CHAPTER IV

SIMULATION MODEL

4.1 Overview of the Simulation Model

In this chapter, we will describe the simulation model of Mobile IP, Paging Mobile IP, Paging Mobile IP Post Registration, Paging Mobile IP Regional Registration, Proposed Method, and Proposed Method with Link Layer Movement Detection. Simulation environment is built using Borland Delphi 7 programming language. This programming language is an object oriented programming language (OOP) so that we can create the simulation environment that resembles the real network implementation. Our simulation is based on discrete time simulation in which every event in the simulation happens in the sequence of time. We use the source codes that are used in the work of Reference [5] for Mobile IP, Paging Mobile IP, and Paging Mobile IP Post Registration. We do not modify these source codes and only adjust some parameters in the program interface to check the performance of every protocol. We then use and modify these source codes to develop the simulation environment of Paging Mobile IP Regional Registration, Proposed Method, and Proposed Method with Link Layer Movement Detection.

The network topology should be designed before developing the simulation environment. The network consists of several entities such as Home Agent (HA), Gateway Foreign Agent (GFA), Foreign Agent (FA), and Mobile Node (MN). GFA is replaced by an ordinary router in Mobile IP, Paging Mobile IP, and Paging Mobile IP Post Registration. Internet is assumed to be the separator between the home network and the visited network. There are one MN, one HA, and one GFA/router in the simulation environment. Two or more FAs construct a paging area. Every FA is associated to a cell with an overlapping cell scenario and equipped with antenna and wireless device. The MN is designed to move in straight direction and assumed to use the same channel and frequency with FAs thus the MN can communicate with both FA in the case of handoff. We assume that the system supports security, paging, and multicasting. Every entity has its own functionalities and tasks which depend on the standard of each protocol. The details of every entity will be explained later. The HA, internet, GFA/router, and FAs are connected each other by means of wired connection. On the other hand, the FA and MN are assumed to be connected via wireless communication. The links and entities are assumed to have a specified processing delay. Figure 4.1 shows the hierarchical topology of the simulation model.

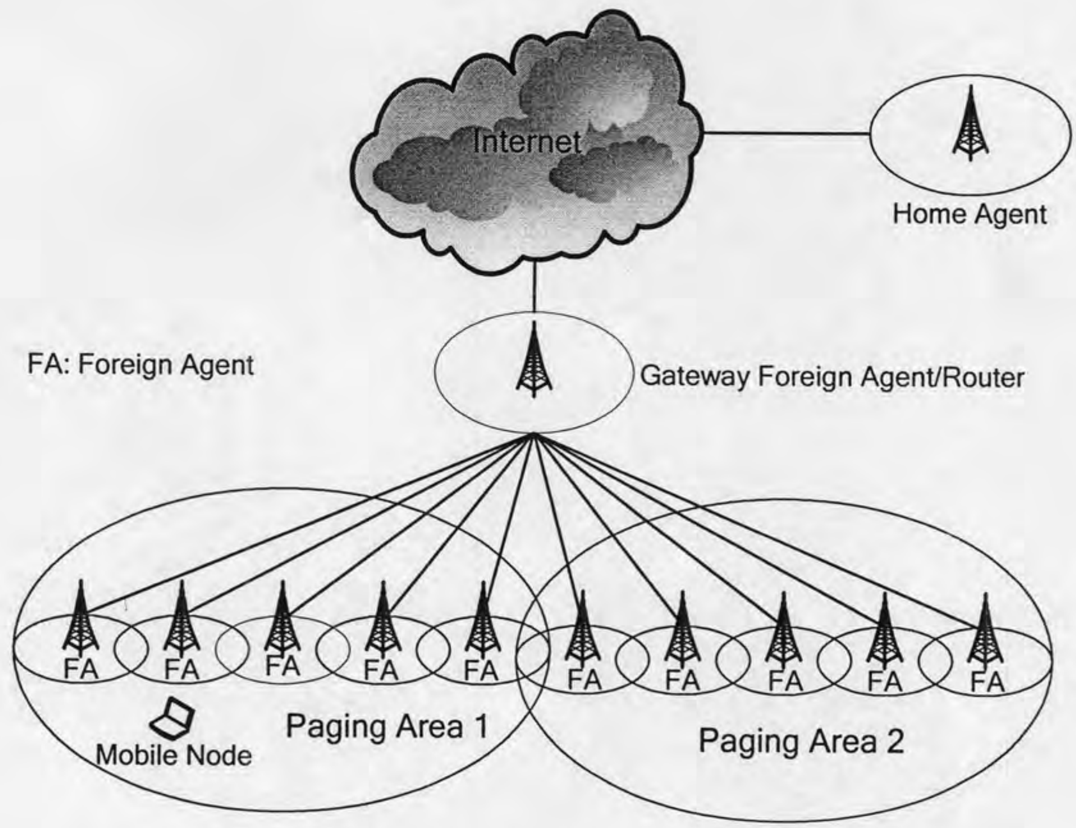

Figure 4.1 Hierarchical topology of the simulation model.

In general, the simulation simulates the events that take place during the movement of an MN while the HA as the source of data packets is sending packets to that MN. The main focus is the handoff process when an active MN moves from one cell to another. There are two main parts of the simulation: visual interface and source code of the program. Visual interface makes the simulation is easy to be conducted. Visual interface is used both to give the input to the program and take the results of the simulation. In this research, the visual interface is designed for several purposes as follows. First, visual interface is used to construct the network model. Network parameters such as the radius of the cell, overlap between two cells, link delay, processing delay in each entity, signaling messages and packet size, period of Agent Advertisement message and data packet, link transmission rate, buffer size in GFA or FA, active timer period, and the lifetime of Agent Advertisement message are defined through the user interface. Others parameters that are varied to check the performance of the system such as the MN's speed, number of cells in one paging area, active time percentage, number of hops in core network, and simulation duration are also entered at the visual interface at the beginning of the simulation. All parameters are used as the input for the source code during the simulation. Second, the visual interface is utilized to get the results of the simulation. The output of the simulation can be monitored through the visual interface such as the wired and wireless data and signaling hop, position of the MN, number of lost packets, and handoff time. As the example, the visual interface of the first proposed method is shown in Figure 4.2.

