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Main Theme

CISSE 12 provides a virtual forum for presentation and discussion of the state-of the-art research on computers, information and systems sciences and engineering. The virtual conference will be conducted through the Internet using web-conferencing tools, made available by the conference. Authors will be presenting their PowerPoint, audio or video presentations using web-conferencing tools without the need for travel. Conference sessions will be broadcast to all the conference participants, where session participants can interact with the presenter during the presentation and (or) during the Q&A slot that follows the presentation. This international conference will be held entirely on-line. The accepted and presented papers will be made available after the conference both on a CD and as a book publication. Springer, the official publisher for CISSE, published the 2005 proceedings in 2 books [Book 1 (Flyer) and Book 2 (Flyer)], CISSE 2006 proceedings in four books [Book 1 (Flyer), Book 2 (Flyer), Book 3 (Flyer) and Book 4 (Flyer)], and the CISSE 2007 proceedings in four books [Book 1 (Flyer), Book 2 (Flyer), Book 3 (Flyer) and Book 4 (Flyer)], the CISSE 2008 proceedings in four books [Book 1 (Flyer), Book 2 (Flyer), Book 3 (Flyer) and Book 4 (Flyer)] and the CISSE 2009 proceedings in two books [Book 1 (Flyer) and Book 2 (Flyer)]. CISSE 2010 proceedings in the book [Book (Flyer)] and CISSE 2011 proceedings in the book [Book (Flyer)].

Conference participants - authors, presenters and attendees - only need an internet connection and sound available on their computers in order to be able to contribute and participate in this international ground-breaking conference. The on-line structure of this high-quality event will allow academic professionals and industry participants to contribute their work and attend world-class technical presentations based on rigorously refereed submissions, live, without the need for investing significant travel funds or time out of the office. Potential non-author conference attendees who cannot make the on-line conference dates are encouraged to register, as the entire joint conferences will be archived for future viewing.

CISSE 2012 is the eighth conference of the CISSE series of e-conferences. CISSE is the World's first Engineering/Computing and Systems Research E-Conference. CISSE 2005 was the first high-caliber Research Conference in the world to be completely conducted online in real-time via the internet. In 2005, CISSE received 255 research paper submissions and the final program included 140 accepted papers, from more than 45 countries. Last year, CISSE 2011 received a more than 300 paper submissions and the final program included 103 accepted papers, form more than 80 countries. The concept and format of CISSE is very exciting and ground-breaking. The PowerPoint presentations, final paper manuscripts and time schedule for live presentations over the web had been available for weeks prior to the start of the conference for all registrants, so that the participants can choose the presentations they want to attend and think about questions that they might want to ask. The live audio presentations were also recorded and are part of the permanent CISSE archive, which also includes all the papers, PowerPoint and audio presentations.

The CISSE conference audio room provides superb audio even over low speed internet connections, the ability to display PowerPoint presentations, and cross-platform compatibility (the conferencing software runs on Windows, Mac, and any other operating system that supports Java). In addition, the conferencing system allowed for an unlimited number of participants, which in turn granted us the opportunity to allow all CISSE participants to attend all presentations, as opposed to limiting the number of available seats for each session.

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Stream Collision Management in MIMO Ad-Hoc Network Sustaining the Lower Bound of QoS

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***Abstract*—The ad hoc wireless network that operates in the rich multipath propagation environment is considered. It is supposed that the node-to-node communication link are performed with multi-element antennas and MIMO spatial multiplexing transmitting-receiving strategy in use. The signal-to-interference-plus-noise-ratio (SINR) in the presence of interpath interference is analyzed. The cooperation among transmitted node is used to avoid the stream collision through the concurrent paths when the performance criteria is the quality of service (QoS) of peer-to-peer links is considered. The revised water pouring algorithm (RWPA) that helps to redistribute the power among the transmitted antennas according to QoS performance criteria is discussed. The proposed approach of the stream collision management allows to avoid the interpath interference as well as to maintain at least lower bound of QoS. The simulation part analyzes scenario with two pairs of node-to-node communication links.**

***Index Terms*—Ad hoc networks, array signal processing, channel state information, MIMO, multiuser communications, spatial multiplexing, water pouring algorithm.**

I. Introduction

Wireless ad hoc networks is basically peer-to-peer network of hosts that have not fixed communication infrastructure [1]. Extending MIMO concept to ad hoc network applications by using the medium access protocols such as IEEE 802.11n helps to achieve much higher spectral efficiencies than that of the traditional single-input-single-output (SISO) omnidirectional antennas nodes networks providing higher data throughput and improving system performance [2], [3].

A serious challenge is how to efficiently allocate the transmission powers among multiple antenna elements for each peer to peer link maximizing network throughput in the presence of mutual interfering paths (interpath interference). A lot of efforts in the literature have been undertaken to solve this problem. For example, multiuser water-pouring algorithm (WPA) is described in [4], where the interference path at the receiver can be suppressed with "whitening of the channel matrix" by matrix inversion operation. The noncooperative maximization of mutual information in the vector Gaussian interference channel via game theory is considered in [5]. Among other, some suitable solutions have been also discussed in [1], [2], [6]. The rigorous solution, as a rule, accompanies the high-priced computational procedure. However, sometimes less tense criteria than overall throughput are more essential for practical applications, for example, when the QoS of peer-to-peer links plays the dominant role.

