Processing Interference at the Physical Layer to Enhance Information Flow in Wireless Networks

(Invited Paper)

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***Abstract*—Interference in wireless networks results in interdependent communication links between the nodes. Therefore, cross-layer design is essential and makes optimization of wireless networks complicated. In this paper, we study the problem of maximizing the information flow for a multicast session over a wireless network. Different scheduling and coding strategies to handle the interference, including the commonly used interference avoidance strategy, are compared. Results in information theory on achievable rate regions for interference networks are incorporated in the flow optimization to achieve significant improvement. Numerical results illustrate that processing interference at the physical layer results in better information flow compared to interference avoidance.**

I. Introduction

The wireless channel is a shared medium. Transmitted signals intended for a particular receiver also reach other receivers. This broadcast property leads to interference between simultaneous transmissions between multiple transmit-receive node pairs in a wireless network. Therefore, the information rates achievable between a given transmit-receive node pair are dependent on the rates between other transmit-receive pairs. Such a network with interfering transmit-receive pairs is an *interference network* [1]. The set of achievable rates between the various possible transmit-receive pairs is described by a *rate region*. This rate region cannot be described by independent constraints on the rate of each link. Joint constraints on the rates are required in general. Optimizing the information flow for unicast or multicast communication over such a wireless network involves cross-layer optimization [2]–[8].

A common method of handling interference is to assume an interference range for each transmitter and use scheduling to avoid interference, i.e., choose transmitters whose interference ranges do not overlap [2], [4], [6], [8]. This interference avoidance (IA) approach reduces the dependence between links to scheduling constraints and allows each link to be described by a single rate. Another approach is to treat interference as noise. Both these approaches are sub-optimal, in general, for an interference network. While the *capacity region* (the best achievable rate region) is not known for an interference network, several coding and decoding strategies that have significantly better rate regions than that achieved by interference avoidance and treating interference as noise have been extensively studied [9]–[15]. However, the impact of these improved rate regions on network information flow optimization for a multicast session has not been studied. In this paper, we focus on enhancing information flow in a multicast session using interference processing techniques that achieve better rate regions than interference avoidance. The conventional flow optimization formulation is modified to incorporate these rate regions for interference processing and solved numerically. Every feasible solution to this optimization problem corresponds to a valid network code achieving a flow corresponding to the optimal value of the problem [2], [7], [16].

The above problem has also been extensively studied for the unicast case as the problem of finding capacity of a relay network. The classical relay channel was introduced in [17]. While the capacity is still not known, several outer bounds, achievable rates, and approximations have been derived in [18]–[22] for relay networks. For specific network topologies, capacity achieving schemes for certain ranges of channel gains have been shown in [23]–[27]. Interference processing is allowed in general in these works. In order to arrive at these results, various assumptions regarding the relays and the channel conditions are required. Full-duplex relays are assumed in [18], [22]. The high signal-to-noise-ratio (SNR) regime is studied in [22], [28]. Further, the links are assumed to be directed in [22]. In our work, we assume half-duplex relays, arbitrary topology, and finite SNR. We also assume that cooperative encoding and decoding among relays is not permitted.

Initial work on the unicast case using simple scheduling strategies and Common Broadcast (CB) coding was presented in [29]. More complicated coding strategies – superposition coding (SC), and dirty paper coding with common broadcast (DPC-CB) – were proposed in [30] for the unicast case. A schedule based on the paths between source and destination was also presented. In this work, we compare all the above schemes (CB, SC, DPC-CB) for the *multicast problem* and also include the dirty paper coding scheme with superposition coding (DPC-SC) scheme. The schedule based on paths for the unicast case is also extended to the multicast case.

The rest of the paper is organized as follows. Section II describes the half-duplex wireless network model. Section III

978-1-4244-8953-4/11/$26.00

presents interference avoidance scheduling and the proposed scheduling strategies. Section IV presents the coding strategies and the flow optimization model after incorporating the interference processing rate regions. Section V presents the numerical results obtained by solving the flow optimization for multicast over a rectangular grid network. The conclusions are in Section VI.

