Wireless Communication

OFDM based NOMA for fair power allocation

First Project Review

Team 8

Pushkal Mishra | EE20BTECH11042

Utkarsh Doshi | EE20BTECH11052

Motivation

- 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.

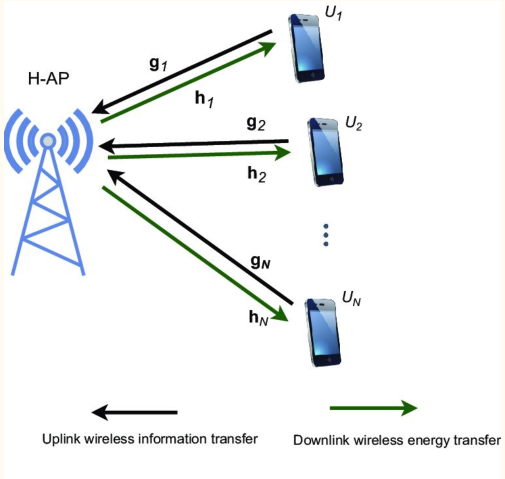
- Proposed technologies like 5G will provide the enhanced capacity for the increased mobile traffic and user connections.

Multiple Access Techniques

- This technique enables multiple users to communicate with the same base station using the same signal coming through different channels.

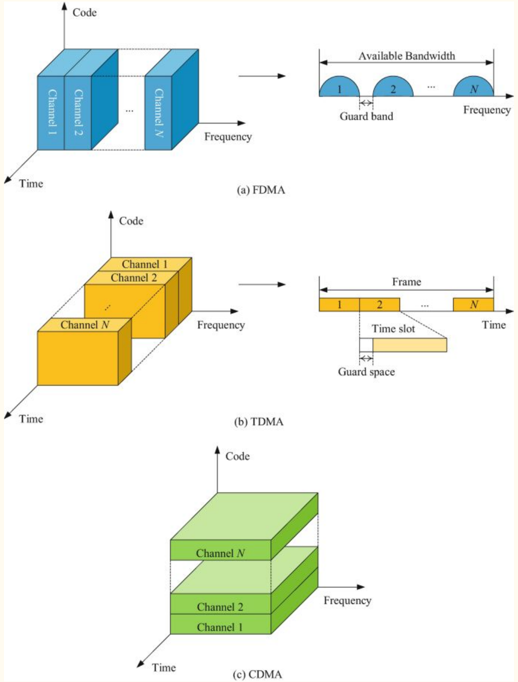
- The base station transmits only one signal for all users!

- It can broadly be categorized into two different approaches-
  - Orthogonal Multiple Access (OMA)
  - Non-Orthogonal Multiple Access (NOMA)



Orthogonal Multiple Access (OMA)

- OMA scheme allows a perfect receiver to entirely separate it’s signal from other signals.
- To perform this, different users are assigned mutually orthogonal signal basis to avoid interference.
- It can be performed in three different ways-
  - Time division multiple access (TDMA)
  - Orthogonal frequency-division multiplexing (OFDM)
  - Code division multiple access (CDMA)
- We will talk about OFDM scheme here as it can be integrated with NOMA method.
- Technologies till 4G use this scheme.

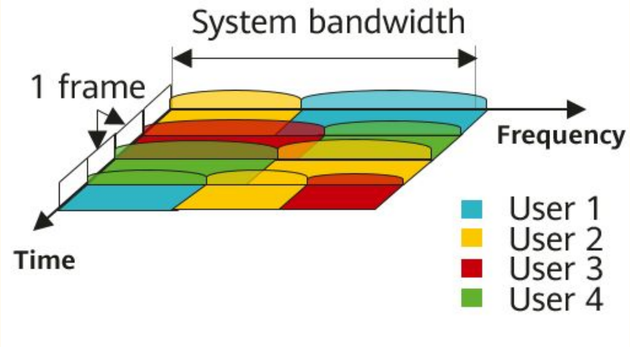


Orthogonal Frequency Division Multiplexing (OFDM)

