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Non-Orthogonal Multiple Access (Noma): A Review

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Abstract: Non-orthogonal multiple access (NOMA) is an emerging and promising technology that is set to have a significant impact on the development of 5G wireless communication systems. It is perceived as a promising access strategy for the next generation of cellular communication networks. This report provides a literature review on the works related to NOMA in the context of 5G communication networks.

***Index Terms* - Non-Orthogonal Multiple Access, NOMA Basics, Features of NOMA. 5G, Spectral Efficiency, Data Traffic**

1. Introduction

Mobile technology has become an essential part of our modern world. With the rapid growth of mobile internet and development of the Internet of Things (IoT), there are multiple requirements in 5G networks that need to be met. These include enhancing mobile broadband, providing mission-critical services, and enabling massive IoT. Meeting the demand for expanding mobile broadband requires extreme capacity and data rates.

Throughout the history of wireless communications, various multiple access schemes have been implemented for different applications. From the First Generation (1G) to 4G, these schemes have been crucial in distinguishing different wireless systems. For instance, Frequency-Division Multiple Access (FDMA) was used for 1G, Time-Division Multiple Access (TDMA) for 2G, Code-Division Multiple Access (CDMA) for 3G, and Orthogonal Frequency-Division Multiple Access (OFDMA) for 4G, which are primarily Orthogonal Multiple Access (OMA) schemes[4].

Future cellular networks may become denser with the introduction of tiny cells. Multi-layered networks, including macro-cell layers covering relays, pico-cell, and femto-cell layers, are emerging as an option for better coverage, capacity, and spectral efficiency [5][6]. The overall goals for 5G systems include higher output per area and per user, as well as lower latency. These systems are expected to support a large number of devices with lower energy consumption compared to current systems. Therefore, addressing the challenge of explosive data traffic and achieving high spectral efficiency is crucial. Furthermore, due to the rapid growth of the Internet of Things (IoT), 5G needs to support massive connectivity of users and devices to meet the demand for low latency, low-cost devices, and diverse service types. To address these requirements, enhanced technologies such as massive MIMO, millimeter wave communications, ultra-dense networks, and Non-Orthogonal Multiple Access (NOMA) have been proposed as potential candidates to tackle the challenges of 5G[5].

NOMA represents a promising advancement in 5G wireless communication systems. This technique multiplexes multiple users into one subcarrier by using non-orthogonal resource allocation, enabling the efficient use of bandwidth resources and improving spectral efficiency [7]. NOMA allows different clients to share time and frequency resources in the same spatial layer through power domain or code domain multiplexing, attracting significant attention with several recent schemes[6].

2. NOMA BASICS :

NOMA, as a broadcasting method in 5G networks, utilizes non-orthogonal transmission to increase throughput in transparent radiance technology. Non-Orthogonal Multiple Access transfers signals in the Base Station, accepting signals at both User Equipment receivers to produce a superposition of transmitting signals. This method allows many users to operate in a compact cell and offers advantages in comparison to diverse systems. To illustrate the concept of NOMA, consider a NOMA downlink transmission with two users. These two users can be served by the base station at the same time, code, or frequency, but with different power levels.

