# "CSMA-Based Link Scheduling in Multihop MIMO Networks using SINR Model "

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***Abstract –***The main aim of this study to resolve the problem of distributed scheduling in multi-hop MIMO networks. We will first develop a "MIMO pipe" model which will provide the required SINR , which gives the rate-reliability tradeoff in MIMO communications.Here we are going to study development of CSMA-based MIMO-pipe scheduling especially under the SINR model.We are going to choose the SINR model over the conventionally studied matching or protocol-based interference models because it has ability to capture the impact of interference in wireless networks. Here each node is equipped with an antenna array. In CSMA based scheduling, nodes will first sense the channel activity before attempting transmissions, whenever the channel is sensed to be idle, the nodes will continue with data transmissions. When the channel is detected to be busy, the nodes have to wait for a random amount of backoff time before reattempting the transmission.We will study that protocol model based throughput-optimal CSMA based scheduling, would not work well under the SINR model because its has dynamic and intrinsic link coupling. To tackle this challenge,CSMA-based MIMO-pipe scheduling is develpoed in both discrete-time system and continuous-time system.

***Keywords-*** *CSMA , MIMO, SINR, Scheduling, DTMC.*

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## I. INTRODUCTION

The developed wireless devices such as smart phones and tablets are pushing the demand for higher and higher wireless data rates while causing significant limitations to existing wireless networks. Enterprise networks have been deployed following this paradigm for years. Nowadays, the density of access points has increased such that additional gains are being cancelled by intercellular interference from even denser deployments. One cannot leave the wireless network consisting of a large number of overlapping small cells to operate in a completely decentralized manner. The industry has demanded to the need to efficiently manage such networks with tools which are mostly based on simulations, and over-simplistic analytical models. These tools perform three main operations on the basis of available public information about such tools in the enterprise: (i) interference management between links by channel allocation and power control, (ii) user load balancing among links, and (iii) optimization of the Clear Channel Assessment CSMA threshold to allow for concurrent transmissions which will tolerate interference from nearby links. We are going to develop an appropriate Multiple Input Multiple Output model that provides an abstraction of the rate reliability tradeoff in MIMO communications, here scheduling complexity is kept low for scheduling. A naive MIMO model that is not optimal for MIMO scheduling as chooses the highest rate for a given SINR and since it prevents other links from being simultaneously active. Hence it will degrade the overall throughput. In case of our proposed MIMO-pipe model it considers the set of feasible rates and the corresponding SINR requirements. Here the notable thing is that the possible number of network states is tremendous. Therefore, the scheduling has to be distributed and adaptive using local information only. There is an excellent candidate for distributed scheduling-Carrier Sense Multiple Access (CSMA)-based distributed scheduling.

## II. LITERATURE REVIEW

Link scheduling in MIMO networks is a major performance bottleneck in wireless especially multihop networks. It determines which transmitter-receiver links are to be simultaneous activated at a given moment so that to achieve high throughput, fairness, low delay, etc. A variety of link scheduling algorithms under different interference models have been previously studied to achieve high performance and low complexity. The problem of achieving high throughput optimality in wireless MIMO networks has been extensively studied. In [4] it is shown that Max-Weight Scheduling (MWS) algorithm has achieved throughput optimality at the cost of the very high time-complexity.but it needs centralized implementation. Greedy Maximal Scheduling (GMS) [4], [5], [6], [7] is a well known sub-optimal solution that approximates Maximum weight scheduling. GMS picks links in decreasing order of their queue lengths without violation of their underlying interference constraints.

In [8], the authors have developed Local Greedy Scheduling (LGS) and addressed the difficulty in global ordering. This scheduling suggests that the local ordering is sufficient to achieve high performance in practice. Empirical results show that LGS provides sufficient throughput and delay performance at the lower complexity. Although LGS requires only local message exchanges of queue length information among neighboring links, this algorithm have to suffer from high message-passing overhead, if the number of local neighboring links is large.

In the paper by Ashutosh Deepak Gore, he has provided a brief view of three classes of link scheduling algorithms, each with its relative merits and demerits. For example, the protocol interference model base algorithms have low computational

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10 - 13

complexity but are simple to implement. However, it yields low network throughput. On the other hand, algorithms that are based on SINR graph have higher computational complexity and are more bulky to implement, but can achieve higher network throughput. Also, there exist algorithms based on communication graph and SINR conditions whose performance characteristics lie between these two classes. Hence, in general, these three classes of algorithms that exhibit a tradeoff between complexity and performance. Hence it can be concluded that algorithms based on the protocol interference model are better suited to model Wireless networks, while the latter two classes of algorithms are better suited to model multihop wireless networks [1].
In [3] the scheduling problem in multi hop wireless networks under SINR-based interference model is investigated. We first develop a fully distributed throughput optimal base line scheme, called DSS which supports carrier sensing and exploits recent result in terms of throughput optimality. There are many problems in scheduling under the SINR model. As most recent communication technologies allow rate adaptation or variable packet sizes based on the received SINR level, it is more desirable to develop CSMA based schemes that achieve high performance under time-varying link rates.

