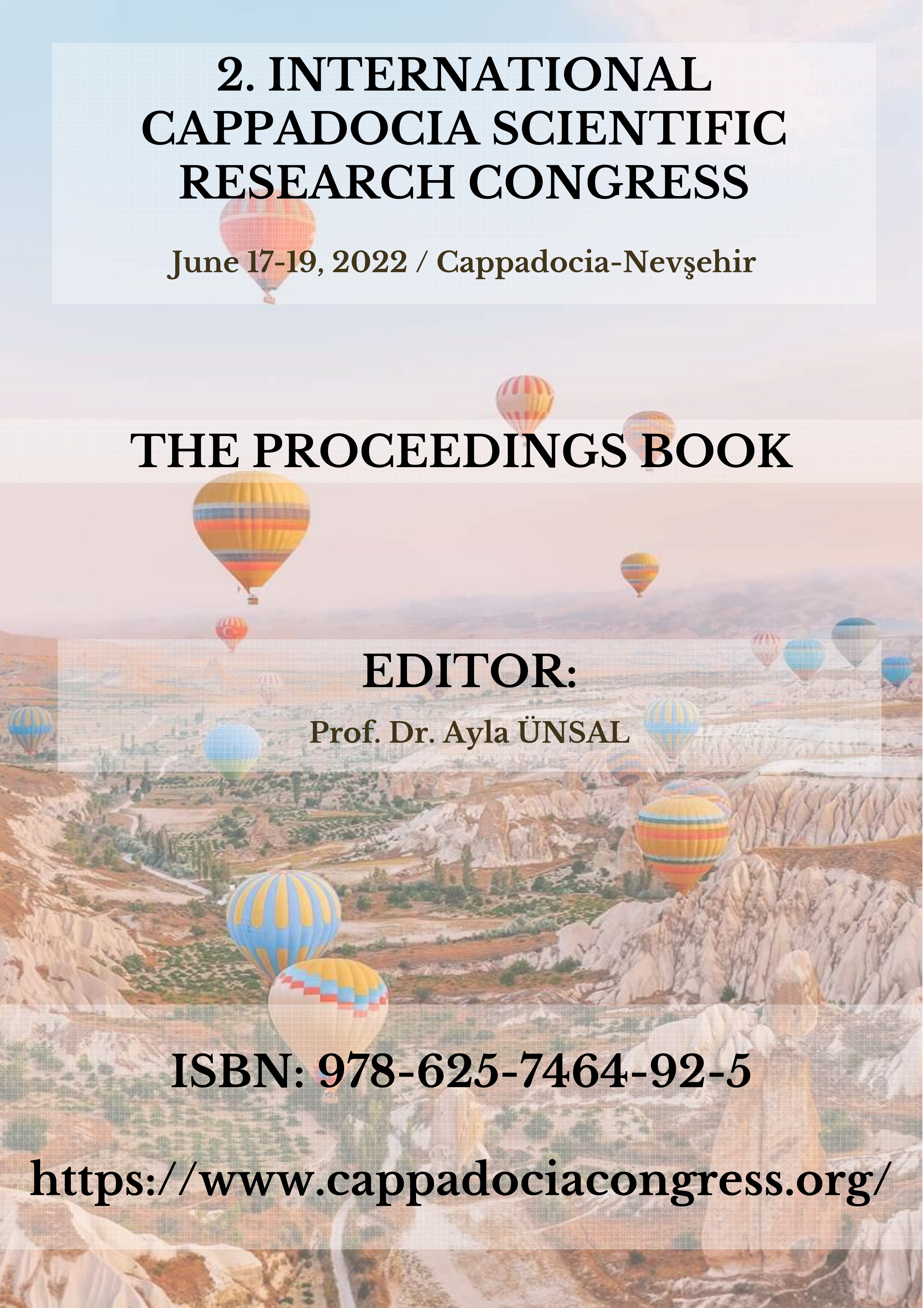

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HEAD OF SESSION: Prof. Dr. Peter Baumli

