Use of Clustering Concept for Chunk Forming based on Constellation Signals on OFDMA Resource Allocation Systems

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***Abstract*—In OFDMA (Orthogonal Frequency Division Multiple Access) wireless system, environmental conditions and mobility of all users make the conditions of propagation of each user on all subcarriers changed at different times. Required radio resource allocation scheme that works with accurate, has a fairly low complexity and it is able to adapt to changing conditions. This research is to answer these issues by developing a new resource allocation scheme that is adaptive to changes in the channel, with the classification of some subcarriers into one chunk is based on the analysis of the constellation signal received on each subcarrier. We propose grouping some subcarriers into one chunk by using clustering concept, the algorithm chosen for the simplicity of the computing process is a K-Mean Clustering. The simulation results indicate that the resource allocation scheme that we have proposed give SSE (Sum Squared Error) improvement and can improve throughput when compared to the conventional scheme which uses clustering on the received signal level.**

Keywords—OFDMA, resource allocation, clustering, chunk forming

I. INTRODUCTION

Currently, the needs of mobile data services are increasing. At the end of 2015, the International Telecommunication Union (ITU) predicts there are about 7.085 billion mobile cellular subscribers with 96.8 per 100 inhabitants. ITU also reported an increase number of mobile broadband cellular subscribers of 11.5 per 100 inhabitants in 2010 to 47.2 per 100 inhabitants at the end of 2015 [1], or increased to more than four times.

On the other hand, wireless access network as a leader in expanding the infrastructure to provide services, have limited resources such as frequency, power and timing. So, we need a method of resource sharing by implementing resource allocation in order to remain efficient resource and have the quality of service is maintained. Standard Third-Generation Partnership Project-Long Term Evolution (3GPP-LTE) capable of providing data rates up to 100 Mbps at the user level that are vehicular mobility.

In order to achieve high speed data transmission through wireless channels, a novel resource sharing methods continue to be discovered and developed in OFDMA systems and SC-FDMA (Single Carrier-Frequency Division Multiple Access) systems. One is the radio resource allocation technique that allocates radio resources such as frequency, power and bits to the many users. In the study [2] - [5] proposed resource allocation scheme by dividing into power allocation and subcarrier allocation. Water filling power allocation using power allocation and subcarrier allocation is done per unit of the subcarrier. In [3] and [5], the objective of the allocation is to maximize the amount of spectral efficiency while [3] and [4] is to maximize fairness.

To reduce complexity, In studies [6] - [10] simplify the allocation subcarrier be allocated per unit chunk, with the allocation of power and a bit in the downlink direction and allocation of power using equal power allocation in the uplink direction. Chunk is a set of combined subcarrier based on quality criteria. In [6] - [10] still using classification / grouping multiple subcarriers into one chunk by SNR (signal to noise ratio) or BER (bit error rate), so it can still be developed alternate methods of classification of some subcarriers into one chunk especially those that can improve accuracy.

This proposed study is also in the area, with emphasis on classification / grouping multiple subcarriers into one chunk is based on the concept of clustering. Clustering here is grouping constellation signaling signal after passing through the downlink wireless channel, signal constellation which has a similar Euclidean distance will grouped into a subcarrier group called chunk.

The contents of this paper consist of the following sections: explanatory summary of research on resource sharing in chapter 1, the discussion of system OFDM (Orthogonal Frequency Division Multiplexing), OFDMA and SC-FDMA and radio resource allocation described in section 2, OFDMA system resource allocation model, chunk forming with the clustering concepts, wireless channel model discussed in section 3, the simulation results presented in section 4, while conclusions and discussions presented in section 5.

II. COMMUNICATION SYSTEMS OFDM, OFDMA, RESOURCE ALLOCATION

A. OFDM Communication Systems

The basic concept OFDM is to divide the high-speed serial data into low-speed parallel data that is transmitted with multiple subcarriers. Each subcarrier made mutually orthogonal that allows spectral overlap to improve bandwidth efficiency. Another advantage of OFDM systems is the ability to reduce the effects of multipath channel, since channel with frequency selective fading properties of the OFDM signal will be considered to be flat fading on each subcarrier.

