1

LowencomptexRysResource Addiocation for Useired Paires RSMA FintFuture 6 GirWirelesstNetworks

JitiweenHelm,Galagn Libim/Withah elE-EEEE Ebedge Ma, Magribbern leEEEE Ming Ming , Naui p 8 Minn birted til EEE, 100 Elingzhi Ping Fain Faell Bell leEEE EE

Abstract+-Rate-splitting-gnultiple laccesses (RSMA) Laplin le line quines coptimization of decoding longer and power allocation; while decoding corder is addiscrete visiable, and ablis, wend complexe to find plue optimial decoding corder if debeling mode of diserbots large brough. This letter proposes aglow-Complexity user pairing-based resource also cation algorithms with the objective of timininizing the matkinthum latericy; which is ignificantly reduces the loomputational compilexity and also cachieves similar pierformance to impaired algorithm expression for power land. Bandwidth allocation is first decive do another and is entitly the librorose algorithm is first decived as resource allocation definally, the laptoposed algorithm is compared with cutopaired in SMA, paired proposed algorithm is compared with cutopaired in SMA, paired proposed algorithm.

the proposed algorithm. Index Terms—rate-splitting multiple access (RSMA), decoding order usef pairing; are source allocation, 6G Wireless Networks.

I. INTRODUCTION

6G takes the upper bound of wireless access capacity to a new level, and it expects ubiquitous connectivity, which is 60e/whet/thingufoperxistingdsystems.leAn aexcellent/mult/iptle access settemes dait effectively significate above problems; and RSMAvikelipiomising vistitus terateurs. A treme elleut multiple acRSMA hapties than messagio elythol transmitter and transmits in the Subdeposition reciting, which place ones is the other receivler usiRS Mulconstive that enference at an bellation of SIG), and RSMA downlinklytheomespaget infreachlusgr ishaptitlintodesprivate plat and averaming party and the bootiment parts of all busins (& Cit-LodelShtA one workinkon/stream-and transmitted superimposed with abority state are considered to a compare the relation increases After of other leveline the message, the common stream stream decbded by titeating aptrusers) private threbany as noiset them the interference of bornmon suitams ideprivate streams is reintoved by saving, SDE, candiforally the privatet streamlers discould by meating other users private streams as thouse 121, iThe RSMA

This workelis jointly is hiported by r NSF Copro NSF Grant North 197 (250); Chook g (1718 30) ni Clock & did not in the Standard of the Standa

The worn Hillusis currently that guing other PhDD. Ring Pet de Schoolt of differing from Science and defect nodely Contains, Science and defect nodely Contains, Science and defect nodely Contains, Science and Contains, S

Gang Lim is currently aunassociate professociate Scheboif of Information ScienSeiand Technology, nSouthwest Uthowng University, Uthiwarsity, all higanginalisty junedine is with edu.cn).

Zheng Ma is commently a professor att Skilmel off Information Science and Technology, SSouthwest Jilantong University, China. (zma@homeeswjtjtedechn.cn).

Ming Xiao is swith the Department of the firmation Science Suich Engineering, Schooling, Efectual of Agineering, KTH 100444; Stotkholin (SweSeneldentail; Swingk@kth.se).

Pingzbi i Pharis is urrently thy distinguished i pholessorous Southwest ditioners. University, (Chinacsipy an Wiswju (pd from Tswjtu edu.cn).

