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USER PAIRING IMPACT ON THE PERFORMANCE OF HYBRID BEAMFORMING NOMA SYSTEM

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Abstract

This paper proposes a new user pairing technique for a power domain non-orthogonal multiple access (NOMA) deploying fully connected and sub-connected hybrid beamforming (HBF) structures for a typical urban microcell downlink of line-of-sight (LOS) and non-line-of-sight (NLOS) surroundings. NOMA system's configurations are set up for two (multiple input single output) users per cluster down-linking base station equipped with 128 antennas. HBF processing adopts phased zero forcing (P-ZF) for both fully connected (HBF-NOMA) structure (FCS) and sub-connected (HBF-NOMA) structure (SCS) precoders' optimization, and successive interference cancellation zero forcing (SIC-ZF) schemes to optimize the SCS-HBF-NOMA precoder exploiting dynamic power allocation. The new users' pairing exploits users' distance to the base station, namely near and far clusters different from the benchmark angle of arrival- based users' pairing. The proposed users' pairing and the precoding schemes' impact are investigated for finite-resolution HBF structures operating in LOS and NLOS surroundings. The execution under New York University (NYU) mmW channel model is explored for two users in a cluster with different angles of arrival. Results show that the users' pairing based on AoA performs better than the newly proposed users' pairing. However, the proposed users' pairing scheme performs better than their corresponding OMA counterparts, which still make them beneficial for multiple access technique and a scenario, where one of the far cluster users need to access the base station for high data rate service and vice versa. Finally, the modified Liang processing scheme for quantizing SCS-HBF-NOMA precoder is capable of mitigating the quantization error arising from the NLOS environment and the nature of sub-connected (HBF) structure under a low SNR regime.

1.0 INTRODUCTION

Hybrid beamforming (HBF) conjunct with non-orthogonal multiple access (NOMA) is a hybrid technology recently discovered to further allow high data rate in the order of GB per second in post 5G wireless communications. Specifically, the HBF evolved to address the hardware constraint attribute of digital beamforming in massive multiple-input-multiple- output (MIMO) systems, while the NOMA design was presented to further ameliorate the capacity of a conventional multiple users system by allowing more than one user pairing for the same resources of the base station [1]. More specifically, the HBF exploits the full connection or sub-connection of radio frequency chains (RFC) at the output of the

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digital precoder to the antenna connections at the output of the analog precoder. Detail of fully connected HBF and sub-connected HBF structure is referred to the [2].

Moreover, NOMA scheme involves the superposition of same cluster users' symbols before precoding at the base station and successive interference cancellation at each strong user before detection. Effective NOMA communications can be achieved by exploiting appropriate users grouping termed clustering. Hence, existing literature on HBF-NOMA had proposed several approaches for users' clustering, namely: users' clustering on the basis of weak users' channels correlation to the cluster head channels [3], and user's angle of arrival (AoA) [4]. Motivated by the single cluster HBF-NOMA scenario, where users are not on the same AoA, multiple cluster-based HBF-NOMA exploring users' clustering based on distance is expected to be practical for NOMA communications.

Additionally, HBF precoders can be quantized to further reduce the implementation cost and the power consumed by the analog precoder section of HBF. Therefore, extending our investigation to the finite resolution HBF-NOMA systems deploying the proposed users' clustering is crucial to readers. Therefore, this paper tends to study the user pairing (based on cluster distance) impact on the data rate Performance of HBFNOMA Users, considering both finite, and infinite resolution HBF precoders scenarios.

2.0 METHODOLOGY

For the purpose of benchmarking the proposed users' pairing scheme with that of the existing scheme formulated on the basis of AoA in [4], the system model is configured for multiuser-based multiple input single output (MISO) NOMA, where a base station at the center of an urban microcell downlinking the $M = 2$ (two) users per cluster and the total cluster's number is assumed for $N = 2$ to make the system analysis a simple one. Hence the transmit and receive antennas at the base station and users are set to $N_t = 128$ and $N_r = 1$, respectively. The rest system's configurations are similar to that in [4] with an exception to the users' clustering. Hence, users are clustered as near and far users as visualized in Figure 1. Furthermore, the near cluster contains users having different AoA but are nearer to the base station compared to the far cluster.

