Cost-Based Approach to Access Selection and Vertical Handover Decision in Multi Access Networks

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Abstract. In multi access network environments, mobile stations may encounter multiple choices for selecting an access network. Carefully designed access selection schemes can provide not only mobile users with better services but also network operators with better resource utilizations. It is also envisioned that further improvements can be achieved by redistributing mobile stations from one access network to anther (i.e., vertical handovers). Such decisions should be made by following carefully designed, yet simple to implement, protocols. In this paper, we present a cost-based scheme for access selection and vertical handover decision algorithms. The proposed algorithm was implemented in a Java-based simulator called MANSim (Multiple Access Network Simulator) that we developed. Our simulation results show that during the congested periods, the network throughput is significantly improved with greatly reduced call drop rate.

Key words: Multi access networks, access selection, vertical handover, cost value, marginal cost function, network throughput, call drop

1 Introduction

Growing demands for ubiquitous coverage and emerging mobile wireless applications are leading to fundamental changes in the wireless networking paradigms. The wireless landscape consists of a large number of protocols and service providers, providing their services to a variety of users with different traffic characteristics and hardware capabilities. It is expected that new radio access technologies (RATs) will be deployed in the future, but most likely the existing RATs will not be completely replaced by new RATs [1]. Each RAT operates on a different spectrum band and occupies different bandwidth capacities. With different traffic types and arrival processes in different cells, the traffic load of each cell significantly varies, and the resource management should not be uniformly applied across the cells; rather, it should be done by considering various parameters specific to each cell and each RAT. The current research trends

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in wireless communications is to develop technologies that would allow network operators to provide mobile users with access to any network and Always Best Connected (ABC) services [2]. The next generation of wireless networks, commonly referred to as Beyond 3G (B3G) networks, is envisioned to support higher bandwidth requirements on fully digital, all IP based networks that use a common frequency band across all providers and regions. Most of the work in this effort [3, 4] are at the rather conceptual stage while some concentrate on performance gains using simulations or experiments in ad-hoc manners.

2 Access Selection and Vertical Handover Decision

Our proposed approach will be demonstrated using the operational policy discussed in this section. We begin with a description of the system model we consider. **System Model:** The network consists of multiple radio access technologies (RATs) and multi-mode mobile stations that can access to any RAT in the network. The following aspects of the network are considered in our work.

• The network consists of four types of RATs: CDMA1x, EvDO, WCDMA, and HSDPA.

• The CDMA1x and EvDO operate on different spectrum bands while the WCDMA and HSDPA share the same spectrum band.

• Two types of the WCDMA system exist. One is operating alone called WCDMA-alone system. The other is sharing its spectrum with HSDPA called WCDMA/HSDPA system, and a fixed amount of the total power is allocated for WCDMA and HSDPA to share.

• Voice traffic is served only by CDMA1x system or WCDMA-only system, or non-HSDPA part of the WCDMA/HSDPA system.

• Data traffic is served only by EvDO system or HSDPA part of the WCDMA/HSDPA system.

• Voice traffic has higher priority than data traffic. Hence, a new voice traffic may be admitted to a non-HSDPA part of a WCDMA/HSDPA cell by dropping or redirecting existing data traffic in its HSDPA part.

Operational Policy: The following operational policy rules are assumed when admitting new mobile stations generating voice or data traffic into the network or making existing stations handover to other cells of the same or different RATs.

1) The CDMA1x or WCDMA-alone cells have higher priority over WCDMA/HSDPA cells when voice traffic is concerned.

2) The EvDO cells have higher priority over WCDMA/HSDPA cells when data traffic is concerned.

3) Voice traffic has higher priority over data traffic in WCDMA/-HSDPA cells, i.e., a new voice traffic may be admitted to a WCDMA/HSDPA cell by dropping its existing data traffics.

Note that rule 3) is a commonly practiced operational policy in handling voice and data traffics in WCDMA/HSDPA systems. The rules 1) and 2) are then naturally established. From the network operator's perspectives, a clear goal is to maximize the network's overall throughput while minimizing call drops. In order to accommodate burst traffic randomly arriving in any arbitrary cells in an arbitrary time, the radio resource should be managed to balance traffic loads across the cells.

Marginal Cost Functions: We define a marginal cost function of each cell that computes its cost value, i.e., a virtual price, taking the current cell load and the cell capacity as input parameters. Using these cost values, a new mobile station is admitted to a cell with the lowest cost value among all *accessible* cells (i.e., candidate cells to which the mobile station has strong enough signal strength). The cost value of each cell is periodically updated, and existing mobile stations may be forced to perform handovers to other cells of the same or different RATs. A handover to a cell with a different RAT is called a *vertical handover*.

