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Migration from 4g LTE to Advanced PHY Techniques for Unmanned Aerial Vehicle (UAV) Communication

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ABSTRACT
UAV (unmanned aerial vehicles) with their high mobility and low cost, have found a wide range of applications during the past few decades. Historically, UAVs have been primarily used in the military, mainly deployed in hostile territory to reduce pilot losses. With continuous cost reduction and device miniaturization, small UAVs are now more easily accessible to the public; hence, numerous new applications in the civilian and commercial domains have emerged. For the sake of boosting resilience against faults, natural disasters, and unexpected traffic, the Unmanned Aerial Vehicle (UAV) assisted wireless communication systems can provide a unique opportunity to cater for such demands in a timely fashion without relying on the overly-engineered cellular network. However, for UAV-assisted communication, issues of capacity, coverage, and energy efficiency are considered of paramount importance. Starting with LTE (4G), Orthogonal Frequency Division Multiple Access (OFDMA) has replaced WCDMA for cellular mobile communications and it will also be employed in advanced 5G yet, Non-orthogonal multiple access (NOMA) has been recently recognized as a promising PHY technique to significantly improve the spectral efficiency of mobile communication networks. In this paper, we provide an overview of UAV-aided wireless communications, by introducing the basic networking architecture, highlighting the key design considerations as well as the new opportunities to be exploited.

Keywords: LTE (4G), Non-orthogonal multiple access (NOMA), Unmanned Aerial Vehicle (UAV), Wireless communication.

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I. INTRODUCTION

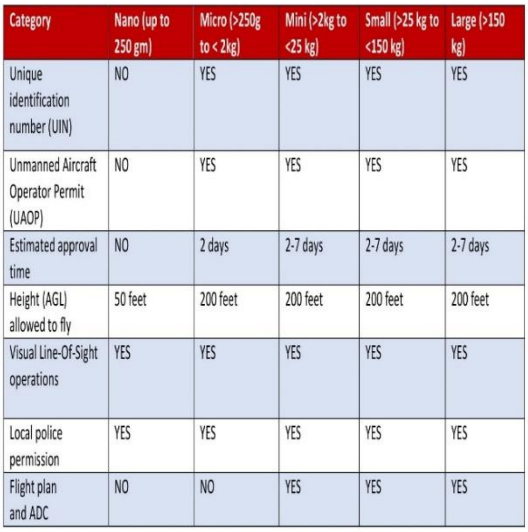
The use of unmanned aerial vehicles (UAVs) will grow rapidly in the next decade. These remotely piloted or preprogrammed aircraft are envisioned for applications in numerous civil settings, including industrial monitoring, scientific data gathering, agriculture, public safety, and search and rescue. Many other applications - presently unforeseen - will inevitably also arise. These vehicles, also known as the unfortunate misnomer of "drones," must be integrated into the national airspace system and into the airspace worldwide. A natural concern in the use of UAV is safety, and this has direct implications for the control and non-payload communication systems that must be used to operate it efficiently. Similarly, navigation and surveillance functions must be made more reliable and more accurate. Because of these factors, many UAV research, development, testing, and standardization efforts are underway by governments, industries, and academia. Despite the fact that piloted civil aircraft have been flying safely for decades, UAV presents distinct new challenges in the form of different flight profiles, e.g., low-elevation flights and more high-dynamic maneuvers; wider required bandwidths, e.g., for video; and different ground site characteristics such as locations in cluttered areas and lower elevation antennas.

In this paper first the evolution of radio technologies considered in UAV wireless communication is reviewed in literature survey and the significant work in the area is highlighted along with the newest challenges. The reminder of this paper is organized as follows.

The promising technology NOMA and its variants are discussed in section three. In Section four the system model and assumptions are presented and in section five the comparative analysis of NOMA with existing popular technology OFDMA (OMA) is given with simulation persormance analysis. At last, the work is concluded in section five.

