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User Offloading using Hybrid NOMA in Next-generation Heterogeneous Network

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Abstract: Millimeter wave (mmWave) enabled Heterogeneous network (Hetnet) has become ubiquitous because of the great demand of mobile network applications. Non–Orthogonal multiple access (NOMA) bids a desired possible assistance, for example condensed inactivity with great consistency, enhanced spectrum efficiency and considerable affinity. NOMA is envisioned to be used with small cells enabled with mmWave environment. This work proposes an ubiquitous connectivity between users at the cell edge and offloading macro cell so as to provide features the macro cell itself cannot cope with, such as extreme changes in the required user data rate and energy efficiency.The amount of inter-cell and performance is analyzed in the boundary and in the midpoint of the cell. It shows a reduction in outage possibility of 90% for cell center user (CCU) and 48% for cell edge user (CEU). Thereby alleviating dead zones and energy efficient support is shown for transmission using carrier sensing NOMA.

Keywords: Heterogeneous network; millimeter wave; Non-Orthogonal multiple access; Small cells

Uporabniška razbremenitev z uporabo hibridnega NOMA v heterogenem omrežju naslednje generacije

Izvleček: Heterogeno omrežje (Hetnet) z milimetrskim valovanjem (mmWave) je postalo vseprisotno zaradi velikega povpraševanja po mobilnih omrežnih aplikacijah. Neortogonalni večkratni dostop (NOMA) ponuja želeno možno pomoč, na primer zgoščeno neaktivnost z veliko doslednostjo, izboljšano učinkovitostjo spektra in veliko naklonjenostjo. NOMA naj bi se uporabljal z majhnimi celicami, ki jih omogoča okolje mmWave. To delo predlaga vseprisotno povezavo med uporabniki na robu celice in razbremenitev makrocelice, da se zagotovijo funkcije, ki jih makrocelica sama ne more obvladati, kot so ekstremne spremembe zahtevane hitrosti prenosa podatkov uporabnikov in energetske učinkovitosti. Pokaže se zmanjšanje možnosti izpada za 90 % za uporabnika v središču celice (CCU) in 48 % za uporabnika na robu celice (CEU). S tem se ublažijo mrtve cone in prikaže energetsko učinkovita podpora za prenos z uporabo zaznavanja nosilcev NOMA

Ključne besede: Heterogeno omrežje; milimetrski valovi; neortogonalni večkratni dostop; majhne celice

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1 Introduction

Fifth generation (5G) cellular networks require up to about a thousand times (1000x) more surface capacity than current long-term networks. In view of its benefits sub-channel allocation is adapted using the orthogonal frequency division multiple access (OFDM) multiplexing technique. [1] Achieving wireless multiple access on OFDM-based systems is implemented in two ways - orthogonal frequency division multiple access (OMA) [2] and non-orthogonal multiple access (NOMA) [3]. By exploiting the multi-user diversity gain, system throughput can be exploited in OMA [4]. It relies on the known channel state information of all sub-channels and accordingly sub-channel allocation is done for only one user. Regardless of the throughput system,

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OMA has a disadvantage when communicating at very high data speeds. It does not allow frequency reuse in a cell [5], since a subcarrier in an OFDMA cell is allocated to only one user, which limits the sum data rate of the cell significantly. Unlike OFDMA, NOMA technique allocates a subcarrier to more than one user at a time in a cell, which ensures higher throughput due to subcarrier reuse and therefore NOMA is considered as a major enabler for the next-generation heterogeneous networks. [6,7]The convergence of fixed and mobile access networks can be resolved by the NOMA access network. The system should allow the transmission of numerous types of broadband telecommunication traffic since the end user desires wireless broadband access. [8] The congestion is reduced in traditional wireless networks by offloading with small cells in Hetnet.