dőwnlinki ási helavályisestearghéda (butstheauplink hasi not-chebn well gin VEstigated, fisoathis stetter focuses to nathe RSMA diplinky treating RSMA uplink, the vates sage a freach users is split Trite RVS\\partslogachiparts is rencoded sndependently, and trafisrkitted superimposed||ThevSIGgechnique islusell-tatchefbase estation(for Recording phinks pecified decoding order [?]. In existing works on IRSMAR@Mnk, utbeinalathors in essa gendiedathe performance infratered in the company of the com and subjevelsky sum pated and heaviethed exact relies and subject to the clean of the control of ekpressiont dright forced cathing litting (FRS) and ecognitive rate \$20 littlinge(GRS) of owtwhsuser up link Area pludked their imputoiveruser falmess land blutage performance fand oauslosed pform Expless sione for sthe outage probability visagivench The abuthors in af 2] investigated becoming unable difficiling entransface. (RIS) Passisted two-usphiRSMAEDISik and optimized the transliniting werland beamforming withinke objective of maximizing the cachievable ratel. (?))tstudjedrfhertwo-usen RSMA upklinkawhielipfiestsideri (os closed-form expressions forgoutageTprobabilities (and?) then usestighend to-colorige ruskele throulighput swirfinge middfilmssicoust control epilolólóló baséd konutherstóttédecA LOHArandi RiSMA: GodphratingoNGMAv(ClNOMA)) and iveoperating iRSMA (Ge ReSNEAs) bfor ratio, users updied where t proposed RSNPA and the prioportifinal fdimiess coldificient was exposidered to formulate two baptilitization of problems of the comparison one user throughput wifAilaabovleustudieseare.datsed pnotwooldserse.dhowelverslowhed the Othraben doll Sidra, is danger enough Othra optional Metal ding ondereof the SMES hip An kGs Rishfixled finite gero non-linear lipriograme mingosandithéré ásidacke of roffoctiveia/vayaitnesolvo efficiEhe authors nisid (?) doptimized with the power option at it is in a not repair in a contract of the contract of t beamformingsfor users of RIS-assisted uplink RSMA systems with ltbd: objective: esfamakimization vsum-state. End/proposed:a shboptimabdedodingsoisden based on ghailne bgairn and Imessläge splittingsfraR&MAl addipted ian exhaustive i seageb mothede to findsthenophimaladdcolding orderland infraducedvasert-pairing to. reduce antehromplex (b) of phenalgorithm. power allocation anMostssivetheaexisting ngesoarcises s for iRIS insuisated aimiesk R6d rates ortenter ruption i probability, ewdfiler incisoine tautomatic control scenarios; slatencys is a prioreal importal in parameter, such ası automaticgaintroid ofnevelaiçle splattinging tiwhere the plead webiedeanee itse tseaweit steetdolkedto the chrovementustatuse of ingl plateoning intriducebefore prairing toomtoketbisions, platich néedse tolgmitthmize the maximum latency for all users. In addition, of the complexity referentiating only or ithmsets found else furtherateducedaterruption probability, while in some auto Inathis detterolyseceptimize lateuplink RSMA rewith phetabt jective of minimizing the maximum latebox. Since the obstimal degodingsordereisleifficath toleindsedset pairing is employed to

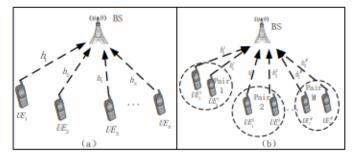


Fig. 11. (a)a)UjlinkirRSM9A/withouthuser paseingos(b)idjplijtk) RSMfAlwittShfeb paiting ser pairing.

reduce the computational complexity. Then the optimization movement status of all platooning vehicles before making variables are changed from decoding order and power allocation to decisions, which needs to minimize the maximum tion to bandwidth allocation and power allocation, by making latency for all users. In addition, the complexity of existing use of the fact that the optimal decoding order of two users algorithms should be further reduced, can be determined. We derive the closed-form expressions for power and bandwidth allocation, respectively, and the optimize the subjective of any invitation of the specific power that bandwidth allocation, respectively, and the optimize the power that bandwidth allocation, respectively, and the optimize Schiertiy or the riginizing of her business blateer by Since the anctional changing order circles with the fargorment reviews de employed to reduce the computational complexity. Then the optimization variables are changed from decoding order and power allocation to bandwidth allocation and power allocation TEM MODIEL AND PROBLEM that the optimal decoding order of two tisers can be determined. Wwwterious this degelerating conserver some as any emphasized and the west and the conserver some and the conserve width allocatists of spetitives MAdithe metition as subject to the oppinionation analysm is a standby (Bisection Methods The Unanther effectivements asking algorithm denoteritied the Using RSMA uplink transmission, the information x_n of user n is divided into x_{n1} and x_{n2} . The message received by BS can be expressed as $y_{BS} = \sum_{n=1}^{N} \sum_{j=1}^{2} \sqrt{h_n} \cdot x_{nj} + n_0$, where n_0 denotes additive Gaussian white noise. After SIC is performed at BS, the rate of x_{nj} can be expressed as $r_{nj} = B \log_2(1 + \frac{\text{FOR MIJJATION}}{\sum_{\{(n' \in N, j' \in J) \mid \pi_{n'j'} > \pi_{nj}\}} h_{n'}p_{n'j'} + \sigma^2 B})$, where B is the bandwidth, p_{nj} is the transmission power allocated to without lass of generality, this letter consider a single x, Without the decoung differ this lettern operide the pionele inputaring Ising the Gardian Plake RSM the transmission rate by wacing Fean Be exhibits contains a base stational Bal mulsi Mission sate from the paser n. two BS ip Length backage Usign of Saset uplinksotran autoriane the best strain the by weeds not so that the fortunation from an 2 users e bereise affakingei verlurby deel stons, be expressed the following Soptimization problem to minimize the omaximum additivesi Graniev, white noise. After SIC is performed at BS, the rate of x_{nj} can be expressed as $r_{nj} = B \log_2(1 \frac{P_1}{\sum_{\{(n' \in N, j' \in \mathcal{B}) \mid \pi_{n'j'} > \pi_{nj}\}} h_{n'} p_{n'j'} + \sigma^2 B})$, where $B(\mathbf{i})$ the bandwidth no is the transmission power abocated to x_{nj} , π_{nj} is the decoding order of x_{nj} , and σ^2 is the power spectral density of the Gaussian noise. So the transmission rate of user n can be expressed as T_n , $T_n = \sum_{i=1}^{2} T_i N_i$, and the transmission latency with as $t_n = PL_n/r_n$, where PL_n is the package length of user n. In some automatic whence $p_{\text{system}}p_{\text{s}1}$ the $p_{\text{s}2}$ $p_{\text{s}2}$ $p_{\text{s}2}$ $p_{\text{s}2}$ $p_{\text{s}3}$ $p_{\text{s}4}$ p_{\text olderserof IdeCodingalaridg P@fitros decisiaxisms mytralisticitis sibre poweriog userimization problem to minimize the maximum

