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K-Mean Clustering for Chunk Formation based on Channel Response on OFDMA Radio Resource Allocation Systems

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In this paper, we propose a novel method of the chunk formation using K-means clustering on the resource allocation for OFDMA (Orthogonal Frequency Division Multiple Access) system. The method has been used in the chunk formation process is based on the received signal level by utilizing the channel gain information. In this study, we use the basic feedback information of downlink channel response that is complex numbers received by the base station. The simulation results show that the process of chunk formation using the K-Means Clustering gives SSE (Sum Squared Error) smaller and the total SSB (between group sum of squares) higher than the chunk formation based on the received signal level. Based on simulation results also indicated that the application of the proposed method of chunk formation gives the average throughput system better when compared with conventional methods.

Keywords: OFDMA, Resource Allocation, Channel Response, Clustering.

1. INTRODUCTION

Based on the statistical data issued by ITU (International Telecommunication Union), at the end of 2015, an increasing subscriber number of mobile broadband cellular almost five times more than in 2010. In 2010 the subscriber number of mobile broadband cellular original 11.5 per 100 inhabitants increased to 47.2 per 100 inhabitants[1]. With the greater number of customers, it needs an access method which can produce a high throughput, spectrum efficiency is good, and allow the use of frequencies simultaneously. Multiple access system recommended by 3GPP-LTE (3rd Generation Partnership Project–Long Term Evolution) and very promising is the OFDMA-based OFDM (Orthogonal Frequency Division Multiplexing) [2].

The main problem of mobile wireless communication systems is multipath fading channels, due to the reflection or diffraction of various objects between the transmitter-receiver and the time varying channel due to movement of the user or objects around which could degrade the quality of communications[3]. Due to multipath fading, the broadband communications systems will experience frequency selective fading on nearly all signals received, it can be resolved with OFDM / OFDMA systems[2]. As a result of the movement of the user or objects around, there will be a change of channel response at the time of signal transmission is different. For the purpose of maintaining throughput and spectral efficiency in time varying channel in OFDMA systems becomes very interesting to study.

In the OFDM system, the allocation to the different users can be placed on different subcarriers dynamically depending on the channel conditions of each subcarrier. To maximize system throughput, minimize transmit power and spectral efficiency already done research on the adaptation of transmitting power, subcarrier and bit allocation in the downlink direction[4-7] and uplink direction[8, 9]. Subcarrier allocation only fits on the number of subcarriers slightly, while for the very large number of subcarriers that it will require a high complexity. To

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reduce the complexity of the system then has done research on chunk allocation for the downlink direction[10-12] and uplink direction[13, 14]. Chunk is a collection of some of the subcarrier which has almost the same quality. However, in these studies[10-14], classifies multiple subcarriers into one chunk by SNR, BER and channel gain. These three basic groupings are only received signal level or just channel gain without regard to the phase signal is received.

In the field of computational science, has conducted research that discusses the application clustering algorithm for clustering of biological data[15]. According to the study[16], clustering algorithms can be applied to the fields: finance, marketing, insurance, health, medicine, chemistry, machine learning, data mining, and others. The application of the concept of clustering in the field of wireless communication is only one study, namely the Chunk Forming based on Constellation Signals on OFDMA Resource Allocation Systems[17].

Research in the resource allocation process of OFDMA systems is still very interesting to do further research. The research that we propose in this paper still in the OFDMA radio resource allocation, but our focus on grouping several subcarriers into one chunk base on the channel response. Channel response is a response on a transmission channel if a specific signal is transmitted, the transmitted signal is usually experienced attenuation or gain and delay. Gain or attenuation usually expressed in channel gain, while the delay is usually included in the phase. The mathematical expression of channel response is usually expressed in a complex number that has magnitude (channel gain) and phase (the delay) or has a real part and an imaginary part. The grouping that we propose using K-means clustering algorithm.

The composition of our paper as follows. In section 2, we discuss about OFDM/OFDMA system, and radio resource allocation. In section 3, OFDMA resource allocation model, the K-means clustering for chunk formation, SSE, SSB and wireless channel model are presented. The simulation results of comparing our proposed algorithm with conventional algorithms are presented in section 4. Finally, in section 5 we present the conclusions of our work in this paper.