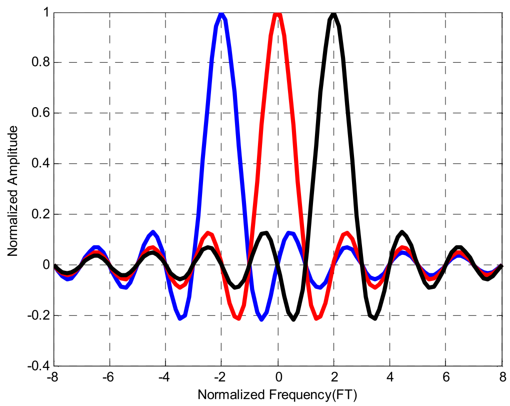


Figure 1. Spectrum of OFDM signals for three subcarrier [11]

The use of discrete Fourier transforms (DFT) on the OFDM system will reduce the level of complexity of the transmitter and receiver system. DFT is used in order to generate subcarriers that is orthogonal, each other, to shorten the computing time can be implemented algorithms of Fast Fourier Transform (FFT). But the FFT process is still done at the baseband level.

To generate baseband OFDM symbol, the first serial data sequence modulated using a modulation scheme such as Phase Shift Keying (PSK) or Quadrature Amplitude Modulation (QAM). This data Symbols are then converted into a sequence of parallel data by using a serial to parallel before multicarrier modulation. Each subcarrier sampled with a sampling rate N/T_s, where N is the number of subcarriers and T_s is the OFDM symbol duration. The frequency separation between the adjacent subcarrier is 2π / N. OFDM symbol is the sum of each subcarrier expressed by the following equation [11]:

$$x_m = \frac{1}{N}\sum_{n=0}^{N-1} X_n \exp\left\{ j\frac{2\pi mn}{N} \right\}, \quad 0 \le m \le N-1 \qquad (1)$$

Where:

N = number of point IDFT (subcarrier total) used
X_n = the symbol data transmitted on the n^{th} subcarrier (frequency region)
x_m = OFDM symbol output in IDFT process

The purpose of this process is to ensure orthogonality between subcarrier, although the spectrum can be made to overlap each other. IDFT can be implemented using Inverse Fast Fourier Transform (IFFT). With the IFFT, computation process has also become faster.

B. OFDMA and SC-FDMA

Third Generation Partnership Project (3GPP) has introduced LTE (Long Term Evolution) as the standard of 4^{th} Generation (4G), which has adopted as a standard OFDMA multiple access technology in the downlink direction to accommodate a wide variety of broadband services based Internet protocol. In the OFDMA system each user occupies a different frequency, each user occupies a space between the subcarrier with subcarrier designed by *Rs* (symbol rate of each subcarrier). As for the direction uplink, systems use SC-FDMA as a multiple access technology standard that uses a single carrier for each user [12]. Illustrations difference OFDMA and SC-FDMA can be described as Figure 2.

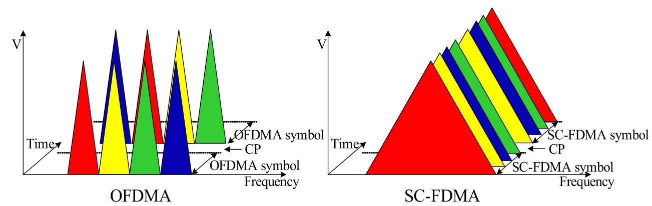


Figure 2. Differences OFDMA and SCFDMA [13]

C. Problems in systems OFDMA and SC-FDMA

After passing through the propagation channels which are frequency selective fading and time varying channel, so each different user will have different responses as well as shown in Figure 3. To achieve better communication quality, maximum throughput, spectral efficiency and energy are needed solution resource allocation scheme that can adapt to changes in channel conditions.

