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Resource Allocation in LTE: An Extensive Review on Methods, Challenges and Future Scope

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ABSTRACT
With the increase in the multimedia applications that requires the high speed, high data rate in real time basis, and continuous connectivity supporting mobility. In order to facilitate effective ubiquitous or pervasive computing, stress the need for efficient utilization of the LTE characteristic. For efficient utilization of the characteristic needs focus on the maximum usability of the resource allocated. Various challenges in a different scheme of resource allocation such as downlink, uplink, and radio resources allocation is thoroughly analyzed. This paper extensively focuses basic of resource allocation, and concentrates on different kinds of issues faced by various resource allocation schemes and aims at fulfilling the needs of students, academician as well as industry in the particular aspect.

Keywords
Downlink, Resource-allocation, LTE, Uplink, Ubiquitous.

1. INTRODUCTION
Long term evolution (LTE) is an evolutionary step beyond the 3G in mobile wireless communication.LTE incorporates different technological innovations from various research domains such as digital signal processing, Internet Protocol, network architecture and security which have changed the scenario of mobile usage worldwide. In compare to 3G, LTE uses clean-slate design approach for all components of network including transport network, radio access network, and core network [1]. LTE is standardized by 3GPP (3rd Generation Partnership Project).3GPP involves the partnership of 6 regional standards organizations.

- Association of Radio Industries and Businesses ARIB (Japan)
- Alliance for Telecommunications Industry Solutions (ATIS, USA).
- China Communications Standards Association (CCSA,china)
- European Telecommunications Standards Institute (ETSI,Europe)
- Telecommunications Technology Association (TTA,South Korea).
- Telecommunication Technology Committee (TTC, Japan).

Resource allocation is a significant parameter in a fourth generation wireless network like LTE.LTE architecture is developed such that it provides support for high-speed data rate. Various access methods are used in LTE for radio resource allocation such as OFDMA (optical frequency division multiple access) for downlink and uplink uses SC-FDMA (Single Carrier Frequency division Multiple Access).In LTE kind of wireless system, where QoS is significant parameter inappropriate resource allocation may lead to serious degrading in service. In order to maintain minimal QoS proper utilization of the bandwidth in the form of appropriate distribution is to be done. The resource allocation impacts on the applications utilizing the LTE network. VoIP, video conferencing, online gaming are some of the real time application whereas the HTTP, FTP, P2P are the examples for non-real time applications that are widely used in LTE. Researchers have proposed various mechanism for resource allocation scheme for uplink system .Different mechanism such as based on opportunistic approach, scheduler with Proportional Fairness (PF) based utility function such as First Maximum Expansion (FME), Recursive Maximum Expansion (RME), Minimum Area Difference (MAD), Proportional fair-Frequency Domain Packet Scheduler (PF-FDPS) are introduced and tested by various authors [2].

Table 1. Evolution of Mobile Communication

Generation	Requirement	Comment
1G	No official requirement Analog technology	Deployed in 1980’s
2G	No official requirements. Digital Technology.	First digital systems. Deployed in the 1990s. New services such as SMS and low-rate data. Primary technologies include IS-95 CDMA and GSM.
3G	ITU’s IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	Primary technologies include CDMA2000 1X/EVDO and UMTS-HSPA. WiMAX now an official 3G technology.

4G	ITU's IMT-Advanced requirements include ability to operate in up to 40 MHz radio channels and with very high spectral efficiency.	Ip based. Key contributor EPS and E-UTRAN.

Section 2 discusses about the evolution of the mobile communication followed by discussion on LTE protocol architecture in Section 3. Section 4 discusses about the radio resource management in LTE networks. Frequently used techniques and existing literatures are discussed in Section 5 followed by discussion on research gap in Section 6. Finally Section 7 highlights the conclusion of the study.

2. MOBILE COMMUNICATION

The Table 1 summarizes the evolution of the mobile communication along with the various technologies being used at different point of time. In the first generation it is seen that analog technology largely contributed to the communication. First generation communication was deployed in 1980.With emergence of digital technology, gave rise to new features such as SMS and low-data which were the result of new technologies like CDMA and GSM. Further increase in mobile users and requirement of high data rate applications and features contributed to the evolution of the Third generation mobile communication, which supported high data rate applications. It was supported by various technologies like CDMA2000, 1x/EVDO and UMTS-HSPA. The need of well framed support for mobility supporting high date rate application lead to evolution of LTE [3].

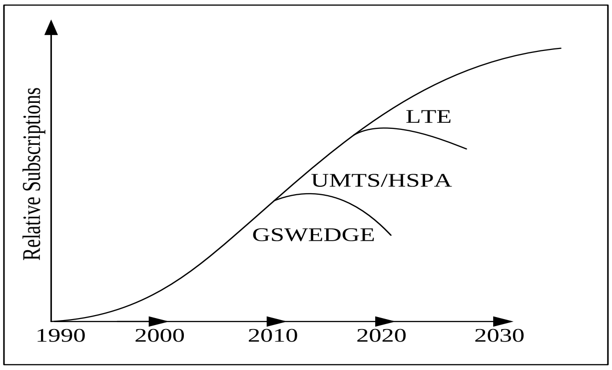

Fig 1: Relative adoption of Technologies.

