Rev. Téc. Ing. Univ. Zulia. Vol. 39, Nº 10, 13 - 28, 2016

doi:10.21311/001.39.10.02

Incremental relay selection with reduced power consumption and jamming for secure cooperative networks

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Abstract

This paper shows the cooperative transmission for securing a decode-and-forward (DF) two-hop network where multiple cooperative nodes coexist with a potential eavesdropper. Under the more practical assumption that only the channel distribution information (CDI) of the eavesdropper is known, this paper proposes an incremental relaying with artificial jamming and beam forming secrecy scheme, where a "best" cooperative node is chosen among a collection of N possible candidates to forward the confidential signal and the others send jamming signals to confuse the eavesdroppers with the help of signal to noise ratio. First, the ergodic secrecy rate (ESR) maximization problem is investigated by optimizing the power allocation between the confidential signals and jamming signals. Although the optimization problems are non-convex, a sequential parametric convex approximation (SPCA) algorithm is proposed to locate the Karush-Kuhn-Tucker (KKT) solutions. Finally, the analysis to the scenario with multiple eavesdroppers is generalized, and gives the asymptotic analytical results of the achievable ESR. Simulation results confirm our analytical results.

Key words: Decode and Forward,Opportunistic Relaying, Extreme Order Statistics, Ergodic Secrecy Rate, Power Allocation, Sequential Parametric Convex Approximation, Outdated CSIs.

1. INTRODUCTION

The concept of cooperative transmission can be found ,where the authors consider an uplink scenario where two users in a cellular network share part of their data, and that part is transmitted coherently using the same codebook. By doing so, the authors show that the capacity region is increased. They propose a multiuser zero-forcing relaying scheme in a network with multiple source and destination nodes. The communication between those source-destination pairs is facilitated by multiple amplify-and-forward (AF) relays. Each node is equipped with a single antenna. The authors propose a novel relay gain allocation scheme to orthogonalize the channel between those source-destination pairs. Multiuser interference is cancelled by this scheme.

A low mobility cellular relaying system is considered in downlink with multiple decode-and-forward (DF)(Angelos Antonopoulos, 2013) relays. DF relays do not cause noise amplification. Thus they may be more preferable in cellular systems. In a cellular system, the relays are usually intentionally placed where there is good wireless connection to the base station. So the base station to relay station (BS-RS) channel is usually very good. Since the system is in low mobility, we assume the relays have channel knowledge about the second hop. But we assume each relay only has its local channel knowledge. That is, each relay only knows the channel from its own antennas to the mobile stations (MS) (Liang, 2010).

Significant improvements in the performance of wireless networks can be made by employing terminals distributed in space. Basic results for single-relay cooperation are presented and references therein. Although interests in cooperative communication have been immensely increased recently, scaling cooperation to more than one relay is still an open area of research. Distributed space-time coding was recently proposed for multiple-relay scenarios. However, the number of useful antennas (distributed relays) for cooperation is generally unknown and time-varying. Additional difficulties arise from the lack of global channel state information (CSI) (Ding, 2012) in distributed environments. For example it is difficult in practice for the destination to acquire CSI between the source and all relays, as needed in the scheme proposed. Furthermore, phased-array techniques devised for co-located multi-antenna transmitters cannot be easily applied to distribute multiple relay (MR) (Dong, 2013) transmissions. As a result, the superposition of MR transmissions at the same time and frequency cannot be assumed as always constructive.

Therefore, simplification of cooperative communication techniques is crucial. Antenna selection, invented for classical multiple-antenna communication, is one approach to minimize the required cooperation overhead and to simultaneously realize the potential benefits of cooperation between multiple relays. In particular, a simple, distributed, single-relay selection algorithm was proposed for slow fading wireless relay channels, which are fundamentally different than co-located multi-antenna links (Arjun, 2016). This single-relay opportunistic selection provides no performance loss from the perspective of diversity–multiplexing gain tradeoff, compared to other schemes that rely on distributed space–time coding. In this paper,both reactive and proactive relay selection depending on whether the relay selection is performed after or before the source transmission. Under an aggregate power constraint, both reactive and proactive opportunistic relay selection with DF processing strategy is outage-optimal, that is, they are equivalent in outage behavior to the optimal DF (Ding, 2012)strategy that employs all potential relays.

Ahalf-duplex dual-hop communication scenario in a clustered environment is taken, where the direct path between the source and destination is blocked, while relays are located at the periphery of the obstacle. The DF relays can communicate with both endpoints (source and destination).

MPR (Multipoint Relay) selection (Jung, 2002) procedure can be used to get efficient broadcasting (Gopala, 2008) in that method nodes should be chosen as the relay node in a periodic manner. Relay nodes (Kirkidis, 2012) are selected in a random manner within the coverage area. A new way of broadcasting technique called Efficient Power Aware Broadcasts (EPAB) to provide an optimal path with suitable bandwidth and battery capacity. Throughput can be increased and packet loss can be reduced by using relay selection procedure. When combining relay method and network coding (Li, 2013) method advantages will be increased, integrating an energy efficient scheme, namely, network (Liang, 2010) coding, with clustering and duty cycling may facilitate the design of a new cluster based data collection scheme. Data rate should be high in order to get good energy efficiency. (Narayanaswamy,2002) Coverage area can be assigned for a node in order to reduce flooding of data packets. The efficiency of network should be improved by reduce redundant messages in the network. Tree based schemes such as minimal connected dominating set (MCDS) are better in reducing resource consumption in a low mobility environment probabilistic broadcast (Monks, 2001) approach can be used to avoid storm problem.

1.1. Broadcasting

Broadcast protocols can be classified into deterministic and probabilistic approaches. The probabilistic approach, usually offers a simple solution in which each node, upon receiving a broadcast packet, forwards the broadcast message with probability p. However, the probabilistic approach cannot guarantee full coverage. The deterministic approach guarantees full coverage and can be further classified based on the type of neighborhood information used: location-information-based and neighbor-set-based (Zhou, 2016). In location-information-based broadcast protocols, location information of neighbors is available, whereas in neighbor-set-based broadcast protocols, only neighbor set information is available. Location information facilitates efficient broadcasting in terms of generating a small forward node set; however, it comes with a cost—location information requires additional hardware, such as GPS. Other types of information can also be used which fall in between the above two models: directional information, where messages arrive from a certain angle-of-arrival (AOA), and distance information based on the signal strength received. All these models assume some sort of special hardware.

1.2. Problem Definition

In a broadcast process, each node decides its forwarding status based on given neighborhood information and the corresponding broadcast protocol. Most existing broadcast schemes assume either the underlying network topology is static during the broadcast process such that the neighborhood information can be updated in a timely manner. The results in show that existing static network broadcast schemes perform poorly in terms of delivery ration when nodes are mobile. There are two sources that cause the failure of message delivery

Collision: The message intended for a destination collide with another message. In Fig.1, if messages from nodes w and x collide at node y, node y does not receive any message.

Mobile nodes: A former neighbor moves out of the transmission range of the current node (i.e., it is no longer a neighbor). In Fig.1, when node w moves out of the transmission range of u, the nodes along the branch rooted at w of the broadcast tree will miss the message.

