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Limit Portable Computing for Non-Orthogonal Data Transmission Access using Difference Time

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ABSTRACT

Non orthogonal multiple accesses (NOMA) [3] have the ability for efficiently enhancing the system's spectral efficiency when multiple users are assigned with the same resources. MEC systems used NOMA for reducing task delay and the consumption of energy in a few works [4]. In mobile devices, the computing ability is enhanced when using multi-access edge computing (MEC), whereas high data rates are provided when using NOMA. To combine the two might be beneficial for the networks with spectrum and energy efficiency for minimizing the transaction time difference related to 2 paired users of NOMA offloading data into the servers of MEC through enhancing the transmission power and computational resources of severs by means of the approach of the successive convex approximation. Furthermore, the transaction time equalization for the paired users decreases waste of computational and frequency resources, and enhances effective system throughput to 19% on average.

Keywords: portable computing, data transmission, difference time.

INTRODUCTION

Limited media arbitration and resources are a few of the major issues in current wireless networks. Millions of devices with heavy traffic are using the transmission medium, it is assumed that such number will be increased by 1000-folds in the next 10 years. Therefore, this might lead to services necessitating reliability, high connectivity, high throughput, ultra-low latency enhanced fairness and so on. NOMA was presented for muddling through the epoch demands. In NOMA, a major aim is serving multiple users via the use of the same resource block. A balanced tradeoff between user fairness and system throughput is provided via NOMA [1], also it is suggested that it will be one of the vital technologies in 5 G network. Also, the 5 G-enabled devices are anticipated to have a constraint of latency as well as computationally-complicated applications that run on them

Initially, an overview of NOMA-MEC systems and MEC architecture is provided. The latest study on resource allocation to minimize task delay and consumption of energy is provided for the NOMA-MEC systems. Also, MEC is anticipated as one of the vital technologies for next-generation wireless networks because of its good efficiency in reducing latency and the consumption of energy [3]. As can be seen in Fig. 1, MEC has the ability for supporting many user types like mobile phones, IoT devices and self-driving cars at network edge, in which base stations (BS) which are supplied by servers of MEC might offer cloud such as computing services concerning the mobile devices with delay sensitive and computational intensive tasks [4]. With regard to MEC networks, almost all the computational tasks might be off-loaded to the server of MEC at BSs for remote computations. Tasks results might be downloaded to mobile devices following the task computation at BS [5], [6]. In terms of MEC offload, the tasks might be binary offloaded (for instance, computational task can't be partitioned and should be computed locally or fully-offloaded to the server of MEC) [7]– [10] or partial offloaded [1]

Thus, signals can be transmitted simultaneously by multiple users with low interference compared to OMA (i.e. orthogonal multiple access). Because of the high spectral efficiency, NOMA's resource optimization might accomplish better efficiency compared to OMA regarding the energy efficiency and the system sum rate [13] [14]

LITERATURE REVIEW

- MDPI/ "A Survey on Non-Orthogonal Multiple Access" (2020) – reviews SE and energy-efficiency tradeoffs; discusses NOMA+MEC and energy aspects. Use this for energy-centric arguments.
- Zaki, "Non-orthogonal multiple access system based on time diversity" (2022) – introduces TD-NOMA concepts and BER improvements via time diversity; useful for time-domain variant discussion.
- Celik et al., "Grant-Free NOMA" (Sensors, 2023) – grant-free synchronous NOMA design with low-complexity power control and UE clustering – directly relevant to reducing device complexity.
- Gupta et al., "NOMA-Enabled Computation and Communication Resource Trading for MEC" (2022) – concrete framework that jointly optimizes offloading and NOMA resource allocation to cut UE compute time; good for MEC+NOMA solutions.