Notwithstanding, user $U_{n,m}$ indicates mth user in n cluster, where $m = [1,2]$ and $n = 1$ as well as $n = 2$ represent the near user and far user, respectively. Therefore, $U_{1,1}$ and $U_{1,2}$ denote the first user and second user in the near cluster, respectively, while $U_{2,1}$ and $U_{2,2}$ symbolize the first user and second user in the far cluster, respectively. Whereas Figure 1 of [4] have the cluster formulation on the basis of AoA rather than distance and named $U_{1,1}$ and $U_{1,2}$ as the first (near) user and second (far) user in the (10^o AoA) first cluster, respectively, as well as $U_{2,1}$, and $U_{2,2}$ are named as the first (near) user and second (far) user in the (20^o AoA) second cluster, respectively. Therefore, it can be inferred that the proposed new user pairing adopts the "near" and "far" distance-based clustering approach rather than the "first" and "second" AoA-based clustering approach in [4]. Common to the two clustering approaches to be studied here is that the users in each cluster can be classified into strong and weak users depending on their channel coefficients' magnitude. Usually, in each cluster, a user located at a nearer distance measured from the base station becomes a strong user, while the other one is regarded as a weak user.

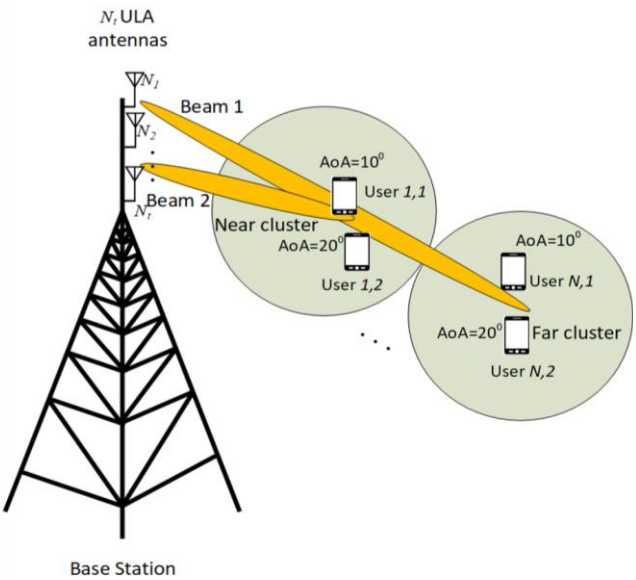


Figure 1: HBF-NOMA System deploying users clustering based on distance

Hence, the proposed user pairing based on the user's distance enables the feasibility of categorizing the user in the near and far clusters as either a strong or weak user. On the other hand, the user pairing based on AoA allows the near and far users in each cluster to be configured for strong and weak users, respectively. In this regard, the weak user in the AoA framework becomes a strong user in the proposed user's distance framework. The base station is equipped with the fully connected structure (FCS) and sub-connected structure (SCS) HBFs configured for MISO-HBF-NOMA framework in [4]. Hence, the hybrid precoding method on the basis of phased zero forcing (P-ZF), and successive interference cancellation zero forcing (SIC-ZF) schemes are adopted to investigate the proposed user pairing approaches and that of AoA methods. Moreover, the dynamic power allocation method proposed in [2] is also adopted to optimize the power allocation coefficient deployed for NOMA scheme. Therefore, details of optimizing the HBF (using P-ZF and SIC-ZF processing) and dynamic power allocation factors are referred to [4] [2].

A. mmWave MISO Channel Modelling

Each MISO user's channel coefficient; a constituent of a multiuser HBF-NOMA channel is based on the NYU mmW channel model [5]. Hence, each user's channel coefficient $h_{(n,m)}$ is modelled as

$$h_{(n,m)} \in \mathbb{C}^{1\times N_t} = \sum_{v=1}^{V} \gamma_{(n,m,v)}{}^{e^{j\Phi_1} e^{-j\Phi_2}} a_t(\emptyset_{(n,m,v)}) \quad (1)$$

Where; Φ_1 and Φ_2 denote $\Phi_{(n,m,v)}$ and $2\pi f\tau_{(n,m,v)}$. respectively, and $\gamma(n,m,v)$, $\Phi(n,m,v)$, f, $\tau(n,m,v)$, and $a_t(.)$ denote amplitude of the channel gain in the vth resolvable multipath component, the phase of the multipath component, carrier frequency, time delay and array steering function depending on the angle of departure (AOD), ϕ, at the Base station (BS), respectively.

NYUSIM software is configured for both LOS and NLOS scenarios adopting the data from Table 1 in [4] to generate DirPDPinfo.mat for the simulation of $h_{(n,m)}$ exploiting NYU channel model. Users nearer to the base station are clustered together as a near cluster and ordered in subside sequence of their channel measured, namely, $|h_{(n,1)}Fd_n| > |h_{(n,2)}Fd_n|$ for two users per cluster, where F and d_n represent analog beamforming matrix and nth cluster users' digital precoding vector, respectively.