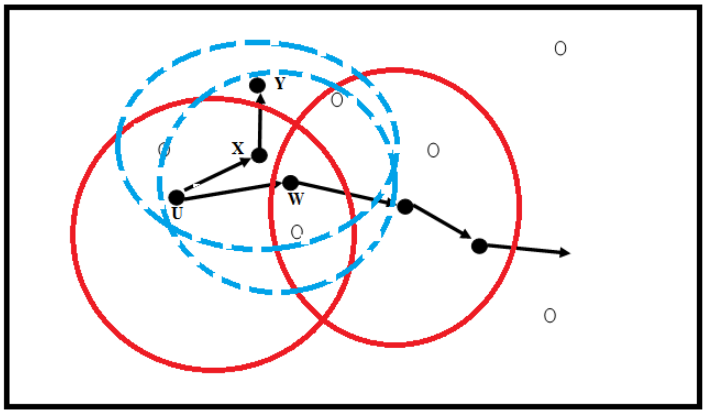

Figure 1. Forward node set in a MANET.

The major challenges in designing a localized broadcast protocol while ensuring broadcast coverage are as follows:

1) The network topology changes over time, even during the broadcast process.
2) The local (1-hop) information is constructed based on “Hello” intervals. To avoid serious collision among “Hello” messages, nodes start their intervals synchronously making it difficult to ensure consistent local/global views among nodes.
3) The collection process for k-hop information incurs delay which may not reflect the current network topology when there are mobility nodes, even for a small k in localized solutions.

1.3.Broadcasting Protocol

Broadcast protocols are categorized into four related areas:

- Simple Flooding: Nodes rebroadcast all received unique packets exactly once.
- Probability Based Methods: Nodes rebroadcast with a predetermined probability.
- Area Based Methods: Nodes rebroadcast if it will reach sufficient additional coverage area.
- Neighbor Knowledge Methods: Nodes rebroadcast based on its neighbor knowledge (algorithms are based on graph theory).
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1.4.The Shortcomings of Existing Broadcast Protocols

The shortcomings of existing broadcast protocols can be listed as:

1. Non-Neighbor Knowledge Methods require more rebroadcasts than the other methods studied, with respect to the number of retransmitting nodes.
2. The schemes that utilize a RAD (such as SBA) suffer in congestive networks unless a mechanism to adapt a node’s RAD to its local congestion level is implemented.
3. The Neighbor Knowledge methods that do not use local information to determine whether to rebroadcast (such as AHBP) have difficulty in mobile environments. The mobility extension for AHBP (AHBP-EX) marks an improvement over AHBP; however, it still under performs the other protocols. SBA naturally adapts to mobility by requiring more nodes to rebroadcast.
4. No single Neighbor Knowledge protocol evaluated performed the best in all studies.

Based on these shortcomings, none of the existing broadcasting protocols are satisfactory for wide-ranging MANET environments. Because the adaptive nature of the developed algorithm SBA showed significant improvements over the non-adaptive protocols, the development of new broadcasting protocols based on machine learning concepts appeared to be advantageous to pursue further work.

1.5. Related Work

A key consideration for any energy efficient protocol is the energy consumption at a wireless node. With respect to network activities (i.e. ignoring energy consumed in lighting up a display, power a hard drive etc.) each node’s radio can be in one of the following three states.

- ***Transmitting:*** The node is transmitting messages with transmission power P_t.
- ***Receiving:*** The node is receiving messages with reception power P_r.
- ***Idle:*** When no message is being transmitted, the node stays idle and keeps listening to the medium, consuming energy at a rate that corresponds to a power level P_{idle}.

  $P_{idle} < P_r < P_t$

Resource limitation, mobility of hosts and changing of wireless link make it difficult for MANET to manage for all quality of services. For efficient operations of network with the changing topology with the node mobility generates higher control message overhead. Methods to reduce energy consumption include:

- Considering residual battery energy while selecting the route.
- Reducing the communicationoverhead of control messages.
- Efficient route reconfiguration mechanisms (effect in topology changes)

Total energy consumption is divided into two parts: $E_{path\text{-}discovery}$, $E_{path\text{-}txion}$. $E_{path\text{-}discovery}$ is directly proportional to number of control packet. The principal sources of energy waste in MAC assume collision, message overhearing and control packet overhead and idle listening.

$$E_{total} = E_{path\text{-}discovery} + E_{path\text{-}txion}$$
$$E_{path\text{-}discovery} \ \alpha \ \text{control-packets}$$
$$E_{path\text{-}txion} = E_{idle} + E_{active} + E_{sleep} + E_{transient}$$
$$E_{active} = E_{receive} + E_{transmit}$$
$$E_{sleep} = 0$$

To increase node and network lifetime the route is established by taking the lightly loaded nodes with sufficient power resources. For longer network life and minimize energy consumption the following approaches are suggested.

- Power management Approach
- Power Control Approach
- Topology Control Approach

To minimize energy consumption of a path can be obtained by

- Minimum total transmission power
- Minimum total transceiving power
- Minimum total reliable transmission power

1.6. Topology Control

Mobility of wireless nodes makes the topology of network changes temporary. It is affected by many uncontrollable factors like node mobility, weather conditions, environmental interference and obstacles and some controllable factors like transmission power, antenna direction and duty cycle scheduling. Topology of network is considered as graph with its nodes as vertices and communication links between node pairs as edges. The edge set is large possible one if communication is established by node's maximum transmission power. In dense network too many links leads to high energy consumption. The primary target of topology control is to replace long distance communication with small energy efficient hops. Dense network ensures tight connectivity and high interference. In sparse network connectivity between nodes is being a question. So there is a tradeoff between network connectivity and sparseness.

Network topology can enhance network throughput because of two benefits. First the interference is reduced if transmission radii of nodes are reduced to near one. Second more data transmission is carried out simultaneously in the neighborhood of a node. A bad network topology has many adverse effects such as low capacity, high end-to-end delay and weak robustness to node failure. Where as a good network topology minimize energy consumption and end to end delay without much affecting the throughput.

1.7. Co Operative Relaying

Physical (PHY) layer security approaches for wireless communications can prevent eavesdropping without upper layer data encryption. However, they are hampered by wireless channel conditions: absent feedback, they are typically feasible only when the source-destination channel is better than the source-eavesdropper channel. Node cooperation is a means to overcome this challenge and improve the performance of secure wireless communications. This paper addresses secure communications of one source-destination pair with the help of multiple cooperating relays in the presence of one or more eavesdroppers. Three cooperative schemes are considered: decode-and-forward (DF), amplify-and-forward (AF), and cooperative jamming (CJ). For these schemes, the relays transmit a weighted version of a re-encoded noise-free message signal (for DF), a received noisy source signal (for AF), or a common jamming signal (for CJ). Novel system designs are proposed, consisting of the determination of relay weights and the allocation of transmit power, that maximize the achievable secrecy rate subject to a transmit power constraint, or, minimize the transmit power subject to a secrecy rate constraint. For DF in the presence of one eavesdropper, closed-form optimal solutions are derived for the relay weights. For other problems, since the optimal relay weights are difficult to obtain, several criteria are considered leading to suboptimal but simple solutions, i.e., the complete nulling of the message signals at all eavesdroppers (for DF and AF), or the complete nulling of jamming signal at the destination (for CJ). Based on the designed relay weights, for DF in the presence of multiple eavesdroppers, and for CJ in the presence of one eavesdropper, the optimal power allocation is obtained in closed-form; in all other cases the optimal power allocation is obtained via iterative algorithms.