METHODOLOGY

A single cell can be represented with 2*N number of users that have been served via single base station. In addition, this base station is considered to be supplied by MEC server with C cores, every one of them with a computational ability of f cycles/s. and a total system band-width of B. In addition, the hybrid NOMA method has been utilized for pairing users into N NOMA clusters, in which there are 2 users in each cluster. The study considers a single cluster with the users. User U can be residing at a distance dist from the base station, while u_2 resided at a distance dista from the base station, in a way that $dist_2 > dist_1$. With no generality losses, one can presume that there's a strong user with the allocated power P, along with the gain of the effective channel hy, yet ty has been a weak user with an allocated power P 2 and gain of effective channel h_2, in a way that $p_1 > p_2 h_2$. Assuming P_2.max and P_1 max were the maximal powers of transmission, which might be assigned respectively to u_2 & $u_{1,}$. It can be assumed that the d_1 bits were offloaded through d_2 and u_1 bits are off-loaded via u_1 to the server of MEC. In addition, complete approach of offloading is taken into account, in which no local computation was done. Each one of the bits is oftloaded through u is requiring a cycle, whereas that of u is requiring cz cycles for the computations at the server of MEC. Besides, the computation complexity regarding the off-loaded data depends on the type of offloaded data (video data requiring more cycles of CPU in comparison to the textual data). The total bandwidth of the system is divided to N frequency resource blocks, while the single resource of frequency block with band-width B = BT/N has been assigned to a NOMA cluster as well as being shared via paired users, comparable, cores at MEC servers have been split to N blocks of computational resources and have been assigned to NOMA clusters. The cluster's allocated computational sources ($C = C_T/N$) were distributed amongst the paired users, based on complexity in addition to the amount of data that is offloaded by them. Assuming ty and t were allocated with Ti and 2, cores.

The time of the transaction that is related to i^{-th} user has been $T_i = T_{txr} + T_{cr}$, iE {1,2}, in which Tie, represents the transmission time and is user's computational time, respectively. Also, the transmission time in terms of the ill user has been Tize=the user's data rate. In the presented study, the 2 user uplink NOMA cluster is taken into account, where U2 and vi experience channel gains of h2, and h in a way that user's u signal is going to be first decoded at the base station. In addition, the achievable data rate related to user i is going to involve the interference from user ty, while the achievable data rate regarding user 2 is going to involve only noise. The data rates depend on effective channel gains (ha, hi) as well as the allocated powers (P_2, P_1), in a way that [10]

$$R_1 = B_W\_\log_2 \left(1 + \frac{P1\,h1}{p2\,h2 + q2}\right) \ (1)$$

$$Pa = B_w \log 2 \left(1 + \frac{P2\,h2}{q2}\right) \ (2)$$

In which $\sigma^2 = B_w$, σ^2, σ^2 representing the noise's power spectral density and effective gain of the channel for the i-th user has been $h_i = \frac{h1}{dist1}$ in which hi represents the exponential gain of the channel (cone sponding to Rayleigh's fading) related to a user and p represents exponent's path loss. Also, the amount of offloaded data and effective channel gain values were related to paired users, yet, powers were optimized for reducing their difference of transaction time. Comparably, computational time in terms of ịth user is provided via T de which represents the number of cores that have been assigned to user i and f represents computational capacity regarding every one of the MEC cores. With regard to certain paired users, f and di were fixed. Furthermore, the amount of the computational resources that have been assigned to a user has been enhanced for balancing load over cores for reducing the differences between the time of the transaction. Through alterations, it has been inferred that T_1 and T_2 are identical, when

$$\frac{d_1}{R_1} + \frac{d_1 c_1}{n_1 f} = \frac{d_2}{R_2} + \frac{d_2 c_2}{n_2 f}$$
$$\frac{n_1 f d_1 + d_1 c_1 R_1}{n_1 f R_1} = \frac{d_2 n_2 f + d_2 c_2 R_2}{n_2 f R_2}$$
$$\frac{d_1 (n_1 f + c_1 R_1)}{n_1 R_1} = \frac{d_2 (n_2 f + c_2 R_2)}{n_2 R_2}$$
$$\frac{d_1}{d_2} = \left(\frac{R_1}{R_2}\right)\left(\frac{n_1 n_2 f + n_1 c_2 R_2}{n_1 n_2 f + n_2 c_1 R_1}\right)$$

