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Mobility Load Balancing - Concept and Importance

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***Abstract*: The main aim of this paper is to introduce to the concept of mobility load balancing (MLB) in cellular networks.It also discusses the different categories of load balancing algorithms that are used.**

Cellular networks are the source of communication and there is a requirement to ensure that this communication medium is undisturbed. To maintain the quality of service of these communication networks, there is a need for some algorithms/techniques that optimize the network without causing much operational cost to the service providers of the network. One such network optimization algorithm is "Mobility Load Balancing".

***Keywords*: Cell, MLB, Network Optimization, Handover (HO), Congestion, Quality of Service (QoS).**

1. Introduction

Cellular networks are the source of communication. In the recent decades, mobile communication has become more complex and expensive with the requirement of quality of service and efficiency [1]. Many algorithms have been proposed to reduce this operational cost of maintaining and monitoring the network performance. In the wireless cellular network, the load in different cells is often substantially uneven, and the load in different cells is time-varying due to user mobility [1]. To ensure there are no call-drop, call -blocking in the heavily loaded cells, there is a need of an algorithm that properly monitors and maintains the state of the network at its best. One such algorithm is "Mobility Load Balancing".

As the name indicates it is an algorithm that distributes the incoming load, (the incoming load to any cellular networks are the service requests in terms of voice, data or video content) across the network to ensure the performance of the network is not degraded.

Before jumping to the in-detail discussion on MLB, let us understand some basic concepts of cellular networks that are essential in understanding MLB concept.

1. A cell in cellular network terminology is the service coverage area of a particular Base Station (BS) [2].
2. A BS is the service providing entity of the cellular networks and it is fixed [2].
3. A Cell radii can vary from tens of meters in buildings, and hundreds of meters in cities, up to tens of kilometers in the countryside [2].
4. The users (cell phones/tablets/ laptops) that are getting services from a BS, through an operator are called 'User Equipments' (UE's).
5. Handover, normally called HO, is a procedure that a BS performs on a UE to transfer it from one cell to another.
6. When a cell is unable to service any more UE's, then that cell is said to be 'Congested'.
7. A congested cell is normally referred to as a 'Hot cell' and the lightly loaded neighbouring cells are called as 'Cool Cells' [2].

The organization of the paper is as follows: Section 2 presents the detailed concept of MLB and its importance in the current situation. Section 3 presents different algorithms / techniques that are used in solving the problem of congestion through MLB. Section 4 concludes the paper.

2. Mobility load balancing

As mentioned in Section I, a BS is a fixed entity. Whereas the UE is a mobile entity. The UE keeps moving from one cell to another with multiple HO's that will be happening in the background. This behaviour of an UE is expected. A cellular network is configured to handle this situation.

While on the move, an UE might encounter a hot spot. A hot spot is the area where the service requests are far more than the service providers (BS's) which lead to a situation of scarcity of resources and hence raising an issue of congestion. When many UE's start entering the same hot spot area, the situation worsens leading to call-drops, call-blocks and hence degrading the quality of service promised to the consumers. To handle this situation effectively, there is a need that the load on a cell is shared across the neighbors. This sharing of load is what is termed as "Mobility Load Balancing".

Let us discuss this sharing terminology more technically. The cell radii are determined by a parameter called as 'Cell Individual Offset (CIO)'. A raise in value of CIO indicates a raise in coverage of the cell and viceversa [3]. To adjust the load across the neighbors, the congested cell shall decrease its coverage area and the neighbors shall increase their coverage area. As a result, some of the UE's in the border, through the procedure of HO move from congested hot cell to neighbouring cool cell. Thus the problem of congestion is mitigated. Figure 1 indicates the CIO change in a hexagonal cell.

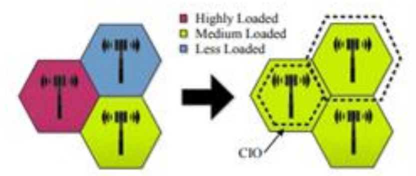

Fig. 1. Change in CIO Values based on load [3]

Any MLB algorithm is a two phase process.

