

Surplus Process Modeling for Throughput of Wi-Fi Co-Existing with LTE-U

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Abstract

Coexistence of LTE and Wi-Fi systems in unlicensed band can improve performance of LTE technologies in terms of spectral efficiency. With the benefits of spectral efficiency, there comes interference issues to the existing technologies operating on unlicensed spectrum. Coexistence of LTE and Wi-Fi networks is not trivial due to dissimilarities in terms of wireless access protocols in both networks. This issue is addressed in this paper where redundant spectral resources of Wi-Fi network are allocated to LTE. The redundant resources are calculated using Surplus process and are allocated to LTE while satisfying Wi-Fi throughput above a threshold.

1. Introduction:

Higher data rate demands are continuously increasing in mobile cellular systems which has resulted in spectrum scarcity in 5G cellular networks. Lot of efforts are being made to improve the spectral efficiency as well as hunting for new spectrum resources is also in progress. As there are lot of coexistence issues in Wi-Fi and LTE, tradition ways of LTE HetNets as proposed in [1] can't be applied.

One of the new spectrum resources is unlicensed band used in Wi-Fi networks. The redundant resource from Wi-Fi systems can be allocated to LTE users. This coexistence of cellular networks with Wi-Fi networks is termed as LTE-Unlicensed (LTE-U).

LTE-U is a promising technique to improve the spectral efficiency for cellular networks. Coexistence of cellular networks and Wi-Fi networks is not trivial due to differences in the mechanisms of accessing the wireless channels. LTE cellular networks are based on TDD access where each user can access channels on fixed slots while Wi-Fi networks access the channel on contention based system.

LTE-U is a hot trend and lot of research work is being done in this area. In [2], authors proposed to allocate unlicensed resources of Wi-Fi in uplink and downlink communication of cellular users using time sharing. In our previous work [3], we analyzed the performance of channel allocation modeled as Markov chain.

In this paper, we proposed a fair channel allocation scheme for LTE-U. Channel availability is ensured with Listen before Talk algorithm. After that, certain Wi-Fi throughput is ensured and redundant resources are allocated to LTE users. Results reveal that the throughput of Wi-Fi users is always satisfied above some threshold. In this way the Wi-Fi networks are not suppressed and rate of LTE users is maximized under the constraint of Wi-Fi fairness.

Rest of the document is formulated as follows. Section 2 will give system model followed by problem formulation in section 3. Section 4 gives results and in section 5, we will conclude our research work.

2. System Model:

In the system model we have a macro base station with many small cell base stations SBSs each coexisting with many Wi-Fi access points represented by N as a set $\{1, 2, \dots, J\}$. These Wi-Fi access points are operating on C channels which can be allocated to both Wi-Fi and small cell users. As shown in Fig 1, when LTE SBS transmits on unlicensed band, it will cause interference for coexisting Wi-Fi networks. LTE-U is usually implemented in downlink in order to meet high data rate demands of cellular users while utilizing unlicensed spectrum of Wi-Fi networks.

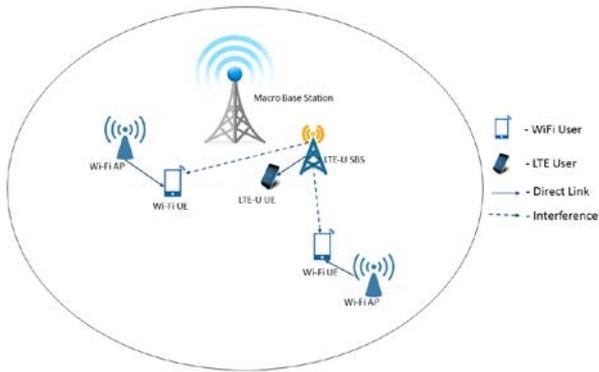


Fig 1: LTE-U model

Our problem is to allocate the redundant resources of Wi-Fi to LTE while providing fairness to Wi-Fi users and avoiding any interference caused by LTE users to Wi-Fi networks.