2.1 LTE Architecture

LTE cellular system adopts System Architecture Evolution (SAE), which is an evolved kind of network and consists of a core network and radio access network. The network is illustrated in Fig 2.

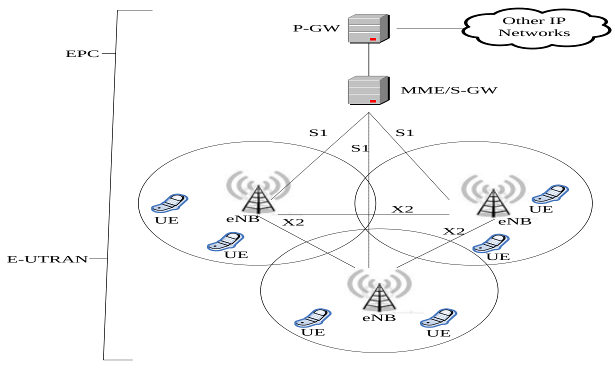

Fig 2: LTE system Architecture Evolution

Evolved Packet Core (EPC),is the core network.EPC is formed by Serving gateway (S-GW),the mobility management entity (MME) and Packet data network Gateway (P-GW).The radio access network which is also known as Evolved-Universal Terrestrial Radio Access Network (E-UTRAN),which consists of User equipment (UE) and macrocells BSs. Using the s1 interface ,connection between PC and E-UTRAN is established between S-GW and macroBSs.X2 interface is introduced to permit interconnections among macroBSs for direct signaling. In EPC,S-GW functions as local mobility anchor point for inter macroBSs handover and inter 3GPP mobility and also for handling of IP packet transfer between the EPC and the associated UEs.MME is used to handle the connection management and user mobility between LTE and other 3GPP technologies. ME is also responsible for handling radio bearer management where a radio bearer is a dataflow or a logical channel that is setup between a macroBss and UE.P-GW functions as a medium between EPC and other IP network like Internet. It is also responsible for performing IP address allocation for UEs and QoS implementation. The uplink and downlink transmission is managed by macroBSs and is also responsible for performing RRM functions and control signaling in E-UTRAN for radio access. LTE cellular system consists of scalable system bandwidth of 1.4 MHZ to 20 MHZ is deployed. Physical layer of LTE uses OFDMA. Channel bandwidth is divided into small orthogonal PRBs (Physical Resource block). PRB is the smallest unit of radio resource that is allocated to UE.LTE uplink uses single carrier frequency division multiple access (SC-FDMA).the aim of using SC_FDMA is to minimize peak-to-average power ratio of UEs, thereby minimizing power consumption. in downlink OFDMA permits allocation of multiple PRBs from any part of channel bandwidth, whereas the SC-FDMA restrains in uplink as only adjacent PRBs can be allocated to individual UE.

2.2 LTE Radio Frame

LTE radio frame consists of 10 sub frame ,each consists of two time slots of 0.5ms.therefore LTE sub frame has a time period of 1ms,which is one transmission time interval. The structure of Radio frame is illustrated in fig 3.two types of LTE frame structure that support Frequency Division Duplexing (FDD) and Time division Duplexing (TDD) modes respectively. During UE connection to LTE network, default bearer is set up for UE which is maintained throughout the connection lifetime. For new specific service a additional bearer called dedicated bearers can be allocated to the UE connected [4].

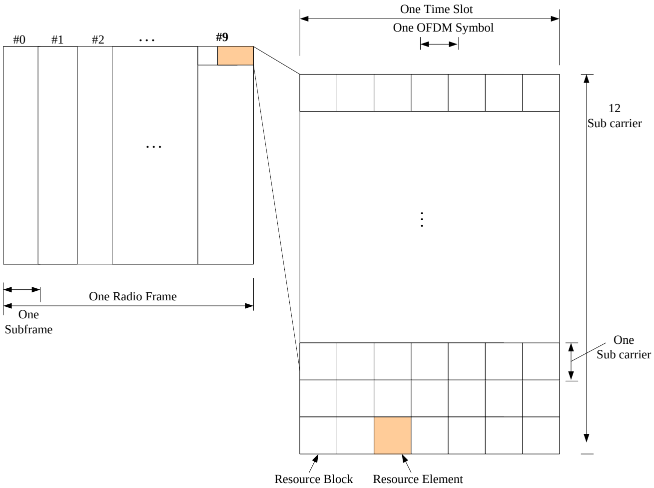

Fig 3: LTE Radio Frame

3. LTE PROTOCOL ARCHITECTURE

The LTE protocol is defined as a hierarchical system, where it consists of different layer having different channels in between to facilitate various form of communication. As depicted in the architecture there are 4 different layers.

- **Layer 1**(Physical Layer): Defines physical layer related to the physical layer process and procedures.
- **Layer 2:** Consists two parts MAC (medium access layer) and RLC (radio Link Control).
- **Layer 3:** Consists of RRC (Radio Resource Control).This layer interacts with the physical layer for controlling and measurement related operation.

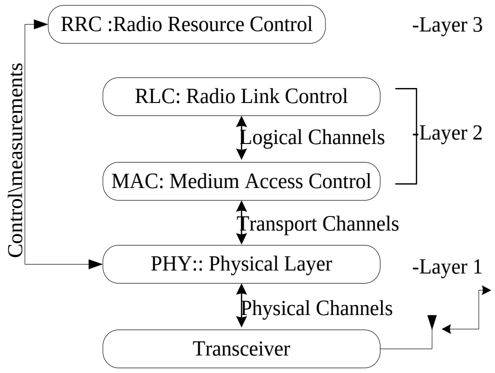

Fig4. LTE protocol Architecture.

