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Improved Sub-carrier Allocation and Relay Selection Scheme based on SC-FDMA in Multi-hop Signage System

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Abstract: ***This paper proposes a sub-carrier allocation scheme based on a single carrier frequency division multiple access (SC-FDMA) using a relay selection. The SC-FDMA can solve the peak-to-average power ratio (PAPR) problem by using a discrete Fourier transform (DFT) as a pre-coding. In a wireless signage system based on SC-FDMA, a multi-hop system using relays can extend communication coverage and solve the problem of the shaded area caused by the obstacle between the signages. In the conventional multi-hop system based on SC-FDMA, the communication between a source and relay does not use a communication resource efficiently. Therefore, this paper proposes a method that can usefully use a communication resource. Additionally, the relay selection scheme has a great influence on the multi-hop system. The new relay selection scheme considers the channel between the UE and the relay and between the relay and the destination in order to select a suitable relay. When the channel between the source and the relay is considered, the sub-carriers that are used for the communication between the source and the relay are only considered. So, the proposed scheme can use the suitable relay selection scheme in the multi-hop system based on SC-FDMA. As a result, the proposed scheme can provide the high signal-to-noise ratio (SNR) of the received signal. The simulation result shows that the performance of the proposed scheme is better than the conventional scheme in various scenarios.***

Keywords: **Signage, SC-FDMA, Relay Selection, Multi-hop System, DFT.**

I. BACKGROUND

Recently, wireless signage communication systems require the high throughput and reliability for high quality services. Thus, the wireless signage communication systems have been based on an orthogonal frequency division multiplexing (OFDM) that can provide the high spectral efficiency, throughput and reliability by using orthogonal sub-carriers [1]. The OFDM technique has robustness to the channels that undergo narrow-band interference and have frequency selective characteristic [2]. Thanks to theses advantages, the OFDM technique is used in many wireless communication systems such as the long term evolution (LTE), wireless fidelity (Wi-Fi), etc.. However, because the OFDM technique has high envelope fluctuations of the transmit signal, it has the PAPR problem [3]. In other words, expensive linear power amplifiers are required to use the OFDM technique. Especially for the uplink, the UE bears the undesirable additional costs [4].

SC-FDMA inherits the advantages of the orthogonal frequency division multiple access (OFDMA). On the one hand, the SC-FDMA can reduce the PAPR problem by using DFT algorithm. Therefore, the SC-FDMA has been adopted by LTE uplink [5]. Also, the SC-FDMA is a promising multiple-access transmission technique for future wireless signage communication system. In the

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SC-FDMA, the DFT pre-coding is used for the spreading, and the output of the DFT is assigned to the sub-carriers of IFFT [5-6].

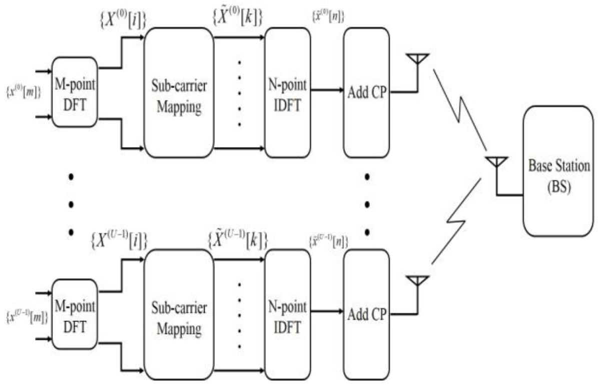

Fig. 1: A business-level Technology acceptance model

Figure 1 shows the transmitter of the SC-FDMA. The input data $x[m]$ is spread with the DFT pre-coding to generate $X[i]$. The $X[i]$ is as follows,

