system capacity of an opportunistic unicast transmission is given by

$$C_u^{\text{sys}} = C_i$$

Outage probability represents the probability that the affordable SNR value for data transmission is less than a threshold value of Γ . According to (9), (13), (25) and (28), the outage probability of a conventional multicast and an opportunistic unicast transmission is given by

$$\begin{aligned} P^{\text{out}} &= P(Z \leq \Gamma) \\ &= \int_0^{\Gamma} f_{z|i}(z|i) dz \end{aligned}$$

The hybrid version of detect-and forward is superior to the simple version, so it is used in this comparative study. In these experiments binary phase shift keying (BPSK) modulation is used with coherent detection at the receiver. For comparisons one must take note that, unlike amplify-and-forward and detect-and-forward methods, coded cooperation is inherently integrated into channel coding. In order to present equitable comparisons, we consider a coded baseline system with the same overall rate of 1/4 for all cases: noncooperative, amplify-and-forward, detect-and-forward, and coded cooperation. For both hybrid decode-and-forward and amplify-and-forward, the users initially transmit a RCPC code word punctured to rate 1/2. This code word is subsequently repeated by the relay, resulting in an overall rate of 1/4 (rate 1/2 code, repeated). For coded cooperation, a cooperation level of 25 percent is used. The two users transmit a code word punctured to rate 1/3 in the first frame. In the second frame, the relay transmits the bits punctured from the first frame such that the total bits received for each user form a rate 1/4 code word. The first plot in Fig. 6 illustrates a case in which the user channels to the base station (uplink channels) have the same mean SNR, while the mean SNR of the interuser channel is 10 dB below that of the uplink channels, showing that diversity improves markedly over a comparable noncooperative system. The diversity, indicated by the slope of the block error rate vs. SNR curves at high SNR, is two for cooperation, which is equivalent to the diversity provided by standard two-antenna transmit or receive diversity schemes. This experiment also demonstrates the robustness of cooperative communication to the conditions of the interuser channel: cooperation provides substantial improvement in error rate performance even when the interuser channel quality is poorer than that of

the uplink channels. The second plot illustrates a case in which the mean uplink SNR for user 1 is 10 dB higher than that of user 2, while the interuser mean SNR is equal to that of the uplink channel for user 2. Two significant results of cooperation can be noted. First, user 2, as one might expect, improves significantly by cooperating with a user that has a better quality uplink channel. More interestingly, however, user 1 also improves significantly, despite cooperating with a user having a poorer quality uplink channel. This result illustrates that even a user with a good uplink channel has strong motivation to cooperate. Second, we note that the difference in performance between users 1 and 2 is significantly reduced by the cooperation methods. This shows that cooperation inherently reallocates the system resources in a more effective manner. In comparing the three cooperative transmission schemes, we see that both amplify-and-forward and hybrid decode-and-forward are not very effective at low SNR. This is due to the fact that their signaling is equivalent to repetition coding, which is relatively inefficient at low SNR.

Chapter 4 Numerical Result

In this section, numerical results of the scheduling-based systems are given in terms of ergodic capacity and outage probability by Monte Carlo simulations. As mentioned above, system capacity of the traditional multicast transmission is the ergodic capacity of the worst channel user multiplied by the number of the users in the multicast group while in the opportunistic unicast transmission only the best channel user in the unicast group contributes to the system capacity. Outage probability is measured by the instantaneous worst channel user in the multicast group and the instantaneous best channel user in the unicast group, respectively. Simulation parameters are notated in Tab.1 and numerical results are as follows.

Tab.1 Simulation parameters

Transmit power	$P=10\text{W}$
Channel bandwidth	10MHz
Thermal noise density	$4 \times 10^{-15} \text{ W/Hz}$
Path loss exponent	$n=2.5$
Gain constant	$G=0.0270$
SNR threshold	$\Gamma = -5\text{dB}$

4.1 System capacity

As shown in Fig.2 and Fig.4, given the distance of r_{rd} (e.g., $r_{rd} = 600\text{m}$), as the number of users increases, ergodic capacity of the traditional multicast and opportunistic unicast transmission with DF and AF relaying will increase. However, multicast transmission utilizes multicasting to achieve multicast gain and unicast transmission exploits channel variation to achieve a multiuser diversity gain .

