Co-tier and Cross-tier Uplink Interference Mitigation using Q-learning

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1 Problem/Proposal

The co-tier or co-channel interference problem is a traditional problem in cellular network. Although it has been investigated intensively in traditional cellular network, in heterogeneous network (HetNet), we face the same problem with new scenarios and challenges. In the HetNet, we have multiple mobile users in the different tiers (macrocell and femtocell). In this scenario, some users have priority over other users. For example, the macro user equipments (MUEs) are given priority access to the network compared to the femto user equipments (FUEs)[1]. Orthogonal scheduling is performed separately by the macro base stations (MBS) and each femto base station (FBS), so the mobile users associated with the same FBS or MBS will surely not interfere with each other. But due to high density of (FBSs) and FUEs, it is very likely that multiple FUEs, each associated with a different FBS, are using the same sub-channel in a nearby area, potentially causing a co-tier uplink interference. Also in HetNet, FBS and MBS are using the same spectrum. Therefore, If a MUE is nearby in the same area of FBSs, co-tier and cross-tier interferences will happen together[2].

Figure 1 displays the possible uplink interference in two-tier femtocell networks. This case is common in an office building scenario. The problem with this setting is that there might be a state of instability in the peer transmission levels and destructive interference in the network which affects the signal to noise transmission level of the users in the network. Hence, solving the power equilibrium problem in this kind of scenario is crucial. To address this problem, there are several approaches that have been proposed in the literature. One of these approaches is using a reinforcement learning technique called Q-learning.

Q learning (QL) is one of the Reinforcement learning (RL) algorithms. RL is a machine learning (ML) algorithm where an agent learns from a dynamic environment through trial-and-error interactions. In QL, an agent can find the optimal decision policies through interaction with the environment. These interactions process can be modeled as Markov Decision Process (MDP) [3]. There have been several papers applying QL to solve the interference problem over the past few years. In [4], Q-learning is used to solve the optimal downlink power allocation of the FBSs. The FBSs can select among a finite set of transmission power levels to mitigate interference to the MUEs.

In this project, we will attempt to mitigate or manage the degree of uplink interference in the network so that each agent (MUE and FUEs) can have an optimal signal to noise ratio. Similar to related work, we will be using Q-learning algorithm to understand the behaviour of the agents. The main reason we want to work in this project is that we have not seen any previous work attempts to solve the uplink interference using Q-learning; most of the existing literature tries to solve the downlink problem.

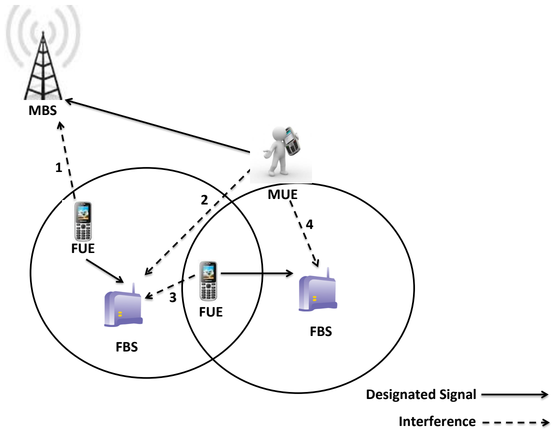

Figure 1: Illustration of the uplink interference in two-tiers femtocell networks. The solid arrows are the designated communication links. The dashed arrows are the uplink interferences to the base stations. Link 1,2,4 are cross-tier interferences and link 3 is co-tier interference.

References

[1] H. Saad, A. Mohamed, and T. El-Batt, *"Distributed cooperative Qlearning for power allocation in cognitive femtocell networks,"*in Proceedings of the IEEE 76th Vehicular Technology Conference, Sep. 2012.

[2] Y. Sun , R. P. Jover and X. Wang *"TUplink interference mitigation for OFDMA femtocell networks* , IEEE Trans. Wireless Commun., vol. 11, no. 2, pp.614 -625 2012

[3] Forum, Femto. *"A proximity-based Q-learning reward," function for femtocell networks"* in IEEE Vehicular Technology Conference, Sept. 2013

[4] A. Galindo-Serrano and L. Giupponi, *"Distributed q-learning for interference control in ofdma-based femtocell networks"*in Vehicular Technology Conference (VTC 2010-Spring).

Biweekly Time Schedule

1. **Feb 2nd – Feb 15th**
   - Study further on how to apply Q-learning to mitigate uplink interference in two-tier femtocel networks.
   - Learn how to implement Q-learning on MatLab, and construct the main function for future development.
2. **Feb 16th – Mar 1st**
   - Complete the Q-learning programming on MatLab. The main function should be able to simulate Q-learning process on MUEs and FUEs at the end of this period.
   - Decide how to use the program to generate figures for performance analysis with MUEs and FUEs.
3. **Mar 2nd – Mar 15th**
   - Study how the reward functions influence the SINR of the MUE and FUE .
   - Design the reward function and apply it to the Q-learning algorithm.
   - Generate some preliminary data for adjustments on the reward function.
4. **Mar 16th – Mar 29th**
   - Improve the reward function to get the expected result.
   - Explain and compare all test figures to illustrate the optimization process.
   - Conclude all findings and finish the paper.

Logbook: We are going to use Wiki on Connex as our logbook.