Distributed Network Slicing and User Association in Unequal STBC-SNR Branch

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Abstract. Virtualized Wireless Networks (VWN) strive to offer efficient power allocation and spectral efficiency to each user assigned to a given slice at any time. We propose a user-slice association based on the softmax of the probability of successful transmission using space-time block code (STBC) to encode the data transmission in a wireless channel. Each slice is defined by a set of Base stations (BS) or relays or Access Points (APs) or Small cell Base Stations and their related physical resources or a combination of such stations. The slices constitute a distributed-space-time block code which provides the data traffic for the mobile terminals. A minimisation of the derived bit error rate (BER) is used to find the optimal transmit power at each slice. The optimisation is constrained by the outage at the small cell located near the cooperating transmit slices. Such constraint improves the initialisation of the iterative algorithm compared to randomly choosing initial points. The proposed optimisation yields a dynamic selection of the slices with power control pertaining to the outdoor mobile terminal performance and the outage. The simulations show that the selection of a slice based on the softmax of the probability of successful transmissions ensures a better probability of successful transmissions compared to a permutation based selection.

Keywords: Virtualization Wireless Network (VWN) · Space-Time Block Coding (STBC) · Softmax

1 Introduction

The next generation cellular wireless networks called 5G is expected to be deployed around 2020. This technology is hailed to provide higher data rate, lower end-to-end latency, improved spectrum/energy efficiency, and reduced cost per bit. In general, addressing these requirements will require significantly larger amount of spectrum, more aggressive frequency reuse, extreme densification of small cells, and the wide use of several enabling technologies (e.g., full-duplex,

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massive MIMO, C-RAN, and wireless virtualization) [1]. Here, we will focus on the issue of wireless virtualization which has been receiving increasing attention from both academia and industry [2,3]. Virtualization enables the decoupling of infrastructure from the services it provides. In this case, Mobile Virtual Network Operators (MVNOs) lease the infrastructure of Mobile Operators (MOs) to offer services to their customers. Each MO or infrastructure providers (InPs) can make available for lease a certain number of slices. A slice is defined by a set of Base stations (BS) or relays or Access Points (APs) or Small cell Base Stations and their related physical resources or a combination of such stations along their radio resources. Considering an MVNO who has agreement with several MOs, the user equipment(UE) subscribed to such MVNO should be able to profit from the services of the MVNO which are provided through different physical infrastructures. Virtualization can offer several benefits. First, decoupling and sharing the network infrastructure can help reduce capital expenses (CapEx) and operation expenses (OpEx) [4]. Another benefit of this technique lies in the fact that the use of resources can be improved by moderating the dynamic demands of users of different MVNOs. This provides the benefits of statistical multiplexing. Reducing limits and problems with small service providers could enrich the services provided to users. Current mobile communication research endeavors to achieve cochannel deployment of MVNO slices and legacy macrocell as a response to the ever-growing demand in wireless channel capacity. In such multi-tier cellular network, transmit power allocation with regard to outage constraint is an issue due to cross-tier interference [6]. Power allocation for STBC transmit diversity can be achieved by selecting two antenna elements out of all transmitters which are optimal in the sense of a dynamic power allocation which minimizes the symbol error rate. Suboptimal and near-optimum transmit power allocations are derived in [12] and [13] respectively. In addition, Outage probability analysis of spatially distributed relaying based on STBC is provided for ergodic and non-ergodic channel. The performance of distributed STBC in the previously cited work is achieved by using channel state information (CSI) availability, in addition to being oblivious to the difference in signal-to-noise ratio (SNR) branch considering large scale fading environment of multi-tier cellular networks. Our proposal derives the two-slices transmit powers independently of CSI while considering path loss effect on unequal SNR branch. In [17], the output SNR of a selected diversity branches with unequal SNRs [16] is maximized through maximum ratio combining. The work in [18] differs from [17] by its application of unequal transmit power allocation to the Alamouti scheme. We propose a slice selection based on sofmax learning. Each slice has at least two antennas and the Alamouti STBC scheme is considered between a slice and a UE. The softmax is training over the bit-error rate of the link between slice and UE. The simulations show that the selection of a receiver based on the softmax of the probability of successful transmissions ensures a better probability of successful transmissions compared to a permutation based selection.