AUTHORS	AFFILIATION	TOPIC TITLE
SUBIKSHA.V	*KSR COLLEGE OF ENGINEERING*	EFFICIENT ADAPTABLE ANT COLONY OPTIMIZATION ALGORITHM IN WSN FOR NETWORK SECURITY
Res. Asst. Fatma RIDAOUI **Asst. Prof. Yakup GENC**	*Izmir Demokrasi University & Gebze Technical University*	USING ADDITIONAL DATA ON DIFFERENT NEURAL NETWORKS
Selin Çiğsem ERCAN **Yakup GENÇ**	*Gebze Technical University*	DEEP FACTORIZATION FOR TEMPORAL RETAIL DATA ANALYSIS
Nuzhat Ahmad Yatoo **I. Sathik Ali**	*B.S. Abdur Rahman Crescent Institute of Science and Technology*	DIABETES PREDICTION USING SUPPORT VECTOR MACHINE
Nour El Houda Benharkat **Souad Bentaalla Kaced** **Chergui Abdelmalek**	*National Polytechnic School of Algiers*	DIGITAL TWINS AND ITS MANIFOLD APPLICATIONS
Furkan KARDAŞ **Mustafa Anıl REŞAT** **Serdar ÖZYURT**	*Ankara Yıldırım Beyazıt University*	PERFORMANCE OF NON-ORTHOGONAL MULTIPLE ACCESS ZERO-FORCING V-BLAST OVER NAKAGAMI FADING CHANNELS
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PERFORMANCE OF MULTIUSER ZERO-FORCING V-BLAST UNDER 1-BIT FEEDBACK FOR USER SCHEDULING

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Abstract
Multiple-input multiple-output (MIMO) system has been acknowledged its capabilities in both achieving high capacity and being reliable over fading channels compared with other wireless communication systems. Many algorithms have been proposed in order to reduce the interference in the received signals of MIMO system. Increasing the data rate and capacity of the system is the main goal of every improvement being made on the transmission schemes of MIMO system. The Vertical Bell Laboratories Layered Space-Time (V-BLAST) system with zero-forcing (ZF) nulling scheme likely has drawn more attention on account of its high spectral efficiency result and comparatively low complexity compared with other transmission approaches. ZF V-BLAST technique achieves full spatial multiplexing gain through parallel and layered transmission without any requirement of channel state information (CSI) being known at the transmitter side. The original V-BLAST concept is based on a single-user scenario developed by Gerard Foschini at Bell Laboratories. In this paper, we study the performance of a downlink multiuser V-BLAST system where a single-user is scheduled in every time slot by the base station. The transmitter is assumed to have two antennas whereas all the users are equipped with r $(r \geq 2)$ antennas. Each user feeds back a single bit related to the sub-channel gain of its own channel matrix. Then, the transmitter chooses one user and communicates with it. Assuming uncorrelated antennas with Rayleigh fading, we investigate the outage probability of the system. A comparison with the analog feedback is carried out.
Keywords: zero-forcing, V-BLAST, layered transmission, user scheduling, multiuser system, multiple-input multiple-output.

INTRODUCTION

Multiple-input multiple-output (MIMO) transmission methods with a number of antennas at both transmitter and receiver have significant roles in establishing the nowadays wireless communication standards and systems (Yang and Hanzo, 2015). The potential of MIMO both in achieving high capacity and being reliable over fading channels have contributed the reason of its massive applications.

The transmission rate of a $t \times r$ MIMO system for a single-user scenario increases linearly with the minimum of t and r while t and r represent the number of transmit and receive antennas, respectively (Telatar, 1999). The transmission still can be implemented optimally in terms of the channel capacity although the channel state information (CSI) is not known at the transmitter side by sending the data streams parallel and at once via the transmit antennas (Telatar, 1999). The Vertical Bell Laboratories Layered Space-Time (V-BLAST) system with zero-forcing (ZF) nulling scheme proposed in work by (Foschini et al., 1999) likely has probably attracted more attention due to its high spectral efficiency and comparatively low complexity compared with other transmission approaches. The high spectral multiplexing gain can be attained by ZF V-BLAST technique through transmission in a parallel and simultaneous way without any knowledge of CSI at the transmitter side. A two step process of the main processing load in layered transmission is implemented at the receiver side, which known as the nulling and canceling steps (Foschini et al., 1999, Loyka et al., 2002, Özyurt et al.,2019). The first step or the nulling process is comprised of multiplying the received signal by a specific matrix with orthonormal columns that is obtained by QR decomposition so that the interference caused by other sub-streams are nullified. The canceling process which is implemented by performing SIC (Successive Interference Cancellation) allows each sub-stream to be decoded without the effects of interference between streams known as ISI (Inter Symbol Interference). The order in which fashion of the sub-streams are decoded influences the error performance of the system directly. Hence, the V-BLAST with non ordering may lead error propagation due to the fact that the error from prior decoding processes will be carried out to the next ones. On the other hand, the V-BLAST with ordering scheme is a solution for the drawback caused by the non-ordering V-BLAST (Foschini,et al.,1999). The ordering scheme detects the modulated symbols in such order that symbols with highest after-processing signal-to-noise ratio (SNR) are processed first.

