Master Thesis

Performance Analysis of Multicast and Opportunistic Unicast Transmission with Amplify-and-Forward Relay

Specialty: Mobile Communication and Wireless Technology

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Abstract

In this work, a hybrid multicast and opportunistic unicast transmission scheme proposed with Amplify-and-Forward (AF) relaying in wireless cellular networking 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 article that deals with the SNR distributions of multicast and unicast with AF relay. The numerical results image that the analytical results are well adapted to the results of the computer simulations on more than 20000 simulations, the overall performance of the system based on the scheduling with DF relay is better than that with the AF relay and the multicast and unicast transmission with Relay AF 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, whereof, 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. Meantime, the NCBC multicast scheme can reach full diversity gain (diversity two for one relay case). Comparing with the known relay scheme, 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

Contents

1 Introduction

With the construction of highway, the speed of the car has been improved [1], the traditional automobile suspension can't adapt to the variability of driving conditions and road excitement……Relay systems have been widely studied in wireless communications as a way to overcome deep fading and thus improve signal quality in multi-path fading channels. The relaying network, signal is transmitted in the first state from a source (S) to a relay (R) and the second signal to the relay (R) is transmitted to the destination (D). At a same time, the source (S) will transmit an additional copy of the signal directly to the destination (D). Therefore, the signal is transmitted from the source (S) directly and via a relay (R), so, the destination will receive the transmitted signal from two links referred as source-relay-destination and source-destination link. Currently the signal received at the relay is forwarded to the destination by attainment two schemes known as amplify forward (AF) and decoded forward (DF). In AF, the received signal at relay is amplified and re-transmitted. In DF, the received signal at relay is decoded then retransmitted furthermore to destination. Previously research was focused on employing single-and multi-antenna system for cooperative diversity technique to exploit fading channels. In the symbol error probability was derived for dual hop with single antenna in Rayleigh and Nakagami m-fading channels and the outage performance of communication system was scrutinized for AF and DF relaying network. Here, the relays and users cooperate in sharing information which in turn increment capacity and coverage area of wireless.

From their introduction in Amplify-and-Forward (AF) relay schemes have been investigates in the context of cooperative communication, estimating the capacity of relay networks, and analog network coding. For cooperating communication, AF scheme provide special diversity to fight against fading; for capacity assessment of relay networks, such schemes provides achievable lower bounds that are known to be optimal in some communication scenarios; and for analog networks coding, given the broadcast nature of the wireless medium that allows the mixing of the signals in the air, to provides a communication strategy that achieves high throughput with low computational complexity at the relay. In this paper, we alarm ourselves mostly with the capacity analysis of a general class of Gaussian AF relay networks.

1.1 Evolution of Cellular Technology

All over the world, wireless communications services have grown dramatically over the past 25 years. Until late 1983 that the first commercial cellular phone in the United States was deployed by Ameritech in the Chicago area. This was called Advanced Mobile Phone Service (AMPS). Today, digital cellular telephony services are available all over the world and have well surpassed fixed telephony services in terms of availability and number of users. Indeed, in March 2010, we have more than 4.8 billion mobile subscribers in the world, which is more than double the number of subscribers to the fixed line and reaches a penetration of more than 60%. The relative adoption of wireless in relation to the fixed line is even more dramatic in the developing world. For example, in India, wireless penetration is more than four times that of fixed line. It took less than 20 years for mobile subscribers around the world to go from zero to more than a billion users. This amazing growth not only demonstrates the desire of people around the world to communicate with each other and to access information while traveling, but also the enormous advances made by technology satisfy and further fuel this need. Developments in manufacture of RF circuits, advanced digital signal processing, and several miniaturization technologies that enable the deployment and delivery of wireless communication services to scale and scope that we see today are quite remarkable.

Today, we are on the threshold of another major wireless revolution. While mobile voice telephony has led past growth of wireless systems and still remains the main application, it is widely clear that wireless data applications will be the impetus for its future growth. Over the past two decades, the Internet has become a curious academic tool to an indispensible global information network providing a wide range of services and applications ranging from e-mail, social network and e-commerce to entertainment. As illustrated in Figure 1.1, global wireless growth over the past decade has been accompanied by a parallel growth in Internet usage. Globally, more than 1.5 billion people use the Internet today and over 500 million subscribers to Internet access services; of these more than 400 million have broadband or high-speed connections to the Internet. The United States, have more than 60% of households broadband access to the Internet.

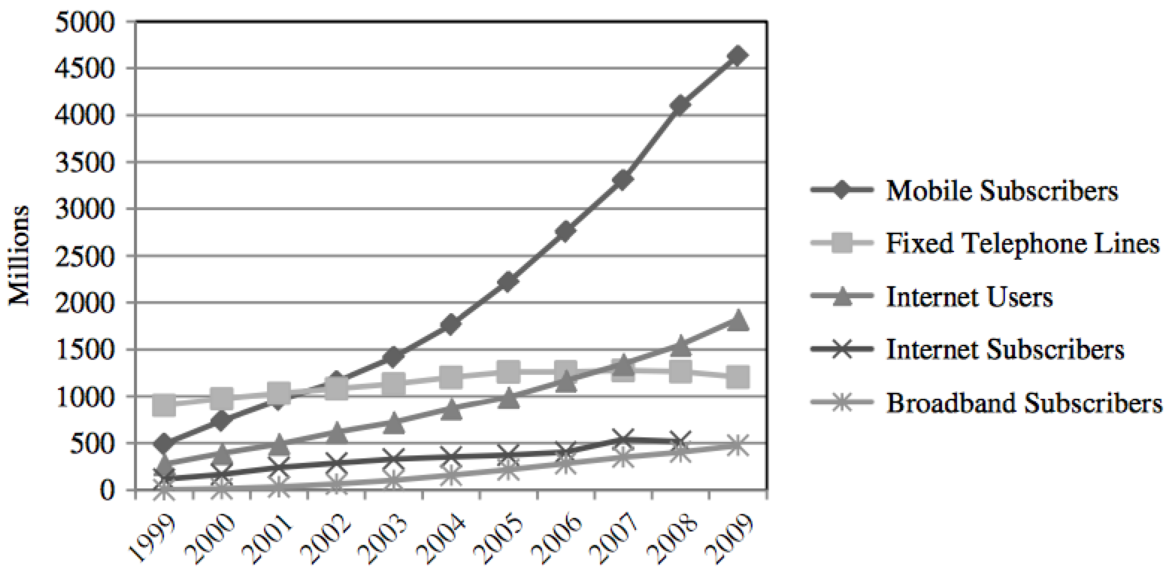


Fig. 1.1 Global growth of mobile, Internet and broadband from (1998-2009)

Users around the world are finding that having broadband access to the Internet greatly changes the way we share information, conduct business, and seek entertainment. Broadband access not only let you browse faster on Web and download faster, but also enables several multimedia applications, such as streaming audio and video in real time, multimedia conferencing, and interactive gaming. Those who have experienced the richness and variety of applications accessible through broadband services in their home or office now clamor for a similar experience wherever they are and while on the move. Providing true broadband experience to mobile users is the next frontier for wireless, and Long-Term Evolution (LTE), the subject of this book, is a key enabling technology for delivering mobile broadband.

In this chapter we provide an overview of the evolution of mobile communication systems. We begin with a brief history of wireless communications and trace the evolution of cellular systems and development standards to the state of the art. We then cover the LTE market and the main technical requirements for its development. In the subsequent section, we describe the key ingredient technologies that enable LTE's superior performance. We then present a brief overview of the LTE architecture and discuss the spectrum options and migration strategies for operators interested in deploying LTE.

First Generation (1G)

1G is the first generation wireless telephone technology, cell phones. They were analog cell phones and were introduced in 1980. Around 1979, the first cellular system in the world set off operational by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan. In Europe two most popular analog systems were Nordic Mobile Telephone (NMT) and (TACS) other analog systems were also introduced in 1980's across the Europe. All the systems offered handover and roaming capability but the cellular networks were unable to interoperate between countries. This was the main drawback of First Generation mobile networks. 1G has low capacity unreliable handoff, poor voice links and no security since voice calls were played back in radio towers making these calls susceptible to unwanted. In USA AMPS was first 1G standard launched in 1982. AMPS system was allocated a 40 MHZ bandwidth within the 800-900 MHZ frequency range by the federal Communication Commission (FCC). Around 1988 additional 10 MHZ bandwidth, name expanded spectrum (ES) was allocated to AMPS.

1G technology replaced 0G technology, which featured mobile radio telephones and such technologies as Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), Improved Mobile Telephone Service (IMTS), and Push to Talk (PTT).

1. Developed in 1980s and completed in early 1990's
2. 1G was old analog system and supported the 1st. generation of analog cell phones speed up to 2.4kbps
3. The Advance mobile phone system (AMPS) was first launched by the US and is a 1G mobile system
4. Allows users to make voice calls in 1 country

Second Generation Technology (2G TO 2.7 G)

2G is the Second-Generation wireless cell phones, based on digital technologies and in early 1990's. In 1991 2G was launched in Finland. 2G provided services such as text message, picture messages and MMS. 2G has greater security for both sender and receiver. Every text messages are digitally encrypted, which enables for the transfer of data in such a way that only intended receiver can receive and read it. 2G system involves digital mobile access technology such as TDMA and CDMA. TDMA divides signal in time slots while as CDMA allocates each user a special code to communicate over a multiplex physical channel. Different TDMA technologies are GSM, PDC, iDEN , iS-136. GSM was first 2G System. CDMA technology is IS-95. GSM (Group Special Mobile) has origin from Europe. GSM is most commend standard of all the mobile technologies customary in more than 212 countries, in the world. GSM standard performs international roaming very common between mobile phone operators, enabling subscribers to use their phones in many parts of the world. GSM uses TDMA to multiplex up to 8 calls per channel in the 900 and 1800 MHZ bands. GSM can't only deliver voice and also circuit switched data at speed up to 14.4kbps. In US FCC also auctioned a prior block of spectrum in the 1900MHZ band. During 20 years, GSM technology has been incessantly improved to offer better services in the market. A new technology has been developed based on the original GSM system, leading to some advanced system, known as 2.5 generation (2.5 G) Systems.

2.5G – GPRS (General Packet Radio Service)

GPRS is extension of existing 2G networks to have the capacity of launching packet based services while enhancing the data rates supported by these networks. The term "Second and a half generation" is used to describe 2G-Systems that have implemented a packet switched domain in addition to circuit switched domain. "2.5 G" is an informal term. GPRS provided data rates from 56 Kbps up to 384 Kbps, using database HLR, VLR, EIR, and AuC with HSCSD, GPRS and EDGE technologies. It supply services such as Wireless Application Protocol (WAP) access, Multimedia Messaging Service (MMS) and for internet communication services such as e-mail and World Wide Wireless Web (WWW) access. GPRS data transfer is characteristically charged per megabyte of traffic transferred, while data communication via traditional circuit switching is billed per minute of connection time, independent of if the user actually is utilizing the capacity or is in an idle state. 2.5G networks may support services such as WAP, MMS, SMS mobile games, and search directory and well internet access.

