

Optimization of Downlink Power Allocation in NOMA-OTFS based Cross-Domain Vehicular Networks

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Abstract—Orthogonal time frequency space (OTFS) and non-orthogonal multiple access (NOMA) are pivotal for enhancing the transmission performance of vehicular communications. This paper delves into the downlink power allocation of a NOMA-OTFS system with a frequency domain linear equalizer (FD-LE), where a high-speed user in delay-Doppler domain and multiple low-speed time-frequency domain NOMA users coexist. Considering the fairness of NOMA users, we optimize the minimum rate of the low-speed users, constrained by the quality of service (QoS) of the high-speed user. To address this problem, we propose an iterative power allocation optimization (IP-AO) strategy and obtain an accurate optimal solution based on the auxiliary variables by transforming the original non-convex problem into a convex one. Moreover, we derive a closed-form solution for the optimal power allocation (OPA). Simulation results validate the superiority of our schemes over traditional power allocation methods in maximizing the minimum user rate in the NOMA-OTFS vehicular system.

Keywords— OTFS, NOMA, Power allocation, IP-AO, OPA.

I. INTRODUCTION

In the 5G landscape, vehicle-to-everything (V2X) has elevated the intelligent transportation system (ITS) with optimized data rate and reduced latency [1], paving the way for autonomous driving. In the V2X scenarios, diverse mobile users converge on a unified wireless infrastructure. To meet the stringent communication demands of V2X, many studies intensively focus on refining communication protocols and advanced multi-access techniques [2].

Orthogonal time frequency space (OTFS) as an innovative modulation technique, was specifically designed to improve the reliability and robustness of wireless communications characterized by high mobility and delay spread [3][4]. It operates by mapping input data in the delay-Doppler (DD) domain into a two-dimensional time-frequency (TF) plane. The mapping approach enables OTFS to effectively mitigate the time-varying Doppler effects caused by the high mobility and multipath propagation [5][6]. Meanwhile, massive multiple-input and multiple-output OTFS (MIMO-OTFS)

systems have been studied to achieve high spectral and energy efficiency with low complexity downlink multi-user precoding [7]. Non-orthogonal multiple access (NOMA) is a unique multi-access, enabling concurrent communication of multiple users on the same TF resource [8]. Compared with the traditional orthogonal multiple access (OMA), NOMA employs power-domain multiplexing and facilitates user differentiation on a singular resource block [9]. This capability makes NOMA achieve superior spectral efficiency and system capacity in dense user scenarios like V2X. In [10], a novel NOMA approach was presented for heterogeneous mobile communications by integrating OFDM and OTFS for users in the TF and DD domains. [11] employed the sparse code multiple access (SCMA) for low-mobility users to improve the bit error rate. H. Cheng *et al.* introduced an optimal power allocation strategy to enhance the system throughput with inherent fairness [12]. A power allocation strategy was presented in [13] to maximize the system's energy efficiency. In [14], the beamforming design for the OTFS-NOMA system was explored for significant performance gains, considering the imprecise channel state information. However, current literature inadequately addresses fair rate allocation in NOMA and its integration with OTFS under high-speed scenarios, with prevailing power allocation strategies remaining highly complex.

In this paper, we present a NOMA-OTFS scheme with a high-speed DD domain user and multiple low-speed users in the TF domain. A frequency domain linear equalizer (FD-LE) is employed to resist the inter-symbol interference in the DD plane. We first derive the signal-to-interference-noise ratio (SINR) of different system users and formulate an optimization problem to maximize the minimum bit rate of NOMA users by ensuring the quality of service (QoS) of the high-speed user and the total power for rate fairness among NOMA users. Given the non-convex nature of the original problem, we propose an iterative power allocation optimization (IP-AO) strategy and utilize auxiliary variables to transform it into a convex problem. We further present a closed-form solution for the optimal power allocation (OPA) with lower complexity. With simulation results, we show the superiority of the proposed power allocation strategies over the traditional methods in maximizing the minimum NOMA user rate of the NOMA-OTFS system.

II. SYSTEM MODEL

A. NOMA-OTFS Resource Allocation

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We focus on the downlink of the NOMA-OTFS vehicular communication system in this paper, where a base station (BS) serves a DD domain high-speed user with OTFS modulation and multiple TF domain low-speed users in a manner similar to traditional OFDM as depicted in Fig. 1.