B. Performance Metrics

Before transmission, the users' symbols are superimposed to s_n at the BS using a dynamic power optimization scheme in [2], that is

$$s_n = \sum_{m=1}^{2} \sqrt{\alpha_{(n,m)} \times p_n \times s_{(n,m)}} \quad (2)$$

where $\alpha_{(n,m)}$, $s_{(n,m)}$, and p_n represent the power allocation factor, the transmitted symbol of a user $U_{(n,m)}$, and nth cluster power, respectively.

At the strong user, SIC has performed on the other weak user's symbols prior to the detection of its own symbol. Hence, a single-stage SIC processing is performed before the weak user finally detects its own symbols for two users per cluster scenario in this paper. This SIC is achievable on the account of the rate of strong users being higher than that of weak users.

Therefore, attainable rate of the user $U_{(n,m)}$ is prepared as:

$$R_{(n,m)} = \log_2(1 + y_{(n,m)}) \quad (3)$$

and $y_{(n,2)}$ of user $U_{(n,2)}$ for $n = [1,2]$ is prepared as

$$\frac{\zeta_{(n,2)}|h_{(n,2)}Fd_n|^2}{\beta_{(n,2)}^{intra}+\beta_{(n,2)}^{inter}+1} \quad (4)$$

as well as $y_{(n,1)}$ of user $U_{(n,1)}$ for $n = [1,2]$ is prepared as

$$\zeta_{(n,1)}|h_{(n,1)}Fd_n|^2 \quad (5)$$

where; $\zeta_{(n,m)} = \frac{p_n \times \alpha_{(n,m)}}{\sigma_{(n,m)}^2}$ denotes signal to noise(SNR) power for user $U_{(n,m)}$ and $\beta_{(n,2)}^{intra} = \zeta_{(n,1)}|h_{(n,2)}Fd_n|^2$ indicates the intra-cluster intercession at the $U_{(n,2)}$ after SIC refining at the strong user in the nth cluster.

Moreover, inter-cluster interference $\beta_{(n,2)}^{intra}$ represents $\sum_{l\neq n}^{2}\sum_{q=1}^{2}\zeta_{(l,q)}|h_{(n,2)}Fd_l|^2$ at the $U_{(n,2)}$ in the nth cluster. Also, F, d, and $\sigma_{(n,m)}^2$ symbolize analog beamforming matrix, digital beamforming vector, and noise variance of additive white Gaussian noise arising through the user $U_{(n,m)}$ antenna, respectively. Hence, we formulate the sum rate execution of the mmW power-domain NOMA system as

$$R_s = \sum_{n=1}^{N}\sum_{m=1}^{M} R_{n,m} \quad (6)$$

C. Sum-rate Optimization Problem

The optimization problem for HBF-NOMA can be formulated as the escalation of sum rate in (6), subject to its associated constraints in (7), mathematically maximize R_s,

$$\begin{aligned}
&\{F, d_n, \alpha_{(n,m)}\}\\
&\text{Subject to } |F_{(i,j)}|^2 = \mathcal{M}_t^{-1},\\
&\text{Blk.diag.}[f_1, f_2][d_1, d_2]\|^2{}_F = N,\\
&R_{n,m} > 0,\\
&\sum_{n-1}^{2}\sum_{m-1}^{2} p_{(n,m)} \leq P,\\
&p_{n,m} > 0, \qquad (7)
\end{aligned}$$

where M_t is the amount of antenna elements of each sub-assembly at the transmitter and blk. diag. denotes block diagonalization for SCS-HBF scenario, which can be replaced by N_t for the FCS-HBF case.

The problem of (7) has been addressed in literature deploying P-ZF-HBF and SIC-ZF designes for user pairing based on AoA. Hence, user pairing based on distance is proposed in this paper deploying the P-ZF, and SIC-ZF (HBFNOMA) schemes under LOS, and NLOS downlink scenarios.