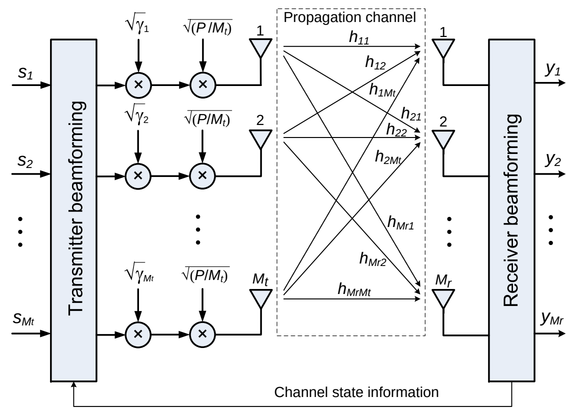

Fig. 1. Transmitter-receiver node pair in MIMO ad hoc network

In this paper we consider the performance of node-to-node communication link in the presence of interpath interference for spatial multiplexing MIMO physical layer when multiple independent data streams are transmitted using channel state information on the transmitter part (CSIT). We propose and analyze inexpensive approach that helps to avoid the stream collision through the concurrent paths and in the same time to maintain the acceptable QoS for each peer-to-peer communication pare. The revised water pouring algorithm (RWPA) that helps to succeed our criteria is considered.

II. SINR in the presence of interpath interference

A typical scenario in MIMO ad hoc networks is where the numerous nodes communicate simultaneously by using the same spectrum band and exploiting the propagation channel diversity. Let us consider an ad hoc network with simultaneously communicating transmitter-receiver node pairs, as Fig. 1 shows. Each node is equipped with M_t transmit antennas and M_r receive antennas. The transmitted signal $\mathbf{s} \in \mathbb{C}^{M_t \times 1}$ is column vector with i.i.d. standard Gaussian entries $s_i,\ i = 1, 2, \ldots, M_t$, and its covariance matrix is $E\left\{\mathbf{s}\mathbf{s}^{\dagger}\right\} = (P/M_t)\boldsymbol{\Upsilon}$, where $\boldsymbol{\Upsilon} = diag\left\{\gamma_1, \gamma_2, \ldots, \gamma_{M_t}\right\}$, is a power allocation matrix, P is a total power allocated to a transmitted node, and $\sum_{k=1}^{K} \gamma_i = M_t$.

All nodes communicate in the Rayleigh fading propagation channel with a rich scattering environment, and each transceiver-receiver pair attempts to avoid the interference through the use of multiple receiver antennas.

We introduce the channel matrix for the arbitrary transmitter-receiver pair as

$$\mathbf{H} = \mathbf{R_r}^{1/2}\mathbf{H}_{\mathcal{N}}\mathbf{R}_t^{1/2}, \tag{1}$$

where $\mathbf{H}_{\mathcal{N}} \in \mathbb{C}^{M_r \times M_t}$ is the i.i.d. complex values $\mathcal{CN}(0,1)$, which are the collection of all channel propagation coefficients, $\mathbf{R}_r$ and $\mathbf{R}_t$ are receiver and transmitter correlation matrix, respectively [7]. Assuming that $\mathbf{R}_r$ is the identity matrix, we consider the case with correlation at the transmitter side only. For the uniform linear array, the correlation coefficient r_{ij} between ith and jth transmitting antennas is [3]

$$r_{ij} = J_0\left[2\pi(i-j)d/\lambda\right], \tag{2}$$

where $J_0(x)$ is the zero order Bessel function of the first kind, and d/λ is an inter-element distance to the carrier wavelength ratio.

Furthermore, we ignore the large scale propagation attenuation of the received signal, assuming that $\sum_{j=1}^{M_t} E\{|h_{ij}|^2\} = M_t, i = 1, 2, \ldots, M_r$, where $E\{\cdot\}$ is the expectation operator, and h_{ij} are the elements of the matrix $\mathbf{H}$. This implies that each of the receiver antenna receives a power, which is equal to the total transmitted power P.

Let us consider the communication scenario with desired link, where one of the node transmits (desired transmitted node) and other node receives (desired receiving node) the data, and *K* interferer links around. The desired receiving node receives the signal of interest $\mathbf{s}^{(d)}$ as well as K interferer signals $\mathbf{s}^{(k)},\ k = 1, 2, \ldots, K$.

The set of the channel matrices related to the desired receiving node is $\{\mathbf{H}^{(d)}, \mathbf{H}^{(1)}, \mathbf{H}^{(2)}, \ldots, \mathbf{H}^{(k)}, \ldots, \mathbf{H}^{(K)}\}$. Let the singular value decompositions (SVD) of the matrices $\mathbf{H}^{(d)}$ and $\mathbf{H}^{(k)}$ are

$$\mathbf{H}^{(d)} = \mathbf{U}^{(d)}\mathbf{\Sigma}^{(d)}\mathbf{V}^{(d)\dagger};\quad \mathbf{H}^{(k)} = \mathbf{U}^{(k)}\mathbf{\Sigma}^{(k)}\mathbf{V}^{(k)\dagger}, \tag{3}$$

where $\mathbf{U}^{(d)}, \mathbf{U}^{(k)} \in \mathbb{C}^{M_r \times M_r}$, $\mathbf{V}^{(d)}, \mathbf{V}^{(k)} \in \mathbb{C}^{M_t \times M_t}$, and $\mathbf{\Sigma}^{(d)}$, $\mathbf{\Sigma}^{(k)}$ are corresponding receiver and transmitter precoding matrices with the orthonormal properties, and the singular values matrices.

The desired receiving node output vector in the presence of K interferer signals is

$$\begin{aligned}\mathbf{y} =& \sqrt{P^{(d)}}\mathbf{U}^{(d)\dagger}\mathbf{H}^{(d)}\mathbf{V}^{(d)}\mathbf{s}^{(d)} \\ &+ \sum_{k=1}^{K}\sqrt{P^{(k)}}\mathbf{U}^{(d)\dagger}\mathbf{H}^{(k)}\mathbf{V}^{(k)}\mathbf{s}^{(k)\dagger} + \mathbf{U}^{(d)\dagger}\mathbf{n}.\end{aligned} \tag{4}$$

Substituting (3) into (4) and afterwards using the orthonormal properties of precoding matrices we rewrite (4) as

$$\begin{aligned}\mathbf{y} =& \sqrt{P^{(d)}}\mathbf{\Sigma}^{(d)}\mathbf{s}^{(d)} \\ &+ \sum_{k=1}^{K}\sqrt{P^{(k)}}\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}\mathbf{\Sigma}^{(k)}\mathbf{s}^{(k)} + \mathbf{U}^{(d)\dagger}\mathbf{n},\end{aligned} \tag{5}$$