2.75 – EDGE (Enhanced Data rates for GSM Evolution)

GPRS network s evolved to EDGE networks with the introduction of 8PSK encoding. Enhanced Data rates for GSM Evolution, Enhanced GPRS (EGPRS), or IMT Single Carrier (IMT-SC) is a backward-compatible digital mobile phone technology that allows improved data transmission rates, as an extension on top of standard GSM. EDGE was deployed on GSM networks commencement in 2003 initially by Cingular (now AT & T) in the United States.

EDGE is standardized by 3GPP as part of the GSM family, and it is an upgrade that supply a potential three-fold increase in capacity of GSM/GPRS networks. The specification achieves higher data –rates (up to 236.8 Kbits/s) by switching to more sophisticated methods of coding (8PSK), within existing GSM timeslots. EDGE technology is an extended version of GSM. It allows the clear and fast transmission of data and information. It is also termed as IMT-SC or single carrier. EDGE technology was concocted and introduced by Cingular, which is now known as AT& T. EDGE is radio technology and is a part of third generation technologies. EDGE technology is preferred despite GSM due to its flexibility to carry packet switch data and circuit switch data. EDGE transfers data in fewer seconds if we assimilate it with GPRS Technology. As an example of typical text file of 40KB is transferred in only 2 seconds as compared to the transfer from GPRS technology, which is 6 seconds. The biggest advantage of using EDGE technology is one does not need to install any supplementary hardware and software in order to make use of EDGE Technology. There are no additional charges for exploiting this technology. If a person is an ex GPRS Technology user he can utilize this technology without paying any supplementary charges.

Keys:-

1. In between 2G and 3G there is another generation called 2.5G.
2. 2.5G represents handsets with data capabilities over GPRS.
3. But this has not brought out any revolution.

Migration path towards 3G Wireless Systems

Soon, a greater demand to remove the distinction between fixed and mobile networks will become apparent. Access to the Internet and Intranets, Teleworking and the advent of the Virtual office are concepts which will become more common place in the near future. For the third generation communication system, the challenge will be the globalization and convergence of office and home applications and services with the help of new communication tools. However, the situation is not the simple. The variety of communication systems in the market today, as discussed above, across different geographical locations, with their own economic, political, regulatory and social issues, make it difficult to bring all the players together to one single convergence point. There are large investments involved already and it is extremely difficult if not possible to develop standards right from scratch. Let’s keeping this in mind, it has been recognized that a standard should be contracted that accommodates the backward-compatibility of the existing networks, while at the same time defining a common framework under which these networks can evolve. This will be an evolution from each of the regional second generation systems – wireless and wireline- and will satisfy market demands for global roaming, service portability and multimedia, allowing for differentiation of services and products.

3G

3G is the third generation of mobile phone standards and technology, superseding 2G, and preceding 4G. It is based on the International Telecommunication Union (ITU) who formulated a plan to implement global frequency band in the 2000 MHZ range, which will support a single, ubiquitous wireless communication standard for all countries throughout the world. This paln is called International Mobile Telephone 2000 (IMT-2000), Standard. 3G evolution for CDMA systems lead to Cdma 2000. Several variants of CDMA 2000 are based on IS-95 and IS- 95B technologies. 3G evolution for GSM is IS-136 and PDC System lead to wideband CDMA (WCDMA), also called Universal Mobile Telecommunication Service (UMTS) , W-CDMA is based on GSM network. Cdma 2000 and W-CDMA, will remain main 3G technology popular. 3rd. Generation Partnership Project (3GPP) has continued that work by defining a mobile system that fulfills the IMT-2000 standard. 3G technologies enable network operators to tender users a wider range of more advanced services whilst achieving greater network capacity through improved spectral efficiency. Services include wide area wireless voice telephony, video calls, and broadband wireless data, mobile television, GPS (global positioning system) and video conferencing all in a mobile environment.

3.5 G – HSDPA (High-Speed Downlink Packet Access)

High-Speed Downlink Packet Access(HSDPA) is a mobile telephony protocol, also called 3.5G (or "3½ G"), which provides a smooth evolutionary path for UMTS-based 3G networks allowing for higher data transfer speeds. HSDPA is a packet-based data service in W-CDMA downlink along data transmission up to 8-10 Mbit/s (and 20 Mbit/s for MIMO systems) over a 5MHz bandwidth in WCDMA downlink. HSDPA implementations encopass Adaptive Modulation and Coding (AMC), Multiple-Input Multiple- Output (MIMO), Hybrid Automatic Request (HARQ), fast cell search, and advanced receiver design.

3.75G – HSUPA (High-Speed Uplink Packet Access)

The 3.75G refer to the technologies beyond the well specified 3G wireless/mobile technologies. High Speed Uplink Packet Access (HSUPA) is a UMTS / WCDMA uplink evolution technology. The HSUPA mobile telecommunications technology is directly allied to HSDPA and the two are complimentary to one another. HSUPA will enhance advanced person-to-person data applications with higher and symmetric data rates, like mobile e-mail and real-time person-to-person gaming. Traditional business applications along with many consumer applications will benefit from enhanced uplink speed. HSUPA will at the outset boost the UMTS / WCDMA uplink up to 1.4Mbps and in later releases up to 5.8Mbps.

Future Trends

Future 3G technologies such as EDGE, UMTS, IVRS, and Broadband will enable a larger amount of data that can be exchanged while on the move and will determine the path the wired and wireless computing field will take. These will create the need for convergence of digital appliances, assimilation of the technologies, fading of content distribution boundaries and therefore, the need to provide a common framework for organizations to meet these challenges. It isn't tough anymore to imagine the near future where the small machine in the pocket will replace a variety of appliances that a person needs to carry — mobile phones, personal computer, driver license, credit card, remote control, security device, smart cash, etc. All combined in a single device.

4G is a concept of inter-operability between different sorts of networks, which is all about high speed data transfer such as 0-100MBPS of either the server or the data receiver set is moving at a speed of 60 Kmph. If the server and the receiver are stationary, the data transfer would be a minimum of 1GBPS. 4G is the next generation wireless networks that will replace 3G networks sometimes in future. In other context, 4G is simply an initiative by academic, R & D labs to move beyond the limitations and problems of 3G which is having trouble getting deployed and meeting its promised performance and throughput.

These days in 3G we can access the internet through our mobile phone with the help of various technologies, like Wi-Fi, Wi-Max, GPRS, EDGE, WAP and Wi-Bro. to another.

Expected issues considered to be resolved in this 4G mobile technology which are as under:

- It is considered to embed IP feature in the set for more security purpose as high data rates are send and receive through the phone using 4G mobile technology.

- 4G mobile technology is going to be able to download at a rate of 100Mbps like mobile access and less mobility of 1GBps for local access of wireless
- Instead of hybrid technology used in 3G with the combination of CDMA and IS-95 a new technology OFDMA is introduced 4G. In OFDMA, the concept is again of division multiple accesses but this is neither time like TDMA nor code divided CDMA rather frequency domain equalization process symbolizes as OFDMA.
- CDMA sends data through one channel but with the division of time in three slots. While CDMA also sends data through one channel identifying the receiver with the help of code. Whereas in 4G mobile technology OFDMA is going to introduce in which data packets sends by dividing the channel into a narrow band for the greater efficiency comprises a prominent feature of 4G mobile technology.
- IEEE 802.16m is processing for the IEE802.16e comprising the 4G brand will define it as WMBA (Wireless Mobile Broadband Access). This is a plain indicator for the internet availability. The implementation is in progress to avoid the call interference in case of data download from a website. It will propose 128 Mbps downlink data rate and 56Mbps uplink data rate which is an extra ordinary step in 4G mobile technology. The service will limit as the availability of hotspot is condition for the internet connectivite. Parallel with WiMAX, LTE is intended to incorporate in 4G mobiles. It is also a wireless technology for the broadband access. The difference between WiMAX and LTE is that LTE goes for the IP Address. It follows the same TCP / IP concept inherited from networking technology. Restricted for the IP addresses it will provide great security as well as high data transferability, avert latency, having the ability to adjust the bandwidth. LTE is compatible with CDMA so fit to back n forth the data in between both networks.
- 3GPP Organization is going to introduce two major wireless standards; LTE and IEEE802.16m. Former is granted permission for the further process while second is under consideration and that will become a part of 4G mobile technology.
- IPv6 is approved by Version as a 4G standard on June 2009.

FIFTH GENERATION (5G)

5G (5th generation mobile networks or 5th generation wireless systems) is the name used in some research papers and projects to indicate the next major phase of mobile telecommunications standards over the upcoming 4G standards, which are expected to be finalized between approximately 2011 and 2013. Nowdays 5G is not a term officially used for any particular specs and in any official document yet made public by telecommunication companies or standardization bodies such as 3GPP, WiMAX Forum or ITU-R. New 3GPP standard releases over 4G and LTE Advanced are in improvement, but not well-respected as new mobile generations. 5G network is assumed as the perfection level of wireless communication in mobile technology. Cable network is now become the memory of past. Mobiles are not only a communication tool but also serve many other purposes.

All the previous wireless technologies are entertaining the ease of telephone and data sharing but 5G is bringing a new touch and making the life real mobile life. The new 5G network is expected to enhance the services and applications offered by it. This paper concludes by looking back at existing wireless technologies and summarizing the next generation wireless communication media in the following table. These technologies, in fact, come a long way to exciting of amazing products are bound to emerge in the years to come.

FUTURE SCOPE:-

5G network technology will open a new era in mobile communication technology. The 5G mobile phones will have access to different wireless technologies at the same time and the terminal should be able to combine different flows from different technologies. 5G technology offers high resolution for crazy cell phone user. We can watch TV channels at HD clarity in our mobile phones without any interruption. The 5G mobile phone will be tablet PC Many mobile embedded technologies will evolve.

Tab. 1.1 Cellular Network Evolution

Generation	Speed	Technology	Time Period	Features
1G	14.4 Kbps	AMPS, NMT, TACS	1970-1980	During 1G Wireless phones are used for voice only
2G	9.6/14.4 Kbps	TDMA, CDMA	1990 to 2000	2G capabilities are achieved by allowing multiple users on a single channel via multiplexing. 2G Cellular are used for data also along with voice.
2.5G	171.2 Kbps 20-40 Kbps	GPRS	2001-2004	2.5G the internet becomes popular and data becomes more relevant.2.5G Multimedia services and streaming starts to show growth. Phones start supporting web browsing though limited and very few phones have that.
3G	3.2 Mbps 500-700 Mbps	CDMA 200 (1xRTT, EVDO) UMTS, EDGE	2004-2005	3G has Multimedia services support along with streaming are more popular. In 3G, Universal access and portability across different device types are made possible. (Telephones, PDA's, etc.)
3.5G	14.4 Mbps 1-3 Mbps	HSPA	2006-2010	3.5G supports higher throughput and speeds to support higher data needs of the consumers.

4G	100-300 Mbps 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax LTE Wi-Fi	Now	Speeds for 4G are further increased to keep up with data access demand used by various services. High definition streaming is now supported in 4G. New phones with HD capabilities surface. It gets pretty cool. In 4G, Portability is increased further. World-wide roaming is not a distant dream.
5G	Probably gigabits	Not Yet	Soon (Probably 2020)	Currently there is no 5G technology deployed. When this becomes available it will provide very high speeds to the consumers.

