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Review of Radio Resource Management For IMT-Advanced System

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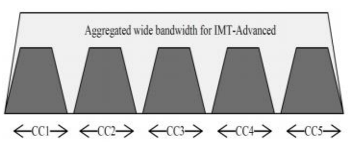

Abstract

This paper provides a review of radio resource management technologies that can be used or proposed for OFDMA-based IMT-Advanced system. IMT-Advanced specifications significantly enhanced the existing IMT 2000 standard which are represented by LTE-Advanced and mobile WiMAX as the main successful candidates. One of the key components for OFDMA is Radio Resource Management (RRM) which is used to manage radio resources for the air interface in a cellular network. The main purpose of RRM is to utilize the available radio resources efficiently. The RRM tools such as power control, handover, packet scheduling, resource allocation and, load and admission control are needed to be controlled to maximize the performance efficiency in the wireless networks. By controlling these RRM tools, we are able to maximize the number of users in the network and let the users experience the best Quality of Service (QoS) and throughput.

Keywords: IMT-Advanced; OFDMA; radio resource management

1.0 INTRODUCTION

Nowadays, people are more likely and gradually becoming familiar with using wireless network medium to transfer various forms of data such as emails, videos, and pictures, all which have benefited from the fast growing wireless communication technologies. Currently, International Telecommunications Union (ITU) is working on the enhancements of the system requirements for next generation mobile communication systems called International Mobile Telecommunications-Advanced (IMT-Advanced) and beyond. IMT-Advanced systems are mobile broadband communication systems that include new capabilities that go significantly beyond those of the IMT-2000 family of systems such as wideband code-division multiple access (WCDMA) or WiMAX and Long Term Evolution-Advanced (LTE-Advanced). The main reason ITU introduced IMT-Advanced is to enhance the capability of previous technology and eliminating the limitation in communication networks to provide a better service. Basically, the performance of IMT-Advanced will support low to high mobility of applications in which case 100 Mbit/s for high and 1 Gbit/s for low mobility conditions [1][2].

Orthogonal Frequency Division Multiple Access (OFDMA) has been recognized by ITU as the core PHY layer technology for the next generation of IMT-Advanced systems, especially for mobile broadband services with higher data rates and Quality of Service (QoS). Besides that, OFDMA, which is the combination of FDMA and OFDM, is growing steadily and used modulation/multiple access techniques [3] because this promising technique provides an air interface for the next generation of wireless system. For OFDMA modulation technique, the base stations enable multiple users to transmit simultaneously on different subcarriers during the same symbol period.

Radio Resource Management (RRM) is one of the key components of OFDMA modulation technique in wireless system. RRM is the system level control of co-channel interference and other radio transmission characteristics in wireless communication systems, for example in cellular networks, wireless network and broadcasting systems. This concept of modulation is well developed and a number of techniques are already in existence and have been implemented in the latest releases of IEEE802.16m and 3GPP Release 10 and 11. Table 1 shows the comparison between LTE with WiMAX.

Table 1 Comparison LTE and WiMAX

	LTE	WiMAX
Organize by	3GPP	WiMAX Forum & IEEE
Radio Scheme	OFDMA (DL) / SC-FDMA (UL)	OFDMA
Channel BW (MHz)	1.4, 1.6, 3.5, 10, 15, 20	3.5, 5, 7, 8.75, 10
Frequency Band (MHz)	700/850/1800/ 1900/2500/2600	2300/2500/3300/3500/ 3700

The main objective of this paper is to give an overview on how the performance of IMT-Advanced can be enhanced by controlling the RRM tools. The rest of this paper is described as follows. The first section describes the IMT-Advanced and its content: LTE–Advanced and WiMAX. Then, the second section provides a description of IMT-Advanced while section three deliberates on current issues in Radio Resource Management (RRM) methods used in IMT-Advanced system such as power control, packet scheduling, channel allocation, radio resource allocation and handover. Section 4.0 summarizes all the issues regarding the current RRM tools for IMT-Advanced that have been discussed in previous sections. Finally, Section 5.0 concludes this paper.