In addition to the ordering scheme of SIC, some strategies have been offered in literature to improve the performance of multiuser ZF V-BLAST, e.g opportunistic scheduling (Zhang et al., 2007, Zhang et al., 2008, Yu et al., 2014). The opportunistic scheduling based on the maximum-SNR requires each user to feed back its highest post-processing SNR to the transmitter, then the transmitter schedules the designated user. However, this scheduling scheme burdens the system due to the heavy feedback (FB) load which contains raw information from each user. The threshold-based scheduling comes as an alternative to this drawback in which only users meeting the requirement of the threshold condition feed back their respective SNR values (Gesbert et al., 2004). Moreover, the quantized FB technique in which each user feeds back either bit 1 or 0 depending on its compliance with the requirement reduces the FB load to 1-bit FB (Zhang et al., 2007). In a multiuser scenario with the number of users increasing, the maximum-SNR based scheduling becomes impractical in consequence of its FB requirement. To the best of our knowledge, although multiuser ZF V-BLAST with user selection has been investigated for some feedback techniques (Al-Ghadhban, 2014 and Özyurt et al., 2020), the 1-bit FB technique on the ZF V-BLAST with ordering scheme has not yet been studied.

Throughout the paper, the operators $(.)\_\mathrm{herm}$ and $\|.\|$ represent the Hermitian transpose and Euclidean norm, respectively. Uppercase and lowercase bold letters are used to denote the matrices and column vectors, respectively.

SYSTEM MODEL

We consider a downlink network system between a base station with two transmit antennas and K users, each equipped with r ($r \geq 2$) antennas. The system block of the investigated system is illustrated in Figure 11. Each user is required to feed back a single bit related to its sub-channel gain to the transmitter. Assuming that each user only has the information of its own channel matrix, the feedback of each user does not consider any other user's channel state information forms in the process. Subsequently, for each training slot, the transmitter selects one user to communicate with, based on the 1-bit feedback information (a total of K-bits at the transmitter for users scheduling). In each communication cycle, the transmitter sends two independently encoded symbols via its antennas simultaneously and in parallel to the intended user. Afterwards, ZF V-BLAST technique is utilized at the scheduled user with the ordering scheme to decode the signals.

Let the channel matrix corresponding to the user k by given by h^{k} for $\mathrm{k} \in \{1,2, \dots, \mathrm{K}\}$. The rxt MIMO channel matrices for the users are assumed to be uncorrelated each representing a Rayleigh flat fading channel, i.e., the entries in the channel matrix of any user are independent and identically distributed (iid) complex Gaussian random variables with zero mean and unit variance. The channel for every user remains constant during a transmission period and shifts independently from one transmission to the next. The transmitter sends two symbols to the scheduled user in a parallel and simultaneous fashion. An assumption of using the same rate of capacity achieving code on both sub-streams is taken into account as well in this work. After processing the user selection, the received complex baseband signal at the selected user can be expressed as

$$\mathrm{y}^{\mathrm{k'}} = \mathrm{h}_1^{\mathrm{k'}}\mathrm{s}_1 + \mathrm{h}_2^{\mathrm{k'}}\mathrm{s}_2 + \mathrm{n} \qquad (1)$$

where k' with $\mathrm{k'} \in \{1,2, \dots, \mathrm{K}\}$ represents the index of the scheduled user. Furthermore, s_1 and s_2 denote the modulated symbols and n stands for the additive white Gaussian noise (AWGN) vector at the scheduled user, respectively.

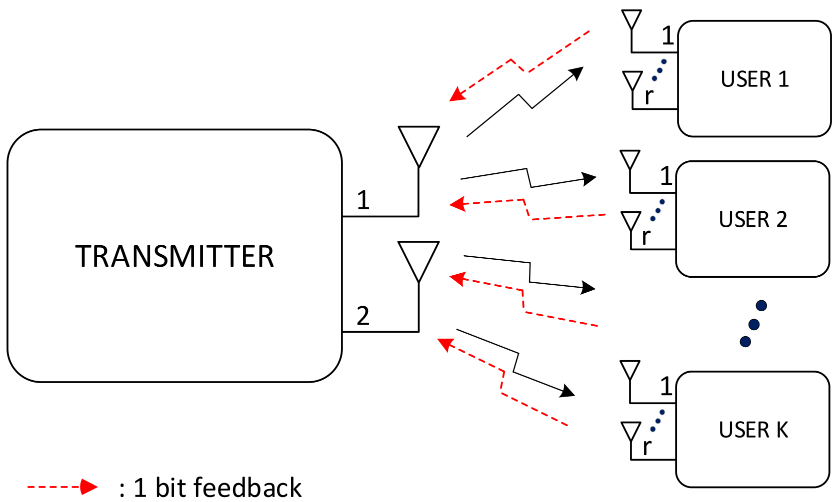

Figure 11 The block diagram of the investigated systems

The ordering scheme of ZF V-BLAST technique is employed for decoding process in order to achieve the minimization of the outage probability. This scheme implements the decoding of the first signal with the largest post-processing sub-channel gain.