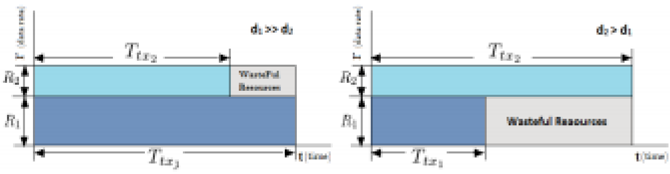

Fig1: Unequal Time of Transmission and Resource Waste

From3, one might divided the original formulated problem to 2 separate sub issues as well as reformulating it as T and T_2 are equal, when T_{iz} and Ting are equal, and when T_1 and T_2 are also equal. Figure (1) indicates un-equal results of transmission time in the waste that is related to allocated resources of frequency. Also, it might be reported that for S T - l time, resources were underutilized, for instance, a new NOMA signal might not be initiated. With the increase in such difference, there will be a decrease in network's spectral efficiency. In addition, the transmission time, Te, is considered to be equal for the two users, if = where R & R were data rates regarding the two users and 12, respectively. Comparably, the disparity in computational complexity and the amount of data that has been off-loaded via paired users (for instance, assigned with the same amount of the cores) leading to a waste of assigned computational sources. Furthermore, the difference of the computational time des = IT. -Til for two users was equal to 0, in the case when

RESULTS AND DISCUSSION

The original issue had indicated in earlier section can be provided as follows:

$$
\begin{aligned}
&(\mathbf{P}) \quad \min \quad \lambda, && (4a)\\
&s.t. \quad \left(\frac{d_1}{R_1} + \frac{d_1 c_1}{n_1}\right) - \left(\frac{d_2}{R_2} + \frac{d_2 c_2}{n_2}\right) \le \lambda, && (4b)\\
&\left(\frac{d_2}{R_2} + \frac{d_2 c_2}{n_2}\right) - \left(\frac{d_1}{R_1} + \frac{d_1 c_1}{n_1}\right) \le \lambda, && (4c)\\
&\lambda \ge 0 && (4d)\\
&0 \le p_i \le p_{i,\max} \quad i \in \{1,2\} && (4e)\\
&0 \le n_i \le C_t \quad i \in \{1,2\} && (4f)\\
&n_1 + n_2 \le C_t && (4g)
\end{aligned}
$$

In the case when problem (P) has been subjected to the constraints (4f), (4e) & (4g), for instance, power that is assigned to individual user has been positive and not more than respective maximal, the amount of the cores that have been assigned to certain user has been positive and not more than the total number of assigned cores. Besides, the summation of the cores that have been assigned for the two users was equal or not more than overall amount of assigned cores. As reported via formation of problem (P), it might be de-composed to 2 separate optimization sub problems. In addition, the original optimization problem results as well as sub problems were similar. The aim of 1st problem of optimization is minimizing the differences of the transmission time regarding certain paired users with identified di's, through enhancing the allocations of the power. From eq. (1) and eq.(2). There is:

$$R_1 + R_2 = B_w \log_2 (1 + \frac{P1h1+ p2h2}{\sigma 2}) \ (5\ a)$$
$$R_1 \leq B_w \log_2 (1 + \frac{P1h1+ p2h2}{\sigma 2}) - R_2, (5\ b)$$
$$= B_w \log_2 (1 + \frac{P1h1+ p2h2}{\sigma 2}) - R_2,$$
$$R_2 \leq B_w \log_2 (1 + \frac{P2+ h2}{\sigma 2}),, (5\ c)$$

For the aim of the power allocation, one might develop new variable; therefore, sub problem of the minimization of the transmission time differences that are related to paired users might be expressed in the following way:

$$(P1)\ \min \mu,$$
$$s.t. \quad \frac{a_1}{R_1} - \frac{a_2}{R_2} \leq \mu, \qquad (6b)$$
$$\frac{d_2}{R_2} - \frac{d_1}{R_1} \leq \mu, \qquad (6c)$$
$$\mu \geq 0 \qquad (6d)$$
$$0 \leq p_i \leq p_{i,\max} \quad i \in \{1, 2\} \qquad (6e)$$

