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Novel Power Allocation Grouping Scheme with NOMA for Multi-User Visible Light Communication

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Visible light communication (VLC) using white light-emitting diodes (LEDs) for both indoor illumination and wireless data transmission is expected to play an important role in future generations of wireless communication networks due to its many advantages, such as the low cost of transceivers, the unregulated optical spectrum, and the secure nature of the transmission. Despite these advantages, one challenge is that when commercially available white LEDs are used as data transmitters, their modulation bandwidth is typically limited to only a few MHz. This limitation could constrain the transmission data rate, particularly when a single LED luminaire needs to support multiple users.

One potential solution to overcome this bottleneck problem is to use non-orthogonal multiple access (NOMA). In radio frequency (RF) wireless communication systems, NOMA has been shown to be a highly efficient approach for improving the spectral efficiency of wireless transmission systems, at the cost of increased demodulation complexity on the receiver side, as data demodulation follows a successive interference cancellation (SIC) process. Despite NOMA's success in RF wireless systems, its study in VLC or optical wireless communication remains limited. This is because VLC typically uses intensity modulation and direct detection (IM/DD), and the transmitted signal must be constrained to be both real and unipolar. Therefore, many NOMA techniques used in RF cannot be directly applied to VLC without significant modifications.

This thesis focuses on the implementation of NOMA in VLC and its integration with optical orthogonal frequency division multiplexing (OFDM) modulation, which is the modulation scheme used in most VLC standards. Specifically, the contributions of this thesis are divided into two stages. In the first stage, NOMA is integrated with an optical OFDM modulation scheme called asymmetrically clipped and DC-biased optical OFDM (ADO-OFDM), considering a special case where two users are paired. This approach differs from the conventional ADO-OFDM scheme, which is designed to support only a single user. In the proposed ADO-OFDM NOMA scheme, the odd subcarriers, modulated with the asymmetrically clipped optical OFDM (ACO-OFDM) component, carry the data intended for the user located farthest from the LED transmitter. Meanwhile, the data for the user closer to the LED transmitter is modulated onto the even subcarriers, which are modulated with the DC-biased optical OFDM (DCO-OFDM) component.

Furthermore, unlike conventional ADO-OFDM, the concept of NOMA is incorporated. The signal components of ACO-OFDM and DCO-OFDM are assigned different power levels based on the users' locations to balance performance between them. Simulation results show that by optimizing the power ratios between these two signal components, the overall bit-error rate (BER) can be significantly reduced.

In the second stage of this study, the proposed ADO-OFDM NOMA scheme is extended to a general case where a large number of users need to be supported. Specifically, the users are divided into multiple groups, with each group containing four users. To group the users efficiently, a grouping algorithm called Minimizing Channel-Gain Average Difference (MCGAD) is proposed. This algorithm depends on the channel gain of individual users, where the two users with higher channel gains are grouped with the two users with lower channel gains. Within each group, the four users are further divided into two pairs, with each pair implementing ADO-OFDM NOMA individually. Furthermore, an algorithm is developed to determine the optimal power allocation ratio between each user pair, as well as the power ratio of individual users within each pair. Simulation results show that by using the new grouping method together with the algorithm to allocate the optimal power ratio, the spectral efficiency of the system can be significantly improved.

In summary, this thesis makes a significant contribution by implementing NOMA techniques in VLC to enable multi-user support through a single LED transmitter. It also explores the integration of NOMA with optical OFDM modulation. Additionally, novel digital signal processing (DSP) techniques and advanced power allocation algorithms are proposed and analyzed to optimize transmission performance. Simulation results are provided to validate the effectiveness of the proposed methods, demonstrating their potential in improving the performance of VLC systems.

Keywords:VLC, NOMA, ACO-OFDM, DCO-OFDM, ADO-OFDM, MCGAD, Subcarrier Partitioning, SIC, Spectral Efficiency, Energy Efficiency