2.0 DESCRIPTION OF IMT-ADVANCED

IMT-Advanced is the term introduced by ITU for radio access technologies beyond IMT-2000. There are two selected technology candidates for IMT-Advanced standards; Long Term Evolution-Advanced (LTE-Advanced) by 3GPP and 802.16m which is known as WiMAX Release 2 or mobile WiMAX by IEEE. WiMAX and LTE-Advanced are the two emerging technologies for high-speed mobile broadband Internet services. These two technologies appear to have similar goals for enabling worldwide wireless data network connectivity for cell phones, laptops and other computing devices.

LTE Release 10 which is under the scope of IMT-Advanced topology has been finalized at the end of 2011 by Third Generation Partnership Project (3GPP). The specifications provide support for positioning services, broadcast/multicast services, and enhanced emergency-call functionality [3]. LTE Release 10 was later enhanced after Release 11 was completed in June 2013 [4]. The capability of LTE-Advanced are highly recommended by 3GPP because it could support transmission bandwidths up to 100 MHz and increase the capacity of the User-Equipment (UE) during the transmission and reception processes [5]. LTE-Advanced allows for operation in both paired and unpaired spectrum by providing a single radio-access technology supporting Frequency-Division Duplex (FDD) as well as Time Division Duplex (TDD) [6]. In the future, LTE Release 12 and 13 will be finalized to provide much better features and performance by overcoming most issues from the previous releases. Figure 1 illustrates the basic operation of LTE when it enables a pair of the frequency spectrum.

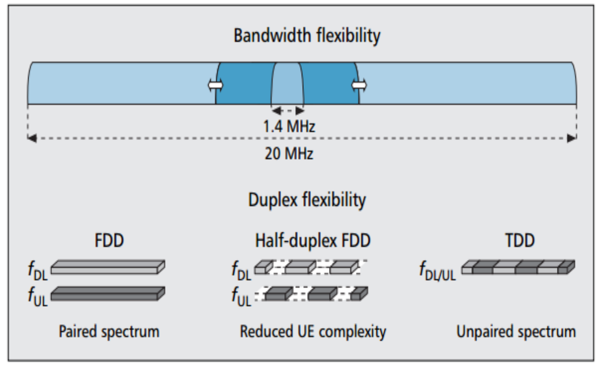

Figure 1 LTE spectrum (bandwidth and duplex) flexibility. Half duplex FDD is seen from a terminal perspective [6]

There are some requirements that LTE–Advanced need to fulfill in order to achieve IMT-Advanced specifications such as peak data rate, spectrum allocation, latency and spectrum efficiency. Table 2 shows the details for LTE-Advanced in comparison with IMT-Advanced requirement to fulfill the standard set by ITU and 3GPP.

Table 2 ITU and 3GPP requirement for LTE-Advanced [7]

Quantity		IMT-Advanced	LTE-Advanced
Peak data rate	UL	-	1 Gbit/s
	DL	-	500Mbit/s
Spectrum allocation		Up to 40MHz	Up to 100MHz
Latency	User plane	10 ms	10 ms
	Control plane	100 ms	50 ms
Spectrum efficiency (4 ant BS, 2 ant terminal)	Peak	15 bit/s/Hz DL 6.75 bit/s/Hz UL	30 bit/s/Hz DL 15 bit/s/Hz UL
	Average	2.2 bit/s/Hz DL 1.4 bit/s/Hz UL	2.6 bit/s/Hz DL 2.0 bit/s/Hz UL
	Cell-edge	0.06 bit/s/Hz DL 0.03 bit/s/Hz UL	0.09 bit/s/Hz DL 0.07 bit/s/Hz UL

Worldwide Interoperability for Microwave Access (WiMAX) is a wireless broadband technology that delivers WiFi-like speeds to wide areas. WiMAX 4G wireless data network is based on the IEEE 802.16e specification, and operates in the 2.5-GHz band. The WiMAX system is originally designed to be a data centric network based on the IP technology, that mostly different from the existing voice-centric mobile communication network that used circuit-mode technology [8]. In fact, the OFDM physical layer used by WiMAX implement more Multiple Input Multiple Output (MIMO) technologies rather than using Code Division Multiple Access (CDMA) modulation techniques based on the standpoint of the required complexity for comparable gain. In order to improve capacity, it would be an ideal situation to exploit frequency diversity and multiuser diversity by applying OFDM [9]. Table 3 shows the technical comparison between the current and the previous releases of WiMAX. It can be said that WiMAX Release 2 fulfils one of the requirements of IMT-Advanced; the throughput.