1.2 Previous Work

With a growth in the number of cellular subscribers, and the scarcity of frequency spectrum, cellular systems have encountered difficulties in providing a satisfactory signal to noise ratio (SNR) to users, particularly to those at the cell edge.

Various cooperative relay programs have been probed in the literature because their deployment in wireless networks has potential to bid a number of significant performance advantages, including hotspot throughput improvements and signal coverage improvements cellular. The advantages of cooperative diversity come are to the detriment of a loss in spectral efficiency from the source and relay transmitting in orthogonal channels. The inefficient use of the channel resources can be mitigated by relay. In the diagram, a single relay for retransmission to the destination. Hence, only two orthogonal channels are required in this case. It was shown in the relay with end-to-end path between the source and the destination, a diversity gain which require channel state information (CSI).

A cell phone is a full-duplex device. This means you can use one frequency for talking and a second, separate frequency for listening. Both people on the call can talk at once.

Division of a city into small cells, which allows extensive frequency reuse across a city, so that millions of people can use cell phones simultaneously. Cell phones operate into cells, and they can switch in cells as move around it. Cells give cell phones incredible range. Someone using a cell phone can drive hundreds of miles and steady a conversation the entire time because of the cellular approach. Each cell has a base station that consists of a tower and a small building containing radio equipment.

Cell phones have low-power transmitters in them. Umpteen cell phones got two signal strengths: 0.6 watts and 3 watts. The base station also transmits at low power. Low-power transmitters have two advantages:

The transmissions of a base station and the phones into its cell do not perform it very far outside that cell. Therefore, 2 different cells can reuse the same 56 frequencies. Hence, the same frequencies can be reused extensively across the city.

The power consumption of the cell phone, which is normally battery-operated, is quite low. Low power means small batteries, and this is what has made handheld cellular phone.

The cellular approach claims a large number of base stations in a city of any size. A typical large city can have hundreds of towers. Although because so many people are using cell phones, costs remain low per user. All carrier in each city also implements one central office called the Mobile Telephone Switching Office (MTSO). This office handles all of the phone connections to the normal land-based phone system, and controls all of the base stations.

ESN is a permanent part of the phone while both MIN and SID codes are programmed into the phone when a service plan is purchased and the phone is activated.

So here are a few terms that you will now find frequently in the coming section

- Base Station: It is a fixed station that consist of transmitters and receivers mounted on tall Towers strategically placed at different locations.
- Control Channel: Radio channel used for transmission of control signals.
- Voice Channel: Radio channel used for transmission of voice signals.
- Forward Channel: Radio channel used for transmission of information from n base station to mobile phone. (Includes Control and Voice Channels).
- Reverse Channel: Radio channel used for transmission of information from mobile phone to base station. (Includes Control and Voice Channels).

How a Mobile Phone Call is Made

Before a mobile phone can establish a call, it first needs to establish a connection to the available service provider’s network. Whenever a mobile phone is switched on, it first scans the group of forward control channels to determine the strongest one. Then it keeps on monitoring the same channel until the signal level drops below a minimum level after which it again starts to scan. Every mobile phone repeats this process as long as it is kept switched on. The signal level of the current channel which the phone is locked to will be displayed on the handset.

So now let’s see the steps that occur when a mobile phone user dials a number to make a call. First of all, a call initiation request is sent on the reverse control channel. Along with this request, the mobile phone also sends its Mobile Identification Number (MIN), Electronic Serial Number (ESN) and the dialed telephone number. The base station receives this data and sends it to the Mobile Switching Center (MSC). The MSC validates the request by checking the MIN with the records on its database. If it is valid, a connection to the called party is made through Public switched Telephone network (PSTN). Then the MSC requests the base station to move the mobile phone to an unused voice channel so that the conversation can begin. Once a call is in progress, the MSC adjusts the power transmitted by the mobile phone as it moves in and out of the coverage area of each base station.

In cooperative relaying, communication between the source and the destination nodes is performed with the aid of multiple relays acting as the retransmits. This technique presents a generalization of the classical automatic repeat request (ARQ) mechanisms. It provides a substantial increase in the diversity gain compared to conventional ARQ, especially in the case of the so-called long-term quasi-static ARQ channels, where the channel connecting the source and destination nodes varies very slowly from round to round. A prominent alternative to reducing the throughput loss in relay-aided transmission mechanisms is the combination of both ARQ and relaying. This approach would significantly reduce the half-duplex multiplexing loss by activating ARQ for rare erroneously decoded data packets, when they occur.

1.3 Types of Relays

The relay can be classified generally into the tow types amplify-and-forward relay station and decode-and-forward relay station. An AF relay receives the signal and simply amplifies it before transmitting the copy. As the signal is not decoded, the signal quality is degraded. The AF relay is of low complexity and easy to implement. A DF relay decodes the received signal and recodifies it before forwarding a copy. Due to decoding, the noise in the received signal is cleaned out. Because of the presence of decoder and encoder, the DF relays are of high complexity.

- Transparent relays: Transparent relays does not communicate entire control signal into the mobile station (MB). The MS is essentially unaware of the presence of these relay. In uplink, it’s simply got the transmission of MS to the BS and forward a decoded and re-encoded copy to the BS when requested to do so. Since the MS does not exchange control signals with the relay, it performs power control according to the uplink channel at the BS, and not to the relay. Thus, introduction of transparent relay does not help to save the transmission power of the uplink of the MS. However, if the BS-MS channel is in a deep fade, the relay provides spatial diversity and enhances the network coverage of these MSs.
- Non-Transparent relays: It can transmit control signals to the MS. They can perform most of the functions of a full-fledged base station. When an MS moves away from the BS and is close to a relay, it is handed over to the relay by a procedure similar to an inter-BS handover. The main difference between a relay and a full-fledge BS is that the RS is not directly connected to the backhaul network.

1.4 Current research on multicast network

Wireless multicasting 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 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).

Multicast service is provided by a satellite network, such as S-DMB (Satellite-Digital Multimedia Broadcasting).

Multicast service is provided by a cellular system, such as MBMS (Multimedia Broadcasting and Multicast Services), BCMCS (Broadcast and Multicast Services) and MBS (Multicast Broadcast Services). In this article, we will study the case where multicast and unicast services are carried over a cellular system. In a conventional wireless multicast system, the transmitter will select a data rate grant to the worst channel user in the multicast group to underwrite the reliable delivery of data to all the multicast users. However, since 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 user will be very low, and therefore capacity of the multicast transmission will be low.

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 distribution 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 term 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 the section V. Finally conclusion is given in section VI.

1.5 Cellular Approach

With limited frequency resource, cellular can be used as an accessible cost. In a cellular network, total area is subdivided into smaller areas called “cells”. Every cell can shield a limited number of mobile subscribers within its boundaries. Each cell may have a base station with a number of RF channels.

Frequencies used in one cell area will be reused at the same time in another geographically separated cell. For example, a typical seven-cell model can be considered.

Fig. 1.2 Mobile Networks Cell

Total available frequency resources are divided into seven parts, each part consisting of radio channels and allocated to a cellular site. In a group of 7 cells, the available frequency spectrum is consumed totally. The same seven frequency sets can be used after certain distance. The group of cells where the available frequency spectrum is totally consumed is named a cluster of cells. Two cells with the same number in the adjacent cluster use the same set of RF channels and therefore referred to as “Co-channel cells”. The distance between the cells depends the same frequency must be sufficient to maintain the co-channel (co-chl) interference to an acceptable level. Hence, the cellular systems are limited by Co-channel interference.

Hence a cellular principle enables the following.

- More efficient usage of available limited RF source.
- Manufacturing of every piece of subscriber's terminal within a region with the same set of channels so that any mobile can be used anywhere within the region.

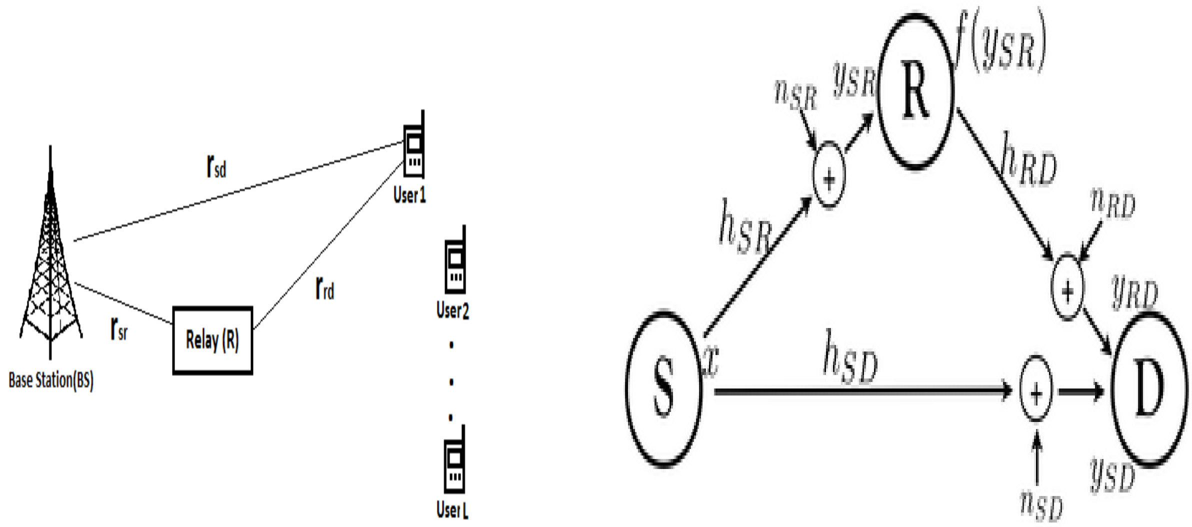
1.6 System Model

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 *D1, D2,…, DL* respectively. Among *L* users, there are Lm multicasts users and Lm unicast users. Suppose that the transmissions from *S* to D_i $(i = 1, 2, \dots, \mathrm{L})$, *S* to *R*, and *R* to D_i $(\mathrm{i} = 1, 2, \dots, \mathrm{L})$suffer from quasi-static fading with independent Rayleigh distribution. Then the channel gains from *S* to D_i $(i = 1, 2, \dots, \mathrm{L})$, *S* to *R*, and *R* to

D_i $(i = 1, 2, \ldots, L)$, 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:

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

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 between each user to the relay is approximately equal r_{rd}, and the distance between the relay and 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 $\rho = GN/N_0$ respectively (where G is a constant influenced by the carrier frequency, antenna gain and antenna height, etc.). Base Station (BS) and Relay (R)



(a) Wireless Cooperative Multicast System. (b) The relay network with signal notations.

Fig. 1.3 Network Systems

Notation: In Fig. 2 we introduce the typical notations for the node relay channel, as follow:

- x – the sent signal from the source
- y – received signal (ex. y_{sr} denotes the received signal from S to R)
- h – channel coefficient
- n – noise on the channel
- $f(y_{sr})$ - the relay function, also known as the signal processing at the relay. This is what R forwarding to D to help the communication between S and R.