3.1 Requirement for LTE

The Table 2 illustrates the basic requirement for LTE system; it provides insight about the Peak data rate, cell capacity, latency, Mobility, spectrum flexibility and supported as well as extended features [5].

Table 2. Requirement for LTE

Peak data rate	100 Mbps in Downlink/50mbps in uplink within a bandwidth of 20Mhz.
Cell capacity	Support 200 active user within a bandwidth of 5MHz.
Latency	Less than 5ms in user plane.
Mobility	Must be optimized to support 0~15km/h,
Spectrum flexibility	1.25 ~ 20 MHz
Provide	EMBMS (Enhanced Multimedia Broadcast Multicast service)
Extend	End to end QoS.

Table 3 describes the key features in the LTE system which gives description about the Architecture, modulation techniques, and mode of operation as well as peak data rate.

3.2 Key Features of LTE

Table 3. Key Feature of LTE

Wider Bandwidth	20MHz
Flat IP Architecture	Supports direct communication between base stations reduces latency.
MIMO	Supports multiple data transmission and reception. , increases signal quality and data reception.
Multiple carrier based air interface enabled	Uses OFDM/OFDMA and SC-OFDMA.
Spectrum flexibility	1.25 ~ 2.5 MHz
Mode of operation	FDD and TDD
Peak data rate	Downlink (326.4 mbps), uplink (86.4 mbps).

3.3 Techniques[6]

LTE makes use of OFDMA, multi-carrier mechanism that is used for allocating radio resource to multiple users. In LTE, the carrier frequency bandwidth is splitted into many small subcarriers spaced at 15 kHz; latter modulating each individual subcarrier using QPSK, 16-QAM, or 64-QAM digital modulation formats. The user bandwidth is assigned to each subcarrier needed for their transmission. In order to minimize the power consumption and interference the unassigned subcarriers are off. OFDMA makes use of the OFDM; distinguished nature of the OFDMA is attributed to the scheduling and assigning of resource. Fig.5 OFDM shows the entire bandwidth belonging to user for a period. In OFDMA multiple users are sharing the bandwidth at each point in time.

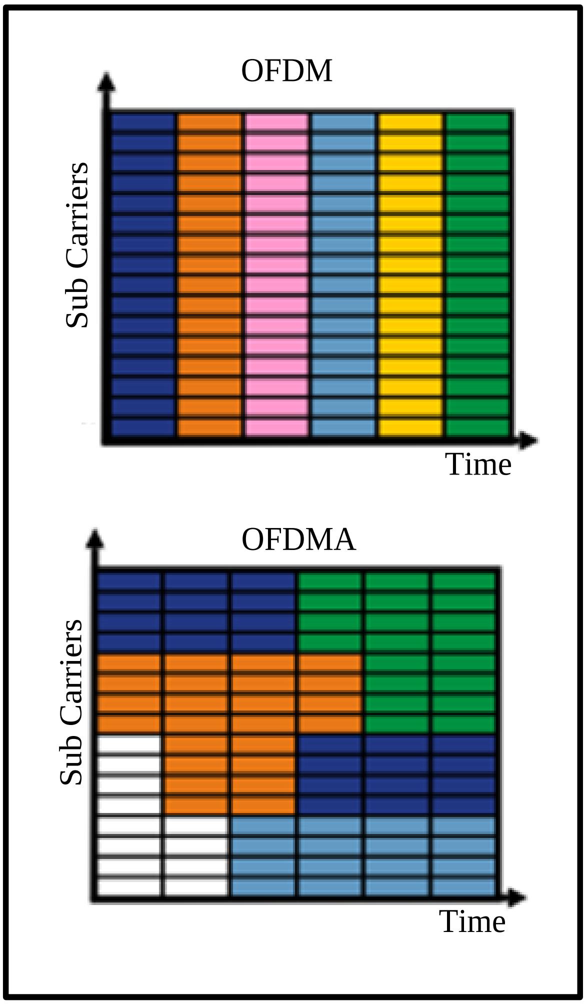

Fig 5. OFDM vs OFDMA

Each color is used to represent a burst of user data. At given time OFDMA allows user to share available bandwidth.

3.4 SC-FDMA

For Uplink LTE makes use of pre-coded version of OFDM known as SC-FDMA. Compared to SC-FDMA has lower PAPR (Peak to Average Power Ratio).lower PAPR minimizes battery power consumption, requires a simpler amplifier design and contributes to improve uplink coverage and cell-edge performance. In compare to OFDMA, In SC-FDMA data's are spread across multiple subcarriers. The requirement of complex receiver makes SC-FDMA unacceptable for downlink. The figure below shows the difference between OFDM and SC-FDMA. In SC-FDMA information is spread across multiple subcarriers. LTE FRAME structure and Bandwidth Concepts.