When pass loss is fixed, multicast gain has more advantage than multiuser diversity gain, and thus ergodic capacity of the traditional multicast transmission grows

faster than that of opportunistic unicast transmission. After all, system capacity of traditional multicast transmission is measured by the ergodic capacity of the worst channel user in the multicast group multiplied by L_m (the number of multicast users). However, note that not necessarily is the multicast capacity always greater than the corresponding unicast capacity. For example, unicast capacity is greater than the multicast capacity for $r_{rd} = 900m$ and $L_m(L_u) = 2$, and approximately equal to for $r_{rd} = 900m$ and $L_m(L_u) = 3$, respectively, as described in Fig.4.

As shown in Fig.3 and Fig.5, given the number of users (e.g., 4), as the distance of r_{rd} varies from 600m to 900m, ergodic capacity of traditional multicast and opportunistic unicast transmission will decrease, which means an increase in the distance of r_{rd} yields a totally reduced SNR at each multicast and unicast user, and thus the relay has to transmit at a lower data rate. However, traditional multicast transmission selects the data rate depending on the worst channel user in the multicast group while opportunistic unicast transmission selects the data rate depending on the best channel user in the unicast group, opportunistic unicast transmission more adapts to channel variation (enjoying multiuser diversity gain) than traditional multicast transmission, and thus ergodic capacity of traditional multicast transmission reduces faster than that of opportunistic unicast transmission even though system capacity of traditional multicast transmission is measured by the ergodic capacity of the worst channel user in the multicast group multiplied by L_m . This trend goes on with the increase of the distance of r_{rd} , e.g., the multicast capacity is already less than unicast capacity for $r_{rd} = 900m$ and $L_m(L_u) = 2$, as illustrated in Fig.5.

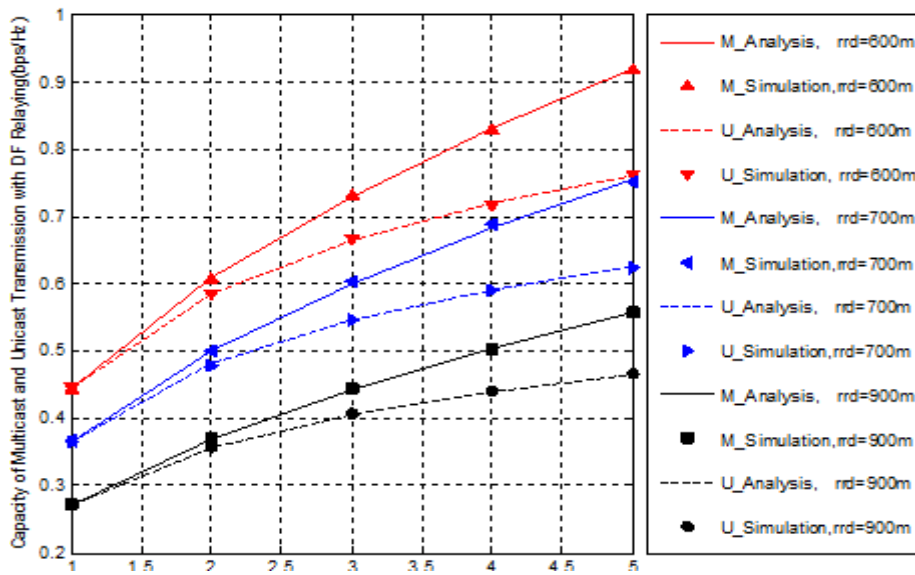


Fig. 2. Capacity of multicast and unicast transmission with DF relaying for varying the number of users ($r_{sr}=400m, r_{sd}=1000m$)