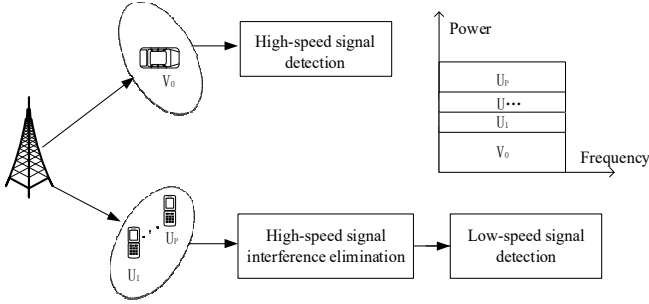


Fig 1. NOMA-OTFS V2X Downlink Model

The presented NOMA-OTFS system can flexibly utilize both the TF and DD domains. Every OTFS frame has a time duration of NT (s) and a bandwidth of $M\Delta f$ (Hz). To ensure symbol orthogonality, T and Δf are chosen to be larger than the maximum delay extension and Doppler shift, respectively. Assuming a single BS communicates with $(P+1)$ users, including the high-speed user V_0 and the low-speed users U_i , $i \in \{1, 2, \dots, P\}$, we can get a NOMA user group. Considering the multipath transmission, the DD domain channel response for each user is represented as

$$h_i(\tau, \nu) = \sum_{t=1}^{P_i} h_{i,t} \delta(\tau - \tau_{i,t}) \delta(\nu - \nu_{i,t}), \quad (1)$$

where P_i denotes the number of multipaths for user i , $i \in \{0, 1, \dots, P\}$. The channel gain, delay, and Doppler shift of the t -th path for user i are denoted by $h_{i,t}$, $\tau_{i,t}$, and $\nu_{i,t}$, respectively. All the channels are independent and identically distributed (i.i.d). For the i -th user, the delay and Doppler taps corresponding to the t -th path are written as $\tau_{i,t} = l_{\tau_{i,t}} / M\Delta f$ and $\nu_{i,t} = k_{\nu_{i,t}} / NT$, respectively. $l_{\tau_{i,t}}$ and $k_{\nu_{i,t}}$ represent the delay and Doppler index of the i -th user's t -th path, respectively.

B. Cross Domain Signal Transmission

The BS transmits MN symbols to V_0 operated in the DD domain and these signals are represented by $x_0^{HS}[k, l]$ with $0 \leq k \leq N-1$ and $0 \leq l \leq M-1$. By inverse symplectic finite Fourier transform (ISFFT), the signal of V_0 in the DD domain can be transformed into a TF domain signal $X_0^{HS}[n, m]$ as

$$X_0^{HS}[n, m] = \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} x_0^{HS}[k, l] e^{j2\pi \left(\frac{km}{M} - \frac{nl}{N} \right)}, \quad (2)$$

where $0 \leq n \leq N-1, 0 \leq m \leq M-1$.

Due to the bandwidth constraints, K ($K \leq M$) out of P low-speed users work take NOMA scheme and the signals of the NOMA users are processed directly on the TF domain. Each NOMA user occupies a sub-bandwidth channel and receives N information-bearing symbols. The TF domain signal for the

i -th NOMA user is denoted as $X_i^L[n, m]$ with the following mapping scheme

$$X_i^L[n, m] = \begin{cases} x_i^L(n) & \text{if } m = i-1 \\ 0 & \text{otherwise} \end{cases}. \quad (3)$$

In NOMA transmission, users share the same spectrum. The received signal for each user in the TF domain is

$$Y_i[n, m] = H_i[n, m] X_a[n, m] + Z_i[n, m], \quad (4)$$

where $X_a[n, m]$ is after multi-user signals superposition and $V_i[n, m]$ is additive Gaussian white noise (AWGN), $H_i[n, m]$ is the channel gain of the i -th user. Here, we use the ideal pulse shaping waveform that satisfies bio-orthogonality [5].