With these notation the system model will be define as:

$$y_{SR} = h_{SRx} + n_{SR}$$

$$y_{SD} = h_{SDx} + n_{SD}$$

$$y_{RD} = h_{SD}f(y_{sr}) + n_{RD}$$

Wireless networks, signal fading resulting from multipath propagation is a particularly serious channel alteration that can be mitigated through the use of diversity [1]. Techniques of spatial or multiple-antenna, diversity techniques are particularly attractive as they can easily be 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 provided in a network. For instance, in a wireless sensor network, sensed information may be intended for multicast to neighboring nodes for information gathering.

2 Relative Technologies

2.1 Cooperative Wireless Communication

In the field cooperative wireless communication, we are interested in 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, it is assumed that each wireless user 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 the 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 due to diversity. In the face of this compromise, its hopes that there will be a clear reduction in the transmit power, since everything else being constant. Similar problems 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 question, whether cooperation is worth the incurred cost, has been answered completely by various studies, and is demonstrated by plots toward the end of this article. Cooperation can also describe 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 the bandwidth of the mobiles lead to significant gains in system performance. In the cooperative allocation of resources, each mobile transmits for several mobiles.

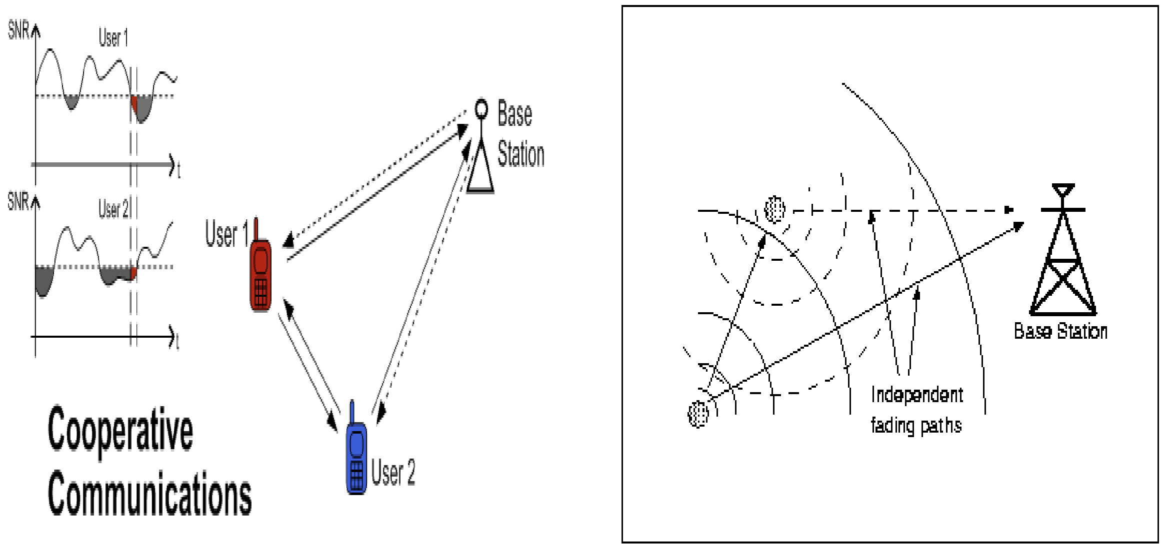


Fig. 2.1: In cooperative communication each mobile is both a user and relay and Cooperative Communication

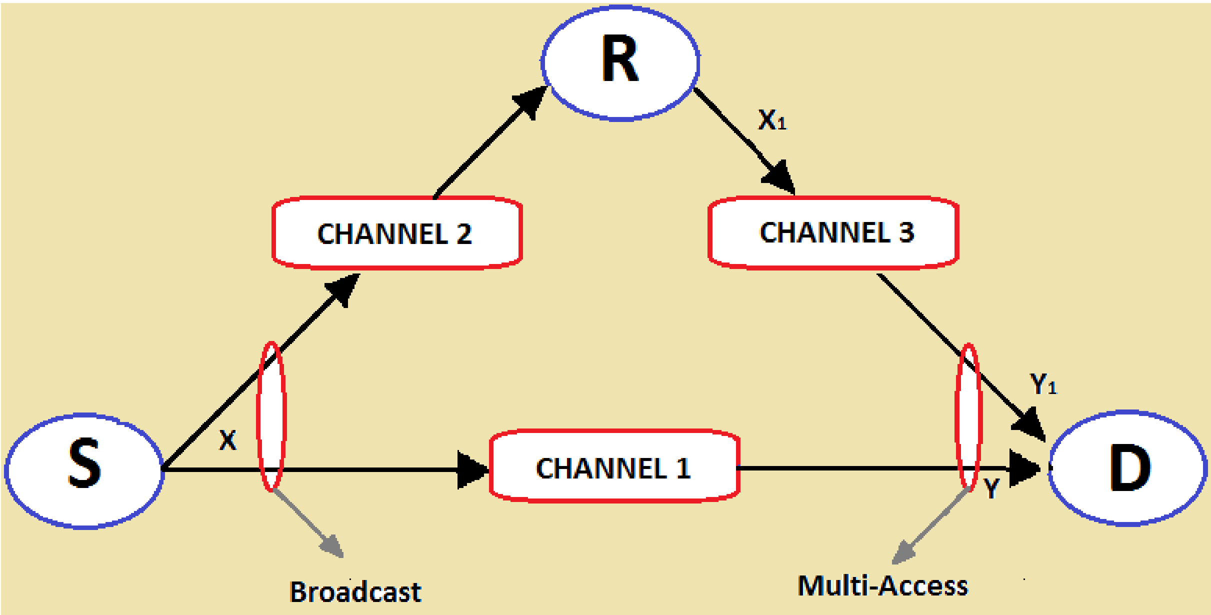


Fig 2.2 The relay channel

2.2 Historical Background

The basic ideas behind cooperative communication can be traced back to the revolutionary work of Cover and E1 Gamal on the information theoretic properties of the relay channel [1]. This work analyzed the capacity of the three-node network responding of a source, a destination, and a relay. It was supposed that all nodes operate in the same band, so that the system can be decomposed within a source broadcast channel from the viewpoint of the source and a multiple access channel from the viewpoint of the destination (Fig. 3). Nonetheless, several ideas that emerged later in the cooperation literature were first exposited in [1].

However, in the respects of cooperative communication we look at is different from the relay channel. First, recent developments are motivated by the concept of diversity in a fading channel, while Cover and E1 Gamal mostly analyzed capacity in an additive white Gaussian noise (AWGN) channel.

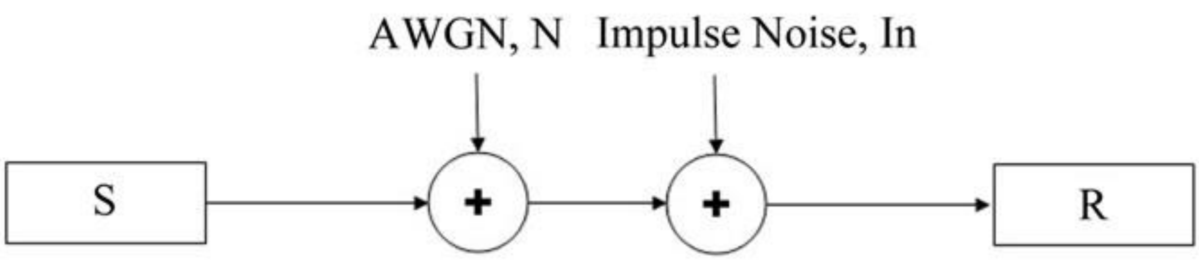


Fig 2.4: The AWGN Channel

Secondly, in the relay channel, the only purpose of relay 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 undeniable, recent collaborative work in cooperation has taken on a somewhat different focus.

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 purpose 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 introduction article. An example of decode-and-forward signaling can be found in the work of Sendonaris at 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 user are paired to cooperate with each other. Each user has its own spreading code, denoted C1(t) and C2(t). The two user's data bits are denoted bi (n) where I = 1, 2 are the user indices and n denotes the time index of information bits. Factors aj 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 X1(t) and signal of user 2 X2(t),

$$X_1(t) = [a_{11} b_1^{(1)} C_1(t), a_{12} b_1^{(2)} C_1(t), a_{13} b_1^{(2)} C_1(t) + a_{14} b_1^{(2)} C_2(t)] \quad (2\text{-}1)$$

$$X_2(t) = [a_{21} b_2^{(1)} C_2(t), a_{22} b_2^{(2)} C_2(t), a_{23} b_1^{(2)} C_1(t) + a_{24} b_2^{(2)} C_2(t)] \quad (2\text{-}2)$$

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 (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 power for the first, second, and third intervals are variable, and by optimizing the relative transmit powers according to the conditions of the uplink and inter-user channels, this method provides adaptability to channel conditions. The power are allocated through the factor ai,j such that an average power constraint is maintained. Roughly speaking, whenever the inter-user channel is favorable, more power will be allocated to cooperation, whereas the inter-user 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 inter-user 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 revert to a non-cooperative mode. This is not unlike the adaptability of coefficients ai, 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 possible to achieve separation in frequency. Separation of signals is closely relates 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 achieved on separate frequency bands. Ordinary mobiles receive only in the downlink band, but cooperative mobiles need 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 query. Another technological issue is transmitted and receives requirements on the mobiles. In TDMA systems this is generally not a problem, since the uplink transmission by definition are non-overlapping 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. The second settlement 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 inter-users 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 inter-user channel is needed in the base station. However, since cooperation is conditional, 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 retains 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.

2.5 Model for Fading Signal

To understand wireless communications; it is necessary to explore what happens to the signal as it travels from the transmitter to the receiver. The most important aspect of this path between the transmitter and the receiver is the occurrence of fading. Many models for probability distribution function (PDF) of the signal amplitude exposed to mobile are there to explain such fading phenomena. Out of these models Rayleigh, Ricean and Nakgami fading models are most widely used because of both academic and practical application points views.

a- Rayleigh Fading Channel: It describes the received signal distribution where all the components are non-LOS. The basic model of Rayleigh fading assumes a received multipath signal consists of a theoretically infinitely large number of reflected waves.

b- Ricean Fading Channel: Similar to that for Rayleigh, except that in Ricean fading a strong dominant LOS component is present.

c- Nakagami Fading Channel: It occurs for multipath scattering with relatively large delay-time spreads, with different clusters of reflected wave.

2.6 Extension and Continuing Work

Whereas many key results for cooperative communication have already been acquired there are many more issues that remain to be addressed. An important question is show there are several issues that dwell 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 central base station, tender the possibility of a centralized mechanism. Assuming that the base station has some knowledge of all the channels between users, partners could be assigned to optimize a given performance criterion, such as the average block error rate for all the 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 relate 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 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 inter-user 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 (Rate-Compatible Punctured Convolutional Codes), while in [8], turbo codes are applied to the coded cooperation framework. Both of these coding schemes were originally developed for non-cooperative system. An interesting open problem is the development of design criteria specifically for codes that optimize the performance of coded cooperation.