D. Hybrid Precoder Quantisation Using Modified Liang Procedure

The Analog precoder section of the hybrid precoder has elements differing in analog phases. whereas, the hands-on application of analog precoder is constrained to finite in bit resolution. An adequately quantized phase shifter is capable of consuming lower power on the ground that the power consumed by the phase shifter is commensurate to its bit resolution. In this regard, a hybrid beamformer under the hands-on framework of laboriously quantized phase shifters is investigated. In order to design an energy-efficient precoder. Therefore, the impact of our proposed users pairing based on users' distances on the performance of the FCSHBF-NOMA and SCS-HBF-NOMA deploying either P-ZF or SIC-ZF hybrid precoding scheme is investigated and compared to that of users pairing based on users' AoAs in both LOS and NLOS urban microcell links. Exploiting the Liang quantization algorithm proposed for HBF system in [6] and adopted for HBF-NOMA in [4], analog precoder and digital precoder parts of hybrid beamformer were quantized exploiting Equations (33) to (34) and (35) to (38) from [4], respectfully. Owing to the deployment of SCS-HBF at the base station, which may likely experience strange performance trends for finite resolution SCS-HBF-NOMA communication due to many reasons causing quantization errors, namely i.) users in different AoAs clustered together, ii.) Signal processing scheme deployed for optimization, and iii.) the low signal strength peculiarity of NLOS link.

Therefore, the Liang quantization procedure is modified at Equation (33) of [4] by introducing a mitigating parameter $\mathcal{M}$ to mitigate the quantization errors leading to the elimination of abnormal performance trends. Explicitly, the modified section of Liang finite resolution analog precoder **F** elements' phases using (33) of [4] is modified to

$$\hat{\phi}_m = \sqrt[8]{\mathcal{M}}\,\frac{2\pi\hat{e}}{B} \quad (8)$$

for b-bit resolution, where $B = 2^b$ and $\hat{e}$ is chosen according to

$$\hat{e} = arg \min_{e\in\{0,\ldots B\}} \left|\phi_n(i) - \frac{2\pi e}{B}\right| \quad (9)$$

Notably, $i \in [1,\ldots,N_t]$ and $i \in [1,\ldots,M]$ for FCS and SCS analog precoders, respectively, and $\phi_n(i)$ is the analog phase of the nth vector's (ith) element of F precoder obtained from deploying phased and SIC schemes using (32) and (30) of [4], respectively. Details of the phased scheme for SCS analog precoder are referred to [7]. Hence, the digital precoder can be obtained by exploiting the ZF scheme defined as

$$\mathrm{D} = \overline{\mathrm{H}}_{(n,1)}\left(\overline{\mathrm{H}}_{(n,1)}\overline{\mathrm{H}}_{(n,1)}^{H}\right)^{-1}\bar{\beta} \quad (10)$$

Where β is the modified normalized factor to ensure total power constraint on the digital precoder matrix D $\in \mathrm{C}^{N\times N}$ and the $\sqrt[8]{M}$ is employed to suppress any abnormal performance trend arising from SCS-HBF quantization in an NLOS environment deploying Liang procedure.

The composite hybrid channel comprising various strong users' hybrid channels for $n = [1,\ldots N]$th clusters can be modeled as

$$\underline{H}_{(n,1)} = [\underline{h}_{(1,1)}F_T(\underline{h}_{(2,1)})F_T]_T \quad (11)$$

3.0 RESULTS AND DISCUSSION

Users in two clusters are simulated based on system model configurations. System parameters for both LOS and NLOS links are configured as in [1] and the rest configurations are the same as in Table 1 of [4] to obtain the output files 'DirPDPinfo.mat' and Basic Parameters. mat from the NYUSIM. For readers' convenience, the carrier frequency, RF bandwidth, barometric pressure, humidity, temperature, rain rate, foliage attenuation, and polarization are configured for NYUSIM are presented here as 28 [GHz], 800 [MHz], 1013.25 mbar, 50%, 20^oC, 0 [mm/h], 0.4, and co-polarization, respectively. The two output files are used to simulate the proposed mmW MISO-NOMA systems' channel coefficients. Users in the near and far clusters are ordered on the basis of the users' channel magnitude orders to classify users into either strong users or weak users. Link-level simulations of the proposed HBF-NOMA based on a dynamic power approach in [7] are implemented for $M(= 2)$ users per cluster to benchmark the HBF-NOMA scenario based on the AoA users clustering scheme. Transmit and receive RF chains as well as the number of clusters is preset to 2, 1, and 2, respectively. For LOS and NLOS links, respectively. $d_{n,m}$ is set as shown in Table 1. With the deployment of the deterministic channel model, a single-run simulation is executed owing to the system structure for SNR values varying between $-10[dB]$ to $30[dB]$.