2. OFDMA COMMUNICATION SYSTEMS AND RESOURCE ALLOCATION

Due to multipath fading, the channel impulse response becomes much impulse with a certain delay. If we analyze the frequency domain, the resulting frequency response fluctuates at different frequencies. The frequency range, which has a frequency response that is considered flat and highly correlated called coherent bandwidth. If the bandwidth of the transmitted information signal wider than the channel coherent bandwidth, the signal experiencing frequency selective fading[3]. If the transmitted signal has the potential to frequency selective fading, then we can cope with the multicarrier modulation. Multicarrier modulation which can save bandwidth is OFDM. OFDM can also be used for multiple access with OFDMA term.

a. OFDM/OFDMA Communication Systems

The fundamental concept of OFDM is to provide information wide bandwidth at high speed into a parallel information bandwidth at low speed, then transmitted by several subcarrier. Each made mutually orthogonal subcarriers using DFT (Discrete Fourier Transform) process, spaced frequencies used should be appropriate. DFT and IDFT (Inverse DFT) is used to ensure that each sub-carrier orthogonal, while to accelerate the process of computing can be implemented with FFT (Fast Fourier Transform) and IFFT (Inverse FFT) algorithms. OFDM modulation process using IDFT as follows:

$$x_o = \frac{1}{P}\sum_{p=0}^{P-1} X_p . e^{j\frac{2\pi . o . p}{P}}, \quad 0 \le o \le P-1$$

Where:

x_o = the output OFDM symbol with IDFT process
P = the IDFT point number or subcarrier number
X_p = the transmitted symbol data on the p^{th} subcarrier (In frequency domain)

The OFDM multicarrier system can also be used to carry many users. In the OFDMA systems, each user can occupy different subcarrier for a different time, as shown in figure 1:

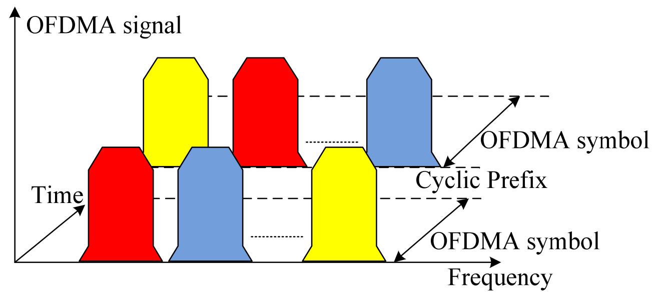

Fig. 1. OFDMA signal in frequency and time domain.

b. Resource Allocation

OFDMA when pass through the propagation channels that are time varying channel, then at a different time each user will also have different channel responses, as shown in Figure 2. In order for the delivery of data produce maximum throughput, spectral and energy efficient, it is necessary solutions resource allocation scheme can be adapted according to channel conditions.

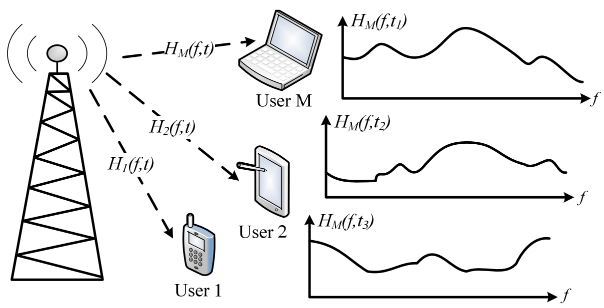

Fig. 2. Frequency response at the different time for M[th] user.

3. OFDMA RESOURCE ALLOCATION MODEL

Figure 3 shows a proposed model of single-cell radio resource allocation in OFDMA system. The number of active users that we use is *M*-user, while the number of chunks that can be selected is *K*-chunk. The resource allocation process is done every TTI (transmission time interval). In the early time of TTI, the base station receives the information of channel response from a number of *M*-user. By utilizing the channel response information from each user, and then do the grouping several subcarriers into one chunk commonly called a chunk formation. This chunk formation using *K*-Means clustering algorithm which is based on the channel responses of each user. Furthermore, the base station allocates chunk, power and bits to all users. We choose K-means clustering algorithm because it is simple and have less processing time.