2.7 Multicast

At the data link layer, multicast describes one-to-many distributions such as Ethernet multicast addressing, asynchronous transfer mode (ATM) point-to-multipoint virtual circuits (P2MP) or infini-band multicast. In an optical mesh network protecting multicast light paths is one of the key concerns. The most straight forward oncoming to protect a multicast tree is to establish a link-disjoint backup tree which establishes dedicated protection. It is much easier to locate an arc-disjoint path for each leaf node in a light tree. The essence of protecting a multicast session is to discover a backup path for each destination node when a link on the running path to that node fails.

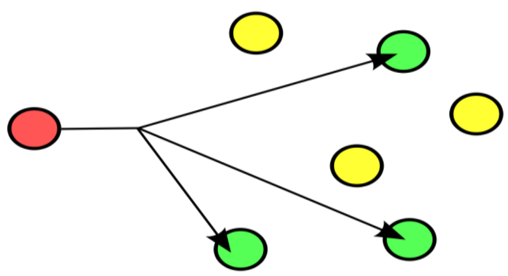


Fig. 2.3 Illustration of the Cooperative Multicast Network.

2.8 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 betwixt *Lm* multicast users, and note that in multicast transmission the user selection should be based on both small-scale fading path-loss. The subscript of the selected user is:

$$i = \underset{k=1,\ldots,L_m}{\arg\max}\{Z_k\}$$

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 (Probability Density Function) of Z_m and i is expressed as:

$$f_{Z_{m,i}}(z,i) = f_{Z_{m,i}}(z)\prod_{\substack{j=1\\ j\neq 1}}^{L_{m,}}\left[1-F_{Z_{m,j}}(z)\right]$$

$$= \frac{r_{sd}^{n} r_{rd}^{n}\left(e^{\frac{-r_{rd}^{n}}{\rho}z}-e^{\frac{-r_{sd}^{n}}{\rho}z}\right)}{\rho\left(r_{sd}^{n}-r_{rd}^{n}\right)}\left[e^{\frac{-r_{sd}^{n}}{\rho}z}-\left(e^{\frac{-r_{rd}^{n}}{\rho}z}-e^{\frac{-r_{sd}^{n}}{\rho}z}\right)\frac{r_{sd}^{n}}{r_{sd}^{n}-r_{rd}^{n}}\right]$$

$$= \frac{r_{sd}^{n} r_{rd}^{n}\left(e^{\frac{-r_{rd}^{n}}{\rho}z}-e^{\frac{-r_{sd}^{n}}{\rho}z}\right)}{\rho\left(r_{sd}^{n}-r_{rd}^{n}\right)}\left[\frac{r_{sd}^{n}\left(e^{\frac{-r_{rd}^{n}}{\rho}z}-r_{rd}^{n}e^{\frac{-r_{sd}^{n}}{\rho}z}\right)}{r_{sd}^{n}-r_{rd}^{n}}\right] \tag{2-3}$$

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:

$$P_{i}^{m}(i) = \frac{1}{L_m} \tag{2-4}$$

2.9 Unicast

The term unicast is distinct 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 allocations. Unicast messaging is used for all network deals in which a private or unique resource is requested. Some network applications which are mass-distributed are too costly to be carried which 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 afford a stream for each unique user. Multicast-based servers can endorse a larger audience by serving content simultaneously to multiple users.

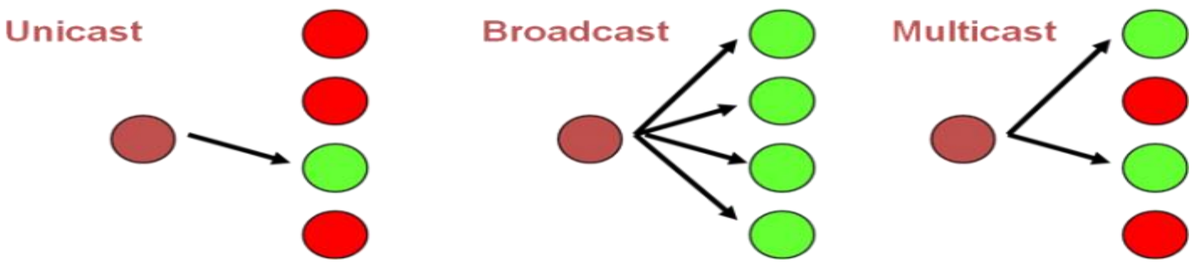


Fig. 2.4 Illustration of webcast Network (First scheme is the Unicast Network)

2.10 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 highest received SNR among Lu unicast users, and note that 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:

$$i = \arg\max_{k=1,\ldots,L_u}\{Z_k\} \tag{2-5}$$

Where Z_k is the received SNR value of the 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 Lu unicast users, user i has a received SNR value Z_u while all the other unicast user have lower received SNR values. Therefore, the joint PDF of Z_u and i is expressed as:

$$f_{Z_{u,i}}(z,i) = f_{Z_{u,i}}(z)\prod_{\substack{j=1\\ j\neq 1}}^{L_{u,}}\left[1 - F_{Z_{u,j}}(z)\right]$$

$$= \frac{r_{sd}^{n} r_{rd}^{n}\left(e^{\frac{-r_{rd}^{n}}{\rho}z} - e^{\frac{-r_{sd}^{n}}{\rho}z}\right)}{\rho\left(r_{sd}^{n} - r_{rd}^{n}\right)}\left[1 - e^{\frac{-r_{sd}^{n}}{\rho}z} - \left(e^{\frac{-r_{rd}^{n}}{\rho}z} - e^{\frac{-r_{sd}^{n}}{\rho}z}\right)\frac{r_{sd}^{n}}{r_{sd}^{n} - r_{rd}^{n}}\right]^{L_{u,}-1}$$

$$= \frac{r_{sd}^{n} r_{rd}^{n}\left(e^{\frac{-r_{rd}^{n}}{\rho}z} - e^{\frac{-r_{sd}^{n}}{\rho}z}\right)}{\rho\left(r_{sd}^{n} - r_{rd}^{n}\right)}\left[1 - \frac{r_{sd}^{n}\left(e^{\frac{-r_{rd}^{n}}{\rho}z} - r_{rd}^{n} e^{\frac{-r_{sd}^{n}}{\rho}z}\right)}{r_{sd}^{n} - r_{rd}^{n}}\right]^{L_{u,}-1} \tag{2-6}$$

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 the user i is given by:

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

Combining the received SNR value Z_u is given by:

$$f_{Z_{u,i}}(z,i) = f_{Z_{u,i}}(z,i)/P_i^u(i)$$

$$= \frac{r_{sd}^n r_{rd}^n \left(e^{\frac{-r_{rd}^n}{\rho}z} - e^{\frac{-r_{sd}^n}{\rho}z}\right)}{\rho(r_{sd}^n - r_{rd}^n)} \left[1 - \frac{r_{sd}^n e^{\frac{-r_{rd}^n}{\rho}z} - r_{rd}^n e^{\frac{-r_{sd}^n}{\rho}z}}{r_{sd}^n - r_{rd}^n}\right]^{L_u - 1} / \frac{1}{L_u}$$

$$= \frac{L_u r_{sd}^n r_{rd}^n \left(e^{\frac{-r_{rd}^n}{\rho}z} - e^{\frac{-r_{sd}^n}{\rho}z}\right)}{\rho(r_{sd}^n - r_{rd}^n)} \left[1 - \frac{r_{sd}^n e^{\frac{-r_{rd}^n}{\rho}z} - r_{rd}^n e^{\frac{-r_{sd}^n}{\rho}z}}{r_{sd}^n - r_{rd}^n}\right]^{L_u - 1} \qquad (2-7)$$

2.10.1 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 all 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 dispersal inherent in Omni directional radio signals. Broadcasting is a very large and significant segment using analog transmission techniques and more recently broadcasters have switched to digital signals using digital transmission.

2.10.2 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 theatrophone ("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 Clement Ader in 1881. Telephone broadcasting also grew to include telephone newspaper service for news and entertainment programming which were introduced in the 1090s, primarily located in large European cities. These telephone-based subscription services were the first examples of electrical/electronic broadcasting and offered wide variety of programming.

-Radio broadcasting (experimentally from 1906, commercially from 1920): ratio 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 sub-channels. History of television broadcasting (telecast), experimentally from 1925, commercial television from 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 downlink), 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 broadcast is called scheduling. All technological endeavors, a number of technical terms and slang have developed. A list of these terms can be established 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 convert box with decoding customers premise equipment, the latter also enables subscription-based channels, pay-tv and pay-per-view services.

3 Multicasts and Opportunistic Unicast Transmission with Amplify-and-Forward Relaying

3.1 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 $D_1; D_2; ...; D_L$; respectively. Among L users, there are Lm multicast users and Lu unicast users. Suppose that transmission from S to D_i $(i = 1, 2, ..., \mathrm{L})$, S to R, and R to D_i $(i = 1, 2, ..., \mathrm{L})$suffer from quasi-static fading with independent Rayleigh distribution. Then the channel gain from S to D_i $(i = 1, 2, ..., \mathrm{L})$, S to R, and R to D_i $(i = 1, 2, ..., \mathrm{L})$, h_{SD_i} , $h_{S\mathrm{R}}$ 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 jh_{SD_i}j2, j$jh_{S\mathrm{R}}$j2 and jh_{rD_i}j2are exponentially distributed random variables with parameter 1, i.e., the small-scale fading component is expressed as:

$\mathrm{f}_{\propto^2}(x) = \exp(-x)$ (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 N0. 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 is $\boldsymbol{\rho}$=GN/N_0respectively (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.

3.2 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 higher received SNR among Lu 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.

3.3 AF Relaying

The first problem considered is relay placement for maximum extension of the cell radius. Increase in cell radius helps reduce infrastructure cost of deploying more base station to support the rapidly growing number of subscribers. Apart from coverage extension, cellular relays also improve to the cell capacity. This is because mobile stations get the advantage of diversity due to two possible signal paths.

In this section, we will derive the received signal-to-noise ratio (SNR) distribution for AF relay transmission. It is assumed that the received signal-to-noise ratio of each transmission client is measurable. Thus the maximum mutual information expression in AF relay mode is:

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

$$= \frac{1}{2}\log_2\left(1 + \rho\left\{\frac{\alpha_{sd}^2}{r_{sd}^n} + \frac{\frac{\alpha_{sr}^2}{r_{sr}^n} + \frac{\alpha_{rd}^2}{r_{rd}^n}}{\frac{\alpha_{sr}^2}{r_{sr}^n} + \frac{\alpha_{rd}^2}{r_{rd}^n} + \frac{1}{\rho}}\right\}\right)$$

$$= \frac{1}{2}\log_2\left(1 + \rho\left\{\frac{\alpha_{sd}^2}{r_{sd}^n} + \frac{\alpha_{sr}^2\alpha_{rd}^2}{r_{rd}^n\alpha_{sr}^2 + r_{sr}^n\alpha_{rd}^2 + \frac{1}{\rho}r_{sr}^n r_{rd}^n}\right\}\right) \tag{2-8}$$

The α_{sr}^2 ; α_{sd}^2 and α_{rd}^2 , represent the small-scale fading gain between source and user, source and relay, relay and user respectively.