1.1 Motivation

In order to improve the system performance, it is very stringent to use a single technology, e.g. Connectivity and the data-rate. NOMA utilizes the knowledge of superposition coding and successive interference cancellation in the transmitter and receiver. [9]. NOMA works in conjunction with various radio interface technologies, such as multi-cell scenarios, millimeter wave [10] and reconfigurable antenna systems [11], and other Internet of things platforms. NOMA technology is used with beamforming technology to improve the device to device communication in the small cell environment [12]. NOMA accomplishes this by multiplexing various transmitted signals into a stream of single signals by taking advantage of the power domain area. In view of the user centric point, successive interference cancellation (SIC) is the technique to receive the desired signal information and the remaining signals are disposed to remove interference. The request for execution of SIC is controlled by the expanding user channel state information (CSI) [13], i.e., the user is considered as the strong cell center user with high channel gain, this part is known as a cell center user (CCU), to unravel and offset data of the low-gain users, this part alluded to as a cell edge user (CEU). As of now, the utilization of NOMA in Hetnet includes device- to-device spectrum allocation and power control.Significantly three methodologies are utilized. In the cooperative NOMA near users (i.e CCU) is utilized to assist a distant user (i.e CEU). The second strategy is to introduce fairness among users by using design variables such as weighted sum-rate and the last strategy is to maintain the minimum requirement of the CEU. Therefore NOMA is treated as a transfer to help far users in wireless communication.[14]

Therefore, the first challenge is to obtain the CSI of the co-channel users. There is strong residual interference among NOMA users without the knowledge of CSI of the interference, reliable communications is questionable. The second challenge is to remove the interference from the different signals of the co-channel users. A novel Interference cancellation technique is necessary to feat information of and suppresses the interference from all the overlapping symbols of the co-interference. It is accomplished using spectrum reuse techniques with NOMA known as user-pairing algorithm.The intra-cell interference is reduced and limited by using spectrum reuse techniques with Hybrid NOMA known as user-pairing algorithm. The contributions are as follows,

- The user-pairing algorithm is applied to cancel out co-channel interference thereby achieving increased sum rate
- Analyzing outage probability for the CCU and CEU thereby achieving offloading macrocells.
- A novel interference cancellation is exploited to reduce intracell and intercell interference thereby achieving spectral efficiency.

2 System model

A two-tier hetnet is considered where the macro and small base stations (BSs) are situated in the focal point of the cell and its inclusion region is a circle of range R. The BS serves Cell User equipment's (CUEs) which are consistently circulated in the inclusion region. The precoding can be utilized to control the obstruction caused among the CUEs. The uplink system model for the nth user access is shown in Fig.1, where small cell environment is shown with cluster of users categorized into CCU and CEU. N is the total number of users in the cell, and N ≥ 2M. The total number of antennas employed at the BS is represented as M. User equipment (UE) is attached with a single antenna. The different bandwidths allocated to UE in the OMA and hybrid NOMA schemes are demonstrated in Fig.2. The hybrid NOMA is served for different users irrelevant to position simultaneously in the same frequency. The femtocell user equipments (fCUE)are indicated in sub-channel which is assisted by femto BSs and indicated as macrocell user equipments (mCUE) in sub-channel which are assisted by macro BSs. The channel fading coefficients of UEs are assumed as

$$h_1^f > h_2^f > h_3^f > h_4^f \ldots\ldots\ldots > h_N^f \quad (1)$$

Where $h_1^f \ldots\ldots h_N^f$ represents the channel fading coefficient of strong signals in ascending order. Thus, in the given scenario, the received signals of the cluster group of uplink (UL) users, y, are given by,

$$y = h^{f}_{iN} x_{iN} + \sum_{l=1,l\neq i}^{N} \sqrt{p_l^f x_l^f} + n_{iN} \tag{2}$$

Where

$$x_{iN} = \sqrt{p_{iN}^f x_{iN}^f}$$

is the desired signal term transmitted symbol and power assigned to UE. $\sqrt{p_l^f x_l^f}$ is the interference from the other symbols n_{iN} denoted as the additive white Gaussian noise (AWGN) with variance σ^2.[15]

2.1 Path loss Model

The mmWave propagation environment is modeled by widely adopted distance dependent path loss model and is given as

$$L_{mm}(r) = \rho + 10\alpha \log(r) + \chi_{mm} \tag{3}$$

In the given equation ρ = 32.4 + 20*log* (f_c) where f_c represents the mmWave carrier frequency and the distance is represented as r. χ_{mm} is the shadow fading in mmWave link. The path loss exponent is denoted as α. [16]