II. Wireless Network Model

We represent a wireless network with m nodes as an undirected graph $G = (V, E)$, where the vertex set $V = \{1, 2, \ldots, m\}$ represents the wireless nodes. An edge $(i, j) \in E$ indicates that Node i and Node j are connected by an additive white Gaussian noise (AWGN) channel with constant gain denoted as h_{ij}. Further, $(i, j) \in E$ implies that Node j is connected to Node i with a channel gain $h_{ji} = h_{ij}$.

Each node is subject to an average power constraint P and a noise variance σ^2. In addition, a half-duplex constraint is imposed on the nodes so that they can either transmit, receive, or be idle at any given time. Therefore, in this work, an m-node half-duplex wireless network can be in $M \leq \mathscr{M} = 3^m$ states that are denoted $S_1, S_2, \cdots, S_M$. In such a network, we are interested in maximizing the communication rate R from an arbitrary source $S \in V$ to an arbitrary sink $D \in V$. Nodes in $V \setminus \{S, D\}$ act as relays.

The total transmission time is normalized to one unit, and state S_k is active for a λ_k fraction of the time (λ_k could be zero) with $\sum_{k=1}^{M} \lambda_k = 1$. As in [23], [26], we assume that the state sequence and the time-sharing parameters are known to all nodes before transmission. Let $I_k = \{i \in V : \text{Node } i \text{ is a transmitter in State } S_k\}$ be the set of active transmitters in S_k, and $J_k = \{i \in V : \text{Node } i \text{ is a receiver in State } S_k\}$ be the set of active receivers in S_k. When S_k is active, simultaneous transmissions from nodes in I_k can interfere at one or more of the receivers in J_k depending on the connectivity of the nodes in I_k and J_k. Thus, each state $S_k = (I_k, J_k)$ is an *interference network* [1] or *hyperedge* with I_k and J_k as the two disjoint vertex sets.

III. Scheduling Strategies

Optimizing the flow of information from the source node to the sinks requires: (1) an appropriate time-sharing (scheduling) of network states, and (2) coding schemes suitable for the chosen interference network states. In this section, we will discuss the scheduling strategies.

For a network with m nodes, there are $\mathscr{M} = 3^m$ states. Since the number of states is exponential in the number of nodes, the number of variables and constraints in the flow optimization problem becomes very large even for networks with tens of nodes. Therefore, it is usually necessary to consider only a subset of all possible states in the optimization. In the IA approach, only states in which there is no interference at any of the nodes in receive state are considered. These states will be referred to as IA states in the rest of the paper. The other states will be referred to as IP states. Choosing only the IA states significantly reduces the number of possible states. Furthermore, for a given choice of source and destination nodes, only a few of these IA states would be needed. However, we will see later that this choice of states is too restrictive and results in significant loss in information rates compared to the optimal flow.

In our work, we include a subset of the interference processing (IP) states in addition to the IA states. A careful choice of IP states can provide significant improvement in flow with a limited increase in optimization complexity. IA states can be determined using hyperarcs (only one transmitter in I_k) in a conflict graph approach as in [2]. In [29], a limited number of IP states were included by using the conflict graph approach with hyperedges that have limited number of interfering transmitters. In this approach, interference processing is used within hyperedges while interference between hyperedges in avoided. In [30], source and destination information are used to further reduce the number of IP states. A path-based schedule is used. In this schedule: (a) at least two node-disjoint paths from source to destination are chosen, (b) states are constructed by activating alternate edges in each path in any given state, (c) the source is always in transmit mode and destination in receive mode. In this paper, we use a path-based choice of states for multicast communication. As in [30], we first choose node-disjoint paths for each destination. Then, a heuristic construction of the states based on the paths is used. The number of states chosen for multicast is not necessarily equal to the number of states for each unicast times the number of sinks. For the rectangular grid example considered in the numerical evaluation with two sinks, we use only 3 additional IP states (shown in Fig. 2 in Section V).

IV. Coding and Relaying Strategies

Information transmitted by intermediate relay nodes in transmit state is a function of the information received during the receive state. A *relaying strategy* specifies the encoding function used at the relays. In this work, we assume that intermediate nodes decode and forward information with the possibility of using network codes to combine information. Since multiple hops are generally required for the information to reach the destinations, these relaying protocols are referred to as multi-hopping decode and forward (MDF) protocols [27]. In [30], MDF protocols are shown to provide significant improvement in performance for unicast flow and also approach the cut-set bound (which is an upper bound for any relaying strategy) for a certain class of networks.