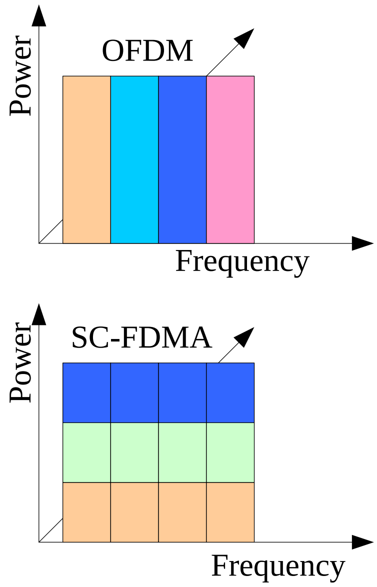

Fig 6. In OFDM, Every Frequency Component Carriers Unique Information.

Resource element is the smallest modulation structure in LTE.A resource element is one 15 kHz subcarrier by one symbol. Resource block is the aggregation of resource element. Resource block consists of dimensions of subcarrier by symbols. Each resource block is formed by 12 consecutive subcarriers in the frequency domain and six or seven symbols in the time domain. Cyclic Prefix (CP) decides the number of symbols. For typical resource block consists of seven symbols. Resource block using extended cp contains 6 symbols. The use of delay spread which exceed the normal CP length signifies the use of extended CP.

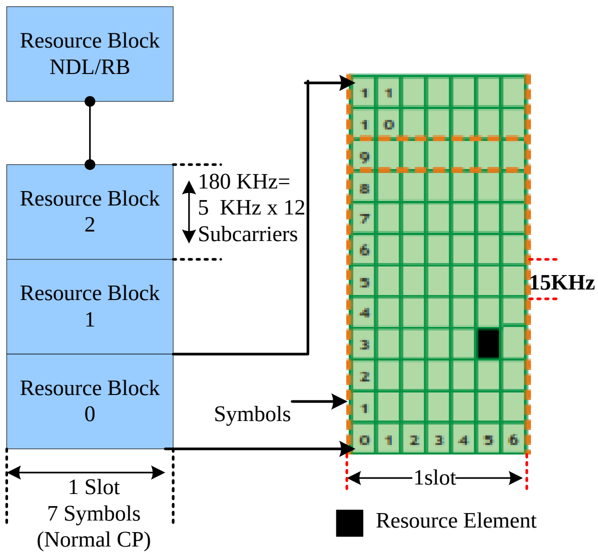

Fig 7. Relationship between slot, symbol and resource block.

NDL/RB is used to denote the maximum number of downlink resource for given bandwidth. Transmission bandwidth is considered as the number of active resource blocks in transmission. With the increases in bandwidth the number of resource block also increases. Configuration of

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transmission block implies the maximum number of resource block allocated for particular channel bandwidth. The maximum bandwidth occupied is computed by the number of resource blocks multiplies by 180 kHz.

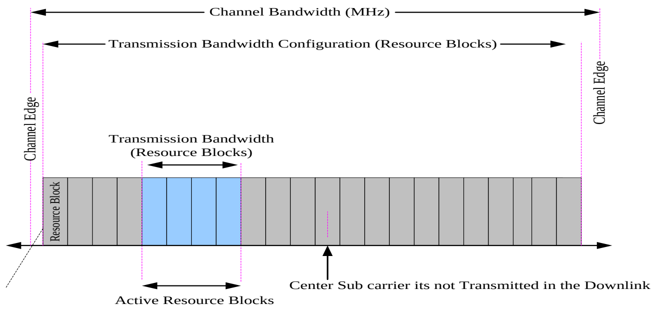

Fig.8. Relation between channel bandwidth, transmission bandwidth configuration and Transmission configuration

4. LTE DOWNLINK CHANNELS AND SIGNALS

Table 4. Transmission bandwidth configuration

Channel Bandwidth (MHz)	Maximum Number of Resource Blocks (Transmission Bandwidth Configuration)	Maximum occupied Bandwidth (MHz)
1.4	6	1.08
3	15	2.7
5	25	4.5
10	50	9.0
15	75	13.5
20	100	18.0

- **Physical Download Shared Channel (PDSCH)**
  - Used for transporting user data.
  - PDSCH is designed for high data rates.
  - Supports various Modulation schemes such as QPSK, 16-QAM, 64-QAM.
  - Using OFDMA,resources block associated with this channel is hared among users
- **Physical Broadcast Channel (PBCH)**
  - PBSCH sends a cell specific system identification for every 40ms
  - Sends access control parameter using QPSK modulation.
- **Physical Control Format Indicator Channel (PCFICH)**
  - PCFICH makes use of QPSK modulation.
  - The value of PCFICH ranges from 1 t0 3.
  - The value of PCFICH indicates the number of OFDM symbols that are used for transmitting the control channel (PDCCH) information in a sub frame.
- **Physical Downlink Control Channel.**
  - PDCCH provides the resource allocation to UEs for uplink and downlink.
  - PCFICH indicates, the total number of symbols used for PDCCH.
  - LTE frame consists of physical channel and physical signal.
  - Signals received from higher layer are carried by channels.
  - Signals are originated from physical layer.
  - Both uplink and downlink have same frame structure, but differ with physical signal and physical channel.