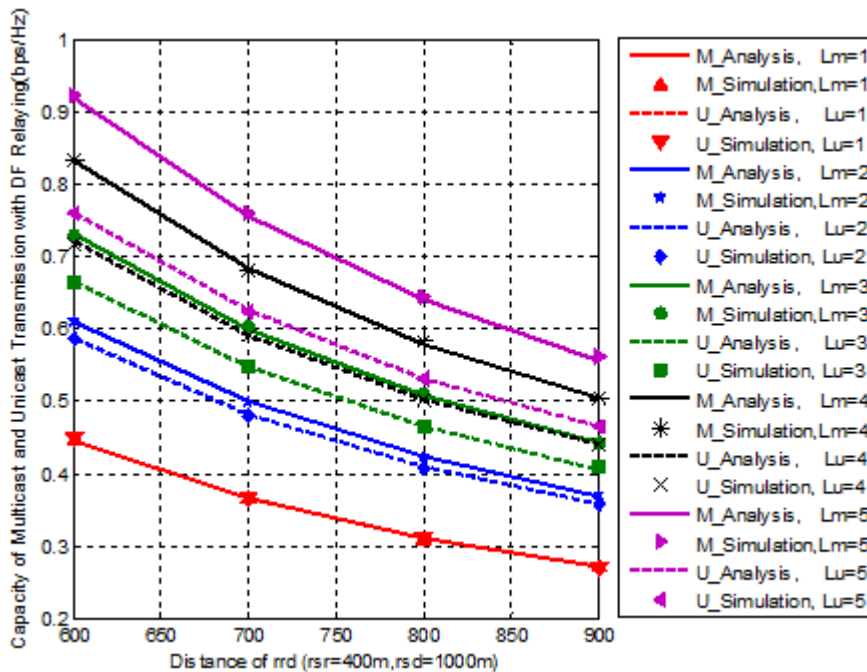


Fig. 3. Capacity of multicast and unicast transmission with DF relaying for varying the distance of r_{rd} ($r_{sr}=400m, r_{sd}=1000m$)

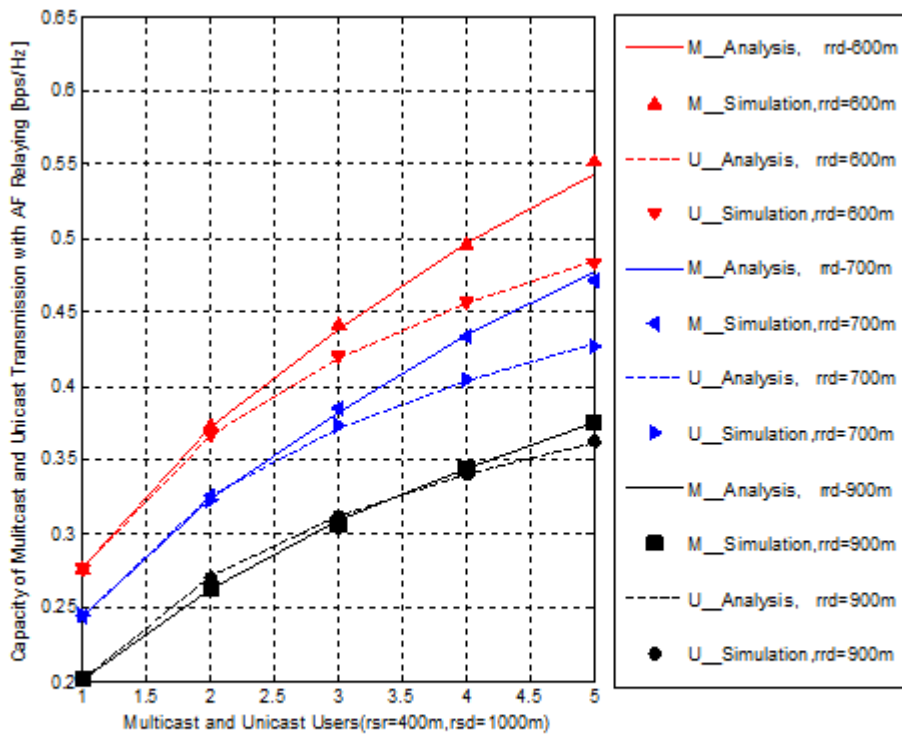


Fig. 4. Capacity of multicast and unicast transmission with AF relaying for varying the number of users ($r_{sr}=400m, r_{sd}=1000m$)