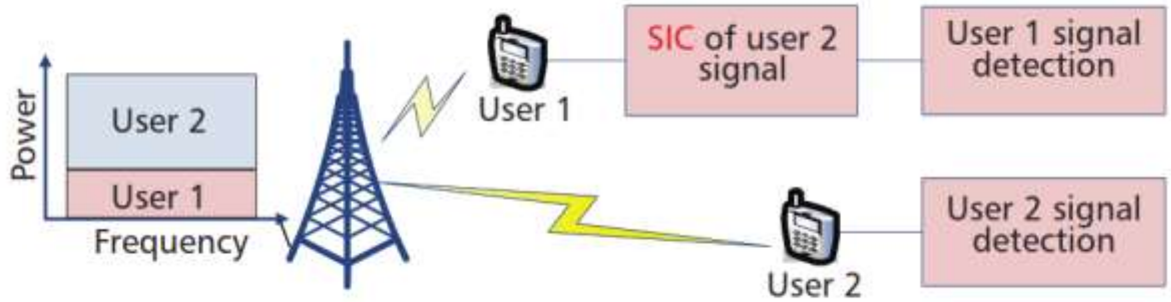

Figure 1 : NOMA Communication System

The figure 1 shows that the Base Station selects two appropriate users and the two users multiplexed into one subcarrier. Near-user (user 1) which is close to the BS, and far-user (user 2) which is distant from Base Station. Both users are selected in such a way that they have enough distance between them. Near-user (user 1) has strong channel gain and the far-user (user 2) has weak channel gain.

The Base Station makes the effective use of transfer power to an individual user on each subcarrier. The Base Station allocates low power to the user near BS and high power to the user far from BS. High power share to far-user (user 2) because the user is far and needed high power to make signal reach the user. Low power share to near-user (user 1) because the user is very near to Base Station and can reach with low power. Both the user share the same time and same frequency. Near-user (user 1) signal has large interference from far-user (user 2) as near-user (user 1) decodes and detects the far-user (user 2) signal first, subtracts interference from the whole signal to get its signal. Hence, far-user (user 2) interference is cancelled. Then near user (user 1) decodes its data from the remaining signal. Far user (user 2) decodes its signal normally and suffers from slight extra interference. The far-user (user 2) is unable to cancel near-user (user 1) interference because it is too weak to be decoded [9].

Recall that conventional power allocation strategies, such as water filling strategies, allocate more power to users with strong channel conditions. Unlike these conventional schemes, in NOMA, users with poor channel conditions get more transmission power. In particular, the message to the user with the weaker channel condition is allocated more transmission power, which ensures that this user can detect its message directly by treating the other user's information as noise. Then again, the client with the more grounded channel condition needs to first distinguish the message for its partner, then subtract this message from its observation, and finally decode its own information. This procedure is called successive interference cancellation (SIC) as shown in Figure 1.

3. LITERATURE REVIEW

The invention of cellular phones has changed the lives of people in most of the developed and developing counties in nonparallel ways. The history mobile communications started in 1946 when AT&T introduced the first public mobile telephone service in 25 cities across the United States of America. The service was later extended to 100 cities with the help of independent Base Stations (BSs) having large power amplifiers and tall towers to cover extended geographic areas. Each of these BSs used all the available frequency channels, and the interference was controlled by geographic separation. This limited the capacity of the network and in order to solve the capacity problem that emerged during the 1950s and 1960s, the breakthrough cellular concept was invented [9].

In the 1970s, the First Generation (1G) mobile telecommunication systems were deployed. In 1G, Frequency Division Multiple Access (FDMA) was used to service multiple users. The increasing demand for large capacity and high-quality communications could not be met with the 1G technology.

The use of digital modulation paved way to the beginning of the Second Generation (2G) mobile telecommunication networks. They were commercially launched for the first time in 1991 [10]. The 2G systems had higher spectrum efficiency than the 1G systems due to the use of digital speech codecs, tighter frequency reuse, and Time Division Multiple Access (TDMA). Additionally, enhanced security was provided. Further, 2G supported new applications like short message services, email access and internet services.

The Third generation (3G) systems were deployed all over the world in the early twenty first century. 3G was developed under the International Telecommunications Union (ITU) and provided much higher data rates, increased voice capacity and supported advanced services, including multimedia. Consequently, 3G was proved to be a significant leap over 2G. To serve multiple users, the 3G systems used Code Division Multiple Access (CDMA).

