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PERFORMANCE ANALYSIS OF TWO-HOP RELAY CELLULAR SYSTEMS: A SURVEY

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Abstract:

Two-hop system consists of a Relay station which lies in between Base Station and mobile devices, which in turn boosts the signal strength to increase the throughput and cellular coverage. Since, spectrum is a scarce resource, using spectrum to its maximum potential is essential and very much required. Relay station helps in doing so and coverage area of cellular networks will also be increased in less cost. In this paper, simulation of this kind of network using some simulation tools to analyse the performance of this two-hop system by making different kinds of changes to the network is built and the metrics in each case is compared (increasing the number of mobile nodes in one cell). Intercell interference can be noticed. In future, this kind of system can be implemented in Hybrid Networks such as cellular/WLAN architecture to offload the load on WLAN.

Keywords: Base station; Relay station; User Equipment.

Introduction:

With the number of mobile users are increasing exponentially day by day, providing bandwidth for every user is a tough task. So, utilising the existing bandwidth and exploiting the technology to full extent is a better choice. Current base stations are not enough to withstand this much load upon them. So, relay stations help in resolving this problem. Relay station is defined as a node which assists in transmission of data between other nodes in the network. A relay system can be either a dedicated relay system or a cooperative relay system depending on the need. A dedicated relay system is one which is totally dedicated to forward data to other nodes, where as a cooperative relay system will help other nodes to forward data when it does not have its own data to forward.

Relay station can be placed in the coverage area of base stations where the load for base stations has been increased. Base station is nothing but a central communication point where all the user equipments are connected to communicate with other nodes. In turn base stations are connected to different antennas for communicating with

other user equipments connected to different base stations. User equipments here may be a mobile phone, laptop, PDA's etc.

In a relay system, user equipment can either connect to base station or it can connect to relay station. User equipment can connect to relay system either directly or indirectly. If it is connected to base station, then it will be scheduled and managed directly by the base station to which it is connected. But, if the user equipment is connected to relay station then it may be scheduled and managed either by relay station or base station.

Scheduling can be done in two ways, centralised scheduling and distributed scheduling. In centralised scheduling, base station takes care of each and every user equipment present in its cell, which includes user equipments of both base domain and relay domain. But in distributed scheduling, relay station will take care of user equipments being connected to it and base station will take care of its user equipments. Distributed scheduling mode can be either fully distributed or semi distributed depending on the involvement of the base station.

Literature Survey:

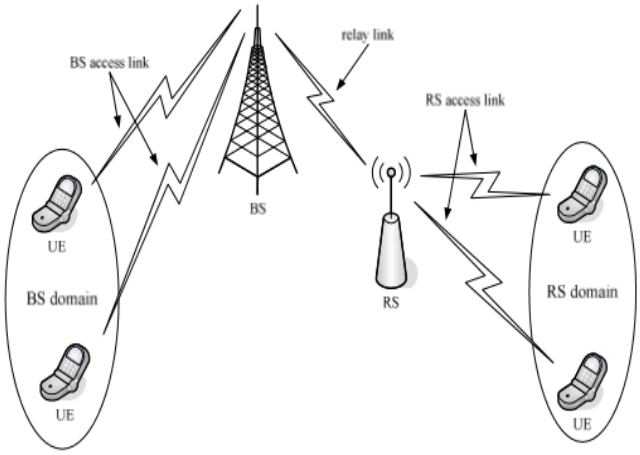

Figure I: System Model[1].

System model presented in figure.1 [1] consists of a base station, relay station, and user equipments. Base station domain will have all the user equipments which are connected to it through a link called Base station access link which in turn are directly connected to base stations. Relay domain will have user equipments which are connected to it through relay station access links which in turn are again connected to base station using some links called relay link. User equipments in relay domain will take two hops to reach the base station. So, this model is called a two hop cellular system. Fan Huang et al[1], have proposed and analysed scheduling strategies for both centralised and distributed two hop relay cellular systems. Analysis is done by simulating all the scheduling strategies and is compared with other scenarios.