Table 1: NOMA Channel Parameters Exploited for NYUSIM

Parameters	LOS	NLOS
$d_{1.1}$ and $d_{1.2}$	16, 38 [m]	22, 25 [m]
$d_{2.1}$ and $d_{2.2}$	16, 38 [m]	22, 25 [m]
$\Phi_{(n.1)}$ and $\Phi_{(n.2)}$	10^o and 20^0	50^0 and 60^o
$\Phi_{(n.1)}$ and $\Phi_{(n.2)}$	10^o and 20^0	50^0 and 60^o
BS and users' height	35 and 1.65 [m]	35 and 1.65 [m]

Figure 2 manifests the attainable sum rates for various single stream SCS-HBF-NOMA schemes operated in LOS link. Under the P-ZF and dynamic power optimization schemes mentioned earlier, the new user pairing based on the Users' distances exhibits a higher performance than the OMA schemes for both fully connected and sub-connected HBF structures. On the other hand, the user pairing on the basis of users' AOAs manifests better performance than that of the proposed users' pairing based on distance. This result indicates that the user's AoA is crucial to the Phased scheme method of analog precoder's optimization. However, determining the AoA for each user can be computationally complex and prone to mean error in a practical system compared to the distance-based users' pairing approach, which can be easily obtained via the time of arrival localization's method [8] [9] [10], which is beyond the scope of this paper. Hence, a swap between the higher sum-rate execution and computational complexity depends on the mobile applications being run by the users. Furthermore, since the new users' pairing performs better than the OMA scheme, the new users' pairing can still be recommended for NOMA while sacrificing capacity to the complexity.

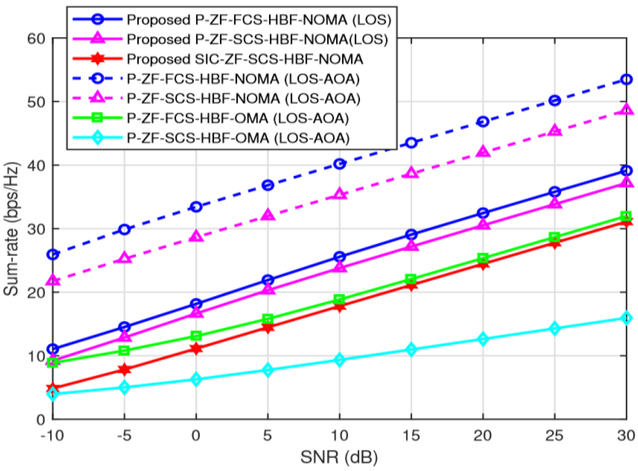
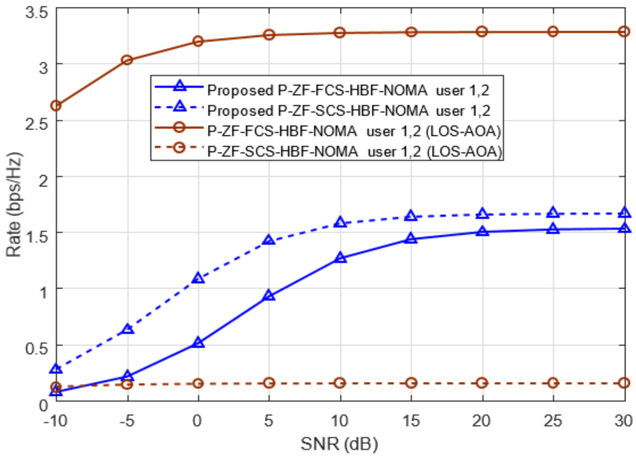
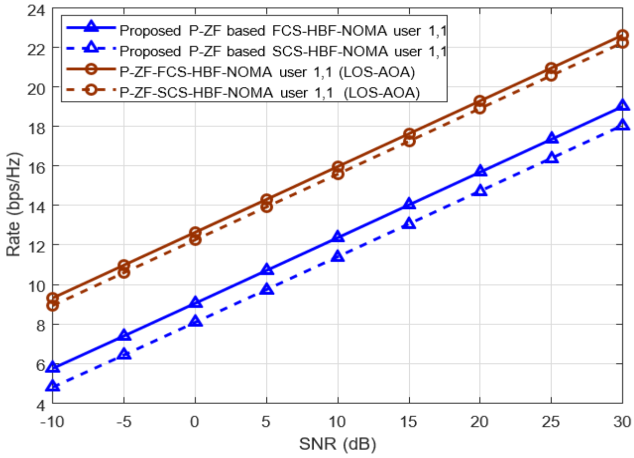


Figure 2: Sum-rate performance of the proposed NOMA scheme on the basis of distance-based user's pairing in LOS link, N_t = 128 and N_r = 1 for N = 2 clusters and M = 2 per cluster.

