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This paper looks to propose a method for quickly estimating the change in power radiated from one LTE cell sector as the network activity in the sector changes, for the purpose of assessing the interference at a receiver a considerable distance away from the sector. The method should be repeatable for any cell sector and be compatible with existing propagation models. The intent is to incorporate this method into new or existing probabilistic models for Long Term Evolution (LTE) network aggregate interference, specifically those that can be sampled in a Monte Carlo simulation. We will explain the justification of the technique in the context of the LTE pprotocol, propose an implementation, and suggest future work.

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Estimating LTE Cell Sector Radiated Power by Modeling Resource Block Utilization

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Abstract

This paper looks to propose a method for quickly estimating the change in power radiated from one LTE cell sector as the network activity in the sector changes, for the purpose of assessing the interference at a receiver a considerable distance away from the sector. The method should be repeatable for any cell sector and be compatible with existing propagation models. The intent is to incorporate this method into new or existing probabilistic models for Long Term Evolution (LTE) network aggregate interference, specifically those that can be sampled in a Monte Carlo simulation. We will explain the justification of the technique in the context of the LTE protocol, propose an implementation, and suggest future work to verify and improve the model.

Introduction

As demand for RF spectrum space increases, there is an increasing need to make more efficient use of spectrum real estate, which includes spectrum sharing[1].This may include active sharing of the same frequency band or sharing between devices that are separated geographically. If frequency real estate is being shared using the latter solution, it is a necessity to assess the interreference emitted by transmitters of one system on receivers in the second system (and vice versa) in order to determine the minimum geographic separation that will allow the systems to operate without degradation of performance. This can be particularly challenging if the transmitting system is a distributed network of transmitters, such as the uplink channel of a cellular network. This is because the transmit powers of cellular network user equipment (UEs) change significantly under different channel conditions, collecting data off of UEs in a live cell network is extremely impractical, and aggregate power is very dependent on network activity which varies significantly throughout the day.

A practical solution for this problem is to develop a statistical model for the aggregate emitted UE transmit power in a cell sector, because a receiver could potentially be exposed to thousands of LTE phones if it is operating near an urban area, and a deterministic solution will not exist. In addition, it is not practical to run measurements on every network that could potentially be an interferer, so any measurements are were collected would need to be extrapolated to the other networks. If a statistical model that agrees with the measurements made in the field can be created, then this model can be extended with some confidence to areas where testing has not been performed and make predictions about how significant the interference would be at that location.

In developing a statistical model, adjusting the emitted power of a sector for the network activity at the simulated time has presented itself as a challenge. There is not a direct way to measure the network load at a given time, so its effects have to be modeled through other parameters. This paper will propose a method for estimating the network activity of an LTE sector given a distribution of UE transmit powers using the average occupancy of resource blocks (RBs) in the LTE grid. We predict this method will be effective because it will take into account the spectrum resource constraints that the LTE scheduler must follow instead of modeling individual devices. We will present this as a general method, as it is applicable in the broader context of modeling LTE systems as interferers, not just the band that this project is concerned with.

Resource Allocation in the LTE Protocol

In the LTE protocol, the bandwidth is divided into resource blocks, which on the uplink channel, the scheduler grants to UEs transmitting in that sector. The larger the channel bandwidth, the more resource blocks can be transmitted in one transmission time interval (TTI). For example, a 10MHz uplink channel would support 50 RBs per TTI[2]. Figure 1 shows an example of the LTE resource grid for a 1.4MHz uplink channel over 10ms (10 TTIs).

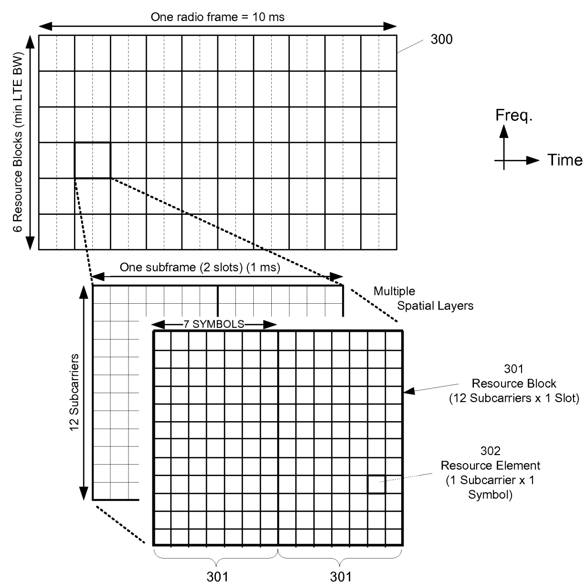

Figure 1: LTE Resource Grid[2]
Source: Patent US9055576B2

The number of RBs a UE is granted is decided by the scheduler at the tower. This number typically depends on the kind of traffic the UE is using. For example, UEs requesting a grant for a HTTP request, voice over IP (VOIP), or video upload would all require different scheduling to meet the bandwidth and latency requirements of the services they are using.

Another matter of concern in the LTE protocol is assigned transmit power. The tower will assign a transmit power for a UE along with its resource grant based on an estimate of the UEs distance from the tower. The power will be assigned such that all transmissions from UEs at different distances and under different channel conditions will arrive at the tower with uniform power spectral density across the frequency band. In other words, UEs will have to transmit each RB at a power such that it will be received at the same power at the tower receiver. A UE at a certain distance will have to transmit twice as much power to send 2 RBs as it would to send 1 RB. This concept of resource block grants and assigned power will be integral to accurately modeling a cell sector's effective radiated power, particularly at large distances from the transmitters.