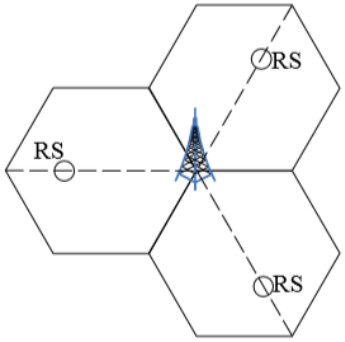

Figure II: Cell model [1].

Simulation is done by building a cell model as shown in fig.2 which consists of relay systems placed at 2/3rd the radius distance away from base station in each hexagonal cell.

In Chunguo Li et al, [2], usual conventional model with both one-hop and two hop transmissions use orthogonal channels through multiple-access scheduling schemes like code division, frequency division. But, this method is not so sufficient enough in utilising the bandwidth, so new spectral-efficient transmission protocol which will have both one-hop and two-hop relayed transmission is used.

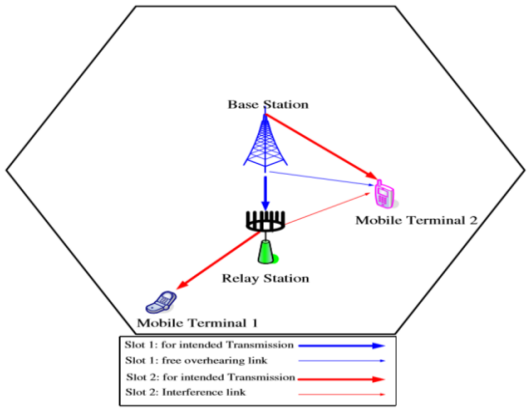

Figure III: Co-existence of one-hop and two transmission relay system [3].

In the work proposed by Baldomero Coll-Perales et al [3], a multi-hop cellular network (MCN) with Mobile Relay (MR) will have integrated system of cellular networks with relay systems by replacing cellular links with multi-hop transmissions with greater energy efficiency. Capacity and energy efficiency of the cellular systems have to be improved without compromising on the factor called QoS. So, opportunistic store, carry and forward technique is be proposed for two-hop cellular systems. This technique also helps in reducing path losses by reducing the distance between the base station and transmission. It also helps in finding out the location from which the relay has to start forwarding information to the cellular networks. All the analytical results show that this technique will have efficient energy utilisation and has applications in future technologies like 5G wireless communications.

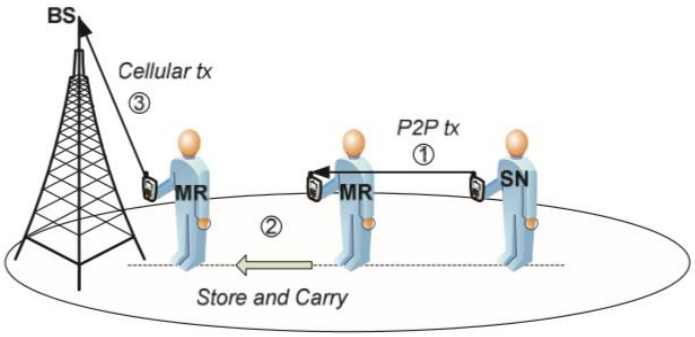

Figure IV: Store, carry and forward principle [4].

In Ning Wei et al [4], relay systems are used in millimetre wave cellular systems in order to effectively utilise the millimetre spectrum. Millimetre wave cellular systems are very prone to blockages and cannot penetrate through solid materials and even human body can attenuate these signals. So, relays are the only solution which helps in increasing connectivity of cellular systems using millimetre waves by overcoming the blockages. Optimised threshold based policy is used for selecting the best appropriate relay system.