1.8. Two Way Relaying

It addresses the security of a two-way relay network in the presence of an eavesdropper, where each node is only equipped with single antenna. A two-phase distributed analog network coding, or distributed beam forming and power allocation to enhance the secrecy sum rate of the data exchange is proposed. In the first phase, the two terminals broadcast their information data simultaneously to all the relay nodes. In the second phase, three different security schemes are proposed: optimal beam forming, null-space beam forming, and artificial noise beam forming. In the first scheme, the objective is to achieve the maximum secrecy sum rate of the two terminals. Mathematically, the objective function is difficult to optimize. In the second scheme, by maximizing the total information exchanged while the information leakage completely is eliminated, subject to the total transmission power constraint. This problem has a unique and global optimum, which can be solved using bisection method. When the instantaneous channel state information of the eavesdropper is not available, an artificial noise beam forming in the third scheme is proposed under the constraints of quality of service (QoS) required by terminals. It is a second-order convex cone programming (SOCP) problem, thus can be efficiently solved using interior point methods.

1.9. Co-Operative Beam forming And Jamming

This Paper addresses, a hybrid cooperative beam forming and jamming scheme to enhance the physical-layer security of a single-antenna-equipped two-way relay network in the presence of an eavesdropper. The basic idea is that in both cooperative transmission phases, some intermediate nodes help to relay signals to the legitimate destination adopting distributed beam forming, while the remaining nodes jam the eavesdropper, simultaneously, which takes the data transmissions in both phases under protection. Two different schemes are proposed, with and without the instantaneous channel state information of the eavesdropper, respectively, and both are subjected to the more practical individual power constraint of each cooperative node. A current state of the art technique for handling such a problem is the semi-definite relaxation (SDR) and randomization techniques.

1.10. Problem Formulation

In this sub section, the analytical result of RS is first derived. However, the obtained analytical result is too cumbersome for the power allocation optimization. As an alternative, employing the order statistics, we build a tractable result for approximating RS, which would facilitate the power allocation optimization. Conditioned on the power allocation strategy $\phi 1$, $\phi 2$, the optimalrelay selection criterion is to maximize RS by selecting k*

$$\mathrm{k}^*=\mathrm{arg}^{max}_{k\in N} min(\phi 1\mathrm{P}|h_{sRk}\ |,\phi 2\mathrm{P}|h_{RkD}|) \tag{1}$$

With the relay selection strategy, the analytical result of the achievable ESR should be derived to design the power allocation.

The noise power at the eavesdropper is typically unknown to S. To guarantee the secure transmission, the worst-case is considered, where the noise is zero. Now, the power allocation optimization is to choose$\phi 1$ and$\phi 2$ maximizing RS. However, since E_i (x) is the exponential integral function which can only be calculated numerically, the direct optimization of RS over $\phi 1$,$\phi 2$ is very difficult, if not impossible. Therefore, instead of optimizing RS directly, here it resorts to a widely used lower-bound technique. In particular, when the objective function is too complicated to maximize directly, an alternative is to find a lower bound of the objective function to approximate the primal objective function and optimize the approximation to maximize the primal objective function indirectly. Here,$\phi 1$ and $\phi 2$ are found by optimizing a lower bound of RS. Since log(x) is a concave function, using the Jensen's inequality.

To get a simple enough expression of for optimizing$\phi 1$,$\phi 2$ directly, in the following, 2the limiting distribution of extreme order statistics to get an asymptotic RL is evaluated when N → ∞. Furthermore, simulations show that even when N is not so large, the so obtained asymptotic results are still very accurate. Extreme order statistics theory has been developed to describe the limiting behaviors of a large number of random variables. Results show that even if N is not very large, the approximation is still very accurate.

1.11. Optimal Energy- Efficient RS and PA (EE-RS-PA)

A relay is defined to be selected if it is allocated with transmit power. Hence, the joint optimization of RS and PA can be modeled as an optimal power allocation problem. The objective is to find the optimal power allocation$\{p_{s,1}, p_{s,2}, p_i\}$ that minimizes the total transmit power subject to satisfying the required end-to-end rates $c_1$and c_2.The problem is formulated as,

$$\text{Minimize } P_{s,1} + P_{s,2} + \sum_{i=1}^{k} Pi$$

$$\text{Subject to } r_{1,2} \geq c_1,\ r_{2,1} \geq c_2$$

$$P_{s,1} \geq 0,\ P_{s,2} \geq 0$$

$$P_I \geq 0,\ i=1, \ldots\ldots, k$$

To facilitate the study, we assume that the noise variance isσ_i^2, σ_{s1}^2 and $\sigma_{s2}^2$are chosen as 1. The Karush-Kuhn-Tucker (KKT) conditions are necessary for a solution in nonlinear programming to be optimal. By substituting and applying KKT conditions, the transmit power of $S_1$and S_2 can be expressed as,

$$P_{s,1} = \frac{\eta 1\ (1+\sum_{i=1}^{k} \alpha i\,|gi|^2\ )}{\sum_{i=1}^{k} \alpha i\,|gi|^2|hi|^2},\ P_{s,2} = \frac{\eta 2\ (1+\sum_{i=1}^{k} \alpha i\,|hi|^2)}{\sum_{i=1}^{k} \alpha i\,|gi|^2|hi|^2}$$

Where $\eta 1 = 2^{2c1}-1$, $\eta 2 = 2^{2c2}-1$ the optimization problem transforms to the following form

$$\text{Minimize } \gamma(\alpha_{1xk}),\ \text{Subject to } \alpha_{1xk} \geq 0$$

$$\text{Where } \gamma(\alpha_{1xk}) = \frac{m\,(1+\sum_{i=1}^{k} \alpha i\ |gi|^2)(1+\sum_{i=1}^{k} \alpha i\ |hi|^2)}{\sum_{i=1}^{k} \alpha i\,|gi|^2|hi|^2} + \sum_{i=1}^{k} \alpha i$$

$$\alpha_{1xk} = [\ \alpha_1, \alpha_2, \ldots\ldots\ldots\ \alpha_k] \text{ and } m=\eta_1+\eta_2$$

To obtain the global optimum of problem, an exhaustive search is needed throughout amplification vectors $\alpha_1 \times k$ to find the overall minimum transmit power. Hence, it is prohibitive in terms of computational complexity. Instead of searching the solution of problem directly, we propose an E-SRS-PA scheme with single relay selection, which is supposed to be the solution.

2. SYSTEM ANALYSIS AND DESIGN

Cooperative diversity networks have recently been proposed as a promising technology to improve performance over fading channels. In this paper, an incremental amplify-and-forward (AF) cooperative diversity networks is considered which employ the *N*th best relay when the best relay is unavailable due to issues such as scheduling or load balancing. The end-to-end performance is analyzed over independent and identical and non-identical Rayleigh fading channels. Closed form expressions for the bit error rate and channel capacity are derived, and results are presented to illustrate the performance.

According to the analysis, the incremental AF strategy can reduce BER greatly when comparing to the conventional direct communication without cooperative, although it cannot get the capacity of conventional direct communication, which is with the power as the total power of source and N^{th} best relay node in AF cooperative network. The incremental AF strategy with N^{th} best relay can improve the capacity in high SNR region comparing to the complete cooperative with N^{th} best relay when BER can be accepted by setting different threshold for SNR of the direct link between source node *S* and destination node *D*. The incremental N^{th} best relay cooperative protocol can be useful when considering improving the error rate and bandwidth efficiency at the same time comparing to the conventional direct system and complete cooperative.

