Toward Opportunistic Semantic and Bit Communications: A NOMA Enabled Approach

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***Abstract*—In this paper, we address the challenge of enhancing communication efficiency in non-orthogonal multiple access (NOMA) networks by exploring a novel paradigm known as opportunistic semantic and bit communication (OSBC). Our goal is to maximize the ergodic semantic rate while ensuring robust communication under variable channel conditions. Firstly, we propose an adaptive communication strategy that integrates semantic and bit level communications for two NOMA users, tailored to the fading characteristics of each channel state. Next, we introduce a resource allocation scheme that optimizes resource usage by adjusting communication paradigm and transmission power according to the channel conditions, thereby ensuring a minimum guaranteed rate for the near user (N-user) while maximizing the rate for the far user (F-user). Finally, we validate the effectiveness of our proposed scheme through extensive simulations. The results indicate that our approach significantly outperforms existing methods, such as orthogonal multiple access (OMA) strategies, in terms of reducing the overall communication resources and improving the ergodic semantic rate under diverse communication scenarios.**

***Index Terms*—Non-orthogonal multiple access, opportunistic semantic and bit communication, rate region, resource management.**

I. Introduction

Semantic communication (SemCom) can extract the meaning of data, thereby achieving more powerful data compression capabilities, and is expected to play a crucial role in the next generation of wireless communications [1]. Specifically, compared with bit communication (BitCom), SemCom uses deep learning (DL) technology to process data. This approach allows all participants to transmit only the most relevant information to the receivers or according to the communication task's objective, thereby reducing the network load.

In [2], the authors proposed an efficient DL enabled semantic communication system (DeepSC) for text data, which can effectively pick up semantic information and be greatly robust for noise. Based on DeepSC, the authors of [3] studied a novel semantic resource allocation model for text transmission. [4] studied a image transmission semantic communication system, achieving tremendous image compression capability. Moreover, [5] proposed a downlink resource allocation method for image semantic communication. In addition, for multi-tasking semantic communication, [6] proposed a quality-of-experience (QoE) aware resource allocation for two types of intelligent missions. Despite SemCom advances expeditiously and performs excellently, when the accuracy of communication is required to be high, BitCom with its extremely high similarity is still irreplaceable [7]. On the other hand, some existing studies, e.g. [2], [4] show that SemCom is potential only in low or moderate signal-to-noise ratio (SNR) regimes. Therefore, BitCom and SemCom are supposed to cooperate so that each one utilizes their respective strengths. [8] developed a novel multiple access (MA) scheme for semantic and bit users which outperforms the conventinoal orthogonal multiple access (OMA) and non-orthogonal multiple access (NOMA) schemes. [7] proposed a multi-carrier hybrid SemCom and BitCom scheme. [9] studied a resource allocation scheme for heterogeneous semantic and bit communication systems. These studies underscore the necessity of integrating SemCom and BitCom in order to achieve superior performance.

As a perspective MA technology, NOMA flexibly manages multiple users on the same resource block, using successive interference cancelation (SIC) to handle interference between users [10]. Recently, NOMA has been introduced into SemCom system for achieving outstanding performance. [11] explored the interaction between NOMA and semantic communication in theory where opportunistic SemCom and BitCom communication (OSBC) was proposed for the first time to provide services to the distant user. [12] proposed a NOMA enabled SemCom system for multiple users which achieves high transmission rate and efficiency. [13] designed a uplink NOMA SemCom system and achieved reliable signal transmission. Note that existing works about NOMA enabled SemCom has advanced significantly in both theoretical analysis and practical implementation, while most of them often neglecting the aspects related to BitCom.

Motivated by the above observations, we leverage effective semantic rate proposed in [11] as the performance metrics and design a novel downlink NOMA enabled OSBC system, where an access point (AP) simultaneously is authorized to select the communication paradigm and transmission power for each one according to users' channel state information (CSI). The AP can send semantic and bit streams to the far user (F-user) and the near user (N-user) over fading channels. We focus on the communication paradigm selection and power allocation to maximize the F-user's ergodic semantic rate, subject to the minimum ergodic semantic rate at the N-user. Note that the problem satisfies the time sharing condition, we drive the optimal solution by the Lagrangian dual method. Simulation results demonstrate that the proposed scheme can effectively utilize the advantages of SemCom and BitCom under different conditions.

