ISSN: 2250–3676

[IJESAT] INTERNATIONAL JOURNAL OF ENGINEERING SCIENCE & ADVANCED TECHNOLOGY Volume-2, Issue-3, 401 – 405

LONG RANGE COMMUNICATION WITH HIGH THROUGHPUTFOR CELLULAR COMMUNICATION

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Abstract

The very high data rates envisioned for fourth generation (4G) wireless systems in reasonably large areas do not appear to be feasible with the conventional cellular architecture due to two basic reasons. First, the transmission rates envisioned for 4G systems are two orders of magnitude higher than those of 3G systems. This demand creates serious power concerns. Second, the spectrum that will be released for 4G systems will almost certainly be located well above the 2 GHz band used by the 3G systems. The radio propagation in these bands is significantly more vulnerable to non line- of-sight conditions, which is the typical mode of operation in today's urban cellular communications. The brute force solution to these two problems is to significantly increase the density of base stations, resulting in considerably higher deployment costs. So to reach these requirements more fundamental enhancements are necessary for the very ambitious throughput and coverage of future systems. It presents quantitative study of the benefits of mobile relays that can provide to the wireless infrastructure – namely, extension of base station coverage and enhancement of wirelessconnection throughput. The end user can choose to connect directly to a base station, or, as an alternative, to establish a two-hop link using a relay. Relay locations are modeled as realizations of a two-dimensional Poisson process with random motion, and as such their availability to forward messages received from a base station or from an end user is analyzed. The results provide insight into the benefits of mobile relays that can offer in terms of improving connectivity or throughput.

Index Terms: *Relays, mobile communication, queuing analysis, throughput***.**

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1. INTRODUCTION

It is generally accepted that the architecture of the present day cellular networks cannot meet the stringent requirements envisioned for 4G cellular systems. Economically feasible solutions are likely to be based on some form of multi-hop relaying allowing uniform coverage at very high data rates and reducing the required number of expensive cell sites. Multi-hop relaying with fixed relays is based on fixed relay stations deployed as part of the network infrastructure.Their incremental cost is offset by reduced requirements on the mobile terminals, and by the simplicity and efficiency of the radio protocols involved. The fixed relay stations are part of the cellular network infrastructure; therefore their deployment will be an integral part of the network planning, design and deployment process. It is necessary to establish strategies and methods for efficient deployment of fixed relay stations, such that the overall cost of the network is minimized. Efficient radio resource allocation to network elements is a critical part of the overall network cost optimization effort. In previous technologies the relays are "fixed" in thattheir locations are either predetermined or optimized in thedesign phase. Mobile relays have been less well studied intheliterature. Themobile relays can increase the capacity of a random networkif arbitrary delay is tolerable.

Path loss is signal attenuation due to the natural diffusion of the signal wave front, absorption, and diffraction. Exceptfor veryspecial scenarios (e.g., a propagation environment resembling a wave guide), signal attenuation is proportional to at least the square of the distance between the transmitter and the receiver. Remote receivers can experience severe signal attenuation, resulting in low through put or poor reliability, or possibly both. Relaying– when applied pru- dently –can break one severely attenuated signal propagation path into several shorter, and thus less attenuated paths.

Mobile relays are distributed in a stochasticmanner, and their locations change with time. So we willconsider the effectiveness of employing mobile relays undertwo scenarios:There is no one-hop connection from the base stationto an out-of-coverage end user. Mobile relaying is usedto establish connectivity. For an end user within the base station coverage area, mobilerelaying may provide alternative (multi-hop) routingwith better end-to-end spectral efficiency (throughput).In this case, the system would choose two-hop relayingwhen it offers better spectral efficiency and directtransmission when a suitable relay cannot be found.

Section II describes the system model, and Section III analyzes coverage range extension. For a particularout-of-coverage end user that wants to communicate with the base station.