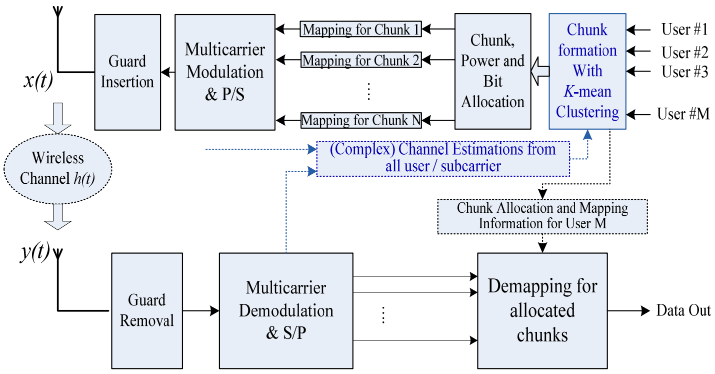

Fig. 3. The proposed model of resource allocation with K-means clustering for chunk formation.

a. K-means Clustering for chunk formation

The *K*-means clustering technique is a simple clustering algorithm. The first time we choose *K* point randomly as initial centroids at the complex channel response plot of each user/subcarrier, where *K* is the number of chunks. Each channel response point is then assigned to the closest centroid, and each collection of points assigned to a centroid is a cluster. The next step is to update the point of the centroid of each cluster with a different point. We continue to repeat these tasks and updating steps until there is no point of changing the cluster, or equivalently, to the centroids remain the same.

K-means is formally described by[18]:

1 Select K points randomly as initial centroids.
2 **repeats**
3 From K clusters by assigning each point to its closest centroid.
4 Re-compute the centroid of each cluster.
5 **until** Centroids do not change

We need a proximity measure that quantifies the distance of a channel response point to the closest centroid. The Euclidean (L_2) distance is frequently and properly used for data points in Euclidean space. The Euclidean distance measure between two objects is generalized by the Minkowski distance metric shown in Equation[18]:

$$d(\mathbf{h},\mathbf{c})=\left(\sum_{i=1}^{n}\left|h_i-c_i\right|^r\right)^{1/r}$$

Where n is the number of dimensions, h_i and c_i are, respectively, i^{th} components of **h** and **c**, and r is a parameter. If the parameter r = 2 and the dimension n = 2, the Euclidean distance is given by the following formula[18]:

$$d(\mathbf{h_m},\mathbf{c})=\sqrt{(h_{m1}-c_1)^2+(h_{m2}-c_2)^2}$$
$$m=1,2,3,\ldots,\mathrm{M}_{\mathrm{user}}$$

In our study, symbol $\mathbf{h_m}$ is the channel response from m^{th} user or subcarrier, it will be clustered, h_{m1} is the real part of $\mathbf{h_m}$ and h_{m2} is the imaginary part of $\mathbf{h_m}$. While **c** is a centroid the cluster, c_1 is the real part of **c** and c_2 is the imaginary part of **c**. Illustration Euclidean distance can be seen in figure 4.

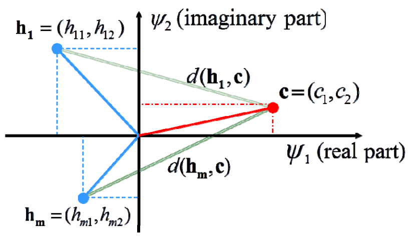

Fig. 4. The example of Euclidean distance.

b. SSE and SSB

To indicate whether the clustering process we are doing excellent or not, we use the sum of squared errors (SSE) and the between group sum of squares (SSB). For SSE, we calculate the error of each channel response to the nearest centroid, and then calculating the sum of the squared errors. SSB is the sum of the squared distance of a cluster centroid to the overall mean of the channel response. We prefer the one with the smaller SSE and the higher total SSB, if we choose the result of the clustering process. SSE and total SSB are defined as follows[18]:

$$\mathrm{SSE}=\sum_{k=1}^{K}\sum_{h_m\in C_k}d(\mathbf{c_k},\mathbf{h_m})^2$$

$$\mathrm{Total\,SSB}=\sum_{k=1}^{K}m_i.d(\mathbf{c_k},\mathbf{h})^2$$

Where $\mathbf{c_k}$ is the central point of cluster C_k, C_k is the k^{th} cluster, $\mathbf{h_m}$ channel response for m^{th} user, and **h** is the overall mean of $\mathbf{h_m}$.

c. Model of Wireless Chanel

We use the OFDMA downlink channel model with base station (one transmitter) and *M*-user (receiver), as shown in figure 2 above and figure 5 below. The representation of the wireless channel impulse response at baseband level for m^{th} user can be describe[19] :

$$h_m(t,\tau)=\sum_{l}\alpha_{l,m}(t).\delta(\tau-\tau_{l,m})$$

Where $\tau_{l,m}$ is the delay of the l^{th} path and $\alpha_{l,m}(t)$ represents complex amplitude caused by large scale propagation and small scale fading. The $\alpha_{l,m}(t)$'s are assumed to be a complex Gaussian process, narrow band and wide-sense stationary, which are independent for different users and paths.

