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Coverage Extension and Throughput Improvement by Using Mobile Relay

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Abstract - **In recent years cellular users have grown exponentially. Because of limited bandwidth availability techniques that extend cellular coverage and throughput, without increasing bandwidth have become very important. In this scenario, mobile relays are seen to have good potential to improve coverage extension and throughput. In this paper, mobile relay techniques are analyzed and simulated. The end user is connected directly to the base Station or as an alternative to establish a two-hop link using a relay. We consider movable relay locations for the realizations of system model over two-dimensional Poisson process .The purpose of relay is to forward messages received from a base station to an end user. An M/M/∞ queuing model is used to capture relay mobility. In this paper, we first analyze four cases where mobile relays offer substantial coverage extension benefits. Secondly we focus on throughput for no relay and normal relay by considering simple and efficient adaptive modulation coding (AMC) decision rule. These results provide benefits offered by mobile relays in terms of coverage extension & throughput enhancement.**

Key Words - **Adaptive modulation coding (AMC), Mobile Relay, Poisson point process, queuing model**

I. INTRODUCTION

Every wireless system has to combat transmission and propagation effects that are substantially more hostile than for a wired system. Channel impairments, such as fading and multipath dispersion. When Relaying is applied single hop breaks into multi hops, resulting in low attenuation and high throughput or good reliability. Conventional cellular network base station has limited coverage area because base station uses omni directional antenna that transmits signal in all directions. By employing cell sectoring in this environment one can overcome this limitation up to certain limit but not fully. In [1], the optimal number of hops for better spectral efficiency was analyzed. In [2], the optimal placement of wireless relay node to maximize the expected throughput capacity of a wireless local area network under different relay strategies was considered. In [1], [3] spectral efficiency and it's relation to routing strategies was analyzed. Routing determines how packets are transmitted from source to the destination. The mobile relays can increase the capacity of random network if arbitrary delay is tolerable, allowing the relay to store the message until it is transfer to the destination [4]. In [5], the authors showed that the relay standard (IEEE 802.16j) is currently being developed for increasing the coverage area of the existing standard (IEEE 802.16e) via the deployment of fixed or mobile relay terminals. Since wireless terminals cannot transmit and receive simultaneously at the same time. Relaying requires at least two phases. In the first phase base station-to-relay (BS → RS) communication takes place and the second phase is used for the relay to forward the received packets from base station to an end user. The multi-hop cooperation schemes must be used only when they can provide end-to-end throughput greater than that of direct transmission i.e. without (w/o) relay. Although the performance of wireless relay networks is thoroughly studied from an informative theoretic point-of view, the work done on the relative performance of various cooperative diversity schemes in a practical multi-user scenario is limited. Mobile relays may be classified in two broad categories: they can be part of the environment, or specifically designed as part of the network infrastructure in this paper we consider mobile relays that are not part of the fixed wireless infrastructure but it is a part of environment. Relay stations which are mounted on mobile units, either vehicular or pedestrian speed and designed to provide relay services to the end user. A unique feature of mobile relays is that their location is not fixed. Rather, mobile relays are distributed in a random manner, and their locations change with time. Thus, mobile relays are positioned in such way that it can provide effective communication between base station and end user. We will consider the effectiveness of employing mobile relays under two scenarios:

- An end user receives signal directly from the base station. Whether end user is within the coverage area or at the cell edge where probability of out of coverage is possible. Here we consider there is no direct link between base station and an end user, only mobile relays establishing a good connectivity between base station and end user.
- When an end user is within the coverage area of the base station, mobile relaying provides an alternative path with better end-to-end spectral efficiency (throughput). In this case, two-hop relaying schemes must be used only when they can provide end-to-end throughput greater than that of direct transmission and direct transmission is used when a suitable relay cannot be found.

In this paper, we run the experiment and simulations for the following cases:

- High/Low Density pedestrian and vehicular speed.
- We analyze when the distance from BS to end user increases with respect to 4 case studies. The real motive is to understand the actual of average connection sustaining time.
- We study what happens when the transmission is conducted considering: a) Normal Relay b) No Relay.