A preliminary performance analysis and protocols for incremental relaying were also given. Closed form expressions have been derived for the error probability, outage probability and average achievable rate for DF and AF with incremental relaying and a single relay. An incremental best relay technique for multiple relays was proposed. Closed form expressions for the error rate, outage probability and average channel capacity were obtained for incremental best relay cooperative diversity networks with DF and AF relays over independent and non-identical Rayleigh fading channels.

As stated previously, the best relay may be unavailable, in which case the N^{th} best relay can be used in incremental relaying. This is called incremental N^{th} best relaying. To the best of our knowledge, incremental *N*th best relaying with the AF protocols has not yet been investigated. Thus the aim of this paper is to present the bit error rate (BER) and channel capacity of incremental N^{th} best relay cooperative networks with AF over independent and identically distributed and non-identically distributed Rayleigh fading channels.

2.1. Proposed Incremental Relay Selection

This section presents a protocol for a multi-relay network with limited feedback, called Incremental Transmission Relay Selection (ITRS). The network consists of a source, M relays, and a destination, where the destination has a fading link to the source as well as the relays. In this protocol, the limited feedback has dual use: it selects the best relay, thus improving diversity, and also enables retransmission HARQ), thus improving spectral efficiency. The broad outline of the protocol is as follows: A packet is broadcast by the source. If the destination cannot decode, a limited-feedback handshake is performed that identifies the best available node (among source and relays), which will retransmit the packet. The ITRS protocol uses a maximum of one retransmission. Further retransmissions would reduce (and eventually eliminate) outage, but also incur further delay. This paper studies the case of one retransmission, which incurs modest delay and yet captures the biggest part of the gains available through retransmissions.

The ITRS protocol includes the source in the competition for the re-transmission, thus improving the diversity as well as throughput, as seen in the sequel. The protocols presented in this paper require feedback, whose transmission in turn requires a channel and a protocol. Feedback often goes through a control channel that exists in many wireless standards. The medium access layer for these channels can be either contention-based or slotted. In the former, all relays contend in sending their RTS to the destination, in which case the relay address (ID) must be attached to the RTS packet.

This avoids collision between relays, but some mini slots may go unused depending on the number of available relays, therefore usage of channel resources may be inefficient.

The process is as follows,

1) The source transmits a packet.

2) If the destination correctly decodes the message, it broadcasts an ACK and system returns to Step 1. Otherwise destination broadcasts a NACK.

3) Upon receiving the NACK, the relays that successfully decoded the packet will declare their status via a one-bit packet (RTS - Request to Send) to the destination. The RTS packet includes a pilot.

4) The destination estimates channel gains, picks the best transmitter from among successful relays and the source, and broadcasts the index of the best node.

5) The best node will retransmit the packet. The destination combines its two received packets and decodes. If unsuccessful, destination is in outage.

3. SYSTEM MODEL

The incremental N^{th} best relay cooperative network model is shown in Fig. 2.A source node *S* and a destination node *D* communicate over a flat Rayleigh fading channel with channel coefficient. A number of nodes are available to relay the signal from the source node to provide the destination with another copy of the original signal. The channels between S and R i , with coefficients hSRi, and between R i and D, with coefficients hRiD , are also flat Rayleigh fading channels. It is assumed that SD, h Sri and h RiD are mutually independent and identical or non-identical distributions. In addition, the channels are corrupted by additive white Gaussian noise (AWGN) with zero mean and equal variances N0. All nodes are equipped with a single antenna. The destination combines the two received signals using a technique such as maximal ratio combining (MRC). The received direct signal from *S* to *D*, and the relay signal from the relay to *D* can be written as

$$y_{SD=h_{SD\sqrt{E_{sX}}}}+n_{SD} \qquad (2)$$

$$y_{RiD=h_{RiD\sqrt{E_{sx}}}}+n_{RiD} \qquad (3)$$

In the second time slot, if the quality of the direct path signal at the destination is insufficient, the *N*th best relay is employed to forward the relay signal to *D*, the signal received at *D* can then be written as

$$y_{RnD=h_{RnD\,\sqrt{E_{sxr}}}}+n_{RND} \tag{4}$$

Which is AWGN on the link between Rn and *D* . When AF relaying is employed, the *N*th best relay is selected to amplify the signal and forward it The feedback (acknowledgment) from the destination is based on a comparison of the received SNR from the source with a threshold , which is the minimum SNR such that the destination can detect the signal successfully without employing a relay signal.

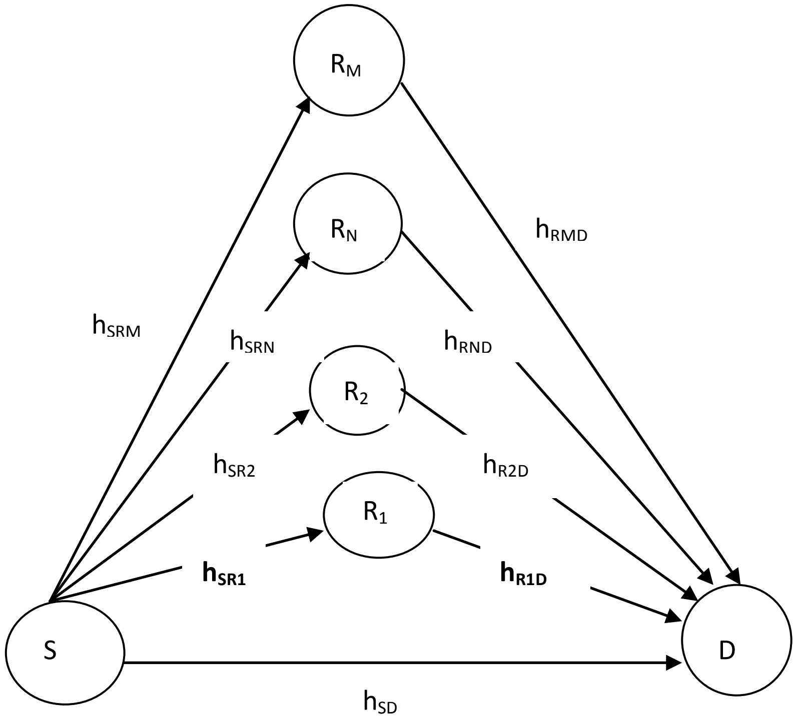

Figure 2. System model

3.1 Optimization Algorithm

The problem is non-convex due to the complex expressions. Although it can be solved by a two-dimensional search, it is very computational expensive, and the optimality depends heavily on the search interval. The general SPCA optimizes a sequence of approximating convex programs to locate the KKT solution of a non-convex program.

In each iteration, each non-convex constraint is replaced by an appropriate inner convex constraint. Under appropriate conditions on the inner convex approximation, a monotone convergence to a KKT point is established. Generally, SPCA has a fast convergence speed.

Setting z1, z2 and introducing the slack variables t1, t2, t3, t4.The constraints are active at the optimal solution. It also uses contradiction to verify this. Suppose that the constraints are not all active at the optimal point, then a feasible point for some θ1, θ2 ≥ 1, and 0 <θ3, θ4 ≤ 1 are constructed such that the constraints are active. It is not hard to see that the point can achieve an objective value larger than that offered by the original optimal point, which is a contradiction.

