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A Joint Backscatter and VLC-NOMA Communication Scheme for B5G/6G umMTC System

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Abstract—This paper proposes a scheme of joint Backscatter communication (BAC) and Visible Light communication (VLC) based on Non-orthogonal Multiple Access (NOMA) for a Beyond-fifth-Generation(B5G)/Sixth-Generation (6G) ultra-massive Machine-Type Communication (umMTC) system. In this proposal, a hybrid RF-VLC channel combined with NOMA supports multi-users gain data from server and sensor information from local IoT items simultaneously. Moreover, benefits from non-interference between RF-VLC channel and more time-frequency resource allocated to each user, the communication performance is improved. A simulation was implemented to verify and estimate our proposal. Results indicated that our proposal gained higher channel capacity and reach lower bit error rate (BER).

Index Terms—VLC, NOMA, Backscatter Communication

I. INTRODUCTION

According to Cisco forecasting, by 2030 the predictable number of connected devices on the Internet will reach up to 500 billion devices. The scalability provided by the most modern centralized cloud system alone, will be insufficient to handle the future networks' efficiently, in an environment of billions of devices equipped with sensors, geared to collect huge amounts of data. To transfer massive amounts of data from the connected devices to the Cloud to be analyzed, creates a very crowded traffic on the network infrastructure. Moreover, the transfer of data back and forth between the Cloud and individual devices increases latency, while many new applications, such as self-driving vehicles, remote surgery, Augmented Reality (AR)/Virtual Reality (VR), 8K video, advanced robotics in manufacturing, and drone surveillance communication, require real-time, ultra-low delay performance. Furthermore, according to Gartner, by 2025, a minimum of 50% of the data created by Internet of Things (IoT) “will be stored, processed, analyzed and acted upon close to, or at the edge of the network”. Additionally, connection density has been identified by 3GPP as a Key Performance Indicator (KPI) for massive Machine Type Communications (mMTC) use cases with an expected increase in connection density to

1,000,000 connected devices per km². Therefore, traditional radio frequency (RF) networks, which are already crowded, are arduous to support the Quality of Service (QoS) for Beyond 5th Generation (B5G)/6th Generation (6G) communication. A large-spectrum and energy-efficient scheme combined with ultra-massive Machine Type Communications(umMTC) is needed in future IoT systems. VLC [1] provides nomadic access in hundreds of Terahertz (THz) of unlicensed optical spectrum, immunity to electromagnetic interference, safety and security, simple implementation, and deployment of systems [2]. Together with developments on light emitting diodes (LEDs) as the primary illumination source, VLC networks appear as a viable solution for simultaneous illumination and communication at low power consumption and with high durability [3]– [5]. In parallel, to meet the ever-increasing data demand of users in VLC for B5G/6G, non-orthogonal multiple access (NOMA) is proposed, which is expected to increase system throughput and accommodate massive connectivity. NOMA allows multiple users to share time and frequency resources in the same spatial layer via power-domain or code-domain multiplexing, which further expand spectrum efficiency [6].

Recently, Backscatter Communication (BAC) has emerged as a promising technology for umMTC systems. Backscatter devices can gather energy from surrounding signals broadcast from ambient sources, e.g., TV towers, FM towers, cellular base stations, and Wi-Fi access points (APs). In particular, the backscatter transmitter can transmit data to the backscatter receiver by modulating and reflecting surrounding ambient signals [7]. Hence, the communication in the BAC system does not require dedicated frequency spectrum and power supply, which reduces the power consumption and improves the channel capacity. Thus, it is an important potential solution for improving spectrum and power efficiency for umMTC in future network [8].