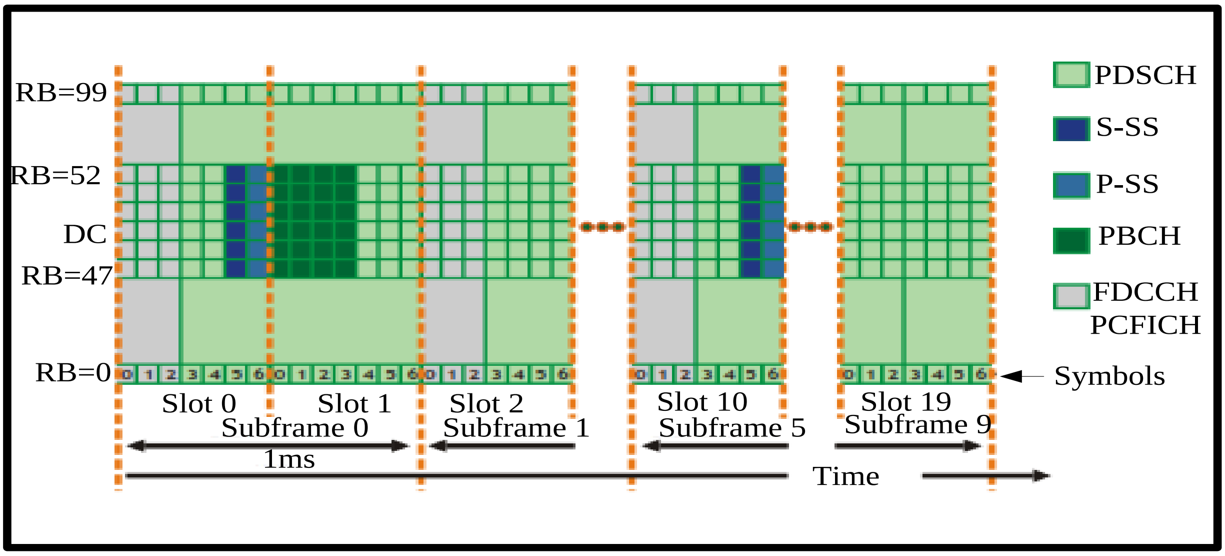

Fig 9. LTE Downlink channels and signals.

5. RESOURCE ALLOCATION IN LTE BASED MIMO OFDMA SYSTEM

With increasing demand and need of mobile broad band service that provide higher data rates and "Quality of service" (QOS), 3GPP initiated working on two parallel projects namely LTE ("long term evolution" and SAE ("system Architecture evolution") [7].These were purposed to define "Radio Access Network" (RAN) and systems network core, and were included within 3Gpp release 8.LTE/SAE is also termed "Evolved packet service" (EPS).It was revolutionary step in wireless industry which aimed in providing highly efficient, low-latency, packet-optimized, and more secure service. This system used OFDM ("orthogonal frequency division multiplexing") waveform has major design parameter in order to evade Inter symbol Interference (ISI) which generally restricts the performance of high-speed systems. MIMO ("Multiple Input Multiple Output") in order to boost data rates. The first public service of the LTE was opened by teliasonera on Dec 14, 2009 at Oslo and Stockholm. Minor changes were introduced in LTE through release 9.Official 4th generation wireless called as the "International Mobile telecommunication Advanced" (IMTA) project was published by ITU-R through a circular letter in July 2008,with a call for "Radio Interface Technologies" (RITS). Six technologies were submitted in oct 2009 including LTE-Advanced,IEEE 802.16m,TD-LTE-Advanced for approval.LTE has already achieved data rate close to Shannon limit, now effort is required in improving "Signal to interference and noise Ratio" (SINR) experienced by the user.

Table 5. Current Communication Specification of LTE

Item	Transmission path	Antenna configuration	LTE (Release 8)
Peak data rate	DL	8*8	300Mbps
	UL	4*4	75Mbps
4Peak spectrum efficiency	DL	8*8	15
	UL	4*4	3.75
Capacity (bps/Hz/cells)	DL	2*2	1.69
		4*2	1.87
		4*4	2.67
Cell edge user throughput(bps/hz/cells/user)	UL	1*2	0.74
		2*4	-
	DL	2*2	0.05
		4*2	0.06
		4*4	0.08
	UL	1*2	0.024
		2*4	-

5.1 Network Architecture

Specification contains 2 major work items LTE & SAE that led to specification of the evolved Packet Core (EPC). "Evolved Universal Terrestrial Radio Access Network" (E-UTRAN), "Evolved Universal Terrestrial Radio Access" (E-UTRA), "Evolved Universal terrestrial Radio Access Network". Each of which corresponds to the core network, radio access network and air interface of the whole system. EPS provides IP connectivity between a user equipment and external data network using E-UTRAN.

5.2 Carrier Aggregation

Carrier Aggregation is used by LTE-A to fully utilize the 100Mhz bandwidth while maintain the backward compatibility with LTE. In carrier aggregation several LTE carrier components are grouped, so as to allowed LTE-A to use large amount of bandwidth simultaneously allowing the LTE device to continue viewing it as a separate component carrier.

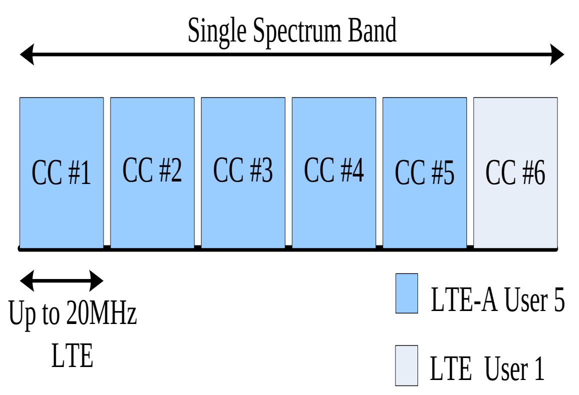

Figure 10 (a).Carrier aggregation in Contiguous bandwidth.