The BS sends the superimposed signal $X_a[n, m]$ after the Heisenberg transformation. After transmission, the TF domain received signal of the i -th user is expressed as

$$Y_i^L[n, m] = \underbrace{\sqrt{\beta_0} H_i[n, m] \left(\sum_{k=0}^{M-1} \sum_{l=0}^{N-1} x_0^{HS}[k, l] e^{j2\pi \left(\frac{km}{M} - \frac{nl}{N} \right)} \right)}_{\text{High speed user interference}} + \underbrace{\sqrt{\beta_i} H_i[n, m] X_i^L[n, m]}_{\text{Effective signal}} + \underbrace{H_i[n, m] \sum_{i'=1, i' \neq i}^K \sqrt{\beta_{i'}} X_{i'}^L[n, m]}_{\text{Interference from other low-speed users}} + \underbrace{Z_i[n, m]}_{\text{noise}}, \quad (5)$$

where β_0, β_i is the power allocation of V_0 and U_i , respectively.

The signal of V_0 has significant intensity in the DD domain, which should be demodulated first, and the NOMA users' signals can be treated as the noise through serial interference cancellation (SIC). The received signal of user V_0 in the DD domain is written as

$$\begin{aligned} y_0^{HS}[k, l] &= \text{SFFT}^{-1} \left(Y_0^{HS}[n, m] \right) \\ &= \frac{1}{NM} \sum_{i=1}^K \sqrt{\beta_i} \sum_{k'=0}^{N-1} \sum_{l'=0}^{M-1} x_i^L[k', l'] h_{w,0} \left(\frac{k-k'}{NT}, \frac{l-l'}{M\Delta f} \right) \\ &\quad + \frac{1}{NM} \sqrt{\beta_0} \sum_{k'=0}^{N-1} \sum_{l'=0}^{M-1} x_0^{HS}[k', l'] h_{w,0} \left(\frac{k-k'}{NT}, \frac{l-l'}{M\Delta f} \right) + z_0[k, l], \end{aligned} \quad (6)$$

where $x_i^L[k', l'], 1 \leq i \leq M$ is the delay-Doppler representation of $X_i^L[n, m]$ after symplectic finite Fourier transform (SFFT). The representation of channel $h_{w,0}(\nu, \tau)$ for V_0 is shown in [5].

The received signal of the high-speed user is expressed as

$$y_0^{HS}[k, l] = \sum_{i=0}^K \sqrt{\beta_i} \sum_{t=0}^{P_i} h_{0,t} x_i \left[(k - k_{0,t})_N, (l - l_{0,t})_M \right] + z_0[k, l], \quad (7)$$

where $(\cdot)_X$ is mod X operation. We define

$$\mathbf{y}_{0,k}^{HS} = [y_0^{HS}[k, 0] \cdots y_0^{HS}[k, M-1]]^T \text{ and } \mathbf{y}_0^{HS} = [\mathbf{y}_{0,0}^{HS} \cdots \mathbf{y}_{0,N-1}^{HS}]^T.$$

Similarly, $\mathbf{x}_i$ and $\mathbf{z}_i$, $0 \leq i \leq K$, are the matrix version of

$x_i[k, l]$ and $z_0[k, l]$. The received signal vector of V_0 is

$$\mathbf{y}_0^{HS} = \sqrt{\beta_0} \mathbf{H}_0^{dd} \mathbf{x}_0^{HS} + \sum_{i=1}^K \sqrt{\beta_i} \mathbf{H}_0^{dd} \mathbf{x}_i^L + \mathbf{z}_0, \quad (8)$$

where $\mathbf{H}_0^{\text{dd}}$ is the channel gain vector expression as

$$\mathbf{H}_0^{\text{dd}} = \begin{bmatrix} \mathbf{G}_{0,0} & \mathbf{G}_{0,N-1} & \cdots & \mathbf{G}_{0,1} \\ \mathbf{G}_{0,1} & \mathbf{G}_{0,0} & \ddots & \mathbf{G}_{0,2} \\ \vdots & \ddots & \ddots & \vdots \\ \mathbf{G}_{0,N-1} & \mathbf{G}_{0,N-2} & \cdots & \mathbf{G}_{0,0} \end{bmatrix}_{MN \times MN}. \quad (9)$$

Then, the FD-LE is taken to mitigate inter-symbol interference. Its implementation includes the following two steps:

Step1: Detect high-speed user's signal and substitute the detection matrix $\mathbf{F}_N \otimes \mathbf{F}_M^H$ to (9) as

$$\hat{\mathbf{y}}_0^{\text{HS}} = \mathbf{E}_0 (\mathbf{F}_N \otimes \mathbf{F}_M^H) \left(\sqrt{\beta_0} \mathbf{x}_0^{\text{HS}} + \sum_{i=1}^K \sqrt{\beta_i} \mathbf{x}_i^L \right) + \tilde{\mathbf{z}}_0, \quad (10)$$

with $\hat{\mathbf{y}}_0^{\text{HS}} = (\mathbf{F}_N \otimes \mathbf{F}_M^H) \mathbf{y}_0^{\text{HS}}$ and $\tilde{\mathbf{z}}_0 = (\mathbf{F}_N \otimes \mathbf{F}_M^H) \mathbf{z}_0$. $\mathbf{E}_0$ is a diagonal matrix which $(kM+l+1)$ -th main diagonal element is

$$E_0^{k,l} = \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} a_{0,n}^{m,1} e^{j2\pi(\frac{lm}{M} - \frac{kn}{N})}, \quad (11)$$

where $a_{0,n}^{m,1}$ is the element of the $(nM+m+1)$ -th row and the first column of $\mathbf{H}_0^{\text{dd}}$.

By multiplying $\hat{\mathbf{y}}_0^{\text{HS}}$ by $(\mathbf{F}_N \otimes \mathbf{F}_M^H)^{-1} \mathbf{E}_0^{-1}$, we can get

$$\hat{\mathbf{y}}_0^{\text{HS}} = \sqrt{\beta_0} \mathbf{x}_0^{\text{HS}} + \sum_{i=1}^K \sqrt{\beta_i} (\mathbf{F}_N \otimes \mathbf{F}_M^H) \hat{\mathbf{x}}_i^L + (\mathbf{F}_N \otimes \mathbf{F}_M^H)^{-1} \mathbf{E}_0^{-1} \tilde{\mathbf{z}}_0, \quad (12)$$

with $\hat{\mathbf{y}}_0^{\text{HS}} = (\mathbf{F}_N \otimes \mathbf{F}_M^H)^{-1} \mathbf{E}_0^{-1} \hat{\mathbf{y}}_0^{\text{HS}}$ and $\hat{\mathbf{x}}_i^L = (\mathbf{F}_N \otimes \mathbf{F}_M^H)^{-1} \mathbf{x}_i^L$. It is assumed that all user signals carry an equal amount of information and the noise power has been normalized. The transmit signal-to-noise ratio (SNR) can be defined as $\varphi = E\left\{x_0^{\text{HS}}[k,l]^2\right\} = E\left\{x_i^L(n)^2\right\}$.

Thus, the SINR of V_0 is calculated as

$$\text{SINR}_{0,kl}^{\text{HS}} = \frac{\beta_0 \varphi}{\varphi \sum_{i=1}^K \beta_i + \frac{1}{MN} \sum_{k=0}^{N-1} \sum_{l=0}^{M-1} |E_0^{k,l}|^2}. \quad (13)$$

Step2: Detect the NOMA users' signals. we first detect the signal of V_0 in the DD domain. After demodulation, the NOMA users' signals are processed in the TF domain.

$$\mathbf{y}_i^L = \sqrt{\beta_0} \mathbf{H}_i^{\text{TF}} \mathbf{x}_0^{\text{HS}} + \underbrace{\sum_{q=1}^K \sqrt{\beta_q} \mathbf{H}_i^{\text{TF}} \mathbf{x}_q^L}_{\text{Interference and noise}} + \mathbf{z}_i, \quad (14)$$

where $\mathbf{H}_i^{\text{TF}}$, $1 \leq i \leq K$, is the TF domain block diagonal channel of U_i and its diagonal block is $\mathbf{G}_{i,0}$.

Assuming that the NOMA users' channels are time-invariant, we can simplify the channel of the i -th user as

$$h_i(\tau) = \sum_{a=0}^{P_i} h_{i,a} \delta(\tau - \tau_{i,a}). \quad (15)$$

Similar to the detection of the high-speed user's signal in Step 1, the signal of NOMA users after adding the detection matrix $\mathbf{F}_M^H$ is [10]

$$\tilde{\mathbf{y}}_i^L = \bar{\mathbf{E}}_i \mathbf{F}_M^H \left(\sqrt{\beta_0} \mathbf{x}_0^{\text{HS}} + \sum_{q=1}^K \sqrt{\beta_q} \mathbf{x}_q^L \right) + \tilde{\mathbf{z}}_i, \quad (16)$$

where $\tilde{\mathbf{y}}_i^L = \mathbf{F}_M^H \mathbf{y}_i^L$, $\tilde{\mathbf{z}}_i = \mathbf{F}_M^H \mathbf{z}_i$, $1 \leq i \leq K$. $\bar{\mathbf{E}}_i$ is the diagonal matrix with dimension $M \times M$, whose $(l+1)$ -th main diagonal element is $\tilde{E}_i^l = \sum_{m=0}^{M-1} b_{i,0}^{m,1} e^{j2\pi \frac{lm}{M}}$ and $b_{i,0}^{m,1}$ is the element at the $(l+1)$ -th row and the first column of $\mathbf{G}_{i,0}$.