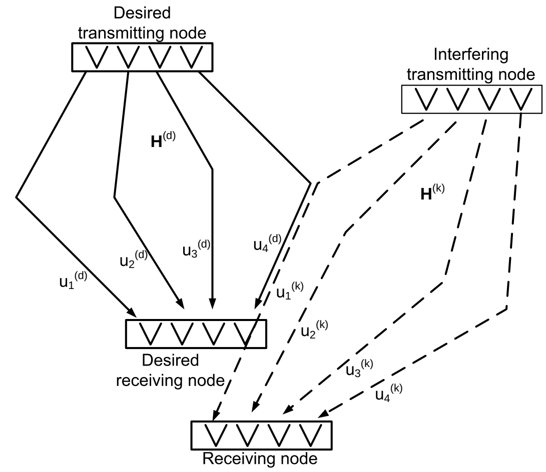

Fig. 2. MIMO communication scenario with collision of two streams

where the first term is the desired signal and the second term is an interfering signal in the output, and $\mathbf{n}$ the AWGN vector with the variance σ_n^2. Taking into account that $E\left\{\mathbf{s}^{(d)}\mathbf{s}^{(k)\dagger}\right\} = E\left\{\mathbf{s}^{(m)}\mathbf{s}^{(k)\dagger}\right\}_{m\neq k} = 0$, the overall average SINR in the output of the MIMO receiver in the spatial multiplexing mode regarding to each partial virtual subchannel yields

$$SINR_i = \frac{P^{(d)}\gamma_i^{(d)}\lambda_i^{(d)}}{\sum_{k=1}^{K} P^{(k)}\mathbf{u}_i^{(d)\dagger}\mathbf{U}^{(k)}\mathbf{\Lambda}^{(k)}\mathbf{\Upsilon}^{(k)}\mathbf{U}^{(k)\dagger}\mathbf{u}_i^{(d)} + \sigma_n^2}. \tag{6}$$

where $\mathbf{u}_i^{(d)}$ and $\lambda_i^{(d)}$ are *i*th eigenvector and *i*th eigenvalue of the matrix $\mathbf{H}^{(d)}$, respectively.

As (6) shows, the level of interfering signal in the output of the *i*th virtual subchannel is completely determined by the product $\mathbf{u}_i^{(d)\dagger}\mathbf{U}^{(k)}$. When $\mathbf{u}_i^{(d)\dagger}\mathbf{U}^{(k)} = \mathbf{0}$, the vector $\mathbf{u}_i^{(d)}$ is orthonormal to all columns of the matrix $\mathbf{U}^{(k)}$, meaning no stream collision, i.e., the non-interfering scenario is running. However, $\mathbf{u}_i^{(d)\dagger}\mathbf{U}^{(k)} \neq \mathbf{0}$ indicates that some path of the desired link concurs with some path of the interferer link. For example consider scenario shown in the Fig. 2, where $\mathbf{u}_i^{(d)\dagger}\mathbf{U}^{(k)} = \mathbf{0}, i = 1, 2, 3$, and $\mathbf{u}_4^{(d)\dagger}\mathbf{U}^{(k)} = \left[\begin{array}{cccc} 1 & 0 & 0 & 0 \end{array}\right]$, meaning that fourth path of desired link is concurs with the first path of interferer link, and corresponding streams collision occurs. Hence, when the number of collision is L, the expression of average SINR for *i*th virtual channel (6) can be rewritten as

$$SINR_i = \frac{P^{(d)}\gamma_i^{(d)}\lambda_i^{(d)}}{\sum_{j=1}^{L} P^{(k)}\gamma_j^{(k)}\lambda_j^{(k)} + \sigma_n^2}, \tag{7}$$

where *L* is a number of nonorthogonal paths between $\mathbf{u}_i^{(d)}$ and $\mathbf{U}^{(k)}$, or number of stream collisions.

As follows from (7), the more jointly nonorthogonal virtual channels the higher the level of interference and as a consequence, the lower ratio of SINR in the output of *i*th virtual channel. The total impact of *k*th interfering link into overall average SNIR of the desired link can be estimated by forming the product $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$. For example, for the scenario shown in Fig. 2 the result is 4×4 matrix with all zero elements except one with the unit value in the crossing of first column and fourth row.

III. Stream allocation Strategies in the presence of interpath interference

Obviously that the non-interferer scenario for the desired link is when the matrix $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$ has all zero elements. It can be achieved by suppression of all interferer paths on the desired receiver side using spatial-temporal processing [8], [9]. However, it is almost useless when interfering and desired streams are not spatially resolved; but even if they are spatially resolved the spatial-temporal processing requires enormous computational work diminishing the power efficiency of affected node.

We propose other solution, where the nonzero elements of the matrix $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$ are forced to zero by discarding those virtual channels which causes the stream collision. This approach does not require big computational efforts (that could be rigorously found in the full version of paper), however, it requires the transmitted power redistribution in the transmitter side of the link. We discuss the virtual path discarding strategy based on the game-theoretic framework [6], where the payoff function of the game is the certain level of QoS of each player, i.e. $C_j \geq C_{min}$, where C_{min} is a link capacity that still able to maintain a certain level of QoS. The players are the peer-to-peer links with corresponding channel eigenvalues entries, and available transmitted power (further without loose of generality we set $P^{(d)} = P^{(k)} = 1$). Furthermore, some sort of cooperations among transmitted nodes are implicated.

Let us consider the scenario where desired transmitting and receiving nodes try to establish the communication link in the presence of already operating K interfering links. To avoid the stream collisions the following operations should be done on the desired transmitter side to satisfy the payoff function:

1. Send the pilot signal and receive back the matrices $\mathbf{U}^{(k)}$ through the reverse channels, then compute the product $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}, \quad k = 1, 2, ..K$, and estimate which virtual paths already in use.