This paper introduces a scheme of joint backscatter-

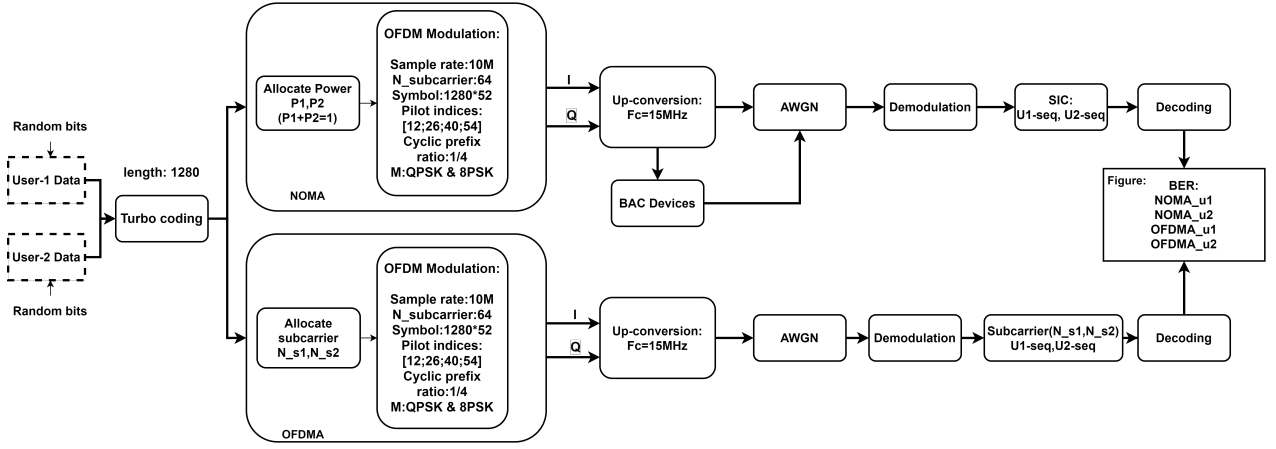


Fig. 2. Simulation Setup

$$y_i(t) = S_{opt}(t) + S_{RF}(t) \quad (1)$$

$$S_{opt}^i(t) = \sum_{j=1}^n \sqrt{P_j} h_{opt}^j * s_j(t) + n \quad (2)$$

$$S_{RF}^i(t) = \sum_{j=1}^m \sqrt{P'_j} h_{RF}^j * s'_j(t) + n' \quad (3)$$

$$C_i = C_{opt}^i + C_{RF}^i \quad (4)$$

$$C_{opt}^i = B_{opt} \cdot \log_2 \left(1 + \frac{P_i |h_{opt}^i|^2}{\delta^2} \right) \quad (5)$$

$$C_{RF}^i = B_{RF} \cdot \log_2 \left(1 + \frac{\sum_{j=1}^m \eta_j P'_j h_{RF}^j}{\delta'^2} \right) \quad (6)$$

Where, $s(t)$ and $s'(t)$ are the optical signal from VLC transmitter and the RF signal from BAC devices. P and P' denote their power. The noise and its power are represented by n and δ . B denotes the bandwidth of signal and η represents transfer coefficient of BAC devices. Channel gain are denoted by h . In this paper, the lights from transmitter are just considered the line-of-sight (LOS) propagation [9]. The Non-line-of-sight (NLOS) propagation of the lights are ignored. The LOS optical wireless channel is shown in equation (7)

$$h_{opt} = \frac{(m+1) * A_{det} * \cos \phi^{m+1}}{2\pi D^2} \cdot g(\psi) T(\psi) \quad (7)$$

$$m = \frac{-\ln 2}{\ln \cos \Phi_{1/2}^i} \quad (8)$$

where, $T(\psi)$ and $g(\psi)$ are the gain of optical band-pass filter and non-imaging concentrator. The order of Lambertian emission m is defined as equation (8), where $\Phi_{1/2}$ is semi-angle at half-power of LED.

III. SIMULATION AND RESULTS

To verify the feasibility and estimate the performance of our proposal, A comparison between a typical Orthogonal Frequency Division Multiple Access (OFDMA) system and our proposed NOMA system with BAC devices was employed through a simulation. Fig.2. shows the simulation setup, two series of random bits were generated to represent the data of two users. After turbo coding, these data passed NOMA system and OFDMA system respectively. In NOMA system, each user's data was allocated with different power and was modulated into OFDM symbols. After up-conversion, signal was emitted by a VLC transmitter and passed an Additive White Gaussian Noise (AWGN) channel. Once the signal was received and demodulated, the target user data was extracted. Meanwhile, BAC devices captured the signal from transmitter and re-modulated this signal to add their sensor information. The signal of each BAC device was set in different frequency band. In OFDMA system, we assumed all the sensor information and user data transmitted from server. Besides, the power allocation is replaced by subcarriers allocation to distinguish different users. Finally, bit error rate (BER) was calculated to compare and estimate communication performance.

Firstly, the comparison of channel capacity between two systems was shown in Fig.3. Within the same bandwidth, the channel capacity of NOMA-BAC system increase significantly with the growth of BAC devices. It matches with the theory that with the number of BAC device increasing, channel capacity will be extended.