transingsaido denotes the upper bound of latency for all users, we have $t_n \le \tau, 1 \le n \le N$. Then problem P1 can be transformed into:

P2:
$$s.t. p_{nj} > 0, 1 \le n \le N, j \in [1, 2];$$
 (1a) $\min_{\pi p} \frac{\tau}{\pi} \in \Pi;$ (1b)

s.t.
$$r_n \ge \frac{2PL_n}{p_{nj}}, 1 \le p_n \le N, j \in [1, 2];$$
 (2a)
 $p_{nj} \ge 0, 1 \le n \le N, j \in [1, 2];$ (2b)

$$p_{nj} > 0, 1 \le n \le N, j \in [1, 2];$$
 (2b)

where $\mathbf{p} = [p_{11}, \overline{p}_{12}, \overline{p}_{21}, ..., p_{n2}], \Pi$ denotes all possible orders of decoding and P_n^{max} is the maximum transmission power of user n. $\sum p_{nj} \leq P_n^{max}, 1 \leq n \leq N;$ (2d)

Using τ to denote the upper bound of latency for all users, we have $t_n \leq \tau$, $1 \leq n \leq N$. Then problem P1 can the decoding order π in problem P2 is a discrete variable, and the condition (2a) is in the form of the sum of two logarithm R2 function R1 R2 can exhaust π and use the success R2convex approximation (SCA) algorithm to transform condition (2a) into a sconvex, form to find the approximate solution However, the decoding order set Π contains $(2N)!/2^N$ elements, which means that the complexity of the algorithm using the exhaustive method will become extremely high as the number of users increases. Existing studies have determined the optimal decoding parder of RSMA transmissions for (Bold) users [?], so we consider pairing every two users to reduce the complexity of the algorithmen P2 is a discrete variable, an As show in part (b) 2f Fig. 22, suppose all users are paired into Mopairs, and each pair contains two users t According to the simulation test, since the change of changel gain is much larger, than, package length, the performance of pairing (mainly depends on the channel gains on this pairing disaperformed according to the order of channel gains [2]. The channel gain of the kithesiser in the methopairnto the BShis denoted by h_{i}^{m} tkio ϵ wiii 2 be $\cos w$ extrMeRescarch $_{i}$ 2 h $_{e}$ hows $_{i}$ that cupling RiSMA transmission of two users can achieve all trate regions hy splitting, the information of anly one user. Without loss of generality, suppose the message of the first user in each pair is split into two parts x_{111}^m and x_{12}^m , and the message of the second user is not split, the optimal decoding order at the BS Safred fit o Alepairs, and each pair contains two users. Accolling following in an analysist for the meth pair of present he gatan qf. affuctr Baland | affurcapable agyptensed, respectively insince of pairing mainly depends on the channel gains, so this pairing is performed according to file order of change gains [?]. The channel ghan of the Rich use Bin the m-th pair to the BS is denoted by h_k^m , $k \in [1, 2], 1 \le m \le M$. Research [?] shows that uplink RSMX transmission of two users can achieve all rahin prejums $2B\alpha$ splitting the information of only one user. Without loss of generality, suppose the message of the first user in each pair is split into two parts x11 and x12 gand the research user is not split, the optimal decoding order at the BS is where $\frac{m}{2} \alpha x_{4,2}^m$ is the bandwidth allocation factor with ∑The following piÿ ap@nadysp@foardtherpolygraitlocated no tille, rate and with respectively con the erape of edsers point melting pair is $r_1^m = r_{11}^m + r_{12}^m$ and the transmission latency of user k in the m-th pair is $t_k^m = PL_k^m / p_{11}^m$ where PL_k^m is the package length of easer k in the m-th pair $+ \sigma^2 B\alpha_m$, (3)

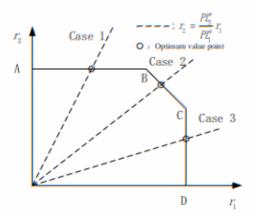


Fig. 2. Rittet region of rapdard in the shore pair when use RSMA RSMA

The optimization of the power and decoding order in P12 can be translated into the optimization of the bandwidth and power allocation in P_{12} as follows: $r_{12} = B\alpha_m \log_2(1 + \frac{h_1^m p_{12}^m}{\sigma^2 B\alpha_m})$