A Case Against Modeling Connected Devices

In the modeling scenario that this paper is concerned with, it is tempting to choose to characterize the emitted power on a per device basis because the transmitters are located at the UEs. An example of a model following this method would be to define a power distribution for a typical UE, estimate the number of connected UEs per TTI, and for each connected UE sample the power distribution. However, this is not exactly the truth. Because power is assigned per RB not per UE, each device would have to also include a distribution for the number of RBs they are transmitting, and the model would have to make sure that collectively the UEs are not transmitting more RBs than the channel allows. Furthermore, the model would then have to ensure that the total number of transmitted RBs reflects the correct level of network activity. This calculation is complicated and could add unnecessary overhead to a Monte Carlo Simulation, because it follows the LTE scheduling process backwards. In addition, this could tempt one to model the activity of the network as a number of connected UEs, which is also inaccurate. Modeling activity this way gives very poor resolution for network load characterization, as the typical number of UEs connected per TTI is in the single digits, typically around 3 connected devices per 5MHz of bandwidth[3]. Instead, one could design an implementation that models the scheduler in a more logical order, starting at the RB grants. This allows one to assure the total transmitted RBs are within realistic bounds for the both the channel bandwidth and sector network activity.

Proposed Implementation

In order to implement a model following this strategy, it is necessary to choose a number of RBs to model, and a number of radiated power distribution samples to draw. Both of these factors depend on the bandwidth, and CSMAC[3] estimates that there are 3 UEs connected per 5MHz of bandwidth, so it is reasonable to draw 3 times per 5MHz. LTE release 8 uses 25 RBs per 5MHz in most cases, more detail is in table (?). These details are important because not only do we want to model the average reduction in radiated power from a hypothetical full load to our modeled load, but we must be careful not to add too many RBs or add too many samples of the radiated power distribution and model the variance incorrectly. This could have a significant impact on the maximum of the distribution, which is of great concern in the context of this model.

The proposed methodology to calculate the radiated power for one sector is as follows:

1. Determine the number of RBs and transmitting UEs to model
2. Divide the RBs evenly among the UEs
3. Sample the device radiated power once per UE, and divide it evenly among the RBs assigned to that UE
4. For each RB, set its power to 0 with probability = 1 – average RB occupancy
5. Sum the power across all RBs

For this particular example, we will model a 10MHz channel. We will assume there are 6 UEs transmitting during this TTI. Also, for the purpose of demonstration, we will use a total of 42 RBs per TTI. A typical 10MHz band will have 50, but this number is divisible by 6 and convenient for illustrative purposes. A diagram of the method using these parameters can be seen in figure 2, and pseudocode in figure 3.

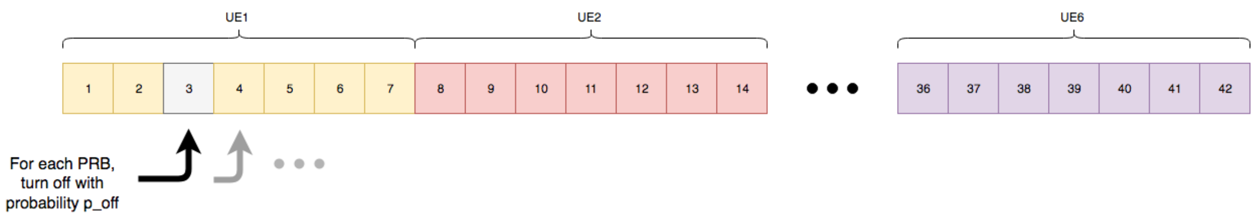

Figure 2: Diagram of RB modeling method

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Assume 6 UEs, 42 RBs

For each sector:
      for each UE:
            eirp <= sample_eirp()
            next 8 RBs <= eirp/8

      for each RB:
            p_off <= 1 - sector.prb_utilization
            p <= uniform(0,1)
            if p > p_off:
                  turn off RB

      sector_power <= sum(all RBs)
```

Figure 3: Pseudocode algorithm for simulated RB Occupancy

This method will generate samples of a random variable for the aggregate interference of any number of cell sectors, provided that the RB occupancy data is available for them. The intended use case would be to propagate each sectors power from the cell tower base provided that the modeled receiver is sufficiently far from the cell towers, which in the context of this simulation is always the case. The algorithm contains relatively few operations, so with an efficient random number generation it should be suitable for a Monte Carlo simulation.

Conclusion and Recommendations

Through analysis of the LTE protocol and principles of signal propagation, we are confident that this method could give accurate results in analysis of LTE systems as interferers in the field. The data required to model real scenarios should be available either in data collection at cell towers or could be collected for a sector using LTE decoders. If applied to a propagation model, this method has to potential to quickly assess if LTE networks can be safely operated within a given distance of a receiver using the same spectrum.

This model could be further improved with more detailed data on RB occupancy. LTE protocol decoders have the ability to not only calculate the percent of RBs that are occupied, but also record which RBs are occupied. This could be used to create per-RB distributions, which could be used to estimate the variation of activity across the spectrum of the LTE resource grid. In the scenario where the bandwidth of the receiver is smaller than the bandwidth of the interfering LTE network, this information could be important because RBs are not always occupied uniformly across the band, and there could be a higher power density inside the receiver band than would be immediately obvious without taking this into consideration.

It is our intention to test this method in the field against a receiver at a recorded distance from an LTE network, and check for correlation between the fluctuation of measured and simulated received power at the measurement location as network activity changes over the course of multiple hours. Our preliminary look into this method was promising, and we believe it justifies further work to assess its correlation to a live LTE network.

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