3.2. Algorithm

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Set $l = 1$ and select arbitrary feasible $\beta(l)$, $\omega1,1(l)$, $\omega1,2(l)$,$\omega2,1(l)$, $\omega2,2(l)$.
While
    The difference of the objective functions in successive iterations is larger than $\vartheta$, for some $\vartheta >0$ do
    Solve the optimization problem
    Set $\beta(l + 1) = t$ and $\omega1,1(l + 1) = t1/z1$, $\omega2,1(l + 1) =t1/z2$, $\omega1,2(l + 1)=t2/z1$, $\omega2,2(l+1)=t2/z2$, $l=l + 1$,
End while
Output: $\varphi1 = 1/z1$, $\varphi2 = 1/z2$.
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Algorithm provides a general solution to optimize $\varphi 1$ and $\varphi 2$ for arbitrary λ_{SR}, λ_{RD}, and γ. As a special case, when $\lambda_{SR}= \lambda_{RD}$, $\gamma = 1$, i.e, the distributions of the legitimate linkshave the same parameters, the optimal $\varphi 1$ and $\varphi 2$ have theclosed-form solutions, as stated in the following proposition.

Proposition 1: The non-convex problem can be transformed into a sequence of convex approximation programs.

Proposition 2: When $\lambda_{SR}= \lambda_{RD}= \lambda$, $\gamma = 1$, the optimal $\varphi 1$ and $\varphi 2$ are equal, and they are one of the following three possible solutions, which lies in (0, 1) and achieves the maximal ESR.

3.3. Impact of the Outdated CSI to the ESR

In a practical wireless system, due tothe time-variations of the channels and the feedback delay, the CSIs based on which optimal relay selection and cooperative jamming design are performed may not be the values of current time instant, i.e., the CSIs may be outdated .In this section, considering the impact of the outdated CSIs also used to analyze the achievable ESR under the proposed cooperative secrecy transmission scheme. Based on the outdated CSIs and the leaked jamming signals in the optimal relay selection should be performed.

Since the exact values of h_{SRi} and h_{RiD} are unavailable, the error-free best relay selection cannot be ensured. Note that since the proposed scheme does not depend on eavesdropper's instantaneous CSI, the outdated CSIs of the legitimate links would not affect the leakage rate to the eavesdropper. Therefore, the analysis of the rate achieved by D according to the optimal relay selection strategy is mostly concentrated. Similarly, we consider its asymptotic performance analysis in the following.

3.4.SRS and MRS Layout

We propose two relay selection schemes, namely both single-relay and multi-relay selection, for protecting the secondary transmissions against eavesdropping attacks. More specifically, in the single-relay selection (SRS) scheme, only a single relay is chosen from the set of multiple SRs for forwarding the secondary transmissions from the ST to the SD. By contrast, the multi-relay selection (MRS) scheme employs multiple SRs for simultaneously assisting the ST-SD transmissions.

We present the mathematical SRT analysis of the proposed SRS and MRS schemes in the presence of realistic spectrum sensing. Closed-form expressions are derived for the intercept probability (IP) and outage probability (OP) of both schemes for transmission over Rayleigh fading channels. The numerical SRT results of conventional direct Fig. 2. A primary wireless network in co-existence with a secondary CR network.Transmission and artificial noise based schemes are also provided for comparison purposes.

It is shown that as the spectrum sensing reliability is increased and/or the false alarm probability is reduced, the SRTs of both the SRS and MRS schemes are improved. Numerical results demonstrate that the proposed SRS and MRS schemes generally outperform the conventional direct transmission and artificial noise based approaches in terms of their SRTs.

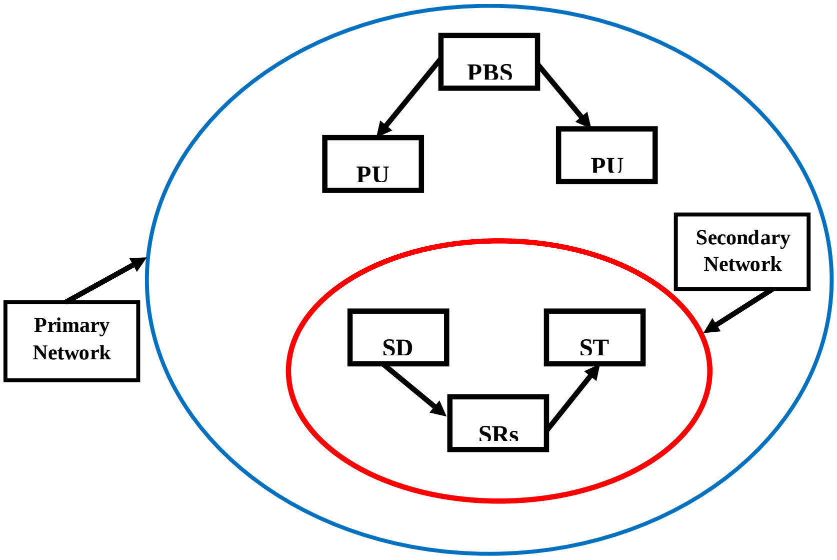

Figure 3. A relay network consists of one ST, one SD and N SRs in the presence of an E

Single Relay Selection

- Assume SD and E beyond coverage area of ST
- If unoccupied ST broadcasts signal to xs to N SRs
- ‘D’ represents set of SRs that succeed in decoding xs
- ‘D’ empty => no SR decodes xs successfully
- ‘D’ non empty => specific SR forwards xs to SD
- Signal received at SR ,SD and E
- Best SR selected based on capacity

$$C_{si}=\frac{1}{2}\log_2(1+\frac{|hsi|^2\gamma s}{\alpha|hpi|^2\gamma p+1})(5)$$

$$C_{bd}=\frac{1}{2}\log_2(1+\frac{\gamma s}{\alpha|hpd|^2\gamma p+1}\max_{i\in Dn}|hid|^2)(6)$$

$$C_{be}=\frac{1}{2}\log_2(1+\frac{|hbe|^2\gamma s}{\alpha|hpe|^2\gamma p+1})(7)$$

Multi-Relay Selection

- Similar to SRS scheme
- All relays used within network
- Than single relay, sum of RV’s used in MRS
- Weight vector introduced ‘w’
- Signal received at SD and E
- Capacity evaluated on an average

$$C_d^{\text{multi}}=\frac{1}{2}\log_2(1+\frac{\gamma s}{\alpha|hpd|^2\gamma p+1}\sum_{i\in Dn}|hid|^2)(8)$$

$$C_e^{\text{multi}}=\frac{1}{2}\log_2(1+\frac{\gamma s}{\alpha|hpe|^2\gamma p+1}\frac{|HdHe|^2}{|Hd|^2})(9)$$

3.5.Power Control of RTS/CTS: Constant Rate

We first consider power control in RTS/CTS-based systems with a fixed transmission rate. Note that the nodes in the RTS range may be unnecessarily blocked. However, this approach catches some basic properties of interference in wireless networks. Loosely speaking, the RTS range can serves as a measurement of how much interference the sender introduces to its neighbors when transmitting the RTS/data packet. The CTS range will be the measurement of “interference” introduced by the receiver that blocks future transmissions around it.

Our protocol minimizes the overall “interference” so that the spatial utilization can be increased. The simple RTS/CTS framework that we study here resembles the IEEE 802.11 protocol. In the IEEE 802.11 MAC protocol, the RTS/CTS exchange reserves a fixed area for transmission, irrespective of the distance between transmitter and receiver. This results in poor spatial utilization. Furthermore, the fixed CTS range cannot prevent collisions. In optimal power control scheme, each link strives to minimize its transmission floor in order to maximize the spatial utilization of the network.

