Performance Analysis of LTE-U based on Markov Chain State Transition

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Abstract

Long Term Evolution-Unlicensed (LTE-U) is a 5G technology where LTE and WiFi systems are merged together for better system efficiency. WiFi and LTE both can work together in 2.5GHz and 5GHz band by sharing the redundant spectrum with each other. Aggregating these two technologies while implementing a fair allocation of resources among them is a challenging task. LTE technology is considered better spectrum efficient and it is more bandwidth hungry, therefore appropriate allocation scheme is to be developed. In this paper, we analyze the limiting distributing of channel allocated to WiFi or LTE users.

1. Introduction:

In order to meet the needs of higher data rate demands in cellular networks, new spectrum bands are to be sought. One option is to utilized unlicensed band for LTE to get better utilization of spectrum resources. This technology is introduced where cellular network data traffic is offloaded to WiFi spectrum by providing unlicensed spectrum resources to LTE network. With the increased requirements of mobile user data traffic, load on cellular networks has increased significantly. In order to overcome this problem, scarcity of spectrum should be resolved. LTE-U provides the solution to the problem of spectrum scarcity by sharing unlicensed spectrum with cellular users.

As there are major differences in the environment, infrastructure, power levels and interference management systems of both LTE and Unlicensed networks, the traditional ways of resource allocation cannot be applied in LTE-U. In order to overcome the power differences between the two merging technologies, LTE-U involve pic cell or small base station resource sharing with WiFi users. In this way, the low power transmission of small cells can significantly reduce interference with WiFi users.

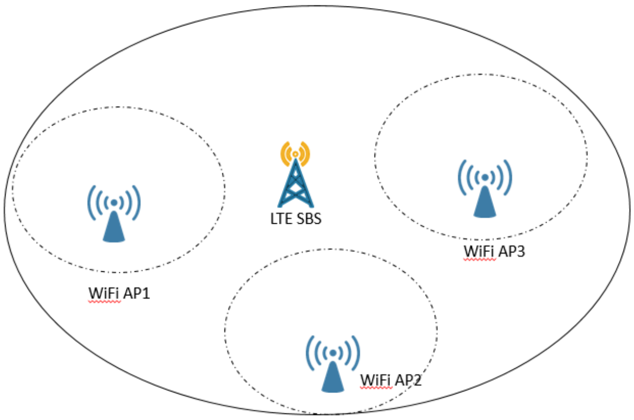

Fig 1: LTE-U model

In order to allocate the spectrum resources to both cellular and WiFi users, wireless channels can be shared among both technologies. In order to keep the problem simple, we have considered that both technologies are being managed by single operator.

There is already some work done for resource allocation in LTE-U environment. In [1] a coexistence algorithm for LTE-U where WiFi and LTE can exist together is proposed. Another work is done by [2] where game between WiFi and LTE users is proposed. Similar work is done in [3][4]

In this paper, we analyze the spectrum utilization of LTE and WiFi users in order to maximize the efficiency of resources. We have used Markov Chain to find the state of each channel and have observed the air time of channels used by both technologies.

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:

Our system model is a large base station with multiple small cell bases stations represented by *M* as a set *{1,2,...,m}* and WiFi access points represented by *N* as a set *{1,2,...,n}*. We have considered a single operator managing both cellular and WiFi networks. Therefore, the channels pool with *C* channels can be shared with both WiFi and Cellular users under single controller.

There can be two channel states

- LTE State: When Channel is allocated to LTE network
- WiFi State: When channel is allocated to WiFi network

Each channel state is independent of each other because allocation of resources in both systems is independent of each other.

3. Problem Formulation:

As shown in the previous section that each channel can be represented in two channel states. We have modeled the problem with Markov Chain having two states. State representation diagram of Markov Chain is given below.

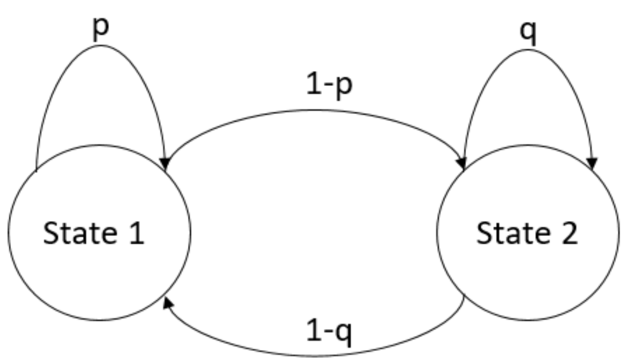

Fig 2: State Transition Diagram

Corresponding Transition Probability Matrix of above Markov Chain is as follows.

$$P = \begin{bmatrix} p & 1-p \\ 1-q & q \end{bmatrix} \qquad (1)$$

The model is markov chain

As we see from above state representation diagram and transition probability matrix, the given Markov Chain holds following properties.

- Recurrent: As the probability of reaching each state at any time slot is always 1, therefore each state is recurrent.
- Irreducible: This Markov Chain is irreducible because all states belongs to the same class of Recurrent
- A-periodic: Period of given Markov Chain is one there this model is Aperiodic.

On the basis of above mentioned properties of a Markov chain, it is clear that the Markov Chain model in our problem is Ergodic {Positive Recurrent, Irreducible and Aperiodic}. Therefor the properties of Ergodic Markov Chain can be applied here.

We know the state transition probability matrix as represented by P, or P_{ij} so state distribution can be found with the following relation.

$$\pi_j = P^T \pi_i \qquad (2)$$

Based on the above model, initial condition can be used to find the transition probability after each iteration. Simulation results of the these results are shown in next section.

5. Simulation Results:

We have implemented the proposed model to observe the results. Markov Chain state distribution is used in order to find the stationary distribution which is further applied in order to get the simulation results.

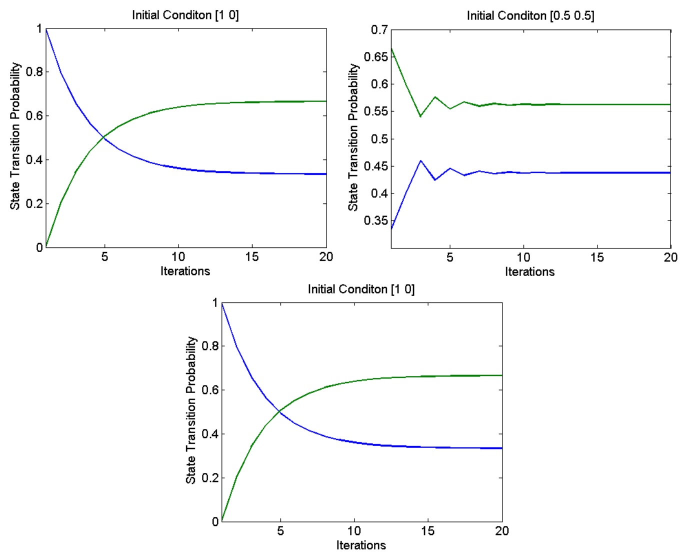

Fig 3: Convergence of State Transition

Above figure shows the simulation results of the

Markov Chain. These results show that irrespective of the initial condition of Markov Chain, the probability distribution converges after few iterations. Results also show that LTE has higher probability of getting the channels. This means that LTE system can get better channel utilization and it gains more number of channels for giving better performance.

6. Conclusion and Future Work:

In this paper, we analyzed the performance of LTE-U system with the help of Markov Chain. States of WiFi and LTE are analyzed for channel allocation. Final results show that LTE can get better performance in terms of channel utilization.

Acknowledgement:

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