II. LITERATURE SURVEY

Drones variously known as unmanned aerial vehicles (UAVs), unmanned aerial systems (UAS) or remotely piloted aircraft system (RPAS), are used in several parts of the world for surveying and aerial mapping, disaster management work, monitoring crop production and infrastructure activities, besides commercial photography and courier delivery. The viability of UAV as a multipurpose research vehiclehas driven great interest since recent decades[1]. The basictechnology building blocks responsible for the current advancesinclude airframes, propulsion systems, payloads,safety or protection systems, launch and recovery, dataprocessor, ground control station, navigation and guidance,and autonomous flight controllers. The following briefsurvey is focused on the area of navigation, guidance andcontrol of UAVs. Various control design for UAVs has beenproposed ranging from linear to nonlinear synthesis, timeinvariant to parameter varying, and conventional PID tointelligent control approaches. The developed controllershave been implemented for different aerial platforms: airship(blimp), fixed-wing UAV, small scale helicopter,uad-rotors, and MAV. Wireless communication systems that include unmanned aerial vehicles promise to provide cost-effective wireless connectivity for devices without infrastructure coverage. Compared to terrestrial communications or those based on high-altitude platforms, on-demand wireless systems with low-altitude UAVs are in general faster to deploy, more flexibly reconfigured, and likely to have better communication channels due to the presence of short-range line-of-sight links. However, the utilization of highly mobile and energy-constrained UAVs for wireless communications also introduces many new challenges. In India for the regulation and safety purpose in commercial and survilence applications, the policy guideliens also introduced as below :



Category	Nano (up to 250 gm)	Micro (>250g to < 2kg)	Mini (>2kg to <25 kg)	Small (>25 kg to <150 kg)	Large (>150 kg)
Unique identification number (UIN)	NO	YES	YES	YES	YES
Unmanned Aircraft Operator Permit (UAOP)	NO	YES	YES	YES	YES
Estimated approval time	NO	2 days	2-7 days	2-7 days	2-7 days
Height (AGL) allowed to fly	50 feet	200 feet	200 feet	200 feet	200 feet
Visual Line-Of-Sight operations	YES	YES	YES	YES	YES
Local police permission	YES	YES	YES	YES	YES
Flight plan and ADC	NO	NO	YES	YES	YES

Table :1UAV communication Policy Guidelines for commercial and surveillance purpose

III. MIGRATION FROM 4G LTE TO 5G

The fruitful deployment of UAV based communicationsystems for 4G and beyond future wireless networks is highlyinvolved in finding joint solutions to challenge of ubiquitousconnectivity with both a multitude of devices in a spectralefficient way as well as with energy-efficient transmissionand operation of the UAV-BS for maximized and armonizedcoverage and capacity [2],[3]. It should be noted that suitableenergy efficiency for the UAV-assisted ommunication systemachieves paramount importance in the overall performance ofthe system. Efficient energy consumption results in enhancedairtime for the communication system, improving bits/Joulesfor a given energy level. Furthermore, coverage and capacityof an aerial cell are attributed to many factors such as thetransmission power, antenna gains, UAV altitude, deploymentenvironment, and prominently radio access technology [4].

4G is the fourth generation of broadband cellular network technology, succeeding 3G and besides the popular techniques in 3G/4G i.e TDMA/WCDMA/OFDMA , a new radio access technology NOMA is also developed by researchers to be used in communication networks due to its capability in increasing the system capacity. Recently, non-orthogonality based system designs are developed to be used in communication networks and have gained significant attention of researchers. Hence, multiple access (MA) techniques can now be fundamentally categorized as orthogonal multiple access (OMA) and non-orthogonal multiple access (NOMA). In OMA, each user can exploit orthogonalcommunication resources either within a specific time slot, frequency band or code in order to avoid multiple access interference. The previous generations of networks have employed OMA schemes, such as frequency division multiple access (FDMA) of first generation (1G),time division multiple access (TDMA) of 2G, code division multiple access (CDMA) of 3G, and orthogonal frequency division multiple access (OFDMA) of 4G.

In NOMA, multiple userscan utilize non-orthogonal resources concurrently by yielding a high spectral efficiency while allowing some degree of multiple access interference at receivers . Recently, NOMA reputations have climbedsharply as a fundamental solution to the challenges encompassingthe next generation wireless networks [5][6].NOMA has been proved to exhibit improved spectral efficiency,balanced and air access as compared to OMAtechnologies[6], with the ability to cater for multipledevices in the same frequency, time, or code resource thusproviding efficient access to massive connected devices . Furthermore, NOMA is also instrumental in reducingthe interference by employing orthogonal resources as inOrthogonal Frequency Division Multiple Access (OFDMA)[7][17] or by sharing a single beam between multiple users forintra-cluster access and using NOMA for inter-cluster access[18].Current studies have focused on provisioning Air to Ground(A2G) communication services mainly through placement op- timization under various viewpoints in literature. The performance of UAV based communication systems hasalso been addressed for the underlaid Device to Device(D2D) deployment scenario. This work assumed interferenceraised by D2D network nodes, without considering the presenceof terrestrial BS. Additionally, there have been a fewstudies discussing the performance of NOMA for UAV basedcommunication system[8]. A NOMA enabled fixedwingUAV deployment was proposed in [8] to support coveragefor ground users situated outside BS offloaded location.