For a cell v serving voice calls, its load x_v (or capacity c_v) is defined as the number of voice calls currently served (or the maximum number of voice calls that can be served) by v. For a cell d serving data traffic, its load x_d (or capacity c_d) is defined as the total amount of bandwidth provided by d to mobile stations currently in the cell (or the maximum bandwidth that d can provide). For a WCDMA/HSDPA cell that serve both voice and data traffics, the voice capacity is defined as the maximum number of voice calls that can be served using all the power allocated to the system, and the capacity of data traffic is defined as the maximum amount of bandwidth that the system can provide using all the power allocated to it.

Let α be a real number in $0 < \alpha < 1$. A marginal cost function for each cell (voice or data) with a certain RAT is then defined as follows.

• For CDMA1x, $f_{voice}(x_v)$ is defined as $(x_v/c_v)^2$ if $x_v/c_v < \alpha$ and $(x_v/c_v)^2 + 1$ otherwise.

• For WCDMA-alone, $f_{voice}(x_v)$ is defined as $(x_v/c_v)^2$ if $x_v/c_v < \alpha$ and $(x_v/c_v)^2+1$ otherwise.

• For EvDO, $f_{data}(x_d) = (x_d/c_d)^2 + 1$.

• For WCDMA/HSDPA, $f_{data}(x_d) = (x_d/c_d)^2/(1 - x_v/c_v)^2 + 1$ and $f_{voice}(x_v) = (x_v/c_v)^2 + 1$.

The actual value of α should be determined by considering many network parameters such as traffic arrival rate, burstness, time interval on which the cost values are updated and vertical handovers are performed, and the acceptable voice call drop rate set by the operator.

Computing the optimal value of α requires precise network modeling and in-depth analysis, and we simply assume $\alpha = 0.9$ in our simulations.

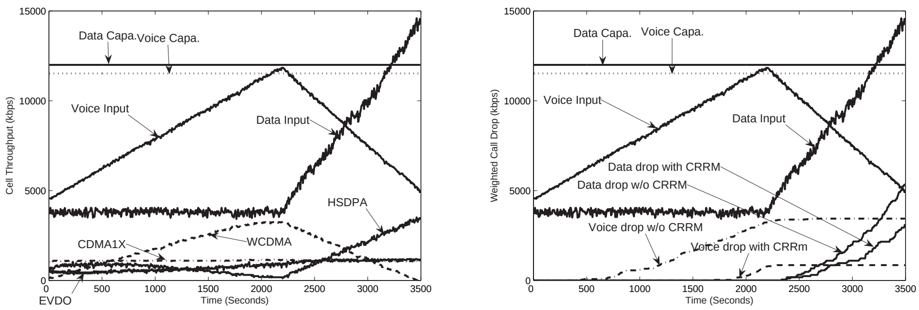
Each base station periodically updates its cost values and reports them to the central resource manager CRRM. When a connection request arrives from a mobile station, the CRRM selects a base station with the minimum cost value, and direct the mobile station to connect to the selected base station. For vertical handover, either network make decision for each mobile station, or each mobile station make decision according to the cost values broadcasted by surrounding base stations.

3 Performance Analysis

The performance of our CRRM is analyzed using MANSim that we developed. The network consists of the following cells: four CDMA1x cells, four EvDO cells, and two

WCDMA/HSDPA. (The cell with WCDMA-alone is not included.) The CDMA1x cells and EvDO cells both cover the entire simulation area. The WCDMA/HSDPA cells each overlapping with at least one other WCDMA/HSDPA cell are deployed in a certain simulation area. The cell capacity of each cell type is defined as follows: 80 voice traffics (equivalently about 1.15Mbps) can be accommodated in a single CDMA1x cell; 1.2Mbps in an EvDO cell; 240 voice traffics (equivalently, about 3.45Mbps) in a WCDMA cell when no HSDPA data traffic is served; and 3.6Mbps in a HSDPA cell when no voice traffic is served. Each mobile station generates one of the five service types of traffic that are WAP, VOD Streaming, VOD Downloading, Video Conferencing and Voice. Because of the space limit, the simulation results for network-based handover decision are shown only.

Figure 1 (a) shows the cell throughput in each RAT, and (b) shows the weighted call drop with and without our CRRM applied in which the weighted call drop denotes the total amount bandwidth requested by the mobiles stations dropped from the network.



(a) Throughput (b) Weighted call drop

Fig. 1.

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