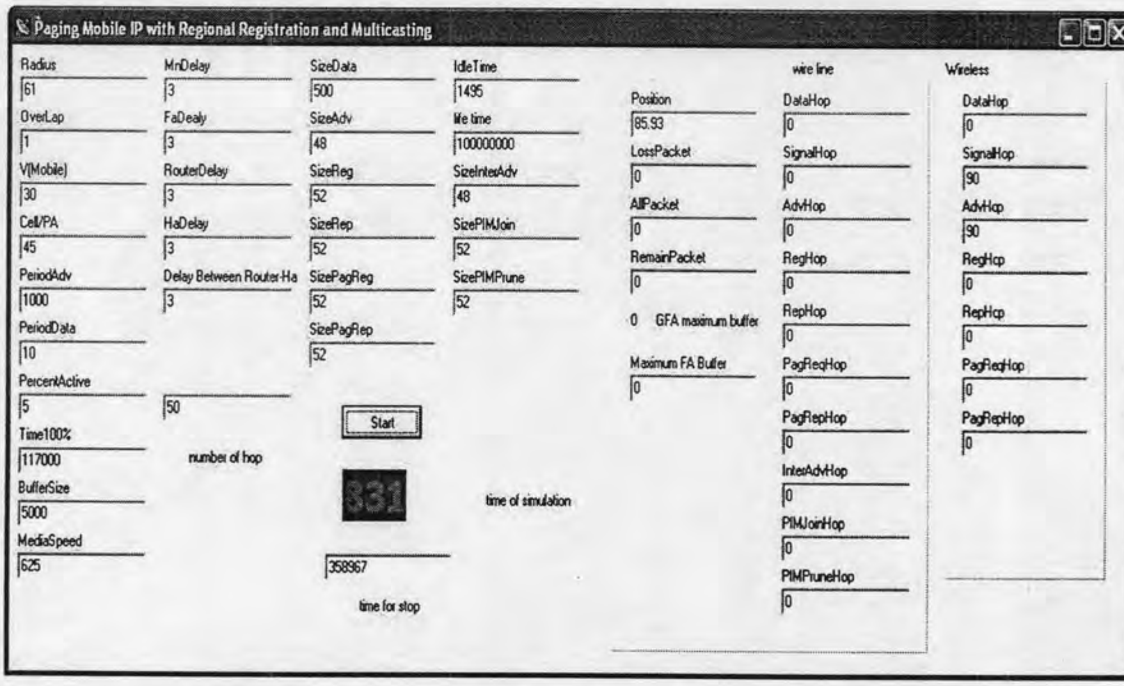

Figure 4.2 Visual interface of the first proposed method.

The main part of the simulation is the program source code. This part determines the processes in the simulation. The source code simulates the designed communication scenario in sequence of discrete time in every protocol. The entities in the communication such as FA, GFA and MN and the signaling messages such as Agent Advertisement, Paging Request and Regional Registration Reply messages are constructed based on class, record and procedure. These classes, records, and procedures work together in the program to build the specified protocol. In the rest of this chapter, the simulation model of every protocol will be described with the simulation scenario in the program source code as the focus of discussion.

4.2 Simulation Model of Mobile IP

In the simulation of Mobile IP, the most important part is the handoff process. The MN will register to the HA every time it detects that it has moved to new cell.

The movement detection to start the registration process in Mobile IP is completely managed at Network Layer. Eager Cell Switching algorithm is used for movement detection in the simulation. Here, the MN monitors and compares the network identifier that the MN receives from the Agent Advertisement message sent periodically every 1 second by each FA. When the MN finds that the received Agent Advertisement is still from the same FA it has registered before, it does nothing. Otherwise, if the MN detects a new Agent Advertisement message with different network identifier from another FA, the MN decides that the handoff has happened. The MN then starts the registration process to the HA through the new FA.

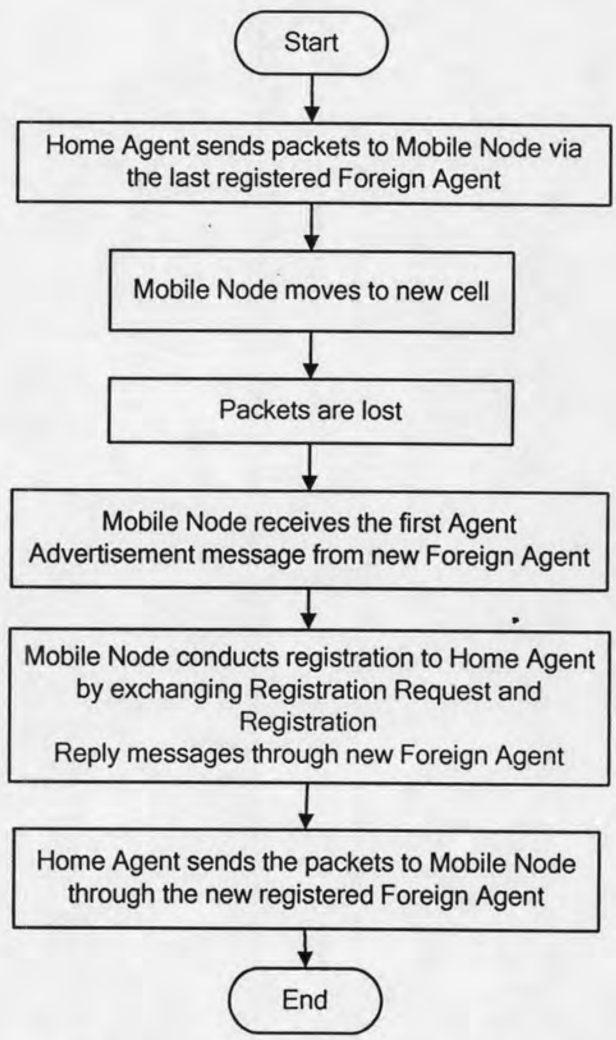

Figure 4.3 Flowchart of Mobile IP when the Mobile Node moves to new cell while receiving packets from Home Agent.

The MN sends Registration Request message to the new FA when the MN receives the Agent Advertisement message from that FA for the first time. After recording the MN's information and adding its own address as the Care-of Address, the FA forwards the Registration Request message to the HA. HA then records the

CoA of the MN from that message. This CoA will be useful for forwarding of data packets to the MN. HA later sends Registration Reply message to the FA. The FA then passes on this message to the MN. The MN finally records the information of the new FA and can receive data packets from the HA via this FA. Serious problem in Mobile IP happens when the MN moves to the new cell while it is receiving packets through the previous FA. During this period of time, when the MN has left the previous FA and has not yet conducted registration to the HA via the new FA, the data packets are still sent to the previous FA by the HA. As the result, the packets are lost until the MN has finished the registration process to the HA at the new FA. Figure 4.3 shows the flowchart of Mobile IP when the HA sends packets to the MN and during the transmission of the packets the MN moves to new cell.