In this section, we present the four MDF strategies that we study in the context of a general relay network with half-duplex nodes. In all these strategies, the network operates by time-sharing between the states, where each state is an interference network in general. The strategies differ in the encoding scheme in each state. The decoder at each receiver employs successive interference cancellation (SIC). Let $C(x) = \frac{1}{2}\log_2(1 + x)$.

A. Common Broadcast (CB) Scheme

In state $S_k = (I_k, J_k)$, each transmitter $i \in I_k$ sends a common message at rate R_i^k to the set of all its receivers denoted Γ_-^i. Each receiver $j \in J_k$ must decode the messages from the set Γ_+^j (say) of all the transmitters connected to j. The decoding constraints at each receiver for achievability are the constraints for the multiple access channel corresponding to the SIC receiver. Therefore, the achievable rate region for each state S_k is defined by the constraints:

$$\sum_{i\in A} R_i^k \leq C\left(\frac{\sum_{i\in A} h_{ij}^2 P}{\sigma^2}\right), \tag{1}$$

for all $A \subseteq \Gamma_+^j$ and for all $j \in J_k$. When each transmitter is connected to all receivers, i.e., $\Gamma_-^i = J_k$ for each $i \in I_k$, the above region is the same as the compound multiple access rate region in [14].

B. Superposition Coding (SC) Scheme

In this scheme, in state S_k, each transmitter $i \in I_k$ sends d_-^i independent messages to its receivers in Γ_-^i using superposition coding. For simplicity of notation, we assume that the d_-^i receivers in Γ_-^i are arranged in descending order of channel magnitude from transmitter i, and $\Gamma_-^i[p:q]$ denotes the set of elements of Γ_-^i starting from the p^{th} element to the q^{th} element. Let the j^{th} codeword transmitted from transmitter i be $\mathbf{x}_{ij}$. Let the power used for this codeword be $P_j = \alpha_{ij} P$ and R_{ij}^k be the rate. Therefore, the transmitter i transmits a superposition of codewords given by $\mathbf{x}_i = \sum_{j\in\Gamma_-^i} \mathbf{x}_{ij}$. The received word at receiver j is

$$\mathbf{y}_j = \sum_{i\in\Gamma_+^j} h_{ij} \sum_{l\in\Gamma_-^i} \mathbf{x}_{il} + \mathbf{w}_j,$$

where $\mathbf{w}_j$ is the additive white Gaussian noise at receiver j. Each receiver j decodes the codewords intended for itself and all other *weaker* receivers. Let receiver j be the l_i^{th} receiver in Γ_-^i. The codewords with indices l_i to d_-^i are decoded at the j^{th} receiver. The codewords of the weaker receivers $\Gamma_-^i[l_i + 1 : d_-^i]$ are canceled in the SIC receiver. Therefore, only the codewords to the stronger receivers $\Gamma_-^i[1 : l_i - 1]$ will interfere. The received word can be written as

$$\begin{aligned}\mathbf{y}_j = & \underbrace{\sum_{i\in\Gamma_+^j} \sum_{l\in\Gamma_-^i[1:l_i-1]} h_{ij}\mathbf{x}_{il}}_{\text{interference codewords}} + \\ & \underbrace{\sum_{i\in\Gamma_+^j} h_{ij}\mathbf{x}_{ij} + \sum_{i\in\Gamma_+^j} \sum_{l\in\Gamma_-^i[l_i+1:d_-^i]} h_{ij}\mathbf{x}_{il}}_{\text{decoded codewords}} + \mathbf{w}_j.\end{aligned}$$

Therefore, the achievable rate region for each state S_k is defined by the following constraints:

$$R_{ij}^k \leq C\left(\frac{h_{ij}^2 \alpha_{ij} P}{\sigma^2 + \sum_{l\in\Gamma_-^i[1:l_i-1]} h_{ij}^2 \alpha_{il} P}\right), \forall i \in I_k, \tag{2}$$

$$\sum_{j\in\Gamma_-^i} \alpha_{ij} \leq 1, \quad \forall i \in I_k, \tag{3}$$

$$\sum_{(p,q)\in A} R_{pq}^k \leq C\left(\frac{\sum_{(p,q)\in A} h_{pj}^2 \alpha_{pq} P}{\sigma^2 + \sum_{i\in\Gamma_+^j} \sum_{l\in\Gamma_-^i[1:l_i-1]} h_{ij}^2 \alpha_{il} P}\right), \tag{4}$$

$\forall A \subseteq Q_j = \{(p, q) : p \in \Gamma_+^j, q \in \Gamma_-^p[l_i : d_-^i]\}$ and $\forall j \in J_k$.