II. System Model and Problem Formulation

In the framework under consideration, as shown in Fig. 1, we proposed a semantic and bit collaborative communication framework based on downlink NOMA, where a single-antenna AP sends semantic or bit stream to two single-antenna users. We assume that the CSI of all users at the AP can be perfectly obtained. The channel is modeled as quasi-static fading channel, with the state staying fixed within a block. The AP selects the communication method based on fading channel, considering power limitations.

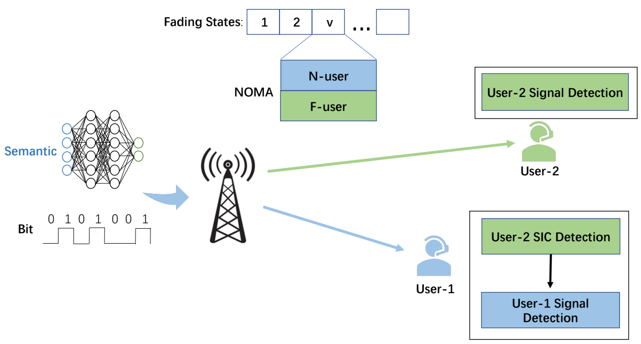


Fig. 1: Architecture of the proposed NOMA enabled OSBC system.

A. Signal Model

In our framework, we have two users served by a AP, which can choose the optimal communication paradigm in the event of channel changes, while simultaneously reusing the same channel block time. Let $x_n(v)$ and $x_f(v)$ denote the information symbol after semantic or bit encoder during any fading state. Therefore, the transmission signal at the AP can be represented as

$$x(v) = \sqrt{P_n(v)}x_n(v) + \sqrt{P_f(v)}x_f(v). \tag{1}$$

where $P_n(v) \geq 0$ and $P_f(v) \geq 0$ denote the power allocated by the AP to N-user and F-user. Let $h_n(v)$ and $h_f(v)$ respectively represent the channel coefficients of N-user and F-user. Then the received signal at the N-user is given by

$$y_n(v) = h_n(v)x(v) + q(v). \tag{2}$$

where $q(v)$ denotes the additive white Gaussian noise (AWGN) at the N-user with mean zero and variance σ^2. The received signal of F-user can be similarly obtained.

When a user receives a mixed signal, the decoding strategy varies based on channel gain. For strong channels, the receiver demodulates the high-power signal first, removes it, and then decodes the rest. For weak channels, the receiver treats the other signal as interference and decodes the intended signal directly. [10]. Therefore, the SNR received by the high channel gain user is given by

$$\gamma_1(v) = \frac{P_1(v)\left|h_1(v)\right|^2}{\sigma^2}, \tag{3}$$

where $P_1(v)$ and $h_1(v)$ denotes the high channel gain user's power and channel coefficient. Then, the SNR for the low channel gain user is given by

$$\gamma_2(v) = \frac{P_2(v)\left|h_2(v)\right|^2}{P_1(v)\left|h_2(v)\right|^2 + \sigma^2}. \tag{4}$$

where $P_2(v)$ and $h_2(v)$ denotes the other user's power and channel coefficient.

B. Semantic Rate and Equivalent Conversion

Based on the classical SemCom system DeepSC, [3] proposes semantic rate (suts/s/Hz), a new indicator to measure the SemCom. Semantic rate represents the semantic information transmitted per second within a unit bandwidth, which is given by

$$S(v) = \frac{\mu(v)I}{KL}\xi(K, \gamma(v)). \tag{5}$$

where I denotes the expected amount of semantic information per sentence, and L denotes the expected number of words per sentence, K represents the average number of semantic symbols mapped by each word. $\mu(v)$ denotes the time portion allocated to user during a unit channel block time, i.e. T = 1. Specifically, $\xi(K, \gamma(v))$ denotes the semantic similarity function run by DeepSC. $0 \leq \xi \leq 1$,where $\xi = 1$ denotes two sentences have excellent semantic similarity and $\xi = 0$ shows that there is no similarity between the two sentences. As for semantic similarity, [8] used the logistic regression function to approximate it, which is given by