Consider a transmitter-receiver pair (i, j). Using (1) and (2), the maximal interference that the receiver j can tolerate (power margin at node j) is

$$P_{\text{margin}}(j)=\frac{P_t^{(i)}G}{d_{ij}^{\alpha}\beta}-P_n\ (10)$$

If a node k is transmitting at the maximal power $P_{\max}$ and has a distance of d_{ij} to the receiver and if

$$P_r^k(j)=\frac{Pmax\ G}{d\ kj^{\alpha}}\geq\frac{P_t^{(i)}G}{d_{ij}^{\alpha}\beta}>P_{\text{margin}}(j)(11)$$

then node k will interfere with the reception of node j. From () we have

$$d_{kj}\,(\frac{P_{max\ d_{ij\beta}^{\alpha}}}{P_t^{(i)}})^{\frac{1}{\alpha}}\leq(\frac{P_{max\ d_{ij\beta}^{\alpha}}}{P_t^{(i)}})^{\frac{1}{\alpha}}(12)$$

Define $d_{int}^{j} =(\frac{P_{max}\ d_{ij\beta}^{\alpha}}{P_t^{(i)}})^{\frac{1}{\alpha}}$, which is the distance threshold within which a node transmitting at P_{max} can interfere with node j’s reception from node i. The transmission range of CTS should be atleast d_{int} (j) which gives the lower bound of the reserved transmission floor. To ensure that all nodes within d_{int} (j) can decode the CTS message, the received power of the CTS at a distance d_{int} (j) must satisfy

$$\frac{P_t^{(i)} G}{P_{int}^{\alpha}\,(j)} \quad \geq P_{recv} \quad (13)$$

to make neighbors hear the CTS message, where P_{recv} is the receiver sensitivity. So the receiver transmitter power must be

$$P_t^{(j)} \geq \frac{Precv\ P\ max\ dij^{\ \alpha}}{P_t^{(i)} G}\beta \quad (14)$$

To comply with the maximal transmission power, the possible link length of d_{ij}should be smaller than thed_{max}. Otherwise the CTS message will not be able to inform all possible interfering neighbors.

From (13) we can see that the transmission power of CTS $P_t^{(j)}$ is inversely proportional to the transmission power of data and RTS$P_t^{(i)}$. So there is a trade-off between transmission power of RTS and CTS.The maximal transmission range is given by

$$d_{max}=\left(\frac{GP_{max}}{P_{recv}}\right)^{1/\alpha} \quad (15)$$

Combining (13) and (14) we get

$$P_t^{(j)} P_t^{(i)} \geq (\frac{d_{ij}}{d_{max}})^{\alpha} P_{max}^2\, \beta \quad (16)$$

The transmission range of CTS and RTS, defined as $d_c=(\frac{P_t^{(j)} G}{P_{recv}})^{\frac{1}{\alpha}}$ and $d_r=(\frac{P_t^{(i)} G}{P_{recv}})^{\frac{1}{\alpha}}$, will satisfy

$$d_c d_r =(P_t^{(j)} P_t^{(i)})^{\frac{1}{\alpha}} (\frac{G^2}{P_{recv}^2})^{\frac{1}{\alpha}}$$

$$\geq \frac{d_{ij}}{d_{max}}$$

$$\geq \frac{d_{ij}}{d_{max}} (\frac{P_{max}^2\ G^{2\beta}}{P_{recv}^2})^{\frac{1}{\propto}} \quad (17)$$

$$= \beta^{\frac{1}{\alpha}} d_{max}\, d_{ij}$$

Let the area of the transmission floor be$A_{ij}(d_c,d_r)$. This area must be larger than the RTS or the CTS region. Thus we have

$$A_{ij}(d_c,d_r) \geq \max\{\pi d_c^{*2} , \pi d_r^{*2} \} \qquad (18)$$

The selection of $d_c$and $d_r$is subject to the following constraints:

$$\geq \beta^{\frac{1}{\alpha}} d_{max}\, d_{ij}$$
$$d_c \geq d_{ij}$$
$$d_r \geq d_{ij} (19)$$

When $\beta^{\frac{1}{\alpha}} d_{max}\, d_{ij} > d_{ij}$, it is easy to see that $\max\{d_c, d_r\} \geq \beta^{\frac{1}{\alpha}} d_{max}\, d_{ij}$, and we get

$$\mathrm{Min}\{A_{ij}(d_c,d_r)\} \geq \beta^{\frac{1}{\alpha}} d_{max}\, d_{ij} \quad (20)$$

It is seen that$A_{ij}(d_c,d_r)$ is actually minimized when we have $d_c^* = d_r^* =\sqrt{\beta^{\frac{1}{\alpha}} d_{max}\, d_{ij})}$.
This hints an optimal way of setting the transmission power, given the link distance. The upper bound of the area of the reserved transmission floor is

$$\mathrm{Min}A_{ij}(d_c,d_r) \leq \pi d_c^{*2} + \pi d_r^{*2} = 2^{\pi\beta^{\frac{1}{\alpha}} d_{max}\ d_{ij}} \quad (21)$$

Thus together with lower bound it can be seen that

$$\pi\beta^{\frac{1}{\alpha}} d_{max}\, d_{ij} \leq \mathrm{Min}\{A_{ij}(d_c,d_r)\} \leq 2^{\pi\beta^{\frac{1}{\alpha}} d_{max}\, d_{ij}} \tag{22}$$

Thus the area of the reserved floor is $\Theta\,(\beta^{\frac{1}{\alpha}} d_{max}\, d_{ij})$ when using the optimal power control scheme.

4. RESULTS AND DISCUSSIONS

4.1. Incremental Relays

The number of relays considered for simulation is 5. More number of relays can also be used. SNR and ESR of each relay is calculated and compared, from these a best relays is chosen. Signal to noise ratio is the ratio of strength of signal carrying information to the unwanted interference.Based on the ergodic secrecy rate and signal to noise ratio a legitimate relay is selected. Confidential information is forwarded through this relay. Relay selection is done by source node and broadcast to all other nodes.

From the CDI of eavesdropper source calculate SNR and ESR to improve secrecy. Here only this relay is above the threshold value. Confidential signal is send through this relay. Remain sent jamming signal.

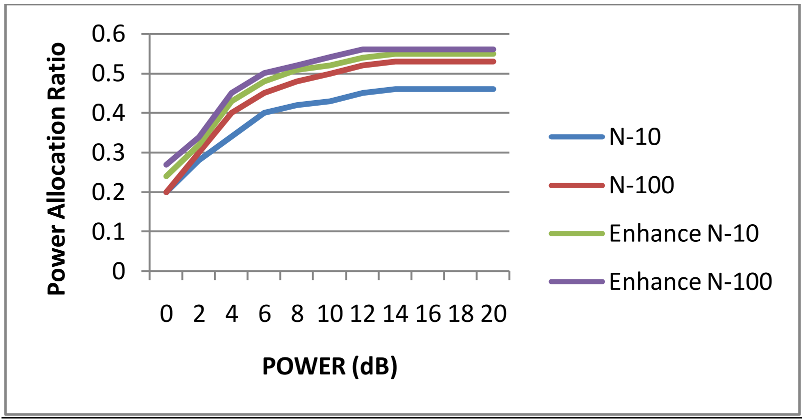

Figure 4. Performance of previous and enhanced methods

This graph shows the performance of previous and enhanced methods. Number of relays considered for this analysis is 10 and 100. Power allocation ratio of enhanced method is better than the previous method.