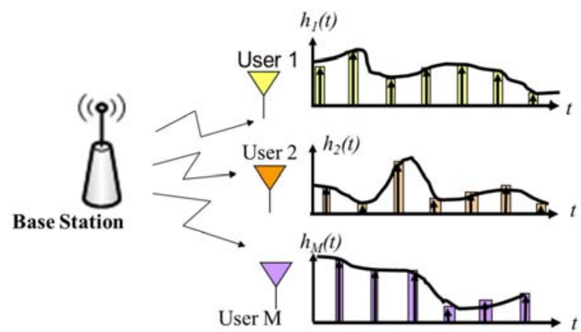


Figure 3. Each user goes through different responses

Figure 3 illustrates the communications downlink direction. User 1 passes through the different propagation channel with other users, so it had a different response.

D. Radio Resource Allocation

The idea of the use of channel state information (CSI) at the transmitter to increase the performance of the communication system was first conceived in [14]. The basic idea is the use of the knowledge of the transmission channel to set the parameters in order to maximize communication performance. The concept was first known as the concept of adaptive modulation and coding. The use of adaptive modulation and coding developed further in the case of a single user at [15] - [16].

The development of the concept of adaptive modulation to schedule users on a multiuser wireless system evolve since introduced the term multiuser diversity [17] and the proportional fair scheduling [18]. In both of these studies, the wireless channel affected by fading can be seen as a means to improve system performance when it is used for multiuser applications.

In a system of OFDMA and SC-FDMA does not occur multiple access interference (MAI) phenomenon for each user using a set of subcarriers or chunk which differ from one another in one TTI (time transmission interval) when the session traffic exchange. The division of use subcarrier every user is done through the process of resource allocation. The process is carried out at the beginning of each TTI by allocating all N available subcarriers to a number of such K-user that in one TTI does not happen multiple access interference.

Resource allocation utilizing the diversity of instantaneous channel state information conditions in the duration of one TTI. As a result of the mobility of the user, the propagation channel changes in the frequency and time domain. Subcarriers experiencing fading at a particular user can be viewed as a subcarriers that are not experiencing fading by another user. So it can be done available subcarrier allocation and power of each subcarrier to all users individually by the scheduler. The scheduler can view this condition as a condition of multiuser diversity because there are variations of propagation conditions on all the subcarriers available for all users.

III. OFDMA RESOURCE ALLOCATION SYSTEM MODEL

Model of resource allocation in OFDMA system for single cell is shown as in Figure 4, where there are *M* active users and *N* chunk. The total system bandwidth available is *B* and the bandwidth of each subcarrier is b_s. In the model, at the beginning of a transmission time interval, the base station sends the same symbol mapping/modulation signal to *M*-user using signaling channel. At the receiver in each user, OFDM demodulation process is carried out using the FFT process. The output of the FFT is the symbol with the constellation same as on the transmitter, the difference is that the symbol on the receiver already passed the downlink wireless channel. Constellation these signals are fed back to the base station, assuming the feedback works perfectly. By utilizing the signal constellation information of each user, then grouping subcarriers that have quality similar / almost equal to one chunk commonly referred to as a chunk forming. Furthermore, the base station allocates power and bit into each chunk, and allocate an available chunk of all users.

A. Use of Clustering for Chunk Forming

Cluster analysis is an attempt to find a group of objects that represent a character of the same or similar between one object to another object in a group and have differentiated or not similar to the objects in other groups. Clustering algorithms trying to find a group of natural objects, based on some similarities [19].

The most important concept to realize is that the clustering process that will result in clusters with high quality if it has a high degree of similarity in one class (high intra-class similarity) and a low level of similarity between the classes (low inter-class similarity). Similarity is a numerical measurement of the two objects. In measuring the value of similarity has often used methods of Euclidian Distance.