- It divides the available bandwidth into multiple subcarriers which are then uniquely assigned to users.
- These subcarriers are orthogonal to each other and each user can decode their component unambiguously.
- Each subcarrier can have different modulation schemes and that won't affect the other subcarriers.

$$s(t) = \sum_{k=-\infty}^{\infty} X[k]e^{j2\pi k\Delta f t}$$

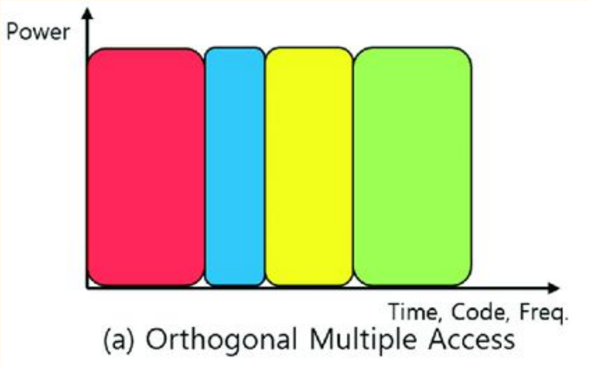
s(t)- OFDM signal
X[k]- Complex valued data signal
k- Subcarrier
Δf- Subcarrier spacing



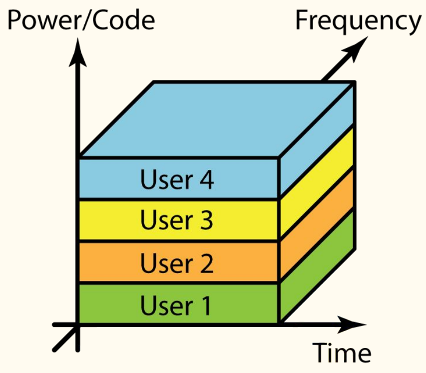
Non-Orthogonal Multiple Access (NOMA)

- Based on principle of superposition (in time and frequency) of multiple user signals which can be transmitted simultaneously.
- This again has two types-
  - Power domain NOMA
  - Code domain NOMA
- We will look at Power domain NOMA.

OMA vs NOMA



(a) Orthogonal Multiple Access



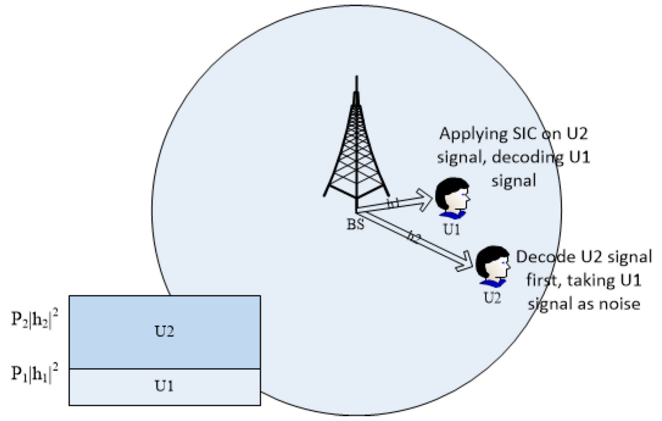
Power domain NOMA

- It is a multiple access technique that allows users to share same frequency and time resources by allocating different power levels.

- The transmitter assigns high power to the weaker user (in terms of channel gain) and vice-versa.

- The strong signal receiver will have a higher SNR which enables decoding its signal efficiently.

- The weak user can decode it's signal instantaneously as it considers the strong user's signal as noise.



Superposition Coding (SC)

Transmitted signal at base station:

$$s = \sum_{i=1}^{L} \sqrt{a_i P_s} x_i,$$

Here-
P_s- Transmission power at BS
a_i- Power coefficient for user i
x_i- Information of user i

Assuming- $|h_1|^2 \leq |h_2|^2 \ldots \leq |h_L|^2$

We have- $a_1 \geq a_2 \ldots \geq a_L$ and $a_1 + a_2 + \ldots + a_L = 1$

Better channel conditions → Less power allocated

Successive Interference Cancellation (SIC)

- At R_X SIC is performed successively until user's signal is decoded.
- User with highest transmission power considers other signals as noise.
- Other users first detect signals stronger than theirs.
- Then subtract this from the received signal.
- This is done until own signal is received

SNR for l^{th} user-

$$\mathrm{SINR}_l = \frac{a_l \gamma \left|h_l\right|^2}{\underbrace{\boxed{\gamma \left|h_l\right|^2 \sum_{i=l+1}^{L} a_i}}_{\text{Signals with better channel conditions}} + 1}.$$

Why NOMA?