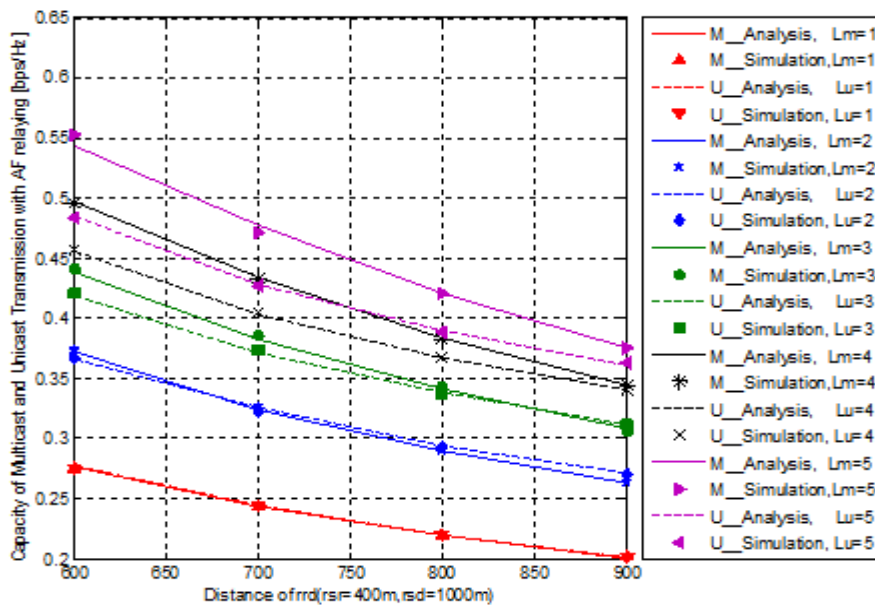


Fig. 5. Capacity of multicast and unicast transmission with AF relaying for varying the distance of r_{rd} ($r_{sr}=400m, r_{sd}=1000m$)

As shown in Fig.6, given $r_{sr} = 400m$, $r_{rd} = 600m$, and $r_{sd} = 1000m$, as the number of users increases, multicast capacity and unicast capacity with DF and AF relaying will increase, however, multicast capacity and unicast capacity with DF relaying is greater than that with AF relaying, respectively. As shown in Fig.7, given the number of users of 3, as the distance of r_{rd} varies from 600m to 900m, multicast capacity and unicast capacity with DF and AF relaying will reduce, however, multicast capacity and unicast capacity with DF relaying are still greater than that with AF relaying respectively. Therefore, performance with DF relaying is better than that with AF relaying in terms of capacity. By the way, all the figures of capacity show that the analytical results are well matched with computer simulation results over 20000 simulation runs. In addition, we can get the same results by illustrating ergodic capacity of traditional multicast and opportunistic unicast transmission for varying the distance of r_{sd} and the number of users (where $r_{sr} = 400m$, $r_{rd} = 1000m$)

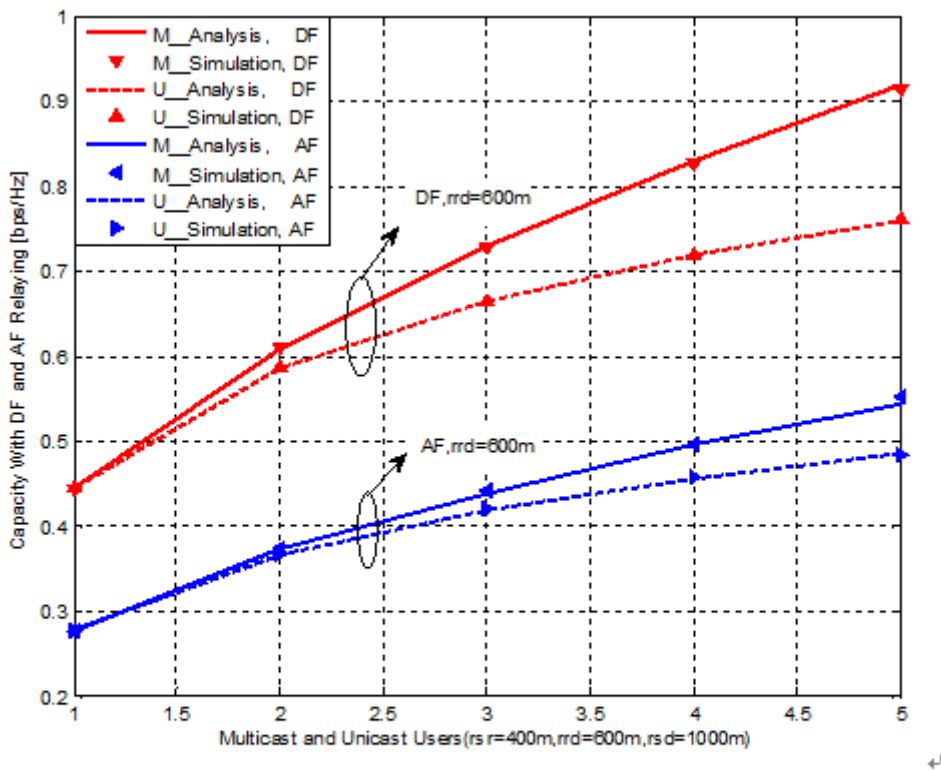


Fig. 6. Capacity of multicast and unicast transmission with DF and AF relaying for varying the number of users ($r_{sr} = 400m$, $r_{sd} = 1000m$)