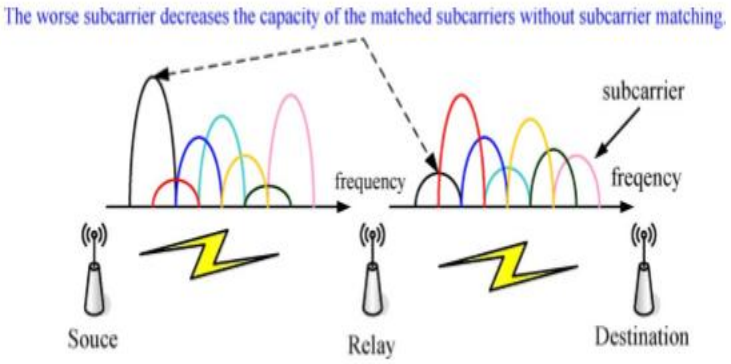

Figure V: System architecture of an OFDM two-hop relay system [5].

The main aim of the work discussed by Wenyi Wang and Renbiao Wu [5] is to increase the performance of relay networks by increasing the capacity of the channel and thereby increasing the coverage area. Orthogonal Frequency Division Multiplexing (OFDM) is one which reduces the frequency selection problem and inter-symbol interference. Optimised allocation of power to different sub-carriers will increase the gain of the entire system. Maximising the system capacity by joint sub-carrier matching and power allocation is done in this reference. Figure 5 show the architecture used for the simulation.

A unified performance analysis of a system consisting of source and destination equipped with multiple antennas which communicates using a single relay system is discussed by Nuwan S. Ferdinand and Nandana Rajatheva[6]. Maximal Ratio Transmission (MRT) at source and Maximal Ratio Combining (MRC) at destination are considered in

one part and in the second part Transmit Antenna Selection (TAS) at source with uncorrelated antennas and MRC at destination with correlated antenna are investigated.

Radha Krishna Ganti and Martin Haenggi [7], suggest that base stations are to be located with deterministic process and mobile nodes are to be placed using point process in which, whichever node having best channel with the destination and which receives information in the first hop acts as a relay. Comparison of two-hop cellular system with traditional cellular systems is done.

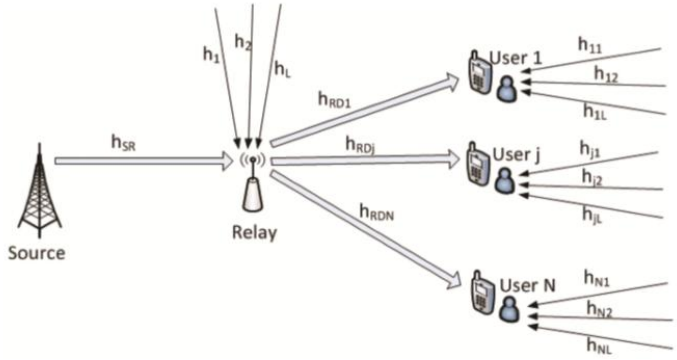

Figure VI: Model used for analysis. [8].

Kasun T. Hemachandra and Norman C. Beaulieu [8], (figure 6) proposed a model for analysing multi user two-hop AF relaying system by using opportunistic scheduling. Analysis of CSI effects on the system along with deriving outage probability results. So, finally numerical results will show that outage probability is less sensitive to the number of interferers at the destination.

Tingting Liu et al [9], uses multi carrier and multi antenna two-hop relay systems without interference linear transceiver. Two kinds of relay systems with three nodes are considered and simulation is done to support the numerical results which show that multi carrier systems using Code-Division Multiplexing (CDM) will benefit from exploiting Carrier State Information (CSI) with all three nodes than multi carrier systems using Frequency-Division Multiplexing (FDM). CSI at each node is acquired by using training symbols for channel estimation and channel reciprocity.

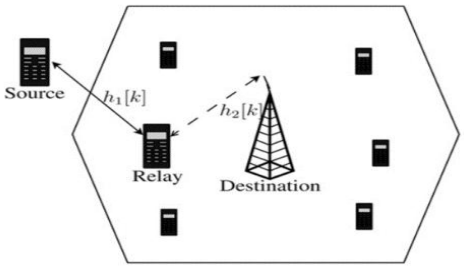

Figure VII: Dual-hop relaying system without direct link [10].