Euclidean distance between two objects or signal *c(t)* and $y_i(t)$ is [20] :

$$dist(y_i, c) = \|y_i(t) - c(t)\| = \sqrt{(a_{i1} - c_1)^2 + (a_{i2} - c_2)^2} \quad (2)$$
$$i = 1,2,3$$

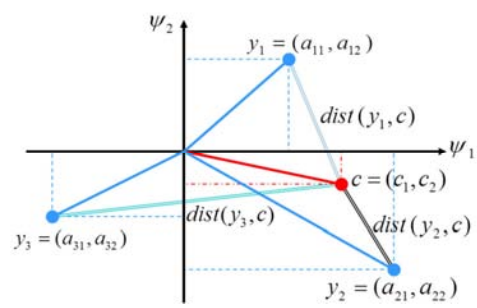


Figure 5. Euclidean distance in the signal space analysis [20]

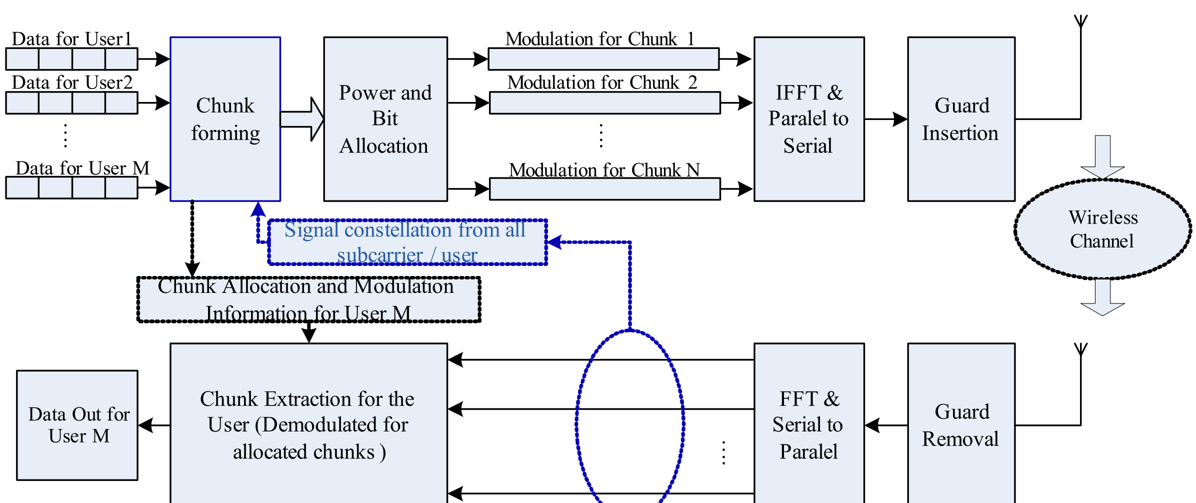


Figure 4. The proposed model of resource allocation in OFDMA systems with chunk allocation, power and bit, modified from [7].

Where $c(t)$ is the central point of a cluster (centroid), while c_1 is a projection of $c(t)$ to the first base function or Ψ_1 and c_2 is the projection of $c(t)$ to the second base function or Ψ_2. Symbol $y_i(t)$ is the data or object will be done grouping or clustering, a_{i1} is projected $y_i(t)$ to the first base function or Ψ_1 and a_{i2} is projected $y_i(t)$ to the second base function or Ψ_2.

In the study of resource allocation, the clustering algorithm will be used in the process of forming chunk as shown in Figure 4 above. Object or data $y_i(t)$ will be clustering is signaling signal constellation received from each user or subcarrier after the FFT process, where there are *M*-user or subcarrier of FFT output. FFT output signal constellation can indicate the condition of the channel passed by each user or subcarrier, so by clustering this constellation signal means also group some subcarriers that have similar quality / almost equal to one chunk.