The specifications for the Fourth Generation (4G) mobile telecommunication technology standards were specified by the ITU in 2008 in order to enhance the capacity [11-12]. Commercial deployment of the 4G networks started in 2010. A major cost reduction strategy for 4G was the all-Internet Protocol (IP)-based communications instead of the traditional circuit-switched functionality. The multiple access technology in 4G employs Orthogonal Frequency Division Multiple Access (OFDMA) which offers a significant increase in the capacity at a lower system complexity.

Since the introduction of 1G systems, a new generation of cellular standard has been evolved and deployed every decade. Currently, 4G is reaching maturity with the worldwide deployment of commercial LTE networks. It is expected that the cellular mobile subscriptions will reach 8.9 billion by 2024 and 95% of that is predicted to be mobile broad-band subscriptions [13]. The demand for mobile traffic data volume is expected to be 1000 times larger in 2020 compared to the data volume in 2010.
The evolution of 5G is not purely driven by huge data rate requirements, but by other factors like massive device density, low latency and high reliability for the different deployment scenarios. The performance requirements for the 5G systems in order to support the future wireless communications have been proposed by the ITU [14,15].

In order to meet the unprecedented and multi-faceted demands for the future wireless services, the existing techniques are considered being insufficient. The design of 5G network architecture is expected to differ from 4G due to the stringent performance requirements such as high spectral efficiency, large system throughput, heterogeneous Quality of Service (QoS) and enhanced energy efficiency (EE). NOMA enables considerable performance improvements in the system throughput and capacity of the connected mobile devices. Moreover, it provides a good backward compatibility with OFDMA[16]

In OFDMA, each user has exclusive access to the sub-channel, whereas each sub-channel in NOMA can accommodate over one user, as shown in Fig.2. In NOMA, the two users are served simultaneously on the sub-channels. It was demonstrated that by properly adjusting the power levels, improved spectral efficiency can be obtained by NOMA compared to OFDMA [17].

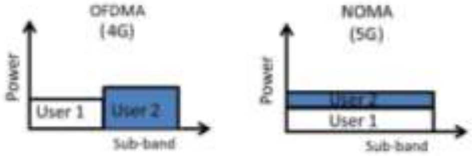

Figure 2 Frequency domain and Power Domain multiplexing in OFDMA and NOMA

In OFDMA, the maximum number of supported users is limited by the number of subchannels. On the other hand, the number of multiplexed users in NOMA can be largely increased since multiple users can simultaneously access the same sub-channel.

Comparison of NOMA and OMA

i) Spectral efficiency : The spectral efficiency in NOMA is higher because the frequency allocated to different mobile users, which has good and bad channel conditions, the frequency methods allocated for weakly user is used by the powerful user together with results in interference which could be reduced through Successive Interference Cancellation process in receiver side of the user. In OMA, a particular type of frequency methods is allocated to individual user balanced to meet a better and inadequate channel condition, for that reason it has lower spectral efficiency.

ii) Massive Connectivity: NOMA in 5g connects billions of machines, factories, hospitals and industries for that it has higher massive connectivity whereas in OMA the massive connectivity is lower [18].

iii) Low transmission latency : NOMA can support low transmission latency. In the grant-based OMA transmissions, a user sends a scheduling request to the BS, and the BS responds by sending a grant over the downlink channel after scheduling the user for the uplink transmission. This procedure results in increased latency and signaling cost. Such dynamic scheduling is not required in some uplink schemes of NOMA [19]. Thus a grantfree uplink transmission is supported. Consequently, NOMA serves as a suitable candidate for the uRLLC deployment scenario in 5G

iv) Compatibility: The conventional OMA such as FDMA, TDMA, CDMA and OFDMA has been compatible with NOMA due to which it utilizes a new power dimension with occurrence in SC and SIC [5]. So, NOMA has the ability to establish good compatibility with the existing Multiple Access methods. Non-Orthogonal Multiple Access had been used for the third generation partnership project long-term evolution advanced which aforementioned challenges in 5G networks by describing several users within the same orthogonal methods. NOMA in future can be used in digital T.V because NOMA has similarity with LDM (layered division multiplexing). In LDM the multiple signals can be transmitted at the same time on the same frequency but with different power[15].