 $P3: \min_{\text{where } \alpha_m \text{ is}^{\alpha_n} \text{the bandwidth allocation factor with}} \tau$ (6) $\sum_{m=1}^{M} \alpha_{w,t} \leq 1 p_{t}^{m} p_{t}^{m}, p_{2k}^{m}, \text{and } p_{m}^{m} \text{ are the power, allocated to } x_{11}^{m}, x_{2}^{m} \text{ and } x_{12}^{m} \text{ respectively. So the rate of user 1 in }$ m-th pair is $rp_{k}^{m} \rightarrow f_{1}^{0} + f_{1}^{m} = f_{1}^{0} + f_{2}^{m} = f_{1}^{0} + f_{2}^{0} = f_{1}^{0} = f_{2}^{0} = f_{1}^{0} = f_{2}^{0} = f_$ of user k in the n-th pair is $t_k^m = PL_k^m/r_K^m$, where PL_k^m is the package length of user k in the m-th pair.

The optimization of the power and decoding order in P2can be translated into the optimization of the bandwidth and power allows in $H_{3,ass}$ to flow $M, k, j \in [1, 2]$;

$$P3: \min_{\substack{j=1\\ \text{or}}} \tau$$
 (68)

III. RESOURCE ALLOCATION ALGORITHM FORA

 $p_{kj}^{m} > 0, 1 \leq m \leq M, k, j \in [1, 2]; \tag{6b}$ Since the expression of transmission rate is a monotonically increasing function of power and bandwidth, we can use contradiction to prove that the optimal solution of P3 is obtained when and only when all users have the same latency, i.e., $t_1^1:t_2^1:t_1^2\sum_{p_{k,j}^m}p_{k,j}^m\stackrel{1}{>}\mathcal{P}_{kmax}^n$; 1 1 $\stackrel{1}{\succeq}m$ $\stackrel{1}{\leq}m$ $\stackrel{1}{\leq}m$, other two rds, the ratio of optimized rates is $r_1^1:r_2^1:r_1^2:\dots:r_2^M=PL_1^1:$ $PL_2^1: PL_1^2: \dots: PL_2^M$. Thus, the rates of two users in the same pair have $r_2^m = \frac{PL_2^m}{PL^m}r_1^m$.

IFIG. PESOUR THE ASHIEVARIA THE NEAR TOP WORLD HAVE BRIDGE RSMA transmission, where the decount order is x_{11}^m , x_2^m and x_1^n Sinable phints: on eladorate fregion gan ibe reached a monotonicalforithe dinen & Burthei power pallocation is and width, we can use contradiction to prove that the optimal solution of P_3 is obtained when align the same läsen@yhasethe_maximuti_ rate as $t_2^M = 1:1:1:...:1$, in other words, the ratio of optimized putes is $r_1^1: r_2^1: r_1^2:$...: $r_2^M = PL_{12}^{nm} PL_{22}^{nm} PL_{12}^{nm} PL_$

two users in the same pair have $r_2^m = \frac{PE_2^m}{PL_1^m}r_1^m$. For the line BC, the power allocation is: using RSM A_{p} ranger is side, when the decorpting, order is x(9)

 x_2^m and x_{12}^m , all points on the rate region can be reached: The sum rate of the two user is: allocation is: $r_1^m + 0r_2^m \bar{p}_{11}^m B_{\Omega} P_{1ma2}^{kog} (1 + p_{12}^m = 0, \frac{1}{\sigma^2} B_{\Omega}^m = P_{2max}^m).$ (19)

UsEor2theasinthCDathenpoweratellocation is:

$$p_{11}^{m} = 0, r_{2}^{m} p_{\pm 2}^{m} B \alpha_{n}^{p_{1}^{m} bog_{2}} (1 + \frac{k_{2}^{m} p_{2}^{m}}{\sigma^{2} B \alpha_{m}} P_{2max}^{m},$$

$$1 \text{ has the maximum rate as:}$$

$$(18)$$

User 1 has the maximum rate as:
For the line BC, the power allocation is:
$$p_{11}^m = P_{12}^m = P_{1max}^m \cdot \frac{1}{p_2^m} P_{2max}^m \cdot \frac{1}{p_2^m$$

According to the above analysis, the optimal power allocation of problem P3 is the intersection of line $p_{2n}^m = \frac{PL_2^m}{PL_1^m} r_1^m$ and the rate region. Assisting in Fig. 12. Because the intersection point may exist three cases.