Advantages-

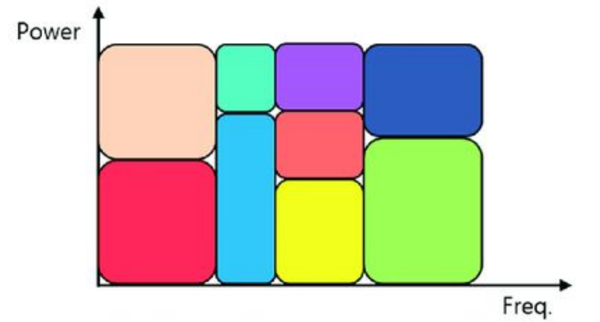
- Higher spectral efficiency
- Low latency
- Enhanced user fairness
- Supporting diverse QoS with Cognitive Radio NOMA

Disadvantage-

- Increased complexity of receivers
- Under similar channel conditions, Power Allocations (PA) causes issues with SIC
  (Topic of our project)
- Multipath effects

OFDM based NOMA

- Entire frequency band is split into various subcarriers.
- These subcarriers can have different spacings, wide or narrow.
- Then we apply NOMA within each subcarrier spacing.
- This reduces complexity as-
  - Don’t have to decode all user’s signal, just the ones present in subcarrier
  - Limits signal complexity

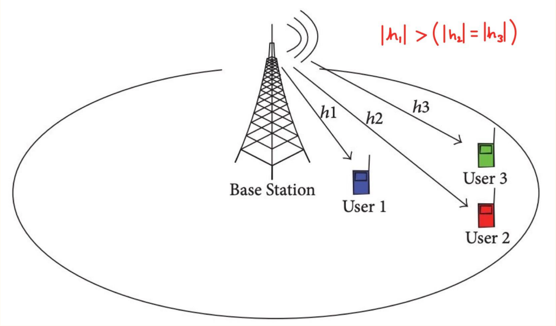


(b) Non-Orthogonal Multiple Access

Advantages of OFDM based NOMA over NOMA

- Improved spectral efficiency
- Better frequency reuse
- Enhanced resilience to interference
- Improved user fairness

Summary of Multi-Numerology paper



- This paper considers a 3 user scenario with two users having similar channel conditions (as seen in the image)

- Traditional NOMA will fail to attain fair power allocation and hence will cause issues with SIC at the user's receivers.

- This is where OFDM is useful.

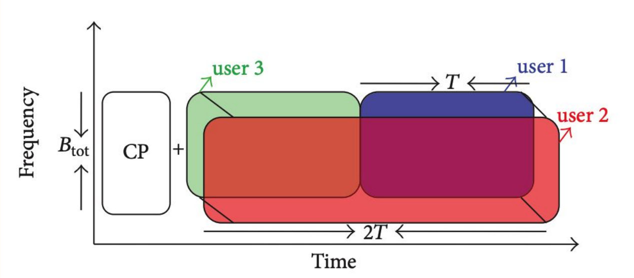
- We assign either user 2 (or user 3) a narrow subcarrier which is less frequently spaced and a wide subcarrier is used for user 1 and user 3 with NOMA scheme.

- This avoids the fairness power allocation issue when pairing user 2 and 3.