2. Using WPA compute the power allocation and channel capacity $C^{(d)}$ if only "clear" virtual paths will be involved to transmit the data.

3. If $C^{(d)} \geq C_{min}$, then discard the eigenvalues that cause the stream collisions and start to transmit the data.

4. If $C^{(d)} < C_{min}$, estimate which virtual sub-channel can be borrowed from some interferer links to achieve C_{min}. For this, send demand to interferer link through concurrent paths, inquiring about possibility to borrow the concurred path.

5. Interferer node receives the demand and recompute its capacity excluding the requested path. If $C^{(k)} \geq C_{min}$ the kth node send the positive confirmation through the reciprocal concurrent path to the desired node, then discard this path from the transmission, and recalculate new power allocation coefficients. If $C^{(d)} \leq C_{min}$ the request is denied.

6. If desired node obtains the required path, it starts to transmit data, if request is denied, it tries to send the request to other interferer links if someone. If all concurrent paths have denied the request the desired node is getting idle, till propagation condition would be more favorable.

When some virtual path is discarded, the power distribution strategy should be revised. It is well know that for the MIMO non-interfering scenarios to distribute the transmitted power optimally between transmitted antennae the WPA provides the optimum solution [10]. In the presence of interpath interference, and criteria QoS in use the conventional WPA should be slightly revised including the following improvements:

1. The eigenvalues of interferer virtual paths should be determined and discarded.

2. The matrix of eigenvalues $\mathbf{\Lambda}$ should be rearranged, and new rank, $r = r - L$ is redefined, where L is a number of discarded eigenvalues.

Further, it is running similarly to WPA. Revised version of WPA we call the revised WPA or RWPA. The computational work to adjust the power allocation factors using RWPA is just about $O(M_t L)$. The power redistribution among transmitted antennae either desired or interferer node yields to the following link capacity

$$C^{d(k)} = \max_{\sum_{j=1}^{r-L} \gamma_j = M_t} \sum_{j=1}^{r-L} \log\left(1 + \beta\gamma_j\lambda_j\right). \tag{8}$$

The proposed approach is a simple way to avoid the interpath interference. Despite the total network throughput could be far from the optimum (because the virtual sub-channels with the good propagation condition could be discarded), it helps to maintain the QoS of each link above the lower limit, C_{min}.

IV. Simulation Result

We consider scenario with two transceiver pairs of nodes, all equipped with uniform linear array (ULA) antennas, $M_t = M_r = 4$, $\lambda/2$ space element distance, and the signal-noise ratio in the receiver is 20 dB. The desired link operates in the presence of kth interfering node, as Fig. 2 shows. The channel matrices $\mathbf{H}^{(d)}$ and $\mathbf{H}^{(k)}$ have been generated and their eigenvalues matrices are computed. The result is $\mathbf{\Lambda}^{(d)} = diag\{35.5181 \;\; 3.4111 \;\; 1.0148 \;\; 0.1743\}$ and $\mathbf{\Lambda}^{(k)} = diag\{32.1907 \;\; 2.1954 \;\; 0.6920 \;\; 0.1597\}$ that indicate that both matrices have a full rank. The potential capacities of desired and interfering links in the non-interferer scenario according to (8) are $15.4303 \; b/s/Hz$ and $14.2346 \; b/s/Hz$, respectively.

We discuss scenario when interferer link already in use, but desired link still idle. The power allocation coefficients for kth interfering node are computed using the conventional WPA in the non-interferer scenario. WPA converged after the first iteration, and the power allocation diagram depicted in Fig. 3, where $n = 1, 2, 3, 4$ is a virtual channels, and the dark areas related to the positive values of γ_n. In the first interfering scenario we suppose that desired nodes pair try to establish the link. Firstly, the transmitter transmit the pilot signal, and the stream collision occurs between fourth desired and first interferer paths as Fig. 2 shows. The interferer receiving node

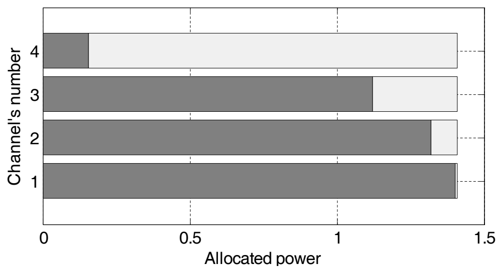

Fig. 3. MIMO link power allocation for non-interfering scenario.

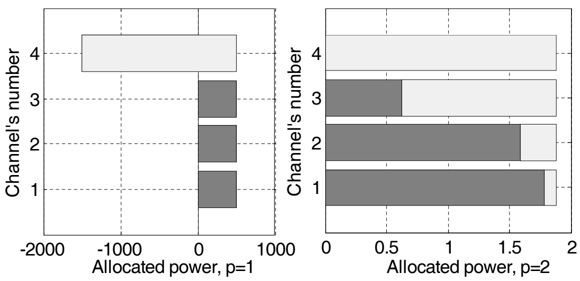

Fig. 4. MIMO interferer link power allocation with RWPA.

detect the collision, and, because of the reciprocity of the channel, transmit the matrix $\mathbf{U}^{(k)}$ to the desired link. The desired transmitter find the product $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$ and determines that fourth path could cause the stream collision with the first interferer path, and estimate $C^{(d)}$ assuming that fourth path is excluded from its own transmission, and the result is $C^{(d)} = 15,4267\ b/s/Hz$. If $C^{(d)} \geq C_{min}$ then the fourth path is discarded, the transmission power is rearranged among antennae with SWPA, and desired link start to transmit by using three "clear" paths.