2 System Model

We consider universal spectrum sharing between a UEs and randomly distributed MVNO slices. Each base slice serves at least one MVNO user. The downlink between the MBS and the MUEs is interfaced by a set of slices as illustrated in Fig. 1. The slices are equally distanced from the MBS. We assume a close access operation of the MVNO slices base stations, i.e. a MVNO slice base station is solely accessed by its registered MVNO slices users.

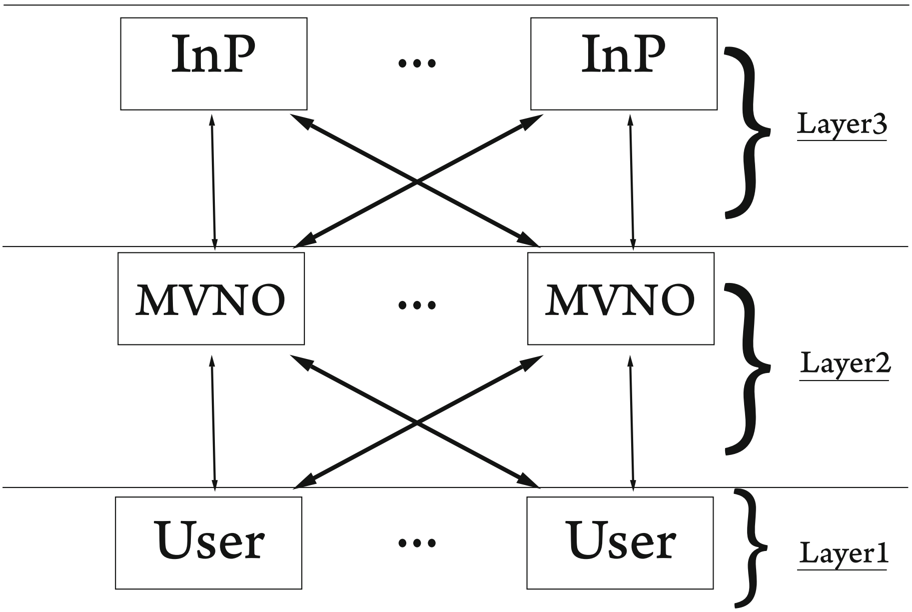

Fig. 1. User association hierarchical model.

We consider VWNs where a transmitter selects its receiver (slice) without knowing whether the transmission will be successful. We denote by Pa the probability of availability of a receiver. We express the probability of a successful transmission as:

$$perf(p,t,i) = \begin{cases} 1, if\ transmission\ successful \\ 0, otherwise. \end{cases} \quad (1)$$

where p, t, i are indexes for mobile user (transmitter), time and selected receiver respectively. A successful transmission can be defined as correctly receiving a certain portion of packets or bits. The reward function is defined to be

$$R(p,t,i) = t(perf(p,t,i)Pa - cost(i)), \quad (2)$$

where $cost(p,t,i)$ is the cost to select the ith receiver.

3 STBC Unequal Branch SNRs

Space-Time block Coding (STBC) is a wireless transmission scheme which exploits multiple antennas at the transmit side without channel state information (CSI) to provide maximum likelihood decoding based on linear processing at the receiver. The receiver can have one or more antenna elements. STBC for two transmit antennas has been discovered by Alamouti [7]. We assume that each station transmits with two antenna elements with the Alamouti encoding scheme and maximum likelihood detection is performed at the receiver. Such encoding and decoding schemes have low complexity [8]. A design a modern wireless system with adjustable transmit powers which minimise the bit error rate (BER) comparing equal and unequal signal-to-noise ratio in STBC wireless communications is presented in [6].