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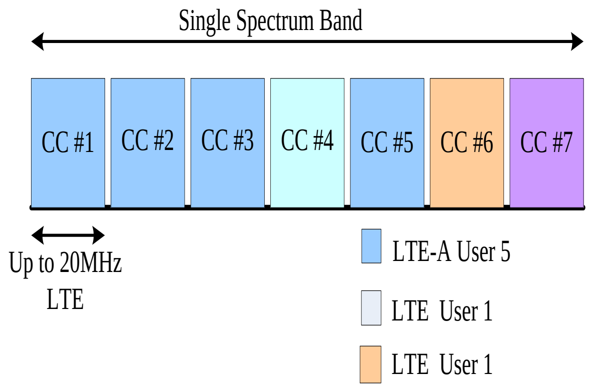

Fig 10(b).Carrier aggregation with non-contiguous bandwidth, single band.

6. EXISTING TECHNIQUES

Here we review the existing RRM mechanism using Femtocell. Typically RRM mechanism is classified into centralized, decentralized and hybrid classes, centralized class. Here in each Het-Net, A single central entity is used for executing RRM functions. Central entity is responsible for collecting information like channel quality and resource demand from both MUEs and FUEs using the serving BSs. On the basis of the information obtained, the central entity performs the allocation of the desired amount of radio resources to each UE. This method provides optimal resource allocation for cellular networks, but results in large impractical amount of signaling. Hence it is only suitable for small-sized Femtocell networks.

Decentralized RRM mechanism: Here the dependency on the central entity is not there, and eNBs and HeNBs are allowed to determine the resource allocation themselves among the associated MUEs and FUEs. Due to low implementation complexity and low signaling overhead, it poses difficulty in optimal resource allocation among UEs and is likely suitable for large-sized Femtocell networks. In order to obtain trade off in centralized as well as decentralized hybrid mechanism is used, which is also known as semi-centralized or partially centralized. Here central entity is used to perform certain global RRM operation, which includes collection of channels and traffic information, whereas the local RRM functions like packet scheduling are decentralized to eNBs and HeNBs. These mechanisms are suitable for moderately large networks. Different RRM mechanism share the same aim of accomplishing certain objective but the principle of working and technology used varies. Based on the working principle or key technology classification RRM mechanism can be done. The key principle and technology in RRM mechanism using Femtocell are frequency scheduling, cooperative approach, frequency reuse, Femtocell-aware spectrum allocation, hybrid spectrum allocation, priority based spectrum allocation, stochastic spectrum allocation, game theory, Femtocell clustering, cognitive radio, graph theory, distributed learning and the power minimization approach. These principles as well as the technologies contribute in framing the capabilities of the RRM mechanism. It also helps in understanding their underlying mechanism. Figure 9 illustrates the above approaches.

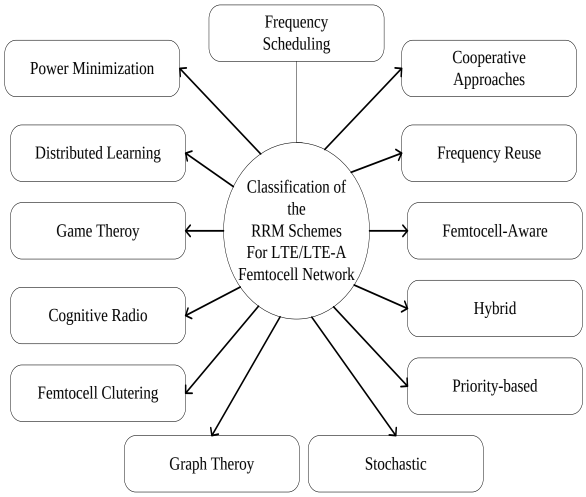

Fig 11. Classification of RRM scheme for LTE/LTE-A Femtocell network on the basis of underlying working principle or key enabling technology.

- **Frequency Scheduling Approaches**:- Is a simple RRM approach for LTE/LTE-A Femtocell networks, that allocates PRBs to both MUEs and FUEs on the basis of information such as channel quality or interference.

- **Cooperative Approaches**:- In this approach in order to facilitate resource allocation BSS performs exchanging of information.

- **Frequency reuse Approaches**:- In multi-cellular network frequency reuse is efficient and effective approach that can avoid interference and maximize resource utilization.

- **Femtocell Aware Spectrum Allocation Approaches**:- In this approach the available bandwidth is partitioned into two parts, macro-dedicated spectrum and femto-sharing spectrum. Also contains a additional femto-inference pool that contains a list of MUEs, which are potential interfere to adjacent Femtocell, and is maintained by the eNB. The members of Femto-interference are allocated PRBs from macro-dedicated spectrum, while MUEs and FUEs are allocated PRBs from macro-dedicated and femt0-sharing spectra.