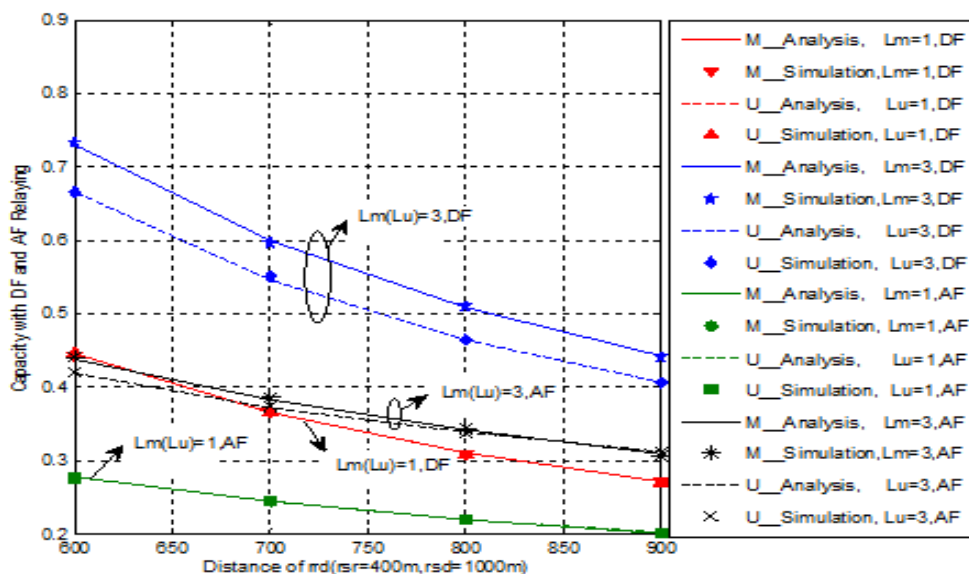


Fig. 7. Capacity of multicast and unicast transmission with DF and AF relaying for varying the distance of r_{rd} ($r_{sr}=400m, r_{sd}=1000m$)⁴

4.2 Outage Probability

As shown in Fig.8 and Fig.10, given the distance of r_{rd} (e.g., $r_{rd}=600m$), as the number of users increases, the outage probability of the opportunistic unicast transmission decreases while that of the traditional multicast transmission increases. The reason is that as the number of users increases, the chance of finding the best channel user in the unicast group increases while the chance of finding the worst channel user in the multicast group also increases. As a result, the selected best channel user in the opportunistic unicast transmission can be easily higher than the given target SNR value of Γ , while the selected worst channel user in the traditional multicast transmission can be easily lower than the given target SNR value of Γ relaying is below 1% regardless of the different distance of r_{rd} , as described in Fig.9