However, if $C^{(d)} < C_{min}$, then the desired transmission node try to borrow the first path from the interferer node sending the request by using its fourth path. The interferer node receives the request and recalculate the capacity assuming that the first path would be discarded, and the result is $C^{(k)} = 7.6490\ b/s/Hz$. If request is succeeded, i.e., $C^{(k)} \geq C_{min}$ in the absence of the first path, then desired node start to transmit the data. The kth interfering transmitted node discards the first path of its link in favor of fourth path of desired link and then optimally (in terms of channel throughput) redistributes the power among the transmitted antenna elements with SWPA. It turns to the modified eigenvalue matrix $\mathbf{\Lambda}^{(k)} = diag\{2.1954\ \ 0.6920\ \ 0.1597\ \ 0.0\}$, i.e, the first eigenvalue is discarded. SWPA converged after the second iteration, as Fig. 4 shows. However, if request is denied ($C^{(k)} < C_{min}$), then desired link can not be established due to unable to satisfy the payoff criteria. In the second interfering scenario we consider the case when the interferer node borrows the fourth path from the desired link. It can be happened when interfering link try to transmit the data when desired link already in use. Firstly, the interferer node compute the potential capacity without first interferer path, and it is $C^{(k)} = 7.6490\ b/s/Hz$, and if $C^{(k)} < C_{min}$ then it try to borrow the fourth path from the desired link. If discarding of the fourth path results $C^{(d)} \geq C_{min}$, then the request succeed. RWPA recalculate the resulting eigenvalues matrix of the desired link as $\mathbf{\Lambda}^{(d)} = diag\{35.5181\ \ 3.4111\ \ 1.0148\ \ 0.0\}$ and desired and interferer link capacities become $C^{(d)} = 15,4267\ b/s/Hz$ and $14,2346\ b/s/Hz$, respectively.

Because C_{min} is a value that very dependable on applications we just estimate the partial and joint capacities for three presented scenarios. Using (8) for both desired and interfering link the total capacity of non-interferer scenario is $C^d + C^k = 15.4303 + 14.2346 = 29.6648\ b/s/Hz$, the first scenario yields $C^d + C^k = 15.4303 + 7.6490 = 23.0792\ b/s/Hz$, and the second one give us $C^d + C^k = 15.4267 + 14.2346 = 29.6613\ b/s/Hz$. The worst case is when the dominant eigenvalue is discarded. However, the QoS of both links could be still acceptable.

V. Conclusions

We consider the stream management strategy for MIMO ad hoc network links in the presence of interpath interference where cooperative transmission strategy among nodes is used and the performance criteria is QoS of peer-to-peer links. We analyzed the SINR for each virtual channel of the receiving nodes. It leads to the receiver precoding matrices $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$ product that provides information about the concurrent virtual transmission data streams. Inexpensive approach to avoid the interpath interference when QoS criteria in use is proposed. The node transmitting power is adjusted by revised water pouting algorithm (RWPA). Proposed stream management strategy can simplify significantly the ad-hoc nodes complexity comparing with the case when the whole network capacity should be optimized, in the same time maintaining the required QoS of each peer-to-peer link.

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Stream Collision Management in MIMO Ad Hoc Network Sustaining the Lower Bound of QoS

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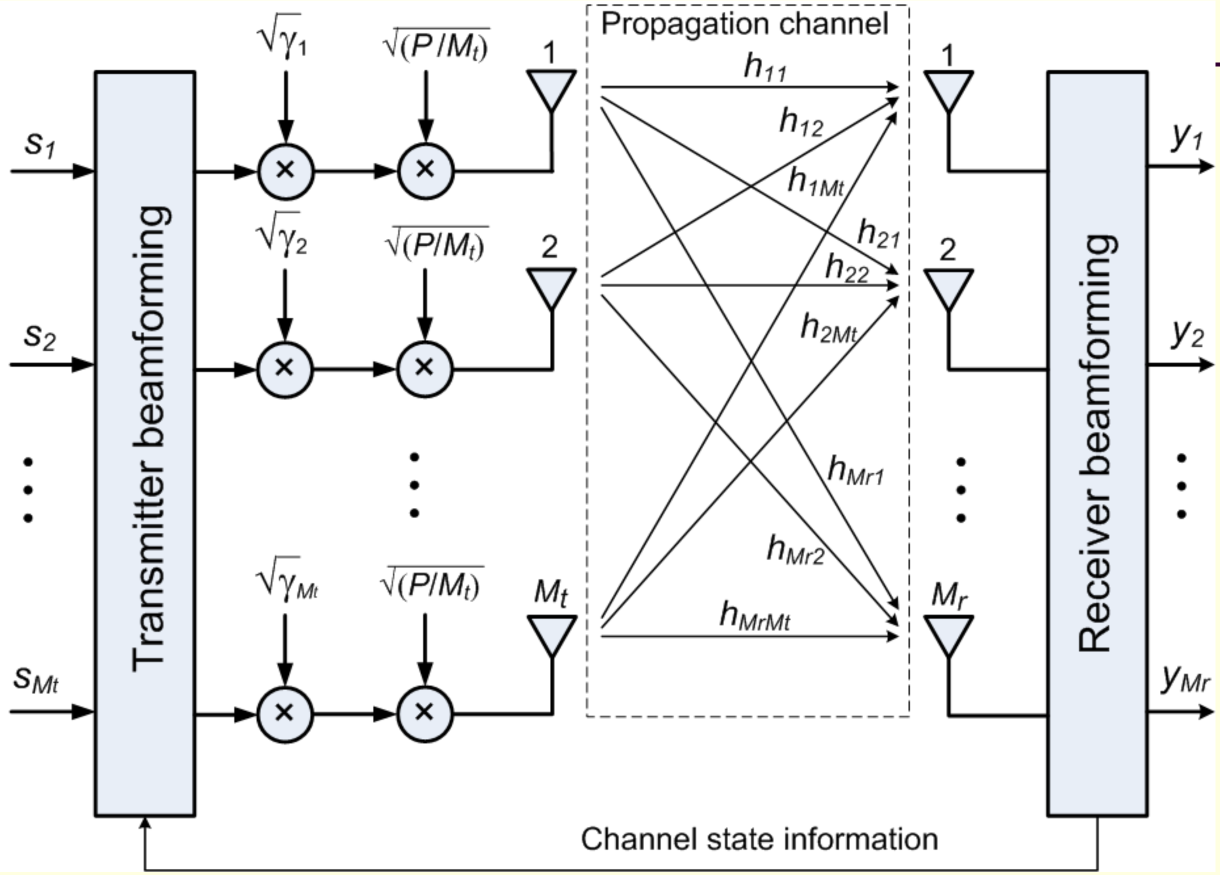
Introduction

- Performance of node-to-node communication link in the presence of interpath interference for MIMO ad hoc network is discussed
- We propose and analyze inexpensive approach that helps to avoid the stream collision through the concurrent paths and in the same time to maintain the acceptable QoS for each peer-to-peer communication pare.
- The revised water pouring algorithm (RWPA) that helps to succeed our criteria is proposed.