$$\xi_K(\gamma(v)) = A_{K,1} + \frac{A_{K,2} - A_{K,1}}{1 + e^{-(C_{K,1}\gamma(v) + C_{K,2})}}. \tag{6}$$

where $A_{K,1} > 0$ and $A_{K,2} > 0$ denote the left asymptote and the right asymptote, $C_{K,1} > 0$ denotes the logistic growth rate, $C_{K,2} > 0$ controls the logistic mid-point. Through this fitting function, we can convert semantic similarity from discrete to continuous to measure semantic rate.

To measure communication rate under the same metric, [3] proposed a fair transform method between SemCom and BitCom:

$$S^b(v) = R_B(v)\frac{I}{\delta L}\xi_c(v). \tag{7}$$

where $R_B(v) = \mu(v)log_2(1 + \gamma(v))$, it denotes the BitCom rate, δ denotes the expected number of bits per word, representing the ability of source encoding. Note that the coding capability of BitCom is limited, so in practice $\delta \gg K$. Compared to SemCom, BitCom exhibits a higher degree of semantic similarity, so we assume $\xi_c(v) = 1$ to represent an extremely high level of precision.

In our model, we adopt the effective semantic rate [11] to measure system rate:

$$S^s(v) = \frac{\mu(v)I}{KL}\xi_K(\gamma_n(v))\Gamma(\xi_K(v) \geq \widetilde{\xi}). \tag{8}$$

where

$$\Gamma(\xi_K(v) \geq \widetilde{\xi}) = \begin{cases} 1, & \xi_K(v) \geq \widetilde{\xi} \\ 0. & otherwise \end{cases}. \tag{9}$$

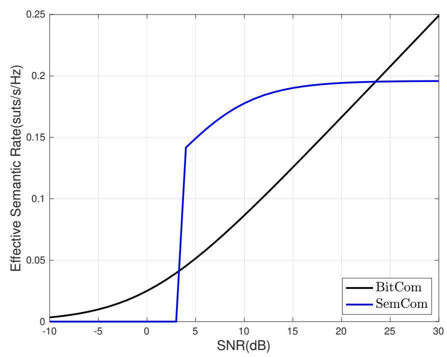


Fig. 2: The effective semantic rate ($\widetilde{\xi}=0.7$) versus the SNR.

in which $\widetilde{\xi}$ denotes represents the minimum semantic similarity implemented in this system, ensuring high communication quality during communication. As shown in Fig. 2, based on this conversion rule and the effective semantic rate, it is observed that SemCom outperforms BitCom in moderate SNR scenarios, while BitCom excels in high or low SNR scenarios. Therefore, selecting the right communication paradigm under varying fading conditions is crucial for optimal performance.

Based on the above research, we can easily determine the OSBC system rate in each fading state:

$$S^o(v)=\chi(v)S^s(v)+(1-\chi(v))S^b(v). \tag{10}$$

where $\chi(v)$ is a binary variable, whose value is 1 when SemCom is adopted; and 0 denotes that BitCom is adopted. Let $\alpha(v)$ and $\beta(v)$ indicate the N-user's and the F-user's communication paradigm.

C. Problem Formulation

We aim to find the rate region for two users with limited resources. And we must balance one user's rate while maximizing the other's, considering communication paradigms and power allocation.

