LTE-U Sum-Rate Maximization Considering QoS and Co-existence Issue

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***Abstract*—Wireless communication industry is facing storm of exponential mobile traffic increase due to richer contents sharing over the network through smart devices. A innocent resolution for envisaging this contravention is to employ more licensed spectrum. But this is a scare resource and sufficient additional spectrum will be unavailable in the upcoming days. So, both academia and industry are engaging different new technologies to deal with this traffic cyclone in cellular networks. Long Term Evaluation-Advanced (LTE-A) is such a recent technology that serves heavy mobile traffic. But with insufficient licensed spectrum, LTE-A also cannot meet the quality of service (QoS) requirements of all it's users. So, by augmenting the benefits of LTE-A into unlicensed spectrum known as LTE-U with the help of carrier aggregation (CA) technique, we can boost the performance of 4G/5G cellular network. The process will degrade the performance of other technologies which are already using same unlicensed band. Moreover, if multiple cellular network operators (CNOs) use the same unlicensed band then they will diminish the benefits of each others. In this paper, we explore the CA of licensed and unlicensed spectrum when QoS of user cannot be met with licensed spectrum by deploying dual mode small cell base station (SBS) and considering minimum requirement of unlicensed WiFi access points (WAP). Here, we formulate the resource allocation as an optimization problem which wants to maximize the sum-rate of LTE-U system. Then we solve this problem with the help of Nash bargaining game (NBG) between LTE-U and WAP by cooperative approach. Simulation results show the effectiveness and efficiency of the proposed approach considering QoS requirement of LTE-U users and coexistence issue with WAPs.**

I. Introduction

Multimedia rich applications are getting popular among the vast consumers with the inauguration of smart devices like smartphones, tablets etc and it brings immense challenges in the current cellular network infrastructure. During the past decade, mobile data traffic has already shown exponential outgrowth and in the next five years, it is anticipated to flourish the amount 1000 times[1]. Both industry and academia are investigating advanced techniques to tackle this upcoming cyclone of data demand in the mobile network. In this pursuance, new technologies like LTE or LTE-A, massive multiple-input multiple-output (MIMO), device-to-device (D2D) communication are coming forward with scarce licensed spectrum. CNOs are trying to meet this huge users' demand by deploying SBSs which require low-cost and low power with the help of reusing technique of licensed spectrum.

But this actions are not enough to cope with the exponentially increasing data traffic and meet the stringent QoS of emerging wireless services in the next generation cellular system using limited licensed spectrum. So, some CNOs have already deployed WAPs to offload part of their traffic in unlicensed band. But such initiatives are not so effective due to the inferior performance of WiFi technology and not cost effective as CNOs also need to invest on backhaul and core network to integrate WAPs with cellular system. This shortcomings can be overcome by extending the blessings of LTE-A in the unlicensed spectrum known as LTE-U. It can boost the capacity and performance of the network better than Wi-Fi does [2]. But the transmission range of unlicensed bands are comparatively small than licensed spectrum due to its' low power regulation and higher frequencies. Consequently, utilization of already deployed SBSs with co-located licensed and unlicensed carriers is more congruent for LTE-U. This can be technically assured via the use of CA technology which was standardized in LTE Releases 10-12. LTE-U is already inaugurated (part of the LTE Release 13) to allow consumers for accommodating licensed and unlicensed carrier under a single LTE network infrastructure[3].

Though LTE-U offers many exciting benefits over the existing LTE/LTE-A networks without huge investments, it could cause considerable performance degradation of Wi-Fi transmissions who are already operating in the same unlicensed band. Besides, WAPs and other CNOs who are operating in the same region and in the same unlicensed spectrum, also creating interference and demote LTE-U users' performance, leading inadequate rate to meet QoS requirement of the desired applications. So, there exists inter-operator and inter access technology interference which can dilute each others' benefits in the unlicensed spectrum. Thus co-existence is the main challenge of LTE-U and we need to design such a mechanism that each others' benefits are preserved in the unlicensed band.