Casette Time inforsection pointals on tAB, and according to

(??),
$$p_{11}^{(2?)} = 0$$
, and $p_{12}^{(2?)} = 0$, we have $p_{12}^{(2?)} = p_{12}^{(2?)} = 0$ and $p_{12}^{(2?)} = 0$ and

User 1 has
$$Be_{m}^{AB} \log_{\mathbf{Z}}(\operatorname{dirt} \frac{h_{2}^{m} P_{2max}^{m}}{\sigma^{2} B_{\alpha_{m}}^{aSAB}}) = \frac{PL_{2}^{m}}{\tau},$$
 (13)

(12)

According to the above Malysis, the optimal all Castion The inversection Proint is by BC cranding ording to (2?) = (12) 2 (12) and (6a) rate region. As shown in Fig. ??, the intersection point may exist pharee cases $L^m + PL^m$

Bease legicle intersection point is on AB, and according to (??), (??), (??) and (6a), we have: (15)

$$B_{12}^{\alpha} = \frac{\log_{12}^{L_{12}^{m}} P_{2m}^{m} P_{2max}^{m}}{P_{12}^{L_{12}^{m}} P_{2m}^{m} P_{2max}^{AB}} \underbrace{\sigma^{2} B_{\alpha} \frac{P_{1m}^{F}}{m}}_{P_{11}^{m}}, \qquad (13)$$

The p_1^m can be obtained by taking p_{12}^m into P_1^{AB} then r_{114}^m $PL_1^{m+1}/\tau - r_{12}^m$, and according $t_0^m(??)$ we can obtain p_{11}^m :

Case 2: The intersection point is on BC, and according $tq_{n}(??), (2^{\frac{1}{12}q_{m}^{\frac{BC}{BC}}}??) \frac{1}{2}(h_{2}^{m}(p_{2}^{m})_{n}^{m} + h_{1}^{m}p_{12}^{m} + \sigma^{2}B\alpha_{m}^{BC})$

 $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + h_2^m P_{2max}^m - PL_1^m + PL_2^m$ $h_1^m P_{1max}^m + PL_2^m + PL_2^m$ $h_1^m P_{1max}^m + PL_2^m + PL_2^m$ $h_1^m P_1^m + PL_2^m + PL_2^m$ $h_1^m P_1$ (??), (??) and (6a): (15)

$$B\alpha_{m}^{CD} = \frac{h_{1}^{m} P_{1max}^{m}}{p_{12}^{m}} \underbrace{P_{2mp}^{CD} P_{2mp}^{CD}}_{P_{2m}^{D}} \underbrace{\rho^{-2} B \alpha_{pn}^{CD}}_{m} \underbrace{\rho^{-2} B \alpha_{pn}^{D}}_{h_{1}^{m}}, \quad (18)$$

The p_{12}^m can be obtained by taking p_{12}^m into (??), then $r_{11}^m = PL^m/\tau - r_{12}^m$ and according to (??), we can obtain of $\alpha_m^{PHB}, \alpha_m^{BC}$ and α_m^{CD} are given in (??), (??) and (??). Where $W(\cdot)$ is the Lambert-W function which satisfies $W(xe^x) = x$. Note that the Lambert-W function has multiple solutions lights. and the appropriate solution should be chosen.

With the Thesial-form tempression is from bandwidth advocating and (p) we'r 2 lead (p) we can solve the problem P3 by the bisection method. For each given τ , a set of α_m^{AB} , α_m^{BC} and α_m^{CD} call the calculated $\frac{\alpha_m^{CD}}{\alpha_m^{CD}}$ (and (21)), and (21)). and the power allocation corresponding to each case can be obtained by $(2^{\frac{p+p}{2}})$, (2^{2}) and (2^{2}) , and then the condition (6d) p_{2}^{m} used to judge which case occurs. The specific algorithm is shown in Algorithm 1.

Theoretinglexity (30f), Algorithmed 1 (3th), each iterationious to checkory hichnehser satisfies the epower (constraint) (6d)d which Whith M is only lekity M function of the M function M is M and M and M and M are M are M are M are M and M are M are M and M VP?)rand (22)s(??Nohe addition) the loomblexitWof the bisection methindewishlutéousachere, isa@(loghg(1;kp))rdphiaso shdutótal somplexity of oAdgorithm 1 is $O(M \log_2(1/\epsilon))$.

$$\alpha_m^{AB} = \frac{-\ln 2h_2^m P_{2max}^m P L_2^m}{\tau B h_2^m P_{2max}^m W(\frac{-\ln 2P L_2^m \sigma^2}{\tau h_2^m P_{2max}^m} e^{\frac{-\ln 2P L_2^m \sigma^2}{\tau h_2^m P_{2max}^m}}) + \ln 2P L_2^m \sigma^2 B},$$
(20)