1) Proposed NOMA enabled Scheme:

In the discussed scenario, our goal is to maximize the ergodic semantic rate for the F-user while simultaneously maintaining a minimum ergodic semantic rate for the N-user. Hence, The optimization problem for the proposed NOMA enabled OSBC system is formulated as

$$\max_{\alpha(v),\beta(v),P_n(v),P_f(v)} E_v\left[S_f^o(v)\right] \tag{11}$$

$$s.t.\ E_v\left[S_n^o(v)\right]\geq \overline{S}_n, \tag{11a}$$

$$P_n(v)+P_f(v)=P_t,\forall v, \tag{11b}$$

$$P_n(v)\geq 0, P_f(v)\geq 0,\forall v, \tag{11c}$$

$$\begin{cases} P_n(v)<P_f(v), if\ \ h_n(v)>h_f(v) \\ P_n(v)>P_f(v), if\ \ h_n(v)<h_f(v)\end{cases},\forall v, \tag{11d}$$

$$\alpha(v),\beta(v)\in\{0,1\},\forall v. \tag{11e}$$

where (11a) indicates the N-user's ergodic semantic rate, (11b) and (11c) denote the power allocation condition, where P_t denotes the total power during a fading state. (11d) is the constraint to ensure the fairness of power allocation when the users' channel condition changes, and (11e) represents the communication selection for users.

2) Comparative OMA enabled Scheme:

For comparison, we propose the OMA enabled scheme for the system, and the optimization problem can be formulated as

$$\max_{\alpha(v),\beta(v),P_n(v),P_f(v),\mu(v)} E_v\left\{(1-\mu(v))\left[S_f^{o'}(v)\right]\right\} \tag{12}$$

$$s.t.\ E_v\left[\mu(v)S_n^{o'}(v)\right]\geq \overline{S}_n, \tag{12a}$$

$$(11b),\ (11c),\ (11e), \tag{12b}$$

$$0\leq\mu(v)\leq 1,\forall v. \tag{12c}$$

where $S^{o'}(v)=\chi(v)S^{s'}(v)+(1-\chi(v))S^{b'}(v)$. Note that different from $S^s(v)$ and $S^b(v)$, here we have $S^{s'}(v)=\frac{I}{KL}\xi_K(\gamma(v))\Gamma(\xi_K(v)\geq\widetilde{\xi})$ and $S^{b'}(v)=log_2(1+\gamma(v))\frac{I}{\delta L}\xi_c$ to separate OMA and NOMA's time portion during a fading state. (12c) represents the optimal slot allocation, the two users adopt orthogonal time slots to transmit data. Meanwhile, we can easily identify $\mu(v)$ remains consistently set to 1 in NOMA enabled scheme.

III. Problem Solution

In this section, the strong duality of the problem is proved, and the optimal communication paradigm of each user in different fading states is obtained by solving its dual problem.

A. Strong Duality's Proof

The authors of [14] first proposed the "time sharing" condition for multi carrier resource optimization. When the optimization problem satisfies this condition, the dual gap becomes zero, indicating the fulfillment of strong duality [15]. Inspired by [11], we get the following lemma and proof.

Lemma 1. *Let* $\left\{\alpha_x(v),\beta_x(v),P_n^x(v),P_f^x(v)\right\}$ *and* $\left\{\alpha_y(v),\beta_y(v),P_n^y(v),P_f^y(v)\right\}$ *denote the optimal solution under the constraint of* $(\overline{S}_n^x,\overline{P}_t^x)$ *and* $(\overline{S}_n^y,\overline{P}_t^y)$*. Then, given any* $0\leq\nu\leq 1$, $(\overline{S}_n^x,\overline{P}_t^x)$ *and* $(\overline{S}_n^y,\overline{P}_t^y)$*, an achievable solution* $\left\{\alpha_z(v),\beta_z(v),P_n^z(v),P_f^z(v)\right\}$ *always exists, such that*

$$E_v\left[S_f^z(v)\right]\geq\nu E_v\left[S_f^x(v)\right]+(1-\nu)E_v\left[S_f^y(v)\right],$$

$$E_v\left[S_n^z(v)\right]\geq\nu\overline{S}_n^x+(1-\nu)\overline{S}_n^y.$$

Proof. Please see Appendix A. □

It purports that the proposed problems satisfy the "time sharing" condition and the proof is completed.