As LTE-U and WiFi are diminishing each others performance and within themselves, this interactions can be modeled as a game theory framework namely bargaining game to improve their performance. There are several proposals to coexist fairly of this two, but few of them have considered inter-operator interaction and nobody has seen it in the eye of bargaining game. In this paper, we have tried to maximize

LTE-U sum-rate considering the QoS requirement of the users and co-existence issue with WAPs by using bargaining game. Here, we formulate the problem as an optimization one and then solve it using bargaining game. Rest of the paper is organized as follows. We describe technological issues of LTE-U and WiFi and literature review in section 2 and 3 respectively. In section 4, we discuss about system model and problem formulation. Solution with bargaining game is discussed in section 5. Performance evaluation have been performed in section 6. Finally the paper is concluded in section 7 with some future direction.

II. Technological Issues of LTE-U and Wi-Fi

LTE and Wi-Fi are two different technologies working on the wireless communication systems specially in case of channel selection and network deployment. LTE-U accommodate an LTE system to take advantage of unlicensed spectrum to offload part of it's traffic to guarantee QoS of the users. Thus it can reduce the congestion burden from the licensed spectrum. Currently, there are three proposed operation mode for LTE-U network: supplemental downlink (SDL), time division LTE (TD-LTE) with CA and standalone LTE-U [4]. Unlicensed spectrum is used only for downlink opportunistically based upon the traffic demand in case of SDL. Licensed spectrum is used as the primary carrier and CA technique can be engaged with the LTE standard upon few changes. For TD-LTE mode, unlicensed band is used both for uplink and downlink traffic. Here control information is exchanged through licensed spectrum and CA technique can be prosecuted. Both data and control information is exchanged using unlicensed one in standalone LTE-U mode.

LTE and Wi-Fi have significantly diverse PHY/MAC protocols. LTE uses a centralized MAC protocol to allocate physical resources to users inside the cell with the help of OFDMA technique. There is no contention among the LTE users for accessing the resources. On contrary, Wi-Fi MAC protocol uses decentralized and contention-oriented random access mechanism depending upon carrier sense multiple access/collision avoidance (CSMA/CA) and distributed coordination function (DCF). CSMA does not guarantee the fair sharing of physical resources among the WAPs but only focuses on the fair access to the medium. So LTE networks can guarantee the QoS of it's users by preallocating resources and Wi-Fi networks do not provide any QoS guarantee.

III. Literature review

There are some works to evaluate the performance of LTE-U in presence of other wireless APs. In [5], authors represent the analytical result of LTE-U and WLAN by employing a simple fractional unlicensed bandwidth sharing technique. By simulating, they show that WLAN performance is severely degraded by LTE transmission if there is no restriction on LTE-U. They also show that this performance of WLAN system can be preserved by controlling activity carefully in LTE system. The authors in [6] show that the WiFi users' performance is reduced about 70% to 100% with the presence of LTE system without inter-system coordination. So LTE-U affects the WiFi users' performance drastically and as a newcomer in the unlicensed band, LTE-U should have some mechanism to coexist fairly with already deployed WAPs.

There are some potential proposal to mitigate interference between LTE-U and WiFi to coexist fairly in the fields. Qualcomm has proposed Dynamic Channel Selection (DCS), Carrier-Sensing Adaptive Transmission (CSAT) and Opportunistic SDL (OSDL) for fair coexistence in their white paper [7]. SBSs choose the unlicensed channel depending on the carrier sensing in case of DCS. If interference is detected in the current channel and there is another better one available, then LTE-U transmission will be changed to the new one. So by providing separate channels, DCS method alleviates the interference between LTE-U and WiFi communications. When LTE-U needs to share the channel with WiFi due to it's unavailability, CSAT mechanism is utilized. In this technique, SBS senses the medium for longer period, notice activities and controls LTE-U transmission proportionally. It can adaptively choose duty cycle period based on active WAPs in the covering area and allow a fair sharing between the two. OSDL uses the unlicensed channel only when QoS of users are not guaranteed by primary licensed carrier and there are active users in the coverage area. It reduces interference to WAPs by not transmitting continuously in the channel.