In general, NOMA schemes can be classified into two types: power-domain multiplexing andcode-domain multiplexing. In power-domain multiplexing, different users are allocated[7][8][9][6][5][1][10] differentpower coefficients according to their channel conditions in order to achieve a high systemperformance. In particular, multiple users' information signals are superimposed at the transmitterside. At the receiver side successive interference cancellation (SIC) is applied for decoding thesignals one by one until the desired user's signal is obtained, providing a good trade-offbetween the throughput of the system and the user fairness. In code-domain multiplexing, different users are allocated different codes and multiplexed over the same time-frequencyresources, such as multi-user shared access (MUSA), sparse code multiple access (SCMA), and low-density spreading (LDS). In addition to power-domain multiplexing and codedomain multiplexing, there are other NOMA schemes such as pattern division multiple access(PDMA) and bit division multiplexing (BDM). Although code-domain multiplexinghas a potential to enhance spectral efficiency, it requires a high transmission bandwidth andis not easily applicable to the current systems. On the other hand, power-domain multiplexinghas a simple implementation as considerable changes are not required on the existing networks.Also, it does not require additional bandwidth in order to improve spectral efficiency. Inthis paper the prime focusis on the power-domain NOMA.Although OMA techniques can achieve a good system performance even with simple receiversbecause of no mutual interference among users in an ideal setting, they still do not have theability to address the emerging challenges due to the increasing demands in future networks andbeyond.

The superiority of NOMA over OMA can besummarized as follows:

_ Spectral efficiency and throughput: In OMA, such as in OFDMA, a specific frequencyresource is assigned to each user even it experiences a good or bad channel condition,thus the overall system suffers from low spectral efficiency and throughput. In contrary, inNOMA the same frequency resource is assigned to multiple mobile users, with good and bad channel conditions, at the same time. Hence, the resource assigned for the weak user isalso used by the strong user, and the interference can be mitigated through SIC processesat users' receivers. Therefore, the probability of having improved spectral efficiency and ahigh throughput will be considerably increased.

_ User fairness, low latency and massive connectivity: In OMA, for example in OFDMAwith scheduling, the user with a good channel condition has a higher priority to be servedwhile the user with a bad channel condition has to wait to access, which leads to a fairnessproblem, and high latency. This approach cannot support massive connectivity. However,NOMA can serve multiple users with different channel conditions simultaneously, thereforeit can provide improved user fairness, lower latency and higher massive connectivity.

_ Compatibility: NOMA is also compatible with the current and future communication systemssince it does not require significant modifications on the existing architecture. For example,NOMA has been included in third generation partnership project long-term evolutionadvanced (3GPP LTE Release 13).

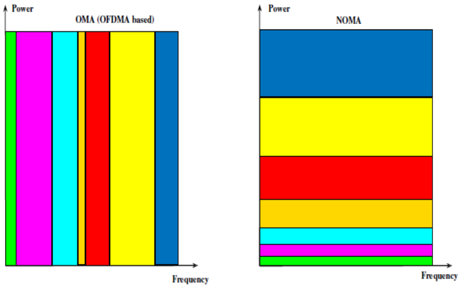


Figure 1 Pictorial comparison of NOMA Vs OMA

Although NOMA has many features that may support next generations,it has some limitations that should be addressed in order to exploit its full advantage set. Thoselimitations can be pointed out as follows: In NOMA, since each user requires to decode thesignals of some users before decoding its own signal, the receiver computational complexitywill be increased when compared to OMA, leading to a longer delay. Moreover, informationof channel gains of all users should be fed back to the base station (BS), but this results in asignificant channel state information (CSI) feedback overhead. Furthermore, if any errors occurduring SIC processes at any user, then the error probability of successive decoding will beincreased. As a result, the number of users should be reduced to avoid such error propagation.Another reason for restricting the number of users is that considerable channel gain differencesamong users with different channel conditions are needed to have a better network performance.

IV. NOMA UPLINK AND DOWNLINK SCENERIO SIMULATION ANALYSIS

In this section, an overview of NOMA in downlink and uplink networks is introduced throughsignal-to-interference-and-noise ratio (SINR) and sum rate analyses. Then, high signal-to-noiseratio (SNR) analysis has been conducted in order to compare the performances of OMA andNOMA techniques[10].