Multiply $(\mathbf{F}_M^H)^{-1} \bar{\mathbf{E}}_i^{-1}$ matrix before $\tilde{\mathbf{y}}_i^L$ to obtain the received SINR of the high-speed user at U_i as

$$\text{SINR}_0^i = \frac{\varphi \beta_0}{\varphi \sum_{i=1}^K \beta_i + \frac{1}{M} \sum_{l=0}^{M-1} |\tilde{E}_i^l|^2}. \quad (17)$$

For SIC in the following, the NOMA users must successfully decode the signal of V_0 . We have $\log_2(1 + \text{SINR}_0^i) \geq R_0$, where R_0 is the threshold at V_0 . Then, SIC can be performed by the NOMA users. With the assumption that the signal of V_0 is successfully demodulated and can be removed ideally, the NOMA signal of U_i in the TF domain is obtained as

$$\begin{aligned} Y_i^L[n, m] &= \sum_{q=1}^K \sqrt{\beta_q} H_i[n, m] X_q^L[n, m] + Z_i[n, m], \\ &= \sqrt{\beta_i} H_i[n, m] x_{m+1}^L(n) + Z_i[n, m] \end{aligned} \quad (18)$$

where the final step follows the mapping in (3). Since the signal of U_i is only related to $Y_i^L[n, i-1]$, the SINR of the NOMA user U_i can be detected by a single-tap equalizer as

$$\text{SINR}_i = \varphi \beta_i |\tilde{E}_i^{i-1}|^2. \quad (19)$$

III. NOMA-OTFS SYSTEM POWER ALLOCATION STRATEGY

A. Iterative Power Allocation Optimization Strategy

In the downlink NOMA-OTFS vehicular system, considering the cross-domain transmission, power allocation can be based on three objectives: (1) Ensuring the high-speed user meet its QoS and target rate R_0 ; (2) Guaranteeing the NOMA users can successfully decode the signal of the high-speed user; (3) Ensuring successful signal detection of the NOMA users.

In this subsection, we propose a convex optimization-based hierarchical power allocation strategy to ensure the fairness in NOMA users and maximize minimum data rates. The optimization problem can be formulated as

$$\begin{aligned} \max. \min. \quad & \{\log_2(1 + \text{SINR}_i), \quad i = 1, \dots, K\} \\ \text{s.t.} \quad & \{\log_2(1 + \text{SINR}_0^i) \geq R_0, \quad i = 0, \dots, K\} \\ & \beta_0 + \sum_{i=1}^K \beta_i = P_T \\ & \beta_i \geq 0 \end{aligned} \quad (20)$$

where SINR_0^i denotes the received SINR at U_i from V_0 and $\beta = [\beta_1 \dots \beta_K]$. The objective function in (20) aims to maximize the minimum data rates of $U_i, i=1, \dots, K$. The constraint guarantees the target data rate of V_0 while ensuring that the NOMA users can successfully decode the signal of V_0 with a given total system power limit. Since the optimization problem is non-convex, auxiliary variable is introduced to transfer the original problem into a convex one as

$$\begin{aligned} \max_{\beta, T} \quad & T \\ \text{s.t.} \quad & \left\{ \text{SINR}_0^i \geq R_0, i=1, \dots, K \right\} \\ & T \leq \text{SINR}_i \\ & \beta \geq 0 \\ & \beta_0 + \sum_{i=1}^K \beta_i = P_T \end{aligned} \quad (21)$$

The above optimization problem is equivalent to (20). In order to optimize the power allocation for each NOMA user, we present the IP-AO algorithm in Table I.