For sharing unlicensed spectrum between LTE networks and WiFi systems, a time-domain resource splitting approach based on almost blank subframe (ABS) was proposed in [8]. By muting some LTE sub-frame, it gives opportunity to WiFi users for using it to increase their throughput. In [9], the authors brought fairness between WiFi and femtocell networks by splitting unlicensed spectrum depending on the QoS requirements of the users. Authors of [10] proposed a spectrum sharing scheme between LTE-U and WiFi networks based on cognitive coexistence. They jointly determined DCS, CA and fractional spectrum access of LTE-U network to maximize the performance while satisfying the WiFi users. But they don't consider the heterogeneity cost of this two.

With the above mentioned techniques, there are some other approaches for coexistence between LTE-U and WiFi. In [11], the authors investigate CA of licensed and unlicensed spectrum by deploying dual-mode LTE MBS by modeling the problem with the help of matching game namely student-project allocation to provide reliable and efficient transmission. They protect the unlicensed users guaranteeing CUs' interference below the energy level of the thermal noise. They don't consider inter-operator interference and also the effect of other CUs to build preference of the CUs. The authors in [12] formulated resource allocation problem by decoupling uplink-downlink and also licensed-unlicensed band as a non-cooperative game for LTE. They preserve the interest of unlicensed users by providing at least a minimum data rate with the help of fraction time slot between LTE-U and WiFi. They solved this problem using machine learning framework namely echo state network. To make LTE-U and WiFi coexist, transmit power control technique has been proposed in [13]. Here LTE users estimate

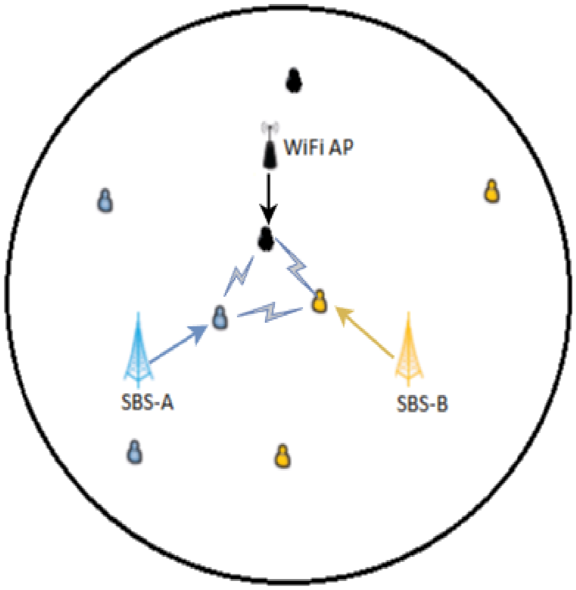

Fig. 1: System Model

the presence and proximity of WiFi users with the assistance of LTE eNBs and adjust it's transmission power accordingly to avoid rampant interference to WiFi.

If LTE-U and WiFi use different unlicensed channel then there is no obstacle to coexist. But as the number of non-overlapping unlicensed channels are limited, there must be situation when LTE-U and WiFi need to use the same unlicensed channel which makes the coexistence problem interesting and challenging.

IV. System Model and Problem Formulation

As SCNs are feasible solution to meet data demand of the users, cellular operators are deploying more and more SBSs to facilitate growing services. This ultra dense nature of SBSs from different operators bound to conflict with each other and also with local WAPs if they want to operate in unlicensed spectrum to provide guaranteed QoS. As each operator can control the interference between MBS and its SBSs, we are considering an environment where there is a set of dual-mode LTE-A SBSs, S={1,2,..,N} operated by N different operators and a set W={1,2,..,M} of M WAPs. Each SBS i can serve downlink operation of maximum users U^i at a time with it's licensed spectrum B_l^i. Both SBSs and it's associated users are distributed randomly in the area of interest. As only one user can be served by WAP at a time, we assume that there are M WiFi users distributed randomly in the same area. Both SBSs and WAPs operate in the same unlicensed band B_u. SBSs work in SDL mode with CSAT and CA technology.