The rest of the paper is organized as follows. Section II describes the system model. Section III presents mobile relaying for coverage extension. For a particular out-of-coverage end user that wants to communicate with the base station but it cannot communicate directly to the Base station, only mobile relay within the coverage can help it. We call the relays that are capable of providing connection feasible relay. In Section IV, we have shown throughput for no relay and normal Relay. Future works and conclusions are drawn in Section V.

II. SYSTEM MODEL

Our analysis is based on the following system model.

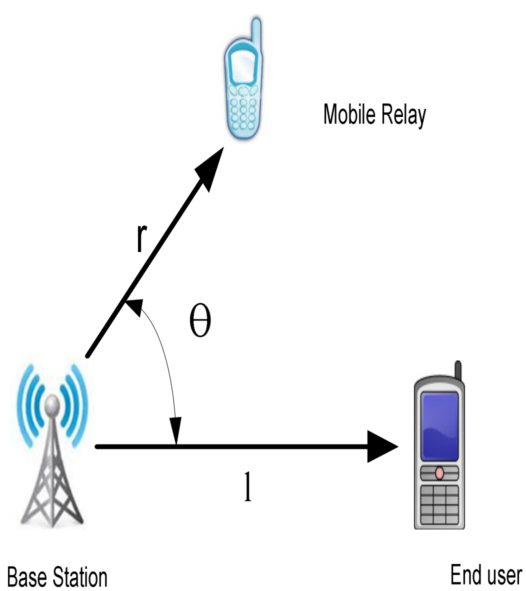

Fig. 1.The base Station, the mobile relay and the end user

Consider a separate base station and a single end user in two dimensions plane, as shown in Fig 1. The base station is at the origin. Without relaying, the coverage area of the base station is normalized to unit radius of a circle. The end user is fixed and its location is given by coordinates (ℓ, 0). When an end user is out of coverage then the base station coverage has been normalized to $\ell > 1$. While $\ell \leq 1$ implies the end user is within the coverage area. The position of a mobile relay is given by the polar coordinates (r; θ). The locations of all the relays will be modeled by a homogeneous Poisson point process (PPP) with intensity ρ over the two-dimensional plane. An M/M/∞ queuing model is used to capture relay mobility. The downlink transmission is considered without loss of generality. The base station is capable of generating a received signal-to-noise ratio (SNR) of γ_1 at unit distance. Similarly, each relay is capable of providing a received SNR of γ_2 at unit distance. The received SNR's γ_1 and γ_2 are used to simplify the presentation and take into account transmit power, symbol duration, antenna gains, and noise level. Also, since mobile relays are not capable of transmitting and receiving at the same time, half-duplex transmission is assumed, and a time-division decode-and-forward relay strategy is adopted. The channels are modeled as additive white Gaussian noise (AWGN) channels with path loss attenuation. The path loss exponent α, 2 ≤α ≤ 4, is assumed to be constant over the two dimensional plane.

III. COVERAGE EXTENSION BY MOBILE RELAY

Assume the end user is out of coverage, *i.e.*, $\ell > 1$. A mobile relay can "extend coverage" to an out-of-coverage end user if and only if there is a two hop route from the base station to the relay to the end user with throughput (spectral efficiency) is at least as high as that provided by direct transmission from the base station to an end user.

A. *Analysis*

Consider a mobile relay is placed at distance r *from* the base station. It forms an angle θ *with* the base station and end user axis, as shown in Fig 1. The locations of all the relays will be modelled by a homogeneous Poisson point process (PPP) with intensity ρ *over* the two-dimensional plane. That is, the number of relays in a region of area A follows a Poisson distribution with mean ρA. A *M/M/∞* queuing model is used to capture relay mobility. The first M from M/M/∞ indicates inter arrival time i.e. events corresponding to relay moving in and out of feasible position and second-M indicates service time distribution i.e. processing time (τ) corresponds to interval during which the associated relay remains in feasible region.