4. FEATURES OF NOMA

NOMA can handle more subscribers than available sub-channels, which contributes to a variety of benefits such as huge connectivity, lower latency, improved spectral efficiencies, and improved channel feedback.

Higher Spectral Efficiency : By abusing the power space for client multiplexing, NOMA systems are able to accommodate more users to cope with system overload. In contrast to allocate a subcarrier exclusively to a single user in OMA scheme, NOMA can utilize the spectrum more efficiently by admitting strong users into the subcarriers occupied by weak users without compromising much their performance via utilizing appropriate power allocation and SIC techniques.

Better Utilization of Heterogenity: As we mentioned before, NOMA schemes intentionally multiplex strong users with weak users to exploit the heterogeneity of channel condition. In this way, the execution pick up of NOMA over OMA is bigger when channel additions of the multiplexed clients turn out to be more particular.

Enhanced User Fairness By relaxing the orthogonal constraint of OMA, NOMA enables a more flexible management of radio resources and offers an efficient way to enhance user fairness via appropriate resource allocation.

QoS Requirements NOMA is able to accommodate more users with different types of QoS requests on the same subcarrier. Therefore, NOMA is a good candidate to support IoT which connects a great number of devices and sensors requiring distinctive targeted rates.

CHALLENGES OF NON-ORTHOGONAL MULTIPLE ACCESS

1) **Non-Orthogonal Multiple Access in Wireless Power Transfer:** The simultaneous wireless information and power transfer (SWIPT) is the technique through which can receive information and harvest energy from the received energy signal, this technique of power harvesting to NOMA explained in cooperative Non-Orthogonal Multiple Access structure. Cooperative NOMA helps the user which has weak channel

conditions by engaging the strong user as a relay. Although the user which will not perform relaying, that would utilize its energy, reduces the battery existence. The Simultaneous Wireless Information and Power Transfer, the powerful user has higher motivation in executing relay also help the weak user. SWIPT is not only suitable to cooperative NOMA scenarios because NOMA uses SWIPT in an uplink network, in which users can harvest power from Base Station and also send the data to Base Station at the same time by operating Non-Orthogonal Multiple Access basis[20]

2) **Non-Orthogonal Multiple Access in Safety Precautions:** The safety precaution has been taken in NOMA because of Successive Interference Cancellation is executed, when the single user decodes the other user's message. The safety precaution also exists for Time Division Multiple Access users that transformed through time period which is not disturbed and attempt to understand the other user's data[20].

Advantages

- NOMA operates many customers for that reason it provides strong spectral efficiency.
- Non-Orthogonal Multiple Access assists many users in regular time. So it has tremendous connective.
- As in NOMA at the same time, there is a communication of total time comparatively than assigned the organized time slot.
- NOMA in MIMO improves system performance.

Disadvantages

- The customer in congregate required to solve the details of every user's which has poor channel gains that produce complication in the receiver side.
- When inaccuracy takes place within one customer because of Successive Interference Cancellation understanding the more customer's documents which would be inaccurate. So this controls more number of customers to assist by each collection of the unit.
- Non-Orthogonal Multiple Access is delicate to achieve the measurements because every user provides channel gain information to Base Station.

5. CONCLUSION

In this article, a promising multiple access technology for 5G networks, NOMA, is discussed. A literature review about NOMA basic, performance and key features of NOMA was discussed. Besides, it displayed the key elements and potential research difficulties of NOMA. It is normal that NOMA will play an important role in future 5G wireless communications.

References

[1] Dai, L., Wang, B., Yuan, Y., Han, S., I, C. and Wang, Z. (2015). Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends. IEEE Communications Magazine, 53(9), pp.74-81.

[2] Qualcomm. (2016). Qualcomm 5G Vision Presentation | Qualcomm. [online] Available at: https://www.qualcomm.com/documents/qualcomm-5g-vision-presentation [Accessed 29 May 2017].

