QoS management for mobile users

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Abstract: The major challenge in wireless environment is the provision of quality of service (QoS) guarantees that different applications demand considering the highly dynamic nature of these environments. In this context, provide to mobile users the QoS required is a very important field of research. Our approach to improve the QoS in the wireless network is based on the user mobility profile, after the determination of this profile, an advance resources reservation is made for the mobile terminal solely in the locations where it can visit. The determination of this location is made after an observation phase during which the user is new and his mobility profile is unknown for the system. During the observation phase, the system can't make advance resources reservation for the user. In this case, we use Agent technology in order to improve the QoS for this user.

1 Introduction

The IETF has launched in 2002, the Next Steps In signaling working group (NSIS), the initial objective of this group was to unify all the existing solutions of IP signaling or to make them coexist.

Initially, the NSIS working group aimed the QoS, and proposed the QoS NSLP [1] signaling application. In order to reduce the impact of the handover on the user quality of service, we propose to use the QoS NSLP messages in order to make resources reservation in advance. This reservation is based on an object called MSpec (Mobility Specification) that determines the future locations of the mobile terminal. The MSpec object is a part of a user mobility profile, which is determined by the mobile terminal. We propose a format for this object, which will be included in the QoS NSLP messages. In order to minimize signaling in the network, we use HMIPv6 architecture for the application of this mechanism. The MAP (Mobility Anchor Point) plays a significant role to reserve the resources in advance on behalf of the mobile terminal.

The determination of the MSpec is made after an observation phase during which the user is new and his user mobility profile is unknown for the system. During the observation phase, the system can't make advance resources reservation for the user. In this case, we use Agent technology in order to improve the QoS for this user.

This paper is organized as follows. First, we present the protocol approach with a synthesis of research relating to resources reservation in a wireless environment, the QoS NSLP signaling application, the user mobility profile which includes the MSpec object, as well as the procedure of resources reservation in advance using the QoS NSLP signaling application and the handover procedure. Then, we present the Agent approach; we describe the main principles of the agent technology, our approach which use Agent technology without resources reservation. Finally, we present the validation of the Agent approach with Petri net tools and the first simulation results for the protocol approach.

2 Protocol approach with advance resource reservation

2.1 Advance resource reservation and mobility profile

Recent researches are interested in advance resource reservation to provide the necessary QoS to the mobile terminals. In the integrated services networks, the majority of research is interested in extending the RSVP protocol in a mobile environment. User mobility prediction also represents a key factor for providing a seamless delivery of multimedia applications over wireless networks.

The authors in [2] proposed a new protocol of resource reservation in mobile environment called MRSVP (Mobile RSVP). In this model of reservation, the mobile terminal can make advance reservations in a set of cells named MSPEC (Mobility Specification). The MSPEC is not very clear, it only indicates the future locations of the mobile terminal but the MSPEC is not described. Authors proposed other RSVP messages in order to treat the user's mobility. This technique requires additional classes of service, major changes of RSVP, and a lot of signaling.

Min-Sun Kim and al [3] proposed a resource reservation protocol in a mobile environment. The proposed protocol introduces the *RSVP agent* concept in order to guarantee the necessary QoS through an anticipation of the resource reservation. In this protocol, there are 3 classes of resource reservation to obtain a better use of resources:

- *The Free class:* it represents the resources used in Best Effort.
- *The Reserved class:* it represents the reserved resources for a specific flow, which are currently used.
- *The Prepared class:* it represents the reserved resources for a specific flow, which are not currently used.

Another way to obtain a better use of resources is to determine the future locations of the mobile terminal. Authors in [4] present the architecture of a mobility prediction agent (MPA) that accurately performs mobility prediction using the knowledge of user's preferences, goals, and spatial information without imposing any assumptions about the availability of his movement's history. Using concepts of evidential reasoning of Dempster-Shafer's theory, the MPA captures the uncertainty of the user's navigation behaviour by gathering pieces of evidence concerning different groups of candidate future locations. These groups are then refined to predict the user's future location when evidence accumulates using Dempster rule of combination.

2.2 Advance resource reservation with QoS NSLP

2.2.1 The QoS NSLP signaling application

The QoS NSLP signaling application makes it possible to generate a signaling in order to provide certain level of QoS.