In the case when the objective function (6 a) was subjected to (5 b, 5 c) data rate and power constraints of (6 e), through changing (6 b), one can obtain:
$\mu R_1 R_2 \geq \mu \geq d_1 R_2 - d_2 R_1$. (7)
In which a_1, & a_2 were the real valued variables with values such that the inequality would hold, eq. (7) equals

$$R_1 R_2 \geq \alpha_1, \qquad (8a)$$
$$\begin{bmatrix} \mu & \alpha_2 \\ \alpha_2 & \alpha_1 \end{bmatrix} \succeq 0, \qquad (8b)$$
$$\alpha_2^2 \geq d_1 R_2 - d_2 R_1, \qquad (8c)$$

In which (8b) represents a convex line matrix inequality (LMI), and (c) represents nonconvex. In addition, nonconvex parts in the left side of (Sc) might be approximated with a use of Taylor series expansions, for the purpose of getting approximated lower bund. Through using 1st Order Taylor Approximation, left side of (Sc) might be approximated as follows:

$$\alpha_2{}^2 \geq \left(\alpha_2^{(j)}\right)^2 + 2\alpha_2^{(j)}\left(\alpha_2 - \alpha_2^{(j)}\right)$$
$$\alpha_2{}^2 \geq \left(\alpha_2^{(j)}\right)^2 + 2\alpha_2^{(j)}\alpha_2 - 2\left(\alpha_2^{(j)}\right)^2$$
$$\alpha_2{}^2 \geq 2\alpha_2^{(j)}\alpha_2 - \left(\alpha_2^{(j)}\right)^2 \qquad (9)$$

In Eq. (9), the right side represents the first order approximation around point (0). Through the substitution of Eq. (9) in left side of (8 c), the (8 c) might be re-written as:

$$2\alpha_2^{(j)}\alpha_2 - (\alpha_2^{(j)})^2 \geq d_1 R_2 - d_2 R_1, \qquad (10)$$

In which, j is showing the number of iterations, a represents the value of 2 throughout jth iteration. Equation (Sa) can be re-written as follows:
$R_1 R_2 \geq \beta^2$ (11)
In which,$\beta^2 \geq \alpha_1$, the problem (PI) that has been specified in Eq. (6 a) that has been subjected to constraints that have been indicated in Eqs. (b), (10) and (11) representing a problem of convex optimization and might be solved effectively with the use of standard tool of convex optimization like CVX [11]. It is going to offer a solution of the lower bound approximation [12] [13] regarding (PI) because of 1st order Taylor's approximation in Eq10. Comparably, the aim of 2nd optimization problem is minimizing computational time differences regarding certain paired users with identified di's & G's through enhancing allocation of core. Through the introduction of new variable S, subproblem of computation resource allocation might be represented as follows:

$$\begin{aligned} \textbf{(P2)} \quad & \min \quad \zeta, & \text{(12a)} \\ & s.t. \quad \frac{d_1 c_1}{n_1} - \frac{d_2 c_2}{n_2} \leq \zeta, & \text{(12b)} \\ & \frac{d_2 c_2}{n_2} - \frac{d_1 c_1}{n_1} \leq \zeta, & \text{(12c)} \\ & \zeta \geq 0, & \text{(12d)} \\ & 0 < n_i < C_t, & \text{(12e)} \\ & n_1 + n_2 \leq C_t & \text{(12f)} \end{aligned}$$