TABLE I: list of symbols and basic notations

Notation List			
Transmission signal at the AP	$x(v)$	Received signal at the user	$y(v)$
User's received SNR	$\gamma(v)$	Semantic rate	$S(v)$
Time slots occupied by communication	$\mu(v)$	Expected amount of semantic information per sentence	I
Expected number of words per sentence	L	Expected number of words per sentence	K
Semantic similarity function	$\xi(K,\gamma(v))$	Logistic regression function parameters	$A_{k,1},A_{k,2},C_{k,1},C_{k,2}$
BitCom rate	$R_B(v)$	Expected number of bits per word	δ
BitCom similarity	$\xi_c(v)$	Effective semantic rate	$S^s(v)$
Minimum semantic similarity	$\widetilde{\xi}$	Communication method selection for two users	$\chi(v),\alpha(v),\beta(v)$
Power allocation of N-user and F-user	$P_n(v),P_f(v)$	Channel gain of N-user and F-user	$h_n(v),h_f(v)$
System rate	$S^o(v)$	N-user's minimum ergodic semantic rate	$\overline{S}_n$

B. Optimal Solution for NOMA enabled Scheme

In the NOMA enabled scheme, we can solve the problem by adopting Lagrangian dual method, the Lagrangian can be given by

$$\begin{aligned} &L_1(\alpha(v),\beta(v),P_n(v),P_f(v),\lambda)= \\ &E_v\left[S_f^o(v)\right]+\lambda\left\{E_v\left[S_n^o(v)\right]-\overline{S}_n\right\}, \end{aligned} \tag{13}$$

where λ is the Lagrange multiplier for the N-user's rate constraint (11a), then the Lagrange dual function is formulated as

$$\begin{aligned} &g_1(\lambda)= \\ &\max_{11(b),11(c),11(d)\,and\,11(e)} L_1(\alpha(v),\beta(v),P_n(v),P_f(v),\lambda), \end{aligned} \tag{14}$$

then the dual problem of (11) is expressed as

$$\min_{\lambda\geq 0} g_1(\lambda). \tag{15}$$

In recognizing a recurring structural pattern within each fading state, our focus narrows to the examination of individual fading states. When giving parameter λ, the Lagrange dual function is given by

$$\max_{11(b),11(c),11(d)\,and\,11(e)} \overline{L}_1(\alpha,\beta,P_n,P_f), \tag{16}$$

where $\overline{L}_1(\alpha,\beta,P_n,P_f)=\beta S_f^s+(1-\beta)S_f^b+\lambda[\alpha S_n^s+(1-\alpha)S_n^b]$, to solve the problem (16), we can first solve the optimal α and β, and then solve the power allocation problem. The problem can be rewritten as

$$\overline{L}_1(\alpha^*,\beta^*,P_n^*,P_f^*)=\max_{11(b),11(c)\,and\,11(d)}\left\{\max_{\alpha,\beta\in\{0,1\}}\Psi(\alpha,\beta)\right\}, \tag{17}$$

Note that there are four combinations of values for α and β, so we have

$$\Psi_1(0,0)=log_2(1+\gamma_f(v))\frac{I}{\delta L}\xi_c+\lambda log_2(1+\gamma_n(v))\frac{I}{\delta L}, \tag{18}$$

$$\begin{aligned} &\Psi_2(1,0)= \\ &\frac{I}{KL}\xi(K,\gamma_f(v))\Gamma(\xi_K(v)\geq\widetilde{\xi})+\lambda log_2(1+\gamma_n(v))\frac{I}{\delta L}, \end{aligned} \tag{19}$$

$$\begin{aligned} &\Psi_3(0,1)= \\ &log_2(1+\gamma_f(v))\frac{I}{\delta L}\xi_c+\lambda\frac{I}{KL}\xi(K,\gamma_n(v))\Gamma(\xi_K(v)\geq\widetilde{\xi}), \end{aligned} \tag{20}$$

$$\begin{aligned} \Psi_4(1,1)=&\frac{I}{KL}\xi(K,\gamma_f(v))\Gamma(\xi_K(v)\geq\widetilde{\xi}) \\ &+\lambda\frac{I}{KL}\xi(K,\gamma_n(v))\Gamma(\xi_K(v)\geq\widetilde{\xi}), \end{aligned} \tag{21}$$