$$X^{(u)}[i]=\sum_{m=0}^{M-1}x^{(u)}[m]e^{-j\frac{2\pi}{N}mi}. \quad (1)$$

And then, the $X[i]$ is allocated as

$$\begin{aligned}\tilde{X}^{(u)}[n]&=\frac{1}{N}\sum_{k=0}^{N-1}\tilde{X}^{(u)}[k]e^{j2\pi\frac{n}{N}k}=\frac{1}{S}\cdot\frac{1}{M}\sum_{m_1=0}^{M-1}X^{(u)}[m_1]e^{j2\pi\frac{n}{M}m_1}\\&=\frac{1}{S}\cdot\frac{1}{M}\sum_{m_1=0}^{M-1}X^{(u)}[m_1]e^{j2\pi\frac{M_S+m}{M}m_1}\\&=\frac{1}{S}\cdot\left(\frac{1}{M}\sum_{m_1=0}^{M-1}X^{(u)}[m_1]e^{j2\pi\frac{m}{M}m_1}\right)\\&=\frac{1}{S}\cdot x^{(u)}[m],\end{aligned} \quad (2)$$

where $n=M\cdot s+m,\ (0\le s\le S-1,\ 0\le m\le M-1)$. In the equations, the u means the index of the source.

The SC-FDMA can be classified into two main types as localized and distributed ones according to the sub-carrier allocation schemes. Figure 2 shows the sub-carrier allocation schemes.

Distributed FDMA (DFDMA) distributes the outputs of M-point DFT over the entire band of total $(N-M)$ unused sub-carriers. On the other hand, localized FDMA (LFDMA) allocates the outputs of M-point DFT to consecutive sub-carriers. The effect of PAPR reduction depends on the way of assigning the sub-carriers [7].

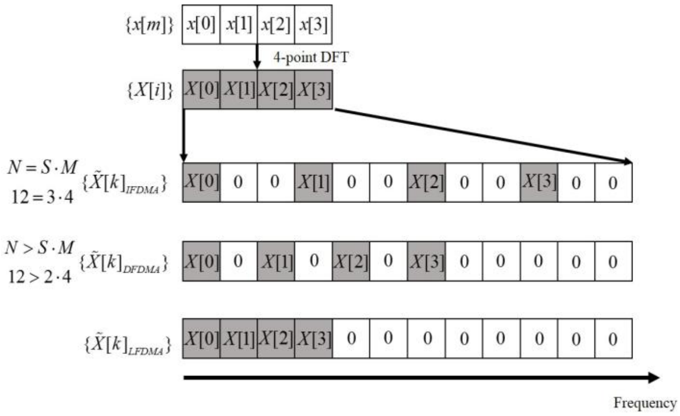

Fig. 2: Types of the SC-FDMA

The multi-hop system can extend the coverage of the wireless signage communication system and solve the problem of the shaded area caused by the obstacle between the destination and the source by using the relays. Therefore, the multi-hop system has been used in the various wireless communication systems. In the multi-hop system, the relay selection scheme has a great influence on the performance of the system. If the channel condition of the relay is poor, the multi-hop system has the performance degradation. On the other hand, if the channel condition of the relay is good, the system has the improved performance [8]. Therefore, when the relays are selected for the multi-hop system, the channel conditions are considered. Because the channel state information (CSI) is necessary for the relay selection scheme, the channel estimation is important.

The goal of this paper is to improve the reliability of multi-hop system by modifying the sub-carrier allocation scheme of the SC-FDMA and using a relay selection scheme considering the state of the channel conditions between the source and relay, and between the relay and destination.

This paper is organized as follows. In the section 2, explains the proposed multi-hop transmission scheme based on the SC-FDMA with the proposed relay selection scheme in detail. The section 3 shows the comparison of the proposed and conventional scheme through the simulation results and conclusion.

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II. METHODS

In this section, the proposed scheme is explained in detail. Figure 3 shows the system model. The system model is based on the SC-FDMA and multi-hop system of uplink. All signages can perform the function of the relay. Also, all relays use a decoded-and-forward (DF) method. There are one source, relay and destination in this scenario. In the system model, it is assumed that there is no the line-of-sight (LOS) between the source and destination.