B. K-Means clustering Algorithm

The K-means clustering algorithm is one of the top ten clustering algorithms, it is simple algorithm [21]. In this study, we use this algorithm because the process is simple. The purpose of this algorithm is to split the data into several groups or *K*-group. This algorithm accepts input in the form of data without a label. Input received is a data or object and k-groups (clusters) as desired. This algorithm will classify data or objects into *K*-group. At each cluster there is a central point (centroid) which represents the cluster.

Basic K-Means clustering algorithm is as follows [22]:

1. Select *K* points as initial centroid randomly.
2. Categorize the data, thus forming *K*-clusters with each cluster centroid point is the centroid point that has been previously selected.
3. Update centroid point value.
4. Repeat steps 2 and 3 until the value of the centroid point are no longer changed.

The process of grouping data into a cluster can be done by calculating the distance (Euclidean distance) of a data closest to a centroid point.

C. SSE (Sum Squared Error)

SSE is used to determine the better clustering results, if the centroid of its initialization is different. SSE calculates the error of each data point, its Euclidean distance to the closest centroid, and then compute the total sum of the squared errors. Given two different sets of clusters that are produced by two different runs of *K*-mean, we prefer the one with the smallest squared error since this means that the prototypes (centroids) of this clustering are a better representation of the points in their cluster. SSE is formally defined as follows [22]:

$$\text{SSE} = \sum_{i=1}^{K} \sum_{y \in C_i} dist(c_i, y)^2 \tag{3}$$

Where c_i is the centroid of cluster C_i, C_i is the i^{th} cluster and y is an object or data.

D. Wireless Channel Model

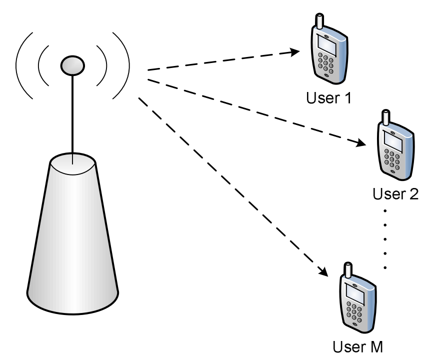
We model the OFDMA downlink network with one transmitter (base station) and *M*-receiver (user), as shown in figure 6(a) below. The complex baseband representation of the impulse response of wireless channel for user i can be describe by [23] :

$$h_i(t,\tau) = \sum_l \alpha_{l,i}(t).\delta(\tau\text{-}\tau_{l,i}) \tag{4}$$

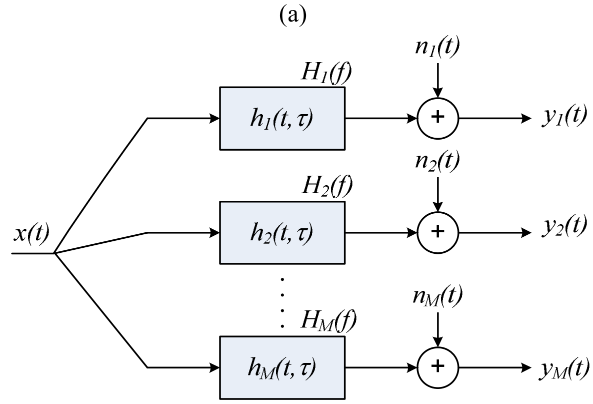
Where $\tau_{l,i}$ is the delay of the l^{th} path and $\alpha_{l,i}(t)$ is the corresponding complex amplitude. The $\alpha_{l,i}(t)$'s are assumed to be wide-sense stationary, narrow band, complex Gaussian process, which are independent for differents paths or users. The frequency response of the channel impulse response can be expressed as [23] :

$$H_i(f,t) = \int_{-\infty}^{+\infty} h_i(t,\tau) e^{-j2\pi f\tau} d\tau = \sum_l \alpha_{l,i}(t) e^{-j2\pi f\tau_{l,i}} \tag{5}$$

If only instantaneous channel conditions are considered, the channel frequency response corresponding to user i is denote by $H_i(f)$. Consequently, the *M*-user wireless channel can be represented as in figure 6(b).



