Cognitive OFDM-NOMA System: A succinct Study

Chavatapalli Tarun Vamsi Krishna¹, Chandana Mani Deepika², B.S.Saranya³, Murrey Neeladri⁴*

¹,²,³,⁴Department of ECE, Aditya engineering college, Surampalem, India
E-mails: tkvamsi12@gmail.com, deepikasrinivas3@gmail.com, saranya.bs@gmail.com, neeladri.m@aec.edu.in

Abstract Integration of non-orthogonal and orthogonal multiplexing used to enhance the capacity of the system is presented here. This is also called as cognitive OFDM-NOMA. Here we overcome some problems which are divided into sub problems i.e., the power allocation optimization, user scheduling and sensing duration, respectively. Orthogonal frequency division multiplexing (OFDM) for multiusers can also be done by clustering based radio allocation (RA) scheme. This will improve maximum usage of wireless communications by optimizing the sum capacity of secondary users. The users in same group have the same OFDM sub channels to enhance spectrum utilization. Mobile networks have used time/frequency/code domain for multiple access, while in NOMA the power domain will be used.

Keywords: 5G, NOMA, Cognitive OFDM, power allocation, capacity maximization.

1. Introduction

Multiple access is divided in to two approaches, namely, “orthogonal and non-orthogonal”. In orthogonal multiple access the signals are not overlapped. This is done using time or frequency division multiple access. Where as in non-orthogonal the signals overlap and is done by utilizing the power domain and code domain. So we can get better performance in non-orthogonal than the orthogonal. In the last decade the growth of many handheld mobile devices have occurred due to the rapid development in the mobile networks. This is the reason for the exponential growth of mass public traffic. “Internet of things (IOT)” will increase the wireless network traffic significantly. Proposed technologies like 5G will provide the enhanced capacity for the increased mobile traffic and user connections. In OFDM the spectrum allocation problem is more and known to all. NOMA has the ability to overcome these problems and provide better quality of service for multiple users. There are many NOMA technologies, in which Power-domain multiple access is the mostly used technology. Hybrid NOMA is also called as multi carrier NOMA and is useful in limiting of signal complexity. While in a solo carrier NOMA there is high complexity as the user with decent channel state has to
decipher all remaining user’s signals. These problems are reduced in multi carrier NOMA because in this user of each subcarrier is limited. So that’s why it is very interesting to combine the OFDM with NOMA to increase wireless networks spectrum efficiency. In this article we suggest the OFDM-NOMA systems and spectrum usage issues. First we consider the problem of spectrum maximization in a half duplex OFDM-NOMA and then we solve the problem of full duplex OFDM-NOMA. The alternate iteration framework based algorithm is proposed for full duplex cognitive OFDM-NOMA.

The important contributions of this paper are

- The issue of utilizing maximum spectrum capacity is worked out for “half-duplex and full duplex OFDM-NOMA systems”. The problem of SD type systems is overcome by cooperatively improving the sensing interval and power division to increase the maximum number of simultaneous users.
- While in case of FD systems sensing duration optimization is not required as a replacement of self-interference is studied.
- The alternate iteration framework based algorithm is used to optimize the size of OFDM-NOMA systems.

2. Literature Review

System Model for Half Duplex Cognitive OFDM-NOMA System

First we have to consider a case where the primary network can be accessed by the base station. The time duration is split into, the sensing duration $\tau$ and the transmission duration $K-\tau$. The base station (BS) senses state of spectrum during the sensing cycle. If the primary users are not detected during the sensing cycle the cognitive station send the data during the transmission cycle. If the primary users are detected then the BS remains silent during the transmission cycle. When the primary users are not detected the BS transmits data to a set of secondary users $A = \{1, 2, \ldots, A\}$ using a single antenna. The spectrum is partitioned into a set of subcarriers $B = \{1, 2, \ldots, B\}$. This channel gain is fed back if the essential system might want to help out the optional system organize for a mutual range usage or accessed by abusing the channel correspondence [2]. The received noise power is denoted as $\beta^2$. Let’s assume the identical detection threshold $\mu$ is set for all the sub carriers. Now the detection probability and the false alarm probability are given below

$$
P_d(\tau) = P\left(\frac{\mu}{\beta + \beta} - \alpha - 1\right) \sqrt{\frac{\tau f_s}{2\alpha}}
$$

$$
P_f(\tau) = P\left(\frac{\mu}{\beta + \beta} - 1\right) \sqrt{\frac{\tau f_s}{4}}
$$

Where, $P(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-\frac{t^2}{2}} dt$

$\beta^2$ is the noise power of the detector, $f_s$ is the sampling frequency and $\alpha$ is the average signal to noise ratio (SNR) of the primary signal.

2.1. A Potential 5G Wireless Cellular Architecture
Implementation of 5G system has many challenges, and significant changes are needed in the core cellular architecture. It is found that people stay indoors for 80% of their time and that includes the wireless users the remaining 20% of the time they are outdoor. The current conventional cellular design is based on outdoor base stations without any considerations of the user being inside or outside a building. When the user is indoor the wireless signals pass through dense opaque objects like walls to reach the base station. This causes high attenuation losses and affects the efficiency of the system[3].