4.3 Simulation Model of Paging Mobile IP

There are two main processes in the simulation of Paging Mobile IP which are registration and paging. The registration process takes place when an active MN moves to new cell, when an idle MN roams to new paging area, and when registered FA pages the MN that has moved to new cell. The registration process is used by the HA to know the location of the MN. It is useful when the HA wants to send packets to the MN. The simulation of an active MN is exactly the same as the MN in Mobile IP as described in the previous section. When active, the MN always registers to the HA through the new FA when it moves to new cell. An idle MN also registers to far away HA when it moves to new paging area. Here, the MN checks the paging area ID within the Agent Advertisement message sent periodically by every FA. If an idle MN registers with this reason, the only difference with Mobile IP is that the MN changes its state to be active after it receives Registration Reply from the HA via the present FA. The MN will be active for a period of time which is defined in the program interface. The MN then will return to idle state after that active timer expires.

The HA begins to send data packets periodically to the idle MN when the defined active time is starting. The HA sends the packets to the last registered FA in its record. The time taken of each packet to arrive at the registered FA depends on the delay in each entity, link delay, and link speed. When the FA receives the packet from the HA, it checks the state of the MN. If the MN is active in its record, the FA forwards that packet to the MN. If the FA receives the first packet and the MN is idle, the registered FA buffers incoming packets and starts paging process by sending Paging Request messages. The registered FA broadcasts Paging Request message in its coverage area and transmits Paging Request messages to all FAs that reside in the same paging area. The registered FA uses unicast transmission to send those messages through router. Every other FA in the same paging area then also broadcasts Paging Request message in its own area to search for the MN.

The MN verifies the FA that transmits Paging Request message when it receives that message. When it finds that the sending FA is still the same as the FA before the MN changed its state to be idle, the MN concludes that it has not moved to another cell. The MN then changes its state to be active and sends Paging Reply message to the FA. The FA then forwards any buffered and incoming packets to the MN. In contrast, once the idle MN finds that it has moved to new cell, the MN registers to the HA by exchanging Registration Request and Registration Reply messages via the new FA. After receiving the Registration Reply message, the MN records the new FA, changes its state to be active, and sends Paging Reply message to the new FA. The new FA then forwards the Paging Reply message to the paging FA that initiates paging through router. When paging FA receives this message, it starts to forward the buffered packets to the MN through the new FA periodically. Receiving packets from paging FA, the new FA forwards these packets to MN. In addition, after the MN has finished the registration to the HA via the new FA, the MN receives the packets from the HA through the new FA. Here, the HA changes the route of the packets from paging FA to the new FA. Figure 4.4 shows the flowchart when the HA sends packets to the MN in Paging Mobile IP.

4.4 Simulation Model of Paging Mobile IP Post Registration

There are three main processes in Paging Mobile IP Post Registration simulation. These processes are when the MN is moving in idle state, when the MN is moving in active state, and when there is packet destined for the MN. The idle MN only conducts Network Layer registration to the HA through the new FA when it enters the new paging area. This is the same as basic Paging Mobile IP, in which the MN monitors the paging area identifier within Agent Advertisement message sent periodically by every FA. When the MN is moving in the active state from one cell to another, the system applies Post Registration scheme. The active MN checks the normal Link Layer beacon which is sent periodically every 100 ms by each FA. MN re-associates with the present FA every time it receives that beacon. When the active MN leaves the previous FA and detects that it receives Link Layer beacon from new FA, it associates with the new FA by exchanging Association Request and Association Response messages.

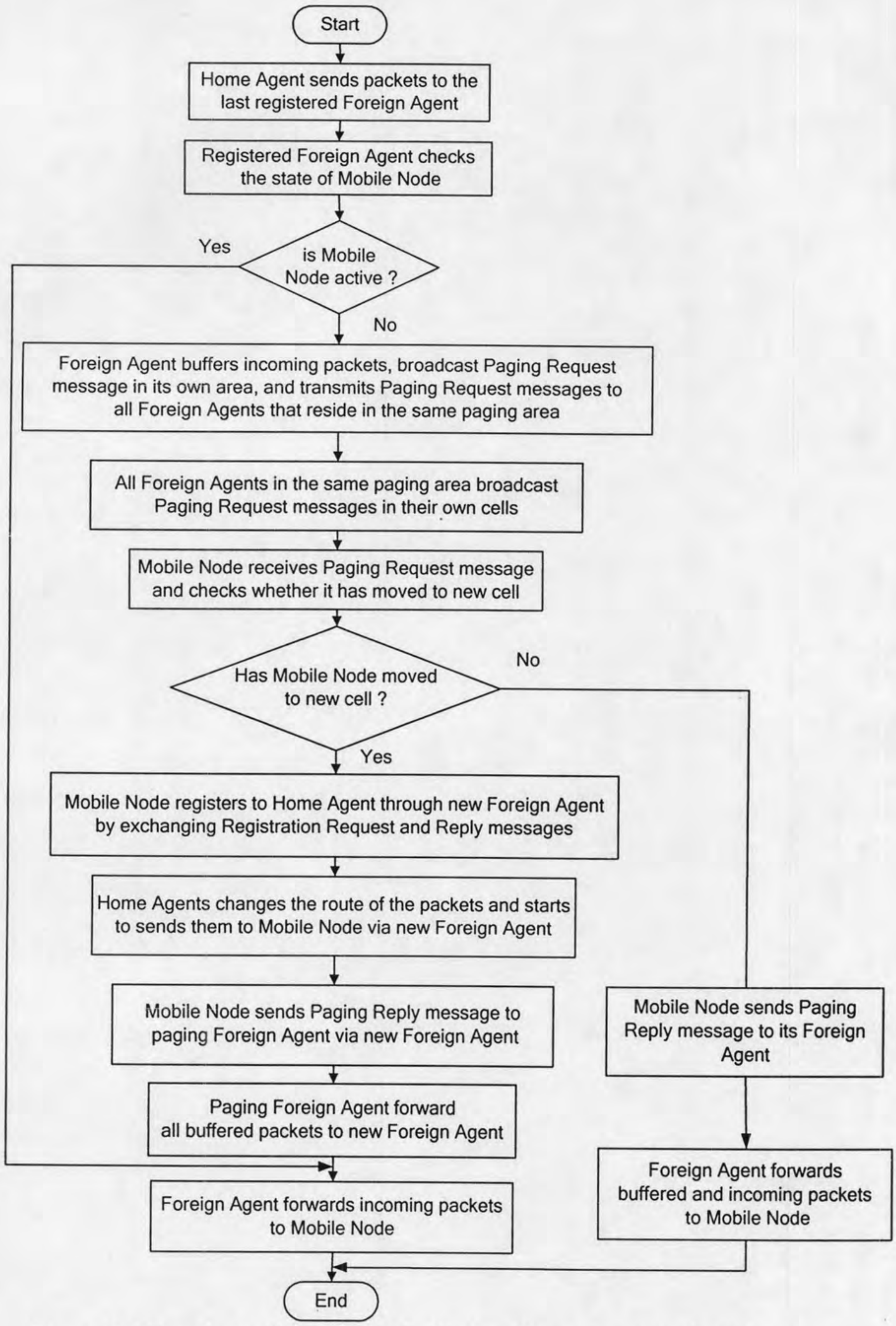

Figure 4.4 Flowchart of Paging Mobile IP when Home Agent sends packets to Mobile Node.