QoS NSLP generates 4 messages types:

- *Reserve*: the only message, which handles the reservation state (refresh, create, remove).
- *Response:* using this message, a response is sent to a message received.
- *Query:* this message is used to require information concerning the nodes, which are on the data path, for example: the available resources.
- *Notify*: using this message, it possible to inform a node without preliminary request.

2.2.2 Mobility profile

The user's mobility profile is built on the basis of its behaviour / movement after **m** associations with the system. The goal of this profile is to build a user's behaviour model. The system model is based on the Continuous Time Markov Chain (CTMC).

Our system can evolve between N states defined by the following set:
$C = (C_1, C_2, \ldots\ldots C_i \ldots\ldots C_n)$.

The system is in the state i = the terminal mobile is in the cell C_i.

P_{ij}: the probability of transition from the cell C_i to the cell C_j.

P_i (t_r): the probability, which defines the location of the mobile terminal in the cell C_i at the time t_r.

The user's mobility profile contains the following information:

- User's identifier: User_ID
- $M = [P_{ij}]$ [N*N]: The Matrix of transition, which contains the P_{ij}.

We note:

t [i, j]: the number of transition from the cell i to the cell j during the **m** associations with the system.

g (i): the number of transition outgoing from the cell i during the **m** associations with the system. We calculate it as follows: $g(i) = \sum_{j=1}^{n} t[i, j]$.

After the **m** associations, the probability of transition from the cell i to the cell j is calculated as follows: $P_{ij} = t[i, j] / g(i)$.

- $V = [P_i(t_o)]$ [N]

P_i (t_o): this probability defines the location of the mobile terminal in the cell C_i at the time t_o.

k (i): the number of associations with the cell i during the **m** associations at the time t_o. We have: $\sum_{i=1}^{n}$ k (i) = m and $P_i (t_o)$ = k (i) / m.

- The MSpec (Mobility Specification): it determines the future locations of the mobile terminal. The proposed format for the MSpec is as follows: MSpec = <MSpec ID> <Duration> <Cell ID>.

  Where:

- *MSpec ID* is the identifier of the MSpec.
- *Duration* is the interval of time (< start time>, <end time >) during which the future locations of the mobile terminal can be determined.
- *Cell ID* : <cell ID1>, <cell ID2>, <cell ID3>, ..., <cell IDn> is a set of cells identifiers. We suppose that each cell is identified by a single identifier.

We use the Continuous Time Markov Chain (CTMC) in order to determine the MSpec.

$P_j (t_{r+1})$: the probability of the mobile terminal's location in the cell C_j at the time t_{r+1}.

We can calculate this probability by the following formula:

$$P_j (t_{r+1}) = \sum_{i=1}^{n} P_i (t_r) * P_{ij}.$$

We define θ ($0 \leq \theta \leq 1$), a threshold which is used to select the cells according to their probabilities. The MSpec is defined as follows: MSpec (t_r) = $\{C_j / P_j (t_{r+1}) \geq \theta \}$.

Before the **m** associations, the system do not calculate the MSpec because the user is new and the system has not the necessary information to calculate the MSpec; it has no information concerning the M Matrix and the V Vector (observation phase).

2.2.3 MQoS NSLP

We name MQoS NSLP, the procedure of resources reservation in advance using the QoS NSLP messages in a mobile environment. This procedure of reservation is applied in HMIPv6 architecture.

In the following, we present a scenario of communication between two mobile terminals where the MH1 is the entity, which generates the flow and which initiates the reservation.

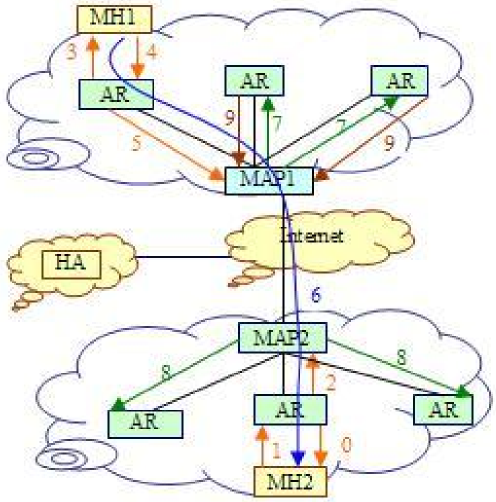


Fig. 1. Advance resource reservation procedure

We note MSpec1 and MSpec2 respectively, the set of future locations of MH1 and MH2 during the communication.