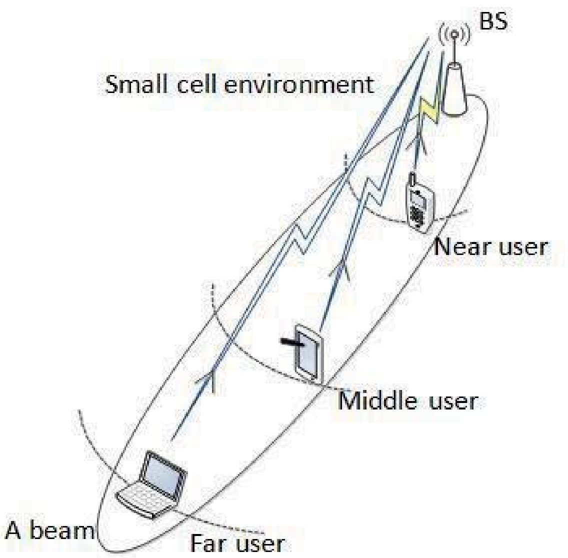

Figure 1: The System model of uplink NOMA-Hetnet

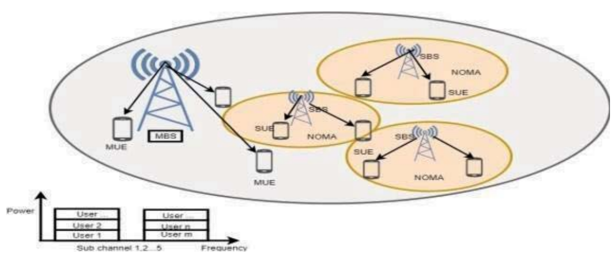

Figure 2: Energy efficient NOMA based HetNets [15]

NOMA uses a successive interference cancellation (SIC) technique to correctly demodulate signals at the receiver since it can allocate a subchannel to several users. The goal of differentiating users is achieved by SIC's ability to remove interference in a certain order based on the power of various users. We presume that every terminal is fully aware of the channel state data (CSI). The uplink channel estimate in time division mode can provide with transmitter-side channel estimation, which can be used to obtain receiver-side channel estimation. Additionally, since one of our optimization goals for the given system is to maximise total harvested energy, we can infer that gathered energy somehow falls below the receiver saturation threshold.

2.2 Performance metrics

The performance of mmWave enabled Hetnet is analyzed based on the metrics as Signal to Interference plus Noise Ratio (SINR), followed by Sum-Rate of an UE and Energy efficiency. Successive detection is carried out in descending order; The SINR is given as

$$SINR_{iN} = \frac{p_{iN}^f x_{iN}^f \left|h_{iN}^f\right|^2 L_{mm}(r)}{\left|h_{iN}^f\right|^2 \sum_{l=i+1}^{N} p_{lN}^f + \sigma^2} \tag{4}$$

The achievable rate of NOMA UL user is denoted as

$$R_{iN} = B \log_2\left(1 + \frac{p_{iN}^f x_{iN}^f \left|h_{iN}^f\right|^2 L_{mm}(r)}{\left|h_{iN}^f\right|^2 \sum_{l=i+1}^{N} p_{lN}^f + \sigma^2}\right) \tag{5}$$

where B is the bandwidth of mmWave enabled hetnets. The conventional OMA sum rate is obtained as

$$R_{iN} = B/N \log_2\left(1 + \frac{p_{iN}^f x_{iN}^f \left|h_{iN}^f\right|^2 L_{mm}(r)}{\left|h_{iN}^f\right|^2 \sum_{l=i+1}^{N} p_{lN}^f + \sigma^2}\right) \tag{6}$$

The important parameter metric is energy efficiency (EE) of the Hetnet. The objective is to target the decreased power consumption so as to increase the overall EE of a network.EE is maximized by optimizing the power allocation coefficients.

$$EE = \frac{Acheivable\ data\ rate\,(bps)}{Total\ power\ consumption\left(\frac{Joule}{s}\right)} \tag{7}$$

Total Power consumption is derived as

$$P_{Total}^f = \frac{1}{\varepsilon_p} \sum \beta_{iN}^f p_{iN}^f + \sum P_{st}^f \tag{8}$$

The first component represented the dynamic power of femto BS which constituted the dissipation of power amplifiers. The term $\varepsilon_p \in \{0,1\}$ denoted the power amplifier efficiency of the femto BS. β_{iN}^{f} is the fair power allocation ratio. The second component represents static power which is consumed by the transmitted signals and operating components.