2. SYSTEM MODEL

Consider an isolated base station and a single end user intwo dimensions, as depicted in Figure 1. The coverage area ofthe base station, without relaying, is normalized to a circle ofunit radius, with the base station at the origin. The end user is fixed and its location is given by coordinates $(\ell, 0)$.

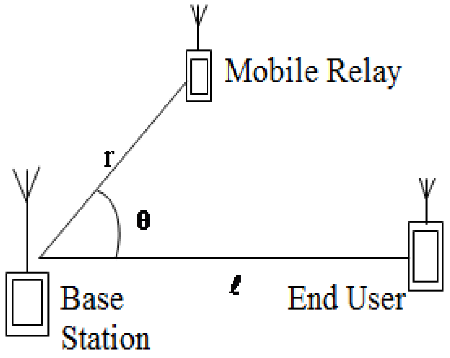

Fig-1. The base station, the mobile relay, and the end user form a triangle

Since the base station coverage has been normalized, $\ell > 1$ corresponds to out-of-coverage users, while $\ell \le 1$ implies the end user iswithin the coverage area.The position of a mobile relay is given by the polar coordinates (r, θ). A Poisson model is chosen to simplify theanalysis.

A $M/M/\infty$ queuing model is used to capture relaymobility. Consider the relays in feasible positions as customersin a queue with an infinite number of processors. Arrivalsto and departures from the queue are events correspondingto relays moving in and out of feasible positions, and eachprocessing time, τ, corresponds to the interval during whichthe associated relay remains feasible. It isalso assumed that each mobile relay moves at a randomlyselected speed with average value E[v]in a direction that isindependent of the speed and uniformly distributed on [0, 2π);

Without loss of generality, downlink transmission is considered.The base station is capable of generating a receivedsignal-to-noise ratio (SNR) of γ_1 at unit distance. Similarly, each relay iscapable of providing a received SNR of γ_2 at unit distance.The received SNR's γ_1 and γ_2 are introduced to simplify thepresentation and take into account transmit power, symbolduration, antenna gains, and noise level,in this a time-division decode-and-forward relaystrategy is adopted. The path loss exponent α, $2 \le \alpha \le 4$, is assumed to be constant over the two dimensional plane.

3. COVERAGE EXTENSION

Assume the end user is out of coverage, i.e., $\ell > 1$. Wedefine connectivity in terms of a minimally acceptable spectral efficiency.

3.1. Analysis

Consider a mobile relay at distance $r$from the base station forming an angle $\theta$with the base station/end user axis, asshown in Figure 1. The distance between the relay andthe mobile user is

$$D = \sqrt{\left(r^2 + l^2 - 2rl\cos\theta\right)} \qquad (1)$$

Assuming capacity achieving transmission, the (bandwidth-normalized) time requiredto transmit each information bit via the relay is thesum of the base-to-relay transmission time and the relay-to-end-user transmission time – i.e.,

$$T_{2h} = \frac{1}{\log\left(1+\gamma_1 r^{-\alpha}\right)} + \frac{1}{\log\left(1+\gamma_2\left(r^2+l^2-2rl\cos\theta\right)^{-\alpha/2}\right)} \qquad (2)$$

For a user at the edge ofthe base station's coverage area, the (bandwidth-normalized) time required for direct transmission of each information bitis

$$T_{ref} = \frac{1}{\log\left(1+\gamma_1\right)} \qquad (3)$$

If the transmission of an information bit to an end user takes longer than T_{ref}, then the end user is not connected.Therefore, for the relay at location (r, θ) to extend coverage to the end user, we require $T_{2h} \le T_{ref}$. all relay positions within the angle are feasible.

$$\left[-\arccos f(r), \arccos f(r)\right]$$

The area of the feasible region can be calculated as a single Integral

$$A = \int_0^1 2r \arccos\left[\min\{1, f(r)\}\right] dr \qquad (4)$$

And the length of the perimeter of the feasible region as

$$L = \int_0^1 2I_{[f(r)<1]} \sqrt{1+\left(\frac{rf^1(r)}{\sqrt{1-f^2(r)}}\right)^2}\, dr \qquad (5)$$