A. Data Rate of LTE-U

As SBS uses OFDMA technique to allocate the resources, there is no intra-operator interference among it's users in licensed and unlicensed spectrum. Users perceive interference from other operators and WiFi system who are also working in the same unlicensed band. SBS will use unlicensed band only when the QoS of it's users are not mitigated by licensed one. When LTE-U user j of SBS i is using both spectrum then the achieved rate of that user by using Shannon's capacity shown in equation (1).

$$R_j^i = (b_{lj}^i + b_{uj}^i) log_2(1 + \frac{(b_{lj}^i + b_{uj}^i) P^i h_{ij}}{\sum_{k \in S, k \neq i} b_{uj}^{ik} P^k h_{kj} + P^w h_{wj} + \sigma^2}) \\ ,\forall i \in S, \forall j \in U^i \quad (1)$$

where b_{lj}^i and b_{uj}^i are the fraction of licensed and unlicensed spectrum respectively allocated for LTE-U user j from SBS i, $\sum_{j \in U^i} b_{lj}^i \leq 1$ and $\sum_{j \in U^i} b_{uj}^i \leq 1$. P^i is the maximum transmit power of SBS i, h_{ij} is the channel gain between SBS i and user j and $h_{ij} = 10^{-L_{ij}/10}$ where L_{ij} is the path loss, b_{uj}^{ik} is the fraction of common unlicensed bandwidth that are used by user j of SBS i and any user of SBS $k \in S, k \neq i$. $\sum_{k \in S, k \neq i} b_{uj}^{ik} P^k h_{kj}$ is the amount of interference generated by other SBS in the common unlicensed subband of user j, $P^w h_{wj}$ is the interference produced by WiFi network and σ^2 is the power of the Gaussian noise. But study [6] shows that WiFi presence affects negligibly to the LTE-U performance. So we can ignor the interference generated by WiFi system to LTE-U user and equation (1) reforms like shown in equation (2).

$$R_j^i = (b_{lj}^i + b_{uj}^i) log_2(1 + \frac{(b_{lj}^i + b_{uj}^i) P^i h_{ij}}{\sum_{k \in S, k \neq i} b_{uj}^{ik} P^k h_{kj} + \sigma^2}) \quad (2)$$

From equation (2), we find that a major part of interference is coming from other SBSs that are also operating in the same unlicensed band. To take the advantage of this band, SBSs can form a coalition and allocate the unlicensed resources in orthogonal fashion like licensed spectrum. In that case there is no interference from other SBSs and equation (2) changes it's form like:

$$R_j^i = (b_{lj}^i + b_{uj}^i) log_2(1 + \frac{(b_{lj}^i + b_{uj}^i) P^i h_{ij}}{\sigma^2}) \quad (3)$$

B. Data Rate of WiFi

According to study [14], the saturation capacity of M WiFi (APs employ CSMA/CA with binary slotted exponential backoff) users sharing same unlicensed bandwidth is shown in the equation (3).

$$R_M^W = \frac{P_{tr} P_s E[P]}{(1 - P_{tr}) T_\sigma + P_{tr} P_s T_s + P_{tr}(1 - P_s) T_c} \quad (4)$$

where $P_{tr} = 1 - (1 - \tau)^M$ is the transmission probability of at least one user in a time slot with τ is the transmission probability of each user. P_s is the successful transmission on the channel with $P_s = \frac{M\tau(1-\tau)^{M-1}}{P_{tr}}$ and $E[P]$ represents the average packet size. T_σ is the duration of an empty slot time, T_s presents the time duration of a successful transmission and T_c illustrates average time of a collision. So, achieved rate of a single WiFi user:

$$R^w = \frac{R_M^W}{M} \quad (5)$$

C. Problem Formulation

R^w is achievable when WiFi network only access the unlicensed channel. But if WAPs and SBSs are deployed in the same conflicting area, then WiFi users get almost no access in the channel and achieve an insignificant data rate. So, for fair coexistence of WiFi and LTE-U need to share the time slot in such a way that WAPs can maintain a minimum data rate and SBS can guarantee the QoS of its users. As LTE-U system manages the physical resource in a centralized manner rather than DCF of WAPs, SBSs need to decide appropriate portion of time to achieve minimum rate of each WAP. So, when SBSs give $T \in [0, 1]$ time slot to WAPs then the achievable rate of LTE-U user and WAP are shown in the equations (6) and (7) respectively.

$$R_j^i(T) = (b_{lj}^i + (1-T)b_{uj}^i)log_2(1+\frac{(b_{lj}^i + (1-T)b_{uj}^i)P^i h_{ij}}{\sigma^2}) \tag{6}$$

$$R^w(T) = \frac{R_M^W T}{M} \tag{7}$$

Our goal is to develop an effective spectrum allocation scheme that can allot both licensed and unlicensed band to maximize the LTE-U system throughput.

$$\begin{aligned} \max_{b_l, b_u, T} \quad & \sum_{i \in S} \sum_{j \in U^i} R_j^i(T) \\ \text{s.t.} \quad & C1 : \sum_{j \in U^i} b_{lj}^i \leq 1, \forall i \in S \\ & C2 : \sum_{i \in S} \sum_{j \in U^i} b_{uj}^i \leq 1 \\ & C3 : b_{lj}^i \geq 0, b_{uj}^i \geq 0, T \in [0, 1] \\ & C4 : R_j^i(T) \geq Q_j^i, \forall i \in S, \exists j \in U^i \\ & C5 : R^w(T) \geq Q_w, \ \forall w \in W. \end{aligned} \tag{8}$$

Constraint $C1$ tells us about the distribution of licensed spectrum of every SBS among it's users. Constraint $C2$ describes about the distribution of unlicensed spectrum among the LTE-U users of all SBSs who requires them. Constraints $C4$ and $C5$ are for QoS requirement of LTE-U user and minimum rate requirement of WiFi APs respectively. LTE-U users can access the unlicensed spectrum if constraint $C5$ is satisfied. The optimization problem (8) is hard to solve in real time if there are many users in the region. So, we use bargaining game to solve this resource allocation problem in real time.

V. Solution with Bargaining Game

Bargaining game is a typical cooperative game that is fair in case of resource allocation. As a newcomer, LTE-U have to protect the minimum requirement of WAPs if it wants to take advantages of unlicensed spectrum. As WiFi uses CSMA/CA to access the medium, only one WAP can be utilized in the conflicting region in the absence of LTE-U. Because different operators affect the performance of LTE-U rather than only WAPs, SBSs can form a coalition so that they can effectively utilize unlicensed spectrum among themselves and can share time slot with WAPs. So, this interaction can be considered as a two player bargaining game shown in Figure 2, where $P = \{W, L\}$ are the set of players. Let **S** be a closed and convex subset of $\mathcal{R}^{|P|}$ which represents the set of feasible payoff allocations that the players can achieve if they cooperate using utility function $U_i(T_i), \forall i$. Let **d** be a set of disagreement payoff. Then the ordered pair (**S**,**d**) is called a $|P|$-player bargaining game [15]. Now we want to find bargaining solution by the means of Pareto optimal notation from **S**.