Using superposition coding allows each transmitter to send messages to a subset of its receivers. This *receiver selection* ability allows better spatial reuse.

C. Dirty Paper Coding (DPC) - CB Scheme

In the DPC-CB scheme, the source is assumed to know the messages transmitted by all the relays since all messages originate from the source. Therefore, when $S \in I_k$, Dirty Paper Coding (DPC) is used by the source to cancel interference to its receiver caused by simultaneous transmissions from relay nodes. Other transmitters in I_k transmit common messages similar to the CB scheme. The receiver r to which the source is sending its DPC-coded message at rate R_s^k is not affected by interference from other relays and will decode only this message. The other receivers must decode all the messages from all the transmitters (except the source) that are connected to it. For example, in the state S_1 shown in Fig. 2(b), S transmits a DPC-coded message to 4 using its prior knowledge of the message transmitted by 8 (and the corresponding channel gains). Transmitters $6, 8, 11$ do common information broadcast. Receivers $9, 10, 12$ decode their respective common messages according to the network connections using SIC decoding. In general, for the above DPC-CB scheme, the achievable rate region for state S_k is given by the following constraints:

$$R_s^k \leq C\left(\frac{h_{sr}^2 P}{\sigma^2}\right), \tag{5}$$

$$\sum_{i\in A} R_i^k \leq C\left(\frac{\sum_{i\in A} h_{ij}^2 P}{\sigma^2}\right), \begin{pmatrix}\forall A \subseteq \Gamma_+^j \\ \forall j \in J_k \setminus r\end{pmatrix}. \tag{6}$$

D. Dirty Paper Coding (DPC) - SC Scheme

In the DPC-SC scheme, the source uses DPC as in the DPC-CB scheme. Other transmitters transmit messages as in the SC scheme. For the DPC-SC scheme, the achievable rate region for state S_k is given by the following constraints: Equation

(5) and

$$R_{ij}^k \le C\left(\frac{h_{ij}^2\alpha_{ij}P}{\sigma^2+\sum_{l\in\Gamma_-^i[1:l_i-1]} h_{ij}^2\alpha_{il}P}\right), \forall i \in I_k \setminus S, \quad (7)$$

$$\sum_{j\in\Gamma_-^i} \alpha_{ij} \quad \le \quad 1, \;\; \alpha_{ir}=0, \quad \forall i \in I_k \setminus S, \quad (8)$$

$$\sum_{(p,q)\in A} R_{pq}^k \quad \le \quad C\left(\frac{\sum_{(p,q)\in A} h_{pj}^2\alpha_{pq}P}{\sigma^2+\sum_{i\in\Gamma_+^j}\sum_{l\in\Gamma_-^i[1:l_i-1]} h_{ij}^2\alpha_{il}P}\right), \quad (9)$$

$\forall A \subseteq L_j = \{(p,q) : p \in \Gamma_+^j, q \in \Gamma_-^p[l_i : d_-^i] \setminus r\}$ and $\forall j \in J_k \setminus r$.

E. Flow Constraints and Optimization

Now, we present a constrained flow problem to compute the achievable rate from source S to a set of m destinations $T = \{t_1, t_2, \ldots, t_m\}$ in the multistage relay network and the corresponding time-sharing between the states. Let $x_{ij}^k(t)$ denote the information flow rate from node i to node j in state S_k towards the sink t. Let z_{ij}^k be the maximum information flow through link (i,j) in state S_k. Let z_i^k denote the total information flow out of node i in state S_k. In the CB and DPC-CB schemes, each transmitter i in a state sends only one message. Since any receiver j can get information only from this message a single flow variable $x_{ij}^k(t)$ is sufficient. However, when SC is used, a receiver j can get information from transmitter i through all messages that it can decode. Therefore, flow variables corresponding to each transmitted message are required. Let $x_{ij,s}^k(t)$ denote the information flow rate from node i to node j via the s^{th} transmitted message by node i in state S_k. In this case:

$$\sum_{s=l_i}^{d_-^i} x_{ij,s}^k(t) = x_{ij}^k(t), \forall j \in \Gamma_-^i, i \in I_k, t \in T. \quad (10)$$