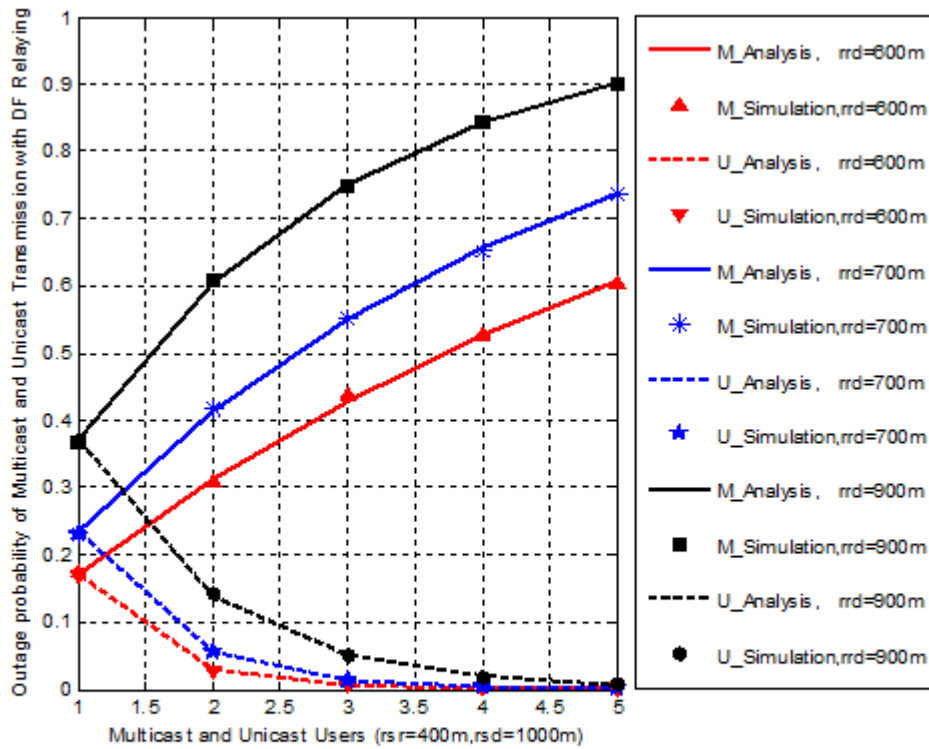


Fig. 8 Outage probability of multicast and unicast transmission with DF relaying for varying the number of users ($r_{sr}=400m$, $r_{sd}=1000m$)

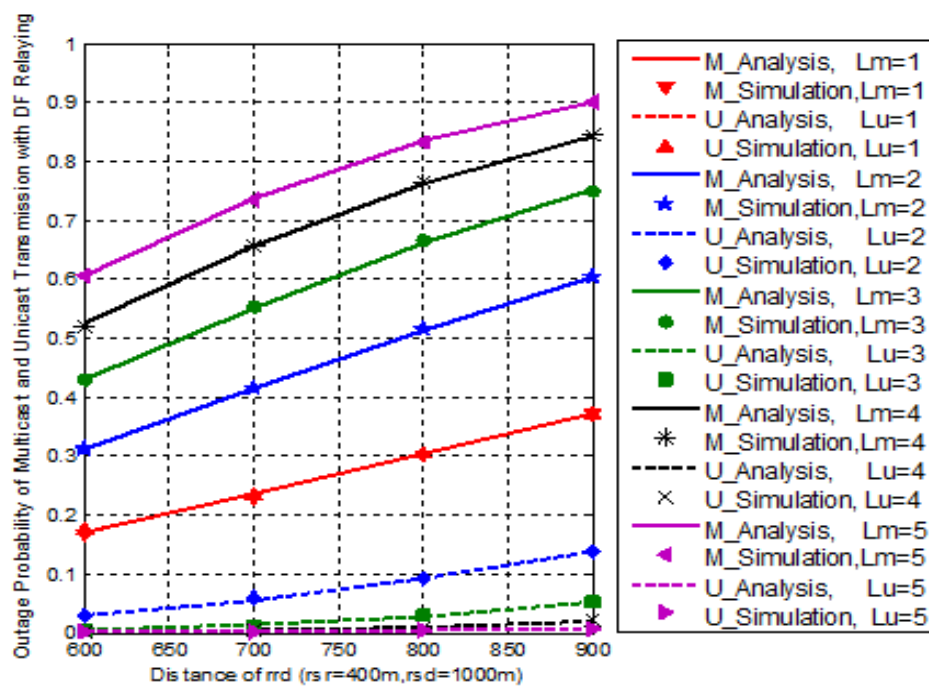


Fig. 9 Outage probability of multicast and unicast transmission with DF relaying for varying the distance of r_{rd} ($r_{sr}=400m$, $r_{sd}=1000m$)

As shown in Fig.9 and Fig.11, given the number of users (e.g., 4), as the distance of r_{rd} varies from 600m to 900m, the outage probability of traditional multicast and opportunistic unicast transmission increases, however, the outage probability of the traditional multicast transmission increases faster than that of the opportunistic unicast transmission. The reason is that as the distance of r_{rd} increases, the received SNR of each user is reduced, and the chance of decoding the best channel user in the unicast group decreases while the chance of decoding the worst channel user gets even worse. However, when the number of users is up to 5, outage probability of opportunistic unicast transmission with DF relaying is below 1% regardless of the different distance of r_{rd} , as described in Fig.9.

