PERFORMANCE ANALYSIS, POWER ALLOCATION AND SECRECY IN RELAYED COMMUNICATION SYSTEMS

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Certificate

This is to certify that the thesis entitled **"Performance Analysis, Power Allocation and Secrecy in Relayed Communication Systems"** being submitted by **Mr. Chinmoy Kundu** to the Bharti School of Telecommunication Technology and Management, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is the record of the bona-fide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree or diploma.

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Abstract

In short distance communication technique like Ultra-Wideband (UWB) communication the log-normal fading model is a generally accepted channel model. In this thesis, we begin by proposing an alternate numerical approach to evaluate average symbol error probability in a log-normal channel. Average symbol error probability for maximal ratio combining Rake receiver in UWB multi-path channel is evaluated using the proposed numerical approach. It is shown that the proposed method is more general with comparable accuracy. We then propose multi-hop decode-and-forward relaying for range extension of UWB system using non-coherent transmitted reference UWB receiver. Distribution of individual hop signal-to-noise ratio is approximated by a log-normal distribution and subsequently end-to-end average bit error rate is evaluated analytically. It is found that the performance improvement in average transmit signal-to-noise ratio is not equal as the number of hop increases. It decreases with increase in hop number in the line-of-sight channel.

In an energy constrained multi-hop relaying network, the end-to-end quality-of-service must be optimized. Hence, joint optimization of power allocation and relay location is proposed for amplify-and-forward relaying over independent log-normal channels. The proposed optimization method maximizes the end-to-end average signal-to-noise ratio. It is observed that joint optimization can even outperform instantaneous signal-to-noise ratio based power allocation. Subsequently, joint optimization of power allocation and relay location is proposed for decode-and-forward relaying using the same system model of amplify-and-forward relaying. Optimization is now carried out in order to minimize the outage probability and end-to-end average bit error rate. All the optimization problems reformulated from the original problems

are shown to be convex except for the optimization of relay location in minimizing outage probability at the low signal-to-noise ratio scenario. It is then solved using properties of concave minimization. It is observed that performance improvement increases with increase in link unbalance and distance based allocation is most effective in performance improvement.

Relaying not only increases the area of interception it can even provide diversity benefit to the eavesdropper. Thus, towards the end of the thesis, a dual-hop amplify-and-forward system is considered in Rayleigh fading channel with an eavesdropper. We consider maximal ratio combining and selection combining diversity by the eavesdropper. Closed-form expressions for upper, lower bounds and approximate secrecy outage are derived. In order to achieve the same performance of selection combining, maximal ratio combining requires relatively higher signal-to-noise ratio at lower rate. It is also interesting to observe that either one of the dual-hop link can equally limit the secrecy outage performance.

Relay selection can further improve the secrecy outage performance. Secrecy outage probability of optimal, traditional and suboptimal relay selection schemes is evaluated for a dual-hop regenerative multi-relay system in Rayleigh fading channel. Partial relay selection schemes are introduced. An optimal relay selection scheme is proposed which does not require any instantaneous channel information. Improvement in eavesdropper link quality affects the secrecy outage more when the required secrecy rate is low. It is also interesting to observe that either of the source-relay or the relay-destination link quality can equally limit the secrecy outage performance.

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List of Abbreviations

Acronym	Meaning
ABER	Average Bit Error Rate
AF	Amplify-and-Forward
ARake	All-Rake
ASEP	Average Symbol Error Probability
ASNR	Average Signal-to-Noise Ratio
ATR	Average Transmitted Reference
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CF	Characteristics Function
CSI	Channel State Information
CTS	Clear-to-Send
dB	Decibel
DF	Decode-and-Forward
DTR	Differential Transmitted Reference
EA	Equal Allocation
EGC	Equal Gain Combining
ICSI	Instantaneous Channel State Information
ISI	Inter Symbol Interference
ISNR	Instantaneous Signal-to-Noise Ratio
JOA	Joint Optimal Allocation
LOS	Line-of-Sight

LT	Long Term
MGF	Moment Generating Function
MRC	Maximal Ratio Combining
NLOS	Non Line-of-Sight
OA	Optimal Allocation
OPA	Optimal Power Allocation
ORL	Optimal Relay Location
PA	Power Allocation
PAM	Pulse Amplitude Modulation
PDF	Probability Distribution Function
PPM	Pulse Position Modulation
PSD	Power Spectral Density
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QoS	Quality-of-Service
RV	Random Variable
RTS	Ready-to-Send
S-V	Saleh-Valenzuela
SC	Selection Combining
SCSI	Statistical Channel State Information
SNR	Signal-to-Noise Ratio
ST	Short Term
STR	Simple Transmitted Reference
TR	Transmitted Reference
UWB	Ultra-Wideband