3 Hybrid NOMA user-pairing algorithm

Multiple users are supported by NOMA simultaneously in the same frequency in hybrid NOMA. Hybrid NOMA is a combined technique of OMA and NOMA,the users per carrier is increased indefinitely without compromising sum rate. A user-pairing primarily based totally suboptimal scheme. It is a proposed hybrid NOMA where different access schemes are combined with NOMA to facilitate the deployment. A user-pairing algorithm for Hybrid NOMA is served in different time slots to offload macrocell and to assure the quantity of accessed users.

Hybrid NOMA user-pairing algorithm is derived to perform multiplexing of more than two users in the same frequency carrier to accommodate more users in hetnet. The user-pairing is done for two scenarios based on the distances of UEs. The user is considered as strong and weak according to the cell position.

Near users is a strong one whereas far users are weaker. In order to offload the macro cell, small cells are assigned to provide ubiquitous connectivity using a user-pairing algorithm.

This work aims to maximise the system's overall energy efficiency while reducing the system's energy consumption. As a result, this formula expresses the link between the system sum rate and overall power consumption. We also take the base station with the energy harvesting unit into account when allocating the subchannel and power resource.

Hybrid NOMA User-Pairing Algorithm	
Initialize	a) Set of users $Ui = \{1,2,3\ldots.N\}$ b) Set of sub-channels $S = \{1,2,3\ldots\ldots.K\}$ c) Set the sub-channel power allocation coefficient β_{iN}^{f} d) Set of power values
Ensure	The number of split sub-channels k, the user-pairing strategy a) Near-Far user pairing (N-F) b) Near-near, far-far user pairing (N-N, F-F)
Sort	Sort transmission powers in ascending order. Assume P1< P2< ::: <Pn.
Order	Channel conditions as $\left\|h_1^f\right\|^2 > \left\|h_2^f\right\|^2 > \left\|h_3^f\right\|^2 > \left\|h_4^f\right\|^2$
Choose	Power allocation coefficient $\beta_{iN}^{f} = 1 \forall Ui$
Obtain	Sum Rate
	End if

Here the far user is given the higher fraction of power whereas the near users are given lower fraction of power. But the cumulative result should not be exceeded 1. For example $\beta_{i1}^{f} = 0.75\, and\, \beta_{i2}^{f} = 0.25$ for two users are assigned. The higher fraction of power is given to the far users. The distances are assumed for far user is d_1=1000 *meters* and near user is d_2=500 *meters*.

4 Results and discussion

Simulation results are furnished to assess the overall performance of hybrid NOMA Hetnet.The overall performance of user-pairing hybrid NOMA schemes has been explored in which we have CCU and CEU ,i.e three UEs in a cell. The parameters are listed in table 1.

Table 1: Evaluation Parameters

Parameter	Default Value
Macro Transmit Power	46 dBm
Femto Transmit Power	18 dBm
Macrocell radius	500 m
Femtocell radius	50 m
Number of fCUE in each femtocell	3
Number of mCUE in macrocell	3
Shadowing standard deviation	10 dB
System Bandwidth	100 MHz
mmWave carrier frequency	28 GHz
Noise power spectral density	-174 dBm/Hz

The transmit power of macrocells and femtocells and their coverage radius are listed. The total number of macro CUEs and femto CUEs are listed as well. However we have evaluated the scenario by increasing the number of UEs.

The proposed user-pairing algorithm offloading CEUs and fair power allocation solutions is evaluated through hybrid NOMA user-pairing algorithm and compared with the OMA strategies. Fig. 3, is portrayed sum capacity in terms of their transmit Signal to noise Ratio (SNR). It is clear from Fig. 3 that hybrid NOMA scheme provides better sum-rate when compared to other schemes in perfect SIC mode. This performance is due to their distinct channel conditions, when the near strongest user (CCU) is paired with the far weak user (CEU), an achievable good sum rate is arrived. The improvement is not significant when pairing near-near and far-far, but still the sum rate performance is better compared to TDMA. The Single carrier NOMA (SC-NOMA) is not up to the level when compared to TDMA and hybrid NOMA. This is due to the overloading of users in the same carrier.