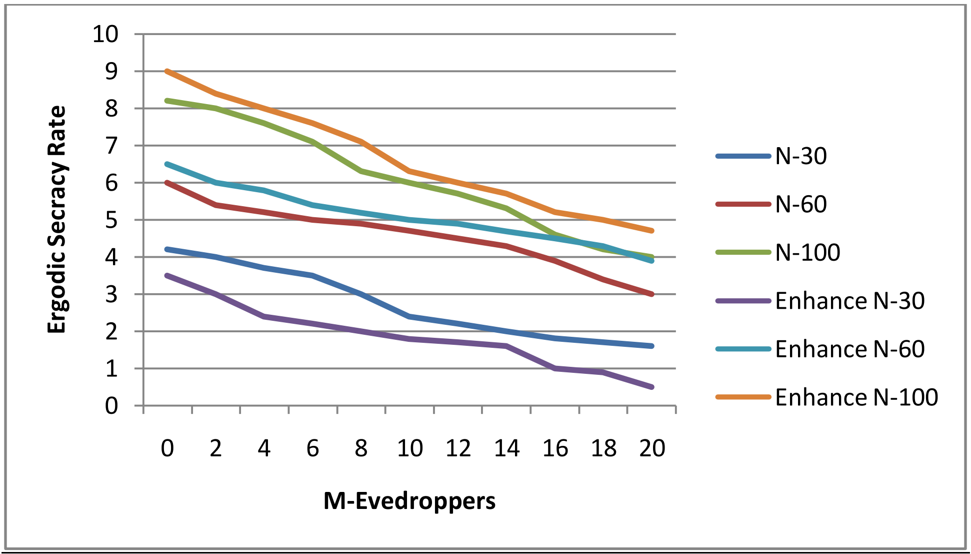

Figure 5. Performance of -eavesdroppers

This graph shows the performance of the system with M- eavesdroppers. Here M=60 i.e number of eavesdroppers considered are 60. Relay nodes are considered to be 30 and hundred. Ergodic secrecy rate of system with these values are calculated and compared with the previous method.

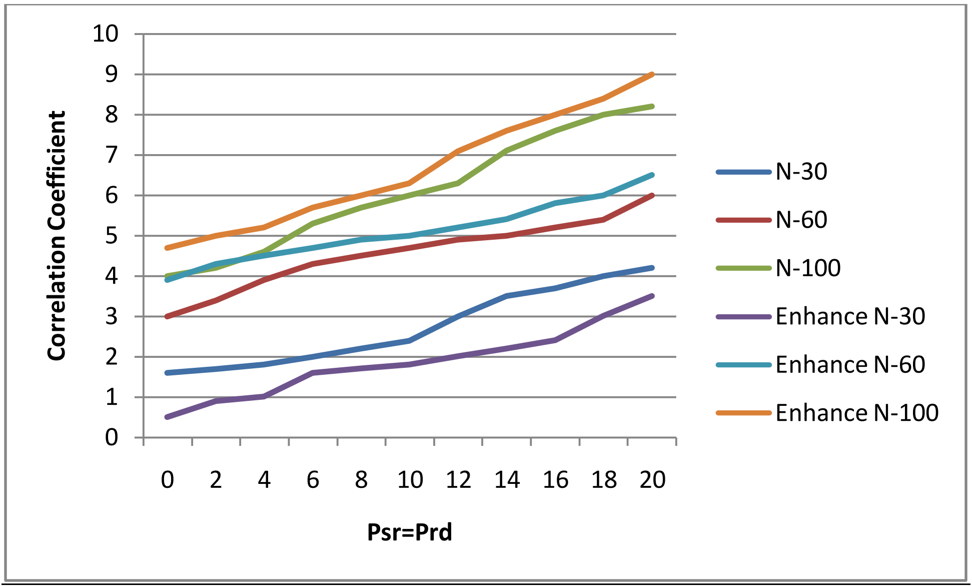

Figure 6. Theoretical performance

The noise power at the opportunistic relay and *D* are normalized to zero. This shows the efficiency of proposed power allocation algorithm. In the proposed strategy a two dimensional exhaustive search algorithm is employed to locate the optimal power allocation for maximizing ESR.

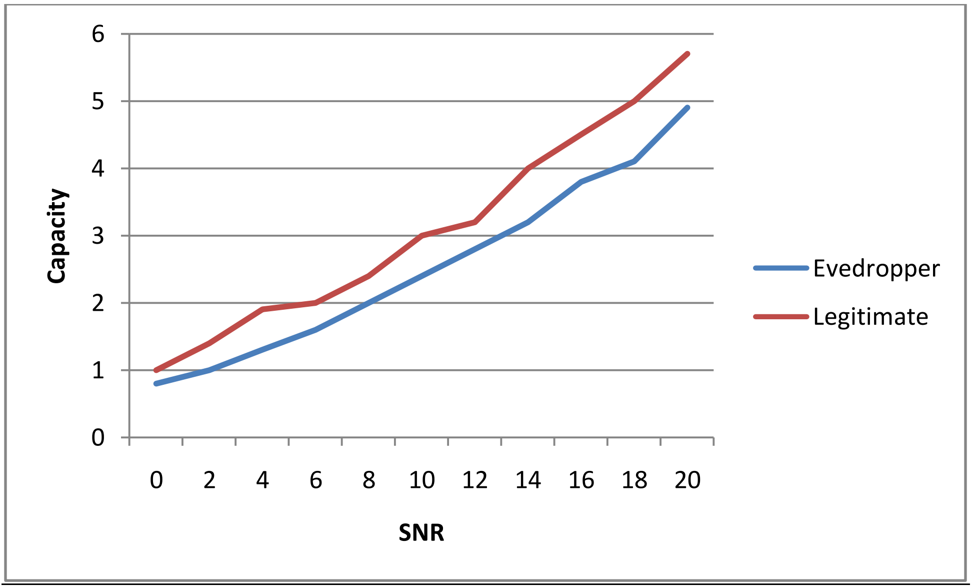

Figure 7. SNR versus capacity of eavesdropper and legitimate receiver

This graph shows the SNR versus Capacity of legitimate receiver and eavesdropper. The channel capacity of eavesdropper is less than that of receiver. Signal to noise ratio increases and the capacity of the channel also increases.

Ergodic secrecy rate increases with increase in power. Theoretical results coincide with the simulation results. Both theoretical and simulation results are compared and both are close to each other. This shows the effectiveness of the proposed secure transmission scheme.