Association Request message triggers the new FA to send Handoff Request message to previous FA. Once receiving Handoff Request, the previous FA replies with Handoff Reply message. At this point, the Bi-Directional Edge Tunnel among the previous FA, router, and new FA has been constructed. Therefore, the previous FA can forward all incoming packets through the Bi-Directional Edge Tunnel to the new FA. The new FA then forwards the packets to the MN. Sometime in the future, the MN conducts Network Layer registration after the MN receives Agent Advertisement message. The MN exchanges Registration Request and Registration Reply with the HA through the new FA. Receiving the Registration Reply message, the FA and MN reset the MN's active state in their record. After Network Layer registration is completed, the HA deletes the previous FA from its record and completely sends the packets to the MN via the new FA. Figure 4.5 shows the flowchart of Paging Mobile IP Post Registration when an active MN moves from one cell to another.

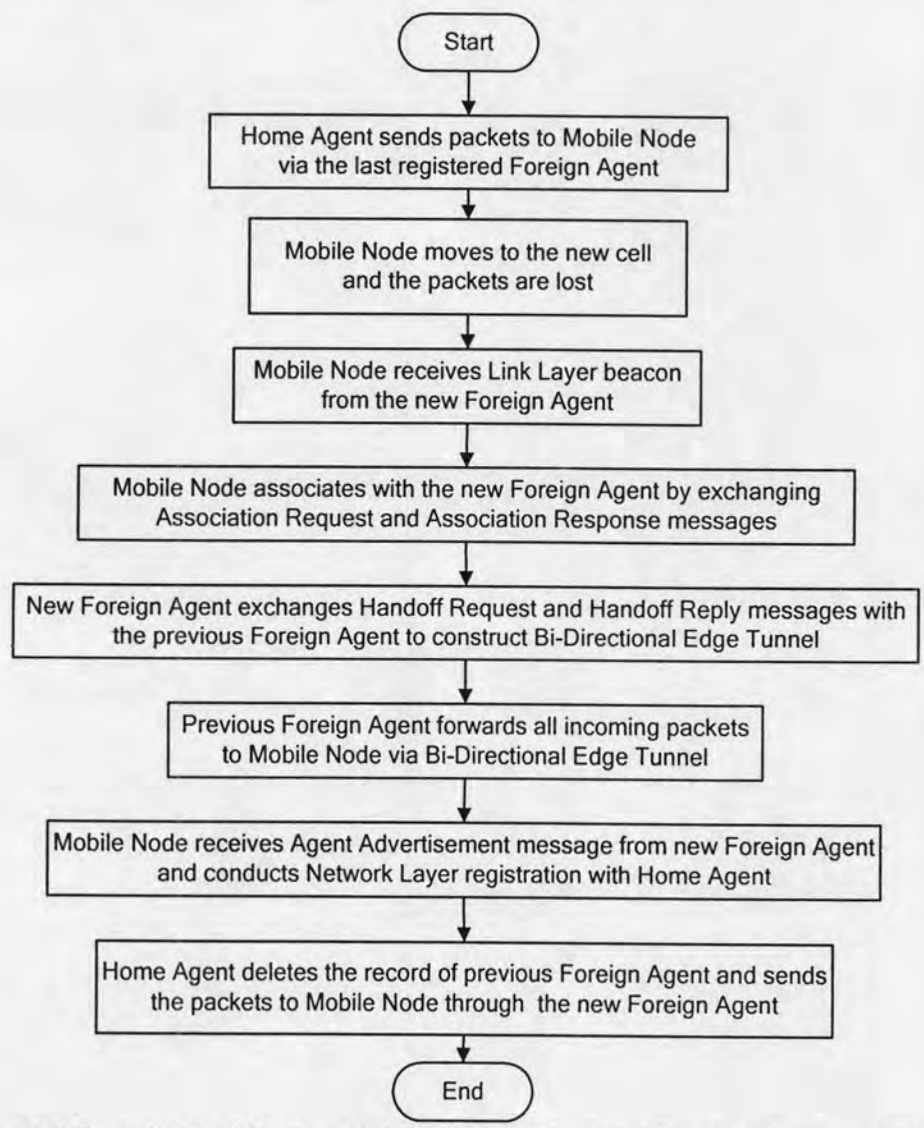

Figure 4.5 Flowchart of Paging Mobile IP Post Registration when an active Mobile Node moves from one cell to another.

The HA first sends packets to the last registered FA when there are packets for the MN. That FA then checks the record for the MN. If the MN is active, the registered FA forwards the packets to the MN. The FA and MN reset the active timer every time they receive the packet. If the MN is in the idle state, the registered FA buffers all incoming packets and conducts paging process. That FA then broadcasts Link Layer beacon in its coverage area and transmits Paging Request messages to all FAs that exist in the same paging area. After receiving Paging Request messages, all these FAs also broadcast the Link Layer beacon in their own area to look for the MN. Here, Link Layer beacon is not broadcast periodically. Once receiving the Link Layer beacon, the MN associates with its present FA by exchanging Association Request and Association Response messages.

If the present FA is the FA that initiates paging, that FA forwards all buffered and incoming packets to the MN. If the present FA is different from paging FA, the present FA sends Handoff Request message to paging FA. Paging FA replies Handoff Request message with Handoff Reply message. Receiving Handoff Request message, paging FA starts to forward all packets in its buffer and also all incoming packets from the HA to the present FA via the router. The present FA then passes on all incoming packets to the MN. Sometime in the future, the MN will receive Agent Advertisement message from the present FA. The MN then conducts Network Layer registration to the HA by exchanging Registration Request and Registration Reply messages. By using the information in the Registration Request message, the HA updates the record of the MN and changes the route of the data packets. HA does not send the packets to the last registered FA anymore but to the present FA. The Bi-Directional Edge Tunnel also disappears after the Network Layer registration has finished. The flowchart when the HA sends packets to the MN in Paging Mobile IP Post Registration is shown in Figure 4.6.

4.5 Simulation Model of Paging Mobile IP Regional Registration

In the simulation of Paging Mobile IP Regional Registration, Gateway Foreign Agent (GFA) class is introduced. Registration Request and Registration Reply classes in the previous simulation models are modified to be Regional Registration Request and Regional Registration Reply messages classes. The idle MN only registers when it moves to new paging area. Unlike the previous protocols, in which the MN conducts home registration to the HA, the MN here only conducts regional registration with the GFA by exchanging Regional Registration Request and Regional Registration Reply messages through the new FA. If an active MN moves from one cell to another, it acts like the MN in Mobile IP except it only conducts regional registration to GFA.

