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Interference Cancellation and Scheduling in Wireless Networks

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Abstract ***- SIC (Successive Interference Cancellation) is an effective way of multiple packet reception (MPR) to fight with interference in wireless networks. Most of the existing methods for SIC in wireless networks are mainly focusing on link scheduling. For characterizing the impact of SIC, two interference models such as layered protocol model and layered physical model are introduced. Various existing scheduling schemes are examined for their performance in a network with SIC. To explain the generic behavior of the scheduling schemes, the capacity of a network with SIC is to be analyzed. The scheduling performance investigates two scenarios such as chain and cell topology. In chain topology, the average throughput values are compared with SIC and without SIC. In cell topology, the normalized throughput is compared with number of receiver nodes with different node density. The performance of proposed scheme has been verified using network simulator to show that the approach is efficient.***

Keywords **- Link scheduling, multiple packet reception, scheduling scheme, successive interference cancellation.**

I. INTRODUCTION

In the present environment interference is a major problem in wireless networks. Which evidently affect the performances during data transmission? The multiple transmission at the receiver side can overlap, collision occurs and reception fails. Multiple packet reception (MPR) is a major technique to fight with interference at the physical layer. At a receiver node can separate the collided signals with the help of MPR, when the links interfering with each other at the multiple transmission. In [1], [2] and [3] the MPR is proposed and it can significantly increase the capacity of a wireless network. To overcome the transmission collisions, SIC is an effective way of MPR in wireless networks.

At the receiver side, that receiver tries to detect the multiple arrived signals, with the help of SIC using an iterative approach. In each iteration, the enhanced signal is decoded and a required signal to interference noise ratio (SINR) is calculated at the receiver side, when the SINR signal falls below to its value then it can be decoded and removed. To understand the performance of MRP, the link scheduling method have been introduced in wireless network with SIC at physical layer. Fighting with interference is one of the major demands in wireless networks. In literature there are two interference models such as layered protocol model and layered physical model are needed. Need to describe when transmission is received successfully by its intended recipient and also will allow for two possible models for successful reception of a transmission over one hop, the two interference models are needed.

SIC in wireless networks mainly focus on link scheduling is nothing but process of deciding how to commit packets between the variety of possible nodes. There are three different aspects need for understanding the effect of SIC. First contribution is given as a scheduling scheme that is unaware of SIC. In [4],[5] shows the link scheduling with SIC is NP-hard in both the interference models. By the use of scheduling scheme the number of simultaneous transmissions will increase at most by a limited factor after SIC is applied. Second contribution is based on the derivation of the capacity of a network with SIC and the finding that it has the same order as that without SIC. In comparing with the result in [6], the capacity order is not changed when SIC is applied. In results, any scheduling scheme can achieve the approximation ratio in a network with and without SIC. Third contribution is for characterizing the impact of SIC in both chain and cell network topologies, SIC improves the performance effectively. The throughput with SIC is calculated higher than the percentage of that without SIC. The overview of this paper can be stated as follows:

Division 2 overviews the related work and division 3 describes the present work. In division 4 provides the scheduling based on two interference models when SIC available. Division 5 analyzes the network capacity and division 6 determining the performance of scheduling with SIC in a network. Division 7 provides the conclusion and further results.

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II. RELATED WORK

For characterizing the influence of SIC, in the literature there are two interference models proposed in [6]. MPR is deals with these protocol models by increasing the number of permitted interferers [7], at that same time the physical model is enriched by allowing the reception with lower SINR threshold [8]. During scheduling the packet transmission in a wireless network without SIC has been verified in [9] and [10] based on protocol model, and in [11] [12] based on physical model. To achieve a constant approximation ratio in protocol model is proposed in scheduling scheme in [13]. The capacity of a wireless network in both the interference models is proposed in [6].

SIC gives the improved performance in variety of wireless networks [14].SIC capacity gains is examined in wireless communication networks shows in [15].SIC is a simple but powerful technique to perform MPR. The scheduling is a classic issue has been extensively examined in [13], there are new challenges posed by SIC. In general, before SIC extracts the desired signal, the receiver must detect and remove the signals with greater strength. When detecting the desired signal, only the interfering signals with weaker strength are retained.

III. PRESENT WORK

A. SYSTEM MODEL

Consider a single-channel wireless network with stationary nodes (i.e., X=X1,….,Xn) and N links. A link is represented as LSl or Ll. Here the transmitter node Sl belongs to area X and receiver node Rl belongs to area X, respectively. The distance between the two nodes is represented as Xi and Xj. We have to assume our network as following,

1. All the nodes in a network are located in a two-dimensional area (i.e., X, Y).
2. Resolving the transmission collision in network with SIC is perfect.
3. The network node is uniform.
4. Each node in a network has an omnidirectional antenna, it is operates in the half duplex mode, at transmitter side same transmission power is transmitted over the common channel, and cannot perform multiple packet transmission simultaneously.