The decision process will be performed using algorithm $\arg\max\left\{\left(h_1^{k'}\_herm\ P_{h_2^{k'}}^{\perp}\ h_1^{k'}\right), \left(h_2^{k'}\_herm\ P_{h_1^{k'}}^{\perp}\ h_2^{k'}\right)\right\}$ where $P_{h_j^k}^{\perp}$ represents the projection matrix onto the null space of the vector h_j^k. The result of arg $\max\left\{\left(h_1^{k'}\_herm\ P_{h_2^{k'}}^{\perp}\ h_1^{k'}\right), \left(h_2^{k'}\_herm\ P_{h_1^{k'}}^{\perp}\ h_2^{k'}\right)\right\}$ indicates the index of the transmitted signal which is best to be decoded first (Loyka and F. Gagnon. 2002). The ZF V-BLAST with ordering scheme (also known as the optimum ordering scheme) yields $\gamma_{k1} = \max\left\{\left(h_1^{k'}{}_{herm} P_{h_2^{k'}}^{\perp}\ h_1^{k'}\right), \left(h_2^{k'}{}_{herm} P_{h_1^{k'}}^{\perp}\ h_2^{k'}\right)\right.$ and $\gamma_{k2} = \min\left\{\left\|h_1^{k'}\_herm\right\|^2, \left\|h_1^{k'}\_herm\right\|^2\right\}$ as the first and second squared subchannel gains, respectively (Loyka and F. Gagnon. 2002). A discussion of user scheduling which utilizes the feedback of each users related to its sub-channel gain is explained in the Scheduling Scheme section.

SCHEDULING SCHEME

In practical terms, the feedback technique used for user scheduling is a technique in which every user sends a feedback based on the predetermined condition. The feedback transmitted from users to the transmitter is accomplished either by sending a scalar or limited feedback. The condition itself is not limited to one criterion and can be optimized through various strategies. There exist different approaches on this such as the work by Samir Al-Ghadhban (2014) which considers several scheduling criteria for V-BLAST users, or the work by Özyurt and Kucur (2020) which employs the threshold-scheme,i.e choosing the largest norm of the user's channel matrix and comparing the squared norm of it with a threshold value. The scenario must be carefully chosen in order to achieve the best results.

The limited feedback or also known as the 1-bit feedback technique is a technique in which users send a bit 1 or 0 to the transmitter relating to the certain condition. In this work, the 1-bit feedback technique implements a threshold-based system in which each user feeds back only one bit of information corresponding to the comparison between its largest resulting squared sub-channel gain on the first layer γ_{k1} and a threshold γ_{th}. If $\gamma_{k1} \geq \gamma_{th}$, then the kth user sends back bit 1 to the transmitter, and bit 0 otherwise. This approach is pursued by all the users. The transmitter forms the set of users sending back bit 1 denoted by B. The transmitter carries out the decision process of scheduling user by inspecting the cardinality of B. If B only contains one element, the transmitter schedules the user in B. When the cardinality of B is greater than unity, the selection of user is conducted by choosing it randomly from B. Then again, when B contains no elements that is all the users send back a bit 0, the transmitter chooses one user out of K users randomly.

In the limited feedback with threshold-based, the optimization of the criterion also extends to the threshold value γ_{th}, e.g Gesbert and Alouini (2004) considers γ_{th} to reach a set scheduling outage probability. The threshold choice process is also applied in this work to obtain the best result.

SIMULATION RESULTS

In this section, a number of numerical results are provided in terms of the average outage probability. The proposed scheme of ZF V-BLAST with optimum ordering and limited feedback is simulated for r = 3 and K = 5. Furthermore, we consider that each sub-channel has a target rate of R = 2 bits/s/Hz. Initially, the process of choosing the right threshold value for each SNR is implemented.