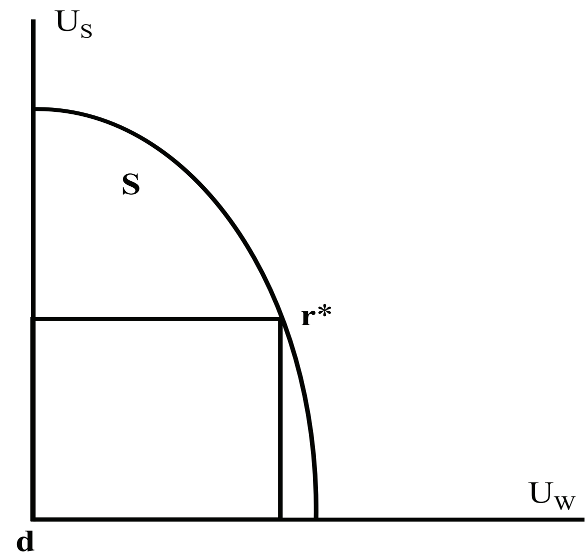

Fig. 2: NBS in two players' game

Definition 1: The point **r** is said to be Pareto optimal, iff there is no other point $\mathbf{r}'$ for which $r_i' \geq r_i$ is true for all players $i \in P$ and $r_i' > r_i$ is true for some player(s) $i \in P$.
In a multi-player bargaining game, there can have infinite number of Pareto optimal points. So, we need some criteria to select the result and fairness can be a possible criteria. In this paper we use the Nash bargaining solution (NBS) concept to bring fairness among the players.

A. Nash Bargaining Solution

NBS gives a unique and fair Pareto optimal point that satisfies the following axioms of Definition 3.

Definition 2(Bargaining Set): The set $\mathbf{B} = \{(r_1, r_2) \in S | r_1 \geq Q_w\}$ which satisfies the first three axioms of Definition 3.
Definition 3(NBS): r is said to be a NBS in **S** for **d** i.e. $r = \phi(\mathbf{S}, \mathbf{d})$ if the following axioms are satisfied where $\phi : (\mathbf{S}, \mathbf{d}) \rightarrow \mathcal{R}^{|P|}$.
1) Individual Rationality: $r_i \geq d_i$ for all players $i \in P$
2) Feasibility: $r \in \mathbf{S}$
3) Pareto Optimality: For every $r' \in \mathbf{S}$, if $r_i' \geq r_i$ then $r_i' = r_i, \forall i$
4) Independence of Irrelevant Alternatives: If $r \in \mathbf{S}' \subset \mathbf{S}$, $r = \phi(\mathbf{S}, \mathbf{d})$, then $r = \phi(\mathbf{S}', \mathbf{d})$
5) Independence of Linear Transformations: For any linear

scale transformation ψ, $\psi(\phi(\mathbf{S}, \mathbf{d})) = \phi(\psi(\mathbf{S}), \psi(\mathbf{d}))$
6) Symmetry: $\mathbf{S}$ is invariant under all exchanges of players, i.e. $\phi_i(\mathbf{S}, \mathbf{d}) = \phi_{i'}(\mathbf{S}, \mathbf{d})$

The bargaining set **B** constructs based on axioms 1, 2 and 3. So, NBS is located in **B**. Fairness is maintained in NBS by using axioms 4, 5 and 6.

Theorem 1: There exists a unique solution concept $\phi(\mathbf{S}, \mathbf{d})$ that satisfies all six axioms of Definition 3 and it follows [15]

$$r^* = \phi(\mathbf{S}, \mathbf{d}) \in argmax_{\mathbf{r} \in \mathbf{B}} \prod_{i=1}^{|P|} (r_i - d_i) \tag{9}$$

B. Algorithm using NBS

As WAPs use DCF, there is no cooperation among themselves. But SBSs can notice the activities of such WAPs by utilizing CSAT like mechanism. So, by exchanging the information among SBSs, they can form a coalition, can run the following Algorithm 1 and take best benefits from unlicensed spectrum.

