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Analysis of Non-Orthogonal Random Access for 5G Networks using MATLAB

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Abstract **- For the next generation of Cellular and Wireless communication systems, the key requirements are to efficiently support a massive amount of User Equipment's. In this paper, to reduce the access congestion problem, the Non-Orthogonal Random Access (NORA) scheme based on SIC is proposed. This scheme identifies multiple user equipment's with an identical preamble by utilizing the time of travel difference which thus enables power domain multiplexing. On Simulation, Results show that the number of user equipment's can be improved by 30% and the access delay is also reduced significantly.**

Keywords**- Include at 5G Mobile Communication, Access Delay, Collision Probability, Message Transmission, NORA, Random access, User Equipment's.**

I. INTRODUCTION

Next generation communications systems are expected to support a variety of services such as high reliabilities and data rates, less delay, etc. Especially the fifth generation, that has drawn the attention of engineers and researchers around the world which expands broadband wireless services beyond mobile internet for critical communication systems, IOT and will support thousands of user equipment's. This generation promises to deliver enhanced end-user experience by offering services and new applications through gigabit speeds and improved reliability which is expected to decrease latency to below 1 ms.

For initial uplink access, the user equipment performs a random-access procedure to connect with the base station. When the number of user equipment's is tremendous, the random-access procedure is inefficient due to collisions which lead to delay and congestion thus resulting in an obstruction for 5G network performance. As no. of user equipment's grow, the congestion increases which end up in repeatedly transmitting preambles until the maximum is reached on which the user equipment's declare the access failure and exit the random-access process. To improve LTE random access performance, most of the existing systems mainly focus on controlling the traffic or increasing the random-access resources which are limited.

II. NON-ORTHOGONAL RANDOM-ACCESS MECHANISM

NORA scheme consists of Physical Random- Access channel transmission and response, layer 3 message transmissions and contention resolution.

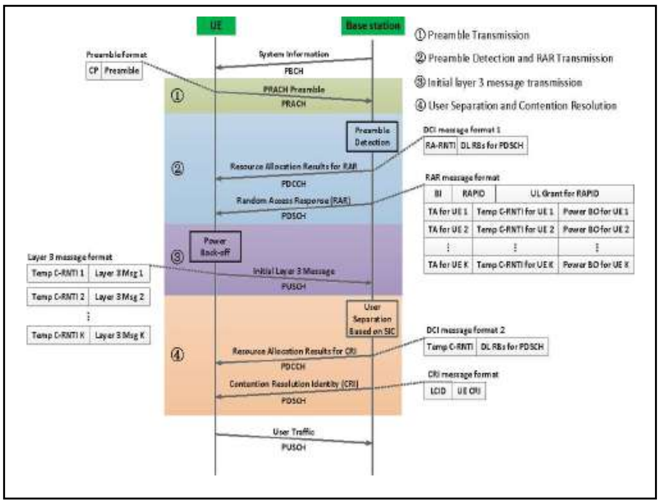

Fig.1. Non-Orthogonal Random Access.

1. Preamble Transmission

Firstly, every user-equipment receives system information broadcast on PBCH which requires necessary information which includes Root sequence Index, PRACH configuration Index etc. and RACH configuration Information for completing the RA process. When user equipment starts to perform random access, it randomly selects a preamble sequence which then broadcasts to the next available random-access slot.

Based on the mechanism, the expected no. of successful transmissions is given as

$$E[S] = R\left(E[Y_r^1] + p^{s2}E[Y_r^2] + p^{s3}E[Y_r^3] + p^{s4}E[Y_r^4] + \cdots\right). \quad (1)$$

The total no. of user equipment's whose preambles are detected in the kth random-access slot is given by

$$U_{k,PS} = \sum_{l=1}^{L} U_{k,PS}[l] \approx \left(1 + \frac{p^{s2}(U_k - 1)}{2(R-1)}\right)\left(\sum_{l=1}^{L} U_k[l]\, p_l\right) e^{-\frac{U_k}{R}} \quad (2)$$

2. Preamble Detection and RAR Transmission

Within a specific time, relevant PRACH signals are first extracted through time-domain sampling from the base station which computed preamble power delay profile. Each cyclic shift defines a zero-correlation zone and the length of each is determined by the cell size. The physical downlink control channel contains the downlink resource block which directs the user equipment to the associated random-access response within the shared channel. In NORA, the user equipment's are considered by eNodB with detected collisions as a group and respond. Based on the received signal strength the user equipment estimates the distance from the base station.