A. Downlink NOMA Network

At the transmitter side of downlink NOMA network, as shown in Fig. 2, the BS transmits thecombined signal, which is a superposition of the desired signals of multiple users with different allocated power coefficients, to all mobile users. At the receiver of each user, SIC process isassumed to be performed successively until user's signal is recovered. Power coefficients ofusers are allocated according to their channel conditions, in an inversely proportional manner.The user with a bad channel condition is allocated higher transmission power than the one which has a good channel condition. Thus, since the user with the highest transmission power considers the signals of other users as noise, and recovers its signal immediately without performing anySIC process. However, other users need to perform SIC processes. In SIC, each user's receiverfirst detects the signals that are stronger than its own desired signal. Next, those signals aresubtracted from the received signal and this process continues until the related user's own signal is determined. Finally, each user decodes its own signal by treating other users with lower powercoefficients as noise. The transmitted signal at the BS can be written as:

$$\mathrm{s} = \sum_{\mathrm{i}=1}^{\mathrm{L}} \mathrm{aiPsxi}$$

where xi is the information of user i (U_i) with unit energy. Ps is the transmission power atthe BS and a_i is the power coefficient allocated for user i subjected to$\sum_{\mathrm{i}=1}^{\mathrm{L}} \mathrm{ai} = 1$ and a1≥a2≥…. ≥aL since without loss of generality the channel gains are assumed to be ordered as $|\mathrm{h1}|2 \leq |\mathrm{h2}|2 \leq \cdots.|\mathrm{hL}|2$. where h_L is the channel coefficient of Lth user, based on NOMAconcept. The received signal at lth user can be expressed as follows:

$$\mathrm{y1} = \mathrm{hls} + \mathrm{nl} = \mathrm{hl}\sum_{\mathrm{i}=1}^{\mathrm{L}} \sqrt{\mathrm{ai}}\mathrm{Psxi} + \mathrm{nl}$$

where $n_l$is zero mean complex additive Gaussian noise with a variance of σ^2.

(1) SINR analysis: By using (2), the instantaneous SINR of the l_{th} user to detect the j_{th} user, j≤ l , with j≠ L can be written as:

$$\mathrm{SINRl} = {}^{\mathrm{al}\gamma|\mathrm{hl}|2}\Big/_{\gamma|\mathrm{hl}|2\ \sum_{\mathrm{i}=\mathrm{l}+1}^{\mathrm{L}} \mathrm{ai} + 1}$$

Where $\gamma = {}^{\mathrm{Ps}}/_{\sigma 2}$denotes the SNR.

(2) Sum rate analysis: After finding the SINR expressions of downlink NOMA, the sumrate analysis can easily be done. The downlink NOMA achievable data rate of lth user can beexpressed as:

$R_l^{\text{NOMA-d}} = \log_2(1 + \mathrm{SINRl}) = \log_2(1 +$ alγhl2γhl2 i=l+1Lai+1

B. Uplink NOMA Network

In uplink NOMA network, as depicted in Fig. 3, each mobile user transmits its signal to the BS. At the BS, SIC iterations are carried out in order to detect the signals of mobile users. By assuming that downlink and uplink channels are reciprocal and the BS transmits power allocation coefficients to mobile users, the received signal at the BS for synchronous uplink NOMA can be expressed as:

$$\mathrm{r} = \sum_{\mathrm{i}=1}^{\mathrm{L}} \mathrm{hi}\sqrt{\mathrm{ai}}\mathrm{Pxi} + \mathrm{n}$$

where hi is the channel coefficient of the ith user, P_{xi} is the maximum transmission power assumed to be common for all users, and n is zero mean complex additive Gaussian noise with a variance of σ^2

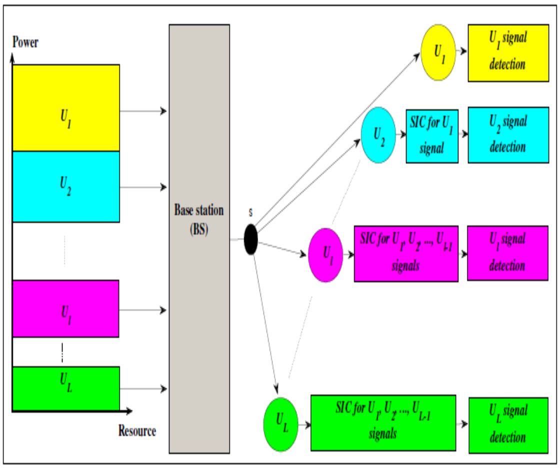


Figure 2 Downlink NOMA network

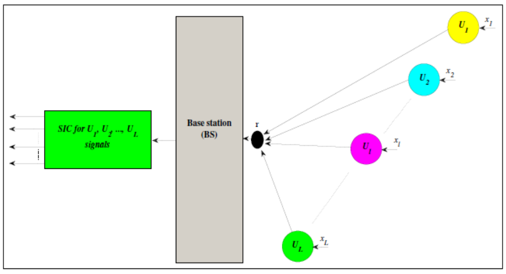


Figure 3 Uplink NOMA network

1) SINR analysis: The BS decodes the signals of users orderly according to power coefficientsof users, and then the SINR for lth user $l \neq 1$ can be given by