B. *Numerical results*

In this framework cellular structure is created along with base station at centre and mobile relays are randomly placed. It also shows circles that represents feasible region. In this frame X and Y Coordinates indicates location of mobile relay. Mobile relay coverage indicates in which cell mobile relay is present. We analyze average connection sustaining time for 4 different cases (High/Low density pedestrian/vehicular speed). We also have shown distance of mobile relay from the base station. We analyze throughput for no relay & normal relay.

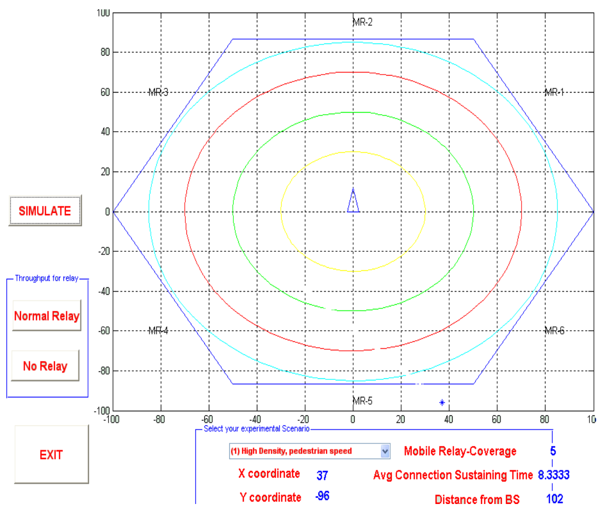

Fig. 2.Simulation framework

IV. Throughput Performance Comparison For No Relay And Normal Relay

In this section, we consider the throughput improvement (i.e. spectral efficiency) which mobile relays can provide to in-coverage users. An “in-coverage user” is one at a normalized distance $\ell \leq 1$ from the base. The focus of the analysis is, again, on the random nature of the relay placement

A. Analysis

a) No relay

This is a direct base station to end user communication assuming that no relay exists in the cell. As expected the throughput decreases as end user move away from the base station. Here throughput (spectral efficiency) is calculated on the basis of signal to noise ratio (SNR) of the link. For calculating SNR distance of the link is also considered. If SNR of direct link (BS-end user) is high means throughput is high otherwise throughput is low. The SNR at the mobile station is given by

$$SNR(dB) = Pt(dB) - Pn(dB) - 35\log(r)$$

Pt represents base stations transmit power, Pn represents power of additive noise and r represents distance of MS from BS. The adaptive modulation and coding (AMC) is decided based on this SNR.

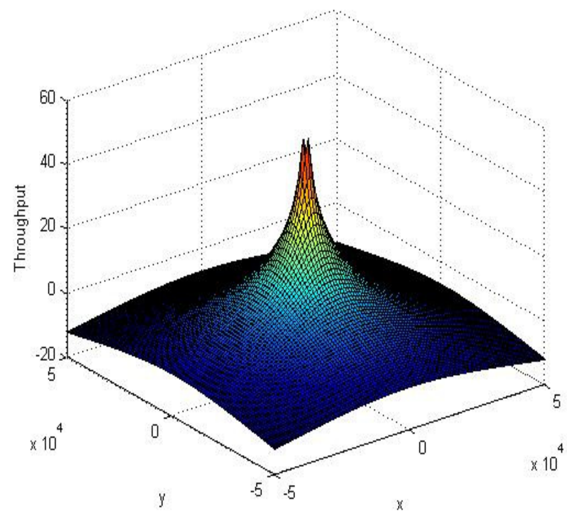

Fig. 3. The throughput for no relay with downlink transmission x=transmitter, y=receiver, z=Throughput