Douglas M. Blough in his paper has mentioned the problem of interference in dense wireless network deployments. The proposed approach is to utilize the interference cancellation and spatial multiplexing capability of multiple-input multiple output links to overcome interference and improve the performance of such multihop networks. Both semi-distributed and fully distributed protocols for 802.11 MAC based wireless networks standard are evaluated. The philosophy of the approach is to minimize modifications to existing protocols especially within client-side devices. They have proposed both semi distributed and distributed protocols that enable the use of MIMO interference cancellation technique. Our design philosophy is to make most of the changes at the access points so as to reduce the burden on the clients as much as possible. Our proposed protocols can use any algorithm for computing the MIMO beam forming and combining weights that cancel interference and support multiple streams on each link [2]. During the data transmission phase, nodes use the MIMO weights computed for the current link set to transmit and receive their data. To begin this phase, the initiator node or its desired client, begins transmitting a data packet. Transmitter nodes begin their data transmissions immediately after they sense the channel busy. During some fixed duration, transmitting nodes aggregate as many data packets as possible so as to occupy the entire transmit duration. Hence, a class of scheduling algorithms that make use of Carrier Sensing Multiple Access/Collision Avoidance (CSMA/CA) have been developed and shown to achieve high throughput optimality. In particular, a discrete time system, named Q-CSMA, has been developed in modeling a multi-hop network as a Discrete Time Markov Chain (DTMC) with a product form stationary distribution [11]. QCSMA allows each link to choose itself with a certain probability that depends on its queue length. It has been shown to yield a stationary distribution of schedules with optimal throughput performance as the selection procedure continues.
Qiao et al. recently developed a CSMA based scheduling scheme that improves delay performance [14]. They employ simplex CSMA algorithm to solve linear programming problems, and promote quick transitions between optimal schedules to achieve better delay performance. All these scheduling schemes have been developed assuming theoretical graph based interference models. But it cannot capture accumulative nature of wireless interference from multiple transmitters. Hence Signal to-Interference-plus-Noise-Ratio among all activated links should be taken into consideration. Although numbers of distributed link scheduling algorithms under the so called SINR-based protocol model have been proposed [10], [11], [12], they attempt to maximize the number of simultaneously activated links and achieves only suboptimal throughput performance. In this paper, we will develop a distributed SINR-based scheduling scheme (DSS) which is throughput-optimal in wireless MIMO networks. Unlike the prior works based on graph-based interference models, they have considered more realistic SINR-based interference model. We have designed a distributed algorithm that operates under the SINR based model, and showed that it achieves a product form stationary distribution of the system state means the set of simultaneously activated links, which implies optimal throughput of the proposed scheduling scheme.

## III. PROPOSED SYSTEM

We have studied study the problem of distributed scheduling in multi-hop MIMO networks. We first develop a multiple input multiple output pipe model that provides the upper layers a set of optimal rates and SINR requirements, which capture the rate-reliability tradeoff MIMO communications [13]. The main goal of this study is to develop CSMA-based MIMO pipe scheduling under the SINR model. Here SINR model is chosen over the priory studied protocol based interference models because it has ability to capture the impact of interference in wireless networks. The coupling of the links caused by the interference makes the problem of inventing distributed scheduling algorithms particularly challenging. Then we explore CSMA protocol based MIMO-pipe scheduling, from two perspectives. First we consider an idealized CSMA network in continuous time. We develop a dual band approach model. In this model control messages are exchanged instantaneously over a channel which is separate from the data channel which shows that CSMA-based scheduling is able to achieve throughput optimality under the SINR model. Then discrete time CSMA network is considered. To overcome the challenge due to the coupling caused by interference, a conservative scheduling algorithm is proposed in which more rigorous SINR constraints are imposed based on the Multiple Input Multiple Output pipe model. We show that this suboptimal distributed link scheduling can achieve an efficiency ratio bounded from below. We are going to take two steps to survey optimal scheduling in MIMO multi-hop networks:
1) We will develop a link schedule that can capture the rate reliability tradeoff for MIMO communications.
2) Then obtain a clear overview of throughput optimal scheduling under the SINR model and then use this as a basis to study distributed MIMO link scheduling.

Consider a network consists of K links, and consider that the scheduler have to decide whether link *i* should be turned on. Under the SINR model, this probability depends on the combinational activity status of all other and there are $2^{(k-1)}$ possibilities. It is obvious that the conventional protocol matching approach will not work well here. Because, for capturing the effect of the SINR model will require exponential complexity [14].