$$\mathrm{SINRl} = {}^{\mathrm{al}\gamma|\mathrm{hl}|2}\Big/_{\gamma \sum_{i=1}^{l-1} \mathrm{ai}|\mathrm{hi}|2 + 1}$$

where $\gamma = \frac{P}{\sigma 2}$.

2) Sum rate analysis: The sum rate of uplink NOMA when $\gamma - \infty$can be written as:

$$R_{sum}{}^{NOMA\text{-}u} \approx \log_2(\gamma \sum_{l=1}^{L} |hl|2$$

C. Comparing NOMA and OMA

The achievable data rate of the lth user of OMA for both uplink and downlink can be expressed

$$R_{sum}{}^{OMA\,=} \sum_{l=1}^{L} \alpha l \log_2(1 + \frac{\beta l\gamma|hl|2}{\alpha l})$$

For the sake of simplicity, sum rates of uplink NOMA and OMA can be compared for twousers. Then, using both the sum rate of uplink NOMA and OMA at high SNR can beexpressed, respectively as:

$$R_{sum}{}^{NOMA} \approx \log_2 \gamma|h1|2 + \gamma|h2|2$$

Here we notice $R^{OMA}{}_{sum} \leq R^{NOMA}{}_{sum.}$ Fig. shows that, NOMA outperforms OMA in terms of sum rate in both downlink and uplinkof two user networks.

V. SIMULATION RESULTS

The Comparative analysis of modelling Downlink and Uplink NOMA in comparison with OMA is simulated and findings are presented that shows superiority of NOMA over OMA with better spectral efficiency for simulation parameters taken as power allocation coefficients a1=0.6, a2=0.4 and channel responses h1 ^{2} =0 DB, $h2^2$=20 DB parameters.

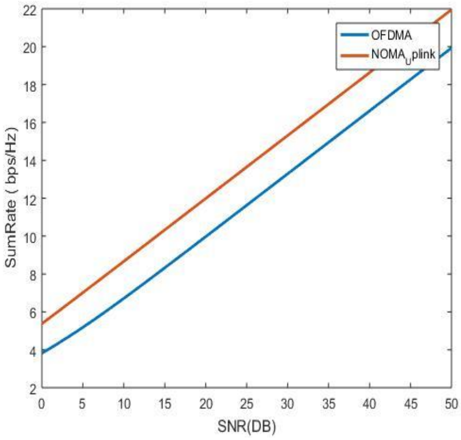


Figure 4NOMA UPLINK

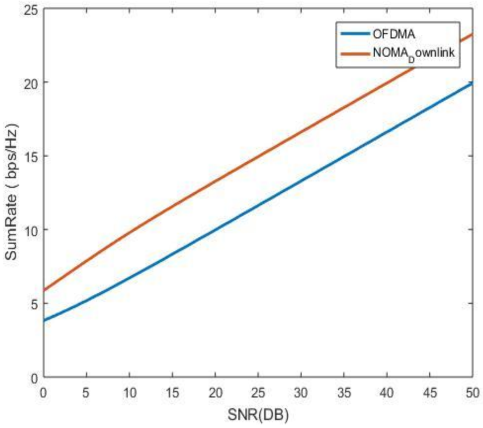


Figure 5 NOMA DOWNLINK

VI. CONCLUSION

This paper investigated an account of NOMA's applicability for UAV-assisted communication systems. NOMA schemes are proposed to improve the efficient usage of limited network sources. OMA based approaches that use time, frequency or code domain in an orthogonal manner cannot effectively utilize radio resources, limiting the number of users that can be served simultaneously. In order to overcome such drawbacks and to increase the multiple access efficiency, NOMA technique has been recently proposed. Accordingly, users are separated in the power domain. Such a power domain based multiple access scheme provides effective throughput improvements, depending on the channel conditions .The crucial need of UAV communication of optimum utilization of available licensed spectrum bandwidth is considered here and simulation results taken presented that NOMA performs better than OMA while fulfilling individual user-rate constraint for both users. The research work can be further carried out investigating joint power and phase allocation of UAV nodes deployment for efficient operations.

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