$$\alpha_m^{BC} = \frac{-\ln 2(h_1^m P_{1max}^m + h_2^m P_{2max}^m)(PL_1^m + PL_2^m)}{\tau B(h_1^m P_{1max}^m + h_2^m P_{2max}^m)W(\frac{-\ln 2(PL_1^m + PL_2^m)\sigma^2}{\tau(h_1^m P_{1max}^m + h_2^m P_{2max}^m)}e^{\frac{-\ln 2(PL_1^m + PL_2^m)\sigma^2}{\tau(h_1^m P_{1max}^m + h_2^m P_{2max}^m)}) + \ln 2(PL_1^m + PL_2^m)\sigma^2 B},$$
(21)

$$\alpha_{m}^{CD} = \frac{-\ln 2h_{1}^{m}P_{1max}^{m}PL_{1}^{m}}{\tau Bh_{1}^{m}P_{1max}^{m}W(\frac{-\ln 2PL_{1}^{m}\sigma^{2}}{\tau h_{1}^{m}P_{1max}^{m}}e^{\frac{-\ln 2PL_{1}^{m}\sigma^{2}}{\tau h_{1}^{m}P_{1max}^{m}}}) + \ln 2PL_{1}^{m}\sigma^{2}B},$$
(22)

Algorithmel closed pairing chased spower of location algorithms titudinital inverse point and lower bound solver the operations P3 by: twhile sertion method door each given τ , a set of α_m^{AB} , α_m^{BC} and $\alpha_m^{CD} = \frac{1}{m} \frac{1}{m} \frac{1}{m}$ be calculated according to (??), (??) and (?O) and the dower allocation corresponding to each case can calculate $\alpha_m^{CD} = \frac{1}{m} \frac{1}{$

Algorithm The Power allowed case $v_{rsatisfies}$ (6d) then r_{shm} . $\alpha_{m} = \alpha_{m}^{AB}$.

```
Initialize in the bowletomicconound rease 2 salisfies (6d)
 2:
     while h \epsilon_{\mathbf{n}b} - \tau_{lb} > \varepsilon do
        set \tau_{\alpha = \frac{\tau_{ub} + BC}{\equiv \alpha_{ub}}}
10:
        for the power allocation of case 3 satisfies (6d) the pulate \alpha_m^{AB}, \alpha_m^{BC} and \alpha_m^{CD} respectively accord-
148
 5:
            \operatorname{ing}_{\mathbf{v}} \operatorname{to}_{\mathbf{v}}(??) \operatorname{gr}(??) and (??).
12:
            Galculate the power allocation for each case ac-
18:
            cording to (??) reak and running (32) respectively.
14:
            in The power allocation of case 1 satisfies (6d)
15
        endhför
16:
        if \sum_{m=1}^{M} \overline{\alpha}_{m}^{\alpha} \alpha_{m}^{AB} 1 then
18
            else if The power allocation of case 2 satisfies (6d)
18:
19:
        <del>10</del>:
21:
```

23. Output $\gamma_m \overline{\alpha}_m \alpha_{p_{11}}^{CD}$; p_{12}^m , and p_2^m .

13: else 14: set $\tau_{lb} = \tau$, break and jump to step 2.

15: IV. simulation result and discussions 16: end for

17-We sinvale the proposed algorithm in this section. N users are uniformly distributed within a radius of 200 m from the BS, and the path loss model is $128.1 + 37.6 \log_{10} d$ (d is in Rm). The dandwidth is set to 1 MHz, and the noise power spectral density is $\sigma^2 = -174$ dBm/Hz [?]. Each user has the same whole limit P_{max} and randomly generates a packet 38.50 ± 200 by the same limit P_{max} and randomly generates a packet 38.50 ± 200 by the same limit P_{max} and randomly generates a packet 38.50 ± 200 by the same limit 38.50 ± 200 by the comparison include unpaired RSMA [?], paired NOMA [?] and unpaired NOMA. All simulation exists the degree of the complexity of 38.50 ± 200 by the same limit of 38.50 ± 200 by the complexity of 38.50 ± 200 by th

IV. SIMULATION RESULT AND DISCUSSIONS

We simulate the proposed algorithm in this section. N users are uniformly distributed within a radius of 200 m from the BS, and the path loss model is $128.1+37.6\log_{10}d$ (d is in km). The bandwidth is set to 1 MHz, and the noise power spectral density is $\sigma^2 = -174$ dBm/Hz [?]. Each user has the same power limit P_{max} and randomly generates a packet of 50-1200 bytes. The algorithms for the comparison include unpaired RSMA [?], paired NOMA [?] and unpaired NOMA are installable or results were performed on all Intel Control of 13000 KF CPU a 5.8 GHz and 32G RANK Rang MATINALS R 2023a.

Fig. ?? shows the transmission latency of each scheme with different power kinds for the number of users N=4, where unpaired RSMA exhausts all decoding orders to obtain the optimal solution. As $P_{\rm bugg}$ increases, the latency decreases for all schemes. It can be seen that RSMA outperforms NOMA, regardless of pairing or non-pairing, the reason is that NOMA is an extreme special case of RSMA, while RSMA carrelander the resource allocation and decoding methods between different packets more flexibly to obtain better performance. In addition, the proposed paired RSMA resource allocation algorithm gives a closed-form solution for power and bandwidth allocation, which significantly reduces the computational complexity and has not much performance loss compared to the unpaired RSMA.