B. LAYERED PROTOCOL MODEL

In this original protocol model, a transmission from source Si to Ri successful when the Si and Ri is within the range of the network. The layered protocol model defined as a M-protocol model. Here M is a predefined system parameter.

Definition 1: when two nodes are transmitting their packets simultaneously to detect their original signals and remove that signal transmitted from the source. The Xi node is transmits over the m-th sub channel to a node Xj. Then this transmission is successfully received by node Xj. If,

$|Xk-Xj| \geq (1+\Delta)\,|Xi-Xj|$. The successfully detected signals has the required condition is,

$$|Sy\ RD+1| > (1+\delta u)\ ru \qquad (1)$$

C. LAYERED PHYSICAL MODEL

The transmission power (P) is calculated with the ratio of total power into the packets transmitted from source to destination i.e.,

$$P\,(i,j)=P/|SiRj|. \qquad (2)$$

During packet transmission, the correlated links can detect the interference signal at the total network. So that time the noise power is denoted as N0. The required condition represented in terms of the ratio of transmission power and noise power. The original protocol model is the same as the M-protocol model when M =1, and the original physical model is the same as the layered physical model when no iterative detection is allowed.

IV. SCHEDULING BASED ON INTERFERENCE MODELS

Scheduling based on two interference models such as layered protocol model and layered physical model are presented.

A. SCHEDULING SCHEME

For packet transmission, in each link the time is partitioned into slots of a constant duration. The performance of the scheduling scheme is measured in terms of scheduling length, is defined as the total number of time slots used by the scheme.

FIGURE I shows the scheduling scheme procedure. Allocate each link at least one slot is the objective of scheduling scheme. So based on the schedule length only the performance of the scheduling scheme is examined. An approximation ratio is defined as the ratio of the schedule length. Below the two interference models, choosing a scheduling scheme is to be examined from its performance in a network with SIC.

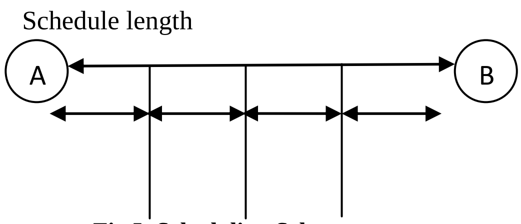

Fig I: Scheduling Scheme

Algorithm 1

- **Data**: A set of links located.
- **Result**: A feasible schedule selection.

Step 1: U ---> all links;
Step 2: node_->coverage! = 0
   Find successful and unsuccessful links.
Step 3: Find the interfering link.
   Remove the interference zone
Step 4: for (int i_=0;i_<God->nodes();i_++)
Step 5: Find a link L in U that has the maximum IN difference.
Step 6: Perform link ordering and slot allocation for scheduling scheme.
Step 7: end

B. SCHEDULING BASED ON M-PROTOCOL MODEL

The scheduling scheme in algorithm 1 is similar to the presented in [4] except the concept of incoming and outgoing degrees.M-protocol model shows the constant approximation ratio with and without SIC.The concept of IN difference is introduced to order the links to be scheduled. The algorithm1 describing the scheduling based on the M-protocol model.

Definition 2:A link from source node to destination node is defined as LSR, Based on the M-protocol model the interfering link LS'R' to be calculated and the interference zone of LSR is defined.

Definition 3: The maximum outgoing degree of LSR is the number of all interfered links.

Definition 4: The IN difference of a link is defined as the difference between the incoming degree and outgoing degree.

In algorithm 1 the scheduling scheme is summarized which has two major procedures.
Link ordering: In the first link,the   maximum IN difference is selected. That time not all links are scheduled,at the same time,select the link with the maximum IN difference and remove the chosen link. The selection process provides a particular ordering of all links.
Slot allocation: The time slots are assigned to all the links in a network from last one to first. Based on the demand multiple slots are assigned. At the result, for every time slot, a feasible link set is designed.
 In [4] shows,when the demand is one for every link, the schedule length of algorithm 1 is bounded by its maximum incoming degree.The approximation ratio of algorithm 1 is presented with two theorems.

Theorem 1.