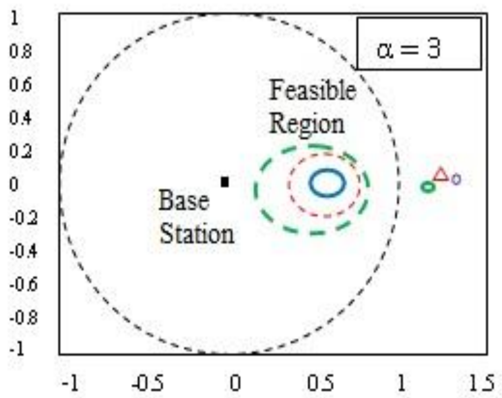

Fig-2. The feasible relay regions for ℓ = 1.1, 1.2, 1.25, respectively, withpath loss exponent α= 3 and $\gamma_1 = \gamma_2 = 3$dB and the length of the perimeterof the feasible region as

$$L = \int_0^1 2I_{[f(r)<1]}\sqrt{1+\left(\frac{rf^1(r)}{\sqrt{1-f^2(r)}}\right)^2}\,dr \qquad (6)$$

Where $f^1(r)$ is the derivative of $f(r)$ and $I_{[f(r)<1]}$ is an indicator function, taking the value zero when $f(r) \geq 1$ and the value one when $f(r) < 1$.

3.1.1. Outage Probability:

For a given out-of-coverage enduser, the number of feasible relays is a Poisson-distributed random variable with mean ρA, where *A*is the area given in(5). Hence the probability that there are no feasible relays is

$$P_f = \exp(-\rho A) \qquad (7)$$

Feasible regions are shownin Figure 2 as examples for several values of ℓ.

3.1.2. Route Sustaining Time:

We now consider how long theseconnections can be sustained once they are established, eitherwith or without re-routing. It has been shown in [9], [10] thatthe average number of relays moving out of a two-dimensionalregion per unit time, when they are uniformly distributed overthe plane, is given by

$$E[M] = \frac{\rho E(v) L}{\pi} \qquad (8)$$

Where **L** is the length of the region's perimeter and E(v) is theaverage speed of the relays; in our case, Lis given by (6). Dueto the presumed equilibrium of the relays, E(M) is also theaverage number of relays moving into the region per unit time.Moreover, the average number of relays in the feasible region is given by $E(N) = \rho A$,and applying Little's law [3] to theinfinite queue of feasible relays, the average relay residencetime is

$$E(T) = \frac{E(N)}{E(M)} = \frac{\pi A}{E(v)L} \qquad (9)$$

Little's law holds for a very general class of queuing problems,so (9) is not limited to the M/M/∞ mobility model.For general mobility models, (9) give an upperbound onthe average connection time when using a particular relay,i.e., the route sustaining time. The memory less property of M/M/∞ queues, on the other hand, implies that E(T)is theexact average route sustaining time.

Thus, the M/M/∞ mobility model can be parameterizedby an arrival rate $\lambda = E(M)$ and a service rate $\mu = 1/E(T)$

3.1.3.Connection Sustaining Time:

Now let T_n denote the connection sustaining time, averaged over all time instantswhen the current number of feasible relays is**n**. The timethe queue stays in state **n** is exponentially distributed with mean $1/(\lambda + n\mu)$, and the state transitions to state N+1 with probability $\lambda/(\lambda + n\mu)$and to state N− 1 with probability $n\mu/(\lambda + n\mu)$. Hence we

$$T_n = X_n + T_{n-1} \text{ with probabilty } n\mu/(\lambda+n\mu) \qquad (10.b)$$

can decompose T_n as

$$T_n = X_n + T_{n+1} \text{ with probabilty } \lambda/(\lambda+n\mu) \qquad (10.a)$$

Where X_n is an exponentially distributed random variable with mean $1/(\lambda + n\mu)$

3.1.4. Connection Duration Outage Probability:

Finally, we define the connection duration outage probability as the probability that the two-hop connection fails to meet the connection duration requirement due to the depletion of feasible mobile relays.