The procedure of advance resources reservation using QoS NSLP is as follows (the registration can start with the MH1 or the MH2, the following scenario considers that the MH2 is the first mobile, which makes the registration):

0: The AR informs the MH2 with the message *Router Advertisement* of the availability of resources. For that, we propose to add a bit Q in this message. If Q = 0 then the AR does not have resources and in this case the MH2 can be connected in BE.

1: During the registration, the MH2 asks its AR for a certain QoS. In this case, we propose to add the MSpec2 object to the *registration request* message. (Here, we are interested only in the interactions between MIPv6 and the QoS NSLP messages, other MIPv6 messages are necessary in order to continue the registration).

2: After the registration with the MH2, the AR sends the QoS request to the MAP2. For that, we use the NOTIFY message with the MSpec2 object included in it. After the reception of the NOTIFY message, the MAP2 analyses the MSpec2 object.

3: The AR informs the MH1 with the *Router Advertisement* message of the availability of resources using the bit Q. If Q = 0 then the AR has not resources and in this case the MH2 can only be connected in BE.

4: during the registration, the MH1 asks its AR for a certain QoS. The MSpec1 object is added to the *registration request* message.

5: After the registration with the MH1, the AR sends the QoS request to the MAP1, for that we use NOTIFY message and the MSpec1 object. After the reception of the NOTIFY message, the MAP1 analyses the MSpec1 object.

6: To reserve the resources between the MH1 and the MH2, the MH1 (NI) sends the RESERVE message, which must contain the QSpec object. This message is transported by GIMPS until the MAP1, sent to the MAP2, to the AR and finally to the MH2 (NR).
7: After the reception of the RESERVE message, the MAP1 sends the NOTIFY message to all the ARs, which are in the MSpec1 in order to receive the RESERVE message.
8: the RESERVE message is forwarded after its reception by the MAP2, in all the ARs, which are in the MSpec2.
9: the ARs, which are in the MSpec1 send the RESERVE message to the MAP1.

The Handover procedure. The stages of the handover procedure are the following (Figure 2):

- Registration of MH2 with its new AR (MIPv6 protocol).
- The new AR sends the RESERVE message to the MH2, (message 1 on the figure 2).
- The MH2 sends the RESPONSE message with the new MSpec2, (message 2 on the figure 2).
- After the reception of the RESPONSE message, the new AR sends the NOTIFY message to the MAP2 with the new MSpec2 (message 3 on the figure 2).
- The MAP2 analyses the new MSpec2, and performs the following actions: (message 4 on the figure 2):
- It keeps the reservation for the old cells, which belong to the new MSpec2.
- It makes advance reservations in the new cells, which do not belong to the old MSpec2.
- It removes the reservation for the old cells, which do not belong to the new MSpec2, except for the current cell.
- Registration of MH1 with its new AR (MIPv6 protocol).
- The MH1 sends the RESERVE message to the new AR with the new MSpec1, it will be forwarded to the MAP1 (message 5 on the figure 2).
- The MAP1 includes the old and the new MSpec1 in a NOTIFY message. Then, it sends this message to all the ARs whose identification is in the new and the old MSpec1 (message 6 on the figure 2).
- Each AR analyses the two MSpec1 objects and performs the following actions (message 7 on the figure 2):
- The old AR keeps the reservation for the old cells, which belong to the new MSpec1.
- Each new AR makes advance reservations in the new cells, which do not belong to the old MSpec1.
- Each old AR removes the reservation for the old cells, which do not belong to the new MSpec1, except for the current cell.

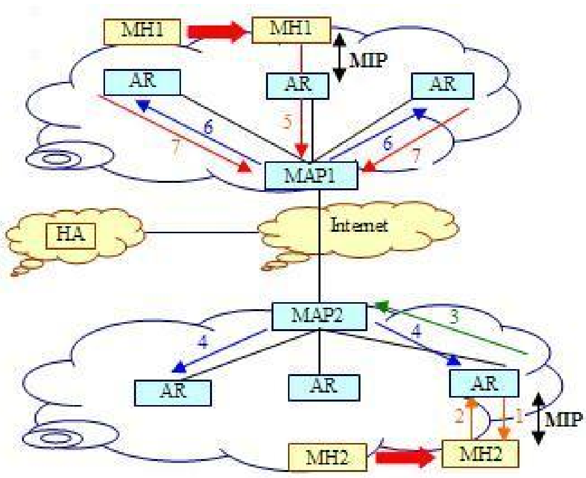


Fig. 2. The Handover procedure

3 Agent approach without resource reservation

3.1 Agent technology

In the case of a new user, the system cannot make advance resources reservation because the user mobility profile is unknown and the MSpec cannot be calculated, without resources reservation, we use Agent technology in order to improve the quality of service for the mobile user.