3.3.1 Cumulative distribution function and probability density function under AF

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

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

Here we found the cumulative probability distribution function (CDF) and the probability density function (PDF) of the received signal SNR,

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

$$Y=\frac{Y_1Y_2}{r_{rd}^{n}Y_1+r_{sr}^{n}\alpha_{rd}^{2}+\frac{1}{\rho}r_{sr}^{n}r_{rd}^{n}}$$

$$Y=\frac{\alpha_{sr}^{2}\alpha_{rd}^{2}}{r_{rd}^{n}\alpha_{sr}^{2}+r_{sr}^{n}Y_2+\frac{1}{\rho}r_{sr}^{n}r_{rd}^{n}} \tag{2-9}$$

$$P(Y\leq y)=P\left(\frac{Y_1Y_2}{r_{rd}^{n}\alpha_{sr}^{2}+r_{sr}^{n}Y_2+\frac{1}{\rho}r_{sr}^{n}r_{rd}^{n}}\leq y\right) \tag{2-10}$$

$\frac{Y_1Y_2}{r_{rd}^{n}\alpha_{sr}^{2}+r_{sr}^{n}Y_2+\frac{1}{\rho}r_{sr}^{n}r_{rd}^{n}}\leq y$, then $\left(Y_1Yr_{rd}^{n}\right)Y_2\leq yr_{rd}^{n}Y_1+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}$

$$Y_1\geq yr_{rd}^{n};\quad Y_2\geq\frac{yr_{rd}^{n}+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}}{Y_1Yr_{rd}^{n}}$$

$$0 \le Y_1 < yr_{rd}^{n},\ Y_2 \ge \frac{yr_{rd}^{n}+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}}{Y_1 Yr_{rd}^{n}};\ \text{so}\ \frac{yr_{rd}^{n}Y_1+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}}{Y_1 Yr_{rd}^{n}} < 0,\ Y_2 \ge O.$$

It can be concluded that the constraint $Y_2 \ge O$.

$$F_y(y) = P(Y \le y) = P\left(\frac{Y_1 Y_2}{r_{rd}^{n}\alpha_{sr}^{2} + r_{sr}^{n} Y_2 + \frac{1}{\rho} r_{sr}^{n} r_{rd}^{n}} \le y\right)$$

$$= \int_{yr_{rd}^{n}}^{+\infty} f(y_1)\mathrm{d}y_1 \int_0^{\frac{yr_{rd}^{n}+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}}{Y_1-Yr_{rd}^{n}}} f(y_2)\mathrm{d}y_2 + \int_0^{yr_{rd}^{n}} f(y_1)\mathrm{d}y_1 \int_{yr_{rd}^{n}}^{+\infty} f(y_2)\mathrm{d}y_2$$

$$= \int_{yr_{rd}^{n}}^{+\infty} e^{-y_1}\,\mathrm{d}y_1 \int_0^{\frac{yr_{rd}^{n}+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}}{Y_1-Yr_{rd}^{n}}} e^{-y_2}\,dy_2 + \int_0^{yr_{rd}^{n}} e^{-y_1}\,\mathrm{d}y_1\,\mathrm{d}y_1 \int_{yr_{rd}^{n}}^{+\infty} e^{-y_1}\,\mathrm{d}y_2$$

$$= 1 - \int_{yr_{rd}^{n}}^{+\infty} e^{-\frac{y_1^2 - y_1 y_{sr}^{n} + yr_{rd}^{n} y_1 + \frac{1}{\rho} y_{sr}^{n} r_{rd}^{n}}{Y_1 - Yr_{rd}^{n}}}\,\mathrm{d}y_1$$

$$= 1 - \int_0^{+\infty} e^{\frac{(t+yr_{sr}^{n})(t+yr_{rd}^{n})+\frac{1}{\rho}y_{sr}^{n}r_{rd}^{n}}{t}}\,dt \qquad (\text{with } t = Y_1 - Yr_{rd}^{n})$$

$$= 1 - e^{-(r_{sr}^{n} r_{rd}^{n})} \int_0^{+\infty} e^{-t-\frac{{}_{sr}^{n}r_{rd}^{n}(y^2+\frac{1}{\rho}y)}{t}}\,dt$$

$$= 1 - 2\sqrt{{}_{sr}^{n}\,r_{rd}^{n}\,(y^2 + \frac{1}{\rho}y)}\,e^{-(r_{sr}^{n}r_{rd}^{n})y}\left(\frac{1}{2}\left(\frac{2\sqrt{{}_{sr}^{n}r_{rd}^{n}(y^2+\frac{1}{\rho}y)}}{2}\right)^{-1}\int_0^{+\infty}\frac{e^{-t-\frac{\left(\frac{2\sqrt{{}_{sr}^{n}r_{rd}^{n}(y^2+\frac{1}{\rho}y)}}{2}\right)^2}{4t}}}{t^{(-1)+1}}\right) \quad (2\text{-}11)$$

$$= 1 - 2\sqrt{r_{sr}^{\ n}\ r_{rd}^{\ n}\ (y^2 + \frac{1}{\rho}\ y)}\,e^{-(r_{sr}^{n}r_{rd}^{n})y}\,\boldsymbol{K}_{-1}\left(2\sqrt{r_{sr}^{\ n}\ r_{rd}^{\ n}\ (y^2 + \frac{1}{\rho}\ y)}\right)$$

The formula (4-5) uses a formula expression in Section 8.432 of the literature [17], the form is as follows:

$$\boldsymbol{K}_v(z) = \frac{1}{2}\left(\frac{z}{2}\right)^v \int_0^{+\infty} \frac{e^{-t-\frac{z^2}{4t}}}{t^{v+1}}\,dt, \qquad \left[|\arg z| < \frac{\pi}{2}, Rez^2 > 0\right]$$

$$\boldsymbol{K}_{-1}(\mathrm{z}) = \frac{1}{\mathrm{z}}\int_{0}^{+\infty} e^{-t-\frac{z^2}{4t}}\, dt\,, \qquad 2z\boldsymbol{K}_{-1}(2\mathrm{z}) = \frac{1}{\mathrm{z}}\int_{0}^{+\infty} e^{-t-\frac{z^2}{t}}\, dt,$$

Then $g(y) = 2\sqrt{r_{sr}^{\;n}\,\mathrm{r}_{rd}^{\;n}\,(\mathrm{y}^2 + \frac{1}{\rho}\,\mathrm{y})}$

So $\boldsymbol{F}_y(\mathrm{y}) = 1 - \mathrm{g(y)e}^{-(r_{sr}^{n}\mathrm{r}_{rd}^{n})\mathrm{y}}\,\boldsymbol{K}_{-1}(\mathrm{g(y)})$

$$X = \frac{\alpha_{sd}^{\;2}}{\mathrm{r}_{rd}^{\;n}}, \qquad Y = \frac{\alpha_{sr}^{\;2}\,\alpha_{rd}^{\;2}}{r_{rd}^{\;n}\,\alpha_{sr}^{\;2}\,\mathrm{r}_{rs}^{\;n}\,\alpha_{rd}^{\;2} + \frac{1}{\rho}\,r_{sr}^{\;n}\,\mathrm{r}_{rd}^{\;n}}\,, \quad Z = \rho(X+Y);$$

$$\mathrm{f}_x(\mathrm{x}) = r_{sd}^{\;n}\,\mathrm{e}^{-r_{sd}^{n}\mathrm{x}}$$

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

$$F_z(\mathrm{z}) = \mathrm{P}(\rho(\mathrm{X}+\mathrm{Y}) \le \mathrm{z})$$

$$= \int_{0}^{z/0} \mathrm{f}(x,y)\, dx \int_{0}^{\frac{z}{\rho}-z} dy$$

$$= \int_{0}^{z/0} f_x\,(x)\, dx \int_{0}^{\frac{z}{\rho}-z} f_y\,(y) dy$$

$$= \int_{0}^{z/0} f_x\,(x) P\left(Y \le \frac{z}{\rho} - x\right) dx$$

$$= \int_{0}^{z/0} \mathrm{r}_{sd}^{\;n}\, e^{\mathrm{r}_{sd}^{n} x\left[1-g\left(\frac{z}{\rho}-x\right)e^{-(\mathrm{r}_{sd}^{n}+\mathrm{r}_{rd}^{n})\left(\frac{z}{\rho}-z\right)}-\boldsymbol{K}_{-1}\left(g\left(\frac{z}{\rho}-x\right)\right)\right]}\, dx$$

$$= \int_{0}^{z/0} \mathrm{r}_{sd}^{\;n}\, e^{\mathrm{r}_{sd}^{n}\left(\frac{z}{\rho}-x\right)\left[1-g(x)e^{-(\mathrm{r}_{sd}^{n}+\mathrm{r}_{rd}^{n})x}-\boldsymbol{K}_{-1}(g(x))\right]}\, dx$$

$$= \int_{0}^{z/0} \mathrm{r}_{sd}^{\;n}\, e^{\mathrm{r}_{sd}^{n}\left(\frac{z}{\rho}-x\right)}\, dx - \mathrm{r}_{sd}^{\;n}\, e^{\mathrm{r}_{sd}^{n}\left(\frac{z}{\rho}\right)} \int_{0}^{z/0} e^{-(\mathrm{r}_{sr}^{n}+\mathrm{r}_{rd}^{n}+\mathrm{r}_{sd}^{n})} g(x)\boldsymbol{K}_{-1}(\mathrm{g}(x)) dx$$

$$1 - e^{\left(\frac{\mathrm{r}_{sd}^{n}}{\rho}-x\right)} - \mathrm{r}_{sd}^{\;n}\, e^{\mathrm{r}_{sd}^{n}\left(\frac{z}{\rho}\right)} \int_{0}^{z/0} e^{-(\mathrm{r}_{sr}^{n}+\mathrm{r}_{rd}^{n}+\mathrm{r}_{sd}^{n})}$$

$$g(x)\boldsymbol{K}_{-1}\left(g(x)\right)dx \qquad (2\text{-}12)$$

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

$$f_{z(z)}=\frac{dF_Z(z)}{dz}$$

$$\frac{d\left(1-e^{\frac{-r_{sd}^{n}z}{\rho}}-\frac{r_{sd}^{\ n}}{\rho}e^{-r_{sd}^{n}z}\frac{z}{\rho}\int_0^z e^{-\left(r_{sd}^{n}-r_{rd}^{n}\right)\frac{x}{\rho}}g\left(\frac{x}{\rho}\right)-K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)\mathrm{dx}\right)}{dz}$$

$$=e^{\frac{-r_{sd}^{n}z}{\rho}}+\frac{r_{sd}^{n}}{\rho}e^{-r_{sd}^{n}z}\frac{z}{\rho}\int_0^z e^{-\left(r_{sd}^{n}-r_{rd}^{n}\right)\frac{x}{\rho}}g\left(\frac{x}{\rho}\right)-K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)\mathrm{dx}$$

$$-\frac{r_{sd}^{\ n}}{\rho}e^{-\left(r_{sd}^{n}-r_{rd}^{n}\right)\frac{z}{\rho}}g\left(\frac{z}{\rho}\right)-K_{-1}\left(g\left(\frac{z}{\rho}\right)\right)$$

$$=\frac{r_{sd}^{\ n}z}{\rho}\begin{pmatrix} e^{\frac{-r_{sd}^{n}z}{\rho}}+\frac{r_{sd}^{\ n}}{\rho}e^{-r_{sd}^{n}z}\frac{z}{\rho}\int_0^z e^{-\left(r_{sd}^{n}-r_{rd}^{n}\right)\frac{x}{\rho}}g\left(\frac{x}{\rho}\right)-K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)\mathrm{dx} \\ -e^{-\left(r_{sd}^{n}-r_{rd}^{n}\right)\frac{z}{\rho}}g\left(\frac{z}{\rho}\right)-K_{-1}\left(g\left(\frac{z}{\rho}\right)\right)\end{pmatrix} \qquad (2-13)$$

3.4 Multicast Transmission with AF relaying

For the multicast transmission in the AF as described in Chapter 3, the transmission rate depends on the channel condition of the worst-channel user in the multicast group. Assuming that user *i* is the instantaneous worst-channel user in the multicast group, the received SNR is the lowest among the multicast groups. That is, the subscript of the selected user is

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

Here is the received signal-to-noise ratio for the Z_m user at each transmission.