3.2. Numerical Results

The parameters in the foregoing analysis must be carefully chosen and properly interpreted to obtain meaningful results. The relay density ρ is related to $\bar{N}$, the average no of usable relays in the cell coverage area (assuming radius), by the expression $\bar{N} = \pi\rho$ .We will use $\bar{N}$ =20 to represent a low density cell and $\bar{N}$ =100 to represent high density cell for numerical evaluation. In Figure 3, the two-hop routing success probabilities are shown as functions of the average number of mobile relays inside the base station's coverage area. Note that, as the feasible region shrinks with increasing ℓ, the chance of locating a relay within the feasible region also declines.

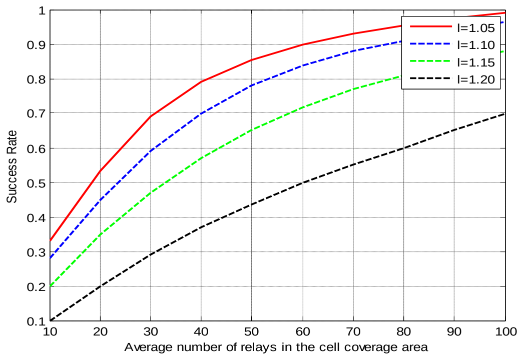

Fig.3 The Probability of finding a feasible relay as a function of the average number N of relays in the base station coverage area, with path loss exponent α = 3 and γ_1 = γ_2 = 3 dB

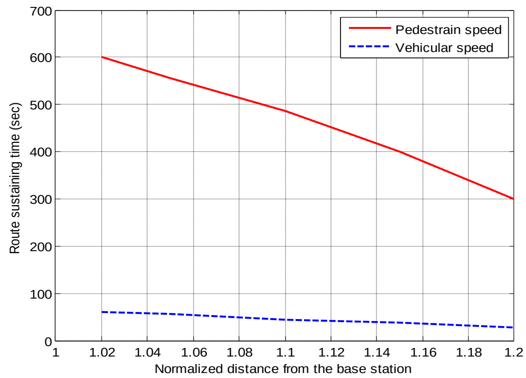

Fig.4 The average route sustaining time for relays moving at pedestrian and vehicular speed, with path loss exponent α = 3 and $\gamma_1 = \gamma_2 = 3$ dB.

Figure 4 shows the average route sustaining time as a function of the distance ℓ from the end user to the base station.

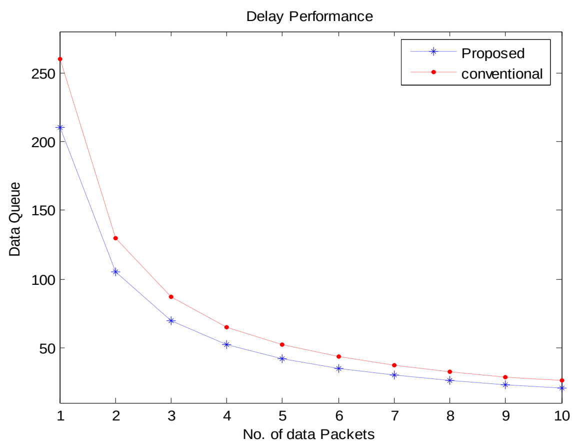

Fig.5. Delay performance

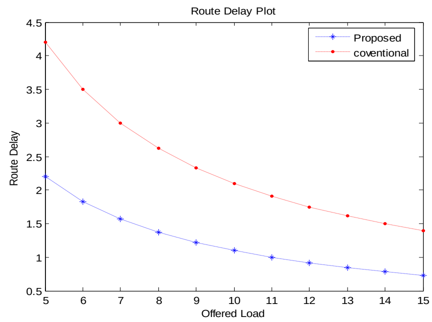

Fig.6 Route delay which occur due to the load in the network

Fig.5 and Fig.6 shows the delay performance of data queue and route delay, as the no of packets increasing the data queue is decreasing, so that every packet is forwarded without loss. And also with increasing load the route delay is decreasing, this indicating in congestion also packets are forwarding with minimum time only.