Separation of the indoor and outdoor situations to avoid penetration losses through the building walls is one of the major changes suggested for the 5G architecture. Different technologies like distributed antenna system (DAS) and MIMO will be used for achieving this. Mobile users who are outdoor will have limited antenna elements, but these limited elements can be combined virtually to form a large antenna array. Large antennas array are placed outside the buildings to connect with the outdoor base station. These large antenna arrays is connected to the wireless access points placed inside the building using cables. The users inside the building will be connected via these wireless access points. This will overcome the issue of penetration losses due to building walls and improve the overall efficiency of the 5G system. In this type of 5G architecture the indoor wireless system can use various short range communication technologies as it has to send or receive the signals within the building. Some of these technologies are visible light communication (VLC), ultra-wide band, mm wave, femtocell, Wifi, etc. Some of these technologies can only be used for line of sight communications as they cannot penetrate solid objects and also get scattered easily.

The 5G architecture use an assorted system with various types of network system being used in combination. In moving vehicles the mobile femtocell concept is used. Mobile femtocell is the concept of combination of femtocell and mobile relay. The femtocells are placed in the vehicle and antenna array is placed outside the vehicle to link with the base stations.

2.2. Devices Used For 5G Technologies [2]

For improving the network from 4G to 5G there are some devices required which are capable of playing crucial part in allocating background information and handling the previously mentioned networks. In the current scenario some devices came into existence which evolve in size, form and functionality without changing their past features. Even though 5G technology is available and developing globally still 3G and 4G are in use. Devices which supports 5G RAT are likely to support “High speed packet access (HSPA)/ Wideband Code-Division Multiple Access (WCDMA), LTE, Bluetooth and Wi-Fi”. In some cases the technology may have advanced in comparison to current systems like LTE and Wi-Fi.
An intersection between transceiver and baseband for 3G, 4G and 5G technologies may arise for interference management. At the intersection devices should identify, characterize and suppress co-channel interferences from other channels and also the band interference to improve the network capacity.

Devices required for 5G technology are:

Application proc, media core, location core, PHY processing, RF proc, sensors, FEM Comms is a connection management block it has Wi-Fi offloading, multi RAT aggregation and traffic shaping. Location core is used to process the location and it has A-GNSS computation and sensor fusion.

Both comms and location core are used for advanced power management, low power operation, and delegated cores.

3. Key Component Technologies of NOMA

Transmission Power Allocation for Multiuser:

The modulation and coding and the SINR used for each user’s data transmission is determined by the power assignment ratios. The throughput for each user is controlled by regulating the power assignment ratios. Thus using advanced power allocation methods the cell throughput for each user can be controlled. [15].

3.1 Algorithm Scheduling

A proper technique is developed to allocate the power to the user from a given set of users. A scheduling algorithm is used to identify the appropriate user from all the users. A proportional fairness scheduler is one of the examples. The user fairness is determined by the scheduling metric program which maximizes the proportional fairness among all the users. Similar scheduler algorithms are also used.
3.2 Design of a Receiver:

Two types of receivers are used for detection of NOMA, i.e. symbol level and code-word level SIC receiver. The main distinction between the two is that the code-word involves channel decoding and re-encoding whereas not in symbol level SIC.

3.3 Symbol-level SIC receiver

For the user at the cell-edge, the signal is demodulated and a replica is created without decoding in the symbol-level SIC receiver. After generating the replica, SIC is carried out to remove the interference from the user at the cell edge and enhance the SINR for the cell user at the center.

3.4 Code word-level SIC receiver

Here the signal of user at the cell-edge is demodulated and decoded. The signal is then re-encoded and re-modulated and cancelled from the received signal. Error propagation is significantly reduced and detection latency is increased. However the channel decoding and encoding requires higher computational complexity.

4. Advantages of NOMA:

NOMA is used to improve the system capacity and spectrum efficiency by using the power domain compared to time/frequency/code.

• Using non-orthogonal multiplexing the channel gain difference of the users is converted to multiplexing gain.
• NOMA provides gain even in high mobility cases.
• The transit antennas need not be increased.
• NOMA is compatible with OFDMA and SC-FDMA.
• NOMA is easily combined with multi-antenna technologies like beamforming and MIMO.

5. Conclusion
Here we reviewed how to solve the maximizing problems for cognitive OFDM-NOMA systems. We also studied about power allocation, user scheduling algorithm for sensing duration adaption are studied based on the matching theory, bisection search method, Lagrangian method with newton’s method. To carry out joint optimization to enhance the capacity maximization, an iteration frame work is studied.

In this paper we also studied, the 5G cellular architecture for outdoor and indoor users using distributed antenna system (DAS) and MIMO. We also studied about some communication technologies like femtocell, mobilefemtocell technologies.

In this we also discussed about power allocation for multiple users, scheduling algorithm, receiver design, etc.

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