Since the algorithmic complexity of the exhaustive method grows exponentially as the total number of users increases, we choose a suboptimal decoding order [?] Fig. 20 Antense perfermancement different power-dimate wherethe number of number of users in Fig. ??, and the power limit is set to $P_{max} = 23$ dBm. It can be seen that RSMA always outperforms NOMA, regardless of paired or unpaired. limatkbitition.tAs Paire therdasesethe tatenoved extrases for att schemes, et can be seen mát RSM à our beforms NOMA o tel pardless of pairing or goog pairing other reason is that NOMAcis anhextreme/special@asfoofiR SM Apwhite RSMAccarlhanttle the fesourbe tallocation and ideeloding smethods between different packets morehitexibly to obtain better therformanceted addition, the proposed bathed RSMA response although a Mobiling gives alleloseit-fordgesofthtiongforthowerlands blandwidth lattications which significantly reduces the computational Poblishexity and has Industriuch epolformatice bosseft ompfateld to the surpaiged RSMAin terms of complexity, Table ?? gives the simulation

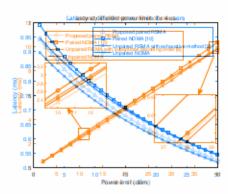


Fig. 43. Hatdnoy/pepferfmancenfor wiffbreitfftotal/tripmber of misters when the power-dimit $B_{\rm MSS} \approx 23.41 {\rm Bm}$.

TABLE I

Comparison of the computational complexity of each scheme Since the algorithmic complexity of the exhaustive method ve choose a suboptimal decoding order 20 atendy nerformance ??.PairddtBeSbower seen that KSMA always outperforms NOMA, regardless of paired strengaired. In addition, the paired schemes are more advantageous when the total number of users is small, and as the total number of users increases, the performance of the unpaired subernes with outperform the paired schemes due to thenfactethatOmore number of26tsers anieans more number of pairs and therefore less bandwidth is allocated to each pair. Overall, the proposed paired-based RSMA resource allocation algorithm greatly reduces the complexity and achieves similar performancesommpaired RSMAmic complexity introduced by Tch further ustalwate chei benefits rofi the optoposed categori blim an deems) of vecomplexity tilabled 20 gives others ithelation of the formeachorspheritey grodifferentlyotahenuthberupfberserfs.usFor impagaeds RSM Ababeontgorithmic complexity pintroduR&MA thig orithaus tgice decoding obfiden methods is oun acceptable, and byenl given alsoboptimal addcoding vesdernther computational tomplexity-drRwMApidiylawheretheloumbempfeusitys increases. On The countrarylethorproposeth pairbd RoSMA calgorithmigivgs

TABLE I
COMPARISON OF THE COMPUTATIONAL COMPLEXITY OF EACH SCHEME

		- 0.1	4 -1 -1		
Schemes	Simulation time				
	N = 4	N = 10	N = 20	N = 30	N = 40
Proposed paired RSMA	0.068 s	0.095 s	0.106 s	0.141 s	0.131 s
Unpaired RSMA with exhaustive method	3447.5 s	-	-	-	-
Unpaired RSMA with suboptimal decoding order	1.783 s	7.378 s		36.117 s	74.457 s
Paired NOMA	4.084 s			7.589 s	10.113 s
Unpaired NOMA				5.106 s	5.271 s
10 —— Urpained PSIMA with suboptimal decoding order [1]					

a closed-form expression for power and bandwidth allocation, and achieves single performance to unpaired RSMA with a very low complexity.

The results demonstrate that the proposed user pairing-based power allocation algorithm achieves good performance with significantly reduced computational complexity. As the total number of users increases, the performance of the proposed algorithm decreases due to the total bandwidth limitation, and the computational complexity of the unpaired uplink RSMA to confirm the optimal decoding order exponentially increases, so there is a trade-off between computational complexity and transmission performance.