The optimization problem can now be stated as:

$$\max_{\{x_{ij}^k(t)\},\{x_{ij,s}^k(t)\},\{\lambda_k\}} R, \text{ subject to:} \quad (11)$$

- Flow constraints: For all $i \in V$ and $t \in T$, we have
$$\sum_{\{k:i\in I_k\}}\sum_{j\in\Gamma_-^i} x_{ij}^k(t) - \sum_{\{k:i\in J_k\}}\sum_{j\in\Gamma_+^i} x_{ji}^k(t) = \rho_i$$
where,
$$\rho_i = \begin{cases} R & \text{if } i = S \\ -R & \text{if } i = t \\ 0 & \text{else} \end{cases}.$$
- Scheduling constraints: $\sum_k \lambda_k \le 1$ and $\lambda_k \ge 0 \; \forall k$.
- Rate region constraints: The achievable rate region constraints for each state depend on the encoding and decoding scheme used. The rate constraints for each of the four proposed schemes for each state S_k and each sink $t \in T$ are as follows:

1) CB scheme:

$$\sum_{j\in\Gamma_-^i} x_{ij}^k(t) \quad \le \quad z_i^k, \quad \forall i \in I_k, \quad (12)$$

$$\sum_{i\in A} z_i^k \quad \le \quad \lambda_k(\text{RHS of (1)}), \begin{pmatrix}\forall A \subseteq \Gamma_+^j \\ \forall j \in J_k\end{pmatrix}, \quad (13)$$

where RHS of (1) is the right hand side of (1).

2) SC scheme: Equations (3), (10) and:

$$\sum_{b\in\Gamma_-^i[1:l_i]} x_{ib,l_i}^k(t) \quad \le \quad z_{ij}^k, \quad \forall j \in \Gamma_-^i, i \in I_k, \quad (14)$$

$$z_{ij}^k \quad \le \quad \lambda_k(\text{RHS of (2)}), \forall i \in I_k, \quad (15)$$

$$\sum_{(p,q)\in A} z_{pq}^k \quad \le \quad \lambda_k(\text{RHS of (4)}), \quad (16)$$

for all $A \subseteq Q_j$ and for all $j \in J_k$.

3) DPC-CB scheme:

$$\sum_{j\in\Gamma_-^i} x_{ij}^k(t) \quad \le \quad z_i^k, \quad \forall i \in I_k, \quad (17)$$

$$z_s^k \quad \le \quad \lambda_k(\text{RHS of (5)}), \quad (18)$$

$$\sum_{i\in A} z_i^k \quad \le \quad \lambda_k(\text{RHS of (6)}), \quad (19)$$

for all $A \subseteq \Gamma_+^j$ and for all $j \in J_k \setminus r$.

4) DPC-SC scheme: Equations (7), (18), (10) and:

$$\sum_{b\in\Gamma_-^i[1:l_i]} x_{ib,l_i}^k(t) \quad \le \quad z_{ij}^k, \quad \forall j \in \Gamma_-^i, i \in I_k \setminus S, \quad (20)$$

$$z_{ij}^k \quad \le \quad \lambda_k(\text{RHS of (7)}), \forall i \in I_k \setminus S, \quad (21)$$