In which the objective function (12a) has been subjected to constraints (12 e), the number of cores that have been assigned to certain user was more than 0 and not more than the total cores that have been assigned to cluster and (12 f), the summation of cores that have been assigned to the two users was equal or not more than the total cores that have been assigned to cluster. Also, the number of cores that have been assigned to certain user should be > 0 for the purpose of ensuring the minimal requirement of a user. Furthermore, integer constraint has been relaxed for 1, through changing (12b), one might have:

$$\zeta n_1 n_2 \geq \zeta \gamma_1 \geq \gamma_2^2 \geq (d_1 c_1) n_2 - (d_2 c_2) n_1, \qquad (13)$$

In which, 71 and 2 were variables with real values. Eq (13) indicates:

$$\begin{aligned} & n_1 n_2 \geq \gamma_1, & \text{(14a)} \\ & \begin{bmatrix} \zeta & \gamma_2 \\ \gamma_2 & \gamma_1 \end{bmatrix} \succeq 0, & \text{(14b)} \\ & \gamma_2^2 \geq (d_1 c_1) n_2 - (d_2 c_2) n_1, & \text{(14c)} \end{aligned}$$

In which, (14b) represents a convex LMI. In Eq (14c), the left side might be approximated with the use of the expansion of the Taylor series for getting approximated lower bound. Through using 1st Order Taylor's Approximation, (14 c) left side might be approximated in the following way:

$${\gamma_2}^2 \geq 2\gamma_2^{(j)} \gamma_2 - \left(\gamma_2^{(j)}\right)^2 \qquad (15)$$

In Eq. (15), the right side represents the first order approximation around point (2). In the case of performing the substitution of Eq15 to left side of (14 c), this (14 c) might be re-written according to the following equation:

$$2\gamma_2^{(j)} \gamma_2 - \left(\gamma_2^{(j)}\right)^2 \geq (d_1 c_1) n_2 - (d_2 c_2) n_1, \qquad (16)$$

Fig2: Difference of the Transaction Time for the Benchmark (or No Optimizations) Cases, method A, B & C

In which, hi's were updated in each one of the iterations and showing the number of iterations. From (14a), one can have:

$$\begin{aligned} & n_1 n_2 \geq \eta^2, \qquad (17) \\ & \eta^2 \geq \gamma_1. \end{aligned}$$

In which, problem (P 2) that has been specified in Eq. (12 a) that has been subjected to the constraints that have been defined in Eqs. (14 b), (16) & (17) represents a problem of convex optimization and might be solved effectively with the use of standard tool for convex optimization like CVX [11].

In terms of certain users' pair, one can acquire optimal values related to number and power of the cores, as soon as optimization has been carried out. Those parameters are leading to minimizing difference of transaction time that will be shown in the upcoming section.

Discussion

The maximal pxwer in terms of 11. Dima, has been 2W and of 2, 2x. was 4W. Initially, pa is 2W and Pi is IW. The dista and dist are 600m and 200 m, respectively. Also, the path loss exponent has 3.80 and cluster band-width has been 200kHz. The difference of the transaction time has been specified for 3 methods, which are: Power Optimization with Equal Core Allocation (A), with Random Core Allocation (B) and proposed with Optimum Core Allocation (C). The optimization of core and power may be reached through the successive convex approximations as it has been indicated in section3. In the case of the equal core allocations, cores are divided equally amongst paired users, in other words, T2=T. In the random core allocations, cores are divided in a random manner amongst paired users Tlz=(1-K) and T = KC, where, K is from uniform random distribution that varies between 0 and I. The offloaded data amount ratio, in other, dz/d and complexity, in other words, C2/C are different for the purpose of studying their impacts upon the time of the transaction.

Fig2 illustrates the difference of the transaction time with no optimization of the power and equal number of the core allocations, in other words, benchmark case, approaches A, B & C in the contour plots from the left to the right. It may be noticed in all of the plots that for a specific value of the dadi various values of c/c yield different differences of the transaction time. The increase in the difference of the transaction time, results in increasing under-utilized sources. It may be noticed that the difference of the transaction time for the 2nd plot (in other words, method A) is overall lower than previous.