TABLE I. IP-AO ALGORITHM

Algorithm 1: IP-AO

- 1: **Input:** $\mathbf{H}_0^{\text{dd}}, \mathbf{H}_i^{\text{TF}}, \varphi$;
- 2: **Initialization:** $R_0 = 0.1 \text{ bps/Hz}$, $P_T = 10 \text{ dB}$, $M = 3$;
- 3: Introduce auxiliary variable T to transform (20) into (21);
- 4: Solve (21) by CVX to obtain β ;
- 5: **return** β and the rate of each NOMA user.

Then, we easily find the maximum value of the minimum rate for all NOMA users through Algorithm 1.

B. Prior Determination based Optimal Power Allocation

The key strategy of this paper is termed as Max-Min power allocation, targeting the maximization of the minimum rate for the NOMA users to enhance the fairness among them. Based on this strategy, the following assumptions can be made:

Assumption 1: For the Max-Min power allocation, we aim to get equal bit rate for all NOMA users.

The validity of Assumption 1 stems from the fairness goal of the Max-Min power allocation approach, and it may achieve a closed-form solution of the optimization problem with the following steps.

Step1: Initialize total power P_T and the channel state information for V_0 and U_i as $\mathbf{H}_0^{\text{dd}}$ and $\mathbf{H}_i^{\text{TF}}, i=1, \dots, K$.

Step2: To calculate the allocated power for the high-speed user while meeting the QoS requirements, the convenience of SIC, and the total power constraints, we can perform the following procedure.

1) To meet the target rate of V_0 and ensure that the SIC can be properly executed, we can get

$$\beta'_0 = \max \left(\frac{R_0 \left(\varphi P_T + \frac{1}{MN} \sum_{k=0}^{N-1} \sum_{l=0}^{M-1} |E_0^{k,l}|^2 \right)}{\varphi(1+R_0)}, \frac{R_0 \left(\varphi P_T + \frac{1}{M} \sum_{l=0}^{M-1} |\tilde{E}_i^{l}|^2 \right)}{\varphi(1+R_0)} \right), \quad (22)$$

where β'_0 is the power allocated to high-speed user V_0 , $E_0^{k,l}$ and $\tilde{E}_i^l$ represent the channel information of V_0 at itself and at the i -th NOMA user U_i .

2) Given the total power constraint and the non-negative power for the NOMA users, the final power allocation for the high-speed user is determined as

$$\beta_0 = \max(P_T, \beta'_0) \quad (23)$$

Step 3: After determining the power for V_0 , the remaining power can be allocated to NOMA users. The allocated power for the i -th user becomes

$$\beta_i = \begin{cases} \max(P_T - \beta_0, 0), & i = 1 \\ \max\left((P_T - \beta_0)F_i / \sum_{i=1}^K F_i, 0\right), & i \geq 2 \end{cases}, \quad (24)$$

with $F_i = \left(\prod_{i=1}^M |\tilde{E}_i^{i-1}|^2 \right) / |\tilde{E}_i^{i-1}|^2$.

Although Assumption 1 provides a simple framework to analyze the optimization problem, the bit rates of all NOMA users may not be exactly the same due to a variety of factors in real vehicular communication, e.g. distance from the user to the BS etc. According to the current analysis, this assumption provides a reasonable starting point and makes a more feasible derivation of the closed-form solution.

IV. NUMERICAL RESULTS

TABLE II. SIMULATION PARAMETERS

Parameters	Values
Subcarrier (M), Time slot (N)	4, 8
Carrier frequency	4 GHz
subcarrier interval (Δf)	10 kHz
Number of NOMA users	3 or 4
Channel estimation	Ideal
Channel model	Rayleigh
Equalization	FD-LE

In this section, Monte Carlo simulation is performed for the proposed power allocation scheme in the NOMA-OTFS vehicular system. The main system parameters are set as Table II. In particular, the delay Doppler indexes of the four multipath channel taps are set to be (0,1,3,5) and (0,1,2,3) for V_0 . The maximum Doppler shift of the channel is 1875 Hz that corresponds to a maximum speed of 140.625 km/h. Different NOMA users exist in the system with maximum transmission delays 12.5 μs , 25 μs , and 37.5 μs . Furthermore, for all user channels, we assume the multipath fading with

$$\sum_{l=0}^P E\{|h_{i,l}|^2\} = 1 \text{ and } |h_{i,l}|^2 \sim \text{CN}\left(0, \frac{1}{P_i}\right).$$

As shown in Fig. 2, both of the proposed power allocation schemes show significant advantages in rate distribution compared with the equal power allocation (EPA) strategy. Both schemes can ensure the rate fairness among NOMA users under different transmit SNRs, while the EPA method leads to obvious rate difference. However, power allocation schemes based on user fairness are realized at the expense of system throughput or efficiency.