$$SNR = \frac{P_1 d_1^{-\alpha_{out}}}{N_0}|h_1|^2 + \frac{P_2 d_2^{-\alpha_{out}}}{N_0}|h_2|^2 \tag{3}$$

$$\lambda_i = \frac{P_i d_i^{-\alpha_{out}}}{N_0} \tag{4}$$

λ_i means the average SNR for the ith MUE transmitting with power Pi at a distance di to the receiver and α_{out} is the outdoor path loss exponent.

$$P_b = \frac{\sqrt{\lambda_1\lambda_2} + \sqrt{\lambda_2}(1+\lambda_1) + \sqrt{\lambda_1}(1+\lambda_2)}{2K_{BER}(\sqrt{\lambda_1} + \sqrt{1+\lambda_1})\sqrt{(1+\lambda_1)(1+\lambda_2)}(\sqrt{\lambda_2} + \sqrt{1+\lambda_2})} \tag{5}$$

where

$$K_{BER} = \sqrt{\lambda_2(1+\lambda_1)} + \sqrt{\lambda_1(1+\lambda_2)}$$

Each slice has at least two antennas; the STBC can be applied to determine the SNR. Each slice is characterized by its SNR. Considering Pb, we can evaluate the performance of each slice. So we can use the BER as parameters for selecting a slice. The softmax allows us to select a slice. The derivation of Pb is done in [6].

4 Proposed Slice Selection Methods

Softmax [5] regression or multinomial logistic regression is a generalization of logistic regression in case we want to treat several classes. The software softmax allows to build neural networks with several standardized outputs. This makes it particularly suitable for creating classifications by neural networks with probabilistic outputs. It is particularly useful for neural networks where it is desired to apply a non-binary classification. In this case, simple logistic regression is not enough. We propose to select a slice based on the highest successful packet transmission rate. Each MO proposes a set of slices to an MVNO. The MVNO selects the slices available to associate each slice or a set of selected slices to one or several of its UEs. Assuming the STBC scheme already described, we use the BER performance as the selective criterion to decide the mobile user(s) to slice association.

5 Numerical Investigation

To investigate the proposal, we set up as a benchmark a slice-user association based on a permutation of the slices, i.e. a UE is associated to a slice by permuting the set of the slices. We assume that the average SNR at each selected slice is chosen from 5.5 dB, 8.9 dB, 11 dB. For instance, if "Slice 1", "Slice 2" and "Slice 3" have the average SNRs "5.5 dB", "8.9 dB" and "11 dB" respectively, then a user is associated to "Slice 1" for the first time slot, to "Slice 2" for the second time slot and to "Slice 3" for the third time slot. For the 4th time slot, the user will be associated with "Slice 1" and so forth. Following such association scheme, the BER is computed and the probability of successful transmission for such user is given in Fig. 2.

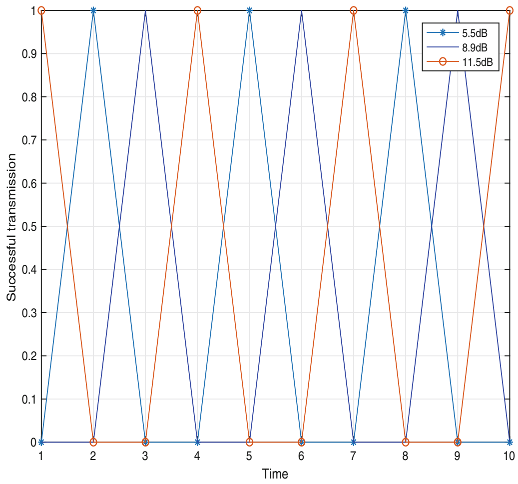

Fig. 2. Probability of successful transmissions per receiver by permutation of the receivers.

The proposed scheme uses the softmax to compute the parameter used to associate a mobile user to a slice. It assumes some training periods. The training consists of using the benchmark for a certain number of time slots and then compute the softmax value by using 6. If the softmax value output at the i_{th} slice is the highest at a given time slot, then the mobile user is associated with the i_{th} slice. We consider a transmitting device as a mobile user or UE. A mobile user can transmit to a any slice. The softmax is computed as:

$$Sfmax(p,i) = \frac{e^{-AvPerf(p,i)}}{\sum_{k=1}^{N} e^{-AvPerf(k,i)}}, \tag{6}$$

where N is the number of mobiles users and

$$AvPerf(p,i) = \sum_{n=1}^{T} perf(p,t,i) \tag{7}$$

is the average of successful transmissions over a period of time T.