V. CONCLUSION

In this letter, to address the requirement of maximum latency among all users in some automatic control scenarios, we propose a resource allocation algorithm for uplink RSMA Firminimize the maximum for differentiated hereby. However, the the power limit Prince 23 PM to confirm the optimal decoding complexity of uptimal RSMA to confirm the optimal decoding order grows exponentially with the total number of users, so user pairing is introduced and a low-complexity resource allocation talgorithm, based on cuser pairing tis, designed to transform, the optimization of power and decoding order into the neptimization of power and bandwidth allocation that achievabler rateitregion, of dtwoeusern publick or RSMAn iste first analyzed nandrthe alosed-form expressions of three possible values of the optimal enemer, and bandwidth allocation are derived. Then the maximum latency Titis determined by the hisection, method, and for each given τ , the corresponding three power and bandwidth allocations are derived. The optimal power allocation scheme is determined by judging which one satisfies the power constraint. Results show that the proper bettery complexity algorithm based on fuser paining significantly/redultersthe insermemplexity/tand/also/lachinges similar performance-to-unpaints uplink RSMAhm for uplink RSMA to minimize the maximum transmission latency. However, the complex EFERENCES RSMA to confirm the ApMishal Yleviorli OgDonthe angrib w Sleectpro TRanti Spliying i Multiple tot Access for 6GP art is Principles, Applications and Eutyre Works ein IEEE a low reamplex it yees query allocation algorithm based on (12)eY. (Mining). iDizdasi@nedle/dx.f: nanSidober, the Popoistaizadidh. of Nober a Rate-Splitting Multiple Access Fundamentals i Surveys and Future Research Trends in TEEE Communications Surveys & Tu-poworals, nool bandwidth philosophicate, Prounting little Value 2022, Paber region 106/Comst202203001987. RSMA is first analyzed, and

the YeloZed-MariWangprZssZbnagofXthGenpaastbYe Cakues Af take optsplitting over othor opala multiples across actions after duplink dumanism sion," 2017 9th International Conference on Wireless Communications the amaximum latency west, determine the by other projection methodd 0.000 Awd 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000blower Lived Dan Tsiffsteth Kallo Kittsoks Sark vielerived H. TVe 2005 i Britis Splitting for Uplink NOMA With Enhanced Fairness and Outage Perfor-power, all 90 9699 rescheme, 18, of the Enhanced Fairness and Outage Perforone7sp#is653-4670, pdyv2020,oust #8i1109/8785020s298597that the blogosett ldw-bimblextty talgorithithibased on was er bistrike ceive and Passive Beamforming Optimization for RIS-Assisted Up-signalic RSMX systems, till PEEE WIFFIED ESTIMATICATIONS CAREST, 405. similar 100/EWC 2023 3 26688 an paired uplink RSMA.

[6] S. A. Tegos, P. D. Diamantoulakis and G. K. Karagiannidis, "On the Performance of Uplink Rate-Splitting Multiple Access," in IEEE Communications Letters, vol. 267 600 \$5 pp. 523-527, March 2022, doi:

Communications Letters, vol. 26; 60008 pp. 523-527, March 2022 doi:

11 A. Mishra, Valance, Dizzlar, and B. Clerckx. "Rate-Splitting March 2022 doi: 10.1109/LCOMM.2022 doi: 10.1201/Lar. and B. Clerckx. "Rate-Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "Bate Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerckx. "But the Splitting Dizzlar and B. Clerckx." But the Splitting Dizzlar and B. Clerck

10.1109/LWC.2023.3266883.

[6] S. A. Tegos, P. D. Diamantoulakis and G. K. Karagiannidis, "On the Performance of Uplink Rate-Splitting Multiple Access," in IEEE Communications Letters, vol. 26, no. 3, pp. 523-527, March 2022, doi: 10.1109/LCOMM.2022.3142102.

[7] O. Abbasi and H. Yanikomeroglu, "Transmission Scheme, Detection and Power Allocation for Uplink User Cooperation With NOMA and RSMA," in IEEE Transactions on Wireless Communications, vol. 22, no. 1, pp. 471-485, Jan. 2023, doi: 10.1109/TWC.2022.3195532.

M. Katwe, K. Singh, B. Clerckx and C. -P. Li, "Rate Splitting Multiple Access for Sum-Rate Maximization in IRS Aided Uplink Communications," in IEEE Transactions on Wireless Communications, vol. 22, no. 4, pp. 2246-2261, April 2023, doi: 10.1109/TWC.2022.3210338.

 Z. Yang, M. Chen, W. Saad, W. Xu and M. Shikh-Bahaei, "Sum-Rate Maximization of Uplink Rate Splitting Multiple Access (RSMA) Communication," in IEEE Transactions on Mobile Computing, vol. 21, no. 7, pp. 2596-2609, 1 July 2022, doi: 10.1109/TMC.2020.3037374.

[10] Z. Ding, P. Fan and H. V. Poor, "Impact of User Pairing on 5G Nonorthogonal Multiple-Access Downlink Transmissions," in IEEE Transactions on Vehicular Technology, vol. 65, no. 8, pp. 6010-6023, Aug. 2016, doi: 10.1109/TVT.2015.2480766.

[11] B. Rimoldi and R. Urbanke, "A rate-splitting approach to the gaussian multiple-access channel," in IEEE Transactions on Information Theory, vol. 42, no. 2, pp. 364⁺C375, 1996.
[12] S. Boyd and L. Vandenberghe, Convex Optimization. Cam-

bridge, U.K.: Cambridge Univ. Press, 2004.