- **Priority Based spectrum Allocation Approaches**: - Rather than sharing the complete bandwidth, HeNB might utilize a certain chunk with a certain priority level. Here channel bandwidth is divided into equal number of chunks in accordance to the number of Femtocell network. Latter each chunk is designated to a Femtocell. The designated chunk is known as priority chunk of the Femtocell. This configuration allows the Femtocell to schedule PRBs from designated chunk other than HeNB are regarded as lower priority.

- **Stochastic Resource Allocation Approaches**:- In this kind of approach the PRBs are allocated on the basis of FUEs based on probabilities. The FUEs is assigned the PRB from chunk of high selection probability. In order to avoid cross-tier interference the MUEs must be avoided allocating PRB with high selection probability.

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- **Graph theory Approaches**:- In case of complex scenario like interference among Femtocell resource allocation is solved using graph theory
- **Femtocell Clustering Approaches**: - Femtocell clustering is a partially decentralized approach which involves the classification of Femtocell into clusters. Clusters are formed by gathering Femtocell which interferes with each other. In order to allocate resource each cluster operates independently from the others. This helps in reducing co-interference effectively. Another advantage is that this approach supports scalability and can be used to any network size. While the implementation is reasonably complex.
- **Cognitive Radio Approaches**: - The objective of cognitive radio is the intelligent identification and exploitation of underutilized as well as un utilized spectrum in a occupied frequency bands. This is achieved using spectrum sensing. Spectrum decision, spectrum sharing and spectrum mobility.
- **Game Theory Approaches**:- In this approaches the decision making plays key role, here the parameters which corresponds to decision making is BSs and Strategies related to resource management.
- **Distributed Learning Approaches**: - In this approach the cellular system is allowed to learn its wireless environment and the learned information is used in the RRM decision making to accomplish optimal resource allocation.
- **Power Minimization**:- Approaches:-In this approach through reducing the power of base station the interference is reduced, herby effectively reusing the radio resource.

Table 5 discusses about some of the frequently used techniques in LTE performance enhancement while Table 6 discusses about the significant work being done

Table 6. Tabulation of Frequently Used Techniques

Approach	Technique	Working Mechanism
Frequency scheduling	OFDMA scheduling	• Scheduling of PRB is on the basis of channel quality of each HeNB subject in order to outage probability as well as power constraints. • In case of the HeNB is aware of its neighbors resource allocation method used is OFDMA scheduling method or else round robin scheduler is used.
	Co-ordinated scheduling.	• Based on identified dominant interferers and conditional CQIs, proportional fair coordinated scheduling is used.
Co-operative	Hybrid resource Allocation	• In downlink PRBs with poor transmission is identified with MUEs and HeNB is informed to cease PRB transmission. • In Uplink, PRBs with poor transmission is identified with FUEs and eNB are informed to cease transmission on PRBs.
	Cooperative resource allocation	• Every HeNB will share its own channel gain and traffic level information with other HeNBs. • Based on Lagrangian method proportional fair scheduling and power allocation is used.
Frequency Reuse	LTE sim	• Applying frequency reuse on femto tier • Two level scheduling algorithms is applied.
	Soft frequency reuse	• On the basis of SFR technique, frequency bands are distributed across multiple macro cell. • MUEs utilize the whole cell edge bands, Cell-edge FUEs utilize the entire bandwidth. • On the basis of ratio of one serving FUEs and other serving MUEs, cell center band is divided into two part.
	Resource reallocation in Femto-tier	• Few PRBs will be reserved for MUEs. • PRB reuse with centralized proportional fair scheduling.
Femtocell Aware	Femtocell aware spectrum arrangement	• Bandwidth is partitioned into two parts, Macro dedicated spectrum and femto sharing spectrum. • PRBs from macro dedicated spectrum are assigned to Interfering MUEs, while PRBs for other UEs are assigned from the two spectra. • Proportional fair scheduling is used.
Hybrid	Fair and QoS oriented resource allocation	• Complete bandwidth is utilized by MUEs. • Certain part of the bandwidth based on the splitting ratio is reserved to FUEs.
	Semi-static resource allocation scheme	• Reallocation of orthogonal resources between eNB and HeNBs. • Uses round robin scheduling • In order to determine the amount of shared PRBs between eNB to HeNB and vice versa, a sharing factor is used.
	Hybrid spectrum arrangement.	• Operation of inner Femtocell is in dedicated channel mode, whereas outer Femtocell operates in co-channel mode.