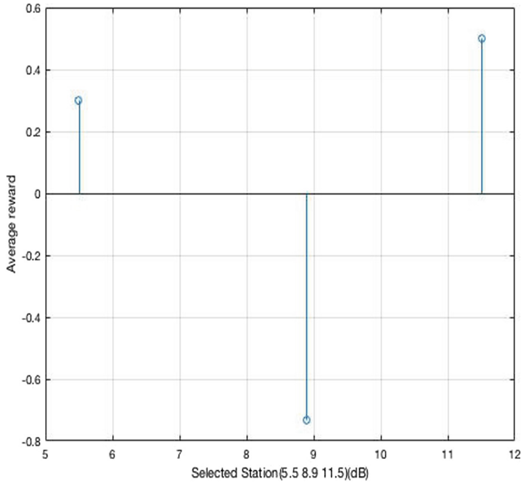

Fig. 3. Reward per receiver by receiver selection based on permutation of the receivers.

Figures 3 and 4 illustrate our proposal which consists of associating a mobile user to a slice if the latter has the highest softmax output. The softmax output is computed by (3). The reward performance illustrated Fig. 3 shows a shorter gap in reward between the slice with 5.5 dB and the one with 11 dB than the gap obtained with softmax-based selection criterion as illustrated in Fig. 4.

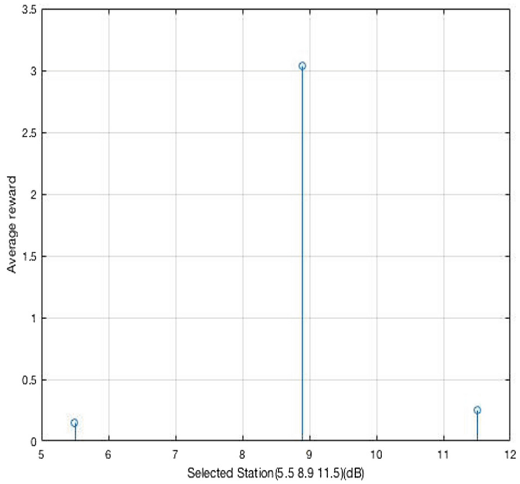

Fig. 4. Reward per receiver by receiver selection based on Softmax.

Figure 4 shows that following the softmax based user-slice association yields a better average reward. Indeed, the best slice is more often selected than the others. In Fig. 3, the slice with the SNR averaging 8.9 dB is selected more often and yields a higher reward than the other slices. We set the signal-to-noise ratio (SNR) for the 3 receivers in the simulations. On Fig. 2, each of the values {5.5, 8.9, 11.5 dB} represents the SNR for the corresponding receiver. Figure 2 presents the probability of successful transmissions given by (1) of an MS selecting a receiver by permuting from one to another each time. This allows the computation of the average of successful transmissions given by (7). Figure 3 can be compared to Fig. 4 for the reward performance evaluated by (2) using the permutation and the softmax (6) respectively. The Fig. 4 shows that the MS selects one receiver which provides the highest probability of successful transmissions most of the time and only selects other receiver a few times.

6 Conclusion and Future Work

The number of slices which can be made available by MOs for wireless virtualized networks can be high and can change adaptively. The mobile users subscribers to the MVNOs services will benefits greatly in an adaptive mobile user-slice association which can be managed by a virtual interface. Our proposal and computer simulation illustrate an implementation of a user-slice association for wireless virtualized networks and the better association it provides compared to a permutation-based one. We would like to extend this work by investigating deeper in the softmax usage in research, and apply more antennas (3 or 4) at the transmitter for the STBC schemes. Additionaly, transmit power allocation will be investigated regarding non equal branch SNR in STBC and MIMO channel uncertainty.

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