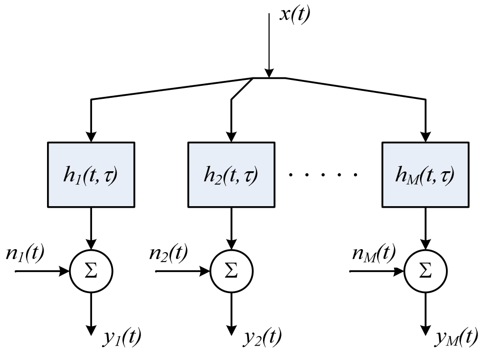

Fig. 5. Channel model.

4. SIMULATION RESULT

In this part, we show simulation results according to the model system in Figure 3 and the channel model in Figure 5. Simulation using Matlab 7.6 or Release 2008a. As an early initiation of each user occupies one subcarrier. Transmitted signal $x(t)$ using Binary Phase Shift Keying mapping signal with the symbol '1' as a pilot bit, multicarrier modulator with IFFT 128 subcarriers and the transmit power of 0 dBW.

Wireless channel $h_m(t,\tau)$ simulated by combining large scale propagation and small scale fading. Large scale propagation influenced by distance and frequency. The distance to the actual condition is the distance between the base station and users scattered in the cell. In this study, the users are assumed to be spread evenly so that the distance is simulated randomly uniformly distributed from 100 m to 3 km. While the frequency is the carrier frequency of each user / subcarrier. In this simulation using 128 user / subcarrier, from the smallest subcarrier frequency 2100 MHz, the next subcarrier frequency utilizing 15 kHz spacing.

Small scale fading simulation using Jake's models, user movement made uniformly distributed random from 3 km/h to 100 km/h. The Jake's model is a deterministic method for simulating time-correlated multipath fading based on summing sinusoids[20]. Furthermore, all active users estimate the downlink channel condition $h_m(t,\tau)$, the estimation is then sent as feedback to the base station to do chunk formation.

Figure 6 shows the results of K-means clustering on 128 user / subcarrier, with K = 5, so the results into five chunks. In the figure 6 simulated on a signal to noise ratio of 0 dB, visible differences between the clustering results based on received signal level (conventional method) and the clustering results based on the channel response (proposed method). To select a good result clustering process required curve SSE and total SSB. In Figure 7 shows the value SSE and total SSB at SNR -10 dB to 30 dB, it appears that results of clustering using channel response based show SSE (average 1.47 x 10^{-18}) lower than the conventional method and total SSB (average 1.49 x 10^{-17}) higher than the conventional method.

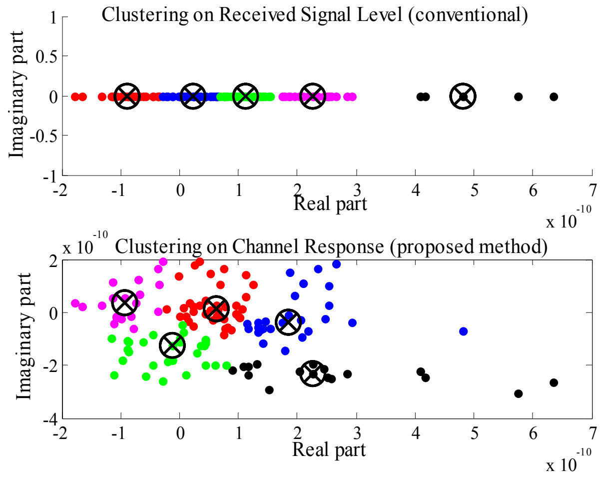

Fig. 6. Comparison of clustering results between the proposed method and conventional at SNR 0 dB.