Table 3 Comparison of WiMAX technologies.

	Mobile WiMAX R2	Mobile WiMAX	Fixed WiMAX
Standards	802.16m	802.16e	802.16d
Throughput	More than 300Mbps	Up to 30Mbps	Up to 75Mbps
Range	1- 3 Miles	1- 3 Miles	4 – 6 Miles
Frequency	Sub 6 GHz	2 – 6 GHz	Sub 11GHz

3.0 RADIO RESOURCE MANAGEMENT (RRM)

Radio Resource Management (RRM) can be defined as a controlled mechanism for the overall system which is used to manage radio resources in the air interface within a cellular network [10]. Both LTE-Advanced and mobile WiMAX technologies implement resource management to ensure that the process of data transmission and reception are done efficiently. Basically, RRM analyzes a number of factors such as traffic load, interference, noise and coverage in order to produce an efficient data transmission and high capacity. RRM performs radio resource monitoring, transmit power control, dynamic channel assignment and coverage hole detection. RRM functions should also take into account the constraints imposed by the radio interface in order to make decisions regarding the setting of the different elements and parameters influencing the air interface behavior.

3.1 Power Control

Power control is seen as an important means to reduce mutual interference between the users, while compensating [11] for time-varying propagation conditions. The main purpose of power control elements is to maximize the received power of wanted signals through compensating the long term variation. Besides that, it could limit the amount of the inter-cell interference (ICI) generated [12]. So, one of the RRM requirements that must be implemented is Power Control (PC) which is used to determine an ideal transmit power in transmitting data to the receiver. In a wireless system, the transmission power gives a big impact to the link's quality and the interference environment [13]. Several methods have been considered in order to improve the capability of the power control technique.

Nagate *et al.* (2009) proposed a Multi-cell coordinated power control to identify a terminal to be dropped from the information of noise level and link gains. The transmit power of every base station will be reallocated accordingly before transmission is done. Eventually, this technique is able to improve the throughput of the system without decreasing the number of terminals to fulfill Signal-to-Interference-plus-Noise Ratio (SINR) requirement. By doing this way, the computational complexity could be reduced at the expense of the performance. The power control algorithm in this paper was evaluated based on the SINR and the average cell spectral efficiency parameter. As a result, the proposed algorithm is able to determine transmit power to satisfy minimum required SINR to avoid any interference.

Meanwhile, Coordinated Multi-point (CoMP) joint transmission has been recognized to further improve cell-edge performance. In [15], the author mentioned that the problem from the user scheduling is treated by assuming all the BSs always transmit at full power. So, the problem in designing a joint scheduling and power control algorithm to support CoMP joint transmission is addressed in [16]. The authors of this paper focus on three BS sectors (BSS) and only on downlink of the CoMP cluster. The algorithm is introduced to maximize the cell-edge throughput under a per-BSS power constraint. By applying this algorithm, the authors state that the proposed algorithm is able to provide a good balance between CoMP joint transmission with interference coordination, and the cell-edge performance can be improved.

Each transmitter in a wireless network has a different transmit power and they are also related to the resource usage of the link. The different power transmission of variable transmitters could cause interference with each other because some of the links occupy the same frequency spectrum for efficiency reasons. Many methods have been implemented by researchers to reduce interference and so improving the power control performance. Next, investigation can be done based on the multi-cluster interference after single-cluster interference is solved. But, it will remain an issue when the number of UEs increases in the future. Apart from that, relay deployments can significantly enhance the coverage and throughput of cell-edge users. Other than that, a further investigation can be done on joint resource allocation with power control in multiple sub-channel systems. This is because the previous investigation only focuses on single cluster sub-channel with flat fading channel. But, when it comes to a multiple cluster, the probability of packet loss and interference will increase.