Then given P_n,P_f,we can determine the optimal α^* and β^* by

$$(\alpha^*,\beta^*)=\begin{cases}(0,0) & max(\Psi_i)=\Psi_1,\\ (1,0) & max(\Psi_i)=\Psi_2,\\ (0,1) & max(\Psi_i)=\Psi_3,\\ (1,1) & max(\Psi_i)=\Psi_4.\end{cases} \tag{22}$$

Then we have

$$\overline{L}_1(\alpha^*,\beta^*,P_n,P_f)=\max_{11(b),11(c)\,and\,11(d)}\Psi(\alpha^*,\beta^*,P_n,P_f). \tag{23}$$

problem (23) can be solved by exhaustively searching over $P_n+P_f=P_t$ and the constraint 11(c) and 11(d). Based on the above derivation, we can effectively solve problem (11) through an iterative process. Our strategy involves solving its dual problem (15). For a fixed λ, we can get the optimal solution for every fading state by (22) and (23), as for the λ, We employ the bisection method for updates until the ergodic semantic rate constraint (11a) is precisely satisfied. The details of the procedures for optimally solving problem (11) are summarized in Algorithm 1. Let V denote the number of fading state channel, Q represent the number of power iterations, and T is the number of iterations required for strict satisfaction of the constraint (11a) to be achieved. Therefore, the total computational complexity of the solving problem (11) is $\mathcal{O}(VQT)$.

C. Optimal Solution for OMA enabled Scheme

For the OMA enabled scheme, we can employ the Lagrangian dual method for resolution, and the solution procedure closely parallels the previous discussion. The disparity can be outlined as follows. We can alternatively formulate its dual problem's subproblem by

$$\max_{11(b),11(c)\,and\,11(e)} \overline{L}_2(\alpha,\beta,P_n,P_f,\mu) \tag{24}$$

Algorithm 1 The Optimal Algorithm to problem (11)

Set $\lambda_u = K$, $\lambda_l = 0$ as the upper bound and lower bound, where K is a significantly large value that can be adjusted.
while $\lambda_u - \lambda_l > 1$ **do**
    $\lambda = \lfloor(\lambda_l + \lambda_u)/2\rfloor$.
    Calculate $E_v\left[S_n^o(v)\right]_\lambda^*$ by solving problem (15) with λ and given $\overline{S}_n$.
    if $E_v\left[S_n^o(v)\right]_\lambda^* > \overline{S}_n$ **then**
        $\lambda_u = \lambda$.
    else if $E_v\left[S_n^o(v)\right]_\lambda^* < \overline{S}_n$ **then**
        $\lambda_l = \lambda$.
    else
        return λ.
    end if
end while

where $\overline{L}_2(\alpha, \beta, P_n, P_f, \mu) = (1-\mu)\left[\beta S_f^{s'} + (1-\beta)S_f^{b'}\right] + \lambda\mu\left[\alpha S_n^{s'} + (1-\alpha)S_n^{b'}\right]$. Then the problem can be formulated as

$$\overline{L}_2(\alpha^*, \beta^*, P_n^*, P_f^*, \mu^*) = \max_{0\leq P_n \leq P_{total}} \left\{ \max_{0\leq\mu\leq 1} \mu \left\{ \max_{\alpha,\beta\in\{0,1\}} \Psi(\alpha, \beta) \right\} \right\} \tag{25}$$

The Lagrange multiplier of OMA scheme is also updated using the binary method. During a fading state, for α^* and β^*, we can adopt similar method in (22), as for μ^* and power allocation, the two dimensional search is employed under the constraint (11b), (11c) and (12c). Let V denote the number of fading state channel, D denote the number of time portion iterations, Q represent the number of power iterations, and T is the number of iterations required for strict satisfaction of the constraint (12a) to be achieved. The computational complexity of the solving problem (12) is $\mathcal{O}(VDQT)$.