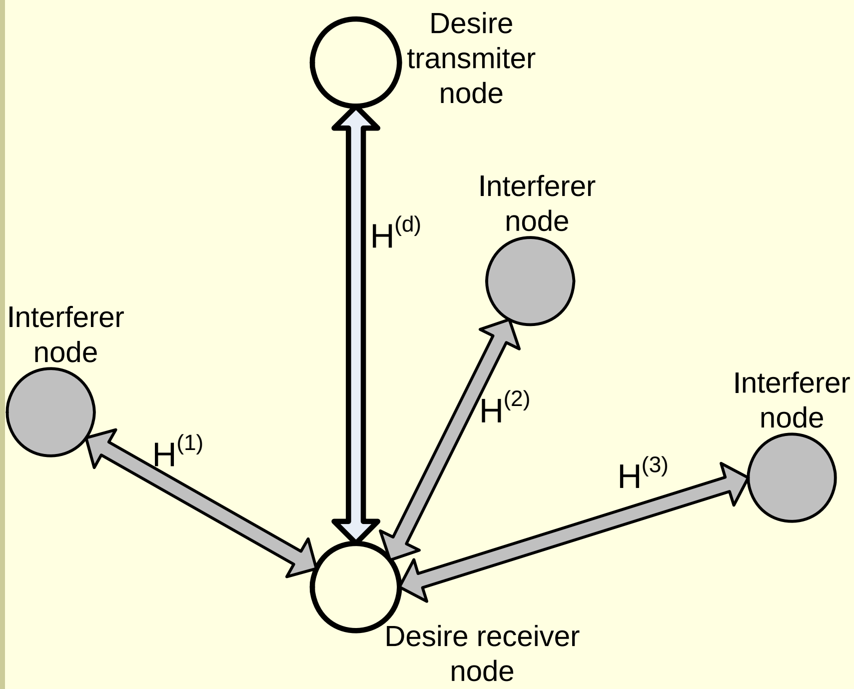
MIMO peer-to-peer link



$$\mathbf{H} = \mathbf{R}_\mathbf{r}^{1/2} \mathbf{H}_\mathrm{N} \mathbf{R}_t^{1/2}$$

$$\mathbf{H}_{\mathcal{N}} = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1M_t} \\ h_{21} & h_{22} & \dots & h_{2M_t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{M_r1} & h_{M_r2} & \dots & h_{M_rM_t} \end{bmatrix}$$

SINR in the output of the ith virtual channel



- The set of the channel matrixes relative to the desire node is

$$\{\mathbf{H}^{(d)}, \mathbf{H}^{(1)}, \mathbf{H}^{(2)}, \ldots, \mathbf{H}^{(k)}, \ldots, \mathbf{H}^{(K)}\}$$

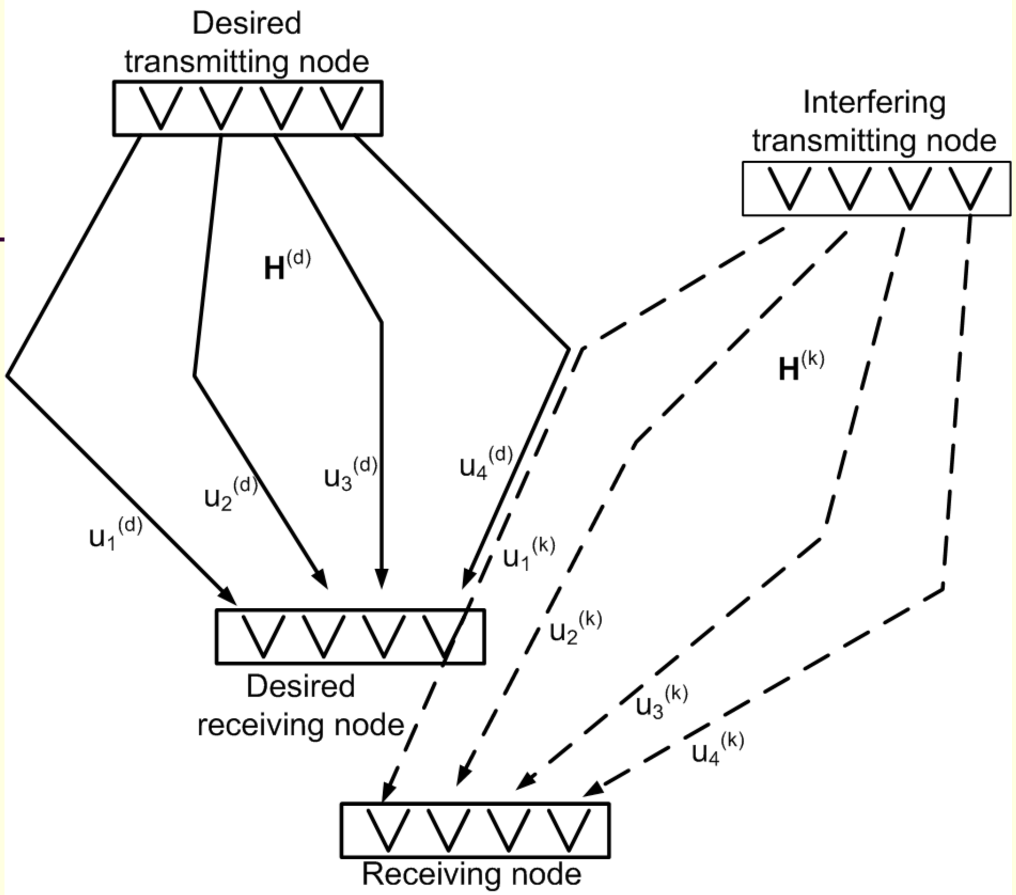
$$\mathbf{H}^{(k)} = \mathbf{U}^{(k)} \Sigma^{(k)} \mathbf{V}^{(k)\dagger},$$