The threshold range is chosen between 1 and 3 for the simulation with varying SNR. Figure 12 shows that determining the suitable value γ_{th} is significant especially for lower SNR case since the resulting average outage probability (AOP) is naturally high at such low SNR values. For SNR = 5 dB , the lowest value of AOP is obtained at $\gamma_{th} = 2.3$, while for SNR = 10 dB is at $\gamma_{th} = 2$. At such higher SNRs, the values γ_{th} which produce the best performance are 2.1 and 1.8, for SNR = 5 and 10 dB respectively. Based on this result, γ_{th} value of 2 can be optimistically selected as the threshold value for the all SNR values concerning that the obtained γ_{th} values from all simulated SNR values are about 2.
Subsequently, the multiuser ZF V-BLAST with the optimum ordering and 1-bit feedback is simulated using each of the obtained values γ_{th} with respect to its SNR value, and the result is shown in Figure 13. The multiuser ZF V-BLAST with 1-bit feedback yields the optimum results as compared to the single-user ZF V-BLAST for varying SNR where both schemes adopt optimum ordering for decoding its symbols. For an AOP of 10^{-3}, the attained SNR gain of V-BLAST with 1-bit feedback is about 3 dB beyond the single-user ZF V-BLAST.

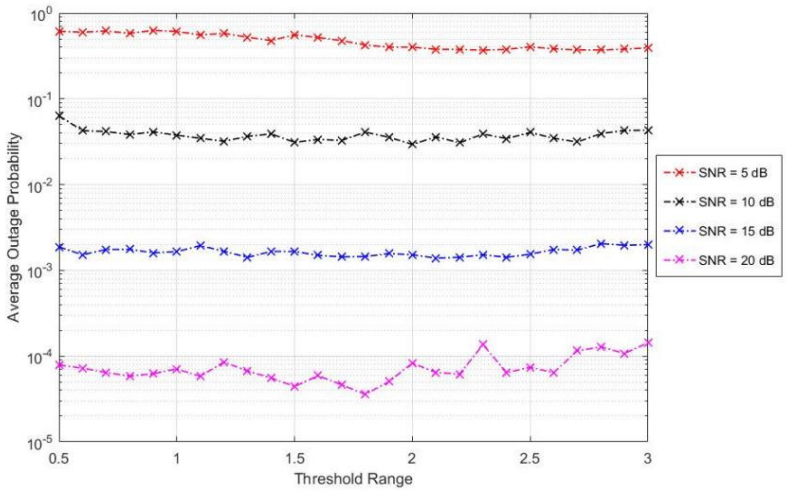

Figure 12 The AOP vs Threshold Range for K = 5 and R = 2 bits/s/Hz with various SNR values

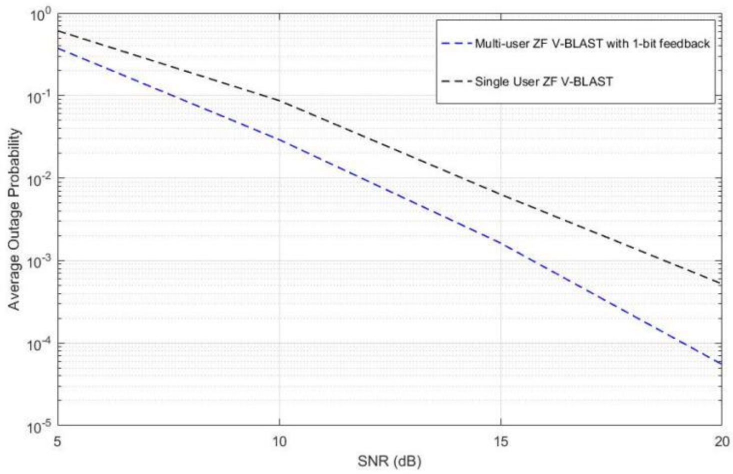

Figure 13 Comparison of multiuser ZF V-BLAST with 1-bit FB with its single user (or random user scheduling) counterpart in terms of AOP for K = 5 and R = 2 bits/s/Hz and varying SNR

CONCLUSION

We have studied a multiuser ZF V-BLAST with optimum ordering and 1-bit feedback in a K-user downlink system where the transmitter and the user are equipped with two and r ($r \geq 2$) antennas, respectively. Every user sends the information in the form of a single bit feedback value (bit 1 or 0) which is related to its sub-channel gain to the transmitter. The transmitter schedules only one user according to the content of the received FB from the users and sends data to this user in each training cycle. The user scheduling process acts in accordance with the threshold concept. The suitable threshold values are examined for a range of SNR values. Then, the benchmark of ZF V-BLAST, i.e a single-user ZF V-BLAST which in fact represents the multiuser ZF V-BLAST with random user scheduling scheme, and the proposed scheme which simulates all the attained values of threshold with respect to its SNRs are compared in terms of AOP. It has been shown that the adopted technique with limited feedback performs better. With only 1-bit FB per user, an SNR gain of 3 dB can be obtained as compared to the single user ZF V-BLAST or the multiuser ZF V-BLAST with random user scheduling.

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