For multicast transmission in AF relay mode, if user *i* is selected as the worst channel user, it means that user *i* has the received signal-to-noise ratioZ_m, and all other users are over the received signal-to-noise ratio. Then the joint probability density function Z_m of *i* and *i* can be expressed as

$$f_{z_{m},i}(z,i) = f_{z_{m},i}(z)\prod_{\substack{j=1\\ j\neq 1}}^{L_m}[1 - F_{z_{m},i}(z)]$$

$$= \frac{r_{sd}^{n} z}{\rho}\begin{pmatrix} e^{\frac{-r_{sd}^{n} z}{\rho}} + \frac{r_{sd}^{n}}{\rho} e^{-r_{sd}^{n} z}\frac{z}{\rho}\int_0^z e^{-(r_{sd}^{n}-r_{rd}^{n})\frac{x}{\rho}} g\left(\frac{x}{\rho}\right) - K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)dx \\ -e^{-(r_{sd}^{n}-r_{rd}^{n})\frac{z}{\rho}} g\left(\frac{z}{\rho}\right) - K_{-1}\left(g\left(\frac{z}{\rho}\right)\right) \end{pmatrix}$$

$$\times (1-(1-e^{\frac{-r_{sd}^{n} z}{\rho}} + \frac{r_{sd}^{n}}{\rho} e^{-r_{sd}^{n} z}\frac{z}{\rho}\int_0^z e^{-(r_{sd}^{n}-r_{rd}^{n})\frac{x}{\rho}} g\left(\frac{x}{\rho}\right) - K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)dx))L_m - 1$$

$$= \frac{r_{sd}^{n} z}{\rho}\begin{pmatrix} e^{\frac{-r_{sd}^{n} z}{\rho}} + \frac{r_{sd}^{n}}{\rho} e^{-r_{sd}^{n} z}\frac{z}{\rho}\int_0^z e^{-(r_{sd}^{n}-r_{rd}^{n})\frac{x}{\rho}} g\left(\frac{x}{\rho}\right) - K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)dx \\ -e^{-(r_{sd}^{n}-r_{rd}^{n})\frac{z}{\rho}} g\left(\frac{z}{\rho}\right) - K_{-1}\left(g\left(\frac{z}{\rho}\right)\right) \end{pmatrix}$$

$$\times (e^{\frac{-r_{sd}^{n} z}{\rho}} + \frac{r_{sd}^{n}}{\rho} e^{-r_{sd}^{n} z}\frac{z}{\rho}\int_0^z e^{-(r_{sd}^{n}-r_{rd}^{n})\frac{x}{\rho}} g\left(\frac{x}{\rho}\right) - K_{-1}\left(g\left(\frac{x}{\rho}\right)\right)dx)L_m - 1 \qquad (2-14)$$

So, all the users in the multicast group have an equal opportunistic to be selected, thus selection probability of user I is given by

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

In this section, the performance of the scheduling-based systems is evaluated in terms of ergodic capacity and outage probability using the 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

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

The system capacity of an opportunistic unicast transmission is given by

$$C_u^{sys} = C_i$$

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

$$P^{out} = \mathrm{P}(Z \le \Gamma)$$

$$= \int_0^{\Gamma} f_{z|i}(z|i)dz$$

3.5 Performance analysis

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

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$$P^{out} = \mathrm{P}(Z \le \Gamma)$$

$$= \int_0^{\Gamma} f_{z|i}(z|i)dz$$

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 one 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 ¼ for all cases: non-cooperative, amplify-and-forward, detect-and-forward, and coded cooperation. For both hybrid decoded-and-forward and amplify-and-forward, the users initially transmit a RCPC (Rate-Compatible Punctured Conventional) code word punctured to rate ½. This code word is subsequently persistent by the relay, resulting in an overall rate ¼ (rate ½ code, repeated). For coded cooperation, a cooperation level of 25 percent is used. The users will 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 admitted for each user from a rate ¼ code word. The fist plot in Fig. 6 illustrates a case in which the user channel to the base station (uplink channels) have the same mean SNR, while the mean SNR of the inter-user channel is 10 dB below that of the uplink channels, showing that diversity improves markedly over a comparable non-cooperative 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 inter-user channel:

Cooperation provides substantial improvement in error rate performance even when the inter-user channel quality is poorer than that of the uplink channels. The second plot illustrates a case in which the denote uplink SNR for the user 1 is 10 dB higher that the user 2, while the inter-user mean SNR is coequal to that of the uplink channel for user 2. Two significant results of cooperation can be noted. Fist, user 2, as one might expect, enhance significantly by cooperation 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 user 1 and 2 is significantly reduced by the cooperation methods. This shows that cooperation inherently reallocates the system resources in a moiré 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.

4 Performance Analysis

4.1 Numerical results

The 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 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 noted in below in the table and numerical result are as follow:

Tab. 4.1 Simulation parameters

Transmit Power	P=10W
Channel Bandwidth	10 MHz
Thermal noise density	$4x10^{-15}W/Hz$
Path loss exponent	n=2.5
Gain constant	G=0.0270
SNR threshold	Γ=-5Db

4.2 System capacity

As show in Fig. 2 and Fig 4, given the distance of r_{rd}(e.g., r_{rd}=600m) , as the number of the 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 path 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 multiple 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 for r_{rd}=900m and $L_m(L_u)$ = 2, and approximately equal to for r_{rd}=900m and $L_m(L_u)$ = 3, as describe 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 increase, 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 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 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 Fig. 5.

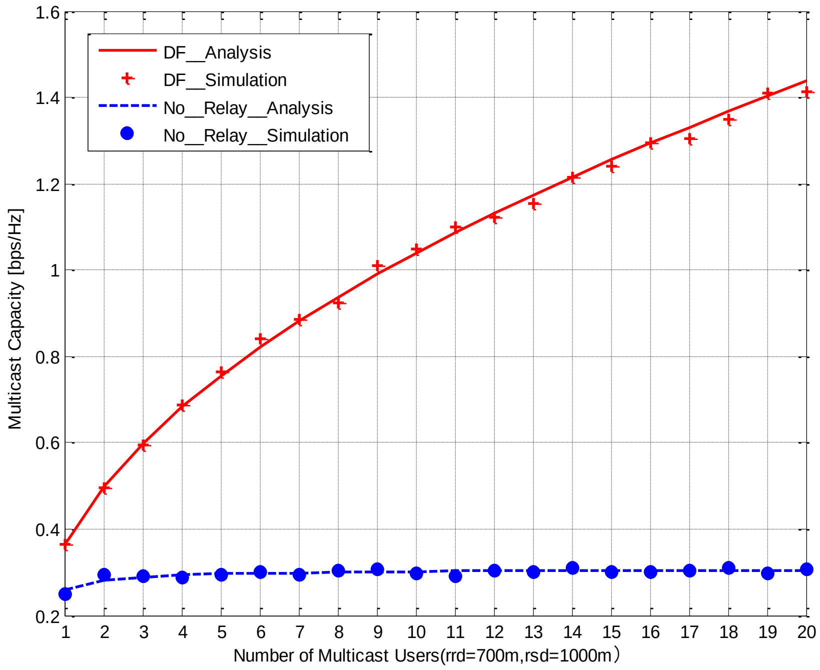

Fig. 4.1 Capacity of multicast and unicast transmission with DF relaying for varying the number of users

(r_{sr}=400m, r_{sd}=1000m)

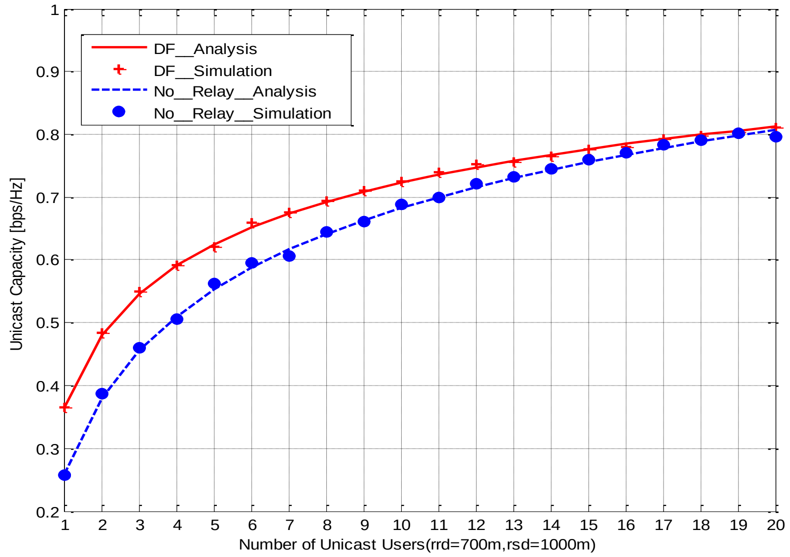

Fig. 4.2 Capacity of multicast and unicast transmission with DF relaying for varying the distance of

r_{rd}(r_{sr}=400m, r_{sd}=1000m)