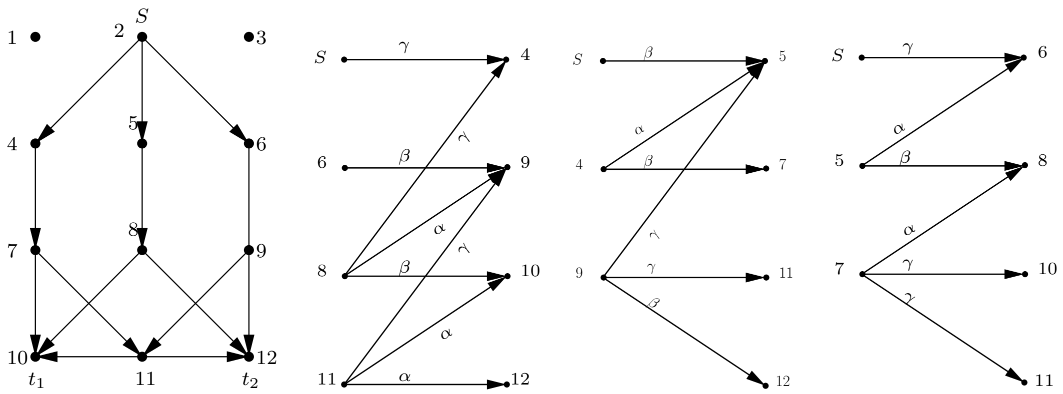
$$\sum_{(p,q)\in A} z_{pq}^k \quad \le \quad \lambda_k(\text{RHS of (9)}), \quad (22)$$

for all $A \subseteq L_j$ and for all $j \in J_k \setminus r$.

For the CB and DPC-CB schemes, the above optimization problem is a linear program. However, for the SC and DPC-SC schemes, it is not a linear program since the power sharing variables α_{ij}'s are also optimized. Numerical solutions for the SC and DPC-SC schemes may be computed using generic constrained optimization routines.

V. Numerical Results

We evaluate and compare the rate achieved by the path-based schedule and MDF relaying with the following coding schemes: (1) CB, (2) SC, (3) DPC-CB, and (4) DPC-SC for the 4×3 grid network shown in Fig. 1. We assume some of the channel gains are equal for simplicity in presenting the results. The rate achieved by each scheme is obtained by solving the optimization problem in (11) with appropriate rate region constraints. The achievable rate with MDF protocols are compared with the rate achieved by the IA scheme.



(a) Information flow paths from S to t_1 and t_2. (b) State S_1. (c) State S_2. (d) State S_3.

Fig. 2. IP States of a grid network generated using path-based scheduling.

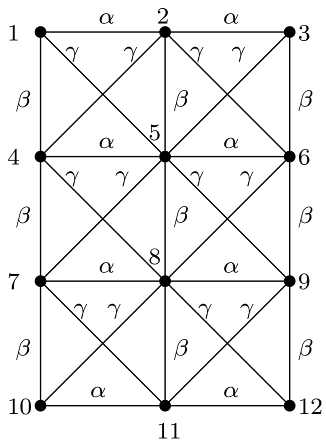


Fig. 1. 4×3 Grid Network.

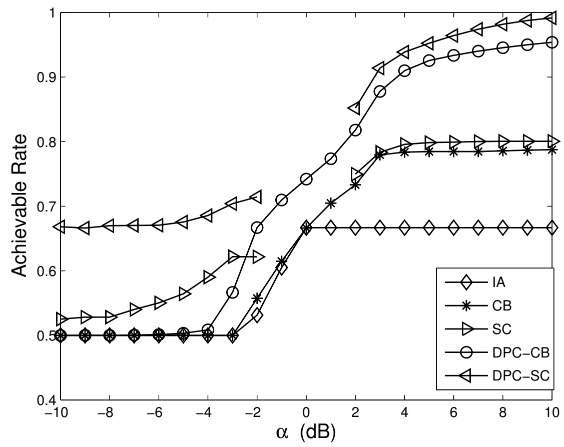


Fig. 3. Mutlicast throughput performance in 4×3 grid network, $\beta = 1, \gamma = 1$, vary α.