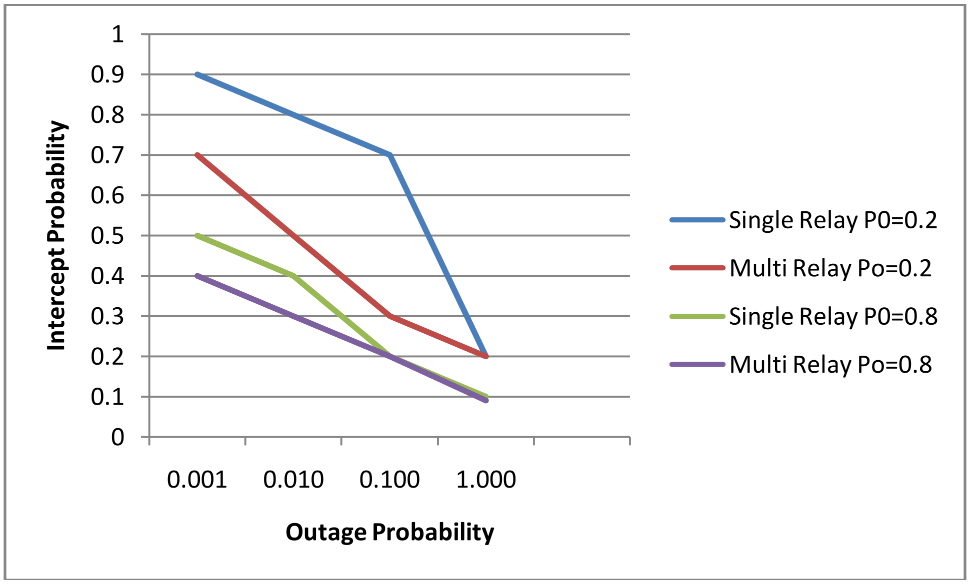

Figure 8. IP versus OP of the SRS and MRS schemes with different P0

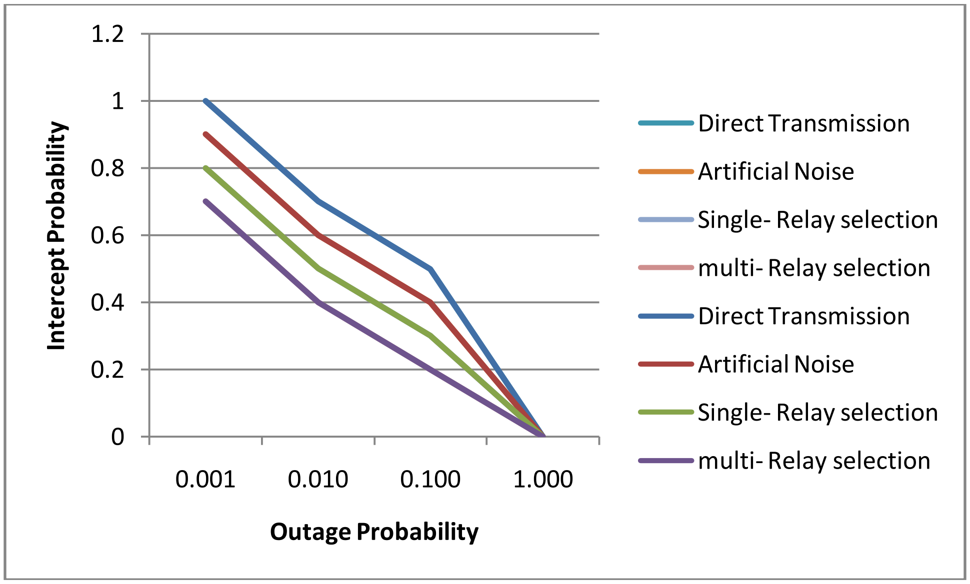

Figure 9. IP versus OP of the direct transmission, the SRS and the MRS schemes

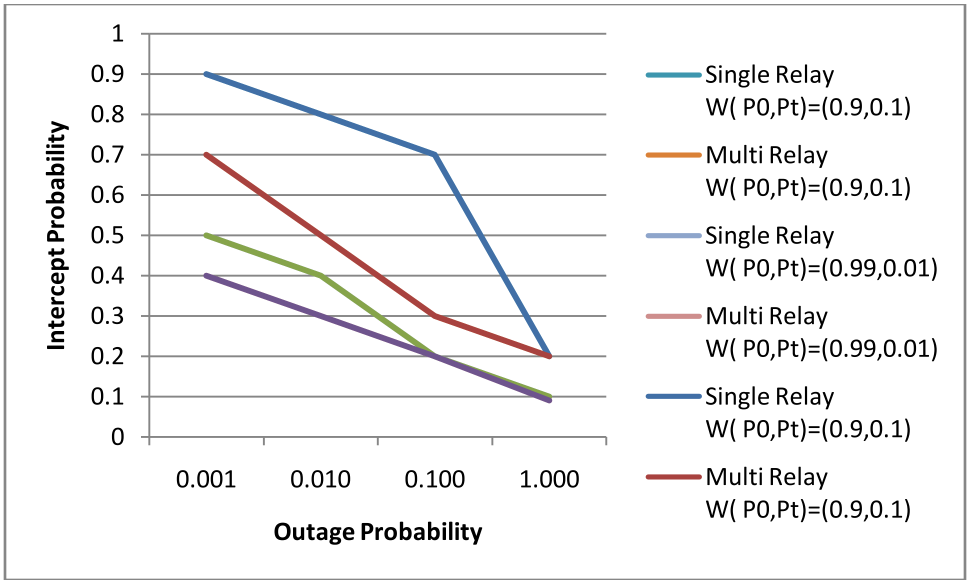

Figure 10. IP versus OP of the SRS and the MRS schemes for different (*Pd* ,*Pf*)

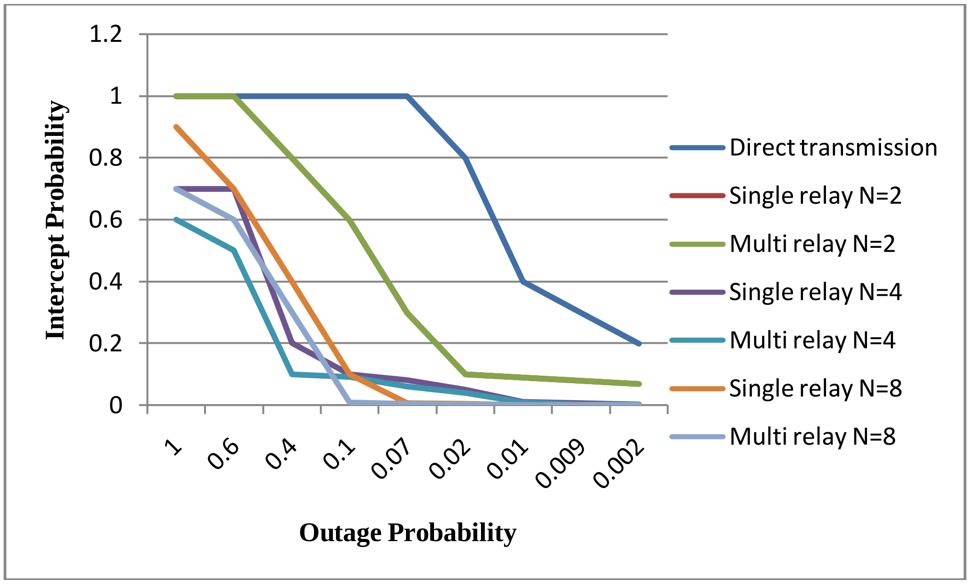

Figure 11. IP versus OP of the direct transmission, the SRS and the MRS schemesfor different *N*

5. CONCLUSION

An opportunistic relay node is adopted for forwarding the confidential information and the other relay nodes send the artificial jamming for confusing the eavesdroppers. The impact of outdated CSIs to the relay selection and the achievable ESR are investigated. Incremental relay selection provides continuous transmission. Jammers can protect the data efficiently even when the eavesdroppers are more than relay nodes. The proposed secure scheme in the presence of multiple eavesdroppers is studied. All the analysis utilizes the limiting distribution theory of extreme order statistics, assuming that there are a large number of cooperative nodes and/or eavesdroppers. Simulation results show that the limiting distribution analysis is a very efficient technique, which coincides the numerical calculations very well even when the number of nodes is not so large. Furthermore, it has been shown that the optimized power allocation tends to allocate more power to the jamming signals and from the asymptotic performance analysis; it is found that the jammers can protect the data transmission efficiently even when the number of the eavesdroppers is larger than that of the cooperative nodes.

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