Algorithm 1 has a constant approximation ratio in a network without SIC,based on the protocol model.
The interference zone of a link is divided into several regions to prove the theorem. FIGURE II shows the interference zone of a link is divided into several regions.the area is called a (k-1, k, α) region with 4 end points are denoted as Ak,1, Ak,2, Ak-1,1 and Ak-1,2. The interference zone is partitioned based on the r and δ and here have to find the node circle. In that, length of the interference,incoming set of link and subset, no of regions are designed.

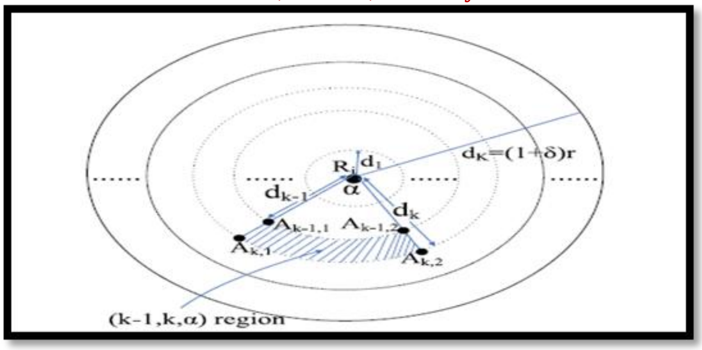

Fig II: Interference Zone Of A Link Is Divided Into Several Regions.The Area Is Called A (K-1, K, A) Region With 4 End Points.

Theorem 2.

Algorithm 1 has a constant approximation ratio in a network with SIC,based on the protocol model.

Theorem 1 is a special case of theorem 2 when M=1. The approach is used to derive the result $M \geq 2$ when,SIC is available. First have to find the interference range in a link and second the set of incoming links is divided into M subsets and third the number of regions are designed.

The algorithm 1 shows the first scheduling scheme to achieve a constant approximation ratio in a network with SIC and also it has advantages of some transmission opportunities from SIC.

C. SCHEDULING BASED ON M-PROTOCOL MODEL

The performance of scheduling scheme is analyzed in algorithm 2 in [12]. The problem is partitioned into disjoint link length classes and then the feasible schedule is designed for each length class using a greedy strategy. The detailed explanation for algorithm 2 is shown in [12].

Definition 5: For a link set L, the length diversity is calculated. g(L) is called length diversity as given by, g(L)=|{m|m € N; Lj€ L:[SiRi/SiRj]=m}| (3) Finding the disjoint link and finding the link length of each link. FIGURE III shows the plane partition and dividing the square region into number of grid cells.

Theorem 3. Based on the layered physical model with uniform transmission power, the approximation ratio of Algorithm 2 is designed in a wireless network with SIC.

Finally, in both the interference models, the scheduling scheme shows the constant approximation ratio. To define why an SIC –unaware scheduling scheme can maintain its order optimality in a network with SIC, for that we need to understand the impact of SIC on the network capacity and scheduling performance in practice when SIC is applied.

Algorithm 2

- Data: A set of links located.
- Result: A feasible schedule.

1. Let R=Ro,…,Rlog(l max) such that Rk is the set of links Li of length, $2^k \leq$ |SiRi| < 2^{k-1} ;
2. t =1;
3. for all Rk $\neq \phi$ do
4. partition the plane into squares of width $\mu . 2^k$;
5. 4-color the cells such that no two adjacent squares have the same color, for j =1 to 4 do
6. Select color j;
7. repeat
8. For each square A of color j, pick one link Li ϵ Rk with receiver Ri in A, assign it to slot t, t =t + 1;
9. until all links of Rk in the selected squares are scheduled;
10. end
11. end
12. return the schedule;

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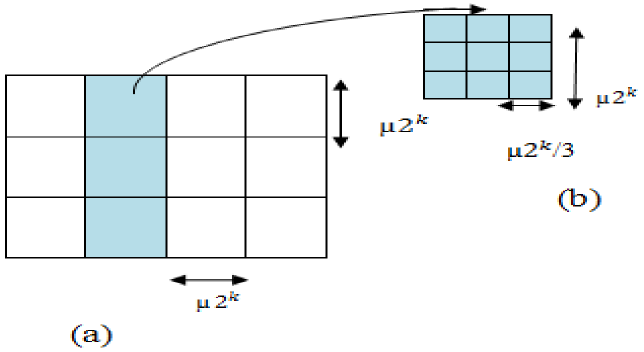

Fig III: (a) partition of the plane into square grid cells. (b) partition of a cell into subcells.

V. ANALYZE THE NETWORK CAPACITY

The capacity in a network with SIC is analyzed, for exploring the generic behavior of the scheduling schemes.

Definition 6([6])**:** The network transports one bit-meter when one bit has been transported a distance of 1 meter toward its destination. The sum of products of bits and the distances over which they are carried is defined as the transport capacity.