M.R. Avendi, and Ha H. Nguyen [10], discuss on a two phase transmission used in which source transmits data to relay and relay then amplifies and forwards the same to the destination. Main two goals of this paper is to analyse the performance of single branch dual-hop relay system using phase shift key modulation and one more goal is to design a multi symbol detection for improving the performance of fast-fading channels.

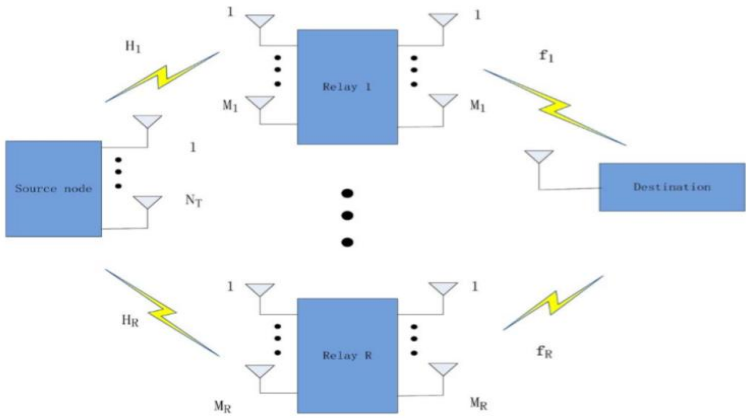

Figure VIII: Two-hop multi antenna multi relay network [11].

Hongying Tang et al [11], considered multi antenna source and multi relay relays in an AF relay networks. Joint source and Beam Forming (BF) design has been fully analysed using both imperfect and perfect CSI cases (Figure 8). Fact is practical network will have multiple antenna with multiple relays, so it is very much needed to investigate the joint source and relay BF for general networks. Finally simulation results are provided to validate the algorithms using numerical convex optimization solver (CVX).

Li Sun et al [12], discuss on Destination Based Jamming (DBJ) which is used to investigate the problem of secure communication in AF systems with untrustworthy relay nodes. Firstly single relay scenario is considered and then DBJ is extended to multi-relay scenario. Channel fading problem can be solved using cooperative relaying in which neighbouring users cooperate with each other. In this paper, Rayleigh fading is used for single-relay system. By combining DBJ ideas with opportunistic relaying, a new relay selection scheme can be proposed.

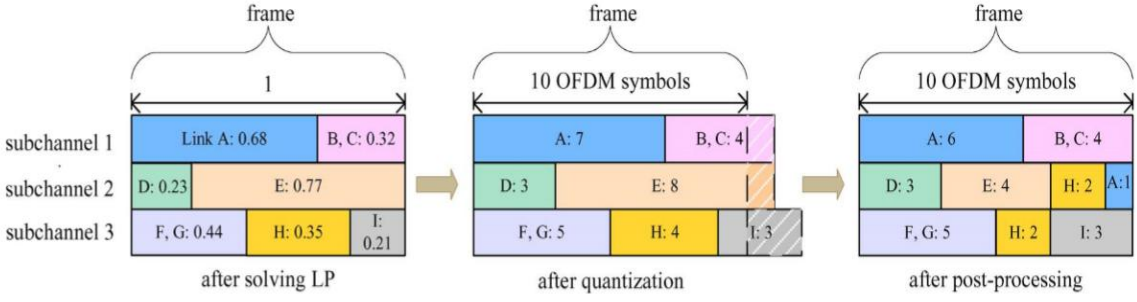

Figure IX: 10 OFDM symbols in a frame. [13].

Wha Sook Jeon et al [13], used the above model (figure 9) to propose an efficient resource allocation scheme for an OFDMA based relay systems. In this model, simultaneous allocation of sub channels with little interference is proposed and a post processing algorithm for adjusting the proposed solution is also proposed.