1. Determining phase
2. Mitigation phase

The determining phase is one where the cell comes to a decision that it is heavily loaded and it cannot handle any more UE's. Th mitigation phase is the one that handles the congestion problem. We discussed the mitigation step already that happens through a change in CIO value.

Now let us consider the determining phase. Any decision is made with reference to particular standard. These standards are referred to as the thresholds in technical terms. This is the decision making phase and it requires some thresholds to look up and make the decision. A network admin through his/her past experiences and his/her observations comes up with these thresholds and they are the key control parameters that determine the occurrence of congestion in cell or not. When the values of certain parameters in the network crosses the set threshold, the cell makes its decision about its state and starts a mitigation phase if necessary.

Figure 2 describes this process of MLB in detail. Max_Load, CIO_Max, CIO_Step are the determining factors.

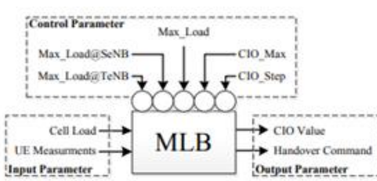

Fig. 2. MLB Working [3]

3. Review of works on MLB

In this section, various works done in the field of MLB are discussed. Some works present a different approach of the two phases discussed in section 2.

A. MLB through power budget tuning and power budget HO prioritization

This method deals with intra frequency HO in 2G cells [5]. This technique uses two different algorithms for two different phases that were mentioned as part of section 2.

It uses the power budget margin tuning algorithm to determine the thresholds.

Power budget determines the maximum allowed signal attenuation between the UE and the BS. It is a factor that indirectly affects the coverage of a cell [6]. This algorithm determines the threshold 'HO Margin PGBT' based on the cell attractiveness and a step function.

The second algorithm that mitigates the problem of congestion is the PGBT HO prioritization. This algorithm unlike earlier mentioned method (wherein a cell specific value is changed) it considers a logical equation that evaluates the AND of source cell and the PGBT criteria with the OR of target cell attractiveness that leads to a decision whether HO for that cell has to be performed or not.

The simulation of this algorithm has shown an improvement of 25% in the network performance without degrading network performance.

B. MLB through Fuzzy Logic Controller

This work under MLB deals with GERAN cellular network that implements a variation of MLB with Fuzzy Logic Controller (FLC). It makes use of Fuzzy Q-learning algorithm that is a type of reinforcement learning [7].

A fuzzy version of Q-Learning is used in this work because it allows treating continuous state and action spaces, to store the state-action values and to introduce a priori knowledge [7].

This method has two phases. Initialization phase, wherein the initial values of the congestion determining parameter, here call blocking ratio (CBR), are set by the network admin. The second phase is where the Q-learning algorithm outputs a change in terms of reward or punishment as a delta change to the HO margins. This method has shown significant reduction in call blocking ratio for congested cells and is proven to be cost effective [7].

C. MLB through Machine learning framework

This method makes use of machine learning in phase 1 of MLB. The cellular network considered for this work is 3G network.

Machine learning has proven to be an aid to decision making process. The algorithm implemented in this paper initially trains the decision making model with values such voice traffic, data traffic, throughput, power utilization and many other parameters. This trained model will then provide a threshold, in terms of power utilization and code utilization, that can be set as thresholds. Whenever a cell crosses the limit of set thresholds, a change in CIO value is performed.

The change in CIO value in this method is based on three other factors as mentioned in [7].

This method has given a 6% increase in average network throughput of highly loaded cells and 3% in all cells.

All the above mentioned methods are a variant in MLB algorithm. To summarize, one method is a straight forward implementation of MLB but with 2G specific cell parameters, other is reinforcement method with CBR as the determining factor and the last one is an application of machine learning in MLB.

4. Conclusion

MLB is a use case of cellular network optimization feature. The implementations of MLB has to be cost effective since the very main aim of MLB is to reduce the operational cost (OPEX) of the network.

Many researches are being carried out in this field to reduce the problem of congestion in cellular networks. This paper presented some of the variants of MLB by discussing the concepts and importance of MLB in current situations.

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