For the purpose of revealing the inherent benefit of the new users' pairing approach, the data-rate performance for various users deploying the P-ZF scheme for HBF-NOMA communication in LOS link is evaluated, namely, weak and strong users in both near and far clusters in Figures 3 and 4, respectively. Specifically, Figure 3(a) reveals that the data rate of the weak user $U_{(1,2)}$ in the near cluster deploying the FCS-HBF-NOMA and SCS-HBF-NOMA with proposed users pairing in the near cluster manifest better performances than SCS-HBF-NOMA with the AoA based users pairing and performs lower than the FCS-HBF-NOMA with the AoA based users pairing. The inference from Figure 3(a) is that the proposed scheme allows the user $U_{(1,2)}$ to yield high-performance improvement and to be far from the outage as the SNR increases. Furthermore, the proposed user pairing employed for the SCS-HBF-NOMA exhibits a higher performance than in the FCS-HBF-NOMA arising from the wider beams produced by the sub-connected HBF structure that mitigates against the effects of channel misalignment from pairing two users having different AoAs in the same cluster. This can further boost the higher energy efficiency of the SCS-HBF-NOMA system than its FCS-HBFNOMA counterpart. On the other hand, Figure 3(b) reveals that the performance trends of the strong user $U_{(1,1)}$ in the near cluster for FCS-HBFNOMA and SCS-HBF-NOMA communication exploiting the proposed users paring is consistent with that of AoA as the SNR increases but performs lower than that of the AoA counterparts at all SNRs.



(3a) Weak user in near cluster $U_{(1,2)}$

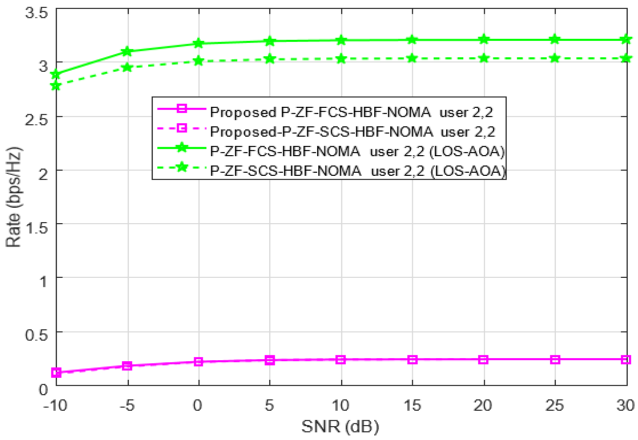


(3b) Strong user in near cluster $U_{(1,1)}$

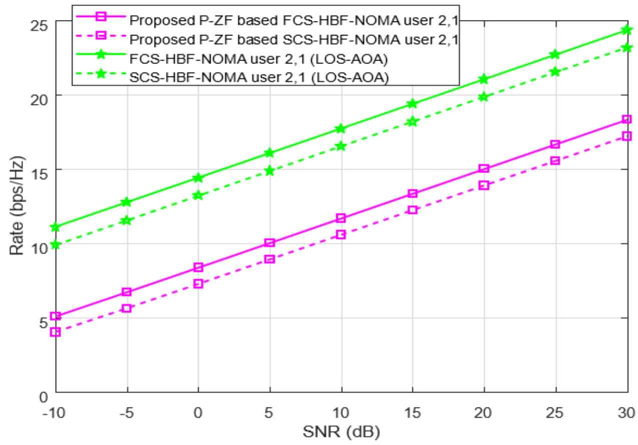
Figure 3: Achievable Data-Rates of the users in the near cluster for the proposed NOMA schemes comparing with those of the user pairing based on

AoA counterparts operated in LOS urban microcell environment.

Figure 4(a) illustrates the data Rates for the weak user $U_{(2,2)}$ in the far cluster for the proposed user's pairing deployed for P-ZF based HBF-NOMA system operated in LOS environment to benchmark with that of PZF based HBF-NOMA system employing user pairing based on AoA. Owing to the weak signal strength at the far cluster, the proposed users clustering approach suffers data rate loss compared to that of the AoA-based users pairing. On the other hand, Figure 4(b) shows that the proposed new users pairing performs lower than its AoA counterpart for strong NOMAuser equipped with fully connected and sub-connected (HBF) structures. For the sake of revealing the impact of the new user pairing on the sum-rate performance of the finite resolution HBF-NOMA system in LOS link, performance simulations are carried out for both (FCS and SCS) HBF structures deploying the P-ZF scheme, and results obtained are presented in Figure 5.



