LTE-LAA and Wi-Fi Coexistence on 5 GHz—A Survey

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Abstract Wireless industry is growing exponentially due to the growth and demand of mobile services. The ever increasing demand of wireless services had forever increased the problem of scarcity of spectrum. The demand of data traffic is increasing day by day and 5 GHz unlicensed band is the best solution to meet this requirement pointed out by wireless industry. The 5 GHz unlicensed band is accessed as per the availability by using LTE technology and this is the best example of this operation to enhance the capacity of end user and to provide good quality of access to the users. This paper provides a comparative and vast survey on LTE-LAA and Wi-Fi coexistence on 5 GHz unlicensed band. In the first part of this paper we have discussed about the present scenario of coexistence of LTE-LAA and Wi-Fi tehnology. In second part we had covered the main key features of LTE and Wi-Fi technology. Finally we had discussed about the main challenges of coexistence of LTE-LAA and Wi-Fi Technology.

Keywords Long term evolution (LTE) · LTE uplink scheduling technique · Coexistence · Wi-Fi · 5 GHz unlicensed frequency band

1 Introduction

With the exponential growth of mobile users and its huge applications, wireless service providers are experiencing major growth in mobile data users in the world [1]. The worldwide mobile traffic is increasing in multiples in every year as per the standard reports from wireless industry, and the wireless industry needs to prepared for providing services to all mobile users in future [2]. Such huge mobile data traffic of multimedia services are resulting a big problem on the system capacity and making it challenging for providing quality of service to future mobile communication systems

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[3]. Wireless industry is in search for more advanced and technical solutions to increase its network capacity along with providing higher level quality of service to their customers. Operator's first choice is to use its licenses spectrum more effectively for providing reliable and secure performance from their network as compare to other networks.

For achieving a higher data rate, carrier aggregation technology standardized in LTE standard (Releases 10–12), and in that multiple small band segments can be divided into maximum 100 MHz bandwidth [2]. In order to provide high speed and good quality localized services along with improved inter-cell interference coordination (eICIC) and frequency reuse mechanism is enabled by deploying small cells overlaid with macro cells to improve licensed spectrum efficiency. This process of deployment is known as heterogeneous networks [4] (HetNets) in LTE release 10, which refers to deployment of co-channel of small cells which is sharing same licensed spectrum with macro cells. The licensed spectrum can get easily congested due to large number of small cells available in the dense deployment scenario of HetNets. This motivates the service provider to use the available unlicensed spectrum in operation. In multimedia services LTE/Wi-Fi coexistence are allowing users to use either licensed LTE or unlicensed Wi-Fi networks [5]. In LTE release 13 it has been stated that LTE-unlicensed (LTE-U) technology is initiated to allow users to access both licensed and unlicensed spectrum under a unified LTE network infrastructure.

2 Existing Surveys on LTE, Wi-Fi and This Paper a Comparative Study

In these surveys, a comparative study of present surveys on LTE and this paper has been neatly explained. We had investigated several surveys from different aspects of LTE-related technologies.

The authors first reviews about the evolution of LTE physical layer and control channels [1]. In papers [2, 4, 6], authors focuses on radio resource management (RRM) for LTE and LTE Advanced (LTE-A) networks. To be more in specific, the authors in [4] explained on Heterogeneous Networks (Het Nets). Resource allocation and link adaptation are overviewed in [2] and in [6] authors said about Radio resource management for spectrum aggregation. In papers [5, 7–11], authors have given information about Uplink (UL) or Downlink (DL) scheduling. In paper [5] authors had classified scheduling of LTE UL for Machine-to-machine (M2M) communications. In paper [7], authors explained about the cooperative Uplink transmissions beyond LTE-Advanced system. In paper [8], authors had given information regarding UL scheduling in LTE and LTE-A.

Authors in paper [10] had explained about the downlink (DL) packet scheduling in LTE network. Different mitigation techniques for DL and UL for Multi-cell coordinated scheduling and inter-cell interference are reviewed in [9]. As per [9], multi-cell scheduling strategies of LTE and LTE-Advanced are also reviewed in [11]. Some

surveys said about the techniques for enabling communications in LTE networks. In paper [12], authors described Machine to Machine (M2M) communications of LTE and LTE-Advanced. In paper [13] author had reviewed Device-to-Device communications in LTE networks. Different Security aspects for LTE and LTE-A networks are overviewed in paper [3]. These papers had focused on study of LTE-LAA and Wi-Fi coexistence in 5 GHz unlicensed spectrum.

At present mobile networks are facing network capacity challenges everywhere. The research community have already started to concentrate their research interest in this area due to special benefits given by the coexistence of LTE and Wi-Fi networks in unlicensed spectrum.

In the Table 1 we have done an extensive survey on LTE and our work related to LTE-LAA and Wi-Fi coexistence on 5 GHz band has been highlighted. In the survey the work of other authors has been also highlighted under the description section of the table sequentially.