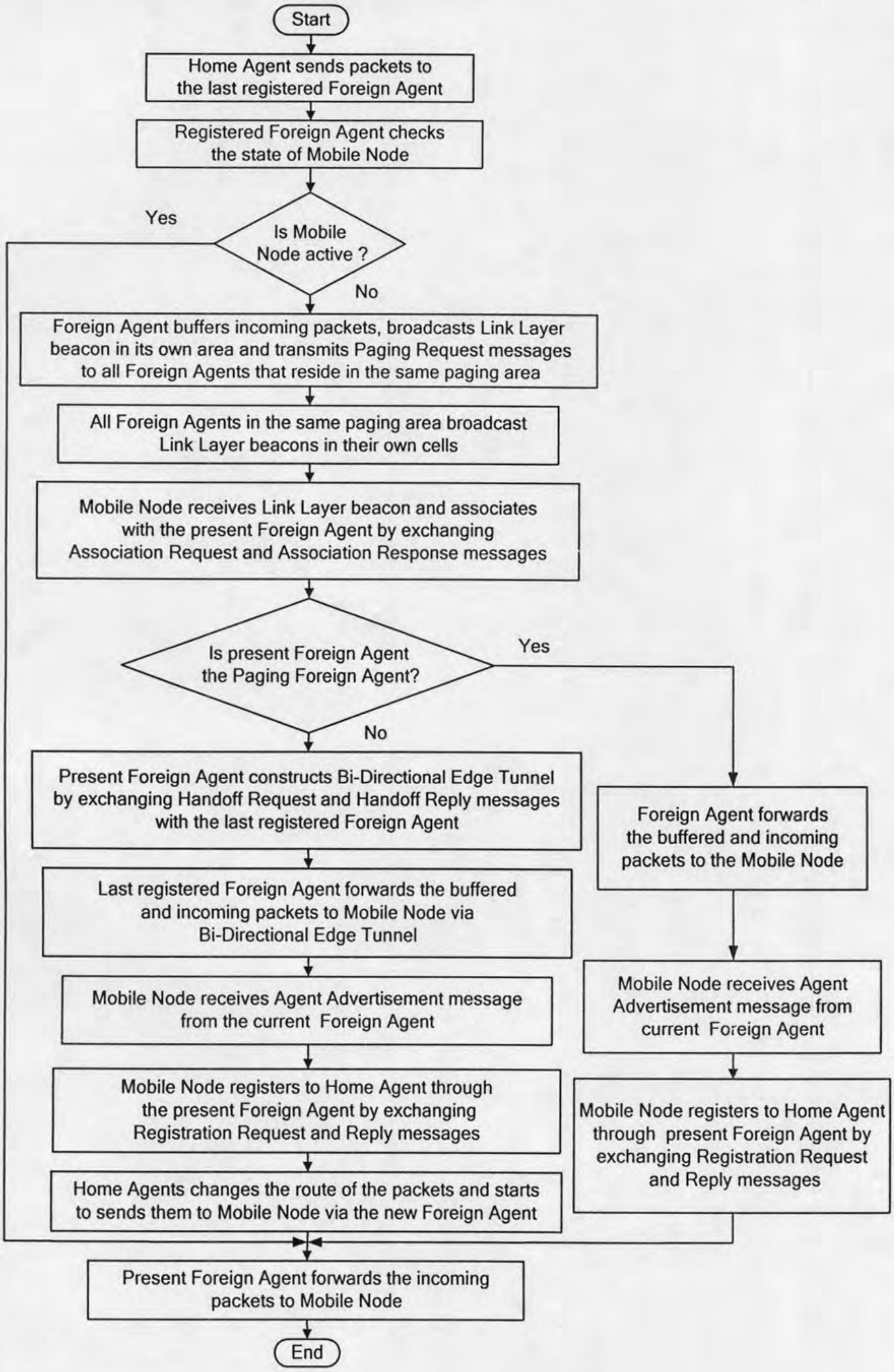

Figure 4.6 Flowchart of Paging Mobile IP Post Registration when the Home Agent sends packets to the Mobile Node.

In this simulation, we assume that the MN has conducted initial registration with the HA. We simulate the system when the MN moves within the GFA domain. Therefore, when there are packets for the MN, the HA will first send the packets to the GFA. The GFA then checks whether the state of the MN is active or idle. If the state of the MN is active, the GFA forwards the packets to the FA where the MN is now located. GFA gets the information of the present FA from the record of the last regional registration process. The present FA then delivered the packets to the MN. If the state of the MN in the GFA record is idle, the GFA then buffers the incoming packets and transmits Paging Request messages to all FAs that reside in the same paging area where the MN was last located. Those FAs then broadcast Paging Request messages in their cell. When the MN receives Paging Request message, the MN checks whether it is still located in the same cell before it entered the idle state. If this is the case, the MN changes its state to be active and sends Paging Reply message to GFA via the present FA. In the other hand, if the MN finds that it has moved to new cell, it conducts regional registration process with the GFA through the new FA. After receiving the Regional Registration Reply, the MN updates the information of the latest FA, changes its state to be active, and sends Paging Reply message to the GFA. Once receiving the Paging Reply message, the GFA changes the state of the MN to be active and starts to forward the buffered and incoming packets to the MN through the present FA. Figure 4.7 illustrates the flowchart of Paging Mobile IP Regional Registration when there are packets destined for the MN.

4.6 Simulation Model of the First Proposed Method

Simulation of the first proposed method is the modification to the simulation of Paging Mobile IP Regional Registration. The network topology is also similar. The MN's messages and functionalities are the same as that of Paging Mobile IP Regional Registration. Modifications are made to the FA and GFA to support multicasting. The FA has three new messages to support multicasting which are Protocol Independent Multicast (PIM) Join, PIM Prune, and Inter-Agent Advertisement messages. In addition, the FAs are equipped with buffer to storage incoming packets if the MN is not located in their area. The GFA has the ability to multicast the packets to the MN's multicast group. The GFA sends the multicast packets to the FAs from which the GFA receives PIM Join message. We assume that the MN has conducted initial registration. We simulate the movement of the MN within the GFA domain. As in Paging Mobile IP, the idle MN only registers when it changes its paging area. It does not conduct regional registration when moving within the same paging area. The idle MN monitors the paging area identifier in Agent Advertisement message sent periodically by each FA every 1 second for this purpose.