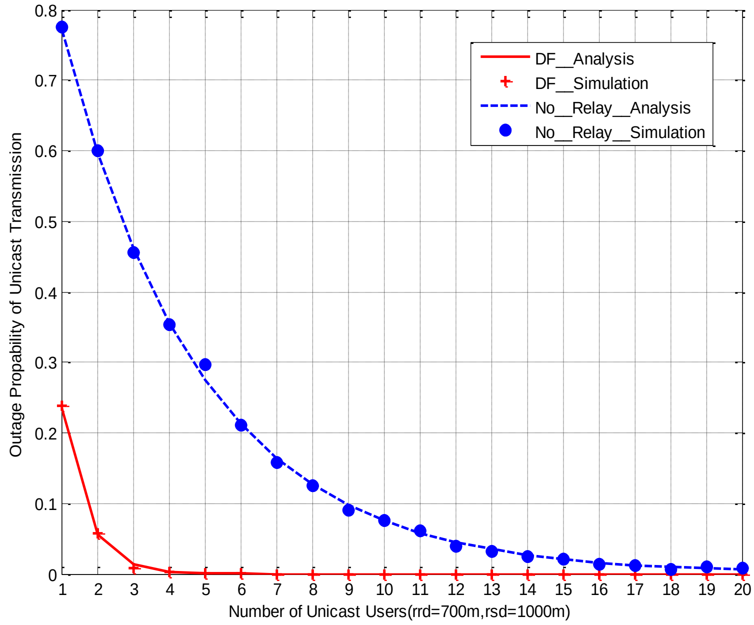

Fig. 4.3 Capacity of multicast and unicast transmission with AF relaying for varying the distance of users

(r_{sr}=400m, r_{sd}=1000m)

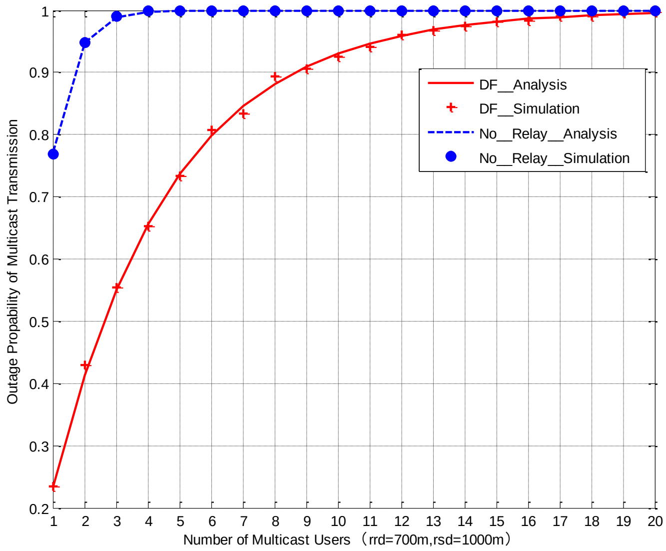

Fig. 4.4 Capacity of multicast and unicast transmission with AF relaying for varying the distance of r_{rd}(r_{sr}=400m, r_{sd}=1000m)

As shown in Fig. 6, givenr_{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_{rd} and the number of users (where r_{sr}=400m, r_{sd}=1000m)

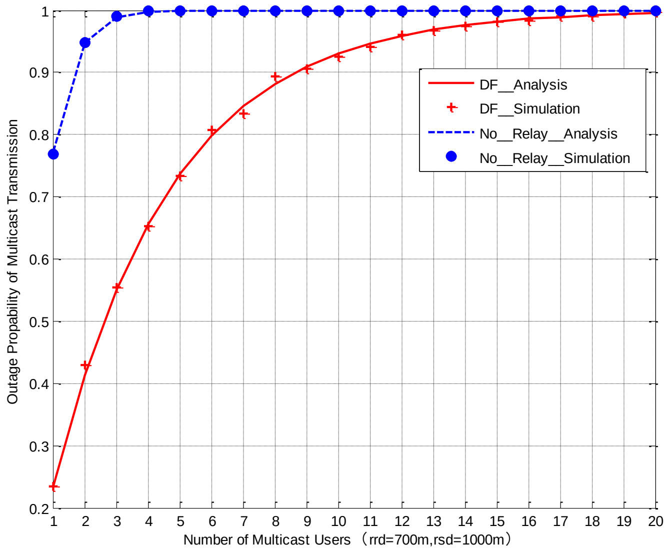

Fig. 4.5 Capacity of multicast and unicast transmission with DF and AF relaying for varying the distance of users (r_{sr}=400m, r_{sd}=1000m)

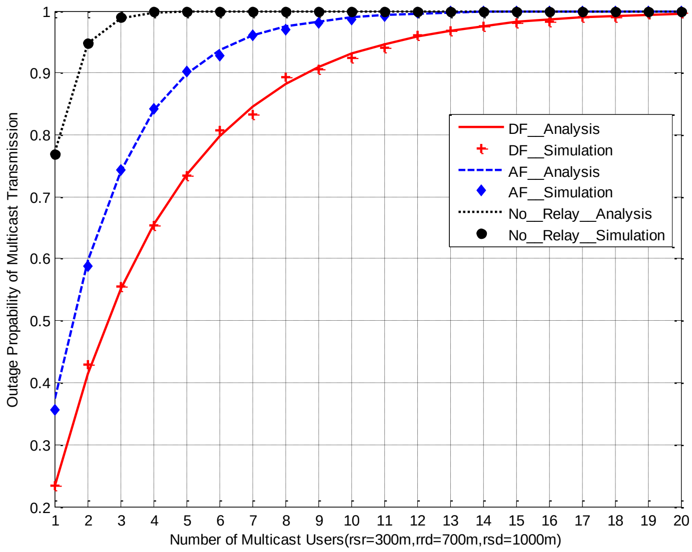

Fig. 4.5 Capacity of multicast and unicast transmission with DF and AF relaying for varying the distance of r_{rd} (r_{sr}=400m, r_{sd}=1000m)

4.3 Outage Probability

Outage probability is a common standard criterion, characterizing the performance of communication system operating in fading environments. By definition, outage probability,

P^{out}, is the probability that instantaneous receive output SNR falls below a certain threshold which is specified according the expected performance (e.g. BER, capacity, etc,) of the system. In order to evaluate the outage behavior of the system illustrated in Fig. 1; 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 multicast group also increases. So a result, the selected best channel user in the opportunistic unicast transmission can 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 percent regardless of the different distance of r_{rd}, as described in the Fig. 9.

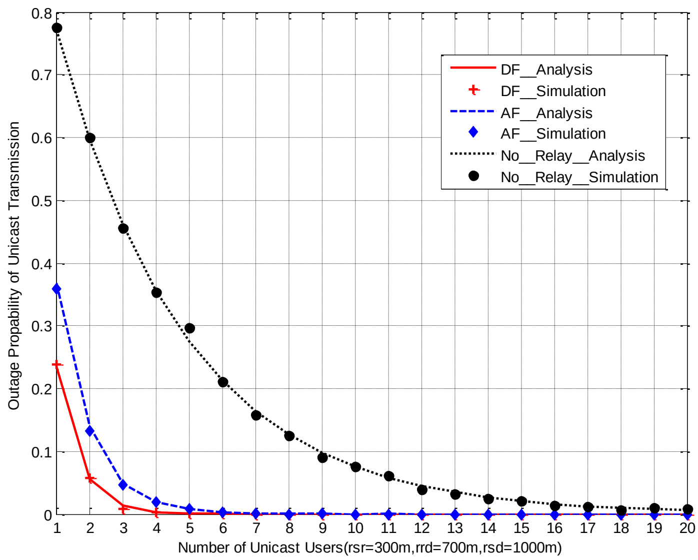

Fig. 4.6 Outage probability of multicast and unicast transmission with DF relaying for varying the distance of users (r_{sr}=400m, r_{sd}=1000m)

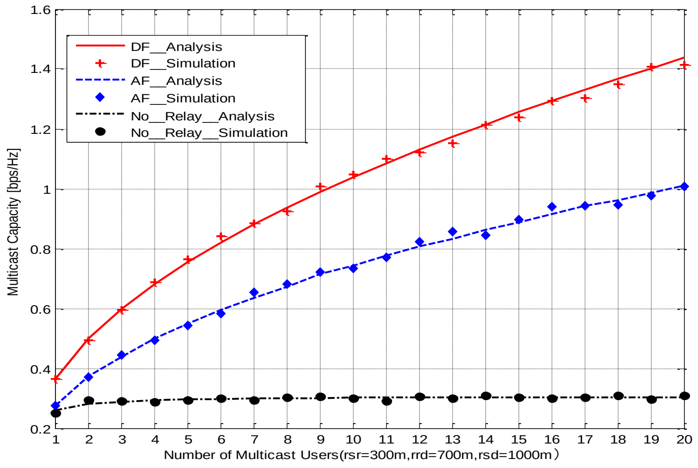

Fig. 4.7 Outage probability of multicast and unicast transmission with DF relaying for varying the distance of r_{rd} (r_{sr}=400m, r_{sd}=1000m)

As show 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, the outage probability of the traditional multicast transmission increase faster than that of the opportunistic unicast transmission . Because the distance 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 percent regardless of the different distance of r_{rd}.

We can see 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 DF or AF relaying, short, outage probability of multicast transmission and unicast transmission with DF relaying is less than that with AF relaying, respectively. As shown in Fig. 12, 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. The 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 r_{sd} and the number of users (where r_{sr}=400m, and r_{sd}=1000m). Also all the figures of outage probability show that the analytical results are well matched with computer simulation results.

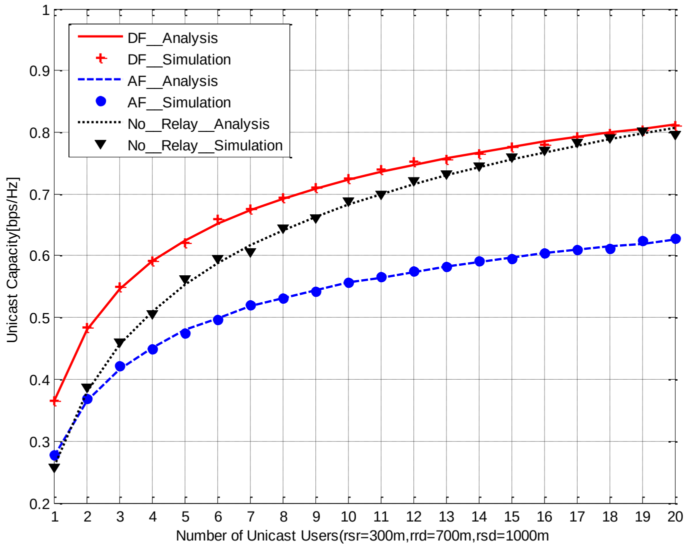

Fig. 4.7 Outage probability of multicast and unicast transmission with DF and AF relaying for varying the distance of users (r_{sr}=400m, r_{sd}=1000m)

5 Conclusion

The introduction of cooperative relays provides additional channels to transmit information, calculation results demonstrate that cooperative relay can promote and trade off in AF and DF scheme. In this work, a hybrid multicast and opportunistic transmission scheme with DF and AF relaying is suggested, 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 play their respective advantages under certain conditions, and the overall performance with DF relaying is better than that with AF relaying. Above all, this work provides a novel basic model for further research.

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Appendix

AF	Amplify-and-Forward
ATM	Asynchronous Transfer Mode
AWGM	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
CDF	cumulative function
CDMA	Code-Division Multiple Access
CSI	Channel State Information
DF	Decoded-and-Forward
LOS	Line-of-Sight
OMS	opportunistic multicast scheduling
PDF	Probability Distribution Function
R	Relay
RCPC	Rate-Compatible Punctured Convolutional Codes
S	Source
SNR	Signal-to-Noise Ratio
TDMA	Time-Division Multiple Access