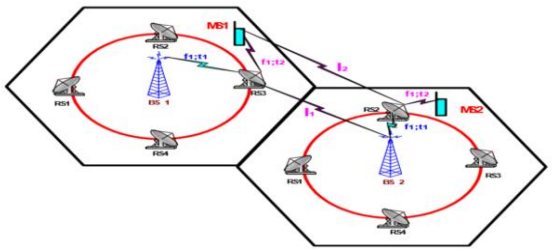

Figure X: Two-hop cellular system model based on TDMA. [14].

Zhang Jingmei et al [14], involves a two-hop cellular system based on TDMA scheme as shown in figure 10, in which relay system will be either Regenerative Relay System (RRS) or Non-Regenerative Relay System (NRRS). Two power allocation schemes viz. Optimal Power Allocation (OPA) and Uniform Power Allocation (UPA) schemes between base station and relay station are compared. Results show that using OPA scheme performance of relay stations are further increased.

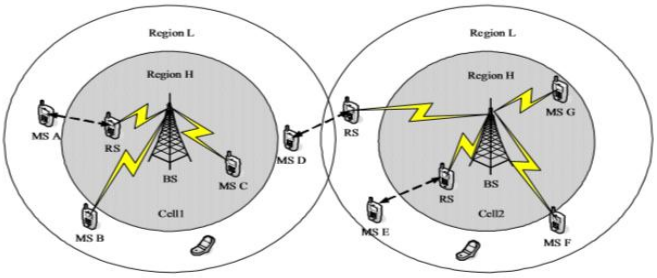

Figure XI: Architecture of two-hop relay WCDMA cellular system. [15].

Wei-feng Lu [15], proposes an architecture as shown in figure 11 which consists of a two-hop relay Wide-band Code-Division Multiple-Access (WCDMA) cellular system. Comparison of WCDMA having two-hop relay and traditional WCDMA is done. Parameters like average downlink transmission rate and call blocking probability of packets of system are numerically calculated for this comparison. Two-hop relay WCDMA with congestion control can even decrease the call blocking rate further.

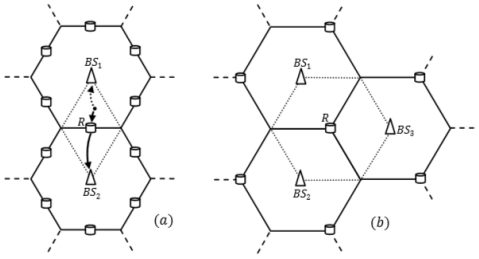

Figure XII: Sectored cells with relays. [16].

Hakimeh Purmehdi and Farshad Lahouti [16], consider hybrid wireless networks which in turn balances the load on cellular networks. Implementation of hybrid wireless networks is done by considering sectored configurations with dedicated relays as shown in the above figure 12.

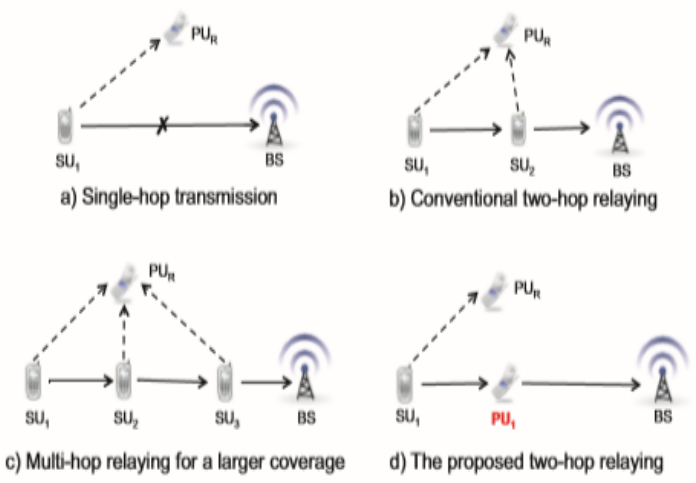

Figure XIII: New paradigm of cooperative relaying. [17].

Minghua Xia and Sonia Aıssa [17], proposed a new model in which spectrum-sharing technique is integrated with the cellular systems. New paradigm as shown in figure 13 is proposed in which an idle primary user serves as a relaying node in order to assist data exchange between its destination and the secondary user. Investigation of an outage probability at the secondary user and at the macro shell base station is discussed.