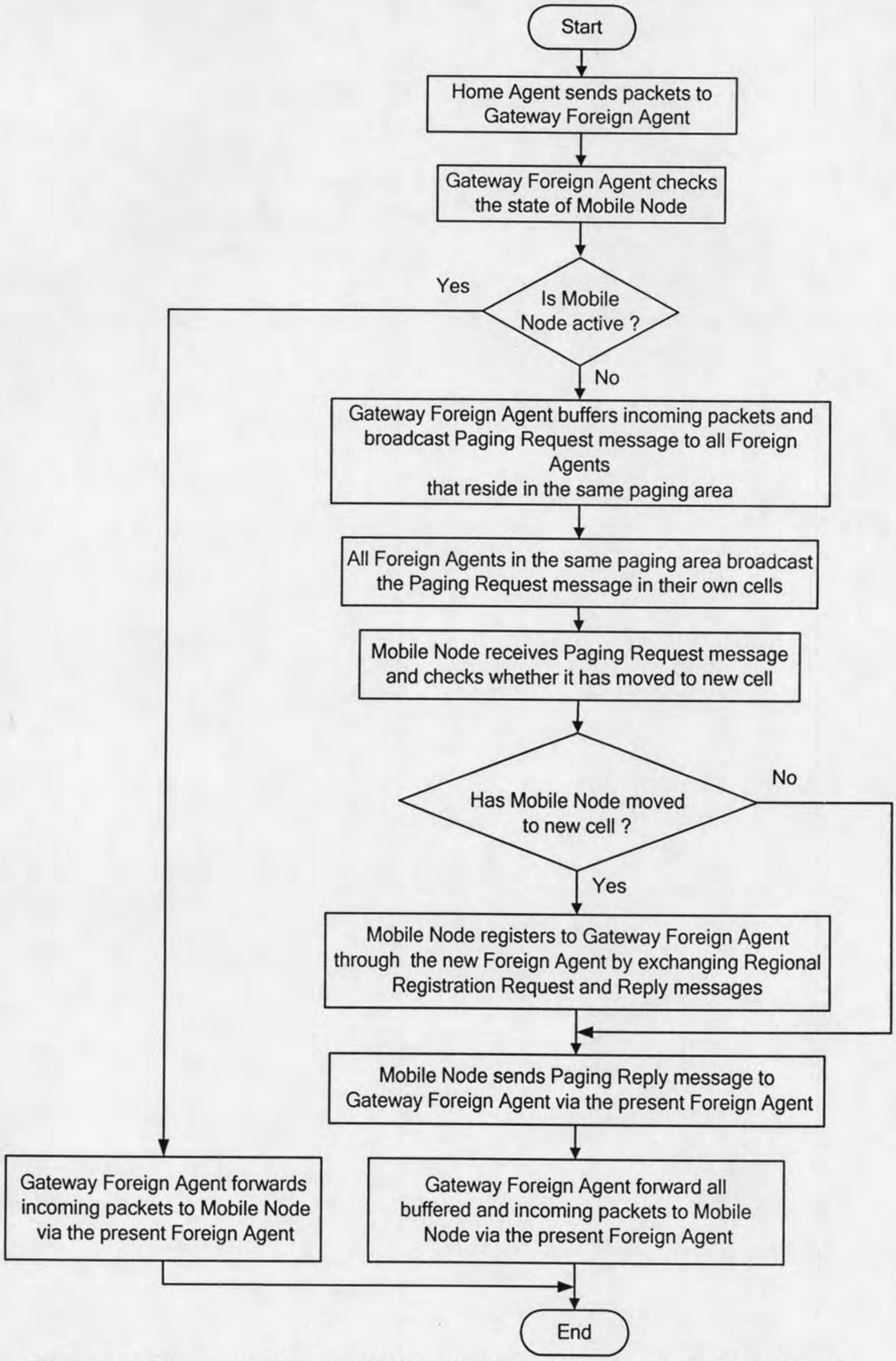

Figure 4.7 Flowchart of Paging Mobile IP Regional Registration when there are packets destined for the Mobile Node.

HA sends data packets to the MN during active time periodically. The packets are first sent to GFA. The GFA then checks the state of the MN in its record. If the MN is in active state, GFA forwards the packets to the MN's multicast group. The multicast group is constructed when the MN registered for the last time. If the state of the MN is idle, the GFA buffers the packets and transmits Paging Request messages to all FAs that reside in the last reported paging area. All FAs then broadcast that message in their own cell. When the idle MN receives Paging Request message, it determines whether it has moved to new cell or not. When the MN finds that it has not moved from the last registered paging area, it sends Paging Reply message to GFA through the registered FA. Receiving Paging Reply message, the present FA joins the multicast group by sending PIM Join message to GFA. The present FA also sends Inter-Agent Advertisement messages to neighbor FAs to construct the multicast group. The neighbor FAs then also send PIM Join message to join the multicast group. On the other hand, if the idle MN realizes that it has moved to new cell, the MN starts the regional registration process.

The MN exchanges Regional Registration Request and Regional Registration Reply messages with the GFA via the new FA for regional registration purpose. After receiving Regional Registration Request message, the present FA forwards that message and also sends PIM Join message to GFA to join the multicast group. The FA then constructs the multicast group for the MN by sending Inter-Agent Advertisement messages to its neighbors after receiving Regional Registration Reply message from GFA. Neighbor FAs then also send PIM Join message to GFA to join the multicast group. After receiving Regional Registration Reply message, the MN sends Paging Reply message to GFA. After that, GFA multicasts the packets to FAs that have join the multicast group. The current FA where the MN is now located forwards the packets to the MN, while other FAs in the multicast group storage the packets in the buffer and forwards the packets to the MN as soon as the MN enters their coverage area. Figure 4.8 shows the flowchart of the first proposed method when the HA sends packets to the MN which has moved to new cell.

An active MN uses Network Layer movement detection method. When the active MN moves to new cell, it waits for the Agent Advertisement message to start the regional registration process. The registration process is as explained above. The MN exchanges Regional Registration Request and Reply messages with GFA. The present FA joins and construct multicast group by sending PIM Join and Inter-Agent Advertisement message. When the new FA receives Regional Registration Request message, it forwards the buffered packets to the MN since the MN has pre-registered via the Inter-Agent Advertisement. Figure 4.9 shows the flowchart of the first proposed method when the active MN moves to new cell.