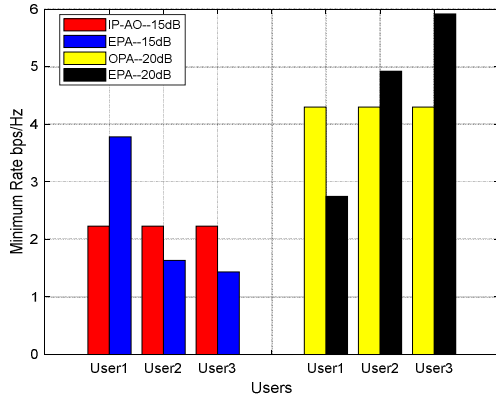


Fig 2. IP-AO and OPA strategy vs. EPA scheme

We compare the NOMA users' minimum bit rates under different power allocation policies and NOMA user numbers in Fig. 3, the proposed IP-AO and OPA outperform both EPA and channel state information-based power allocation (CSI-PA) strategy [9] (the allocated power of each user is proportional to the channel gain). The OPA scheme achieves the maximum system bit rate with minimum complexity. Meanwhile, CSI-PA method exacerbates user unfairness and results in suboptimal performance. Specially, the fixed power allocation yields decreased minimum rates with more users, which is due to the total power constraints.

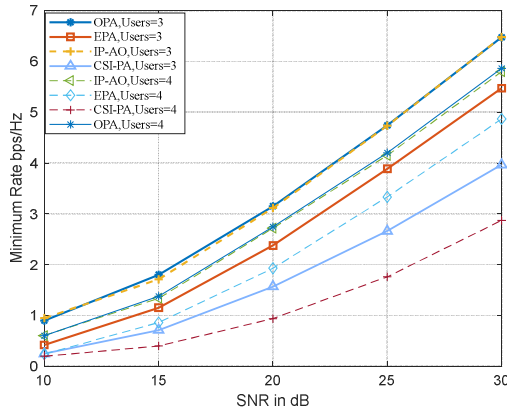
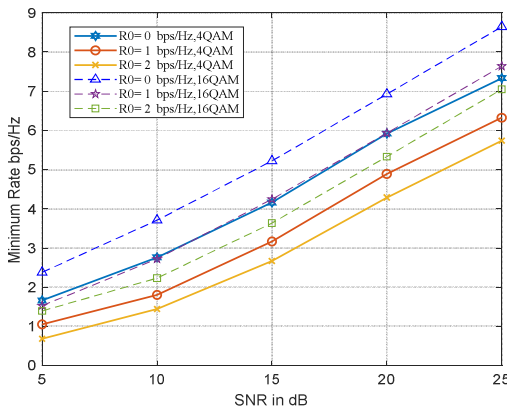
Fig 3. Minimum bit rate of NOMA users with different power allocation schemes and user numbers with 4QAM and $R_0=1$ bps/Hz.Fig 4. Minimum bit rate of NOMA users with different modulation schemes and R_0 .

Fig. 4 depicts the minimum bit rates of NOMA users for OPA policy with different modulation modes and QoS

constraints of V_0 considering three NOMA users, we use the appropriate channel coding scheme respectively. It is seen that the case of 16QAM outperforms the case of 4QAM since it transmits more bits per symbol. As the QoS constraints of V_0 intensify (continuously increasing with R_0), the minimum rate for NOMA users diminishes due to increased power allocation for QoS of V_0 . In the low SNR regions, this depletes the power of the NOMA users, which further impacts the accuracy and performance of SIC. When without rate constraints for V_0 , the high-speed user will not influence power allocation, the NOMA users' rates peaked.

V. CONCLUSION

In this paper, we explore the power allocation in the downlink NOMA-OTFS vehicular communication system and propose two strategies, IP-AO and OPA, to ensure the transmission fairness of NOMA users and guarantee the QoS of high-speed user. Both of the two power allocation strategies are validated through simulation compared with the traditional power allocation strategies, which shows the advantages in the minimum bit rate of NOMA users. The OPA scheme takes both the optimal performance and low complexity into account. Our future work can focus on the impact of fractional Doppler channel conditions on the performance of the NOMA-OTFS system.

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