3. Layer 3 Message Transmission

In NORA based on SIC, the base station performs user separation for which the power back-off scheme is introduced. In a NORA group, the transmit power of the ith user equipment is given by

$$P_{U,i} = \min\{P_{Umax}, P_{O\_U} - (i-1)\delta + 10\log_{10}(M_{U,i}) + \alpha PL_i\} \quad (3)$$

III. PERFORMANCE EVALUATION

1. **Collision Probability (PC):** The ratio between the number of undetected collided preambles and the overall number of preambles. The no. of undetected collided preambles which are equal to the total no. of preambles minus the no. of idle preambles and successfully received preambles.

$$P_C = \sum_{k=1}^{K}\left(R - R\left(E[Y_r^0 | U_k]\right) - U_{k,PS}\right) \Big/ KR \quad (4)$$

Access Success Probability (PS): The ratio between total no. of successfully accessed user equipment's to the total no. of user equipment's arrived in preamble transmission.

$$P_S = R_{RA/U} \quad (5)$$

2. CDF of the Number of Preamble Transmission (F(m)):

It is defined as the cumulative distribution function of the no. of preamble transmissions for performing a random-access procedure for the successfully accessed user equipment's.

$$F(m) = \sum_{k=1}^{K}\sum_{l=1}^{m} U_{k,MS}[l] \Big/ \sum_{k=1}^{K}\sum_{l=1}^{L} U_{k,MS}[l] \quad (6)$$

3. CDF of Access Delay (G (d)):

It is cumulative distribution function of the delay between the first preamble attempt and the competition of the RA process for the successfully accessed user equipment's.

$$G(d) = \sum_{k=1}^{K}\sum_{l=1}^{m_{\max}(d)} U_{k,MS}[l] \Big/ \sum_{k=1}^{K}\sum_{l=1}^{L} U_{k,MS}[l] \quad (7)$$

4. Average No. of Successfully Accessed Preamble Transmission User Equipment's:

The ratio between total no. of preamble transmissions for all the successfully accessed user equipment's and the total number of all the successfully accessed user equipment's.

$$\bar{L} = \sum_{k=1}^{K}\sum_{l=1}^{m} U_{k,MS}[l] \cdot l \Big/ \sum_{k=1}^{K}\sum_{l=1}^{L} U_{k,MS}[l] \quad (8)$$

5. Average Access Delay (DRA):

It is the ratio between the total access delay of preamble transmissions for all the successfully accessed user equipment's and the total number of all successfully accessed user equipment's.

6. Throughput of Preamble Transmission (RNORA):

It is defined as the no. of given successful transmission preambles to the simultaneous preamble transmissions. In NORA, the maximal throughput transmission 20 can be achieved when m is equal to 69 (30% improvement in throughput compared to ORA).

$$R_P^{NORA} = E[S] = m\left(1 + \frac{p^{s2}(m-1)}{2(R-1)}\right)\left(1 - \frac{1}{R}\right)^{m-1} \quad (10)$$

IV. SIMULATION ANALYSIS

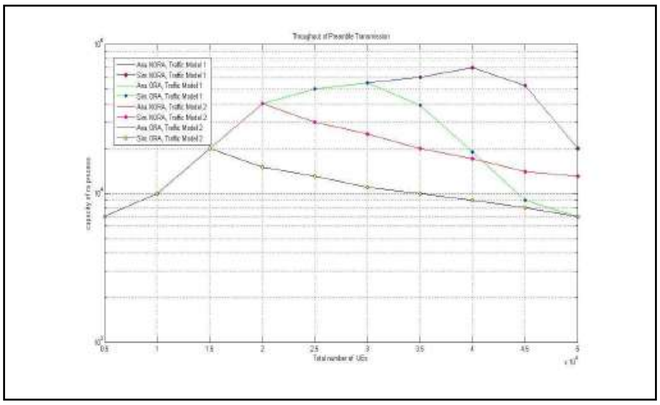

Fig.2. Throughput of Random-Access process of the ORA & NORA schemes.