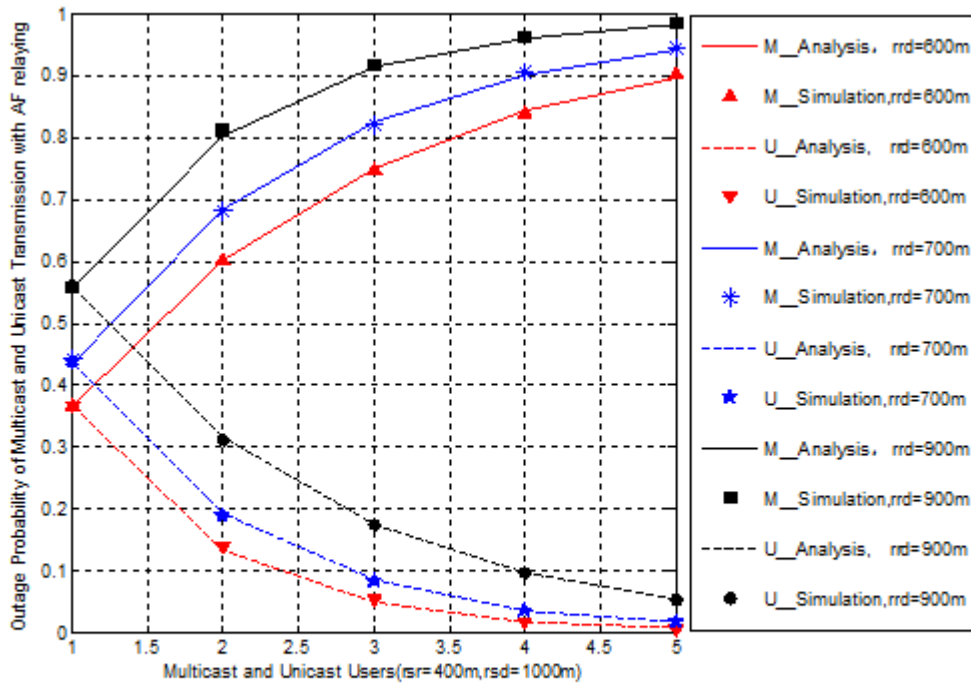


Fig. 10 Outage probability of multicast and unicast transmission with AF relaying for varying the number of users ($r_{sr}=400m, r_{sd}=1000m$)

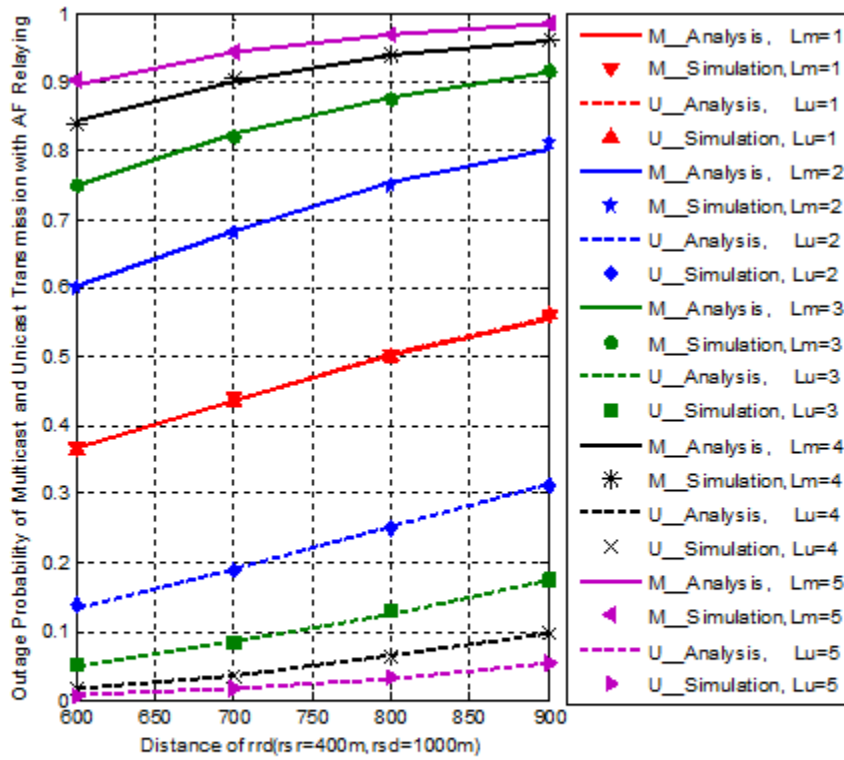


Fig. 11 Outage probability of multicast and unicast transmission with AF relaying for varying the distance of r_{rd} ($r_{sr}=400m, r_{sd}=1000m$)