(a)



(b)

Figure 6. (a) OFDMA downlink network. (b) Channel model [23]

IV. SIMULATION RESULTS

In this section, we present simulation results to illustrate the performance of the proposed chunk forming in resource allocation. Channel model as shown in Figure 6 (b), with transmitted signaling signal $x(t)$ is a BPSK modulated signal with the symbol '1' and the transmit power of 1 watt, emitted by the IFFT 64 subcarriers or 64 users. Whereas $y_i(t)$ is the received signaling signal for each user after passing through the wireless channel.

Wireless channels that are used in the simulation $h_i(t,\tau)$ is a large scale propagation model combined with small scale fading. The large scale propagation model is a function of distance and frequency. The distance in this simulation is made randomly from 100 m until 3 km distributed uniformly. The frequency used from 2100 MHz, using 64 subcarriers at 15 kHz spacing. Small scale fading (due to multipath fading and movement of the user) are using the jakes method with the movement speed of the user is made randomly from 3 km/h until 100 km/h.

In Figure 7, we show the difference in the Magnitude Received Power Level of $y_i(t)$ for 10 TTI of each subcarrier. The differences caused by differences in random distances, multipath fading and random movement speed of each user.

Figure 8 shows the results of clustering using K-means clustering algorithm on 64 subcarriers to 5 chunks on each subcarrier / user after passing through the wireless channel. There are differences in the clustering results based on received signal level (conventional) and constellation signals (proposed method), but the proposed method show more accurate results because the signal is grouped actual signal that has real and imaginary parts.

Figure 9 shows the curve of SSE of the clusters as a function of SNR. From low SNR to high SNR, K-mean clustering algorithm if applied to signal constellation for chunk forming (proposed method) indicate the smaller value of SSE (average 1.239 x 10^{-18}) if compared with Clustering the received signal level (conventional).