3.2 Handover

Handover in mobile cellular systems can be defined when the UE is moving away from the area of service from one cell and entering the area covered by another cell. The call is transferred to the second cell in order to avoid call termination when the phone gets outside the range of the first cell. Meanwhile, mobility in handover provides the communication for a different location and while on-the-move [17] and it is one of the key characteristics of wireless networks. A lot of research have been carried out to expand the capability of the previous handover techniques and below are the descriptions for the enhancement of previous handover.

Firstly, the fast handover authentication scheme has been proposed by [18] that applied Multicast and Broadcast (MBS) to support for IEEE 802.16e and enhanced in IEEE 802.16m and 802.16j. The proposed algorithm provides security based on the assumptions that underlying cryptographic is used for handover authentication. Besides that, the computational cost of this scheme is also lower than the previous handover authentication schemes. The idea that the author tries to share is that the ticket generated using a multi-BS group key can be used for authentication between a MS and a BS without interacting with any other third party whenever a handover occurs. But, the handover scheme limits the fast handover to BS within the multi-BS group and Extensible Automatic Protocol (EAP) is needed for re-authentication during inter-group BS handovers. Figure 2 demonstrates this algorithm, which is implemented in WiMAX, in which the proposed scheme is divided into two phases, namely initial authentication and handover authentication.

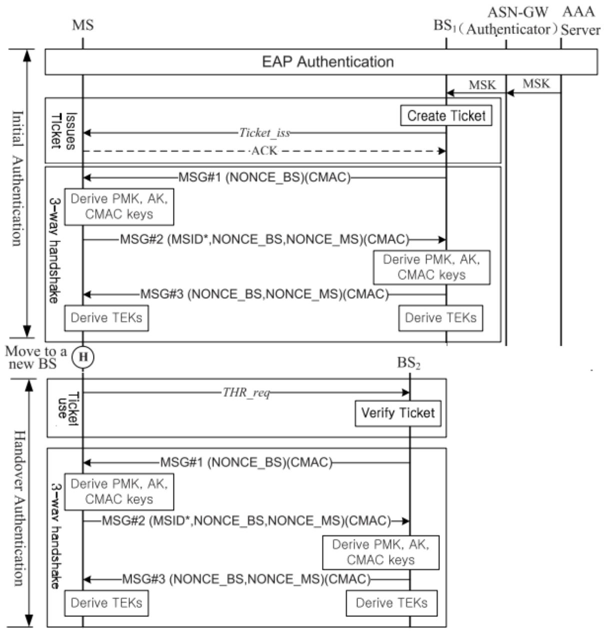

Figure 2 Proposed handover authentication mechanism [18].

Next, for heterogeneous networks, relay system can be used for handover process. Nurzal Effiyana Ghazali *et al*. (2012) have not just come up with a new handover decision making protocol for LTE, in fact, the authors have shortened the delay of the process by having signaling between relay node and MS only instead of having the traditional signaling between UE, relay node and BS. As such, a new algorithmic mechanism has also been proposed by R. Balakrishnan *et al.* (2009) which is called *Relay Station Handover Mechanism* to focus on the procedure for the mobile relay between the serving and target Advanced-BSs (ABS) [20]. Furthermore, the proposed handover mechanism could improve handover mechanism for current relay architecture such as in IEEE 802.16 standards. This solution highlights both control and user planes architectural enhancements to support relay mobility. As a result, this method provides better performance from the current relay standards such as the handover over latency are largely reduced and able to extend the coverage capacity area and produce higher speed mobility support.

In another application, handover latency in Proxy Mobile IPv6 (PMIPv6) is one of the most critical factors for the next-generation all-IP mobile networks. Handover latency is defined as the time that elapses between the moment when the handover completes at the Access Point (AP) and the moment the Mobile Network (MN) receives the first packet after moving to the new point-of-attachment [21]. However, handover latency could be too long in a realtime multimedia application. Once the handover latency has been solved, the aspect that needs some concern is when the Mobile Station (MS) is required to increase traffic load in a cell, the QoS can degrade significantly. Due to this unbalanced traffic load, the packet data distribution between cells can force the traffic load in certain cell to exceed the ultimate capacity of that cell. This will cause an overlapping and interference between cells. So, the idea is to come up with the optimizing handover based on load distribution and identify the specific target of the UE that the packet data will be sent. With a known target, a transmitter is able to avoid the latency from occurring while the UEs switching to different cells. Figure 3 gives an overview how the message transfers through PMIPv6.