Consider mulihop MIMO network with K links consisting of N transmit antennas and N receiver antennas. The received signal at the $i^{th}$ receiver denoted as $y_i$ is given by

$$\mathbf{y}_i = \sqrt{\frac{P}{N d_{ii}^{\alpha}}}\mathbf{H}_{ii}\mathbf{s}_i + \sum_{j \neq i} \sqrt{\frac{P}{N d_{ji}^{\alpha}}}\mathbf{H}_{ji}\mathbf{s}_j + \mathbf{n}_i,$$

The entries of $H_{ji}$ are independent from those of $H_{ji}$ and $n_i$ is the additive White Gaussian noise. The first term in equation stands for desired data signal for link *i*, while the last two terms stand for co-channel interference and noise, respectively. Here we assume as per standard that the channel matrix $H_{ji}$ is known at the receiver but unknown at the transmitter of link *i* [15]. Besides in case of practical systems, it is difficult to derive the MIMO channel matrices from the neighboring interfering links. The reason behind this is that signals from the transmitter are not intended to be sent for the desired link and it is infeasible to track and estimate these complex channel matrices. Based on this view, we assume that the interfering signals are unknown to its receiver and its transmitter for each individual MIMO link. This signal model shows that unlike single-user MIMO systems, multi-hop MIMO networks are interference-limited and MIMO communications systems have intimate relation to the SINR values that are coupled across the links.

### A. SINR Model versus Protocol Model

In MIMO networks, two links can coexist with each other if they are able to transmit simultaneously without affected by interference. An interference model specifies the link coexistence constraint only i.e. which links are to be simultaneously activated. In contrast, under SINR model, the success rate of transmission not only depends on its own channel condition but also on the level of the co-channel interference. A transmission of a link is considered to be successful if it has SINR greater than a threshold value determined previously. Hence the SINR model has ability to capture the probabilistic nature of wireless MIMO multihop communications which is not the case with protocol or matching based models. The SINR model which is built upon recent advances in PHY-layer communication research has opened a new path for more efficient resource utilization and allocation in wireless networks. Consider that transmission power is equally split among all the transmit antennas. As there is no interference information available at the transmitter antenna, transmission rate of each stream is set to be the same, denoted by Rs. Our perception is that the rates for data streams depend on the SINR values that means eventually on interference, which is unknown and time-varying. So it is more practical to set the same rate for different streams. The SINR requirement of stream r at configuration k, can be in general given by

$$\beta_{kr} = f(k, r, H, P_e)$$

This SINR which depends on the BER requirement $P_e$ and channel matrix H for reliable communication, and the function f centers on the physical-layer techniques, such as modulation and coding.

In [15] the example of network with four 2*2 MIMO links is taken. It consists with two possible configurations, Configuration A (R, β1) and Configuration B (2R, β2) such that β2 > β1. The network parameters, such as the transmit power and the distances between the links, are set such that when all the links use Configuration A, they can transmit simultaneously to achieve a throughput [1, 1, 1, 1] and if one link chooses Configuration B then the other link will not be able to transmit at the same time. The expected graph of queue behavior is as shown below,

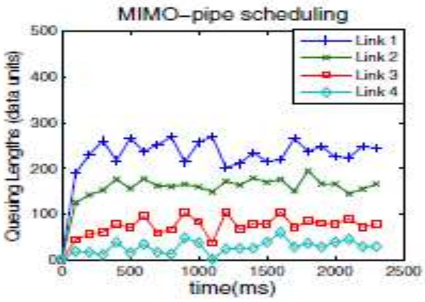


Figure 1. Queue behavior

The CSMA based MIMO-pipe scheduling gives stable queue behavior at both arrival rates, and indicates that it can achieve a larger throughput region than that of the others

## IV. CONCLUSION

Taking into consideration the problem of distributed scheduling in multi-hop MIMO networks CSMA algorithms in multi-hop MIMO networks under the SINR interference model is investigated. We first developed a MIMO pipe model that provides the required SINR and data rate, which can attain optimal rate-reliability tradeoffs in MIMO communications. We then develop CSMA-based MIMO-pipe scheduling considering the SINR model. We observed that throughput-optimal scheduling, under conventional protocol model, will not work efficiently under the SINR model, due to the dynamic and intrinsic link coupling. We explored CSMA-based |Multiple input Multiple Output pipe scheduling in both a continuous-time system and a discrete-time system considering SINR ratio. Hence can conclude that algorithms based on the protocol interference model have low computational complexity and are simple to implement, but yield low network throughput. However, algorithms based on SINR graph representation have are computationally complex but and are more cumbersome for implementation, but achieve higher network throughput.

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