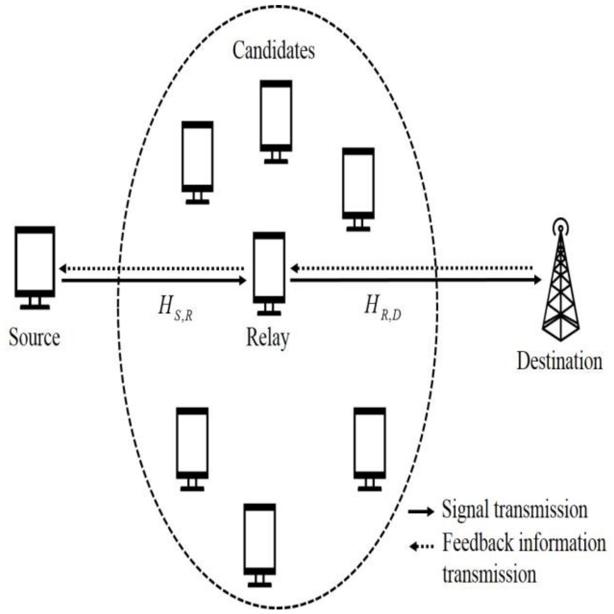

Fig. 3: System model

The number of the relay candidates is C. There is not a direct path between the source and destination. The $H_{S,R}$ means the channel response (CR) between the source and relay, and the $H_{R,D}$ means the CR between the relay and destination. The solid lines mean the information signals and the dotted lines mean the feedback information signals. Because the communication between a source and relay does not consider signals of other signages, it can use a communication resource efficiently. When the sub-carrier mapping step progresses, the conventional SC-FDM schemes use consecutive or constant interval sub-carriers. As a result, when the multi-hop system uses the conventional SC-FDMA such as the LFDMA and DFDMA, the system can not use the suitable sub-carrier that has good channel condition. Therefore, this paper proposes the new SC-FDMA scheme. In the new scheme, the source can know the channel conditions between the source and the relay through the feedback information. And then, the source determines the ranking of the sub-carrier via the channel amplitudes and selects the sub-carriers that will be used. The ranking index r has range from 1 to IDFT size N. If the ranking index is small, the channel condition is good. Also, if the ranking index is large, the channel condition is poor. The number of sub-carriers that will be used is the DFT size M. In other words, only sub-carriers with an index between 1 and M are used for the communication between the source and relay. As a result, because the multi-hop system can use suitable sub-carriers that have good channel condition, the performance of the system is improved. In the proposed scheme, the $X[i]$ is allocated as

$$\tilde{X}_{pro}[k]=\begin{cases} X[i], & i=ranking(k) \\ 0, & \text{otherwise} \end{cases}, \quad (3)$$

where $0 \le i \le M-1$.

Figure 4 shows the sub-carrier mapping of the proposed scheme. Figure 4 shows that only sub-carriers with ranking 1, 2, 3 and 4 are used. Because the communication between the relay and the destination considers the signals of other users, it uses the communication resource allocated to each user. If the proposed SC-FDMA is used for this communication, users that use the sub-carriers of low channel ranking have the serious performance degradation. So, the IFDMA is used for the communication between the relay and destination.

In the proposed multi-hop system, when the source selects the relay, the channel amplitudes are considered. The proposed relay selection scheme can help the source select the suitable relay in the multi-hop system based on the SC-FDMA system. The communication between the source and relay only uses the sub-carriers that have the ranking index r between 1 and M. Therefore, when the channel amplitudes are considered, the channel amplitudes between the source and relay are used according to

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$ranking(k)$.

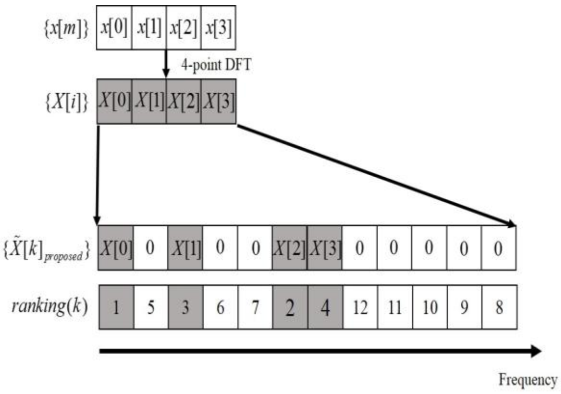

Fig. 4: Sub-carrier mapping method of the proposed scheme.