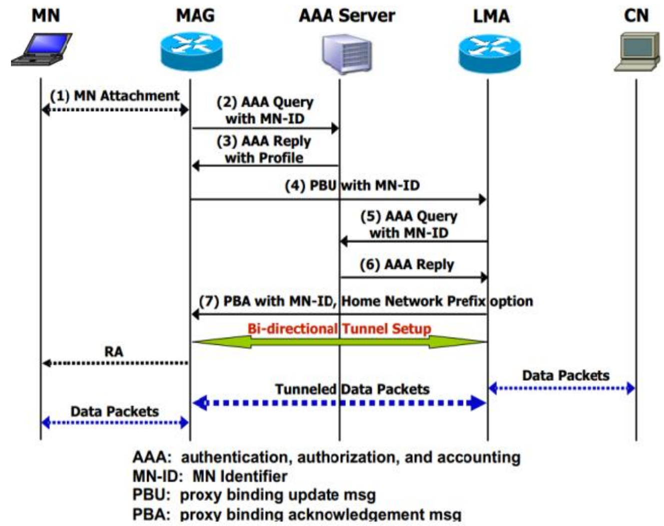

Figure 3 PMIPv6 message flow [21].

3.3 Packet Scheduling

The main purpose of scheduler applied in wireless networks is to determine to or from which terminal and BS to transmit data and on which set of resource block. The packet scheduling of data is one of the critical technologies in transporting multimedia traffic across wireless networks for providing QoS differentiation and guarantees because it determines the overall behaviour of the system. The dynamic scheduling is a basic operation of the scheduler and it is functioning to transmit scheduling information about 1ms Transmission Time Interval (TTI) from the BS to the selected terminal [22]. Besides that, the other dynamic scheduling capabilities are to control both uplink (UL) and downlink (DL) transmission activities.

During the DL, the BS traffic is expected to be very busy as compared to UL traffic, and relay packets are necessarily needed as soon as possible to solve the problem of buffer overflows and ensure latency requirements [23]. The suitable concept of packet scheduler that can be implemented in IMT-Advanced should not be too expensive in terms of required hardware because applying a lot of hardware could increase the cost implementation.

Chung *et al*. (2008) gave an overview about the concept of standard Proportional Fairness (PF) criterion for packet scheduling. The packet scheduling algorithm proposed by the author is based on the PF criterion for DL transmissions with Carrier Aggregation (CA). The algorithm assumes that users in the cell can periodically estimate average signal-to-noise ratio (SNR) on all Resource Block (RB) on the Component Carrier (CC) and BS will receive them back. This algorithm has been successfully done for DL transmissions with CA in both realtime and non-realtime traffics. However, this Packet Scheduling algorithm needs to consider the real-world traffic patterns to achieve the highest QoS requirement.

J. F. Montserrat *et al.* (2009) have proposed a scheduling algorithm called *Traffic Aware Score Based* (TASB) [25]. Actually, this TASB is a modified algorithm from the previous Score-Based (SB) criterion that included the time-utility and priority factors for queueing packets. The main advantage of the proposed algorithm is that it is able to minimize the scheduling delay to maintain efficiency of the system by targeting achieved throughput. However, this scheduler algorithm have to be designed not only to support multiple users simultaneously but also to serve real-time and nonreal-time traffic for a user at the same time at any given scheduling time instant.

For future investigation on effective packet scheduling, the process in designing the packet scheduler, one has to be concerned about delay requirements of scheduling, which may be represented by a time-utility function that can be set as the main priority and also the efficiency of radio resource usage. These requirements must contain both traffic conditions of realtime and non-realtime to support multiple users at the same time in requesting data from the networks. In addition, a flexible scheduler can be developed to improve spectral efficiency because flexible scheduler can be seen to adopt mixed service class scenario and can also be used as a framework for OFDMA.

3.4 Radio Resource Allocation

Radio resource allocation (RRA) is used to assign the available resources in an economic way such as assigning the frequency spectrum efficiently to avoid any traffic congestion. RRA could also serve a subset of the available radio resources such as power and bandwidth for every user in the mobile networks. Besides providing the radio resources, it also needs to look up for the certain optimality based on the link quality experience to avoid any decrease of QoS and throughput.