Algorithm 1 Cooperated Unlicensed Spectrum Utilization Algorithm among CNOs

1: Initialization: Set of WiFi APs $\mathcal{W}$ and set of SBSs $\mathcal{S}$
2: Each $i \in \mathcal{S}$ distributes licensed spectrum among it's users based upon their QoS requirement
3: Each $i \in \mathcal{S}$ determines minimum QoS capacity gap of it's users by $QG_i = \sum_{j \in U^i} max(QoS_j^i - R_{lj}^i, 0)$
4: Each $i \in \mathcal{S}$ senses the active WAPs in the conflicting area
5: Every member of $\mathcal{S}$ exchanges that information to form a grand coalition and one SBS acts as an arbitrator
6: Arbitrator determines the bargaining set **B** depending upon the received information from all SBSs
7: Finds $r^* \in argmax_{\mathbf{r} \in \mathbf{B}} \prod_{\forall k \in P} r_k$ considering $\mathbf{d} = (0, 0)$
8: Finds $T \in [0, 1]$ from r^* during which SBSs will not operate in unlicensed band
9: Arbitrator uses $b_u^i = \frac{QG_i}{\sum_{j \in S} QG_j} B_u, \forall i \in S$ to allocate unlicensed resources to the SBSs and inform them to use it in $1 - T$ time slot
10: Each SBS allocates b_u^i among it's users based upon their minimum QoS capacity gap to use with licensed spectrum using CA to reduce this gap or to meet the requirement

VI. Performance Evaluation

Here, we evaluate the performance of proposed mechanism using simulation with MATLAB. There are five SBSs of different CNOs and five WAPs distributed randomly in the conflicting area of radius 100m. Users of each SBSs and WAPs are randomly distributed in the conflicting area. WiFi network works based on the IEEE 802.11n protocol in 5GHz band with RTS/CTS mechanism. SBSs also work in the same unlicensed band. Some of the WiFi parameters are same as [14] shown in the Table 1 with some other necessary parameters used in our experiment. We assume that SBSs use SDL with the help of CA when the QoS of applications are not satisfied with licensed spectrum. For our simulation, we use typical QoS requirements of multimedia applications as indicated [16] shown in Table 2. For the experiment, we use the path loss model $15.3 + 37.5log_{10}(d_m)$ for licensed spectrum and $15.3 + 50log_{10}(d_m)$ for unlicensed spectrum where d_m indicates distance in meter. We use resource block of 180kHz each in both licensed and unlicensed band and so, each SBS has 25 resource block in licensed spectrum and unlicensed spectrum can be divided into 100 resource block. Unlicensed resource block can be used depending upon SBSs' QoS gap with licensed resources. A sample conflicting environment is shown in the Figure 3 with SBSs (and associated LTE-U users) and WAPs. Figure 4 shows the average achieved rate in case of varying number of users for LTE-A and LTE-U with respect to QoS requirement. From the figure, we find that LTE-A can provide greater average sum-rate than average QoS requirement upto 18 users. LTE-U can provide better average sum-rate or at least same as LTE-A and can grantee QoS for almost all of it's users. Figure 5 depicts individual achieved rate in case of both LTE-A and LTE-U considering that each SBS is serving 25 users. We find from the figure that QoS requirements of many users cannot be guaranteed by using LTE-A but demands of most users can be satisfied by using LTE-U. From 100 runs, we find that around only 46% users get guaranteed QoS in case of LTE-A where as LTE-U can deliver guaranteed QoS to 89% of users for using their desired applications.

TABLE I: Simulation Parameters

Symbol	Value	Comments
W	5	No. of WiFi APs
S	5	No. of LTE-U SBSs
B_l	5MHz	Licensed bandwidth/SBS
B_u	20MHz	Unlicensed bandwidth
P	10x23dBm	Total power of each SBS
U	5 to 25	No. of users/SBS
Q_w	4 Mbps	Min rate for WiFi AP
E[P]	1500 byte	Avg. Packet size
SIFS	16 μs	Short interframe space
DIFS	50 μs	Distributed interframe space
CTS	304 μs	Clear to send
RTS	353μs	Request to send
ACK	304 μs	ACK Timeout
δ	1 μs	Propagation Delay
C	130 Mbps	Channel Bit Rate

TABLE II: QoS Requirements of Multimedia Applications

Application	**Min Requirement (Kbps)**
HD video streaming	800
Video conferencing	700
VoIP	512
Audio streaming	320
File download	200