As shown in Fig.12, given $r_{sr} = 400m, r_{rd} = 600m$, and $r_{sd} = 1000m$, as the number of users increases, outage probability of multicast transmission will increase and outage probability of unicast transmission will reduce regardless of DF or AF relaying, however, outage probability of multicast transmission and unicast transmission with DF relaying is less than that with AF relaying, respectively. As shown in Fig.13, given the number of users of 3, as the distance of r_{rd} varies from 600m to 900m, outage probability of multicast transmission and unicast transmission with DF and AF relaying will increase, however, outage probability of multicast transmission and unicast transmission with DF relaying is still less than that with AF relaying, respectively. Therefore, performance with DF relaying is better than that with AF relaying in terms of outage probability. By the way, we can get the same results by illustrating outage probability of traditional multicast and opportunistic unicast transmission for varying the distance of r_{sd} and the number of users (where $r_{sr}=400m$, and $r_{rd}=1000m$). Also, all the figures of outage probability show that the analytical results are well matched with computer simulation results over 20000 simulation runs.

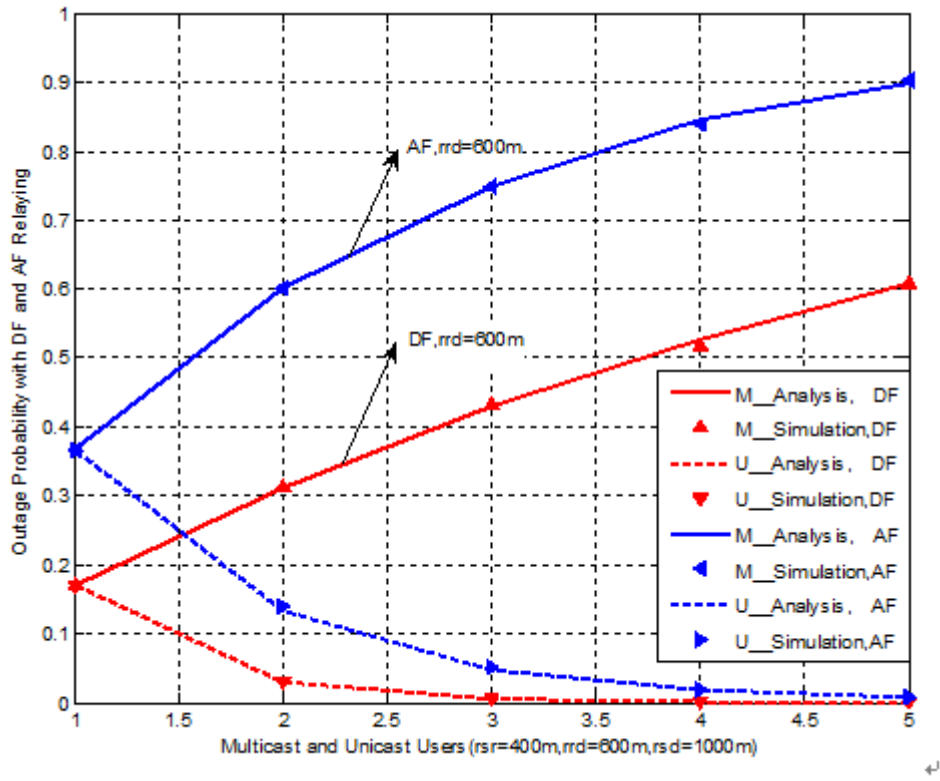


Fig. 12 Outage probability of multicast and unicast transmission with DF and AF relaying for varying the number of users ($r_{sr}=400m, r_{sd}=1000m$)

Chapter 5 Conclusions

. In this paper, a hybrid multicast and opportunistic unicast transmission scheme with DF and AF relaying is proposed, in which multicast transmission utilizes multicasting to achieve multicast gain and increase system capacity while unicast transmission exploits channel variation to achieve multiuser diversity gain and reduce outage probability, thereby securing the QOS requirements of unicast users. Monte Carlo simulations confirm the presented mathematical analysis. Numerical results also show that multicast transmission and unicast transmission with DF or AF relaying can play their respective advantages under certain conditions, and the overall performance with DF relaying is better than that with AF relaying. Most of all, this paper provides a novel basic model for further research.

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