In Figure 2, the throughput of ORA and NORA schemes are 30000 and 40000. The throughput of random-access process in the NORA scheme shows a 30% advantage as of ORA.

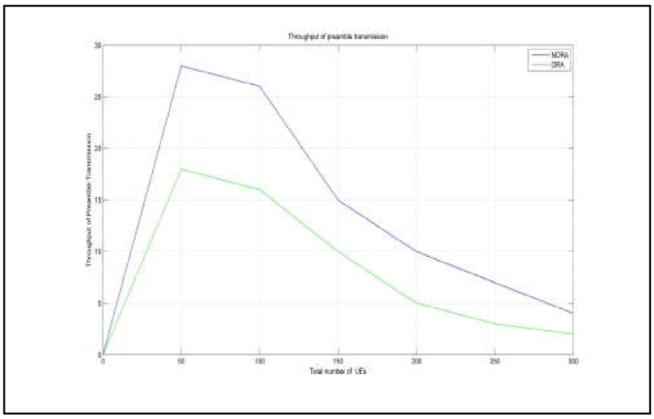

Fig.3.Throughput of Preamble Transmission of both the schemes.

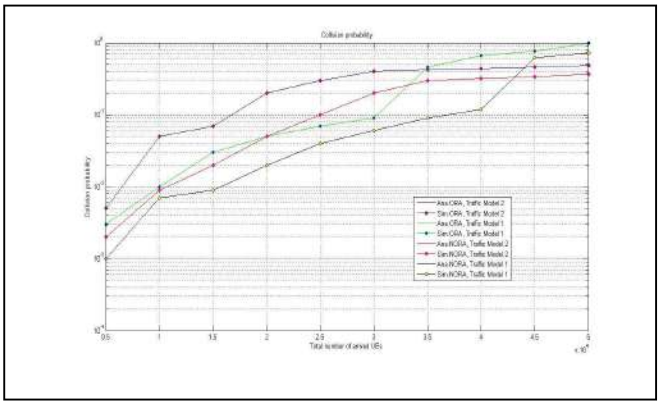

Fig.4. Collision Probability.

Under both models, Fig 4 compares the collision probability of the ORA and NORA.

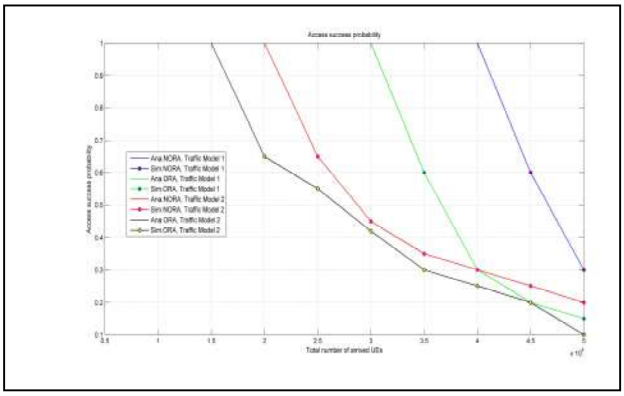

Fig.5. Access Success Probability.

While Figure 5 shows the Access success probability. When compared to ORA, the number of maximum supported user equipment's is improved by 30% in NORA scheme. NORA outperforms EAB when the total no. of user equipment's arrived is smaller than 25000.

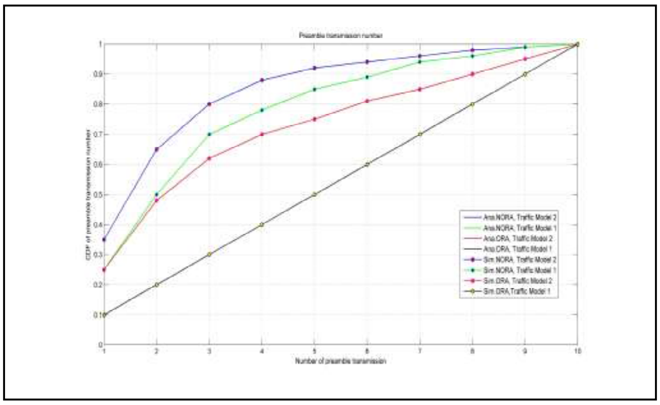

Fig.6. Preamble Transmission Number.