Weifeng Lu et al[18], uses a two-hop relay WCDMA with queuing capability such that call can wait in the buffer present at the Base Transceiver Station (BTS) if all other channels are busy, which will ultimately reduce call blocking rate. Markov model is developed for this system model and evaluation of the performance of the system is evaluated and numerical values are used in the later part of this to do evaluation. Figure 14 gives the architecture used for the performance evaluation.

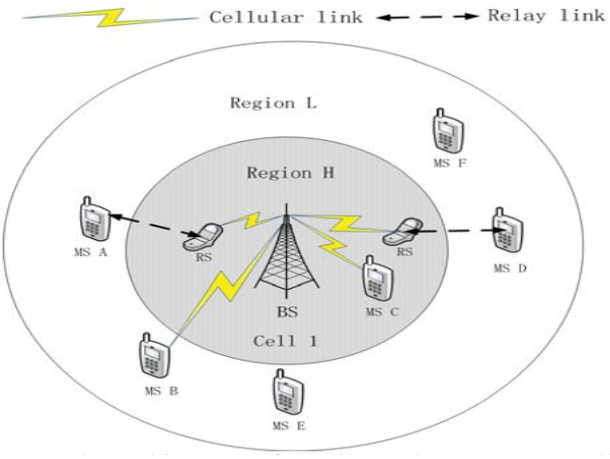

Figure XIV: Architecture of two-hop relay WCDMA cellular system. [18].

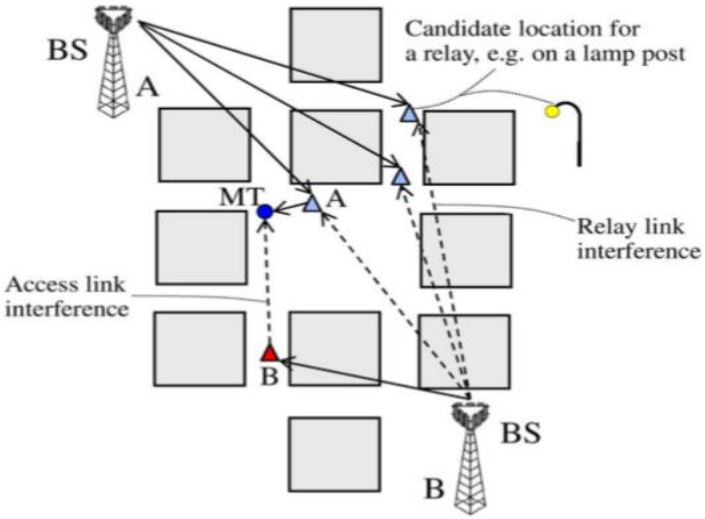

Figure XV: Relay site planning model [20].

Abdallah Bou Saleh et al [20], proposed the Relay site planning model as shown in figure 15. Two simple approaches are used in this paper for planning of two-hop cellular relay networks. Relay location selection and serving cell location approaches are used to enhance the system performance. A simple model is used to for analysing and evaluating both the network planning techniques.

Table-I: Comparison of various existing Relay systems.

Sl. No	Title	Author	Methodology	Advantages	Limitations
1	Performance Analysis of Distributed and Centralized Scheduling in Two-hop Relaying Cellular System	Fan Huang, Jian Geng, Guoxing Wei, Yafeng Wang, and Dacheng Yang	Analysed and compared 3 different scheduling modes. Proposed 3 scheduling strategies and a routing metric.	Signal overhead and system performance are analysed and compared.	Out-of band allocation method is not used.
2	Spectral-Efficient Cellular Communications with Coexistent One- and Two-hop Transmissions	Chunguo Li, Peng Liu, Chao Zou, Fan Sun, John M. Cioffi, and Luxi Yang	New transmission protocol has been proposed for coexisting two-hop traffic and direct traffic flows.	Overhearing based protocol consumes overhead interference.	Inter-flow interference problem with the proposed protocol.