IV. Numerical Results

In this section, numerical results are presented to substantiate the performance of the proposed OSBC system. The large scale path loss is modeled as $\varrho = \varrho_0(M)^{-\phi}$, where $\varrho_0 = -30$ dB represents the path loss at 1 meter, M denotes the transmission distance in meters, $\phi = 4$ denotes the path loss exponent, we assume that the small scale fading of the communication link at each fading state is independently and identically modeled as Rayleigh fading, which is generated as independent circularly symmetric complex Gaussian random variable with zero mean and unit variance. The noise power is configured as $\sigma^2 = -80$ dBm. For SemCom, we set $\widetilde{\xi} = 0.9$ to ensure a high user experience. By using the data in [11], we have $A_{K,1} = 0.37$, $A_{K,2} = 0.98$, $C_{K,1} = 0.2525$, $C_{K,2} = -0.7895$ when $K = 5$; As for BitCom, we set $\delta = 40$ to representing the ability of source coding. And we set $M_n = 20$ meters and $M_f = 30$ meters to denote the distance from N-user and F-user to the AP.

1) Performance of Proposed Scheme: In Fig. 3, we formulate the variation of ergodic semantic of F-user $E_v[S_f^o(v)]$ with minimum ergodic semantic rate of N-user $\overline{S}_n$. The solid line and dash-dot line denote the total power $P_t = 10$ W and $P_t = 5$ W during a fading state. We can obtain that SemCom and BitCom have distinct advantages. Combining them yields optimal performance. However, under increased power, BitCom outperforms SemCom due to its simplicity and lower cost. In Fig. 4, we give the proportion of time for NOMA users when $\overline{S}_n = 0.15$ suts/s/Hz under different total power, we can certificate that SemCom still dominates communication due to its efficient compression capability. When power is insufficient, the proportion of SemCom increases. Furthermore, owing to the overall superior channel conditions for N-user in comparison to F-user, the percentage of BitCom is higher for N-user.

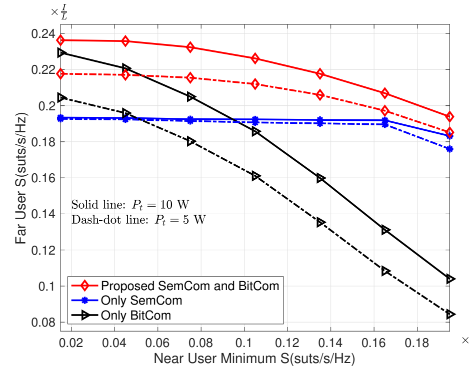


Fig. 3: The ergodic semantic rate of F-user versus $\overline{S}_n$.

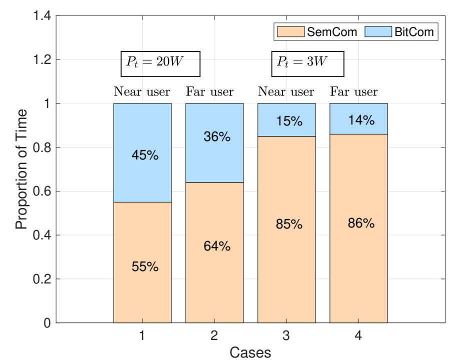
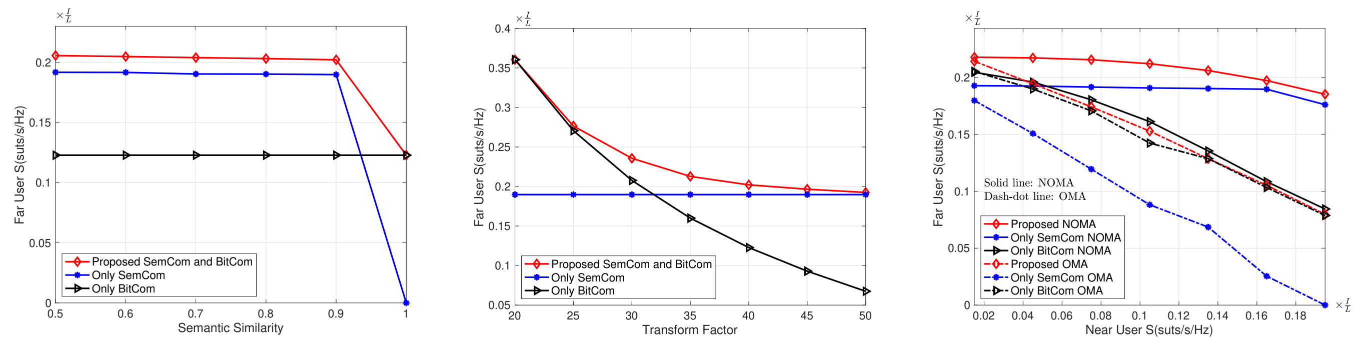