For example, in [26], the authors mentioned about two different algorithms; namely rate adaptive algorithm (RA) and margin adaptive (MA) as the methods to implement radio resource allocation schemes. The MA algorithm states that a given set of data rates is assumed with a fixed QoS requirement. However, there is a problem once this algorithm is applied because adaptive power allocation is not considered in the system model and focuses only on subcarrier allocation [27]. Meanwhile, the purpose of RA algorithm is to maximize the total data rate of the system with the constraint on the total transmit power. But, it is still not a valid indication for each user's satisfaction in multipath fading channels, although the sum capacity of the system provides a good measurement of the spectral efficiency.

The other resource allocation issue can be found in the Coordinated MultiPoint (CoMP) technology [28]. With the objective of maximizing the throughput in CoMP system, the optimization process can be a complex one. So, the authors propose a technique called CoMP-Coordinate Scheduling (CoMP-CS) to overcome this problem. For this approach, the Best Fit (BF) is implemented by starting to schedule the Access Point-User Equipment (AP-UE) link with the highest channel gain. After that, it will calculate the throughput of the scheduling at each available AP-UE link together with the previously scheduled link. Later on, the link with the highest channel gain is chosen. Moreover, by using this method, some problems can still occur, such as power allocation and antenna selection and these problems may need an enhancement towards the said algorithm.

Further investigations can be done to solve other problems such as the efficiency of multi-user selection and flexible formation of cell cooperation. Besides that, we also have concerns about enormously diverse QoS requirements at the UEs side because in order to design a new RRA algorithm for this purpose, such base stations will require a massive number of transmissions which is the most challenging task. This is because the number of users will keep on growing in the future and definitely the current system could not support the need of the users as the users may need a constant high performance although there are an increasing number of mobile users in the networks. So, researchers should come up with new algorithms in which the throughput can be maximized while preserving QoS for all users.

3.5 Load & Admission Control

In wireless networks, overload of any event such as data transmission can result the outer loop power control increases the signal-to-interference ratio (SIR). The method to overcome this problem is by applying load and admission control. Firstly, the load control is functioning to manage the access of the data packet to the network and plays a major role in the avoidance of system congestion. In addition, load control goal is also to ensure the BS are not overloaded for both uplink and downlink communication operations. Meanwhile, for admission control, it can be considered as a validation process in communication system to check whether the proposed connection is already established or not. Moreover, admission control has its own mission in order to stabilize the maximization of bandwidth utilization and to make sure the resource is sufficient for highest priority function.

Y. Wang *et al.* (2010) focused on *Carrier Load Balancing for Multi-carrier Systems*. The area of interest is based on Layer 3 carrier load balancing. This paper comes up with two different methods; namely Round Robin (RR) Balancing to assign the newly arrived user to the carrier that has the lowest number of users and Mobile Hashing (MH) Balancing to distribute among a finite set that maps directly to the Carrier Component (CC) indices. As a result, these algorithms are able to optimize the resource allocation process in a multi-carrier system and are also able to maintain the low complexity of the systems. Besides that, the system fairness and coverage are significantly increased and the gain in the coverage over independent Packet Scheduling (PS) covers up to 90% with full buffer transmission in LTE-Advanced system. Figure 4 and Figure 5 show how the MH Balancing algorithm is done by complying with carrier aggregation.

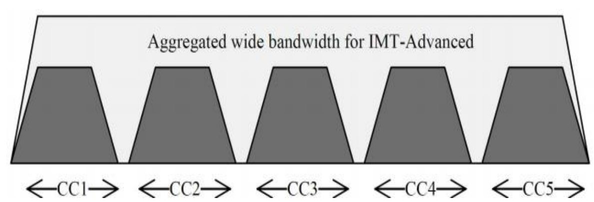

Figure 4 CA of multiple continuous component carrier [29]