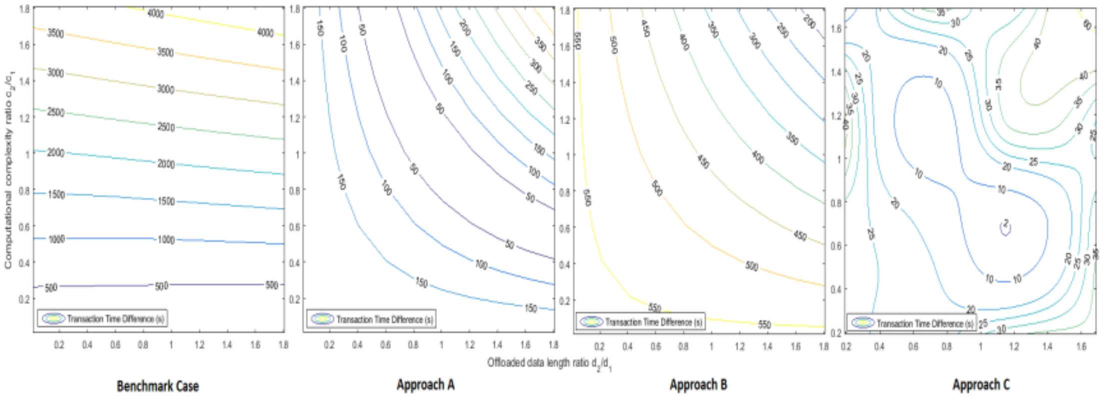

Fig.2: Comparisons of the Results of the Optimization and Simulation

For the same c/cy and da/d, ratios the difference of the transaction time has been decreased through the optimization of power allocations only. The difference of transaction time for the Approach B (3rd plot) is lower compared to difference of the transaction time for the 1st plot (benchmark case). None-the-less, such difference has been similar to the Approach A, as they differ only in core allocations. The difference of the transaction time for the suggested method (Approach C, 4th plot in Fig2), where the power as well as the cores are enhanced is minimal. It's clear as well that paired users have optimum c/c and dz/d values for which difference of the transaction time has been minimal. For example, in 4th plot Fig2, in the case where dz/d = 1.20, the difference of the transaction time has been 2sec. for c/c = 0.70. As dz/d has been increased to 1.70. the gap of the transaction time is increased to 35sec. for an identical ca/c ratio. In the same way, in the case of the decrease of da/di to 0.70, the difference of the transaction time is increased to 20sec.
For the purpose of validating the suggested solution, approach A, approach B and approach C can be solved heuristically as well through searching over entire space of the solutions, which has been referred to as "Simulation" and compared to results that have been obtained for methods A, B & C with the use of the approach of the successive convex optimization, which has been referred to as "Optimization"

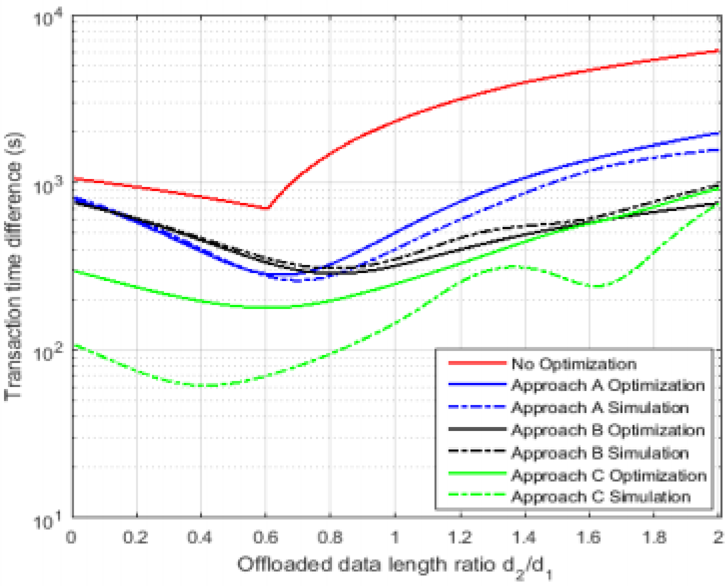

Fig3: Effective Throughput of the System

Fig3. Maximal number of the iterations for results of Optimization for Approach A, Approach B and Approach C has been fixed to 100. In Fig3, in the case where dz/d equals 0.40. the difference of the transaction time without the optimization has been 822sec., about 402sec for the optimized as well as the heuristic solutions of Approach A