Additionally, the BER of two system was compared and shown in Fig.4 and Fig.5. According to the results, it is obvious that NOMA system gains lower BER which indicate that NOMA system has better communication performance. In QPSK modulation scheme, two users of OFDMA system gained the same BER, however, in NOMA system, user-2 gain lower BER than user-1 but require more SNR. It well matches with the theory that due to the power allocation, the user suffered the lowest channel gain is allocated the highest power. Therefore, in low quality condition, BER of user-2 is higher

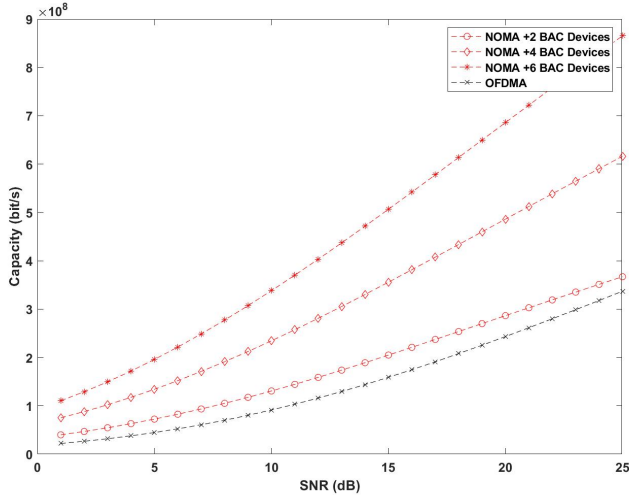


Fig. 3. Comparison of Channel capacity

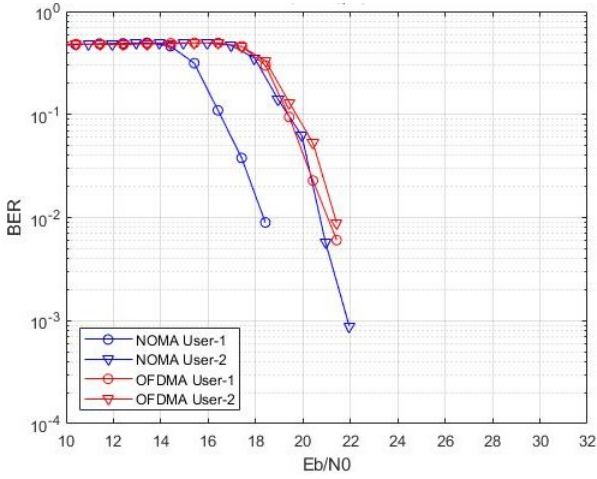


Fig. 4. BER of OFDMA vs NOMA @QPSK modulation

than user-1. Once the SNR is sufficient, user-2 gains better performance. In 8PSK scheme, due to the modulation order increased, to gain the same level of BER as QPSK scheme, the higher SNR is required. Due to the power allocation relationship as mentioned above, user-2 required more SNR to gain the better performance.

IV. CONCLUSION

In this paper, a joint backscatter and VLC-NOMA communication scheme is proposed for B5G/6G mMTC system. Users data from server and local sensor information from IoT items are transmitted to users simultaneously through optical wireless channel and RF channel, respectively. Benefit from its dual non-interference channel and NOMA technology, users gain more time-frequency resource to realize high quality communication. The feasibility of proposed scheme was verified by a simulation which compared the performance between our proposal with a typical OFDMA system. According to the

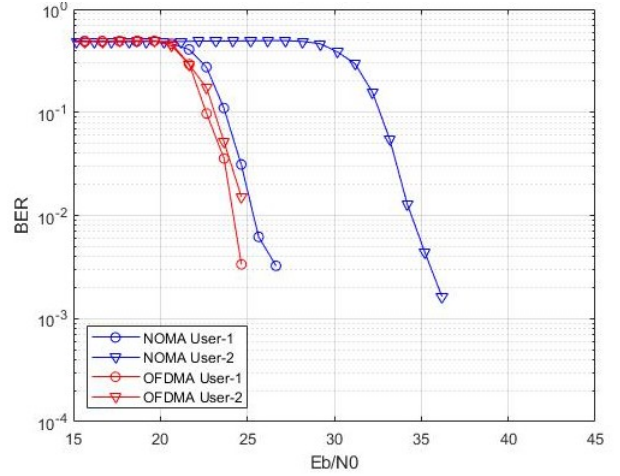


Fig. 5. BER of OFDMA vs NOMA @8PSK modulation

simulation results, our proposal gains higher channel capacity and lower BER in different modulation scheme. In the future, realistic channel and environment conditions will be considered into our proposal. Additionally, a demonstration will be implemented to estimate the feasibility and performance of our proposal.

V. ACKNOWLEDGEMENT

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