The source calculated the values in order to select the relay, and then selects the relay that has the largest value. The value is as follows,

$$V_{SC}[c]=\frac{\sum_{r=1}^{M}\left|H_{S,R}^{r}[c]\right|}{M}+\frac{\sum_{n=0}^{N-1}\left|H_{R,D}^{n}[c]\right|}{N}, \qquad (4)$$

where $r=ranking(k)$, $0\leq k\leq N-1$ and c means the relay candidate index. Because the relay that is selected by using proposed relay selection scheme has good channel condition, it can provide the high reliability. As a result, the destination can obtain the improved SNR of the received signal. Therefore, the new scheme can provide the extended coverage and solve the problem of the shaded area without degraded performance of the system.

III. RESULTS

In this section, the results and parameters of the simulation are explained. The proposed SC-FDMA scheme is used for the communication between the source and relay and the IFDMA scheme is used for communication between the relay and destination. The proposed scheme assumes that there is no LOS scenario between the source and destination. It is assumed that the channel estimation is perfect. Table 1 shows the parameters of the simulation.

Table 1: Description of the samples

Parameters	Type & Value
IDFT Size	256
DFT Size	64
CP Size	(IDFT Size) / 4
Channel Model	Rayleigh fading channel
Multi Path	7-path
Modulation Order	16-QAM
Channel Coding	Convolutional Coding
Code Rate	1/2

Figure 5 shows the bit error rate (BER) performance of the proposed and conventional scheme according to the signal-to-noise ratio (SNR). In Figure 5, the proposed scheme with random relay selects the random relay without the proposed relay selection scheme. The conventional scheme with random relay uses the IFDMA transmission scheme and selects the random relay without the proposed relay selection scheme. The conventional scheme with relay selection uses the IFDMA transmission scheme and selects the relay by using the proposed relay selection scheme. The simulation result shows that the proposed scheme has better performance than the conventional schemes. As shown the simulation result, the scheme using the proposed sub-carrier allocation method has higher BER performance than the conventional schemes in all SNR environments. Also, even if only the proposed sub-carrier allocation scheme is used without using the relay selection scheme, the performance is higher than that of the conventional sub-carrier allocation scheme. Additionally, even if only the proposed relay selection scheme is used without using the sub-carrier allocation scheme, the performance is higher than that of the random relay selection scheme.

This paper proposes the improved sub-carrier allocation and relay selection scheme in the multi-hop signage system based on the SC-FDMA. The proposed sub-carrier allocation scheme can help the source by using the suitable relay for the multi-hop system. So, the signal distortion caused by signal retransmission can be reduced in the relay. Additionally, the proposed relay selection scheme can help the source select the suitable relay. As a result, the proposed scheme can provide the high SNR of the received signals.

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Therefore, the new scheme can provide the improved performance and the extended signage communication coverage.

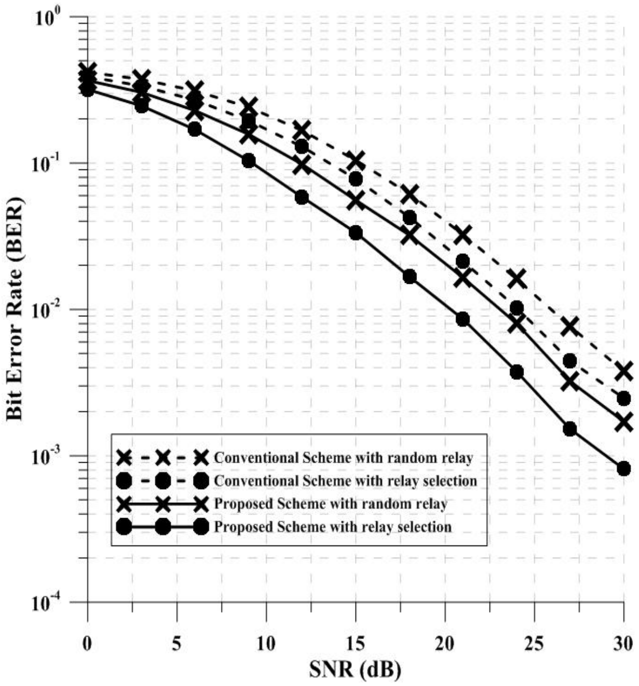

Fig. 5: BER performance of the proposed and conventional schemes according to the SNR.

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