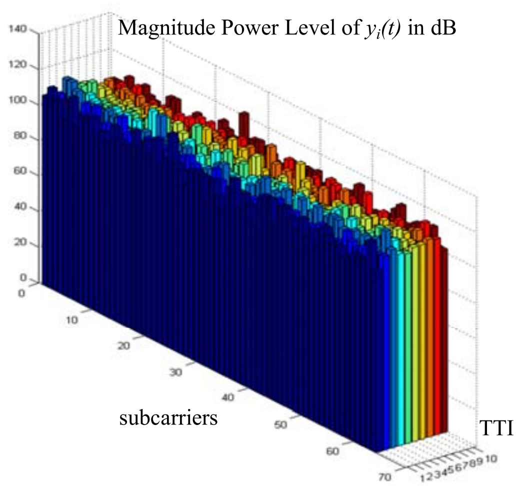


Figure 7. Magnitude Received Power Level

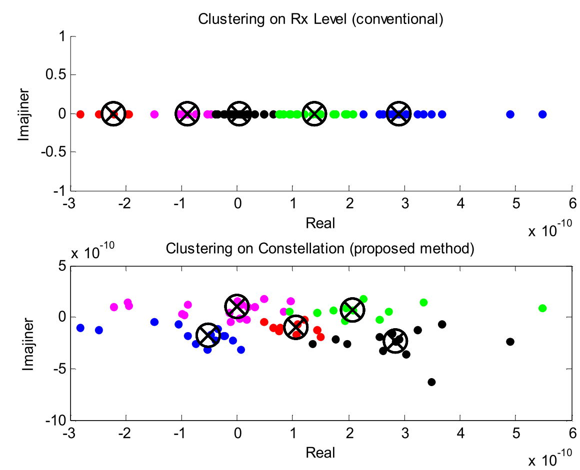
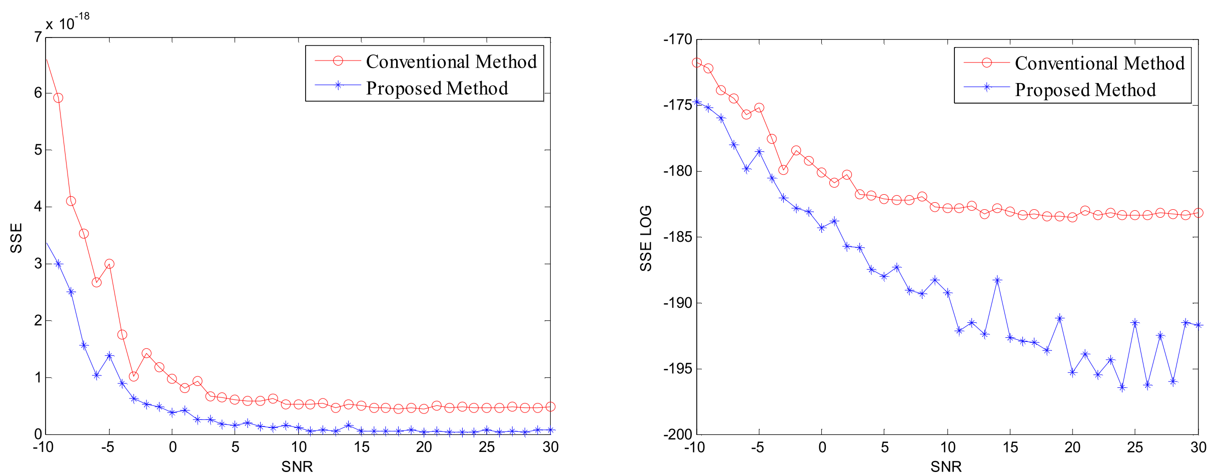


Figure 8. Clustering using K-means clustering algorithm



(a) (b)

Figure 9. Sum Squared Error of the clusters. (a) In numeric, (b) in decibels

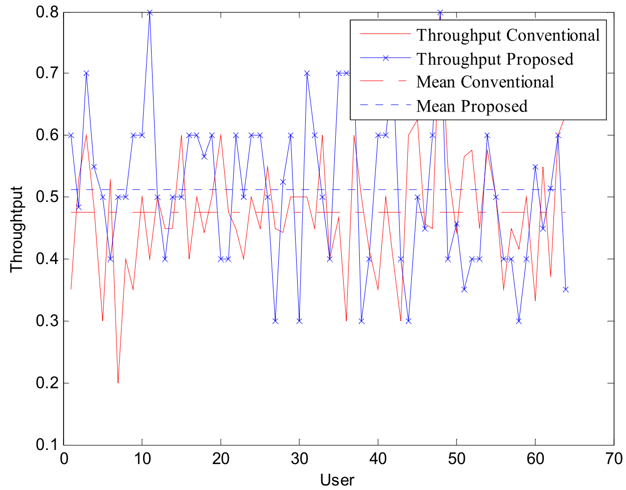


Figure 10. Throughput versus the number of users

Figure 10 shows the throughput curves as a function of the number of users. Throughput value will fluctuate if the number of active users is also different. However, the average throughput with a chunk forming using the proposed methods increase (0.05) when compared to conventional methods.

V. CONCLUTIONS

In this paper, we have presented a novel chunk forming using the clustering concept for resource allocation in OFDMA systems. The proposed method utilizes feedback constellation signal from each user / subcarrier. We proposed clustering process using K-means clustering because it is simple and fast computation process. Simulation results show that using K-means clustering algorithm on the process of chunk forming provide lower SSE compared with clustering using received signal level. Using K-means clustering algorithm on a chunk forming process can also increase the average throughput compared with clustering using received signal level (conventional).

In our study, we use K-means clustering and the maximum number of subcarrier/users by 64. In future studies may use others algorithm and a larger number of subcarriers.

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