- The resulting SINR in the output of the virtual sub-channel in the dominant eigenvalue mode is

$$SINR_i = \frac{P^{(d)} \gamma_i^{(d)} \lambda_i^{(d)}}{\sum_{k=1}^{K} P^{(k)} \mathbf{u}_i^{(d)\dagger} \mathbf{U}^{(k)} \boldsymbol{\Lambda}^{(k)} \boldsymbol{\Upsilon}^{(k)} \mathbf{U}^{(k)\dagger} \mathbf{u}_i^{(d)} + \sigma_n^2}$$

The level of interfering signal in the output of the ith virtual channel is completely determined by the product $\mathbf{u}^{(d)}$ ♣ $\mathbf{U}^{(k)}$

Stream collision Scenario



- $\mathbf{u}_i^{(d)} \clubsuit \mathbf{U}^{(k)}$ = [0 0 0 0], i = 1; 2; 3, and $\mathbf{u}_4^{(d)} \clubsuit \mathbf{U}^{(k)}$ = [1 0 0 0]

$$SINR_i = \frac{P^{(d)}\gamma_i^{(d)}\lambda_i^{(d)}}{\sum_{j=1}^{L} P^{(k)}\gamma_j^{(k)}\lambda_j^{(k)} + \sigma_n^2},$$

Stream allocation strategies approach

- Non-interferer scenario for the desired link is when the matrix $\mathbf{U}^{(d)\clubsuit}\,\mathbf{U}^{(k)}$ has all zero elements
- We propose the solution, where the nonzero elements of the matrix $\mathbf{U}^{(d)\clubsuit}\,\mathbf{U}^{(k)}$ are forced to zero by discarding those virtual channels which causes the stream collision.
- This approach does not require big computational efforts, however, it requires the transmitted power redistribution in the transmitter side of the link.

Stream allocation strategies

- We discuss the virtual path discarding strategy based on the game-theoretic framework, where the payoff function of the game is the certain level of QoS of each player, i.e. $C_j <= C_{min}$, where $\mathbf{C}_{\mathrm{min}}$ is a link capacity that still able to maintain a certain level of QoS.
- The players are the peer-to-peer links with corresponding channel eigenvalues entries, and available transmitted power.

Stream allocation strategies algorithm

1. Send the pilot signal and receive back the matrices $\mathbf{U}^{(k)}$ through the reverse channels, then compute the product $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}, \quad k = 1, 2, ..K$, and estimate which virtual paths already in use.

2. Using WPA compute the power allocation and channel capacity $C^{(d)}$ if only "clear" virtual paths will be involved to transmit the data.

3. If $C^{(d)} \geq C_{min}$, then discard the eigenvalues that cause the stream collisions and start to transmit the data.

4. If $C^{(d)} < C_{min}$, estimate which virtual sub-channel can be borrowed from some interferer links to achieve C_{min}. For this, send demand to interferer link through concurrent paths, inquiring about possibility to borrow the concurred path.

5. Interferer node receives the demand and recompute its capacity excluding the requested path. If $C^{(k)} \geq C_{min}$ the kth node send the positive confirmation through the reciprocal concurrent path to the desired node, then discard this path from the transmission, and recalculate new power allocation coefficients. If $C^{(d)} \leq C_{min}$ the request is denied.

6. If desired node obtains the required path, it starts to transmit data, if request is denied, it tries to send the request to other interferer links if someone. If all concurrent paths have denied the request the desired node is getting idle, till propagation condition would be more favorable.

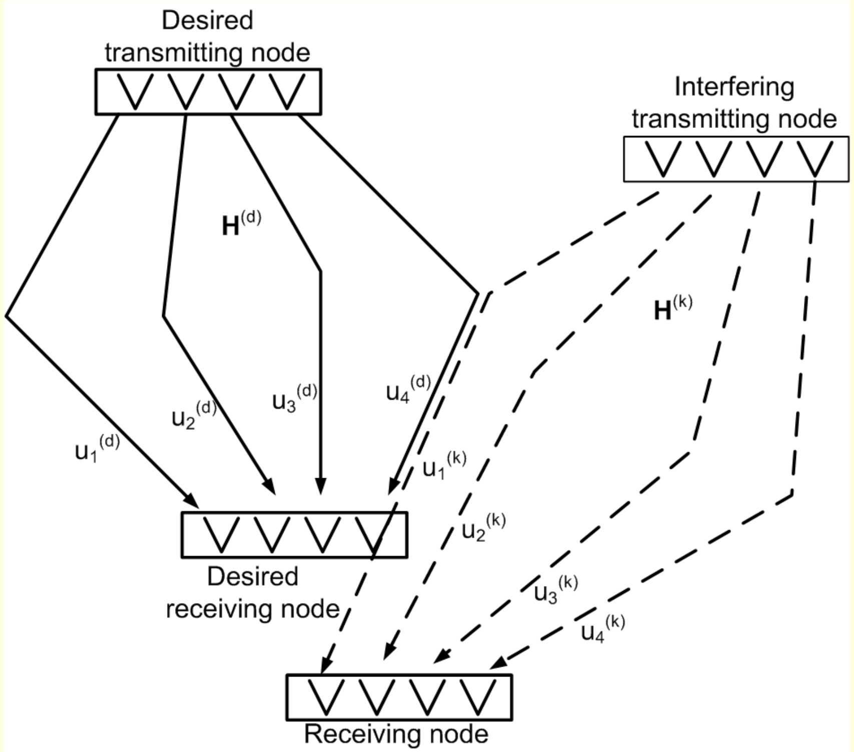
Revised WPA

- When some virtual path is discarded the conventional WPA should be improved:
- 1. The eigenvalues of interferer virtual paths should be determined and discarded.
- 2. The matrix of eigenvalues should be rearranged, and new rank, *r* = *r*- *L* is redefined, where *L* is a number of discarded eigenvalues. Further, it is running similarly to WPA. It yields to the following link capacity

$$C^{d(k)} = \max_{\sum_{j=1}^{r-L} \gamma_j = M_t} \sum_{j=1}^{r-L} \log\left(1 + \beta \gamma_j \lambda_j\right)$$