[3] J. G. Andrews et al., "What Will 5G Be?," in IEEE Journal on Selected Areas in Communications, vol. 32, no. 6, pp. 1065-1082, June 2014.

[4] Wong, V., Schober, R., Ng, D. and Wang, L. (2017). Key Technologies for 5G Wireless Systems. 1st ed. West Nyack: Cambridge University Press, pp.109-116.

[5] Zhiguo Ding, Yuanwei Liu, Jinho Choi, Qi Sun, Maged Elkashlan, Chih-Lin I, and H. Vincent Poor, "Application of Non-Orthogonal Multiple Access in LTE and 5G Networks," Published in IEEE Communications Magazine, February 2017.

[6] Z. Ding, P. Fan, and H. V. Poor, "Impact of User Pairing on 5G Non-Orthogonal Multiple Access," IEEE Transaction Vehicular Technology, vol. 65, no. 8, Aug. 2016, pp. 6010–23.

[7] Y. Sun, D. W. K. Ng, Z. Ding and R. Schober, "Optimal Joint Power and Subcarrier Allocation for MC-NOMA Systems," 2016 IEEE Global Communications Conference (GLOBECOM), Washington, DC, 2016, pp. 1-6.

[8] Hina Tabassum, Md Shipon Ali, Ekram Hossain, Md Jahangir Hossain and Dong in Kim, "Non-Orthogonal Multiple Access (NOMA) in cellular Uplink and Downlink: Challenges and Enabling Techniques" arXiv:1608.05783v1 [cs. NI], 20 Aug 2016.

[9] Gordon A. Gow and Richard K. Smith, "Mobile and wireless communications: an introduction," McGraw-Hill International, 2006.

[10] A. Goldsmith, "Wireless Communications," Cambridge University Press, 2005.
[11] ITU-R M.2134, "Requirements related to technical performance for IMT-Advanced radio interface(s)," Jan. 2008.
[12] 3GPP TR 36.913 (V8.0.0), "Requirements for further advancements for E-UTRA (LTE Advanced)," Jun. 2008.
[13] Ericsson, "Ericsson mobility report Special Edition - World Economic Forum, January 2019," Jan. 2019.
[14] L. Dai, B. Wang, Y. Yuan, S. Han, C. l. I and Z. Wang, "Non-orthogonal multiple access for 5G: solutions, challenges, opportunities and future research trends," IEEE Commun. Mag., vol. 53, no. 9, pp. 74-81, Sep. 2015.
[15] Asif Osseiran, Jose F. Monserrat and Patrick Marsch, "5G Mobile and Wireless Communications technology," Cambridge University Press, 2016.
[16] Fa-Long Luo and Charlie (Jianzhong) Zhang, "Signal Processing for 5G: Algorithms and Implementations," John Wiley & Sons Ltd, 2016.
[17] David Tse and Pramod Viswanath,"Fundamentals of Wireless Communications," Cambridge University Press, 2005.
[18] L. Zhang, W. Li, Y. Wu et al., "Layered-Division-Multiplexing: Theory and Practice," IEEE Transactions on Broadcasting, vol. 62, no. I, pp. 216-232, 2016.
[19] L. Dai, B. Wang, Y. Yuan, S. Han, C. l. I and Z. Wang, "Non-orthogonal multiple access for 5G: solutions, challenges, opportunities and future research trends," IEEE Commun. Mag., vol. 53, no. 9, pp. 74-81, Sep. 2015.
[20] B. Patnaik, A. Agarwal, S. Mali, G. Misra and K. Agarwal, "A Review on Non-Orthogonal Multiple Access Technique for Emerging 5G Networks and Beyond," *2020 International Conference on Smart Electronics and Communication (ICOSEC)*, Trichy, India, 2020, pp. 698-703, doi: 10.1109/ICOSEC49089.2020.9215412.