Chapter 4

Development of Simulation Model
Chapter Overview

This chapter informs about how simulation approach is most commonly used handoff evaluation mechanism. This topic not only discusses about the basic components of simulation model but also describes simulation framework.

4.1 Introduction

Different radio access technologies present distinct characteristics in terms of mobility management, security support, and QoS provisioning. To achieve seamless mobility and end-to-end QoS guarantee for the users, these issues should be carefully addressed while developing interworking schemes. The interworking between different wireless access networks has been a hot research topic in recent years. Most of the researchers mainly focus on interworking between WLAN and 3G cellular networks such as UMTS and CDMA2000, which are the two major standards for 3G mobile/cellular networks specified by the 3rd generation partnership projects, i.e., 3GPP and 3GPP2. There are two main ways of integrating the WLAN and 3G cellular networks, defined as tightly-coupled interworking and loosely-coupled interworking [100].

In tightly-coupled interworking, the WLAN appears to the 3G wireless core network as one of the 3G wireless radio access network. The WLAN emulates functions that are natively available in the cellular radio access network [101]. The corresponding 3G protocols such as mobility management and authentication need to be implemented in the WLAN network cards and the 802.11 gateway. The WLAN data traffic goes through the 3G core network before reaching the Internet. Thus the different networks share the same authentication, signaling, transport and billing infrastructures. However, there are three disadvantages of tightly-coupled interworking: (1) both the 802.11 and 3G cellular network must be owned by the same operator due to the exposed 3G core interfaces to the WLAN; (2) a large volume of traffic from the WLAN to the 3G core network will lead to capacity problem; (3) the WLAN device should be modified in hardware and software. On the other hand, in loosely-coupled interworking, the WLAN connects to the Internet directly. The data paths are completely separated between WLAN and 3G wireless networks [102].
The authentication, billing and mobility management in the two domains can be implemented by different mechanism and protocols. Therefore, the loosely-coupled interworking has several advantages in terms of minimal requirements to modify current WLAN standards, the flexibility and independence of implementing individually different mechanisms with each network, widespread coverage with roaming agreements of different service providers. However the loosely-coupled interworking may have high handoff latency due to a relatively long path which the mobility signaling may traverse. The hybrid-coupled interworking which is the combination of the tightly-coupled and loosely-coupled interworking is proposed. In the hybrid-coupled interworking scheme, traffic paths are differentiated according to the type of the traffic. For the real-time traffic, tightly-coupled network architecture is chosen, and for the non-real time and bulky traffic, loosely-coupled network architecture is chosen. It may support quality of service of real-time traffic and service continuity during vertical handover for WLAN users. However the drawback of tightly-coupled and loosely-coupled interworking still exist and the implementation of this architecture is complicated.

The simulation approach is the most commonly used handoff evaluation mechanism. Several simulation models suitable for evaluation of different types of handoff algorithms under different deployment scenarios have been proposed and used in the literature. Usually, the analytical studies of handoff algorithms consider handoff between two BSs. However, the simulation approach allows incorporation of many features of a cellular system and a cellular environment into the evaluation framework. This approach provides a common testbed for comparison of different handoff algorithms. This approach also provides insight into the behavior of the system. Despite being cost-effective, measurements made at the BSs for handoff performance evaluation are not very useful since they cannot characterize small area performance.

Field measurements are useful, but they are time-consuming and expensive. Software simulation provides fast, easy, and cost-effective evaluation. Simulation models usually consist of one or more of the following components: cell model, propagation model, traffic model, and mobility model. These components are described first, and specific simulation models are discussed next. Figure 4.1 shows the components of a typical simulation model [103].
4.2 Basic Components of Simulation Models

4.2.1 Cell Model:

Cell planning strategies differ in microcells and macrocells, which can be considered as circles while considering handoff between two BSs in a neighborhood of two, three, or four cells. A macrocellular system is sometimes simulated as a 49-cell toroidal system that has seven-cell clusters with uniformly distributed traffic. Few references discuss microcell cell planning in Manhattan environment. The city is modeled as a chessboard with squares representing blocks and streets being located between the blocks.

4.2.2 Propagation Model:

The performance of wireless communication systems depends on the mobile radio channel significantly. The radio wave propagates through the mobile radio channel through different mechanisms such as reflection, diffraction, and scattering. Propagation models predict the average signal strength and its variability at a given distance from the transmitter. Different propagation models exist for outdoor and indoor propagation and for different types of environments (such as urban or rural). Macrocells and microcells have different propagation characteristics. The main features of the models used here have been experimentally validated in the literature. The propagation model usually consists of a path loss model, a large-scale fading model, and a small-scale fading model.
i. Path Loss Model

In macrocells, the path loss model is used for several aspects of cell planning such as BS placement, cell sizing, and frequency reuse. The path loss models of Hata and Okumura can be used for macrocells. Microcells have different models for LOS and NLOS propagation.

For LOS propagation, two frequently used models are a flat earth model and a two slope model. In the flat-earth model, one direct ray and another reflected ray (with 180 degree phase shift) contribute to the total received E-field.

The path loss increases with a certain slope to a threshold distance (called a breakpoint) and then increases with a higher slope. In reality, wave propagation in microcells is complicated and consists of reflections and diffractions in addition to free space propagation. However, the main features of path loss can still be described by empirical models. For certain parameter settings, the two slope path loss model approaches the flat-earth model.

For NLOS propagation, LOS propagation is assumed to the street corner. After the corner, propagation path loss is calculated by placing an imaginary transmitter at the corner with the transmit power equaled to the power received at the corner from the LOS BS [104].

ii. Large-Scale Fading Model:

The distribution of the large scale fading component is close to a log-normal distribution for a majority of LOS and NLOS streets with different standard deviations. The distribution is actually a truncated log normally distributed variation. In simulations, the variation should not be greater than $\pm 3\sigma$. For the measurements obtained in standard reference, the average value of $\sigma$ was found to be 4 dB for LOS streets and 3.5 dB for NLOS streets [105].