A. Normal relay

In this scenario the base station transmits to the mobile relay in the first phase. While in the second phase the mobile relay transmits to the end user. It is assumed that the mobile relay is placed in such a way that it can use the maximum rate of 64-QAM 5/6 adaptive modulation and coding (AMC).Hence the SNR from the mobile relay to end user decides the AMC. Also the base station decides upon the SNR of the end user whether it should relay or should transmit directly .The relay transmit power is also considered while choosing relays the diversity scheme. The throughput in this case is given by

$$\frac{thr(\gamma BR)thr(\gamma RM)}{R(\gamma BR)+R(\gamma RM)}$$

B. Numerical Results

The parameters in the foregoing analysis must be carefully chosen and properly interpreted to obtain meaningful numerical results. Here we consider the BS transmit power = 27.3 dB, mobile relay transmit power = 17.3 dB, BS to mobile relay distance = 10 km, Power of additive noise = -130dB and Path loss exponent =3.5. Adaptive modulation and coding (AMC) is employed which means that the transmitter chooses a suitable modulation scheme based upon the instantaneous value of SNR.

Fig. 3 and 4 illustrate the relation between transmitted data and received data i.e. .throughput. For normal relay throughput is high as compare to no relay. Here we consider quantity of peak not a height of peak.

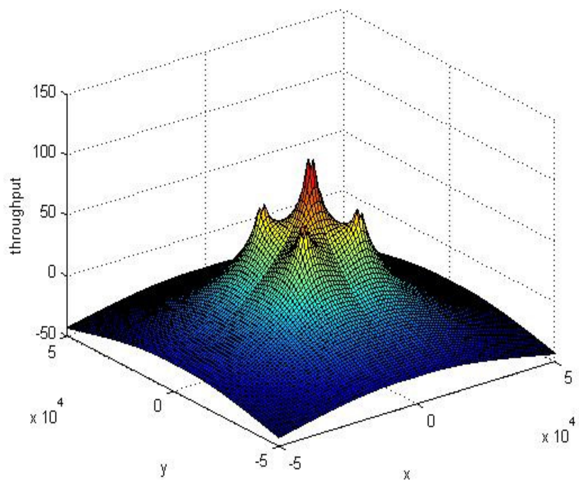

Fig. 4. The throughput for normal relay with downlink transmission x=transmitter, y=receiver, z=Throughput

FUTURE WORK

In the extension of the proposed work, it can be focus on the handoff problem and propose a new handoff decision algorithm based on the relative velocities of user equipment (UE) to the serving access point (AP) and the target AP. It can be shown that the proposed handoff algorithm can significantly improve the handoff successful rate when the mobile relay station changes its moving patterns. Wireless Relay networks have become very important technologies in the future wireless systems. Current research works mostly focus on scenarios where relay stations are either stationary or mobile with uniform velocity. However, in many applications, relay stations are mobile with irregular patterns. In particular, when mobile relay stations (MRSs) are deployed to complement the cellular systems, many issues such as handoff should be carefully investigated.

CONCLUSION

By mobile relays we have existing quantitative studies of the benefits offered - specifically, potential coverage part extension and throughput improvement. We conclude that high density pedestrian speed mobile relay provides high average connection sustaining times as compare to other cases that means mobile relays offer substantial coverage extension benefits. We have also analyzed throughput for no relay and normal relay .We observed that normal relay provides better throughput for out of coverage end user than no relay. As a concluding point, although the results obtainable assumed convinced choices of SNR values, the analysis technique is quite general and qualitatively similar results can be obtained under different SNR assumptions.

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Dr. Ashish Bhargave received his Ph.D from University of California, Irvine in 2006. He has completed his Masters degree from University of California, Irvine in 2001 and B.Tech from National Institute of Technology, Calicut in 1996. He has held academic teaching positions at University of California, Irvine and California State University, Long Beach and K.K Wagh Institute of Engineering Education and Research. He has worked as a Principal Investigator on many US defense research projects. His past research and industry experience includes work as a Research Scientist at Broadata Communications, Inc, USA, as a Systems Engineer at Broadcom Corporation, USA and as a software engineer at IT Solutions, India. He has several international and national publications, and a patent. He is a reviewer for many IEEE publications like IEEE Transactions on Communications, IEEE Electronic letters, ETRI journal. He has received Phi Beta Kappa Scholarship, UC Regents Fellowship at UC Irvine, is listed in Marquis Who's Who in America and is an elected member of Sigma Xi, the scientific research society.