(4a) Weak user in far cluster $U_{(2,2)}$

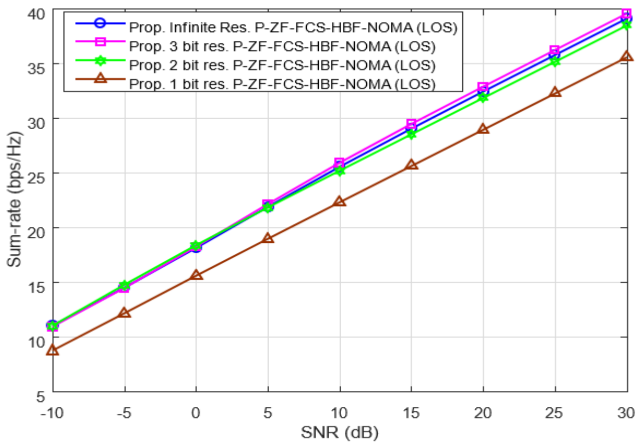


(4b) Strong user in far cluster $U_{(2,1)}$

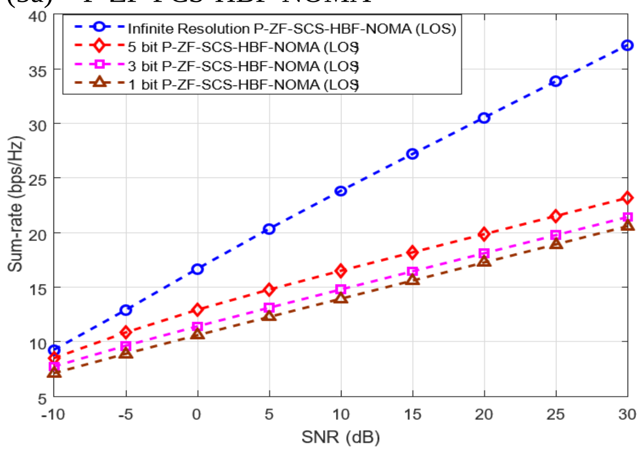
Figure 4: Achievable Data-Rates of the users in the far cluster for the proposed NOMA schemes comparing with those of the user pairing based on AoA counterparts operated in LOS urban microcell environment.

Specifically, Figure 5(a) manifests that the 2-bit resolution of FCS-HBF-NOMA optimized the sum-rate performance to that of the infinite resolution counterpart. Furthermore, extending the quantization bits value to 3 for finite resolution HBF-NOMA results in asymptotic performance to that of the optimal infinite resolution counterpart, which validates 2-bit resolution as the optimal resolution for the Proposed scheme. The lowest performance achievable for the 1-bit quantized FCS-HBF-NOMA arises from the highest quantization error associated with the lowest-bit resolution system.

More specifically, Figure 5(b) reveals that the SCS-HBFNOMA deploying P-ZF scheme and the proposed NOMA users pairing achieves peak performance at 3-bit resolution. This reveals the proposed users' pairing worse impact on the finite resolution SCS-HBF-NOMA deploying Liang quantization algorithm compared to that of users' pairing based on AoA exhibited in Figure 5 of [4].



(5a) P-ZF-FCS-HBF-NOMA

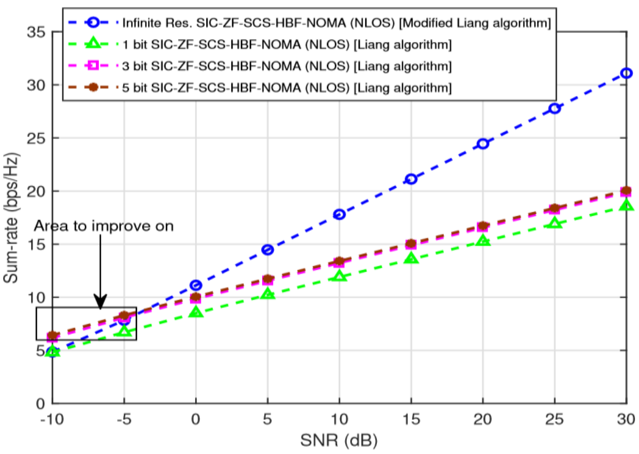


(5b) P-ZF-SCS-HBF-NOMA

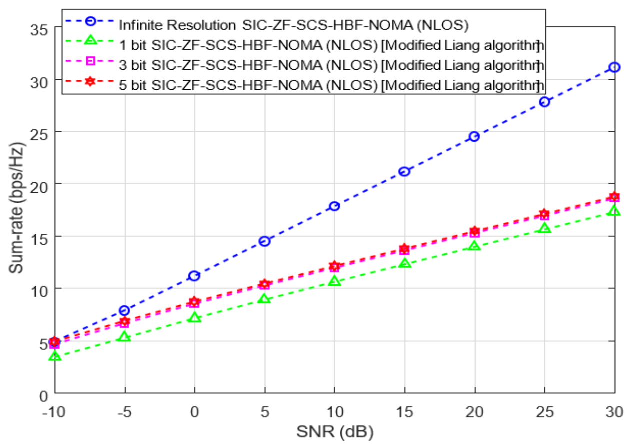
Figure 5: Achievable Sum-rates of the proposed finite resolution HBF-NOMA schemes benchmarking

the infinite resolution NOMA counterpart in LOS urban microcell environment. Notably, 'res.' and 'prop.' on the legend represent 'resolution' and 'proposed', respectively.