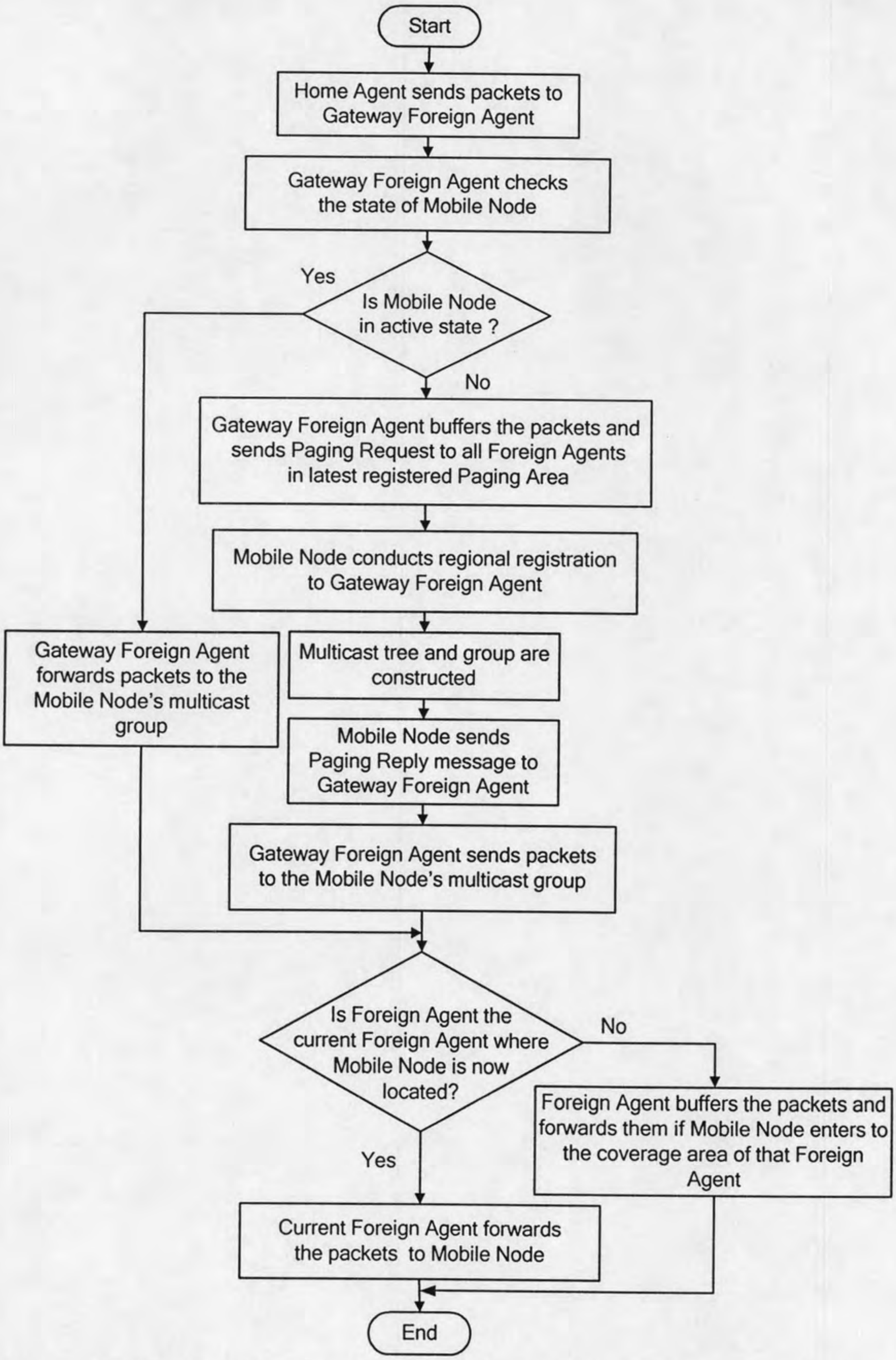

Figure 4.8 Flowchart of first proposed method when Home Agent sends packets to Mobile Node which has moved to new cell.

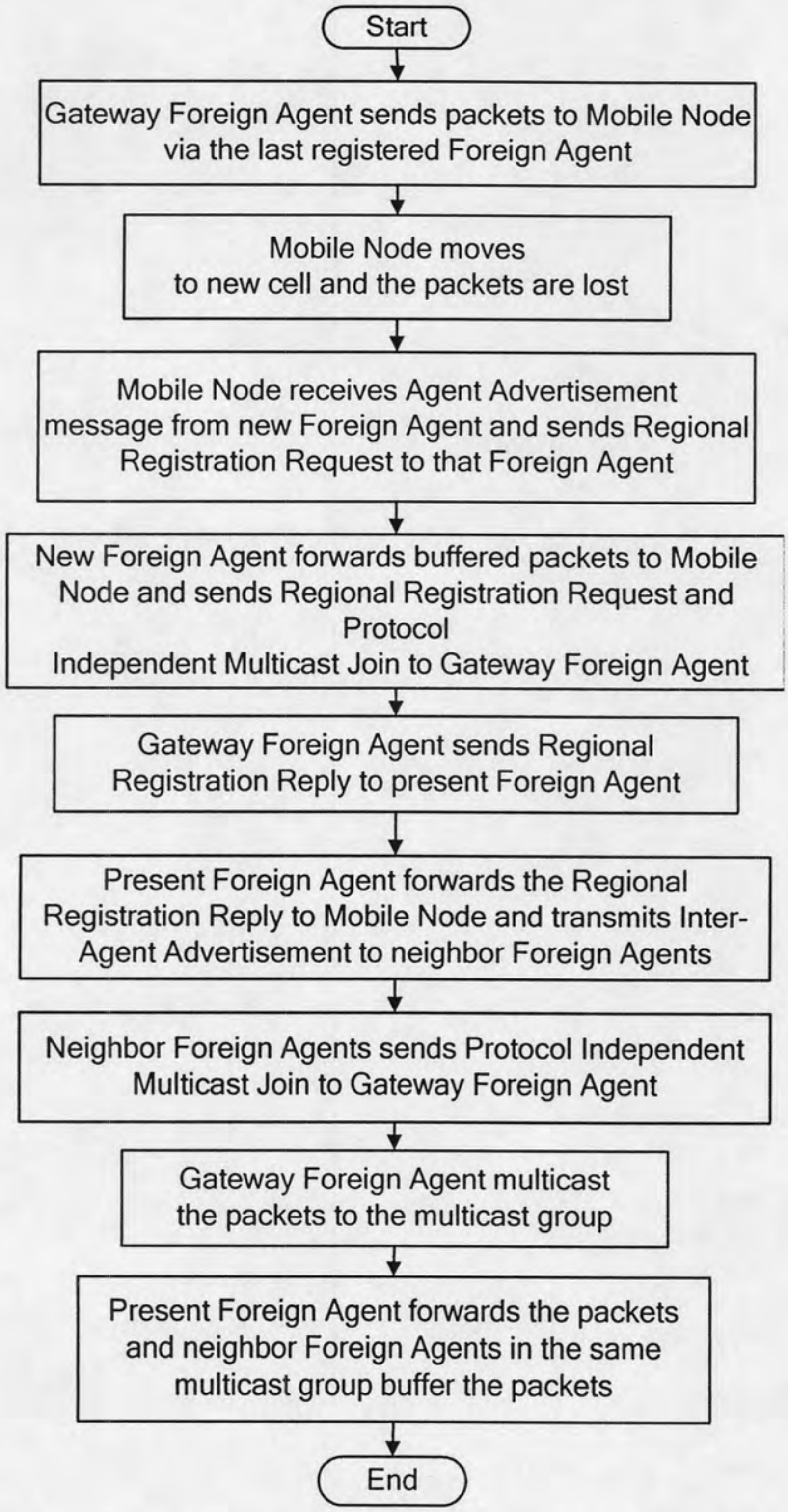

Figure 4.9 Flowchart of first proposed method when an active Mobile Node moves to new cell.