Some references proposed an exponential autocorrelation model for shadow fading in mobile radio channels. The results show that the model fit is good for moderate and large cells; the predictions are less accurate for microcells due to multipath.
iii. Small-Scale Fading Model:

Small-scale (or short term) fading is usually modeled as a Rician distribution where parameter K (Rice factor) varies with distance. When K=0, the variation is Rayleigh fading. Another suggestion is a small scale fading model in terms of polynomials based on the Rician distribution. Small-scale fading is neglected since it gets averaged out due to short correlation distance relative to that of shadow fading.

4.2.3 Traffic Model:

Traffic can be assumed to be uniform for macrocells. However, road structures need to be considered for microcells, and traffic can be allowed only along the streets. The new call arrival process is modeled as an independent Poisson process with a certain mean arrival rate [106]. The new call durations are independent exponential random variables with a certain mean. We have evaluated the system performance for different class of traffic that is voice, data, and multimedia. Further analysis has been carried out for the self-similar traffic [107], [108].

4.2.4 Mobility model:

The MSs have different velocities following a truncated Gaussian distribution. The MS velocity is typically assumed to be constant throughout the call.

4.3 Discrete Event Simulation

In order to check the correction of our analytical model and closed formula for system performance, a disserted-event simulation environment has been developed and established. Disserted-event system change state at discrete points in time, as opposed to continuous systems, which change state over time.

In modeling our handoff system, we need to describe its dynamics composition, the way it accomplishes the handoff procedure. Three entities – activities, processes, and events – are the constructs used to describe the dynamic behavior of discrete handoff system. An activity is the smallest unit of work in our view of system. A process is a logically related set of activities. A process may, in turn, be viewed as an activity of a
higher-level process. An event is a change of state of system entity or time. This change of state results from the action of an activity. The initiation of activities is triggered by events. Our system is viewed dynamically as a collection of interacting processes, with the interactions controlled and coordinated by the occurrence of events. Especially, this process view is a hierarchical one; system is described at a given level of abstraction by a set of process descriptions, each specifying the activities of that process, together with those of the previous level, form the expanded description of the system.

4.4 Simulation Model

4.4.1. Simulation framework:

The simulation model is designed employing a top-down approach using MATLAB. The hierarchical structure of network scenarios, users, and processes are provided as comprehensive developmental environment to model the network. The Discrete Event Simulation method is modeled for all networks under consideration. Simulation model that is made for analysis is as follows.

The simulated system consists of 25 cells each of which has four neighboring cells as shown in figure 4.1.

It is assumed that the top cell (Cell 21, 22, 23, 24 and 25) and the bottom cells (Cell 1, 2, 3, 4 and 5) are connected. That is if a user comes out of 21 from top, he will come in to cell 1. Analogously, it is assumed that the cells (cell 1, 6, 11, 16 and 21) and right cells (cell 5, 10, 15, 20 and 25) are connected too.

Assume the base station of each cell is at the center of square. The handoff threshold can be set at any distance between cell-center to receive-threshold. The area between handoff-threshold and receive-threshold is called handoff area (shaded area of figure 4.2)
The user movement and distribution within the cell pattern is described as follows. When a new call request is generated, the location of the mobile users is random variable, and moving direction is chosen from uniform distribution on the interval as shown below.

<table>
<thead>
<tr>
<th>Random Number (0-1)</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.25</td>
<td>Target cell is North cell</td>
</tr>
<tr>
<td>0.25-0.5</td>
<td>Target cell is East cell</td>
</tr>
<tr>
<td>0.5-0.75</td>
<td>Target cell is South cell</td>
</tr>
<tr>
<td>0.75-1</td>
<td>Target cell is West cell</td>
</tr>
</tbody>
</table>

The moving speed is uniformly distributed between 8 and 25 m/sec. The user's location and RSS is monitored at every second.
4.4.2 Radio Propagation Model

Radio propagation is influenced by the path loss depending on the distance, shadowing, and multipath fading. The relationship between the transmitted power and received power can be expressed as

\[ P(r) = 10^{\xi/10} \cdot 10^{-\alpha} \cdot P_0 \]  

(4.1)

where, \( P(r) \) is the received power; \( P_0 \) is the transmitted power, \( r \) is the distance from the base station to mobile, \( \xi \) in decibels has a normal distribution with zero mean.

Following assumptions are made for simulation

1. Each cell has \( C=30 \) channels.
2. Cell radius = 2000 m
3. Arrival of new calls initiating in each cell forms a Poisson’s process with rate \( \lambda \).
4. Each call requires only one channel for service [109].

Initially call request is generated in the cell, once a new call is admitted into the network, lifetime of this call is selected according to its distribution and then total number of new calls is estimated [110]. If channels are available new call is accepted otherwise it is blocked. Once the call is accepted the parameters of call are updated and signal strength is checked, if signal strength is less than handoff threshold, at the same time if channel is available, handoff request is accepted otherwise it is blocked. Thus new blocking probability and handoff blocking probability is evaluated [111].
Define and initialize system parameter

Generate new call request to cell

Channel available?

Accept the new call

Update the Parameter of the Call

Check the Location and RSS

RSS < Handoff Threshold

Handoff Request to target cell

Accept Handoff Call

Is Channel available?

Block Handoff Call

Figure 4.4: Generic Flow Chart for Simulation
4.5 Concluding Remarks

In this chapter we have discussed the simulation outline and designed simulation model for the research undertaken. The flow chart indicated is generic one. In next chapters we have added only case specific condition for the performance evaluation for the algorithm in consideration.