3. Problem Formulation:

In this section, we are formulating our problem as distributed optimization problem which will be solved at SBSs. LTE can allocate the free resources to its SBSs when Wi-Fi APs are not using those resources. Objective of our problem is to maximize the resource of LTE while providing satisfactory throughput to Wi-Fi users.

Problem Statement:

Based on this problem, our problem statement constitutes as follows.

Maximize the rate for LTE users while

1. Channel is not used by other Wi-Fi user
2. Throughput of Wi-Fi users is greater than some threshold

In order to meet the objective, we are formulating the problem. First constraint of our model is to ensure the channel availability. We are using Listen before Talk (LBT) algorithm for LTE channel allocation. The benefit of using LBT is that we can sense the channel availability and will allocate the channels only when no Wi-Fi transmission is in progress to reduce interference to Wi-Fi networks.

In order to satisfy the threshold for Wi-Fi throughput, we are introducing a decision variable. This variable will ensure that the throughput of Wi-Fi networks is always satisfied and no resources will be allocated to LTE otherwise.

$$x = \begin{cases} 1, & \text{if } avg(w_c) \geq \gamma \\ 0, & \text{otherwise} \end{cases}$$

Optimization Model:

Decision variable is l_c which is the portion of channels to be allocated to LTE. C is the total number of channels, w_c is the channels being used by Wi-Fi networks.

$$\begin{aligned} & \text{maximize} && x * l_c \\ & \text{subject to} && l_c \leq C - w_c \end{aligned}$$

Based on the above model, the outcome of the optimization model is the proportion of the channels to be allocated to LTE users.

Channel allocation to LTE is modeled as surplus process where total unlicensed channels are divided among Wi-Fi and LTE networks. The surplus for LTE is the remaining channels not used by Wi-Fi networks.

This surplus process is modeled in the constraint of the optimization problem. Channels used by Wi-Fi networks are subtracted from total number of channels available in unlicensed band. This forms the surplus for LTE network.

4. Simulation Results:

We have implemented the above model in Julia programming language using Jump solver to solve the optimization problem. 11 number of orthogonal channels in unlicensed band are allocated to Wi-Fi and LTE networks. Simulation is run for 1000 iterations to analyze the convergence of channels allocated to Wi-Fi and LTE-U.

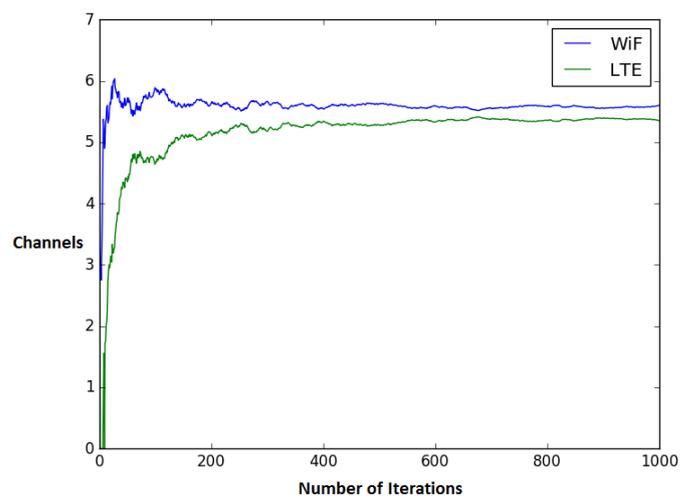


Fig 2: Convergence of Channel allocation to Wi-Fi and LTE

Fig 2 shows the results of simulation where channels

allocated to Wi-Fi users are always greater than the channels allocated to LTE. Results also reveal the convergence to specific number of channels based on the threshold being selected for Wi-Fi.

5. Conclusion and Future Work:

In this paper, coexistence of cellular networks with Wi-Fi networks is proposed using the Surplus process. Redundant resources from Wi-Fi networks are obtained and are allocated to LTE system while providing fairness to Wi-Fi system. Simulation results show that the threshold throughput of Wi-Fi networks is always satisfied.

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