4.7 Simulation Model of Proposed Method with Link Layer Movement Detection

In the simulation of the second proposed method, we make some modifications to the first proposed method. Link Layer functionalities are added since we use Link Layer information for movement detection and multicast group trigger. Inter-Agent Advertisement message is not used anymore to construct the multicast group. The FA is not equipped with buffer since the incoming packets are directly forwarded to the MN if they arrive at the FA. Buffer is only used at GFA to storage incoming packets while the GFA conducts paging process to search for an idle MN. Idle MN acts like in previous proposed method. The MN registers if it detects that it has moved to new paging area. If there are packets for the MN arrive at GFA, the GFA conducts the same procedures as previous method. If the MN is active, the GFA forwards the packets to the MN. If the MN is idle, the GFA conducts paging process. After the present FA receives Paging Reply message, it sends PIM Join message to GFA to join the multicast group. The only difference with the first proposed method is that the present FA does not send Inter- Agent Advertisement message to neighbors FA since the multicast group is constructed based on Link Layer handoff as described in the following paragraph.

When an active MN is moving from one cell to another, it monitors the received Link Layer beacon. If it has not moved from the registered FA area and the Link Layer beacon received is from that FA, the MN only re-associates to that registered FA by sending Association Request message. The registered FA in return sends Association Response message back to the MN. On the other hand, if an active MN receives Link Layer beacon from the new FA, it sends the Association Request message with the sign within that message so that the new FA not only replies with Association Response message but also joins the multicast group. The new FA joins the multicast group by sending PIM Join message to the GFA. Receiving this message, the GFA then sends multicast packets to the previous FA and new FA. At this time, the MN starts to receive the packets from the new FA since it has leaved the registered FA. During the time when the MN has leaved the previous FA but it has not conduct Link Layer handoff to the new FA, the packets are lost. Sometime in the future, the MN receives Agent Advertisement message from the new FA. The MN then registers to the GFA by exchanging Regional Registration Request and Regional Registration Reply messages via the new FA. Regional Registration Reply will be the signal for the GFA to stop sending packets to previous FA since the MN has conduct Network Layer registration. The GFA then only sends packets to the MN via the new FA. Later, the previous FA sends PIM Prune message to GFA to leave the multicast group when the MN's state in that previous FA's record expires. Figure 4.10 shows the flowchart of the second proposed method when an active MN moves to new cell.

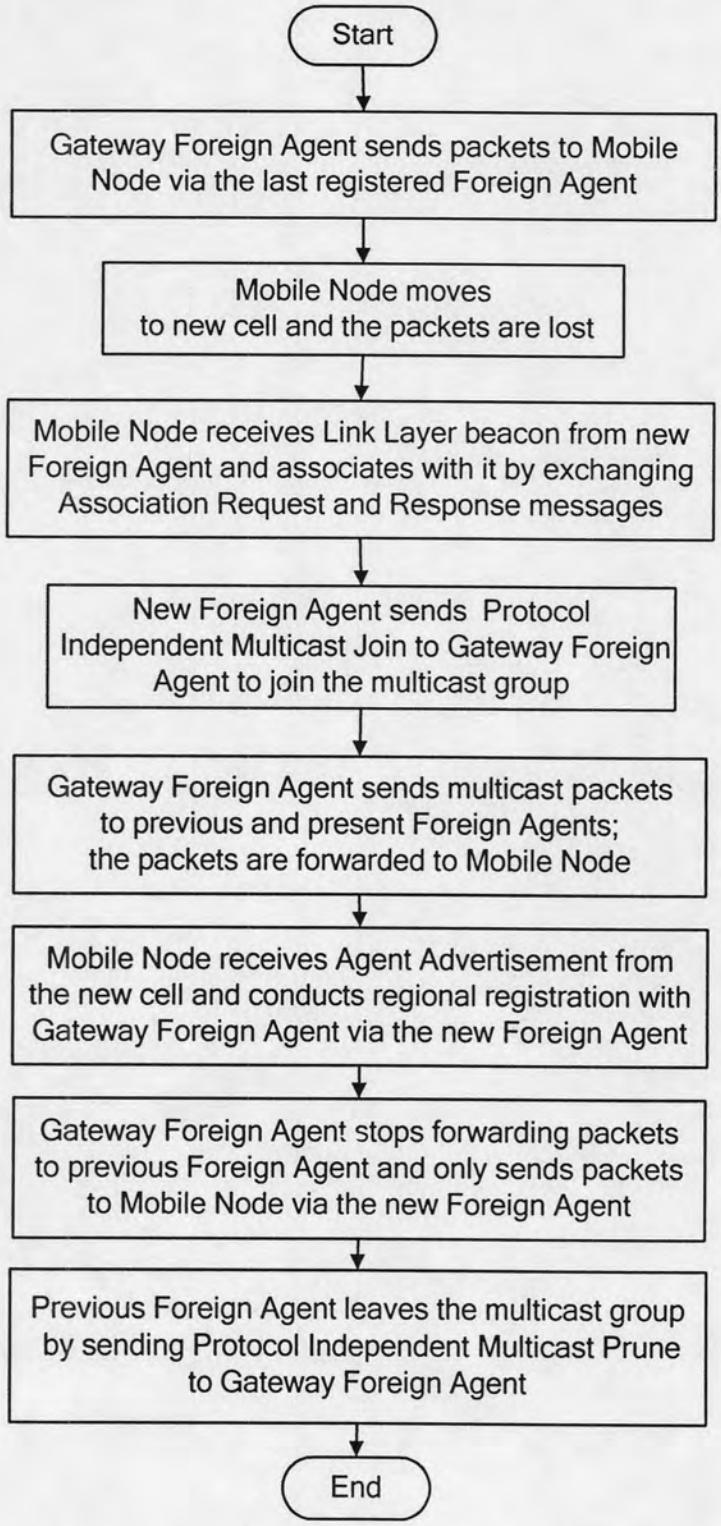

Figure 4.10 Flowchart of second proposed method when an active Mobile Node moves to new cell.