Hence a better algorithm that is capable of achieving an asymptotic performance for 2 or 3-bit resolution SCS-HBF-NOMA as that of the FCS counterpart in LOS link is recommended for future work. In order to reveal the frail performance of SCS-HBF-NOMA exploiting the proposed users' pairing is not peculiar to only the P-ZF scheme in LOS link but also to the existing SIC-ZF scheme in NLOS link [4]. Hence, the simulation is performed for the SIC-ZF-based SCS-HBF-NOMA adopted from [4] and the achievable sum-rate in NLOS link is presented in Figure 6. Specifically, Figure 6(a) presents the simulation results for 1-bit to 3-bit resolution of SCS-HBF-NOMA benchmarking that of optimal infinite resolution SCS-HBF-NOMA, whereby the 2-bit and 3-bit resolution optimized the SCS-HBF-NOMA to the peak sum-rate and the wider margin still exist between the finite and infinite resolution SCS-HBF-NOMA as in Figure 5(b).



(6a) Liang Algorithm.



(6b) Modified Liang Algorithm.

Figure 6: Achievable Sum-rates of the proposed finite resolution SIC-ZF based SCS-HBF-NOMA schemes operated in an NLOS urban microcell environment deploying the modified Liang quantization algorithm to address the performance abnormality at the Low SNR region.

More specifically, at the low SNR rages from -10 to -2.5 [dB], the finite resolution SCS-HBF-NOMA exploiting the proposed users' pairing for the SIC-ZF scheme achieves higher Performance than that of the infinite resolution counterpart in NLOS link.

This abnormal performance arose from the quantization error caused by both the nature of the users' (NLOS) environments and the structure of HBF equipped to users and base station, which is contrary to the quantization theory postulating that infinite resolution HBF-NOMA is an optimal system compared to the finite resolution counterpart. Hence, the modified Liang algorithm proposed to avoid this abnormal performance leads to the results in Figure 6(b). Explicitly, it is observed in Figure 6(b) that the postulated modify parameter $\sqrt[8]{M}$ is capable of eliminating the quantization error associated with the achievable sum rate corresponding to -10 to -2.5 [dB] SNRs. Therefore, an efficient quantization algorithm capable of closing the wider gap between the performance of the proposed user pairing deploying either P-ZF or SCS-ZF for finite resolution SCS-HBF-NOMA and the infinite resolution counterpart in both LOS and NLOS links is recommended for future study.

4.0 CONCLUSION

This paper has studied a new user pairing technique for a power domain non-orthogonal multiple access (NOMA) deploying fully connected and sub-connected hybrid beamforming (HBF) structures for a typical urban microcell downlink of line-of-sight (LOS) and non-line-of-sight (NLOS) environments. HBF-NOMA system was configured for two (multiple input single output) users per cluster down-linked to a base station equipped with 128 antennas. Aided by the dynamic power allocation scheme, HBF-NOMA optimization adopted phased zero forcing (P-ZF) for both fully connected structure (FCS) and sub-connected structure (SCS) in LOS link, and successive interference cancellation zero forcing (SIC-ZF) optimization scheme was adopted for the SCSHBF-NOMA in NLOS link. The new users' pairing approach exploited users' distance to the base station, namely:near and far clusters, unique to the benchmark angle of arrival-based users' pairing.

The proposed users' pairing and the precoding schemes' impact were investigated for finite-resolution HBF-NOMA operating in LOS and NLOS environments. Results showed that the users' pairing based on AoA performed better than the newly proposed users' pairing. However, the proposed users' pairing scheme achieved better performance than their corresponding OMA counterparts, which validate its usefulness for multiple access technique and data rate (access) flexibility scenario, where one of the far cluster users need to access the base station for high data rate service and vice versa. Finally, the modified Liang processing scheme for quantizing SCS-HBF-NOMA precoder was revealed to mitigate against the quantization error arising from the NLOS environment and the nature of sub-connected (HBF) structure under a low SNR regime. Therefore, the results can serve as a clear guide during the design stage of a new radio NOMA for post-5G Systems.

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