		• In case interference, HeNB will be notified by eNB and corresponding PRB is released.
Priority Based	Flexible spectrum usage algorithm for local Area	• Channel bandwidth is partitioned into different chunks and is allotted to distinct HeNB. • In case of need for additional PRBs, HeNB will access other chunks of lower priority. • Round robin scheduling.
Stochastic	Decentralized frequency domain resource allocation..	• System bandwidth is partitioned into number of clusters. • On the basis of Selection Probabilities, FUEs are allocated from PRB clusters. • the initial allocation of indoor and outdoor MUEs from cluster is based on smallest and largest selection probabilities
	Stochastic frequency domain scheduling	• System bandwidth is partitioned into two sets wherein one serves indoor MUEs and other Serves outdoor MUEs. • On the basis of stochastic rule FUEs are allocated from these two sets.
Graph Theory	Resource allocation on the basis of hierarchical approach.	• PRB requirement is estimated by the individual HeNB. • PRB allocation among HeNBs is based on the graph coloring technique that reduces the number of color assigned. • On the basis of maximizing the minimizing rate obtainable by each FUE, packet scheduling and power allocation is done.
	Centralized approximation algorithm	• Interference relationships among UEs are represented using Linl-conflict graph • PRB allocation among UEs is based on the graph coloring technique that reduces the number of color assigned.
Femto-clustering	Femtocell cluster based resource allocation	• Interfering Femtocell are grouped in a clusters, Femtocell are selected as the cluster head in determining PRB allocation. • FUEs Uses feedback method to inform about collision and to remove PRBs shared by other HeNBs clusters. • Scheduling used is Round Robin. • On the basis of reducing tha gap between the number of PRBs required and allocated one resource allocation among HeNBs is done.
	Co-channel framework	• In order to identify unoccupied PRBs cognitive radio is enabled. • Available PRBs are identified using scheduling information from eNB is compared with sensing information from HeNBs.
Game theory	Game theoretic framework	• HeNB's resource allocation problem is modelled as correlated game • game is solved using adaptive regret matching algorithm
	Game theoretic framework	• UEs resource allocation problem is modelled as cooperative coalitional game. • Game solved using distributed coalition formation algorithm.
Distributed learning	Distributed learning algorithm	• Scheduling used is Distributed learning. • Optimal power allocation among HeNBs based on Q-learning Method. •
Power minimization	Self-organizing rule.	• On the basis of minimizing total transmission power subject to throughput demand constraints, PRBs, MCSs and power allocation among UEs done. • Using arbitrary MCS assignment and network simplex algorithm optimization problem is solved.

Table 7. Summary of Existing Literatures

Authors	Problem focused	Technique used	Performance parameter	Limitation
Perez et al [8]	Intercell-interference mitigation	Self-organizing algorithm	System Level	Limits intercell communication
Huang et al [9]	Resource allocation to D2D links	Algorithm and protocol based on Nash equilibrium	Sum rate, Sum rate gain	Used that Each Bs has complete information of other BS.
Alsohaily et al	Multi Radio Access	User access in Multi RAT	System Level	Limiting gains of multimode access

[10]	Technology		simulation	,requires additional function at system Aps.
Xiao et al [11]	Joint RB assignment optimization problem	Computational efficient near optimal algorithm	QoS-aware energy-efficient resource allocation	Not benchmarked
Chuimento et al [12]	Feedback information	Feedback reduction	Simulation and Quantitative cost model	Needs to adapting feedback to scenario.
Alshrao et al [13]	QoS, power consumption	Algorithm based Hungarian method	simulation	Assignment Problem
Jang et al [14]	Resource allocation in LTE SC-FDMA.	QoS constraint resource allocation s cheduling	Simulation, throughput, packet loss ratio	Limits time modulation
Balasubramanya and Lampe [15]	Uplink resource allocation in LTE/LTE-A	Novel heuristic method	Simulation	Computationally expensive
Shajiah [16]	User based resource allocation.	carrier aggregation rate allocation algorithm	simulation	Memory consumption
Kaddour[17]	Efficient allocation of resource block and transmission power to UE	Opportunistic and Efficient RB Allocation (OEA) algorithm	Low computational complexity	Not benchmarked

7. RESEARCH GAP

Resource allocation in any technology is a determining factor for the overall success of the technology where various authors have demonstrated and proposed different algorithms as well as mechanisms to limit the effects and mitigate the constraints in resource allocation concerning to different parameters such as constraints in downlink resource allocation, uplink resource allocation, Resource allocation to D2D links. Multi Radio Access Technology, Joint RB assignment optimization problem, Feedback information, QoS,power consumption, Resource allocation in LTE SC-FDMA., Uplink resource allocation in LTE/LTE-A, User based resource allocation, Efficient allocation of resource block and transmission power to UE, various algorithm are demonstrated to overcome these constraints or limitation. Future work needs to build a bridge between the actual scenario whereas the proposed algorithm are verified over simulation and contribute to few problem that arise with assumption made by the authors which results in problems like inter cell interference, energy consumption, and less effective dynamical resource allocation with user requirement which can result in unsuccessful complete utilization of the resource. After reviewing the existing system, the summary of the significant research gap can be expressed as follows:

- Very few studies were witnessed to address the issues of resource allocation cumulatively. Majority of the existing studies are focused only one single form of resources in LTE.
- There is significant less number of studies that has actually proved the computational complexity of the algorithm being presented.
- Although the existing studies have discussed the numerical and graphical outcomes, but few studies have actually explored standard work to be compared with.

8. CONCLUSION

With the rise of communication-based application, the demands of channel capacity in telecommunication is constantly on rise. 4G as well as Long Term Evolution has acted as a boon for catering up the dynamically increasing demands of the speed and bandwidth in the mobile networks. At the same time, it is accompanied by the challenges too. This paper has concentrated on discussing the issues of resource allocation and management in LTE and provides the significant insights of the evolution of the mobile communication,describes the significance of the LTE.It's also speaks on the application of LTE.The paper discusses briefly about the LTE architecture, LTE protocol management, and aslo breifs about resource allocation in OFDMA-MIMO based LTE system. The paper aims to serves the further work on Resource allocation in LTE for scholars,researchers and industries architectures, techniques for resource allocation. It provides summarized details of various approaches of Radio Resource

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