VII. Conclusions

In this paper, we have tried to meet the QoS requirements of the users by augmenting unlicensed spectrum with licensed one in LTE-A network. Here, LTE-A network use SDL scheme to take advantages of unlicensed spectrum while maintaining

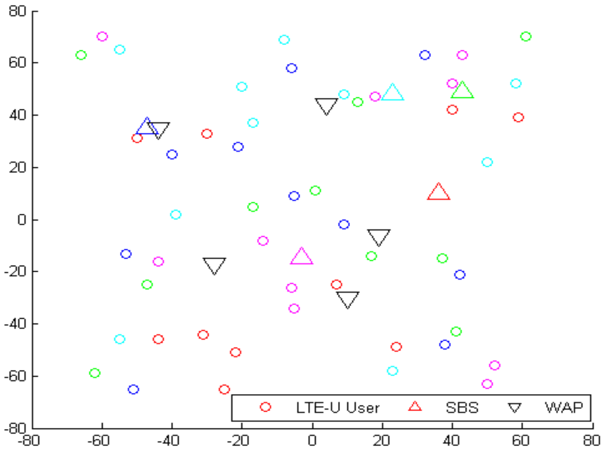

Fig. 3: Sample representation of LTE-U users, SBSs and WAPs in the conflicting area

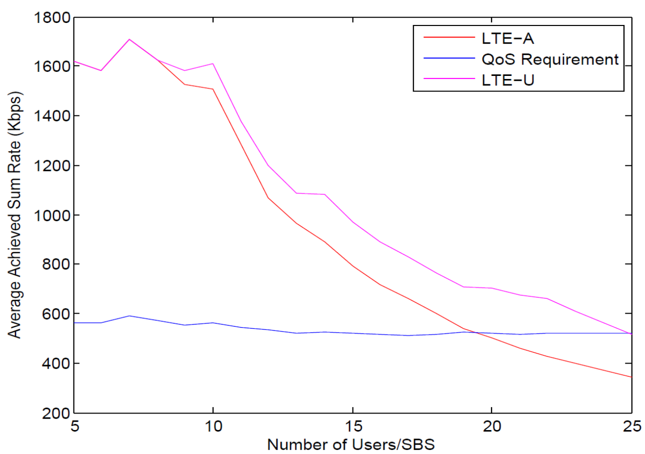

Fig. 4: Comparison of Achieved Rate

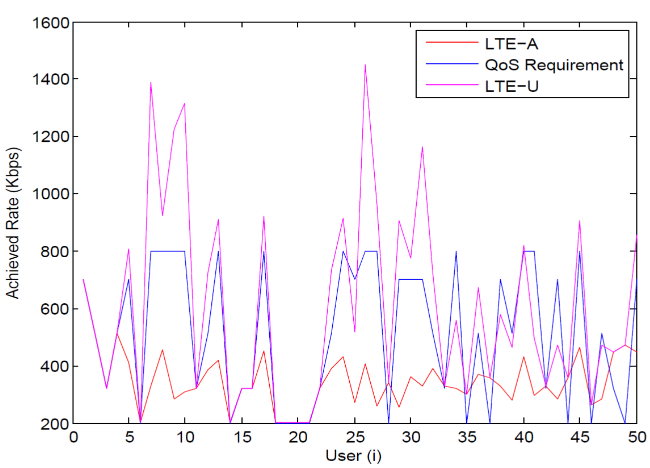

Fig. 5: Achieved Rate of individual user considering 25 users/SBS

minimum requirement of other WAPs who use the same unlicensed band in the conflicting region. For this we have solved the problem by utilizing cooperative approach like NBG which provides a unique solution of the problem. Simulation results show that opportunistic use of unlicensed spectrum in LTE-A network can provide better rate to the users and can meet QoS requirements of around 43% more users than traditional LTE-A system. In future, we will try to meet QoS requirement of all the users by carefully designed mechanism.

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