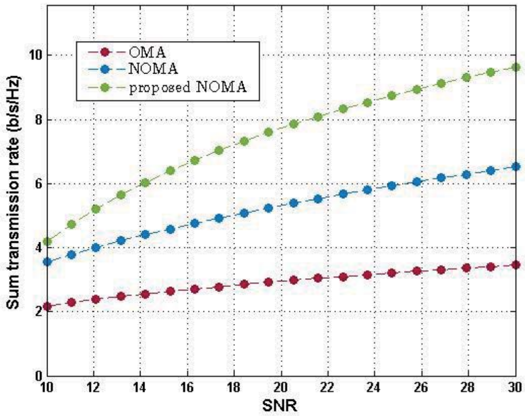

Figure 3: Sum rate comparison between proposed hybrid NOMA scheme with OMA schemes

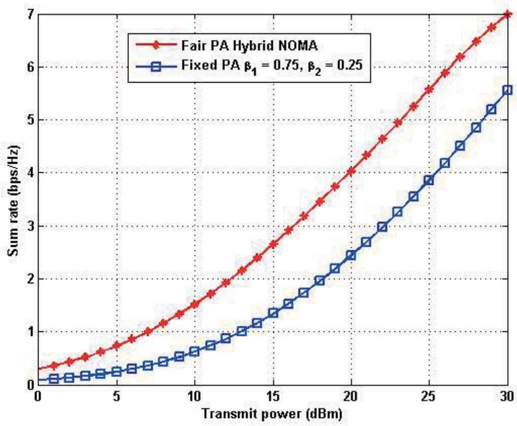

Figure 4: Sum rate comparison between proposed hybrid NOMA scheme with fixed power allocation.

Power allocation factor is the next important parameter that has the peculiar impact in the design performance of hybrid NOMA; hence evaluation is based on the distance between near user and BSs respectively. In Fig. 4 increasing transmitted power produces better sum rate capacity in the midst of lower SNRs. Thereby near user's power to far users' powers raises interference, for this reason fixed power allocation cannot be increased arbitrarily. An unconstraint maximization problem is used to find the optimal power-splitting ratio that returns the maximum instantaneous system throughput.

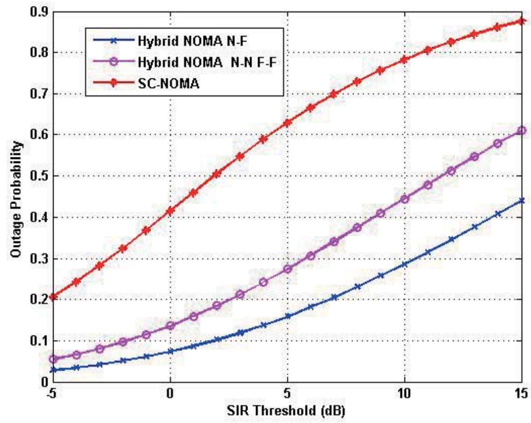

Figure 5: Outage Probability Vs SIR threshold

Fig. 5 shows that outage is increased when the Signal to Interference Ratio (SIR)increases. When the distance increases, the outage probability is also increased for the multiple input multiple output (MIMO)-NOMA system. The greater the distance leads to greater interference.To examine the impact on outage performance, the transmit SNR of the two users is set to be equal and varied from 0 to 60 dB. The figure shows that, at a power ratio of 15 dB, both users' outage performance achieves an interference-limited floor at a transmit SNR of roughly 15 dB, and that additional increases in transmit SNR have no effect on the users' outage probability performance.

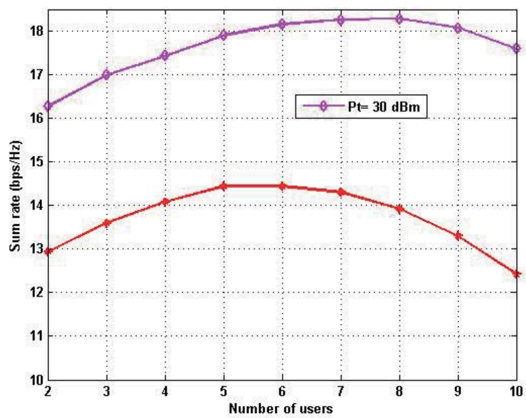

Figure 6: Sum rate comparison vs Number of users

Fig.6 is a sum rate comparison when the number of users increased. This sum rate is the outcome of user-pairing algorithm. It can be compared for individual CCU, CEU and middle users. The first user's signal becomes much stronger than the second user's signal as the power ratio between the users rises, and many of the first user's symbol estimates are highly likely to be accurate.