and 467sec. for B. The difference of the transaction time for Approach C reaches 61.58sec. and 196.10 sec. respectively for the heuristic and optimized solutions,. The differences between the results of the optimization and simulation are a result of using the expansion of Taylor's series for the approximation.
Now, effects of the reduction of the time of transaction on the system's effective throughput are illustrated, which can also be represented as:

$$\Phi_{eff} = \frac{\sum_{i=1}^{2} R_i}{\max(T_1, T_2)}, \quad (18)$$

where the numerator represents summation of the data rates that have been accomplished by paired users whereas denominator represents maximal value of the paired users' transaction times. After the two users have been paired, which is why, resources that have been given to them are only free in the case where the two of them have completed their transaction, therefore, denominator is identified by maximal (.) operator. A reduction in the effective time of transaction results in increasing the effective throughput of system. It has been evident from Fig4 that for the fixed c/c value and a da/d range, the effective throughput of a system for suggested Approach C is higher compared to the rest of the methods. Has been clear as well that the increase in the disparity of the offloaded data, results in increasing the value of the difference between the effective throughput of a system for compared approaches. The reasons behind such trend represents optimum core allocation. In the case where off-loaded data is same in the characteristic (in other words, complexity and amount are similar, the schemes' core allocations are similar (i.e.. the same amount of the cores for no optimization, Approaches A & C) and differences in the throughput appear only due to the allocation of the power. None-the-less, with the increase in the disparity of the offloaded data, the suggested scheme's performance in better than the others. The mean value of the increase in effective throughput of the system has been 19% for case that has been illustrated in Figure 4.

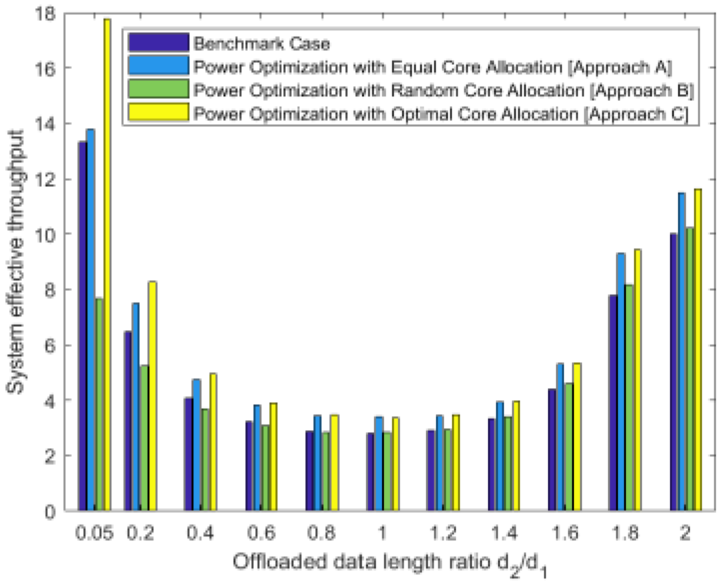

Fig 4. System Throughput Effective

CONCLUSION

In the present, it can be seen that the time of the transaction has a significant impact on the improvement of general utilization of the resources and the difference in the transaction time of 2 users is reduced through the optimization of transmission powers as well as the computational resources allocations separately. The suggested optimization has led to an increase in the system's effective throughput. As one of the future directions to the present study, joint problem may be studied as well at the time of considering the correlations of the communication and the computational resources. The method may be extended into several users in the NOMA clusters. The scheme of the data aware clustering of NOMA may be utilized where users have been paired, taking under consideration disparity of power and their data offload requirements that may play a role further toward improving the system's effective throughput as well as the spectral efficiency.

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