3	Store, Carry and Forward for Energy Efficiency in Multi-hop Cellular Networks with Mobile Relays	Baldomero Coll-Perales and Javier Gozalvez, Vasilis Friderikos	Store, carry, forward technique to improve the energy efficiency.	Identifies the optimum relay location.	Practical Implementation design of MCN-MR is not given.
4	Optimal Relay Probing in Millimeter Wave Cellular Systems with Device-to-Device Relaying	Ning Wei, Xingqin Lin, and Zhongpei Zhang	Using device to device relay systems to increase the connectivity and range of mmWave cellular systems.	mmWave interaction with Bernoulli's blockages is considered.	Heterogeneous scenario is not considered which consists of mmWave links interacting with non-Bernoulli's blockages.
5	Capacity Maximization for OFDM Two-Hop Relay System With Separate Power Constraints	Wenyi Wang and Renbiao Wu	Discussion of resource allocation problem to maximise the system capacity of OFDM two-hop relay system.	Decode and Forward (DF) strategy is used. New method for power allocation. Simplified system architecture.	Amplify and Forward strategy (AF) is not used.
6	Unified Performance Analysis of Two-Hop Amplify-and-Forward Relay Systems with Antenna Correlation	Nuwan S. Ferdinand and Nandana Rajatheva	Performance analysis of Channel State Information (CSI) assisted relay systems and AF relay systems.	Asymptotic analysis is done which gives system performance and diversity gain	Antenna correlation problem.
7	Spatial Analysis of Opportunistic Downlink Relaying in a Two-Hop Cellular System	Radha Krishna Ganti and Martin Haenggi	Analysis of outage in two-hop cellular system which includes node locations.	Distribution of mobile nodes is done. Point process theory and Stochastic geometry are used.	Complicated relay selection schemes, power control mechanisms and other multi-hop techniques are not used.

8	Outage Analysis of Opportunistic Scheduling in Dual-Hop Multiuser Relay Networks in the Presence of Interference	Kasun T. Hemachandra and Norman C. Beaulieu	Analysis of outage probability of multi user relay networks in the presence of Co Channel Interface (CCI).	Network consisting of cochannel interference signals are considered as a practical example.	Model used is a scale-down version of some other reference model.
9	A Unified Analysis of Spectral Efficiency for Two-Hop Relay Systems With Different Resource Configurations	Tingting Liu, Chenyang Yang, and Lie-Liang Yang	Simulation of multi carrier and multi antenna two-hop relay system to find out the asymptotic spectral efficiency values.	Deriving the asymptotic spectral efficiency of a multi antenna or multi carrier with varying CSI values.	Results are applicable to analyse the spectral efficiency of low load factor only. Multiple CSI data stream is not used.
10	Differential dual-hop relaying under user mobility	M.R. Avendi, and Ha H. Nguyen	Proposal of multi symbol detection scheme and numerical and simulation of the same to improve the performance of CDD.	Theoretical and simulation results shows the increase in the performance of CDD in fast-fading channels.	Proposed MSD Scheme has high detection complexity. Cascaded channel is considered.
11	Achieving Global Optimality for Joint Source and Relay Beamforming Design in Two-Hop Relay Channels	Hongying Tang, Wen Chen, Jun Li and Haibin Wan	Proposal of optimal and suboptimal algorithms to solve the source Beam Forming (BF) vector.	Maximising SNR. Robust design with CSI errors also considered.	Issues regarding implementation and complexity.
12	Performance Study of Two-Hop Amplify-and-Forward Systems With Untrustworthy Relay Nodes	Li Sun, Taiyi Zhang, Yubo Li and Hao Niu	Multi relay model is studied for comprehensive analysis of two-hop relay systems with untrustworthy nodes.	AF system with untrustworthy nodes are considered.	Theoretical analysis is done.