The cluster comparison is given in Fig.7.Hybrid NOMA is a beneficial strategy for uplink transmission in future wireless communications since it can solve a significant issue with OMA-based techniques, which is to not allow frequency reuse inside one cell. The impact of power allocation on NOMA communications led to the development of the unique hybrid NOMA technique which can take use of both the near-far effect and frequency reuse.

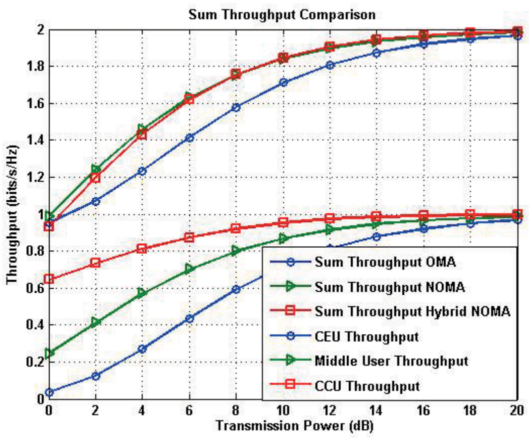

Figure 7: Throughput Comparison between proposed hybrid NOMA schemes with fixed power allocation.

Table 2: Data rate comparison between NOMA and OMA

	Distance	50m	100m	150m
NOMA	mCUE Data rate	2.2 Mbit/s	2 Mbit/s	1.8 Mbit/s
	f CUE Data rate	1.4 Mbit/s	1.2 Mbit/s	1 Mbit/s
OMA	mCUE Data rate	1.8 Mbit/s	1.5 Mbit/s	1.2 Mbit/s
	f CUE Data rate	1 Mbit/s	0.8 Mbit/s	0.4 Mbit/s

Table 2 provides various user data rate experience, which are taken into account. As the average distance increases between users, it can be observed that the performance of OMA declines linearly. Due to lower average SNR, the second and third users achieve less bits per symbol. This is a result of significant user interference. The performance steadily improves as the power ratio rises, although it is still significantly inferior to OMA.

Figure 8 shows the average EE comparison between OMA and NOMA schemes.The performance advantage over Hybrid NOMA grows as the power ratio rises. This is because Hybrid NOMA enables simultaneous access by allusers to a subcarrier. While the feasible bits/symbol for the near and far users are lowered due to the reduced average received SNR, other users' co-channel interference is also reduced.However, the poorest user's energy efficiency decreases to roughly 1.8Mbits/joule when OMA is used.We can see the superiority in attaining EE while using user-pairing scheme.

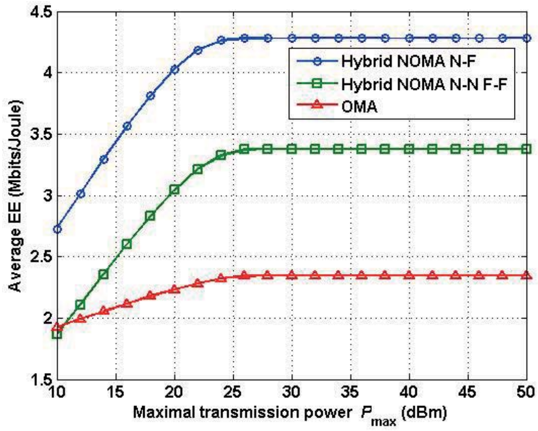

Figure 8: Average EE between proposed hybrid NOMA scheme with OMA.

5 Conclusion

Millimeter wave (mmWave) enabled Heterogeneous network (Hetnet) has offered ubiquitous connectivity with the aid of Hybrid NOMA user pairing algorithm because of the great demand. Hybrid NOMA is envisioned with superior performance with small cells enabled with mmWave environment. This proposed work outage performance is shown and offloading macro cells such as extreme changes in the required user data rate and energy efficiency.The congestion is reduced in traditional wireless networks by offloading with small cells in Hetnet. The outage performance is analyzed for the alluded users particularly in the cell edge weak users. It shows a decrease in outage probability of 90% for near users i.e cell center user (CCU) and 48% for far usersi.e cell edge user (CEU). Thereby alleviating dead zones and energy efficient support is shown for transmission using carrier sensing NOMA. A major enabler for handling the enormous number of Internet of devices that will be deployed in the factory of the future is widely recognized as being NOMA.

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