A. Multicast throughput

We consider a multicast session from source $S = 2$ to destinations $T = \{10, 12\}$. We use the path-based schedule to construct the important IP states. We pick three node-disjoint paths from source to each destination. The paths from S to sink t_1 are: $S \rightarrow 4 \rightarrow 7 \rightarrow t_1$, $S \rightarrow 5 \rightarrow 8 \rightarrow t_1$ and $S \rightarrow 6 \rightarrow 9 \rightarrow 11 \rightarrow t_1$. Similarly, the paths from S to sink t_2 are: $S \rightarrow 6 \rightarrow 9 \rightarrow t_2$, $S \rightarrow 5 \rightarrow 8 \rightarrow t_2$ and $S \rightarrow 4 \rightarrow 7 \rightarrow 11 \rightarrow t_2$. These paths are shown in Fig. 2(a) for illustration. We construct three states by alternatively picking the links in each path. Thus, the IP states are: $S_1 = (\{S, 6, 8, 11\}, \{4, 9, 10, 12\})$, $S_2 = (\{S, 4, 9\}, \{5, 7, 11, 12\})$, and $S_3 = (\{S, 5, 7\}, \{6, 8, 10, 11\})$. We also use the following six important IA states $S_4 = (\{S, 4, 9\}, \{3, 7, 11, 12\})$, $S_5 = (\{S, 6, 7\}, \{2, 9, 10, 11\})$, $S_6 = (\{2, 3, 11\}, \{4, 6, 10, 12\})$, $S_7 = (\{S, 6\}, \{4, 8\})$, $S_8 = (\{S, 4\}, \{6, 8\})$) and $S_9 = (\{8\}, \{10, 11, 12\})$ in addition to the IP states.

In Fig. 3, the gains β and γ are set to 1, and the gain α is varied. The SC and DPC-SC schemes evaluated only for $\alpha \geq 2$ dB and $\alpha \leq -2$ dB. For α close to 0 dB, SC is not expected to be much better than CB. We notice that DPC-SC scheme performs well for all values of α. For $\alpha = 10$ (dB), DPC-SC has a maximum gain of 50 % over IA scheme whereas the gain is 33 % when $\alpha = -10$ (dB). **For large α:** (1) The CB and SC schemes are limited by the interference at receivers 4 and 9 in State S_1 even for large α. (2) The achievable rates of DPC-CB and DPC-SC schemes grow with α. The multicast throughput of DPC-SC scheme reaches one for $\alpha = 10$ which is the maximum achievable under this schedule. **For small α:** (1) The DPC-CB and CB schemes are limited by the common broadcast constraint at the relays. (2) While SC scheme can perform better, it is still limited by interference at relays 9 and 5 in states S_1 and S_2 respectively. (3) The DPC-SC scheme performs the best by selecting the paths $S \rightarrow 4 \rightarrow 7 \rightarrow t_1$, $S \rightarrow 5 \rightarrow 8 \rightarrow t_1$, $S \rightarrow 6 \rightarrow 9 \rightarrow t_2$, and $S \rightarrow 5 \rightarrow 8 \rightarrow t_2$.

B. MDF throughput gain over IA for different sink choices

Now, we compare the performance of the proposed MDF protocol with the CB scheme for different choices of three sinks. There are $\binom{11}{3} = 165$ choices to pick the sinks in the 4×3 grid network. Fig. 4 shows the histogram of the percentage

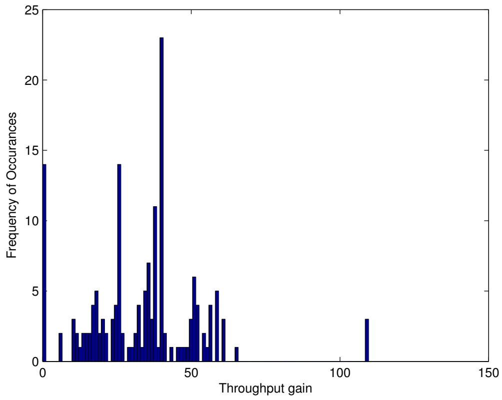


Fig. 4. Mutlicast throughput performance for random choice of sinks in 4×3 grid network.

gain in MDF throughput with the CB scheme over the IA scheme. It can be observed that significant gain is achieved for a large fraction of sink choices. As the SC, DPC-CB, DPC-SC schemes are strictly better than the CB scheme, the throughput gain will be higher for these schemes over the IA scheme.

VI. Conclusions

The utility of interference processing at the physical layer to enhance the information flow in multicast communication over a wireless network was studied. Interference processing provides significant gains in flow compared to interference avoidance. This improvement is achieved using a limited number of additional IP states. A heuristic choice of IP states based on paths was used effectively. Coding strategies based on dirty paper coding and superposition coding and successive interference cancellation at the decoder are shown to effectively process interference. Analyzing the conditions under which the heuristic path-based schedule performs well in multicast scenarios is a possible direction of future research.

Acknowledgment

This work was supported in part by the Indo-UK Advanced Technology Centre.

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