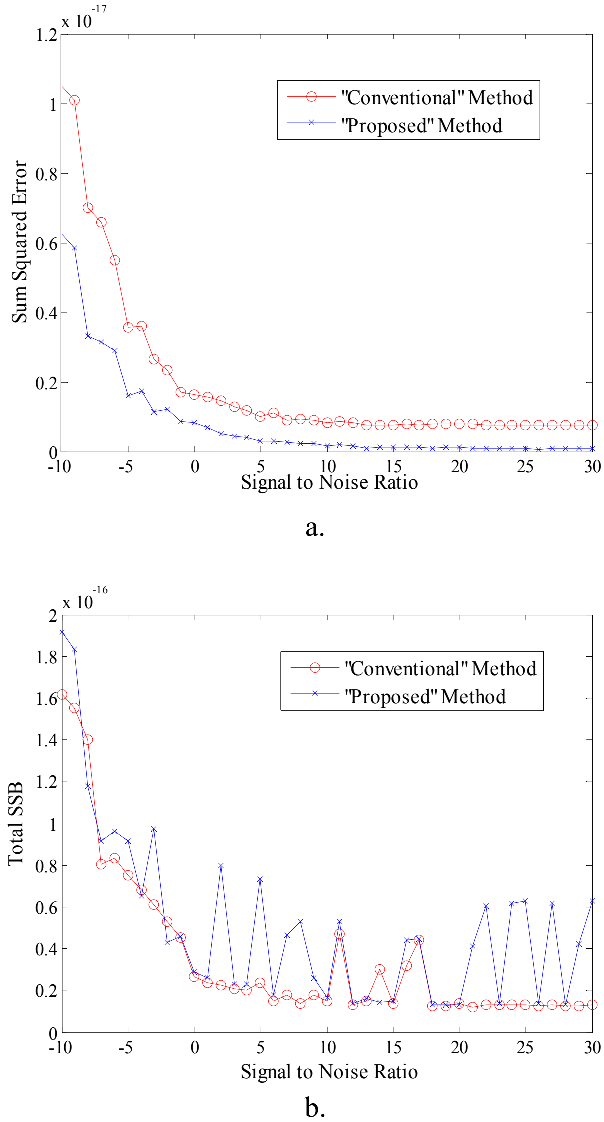

Fig. 7. Comparison of a. SSE and b. total SSB between the proposed method and conventional.

Figure 8 shows the comparison curve throughput system (in percent) between OFDMA system resource allocation with conventional chunk formation, and OFDMA resource allocation system with the proposed method of chunk formation. The results show that the throughput for different number of active users give the fluctuate results. However, the average throughput with the proposed method of chunk formation, an increase when compared to conventional methods of around 6%.

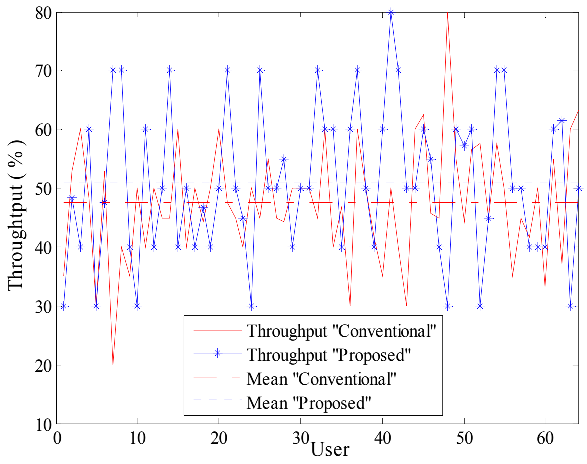

Fig. 8. Comparison throughput system (in percent) between the proposed method and conventional.

5. CONCLUSIONS

In this study, have proposed a new method chunk formation using K-means clustering on radio resource allocation in downlink OFDMA systems, the conventional methods that have been widely studied is a grouping of multiple subcarriers into a chunk based on the channel gain or received signal level or BER. The proposed method utilizes downlink feedback channel response of each active user. The experimental results show that using the K-means clustering algorithm on the process of chunk formation give SSE lower (average 1.47 x 10^{-18}) and total SSB higher (average 1.49 x 10^{-17}) when compared with clustering using received signal level. When compared with clustering using the received signal level, chunk formation process using the K-means clustering algorithm can also improve throughput on average 6%.

In our study, a new discussion on the process of formation the chunk using the K-Means clustering only. In the resource allocation system needs to be studied and analyzed further if applied chunk, power and bit allocation.

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