Fig. 4: Proportion of time for proposed NOMA enabled OSBC system for $\overline{S}_n = 0.15$ suts/s/Hz.

2) Impact of SemCom's $\widetilde{\xi}$ and BitCom's Transforming Factor δ: In Fig. 5(a), we set $P_t = 5$ W, $\overline{S}_n = 0.15$ suts/s/Hz to exploit SemCom and BitCom's performance. We can certificate that though SemCom offers numerous advantages over BitCom, BitCom is still irreplaceable when the accuracy of the communication system is high. In Fig. 5(b), we can obtain that enhancing the encoding capability of BitCom through reducing δ will improve its performance. In the two graphs presented, it is evident that the proposed scheme consistently maintains optimal performance.



(a) The ergodic semantic rate of F-user versus ξ for $P_t = 5$ W, $\overline{S}_n = 0.15$ suts/s/Hz.

(b) The ergodic semantic rate of F-user versus δ for $P_t = 5$ W, $\overline{S}_n = 0.15$ suts/s/Hz.

(c) The comparison between OMA and NOMA enabled scheme.

Fig. 5: The comparison of OSBC system in different scenarios.

3) The Comparison Between OMA and NOMA enabled Scheme: In Fig. 5(c), We provide rate curves for multiple communication schemes between two users at $P_t = 5$ W. It can be inferred that the proposed scheme achieves optimal performance. At the same time, we can observe that semantic communication under the NOMA scheme achieves better performance improvement at a power of 5 W. After analyzing the results, we find that under OMA, only one user is allowed to communicate in each fading state. Due to the slow growth of semantic similarity with increasing power under high SNR, there is a certain performance loss under OMA in SemCom based on DeepSC, which may provide some inspiration for multi access in SemCom.

V. Conclusion

In this paper, we have introduced and validated the NOMA enabled OSBC system. Our approach integrates an adaptive communication paradigm alongside a flexible resource management scheme for efficient information transmission. We have employed the Lagrange dual method to resolve the rate region of two users within a fading channel. Numerical simulations have confirmed that our proposed scheme effectively balances SemCom and BitCom tradeoffs, outperforming conventional OMA enabled schemes.

Appendix A

For any fading state during a time block, an achievable solution $\left\{\alpha_z(v), \beta_z(v), P_n^z(v), P_f^z(v)\right\}$ can be constructed in the following manner. In the time portion ν, we can have $\alpha_z(v) = \alpha_x(v), \beta_z(v) = \beta_x(v), P_n^z(v) = P_n^x(v), P_f^z(v) = P_f^x(v)$, and in the other time portion $1-\nu$, there are $\alpha_z(v) = \alpha_y(v), \beta_z(v) = \beta_y(v), P_n^z(v) = P_n^y(v), P_f^z(v) = P_f^y(v)$. Considering all fading states, we have (1) $E_v\left[S_f^z(v)\right] = \nu E_v\left[S_f^x(v)\right] + (1-\nu)E_v\left[S_f^y(v)\right]$, (2) $E_v\left[S_n^z(v)\right] = \nu E_v\left[S_n^x(v)\right] + (1-\nu)E_v\left[S_n^y(v)\right] \geq \nu\overline{S}_n^x + (1-\nu)\overline{S}_n^y$.

Hence, we have proved the Lemma 1.

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