To analyze the capacity of the network, scaling the network coverage area and considering n nodes. Replacing (1) as $|S_i R_d| > (1+\delta u_x)\ |S_{ix} R_d|$ (4)

Theorem 4. Based on the M-protocol model, the transport capacity of a network with SIC is bounded as follows in (5).

$$\lambda n\overline{B} \leq \sqrt{8}/\sqrt{\prod} * \sqrt{AW}/\delta * \sqrt{n} \quad (5)$$

In M protocol model the capacity of the network with SIC is calculated by minimum of {δ1,……..,δM}.The order of the capacity of the network with SIC is same as that without SIC.

Theorem 5. In the layered physical model with uniform transmission power, the transport capacity of a network with SIC is bounded as follows:

$$\lambda n\overline{B} \leq \left(\frac{2\emptyset+2}{\emptyset}\right)1/\eta\ \sqrt{AW}/\sqrt{\prod} * (1+D)\ 1/\eta\ n^{\eta-1/\eta} \quad (6)$$

Compared to the capacity of a network without SIC [6] ,the difference is the factor (1+D) 1/η. That factor is independent of the network size. Comparision with previous results,our results provides independent of the diameter of the network and its is different from [1]. Also our results provides a deeper understanding of SIC. Compare to [2] and [3] our results obtain a higher order of capacity and simultaneous transmission resolved by a receiver node should be at some orders of the network size.

VI. SCHEDULING PERFORMANCES ANALYZES

The scheduling performance is analyzed with SIC in a network. To analyze the scheduling scheme two scenarios are needed:

<u>Chain topology:</u> The network contains one or more chains. Each chain includes a sufficiently large number of nodes placed on a line.

<u>Cell topology:</u> The network contains one or more cells. Each cell having a receiver node at the center of a circle area and one or more transmitter nodes consistently placed within the area.

A. CHAIN TOPOLOGY

A network consists multiple chains,the number of nodes in a network is sufficiently large and denoted as $X_{i,j}$ ($X_{i,1}, X_{i,2}$,……..) , every chain transmits at one packet or slot to $X_{i,j+1}$. First need to derive the optimal average throughput in a network with and without SIC. Each node can directly communicate with its neighbor nodes.

In FIGURE IV ,shows transmission from transmitter to receiver node (i.e., $X_{i,j} \rightarrow X_{i,j+1}$) and the snapshot shows the optimal schedule at one packet in a network without SIC. The snapshot consists the transmission with three chain. In each chain need to derive the average throughput.The transmission distance between the two nodes are denoted as $r_2$and the interference range between the two nodes are denoted as $2r_2$.In without SIC in a network, when there are four or more chains,the transmission at the first chain does not affect the fifth chain.Now the impact of SIC is shown in FIGURE V, it shows transmission from transmitter to receiver node (i.e., $X_{i,j} \longrightarrow X_{1,j}$, $X_{2,j-1}$) and the snapshot shows the optimal schedule at one packet in a network with SIC.

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The snapshot consists the transmission with two chain,three chain and four chain. In each chain need to derive the average throughput.

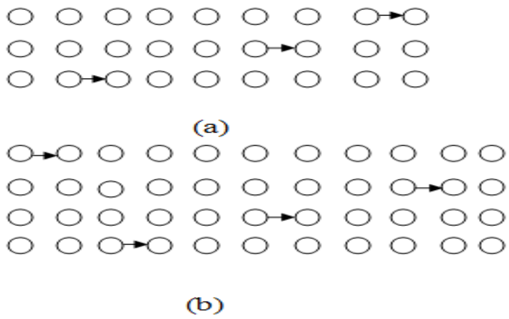

Fig IV: A snap shot of the optimal schedule at one packet/slot in a network without SIC (a) three chains (b) four chains.

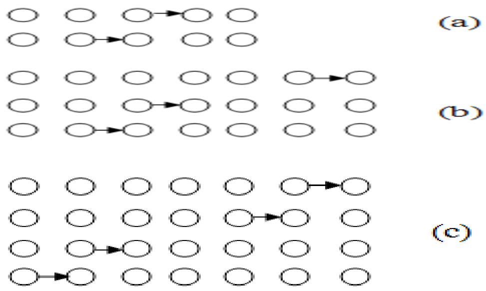

Fig V: A snap shot of the optimal schedule at one packet/slot in a network with SIC (a)two chains,(b) three chains,(c) four chains.