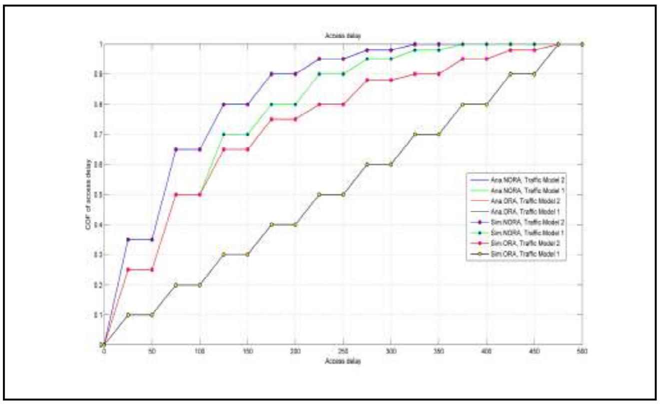

Fig.7. Access Delay.

Fig 6 & 7 shows the cumulative distribution function for the access delay and no. of preamble transmissions accessed user equipment's in both the schemes.

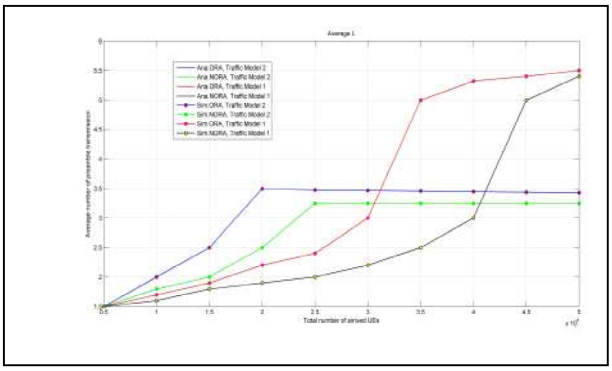

Fig.8. Average L.

Fig 8 shows the average no. of preamble transmissions of ORA and NORA regarding total no. of arrived user equipment's. When U >21000, NORA provides a significant reduction of preamble transmission. Both the schemes maintain a relatively constant value when U exceeds 25000.

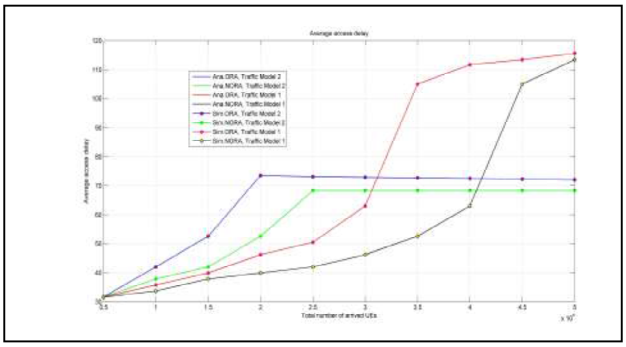

Fig.9. Average Access Delay.

When the total number of arrived user equipment's is lessthan 25000, NORA effectively cuts down the no. of preamble transmissions. In extremely overloaded scenarios, the access delay of EAB declines gradually as total no. of user equipment's increased which gives it superiority.

V. CONCLUSION

In this paper, to reduce the access congestion problem, the Non-Orthogonal Random Access (NORA) scheme regarding the synopsis in 5G Networks which allows simultaneous message transmission of user equipment's which reduces the demand on limited PUSCH resources. Under realistic assumptions and non-stationary arrivals, the analytical model of NORA is investigated besides the evaluation of a number of preamble transmission, throughput, access delay, and access success probability. On analyzing the Simulation results, it indicates that ORA has been outperformed by NORA considering all the factors with an increase in throughput by more than 30% and manages the access delay.

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