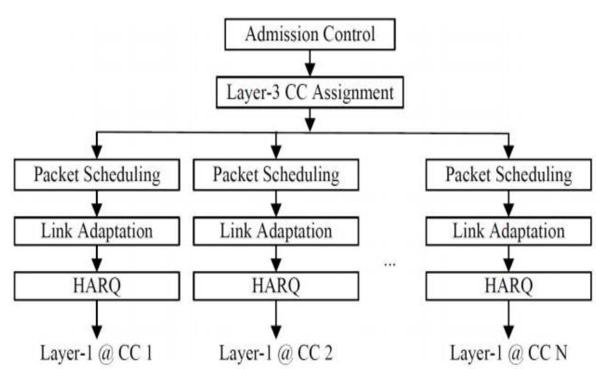

Figure 5 The structure of an LTE-Advanced system with carrier aggregation [29]

Gross (2009) provides an analysis framework for admission control in OFDMA systems by applying channel-dependent resource assignment [30]. This paper is focused on a novel framework for admission control in OFDMA cells and analyzes the performance of OFDMA in various multiple channel access. Basically, the purpose of this algorithm is to provide a significant performance based on the transformation of the channel gains**.** The author states that the basic problem in capacity estimation for OFDMA downlink is that different receivers will experience different gains for any given subcarriers. So, the assignment algorithm framework performs admission control in OFDMA cells to allow the prediction of achievable rates given a certain amount of resources and a certain set of requests. As a result, there is a significant improvement for the admission control schemes in the assignment algorithm in terms of data capacity. However, this algorithm neglect the overall performance improvement based on the exploitation of multiuser diversity in the OFDMA systems due to the NP-hard nature of the optimization problem.

In order to successfully deploy an IMT-Advanced system, we have to take into account the expectations of both service providers and subscribers. This is because the condition of the traffic will change spontaneously and could not be static due to the number of users. For such heavy traffic condition, we should consider tradeoffs between average delay versus maintaining a minimum level of connectivity to users independent of their location. These two elements are the QoS metrics that need to be considered to provide a better performance of the transmission process from the BS to the UEs. This can be extended to other areas such as cell throughput, resource utilization, and handover outage probability because these areas are closely related to load and admission control in order to achieve a good quality performance.

■4.0 DISCUSSION

The priority of all the proposed algorithms mentioned earlier is to eliminate or reduce issues arisen in communication networks including interference issues so that the QoS requirements for all users can be met. The other aspect that needed attention is resource utilization that functions to transmit the packet of data when they are available only. From the base station's perspective, it can also obtain a reliable channel quality measurement in order to serve the users by adapting the radio resources efficiently.

However, there are still more research that can be done to expand the radio resource management capabilities in the future. By pursuing research in this area, we can expand the capability of IMT-Advanced systems for a better communication experience.

The current development of RRM is able to support the need of current usage for communication systems. But, what will happen when the number of users continue to rise and the current technology cannot meet the growing consumer needs. So, there are some features that may be considered to overcome this problem for better RRM. The following are potential features that RRM tools could be applied:

- Bursty data traffic–traffic characteristics are very important to the design and performance of RRM algorithm. In particular, data traffic together with speech and file transfers, can be seen as discontinuous streams of symbols. In these aspects, delay constraints and insufficient information are such a major issue in transmitting data.
- High frequency spectrum–this feature is the most important requirement to provide data transmission. The operators must consider this feature that the users can access the networks with high speed by expanding the bandwidth usage. The reason is future systems are expected to require higher data rates than that of the current systems in order to support the increasing number of users.
- Fairness consideration─the RRM tools such as resource allocation and power control need to be fair enough to contribute the data with the requirement needed for each users. The multiuser diversity can be exploited by resource management to track the channel fluctuations of the users and schedule the transmissions to them with a better channel link quality.

■5.0 CONCLUSION

This paper has described an overview of radio resource management developments for IMT-Advanced. As we know, both LTE-Advanced and mobile WiMAX are selected for IMT-Advanced and both technologies are applying RRM tools in order to deliver data from the transmitter to the receiver. Basically, these RRM tools such as power control, handover and mobility, packet scheduling, resource allocation and load & admission control are very important in delivering packet data to the receiver precisely without experiencing any losses of data. Besides that, these tools are also responsible in ensuring the transmission throughput and Quality of Service (QoS) are maximized. This is because the users want to have great services with the price that they have paid for.

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