13	Efficient Resource Allocation for OFDMA-Based Two-Hop Relay Systems	Wha Sook Jeon, Sang Soo Jeong, and Dong Geun Jeong	Designing of resource allocation scheme for OFDMA-relay system to improve the cell throughput performance.	Frequency-selective channel fading by using an optimisation approach.	Proposed solution is not applicable to practical systems directly.
14	Performance of a Two-hop Cellular System with Different Power Allocation Schemes	Zhang Jingmei, Shao Chunju, Wang Ying, and Zhang Ping	Two-hop cellular system based on TDMA scheme is analysed.	NRRS or RRS in TTD mode is used.	Involves tradeoff between capacity and coverage.
15	Performance Evaluation of Two-hop-relay WCDMA Cellular Systems	Wei-feng Lu, and Meng Wu	Proposed a new architecture for two-hop relay WCDMA cellular systems.	Call blocking probability of packets of the system and average downlink transmission rate are calculated.	Analytical model is used for calculating and evaluating the system's performance.
16	Channel Sharing in Hybrid Sectorized Cellular Networks with Coverage-limited Relays	Hakimeh Purmehdi and Farshad Lahouti	Investigation of two channel sharing schemes for hybrid sector cellular networks.	Hybrid wireless networks with dedicated relays are considered.	Numerical results are used to analyse the proposed hybrid scheme.
17	Modeling and Analysis of Cooperative Relaying in Spectrum-Sharing Cellular Systems	Minghua Xia and Sonia Aıssa	Integration of spectrum-sharing technology into cellular networks.	Spectrum-sharing technology is integrated with cellular systems.	Particularly suitable for delay-tolerant wireless services.
18	Performance Analysis Of Two-Hop-Relay Cellular Systems With Queueing Capability	Weifeng Lu, Mengmeng Gu, and Luxi Yang	Architecture having unlimited queuing buffer for two-hop relay WCDMA cellular networks.	WCDMA with queuing capabilities. Call can wait in incoming buffer at BTS.	Analytical model is used. Numerical calculations are done.

19	A Two-hop AF Relaying Scheme with Interference Suppression at the Relay	Karthik KS and Bhaskar Ramamurthi	Proposed a two-hop AF relaying scheme with multiple antennas which performs optimum combining.	Relay performs optimum combining to increase SINR and forwards the soft symbols to destination.	Base-station relay link will be the bottleneck in certain conditions.
20	Analysis of the Impact of Site Planning on the Performance of Relay Deployments	Abdallah Bou Saleh, Ömer Bulakci, Jyri Hämäläinen, Simone Redana , and Raaf	Analytical study of Relay Site Planning (RSP).	Relay location selection and serving cell location approaches are used	Single interferer scenario is considered for the analysis.
21	Mobile-based Relay Selection Schemes for Multi-Hop Cellular Networks	HaoZhang, PeilinHong and KaipingXue	Two mobile based relay selection schemes are proposed and relay selection in mobile cellular networks is studied.	Obtaining lower relay switching rate and longer relay activation time.	All conditions are not considered for analysis.
22	Performance enhancement of multi-hop relay-based wireless systems based on outage probability	Sami Baroudi, and Yousef R.Shayan	A method to evaluate and to improve the performance of multi-hop relay based wireless systems.	PDF of outage probability is accessed based on SIR evaluations.	Minimum number of relays and their placements has to be found first.

Conclusion:

Work carried out by Fan Huang et al deals with two-hop relay systems where the authors have proposed a model in which many strategies for resource allocation has been proposed and analysed such as Distributed scheduling and Centralised scheduling in which distributed is further divided into two types such as semi-distributed and fully distributed scheduling schemes. Analysis of the same is done by considering key parameters like system edge user throughput and system throughput for evaluation of the performance of the system. The analysis carried out shows that an efficient way of utilising scarce resources such as bandwidth is by using relay systems. Growth of mobile users makes base station overcrowded. Hence, relay system comes into the rescue. A relay system has umpteen numbers of applications. This survey on the two-hop relay cellular system provides a comprehensive understanding

of the system with its performance analysis of various methods highlighting the advantages and disadvantages/limitations of these applications.

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