4. THROUGHPUT ENHANCEMENT

This section considers the throughput enhancement - i.e.,the improvement in spectral efficiency – that mobile relayscan provide to in-coverage users.

4.1. Analysis

Assuming capacity-achieving transmission, the amount oftime required to transmit each information bit in one hop from the end user to the base is

$$T_{1h} = \frac{1}{\log\left(1+l^{-\alpha}\gamma_1\right)} \quad (11)$$

while for two-hop routing with the relay located at (r,θ), the required time for transmitting each information bit is given by(1) with $\ell \le 1$. The route will beeither direct transmission or via the best possible two-hoplink, whichever provides the highest spectral efficiency.Defining the spectralefficiency gain as

$$G \square \frac{T_{1h}}{T_{2h}} \quad (12)$$

Direct transmission should be adopted when $G \le 1$, we are particularly interested in the distribution of Gin the interval $(1, G_{max}]$, where G_{max} is the maximumpossible gain:

$$G_{max} = \frac{T_{1h}}{\min\limits_{\theta=0,0<r<\ell} T_{2h}} \quad (13)$$

The optimal relay position on entire two dimensions. Plane will be $r = \ell/2$, i.e., midway between the base station and the end user, when $\gamma_1 = \gamma_2$.

4.2. Numerical Results

MATLAB routines have been written to numerically evaluate the maximum and average throughput gains. Similarly to Section III-B, we use the average no of relays in the unit circle, $\bar{N} = \pi\rho$, to reflect the relay density.

With the upper bound G_{max} established, we can now study how random relay placement affects the throughput gain. The average throughput gains are shown in Figures 5 for path loss exponents $\alpha = 3$.With increasing relay density, the average throughput gain approaches G_{max}. We also observe that, most of the throughput gain promised by

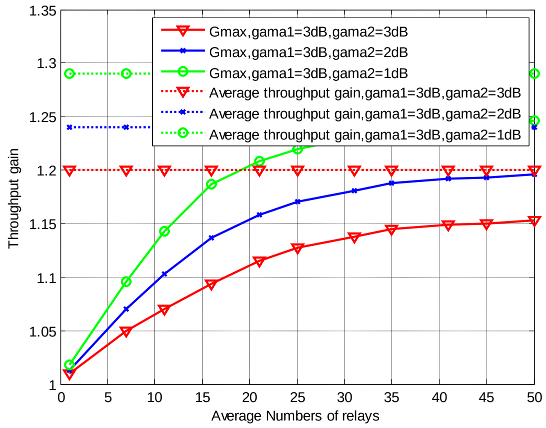

Fig.7 Average and maximum possible throughput gain as a function of the average number of relays.

The path loss exponent α is 3, and the end user is located a normalized distance $\ell = 1$ away from the base station - i.e., at the cell boundary.

G_{max}, which assumes an *optimized* relay position, can be achieved on the average with only a moderate number of randomly placed relays.

5. CONCLUSIONS

We have presented quantitative studies of the benefits offered by mobile relays - specifically, potential coverage area extension and throughput enhancement. For an out of-coverage end-user, connection success probabilities and routing/connection sustaining times were derived, and, for the cases considered, we conclude that mobile relays offer substantial coverage extension benefits. Throughput enhancement gains assuming randomly-placed mobile relays have also been analyzed, and we conclude that significant average throughput gains can be obtained for end users close to the edge of the coverage area with only a moderate number of mobile relays. Finally, although the results presented assumed certain 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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BIOGRAPHIES

Mr.D.R.SRINIVAS obtained his M.S in Electronics and control. He presented more than 10 research papers in various international journals & Conferences. He is presently working as Associate Professor in ECE Department, G. Pulla Reddy Engineering College, Kurnool, A.P, India. His research interests include Wireless communication, microwave engineering.

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