3 Key Features of LTE-LAA and Wi-Fi Coexistence

In order to achieve coexistence of LTE and Wi-Fi and other unlicensed technologies the three features plays a vital role in the process of coexistence.

a. **Channel selection**: channel selection is very effective in low to medium density scenarios considering that multiple 20 MHz channels are available in 5 GHz unlicensed band. In LTE-U small cells always try to select a clean channel to avoid interference with nearby nodes, based on the continuous channel measurements.
b. **Time-domain coexistence techniques**: are expected when there is unavailability of clean channel. As per the regulations of unlicensed band multiple techniques can be there for sharing the channel properly with the Wi-Fi. In case of non listen-before-talk (LBT) markets such as India, US China and South Korea, without changing Carrier Aggregation protocols (Rel-10) for co-channel coexistence CSAT (Carrier Sensing Adaptive Transmission) can be used. For listen-before-talk (LBT) markets in Europe and Japan, Rel-13 LAA is enabling the channel sharing with Wi-Fi by performing clear channel assessment (CCA) based channel availability sensing and adapting the transmission duration on a timescale ranging from 1–10 ms.
c. **Opportunistic SCell operation**: In the LTE-U, unlicensed carriers are designed to operate as secondary cells (SCells) having the principle that at low traffic load, LTE-U small cells are releasing the unlicensed carriers and are be back on to main carrier of licensed spectrum in the process.

Table 1 Comparison and study of coexistence of LTE license assisted access and Wi-Fi technology and our present work

Reference paper no.	Main keywords	Key findings
Our present work	Coexistence	(a) LTE-LAA and Wi-Fi technology coexistence features
		(b) Present research on coexistence of LTE license assisted access and Wi-Fi technology
		(c) Challenges in coexistence and future directions for research
[1]	Physical layer	(a) Information of control channel of LTE and its challenges
		(b) Information of LTE release 11
		(c) Drawbacks of new released design
[4]	Radio resource management	(a) Challenges in heterogeneous networks
		(b) Different schemes of radio resource management
		(c) Comparison of schemes as per approaches
[2]	Radio resource management	(a) Way of encoding and different modes
		(b) Different link adaption methods
		(c) Control signal encoding and channel state feedback
[6]	Radio resource management	(a) Information of different techniques of spectrum aggregation
		(b) Supporting algorithms for carrier aggregation
		(c) Challenges for aggregation in LTE-Advanced

(continued)

Table 1 (continued)

Reference paper no.	Main keywords	Key findings
[5]	Uplink/downlink scheduling	(a) Efficiency in power
		(b) Quality of service
		(c) Scalability and multi-hop connectivity for users
[7]	Uplink/downlink scheduling	(a) Single carrier FDMA and local FDMA comparison
		(b) Information of single carrier FDMA
		(c) Benefits of LTE-Advanced technology
[8]	Uplink/downlink scheduling	(a) Information of scheduling of LTE and LTE advanced technology
		(b) Scheduling problems and different addressing schemes
		(c) Evaluation methodology for comparison of scheduling
[9]	Uplink/downlink scheduling	(a) Single user MIMO
		(b) Multi user MIMO
		(c) Mitigation techniques for uplink and downlink inter cell interference
[10]	Uplink/downlink scheduling	(a) To design resource allocation algorithm for long term evolution networks
		(b) All information of the most recent techniques
		(c) Comparison of performance of above techniques

(continued)

Table 1 (continued)

Reference paper no.	Main keywords	Key findings
[11]	Uplink/downlink scheduling	(a) Information of interference and interference management
		(b) Information of different scheduling strategies
[12]	Communication techniques	(a) Architecture for M2M services
		(b) QOS requirements in M2M communications
		(c) M2M challenges and issues over LTE/LTE advanced
[13]	Communication techniques	(a) D2D communication of LTE advanced networks
		(b) Standard research activity
[3]	Communication techniques	(a) Information on security of LTE and LTE-Advanced networks
		(b) Network design of LTE and LTE-Advanced
		(c) Information and solution to security issues

4 Challenges of LTE-LAA and Wi-Fi Coexistence

(a) Unable to deal with mutual interference and there is problem in coordination.
(b) Interference management are not designed to work with HetNets.
(c) To design a effective coexistence mechanism where the networks have different channel access techniques and also transmission or interference ranges, incompatible time slots and communication mechanism can coexists properly.
(d) Wi-Fi nodes can differ transmission for a random time in order to avoid transmission collisions happened due to interference from other Wi-Fi node or interference coming from the coexistent LTE network. This situation must be avoided.
(e) Different Simulation results show that performance of Wi-Fi is severely degraded with LTE coexistence and needs to be improved.
(f) Effectives regarding to current coexistence mechanisms are not clear to the Industry.
(g) Doubt is still there regarding successfulness of LTE-LAA spectrum sharing method.
(h) Special new and unique mechanism needs to be developed for LTE-LAA and Wi-Fi Coexistence.

5 Conclusion

We have gone through a huge comparative research survey of several coexistence related features of these two technologies i.e. LTE and Wi-Fi and are reached to the final conclusion that Wireless research Industry needs to adapt or develop some new and special beneficial mechanism for LTE-LAA and Wi-Fi coexistence. Till now such a type of mechanism is not available in the market for the fulfillment of 100% demand of users in coexistence of LTE-LAA and Wi-Fi in 5 GHz unlicensed Spectrum band. This can be the probable solution for fulfilling the ever increasing demand of mobile users for providing different services.

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