Simulation Result

- We consider scenario with two transceiver pairs of nodes, all equipped with uniform linear array (ULA) antennas, Mt = Mr = 4, $\lambda/2$ space element distance, and the signal-noise ratio in the receiver is 20 dB. The channel matrices $\mathbf{H}^{(d)}$ and $\mathbf{H}^{(k)}$ have been generated and their eigenvalues matrices are computed.



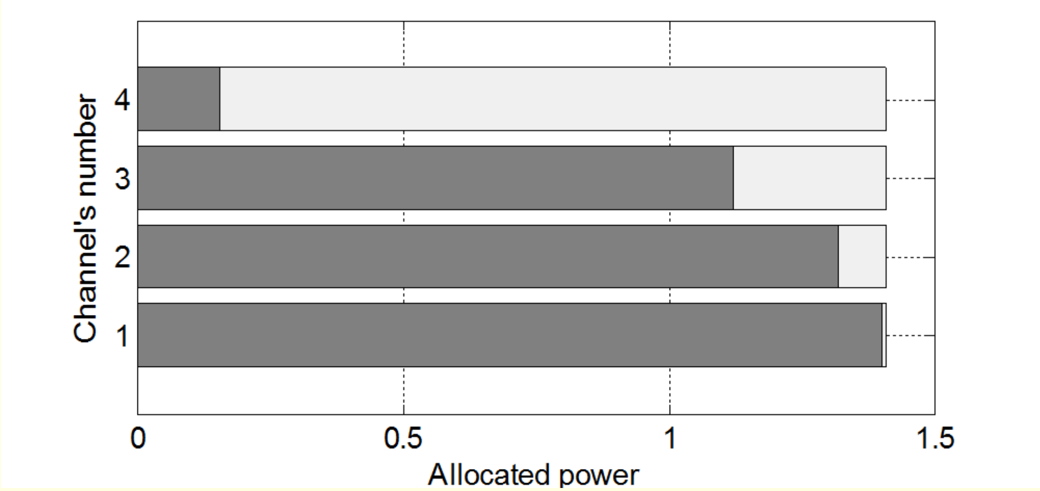
The total capacity

- The total capacity of non-interferer scenario

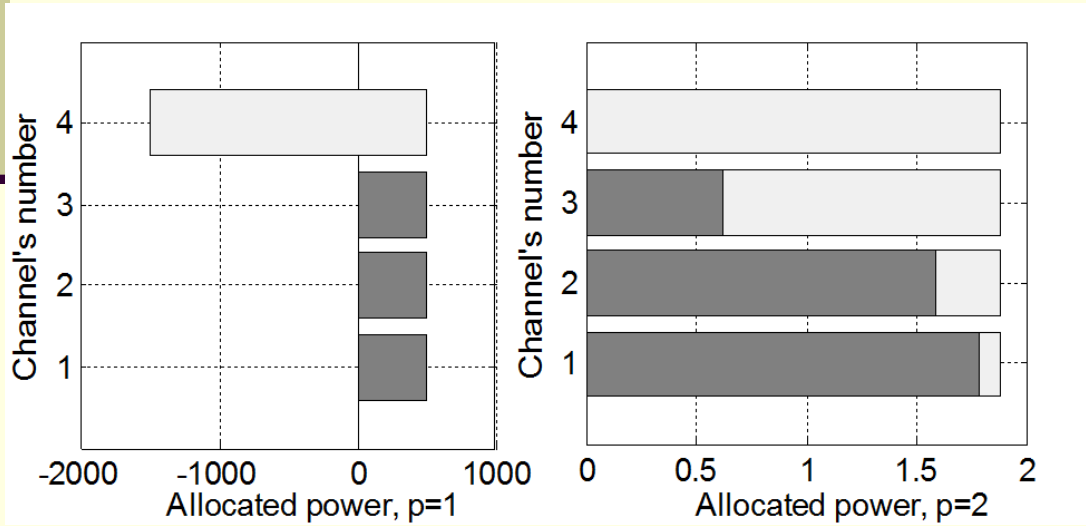
is $C^d + C^k$ =15.4303+14.2346 = 29.6648 b/s/Hz,

- the first scenario: Desired link borrow the first path of interfering node. It yields $C^d + C^k$ = 15.4303 + 7.6490 = 23.0792 b/s/Hz
- the second scenario: Desired link discarded its forth path. It gives us $C^d + C^k$ = 15.4267 + 14.2346 = 29.6613 b/s/Hz.
- The worst case is when the dominant eigenvalue is discarded. However, the QoS of both links could be still acceptable.

Power allocation with RWPA



a) Noninterfering scenario of k-th node



b) Interfering scenario with discarding fist eigenvalue of k-th interfering node.

Conclusions

- Inexpensive approach to avoid the interpath interference when QoS criteria in use is proposed.
- The node transmitting power is adjusted by revised water pouting algorithm (RWPA).
- Proposed stream management strategy can simplify significantly the ad-hoc nodes complexity comparing with the case when the whole network capacity should be optimized, in the same time maintaining the required QoS of each peer-to-peer link.

Thank you

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