Signal representation and design analysis

At the transmitter-

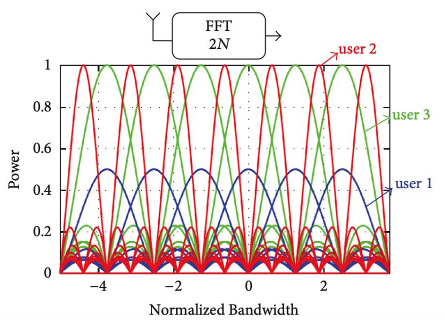
- User 1 and 3’s transmitted signal are generated by taking N-Point IFFT and user 2’s transmitted signal is generated by taking a 2N-Point IFFT.
- Then time multiplexing is performed as shown.
- To avoid interference, narrow-odd subcarriers are used and narrow-even places are filled with zeros.



Time representation

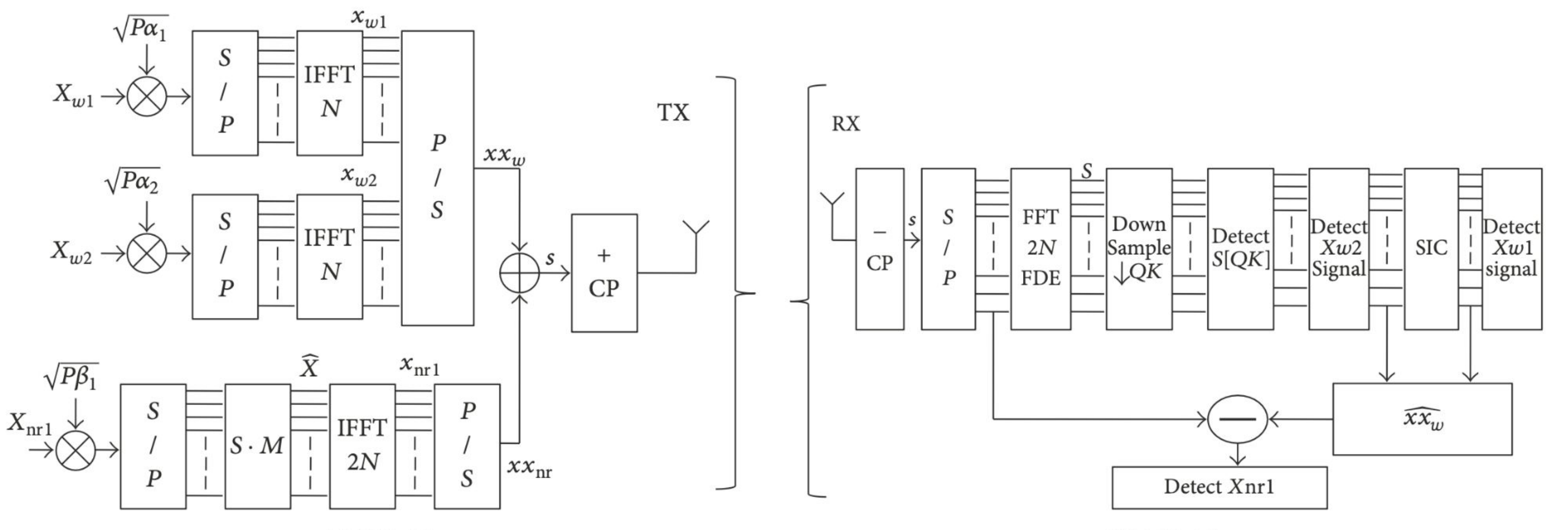
At the receiver-

- 2N-Point FFT is performed



Frequency representation

Transceiver design



(a) TX side

(b) RX side

Work Ahead

One of the major drawback of the approach described above is that if all the users have similar channel conditions then there will be difficulty regarding fair power allocation.

Several power allocation algorithm have been proposed to address this issue, and the choice of this algorithm depends on the specific requirements of the system.

We aim to design a fair power allocation scheme in OFDM-NOMA based systems for multiple users under almost similar channel conditions.

References

- NOMA for Multinumerology OFDM systems, Ayman T. and Huseyin Arslan
  Link
- A Tutorial on Nonorthogonal Multiple Access for 5G and Beyond
  Link
- A Fair Power Allocation Approach to OFDM-Based NOMA with consideration of Clipping
  Link
- Cognitive OFDM-NOMA System: A Succinct study
  Link
- Power domain-NOMA