In chain topology, FIGURE IV and FIGURE V gives the optimal average throughput for variety of network sizes. The SIC gain is calculated from the equation as $(T_w - T_{wo}) / T_{wo}$. Here T_{wo} and T_w refers to the optimal average throughput in a network without and with SIC respectively. SIC will helps to obtain more spatial reuse and a much higher network throughput in a network. In our results, with SIC gives 74% gain in four or more chains compare to without SIC this gain value is 30% more.

In FIGURE VI shows the comparision between the with and without SIC. The Figure compares the throughput of the approximation scheme with the optimal ones. To achieve successive transmission opportunities between the nodes the scheduling scheme is used .

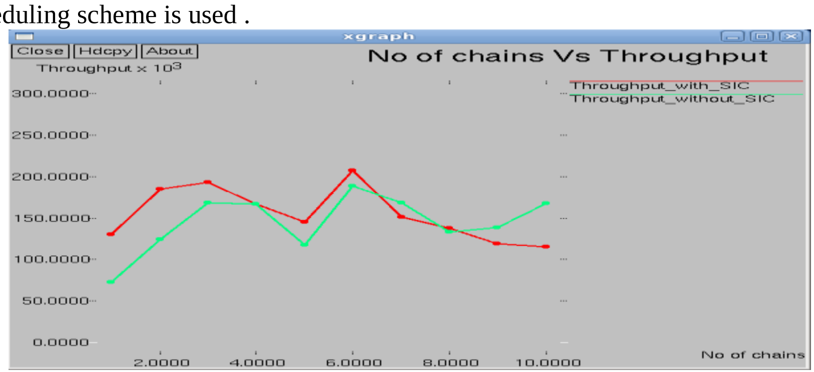

Fig VI: comparision b/w with and without SIC based on no of chains and throughput.

The scheduling scheme can exploit some transmission opportunities from SIC when allocating time slot for a link. In with SIC the throughput of the scheduling scheme is very best one compare to without SIC.

B. CELL TOPOLOGY

In cell topology,a cell is a disk area with radius r_2. In each cell, having a unique receiver node at center and multiple transmitter nodes also placed uniformly within the cell. The normalized throughput with SIC is calculated in cell topology. The simulation (FIGURE VII) shows the performance of normalized throughput with SIC versus the number of nodes with different densities of the transmitter nodes.With the help of the cell topology designing the simulation (FIGURE VII) and calculating the normalized throughput with SIC this is

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compared with no of receiver nodes with different ρ. The node density is denoted as ρ, i.e., the number of the transmitter nodes per unit area.

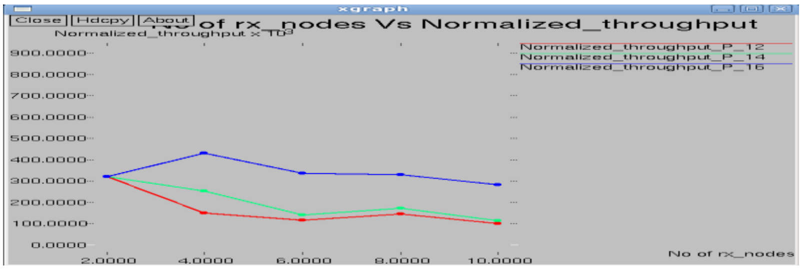

Fig VII: No of receiver nodes vs Normalized throughput with SIC.

The throughput percentage is defined as the ratio of the throughput of the percentage is defined as the ratio of the throughput of the utilization ratio is defined as the ratio of the number of used correlated links to the total number of correlated links. Based on the utilization ratio of SIC we can find the throughput percentage with SIC. In summary, two main considerations are obtained. First the SIC gain is received from the new transmission opportunities due to SIC is considerable. The gain is received as 74%. Second with the help of scheduling scheme the approximation ratio is analyzed. The scheduling performance is analyzed based on the network capacity.

VII. CONCLUSION

This paper look into the performance of SIC with scheduling scheme in wireless networks. To understand the impact of SIC, two interference models are introduced. The capacity in a network with SIC is same order as compared to without SIC.Broadcasting from source to destination has been done with multiple nodes. A link ordering and slot allocation procedure was achieved for scheduling scheme. Capacity analysis for broadcasting using scheduling schemes in terms of energy, delay, throughput, packet delivery ratio was calculated. Compared with existing method, the proposed scheme got 74% efficient throughput value. In Future Work the Power Adaptation Algorithm will be implemented for controlling power, based on the distance between the neighbors in a network and hence, this will give more efficient results in terms of successful delivery of packets in a network. By using power adaptation algorithm, the scope of SIC is further improved and its efficient performance will be compared with existing method's results. The joint design of link scheduling and power control in a wireless network with SIC will be considering in future results.

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