In a Wi-Fi environment, the strategy of changing the access point is static i.e. neither the service provider nor the customer can change the selection of the access point. However this selection can be bad in certain cases. In figure 3, the Mobile Host 5 (MH5) on which the user starts an application requiring a high level of QoS (a video application for example), receives the best signal of AP2; however, the cell 2 is very loaded and consequently QoS necessary for MH5 cannot be assured. A dynamic strategy consists in guiding the MH5 towards cell 1 which is empty and which can provide the necessary QoS.

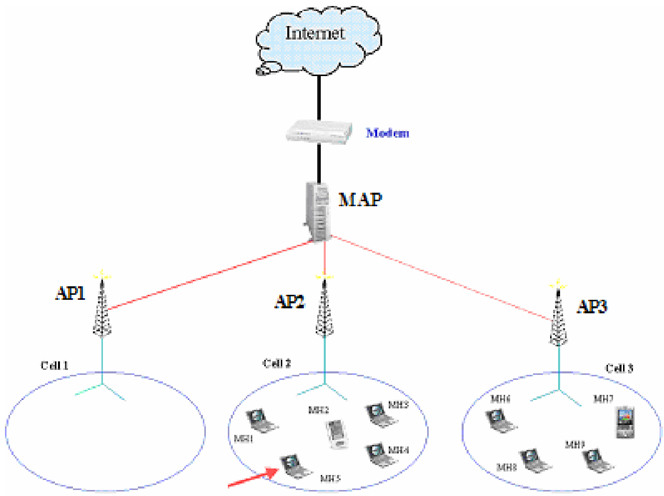


Fig. 3. Example of Wi-Fi network

If all the cells are filled, the user must be able to use another access technology at his disposal which corresponds to his needs. In this example, it is the UMTS technology which will be used; the great number of users on the spot prevents the Wi-Fi from fulfilling the requirements of QoS for the required application. As soon as the user activates another less critical application in term of QoS or that the performance of Wi-Fi becomes acceptable for the application, the user must also be able to reconsider Wi-Fi technology (because of the high cost of the UMTS for example). Different vertical handover must be carried out in a completely transparent way for the user according to the applicative constraints and the user profile.

To provide quality of service on a Wi-Fi network, it is necessary to respect 3 principles [5]:

- The number of hosts authorized to use the channel must be limited;
- The geographical area inside which the users communicate must be limited so that all of them can use the highest throughput;
- The sources must be limited by configuring the conditioners of traffic in the equipment.

In order to provide necessary QoS to a multimedia application, we will respect these three principles and we'll make three assumptions:

- From a certain number of users (N), gathered in the same cell, QoS necessary for a multimedia application will not be ensured any more and the cell will be considered as filled.
- Each access point contains a single "identifier of location".
- According to the work which was realized in [6], an estimate of the position of the MH is made and an application which gives the distribution of the cells in each room of the university (conference room, library...) is downloadable from the server.

3.2 Agent approach

The multi-agent system contains 3 agents:

- *Application agent:* This agent is located on the MH, its role is to associates an application profile to the user, in a first phase, the *Application agent* determines the application type launched by the user.
- *Terminal Agent:* This agent is located on the MH, it establishes the connection between the user and the system, and it communicates with another agent on the access point in order to find the state of the cell and the states of the cells in the neighborhood. It asks for the deployment of another access technology if necessary.
- *State Agent:* This agent is located on the access point; it determines the state of the cell and the state of the neighbouring cells. From N users gathered in the cell, the state of the cell will be regarded as filled. To know the state of the neighboring cells, the State agent contacts the same agents on the neighboring cells, and thus it can recover their states.

Figure 4 represents the modelling of interactions between agents by the AUML model. In this example, the user is in the cell number 2 of the conference room. He consults his emails or makes a transfer file. At the launching of a multimedia application, the Application agent actives the Terminal agent (message m1), the Terminal agent is activated and sends a message (m2) to the State agent in order to know the state of the current cell; the State agent compares the number of users in the cell with the number N. If it is lower or equal to the number of users in the cell, it sends a message (m3) to the Terminal agent to indicate to it that the current cell is filled. At the same time the State agent contacts the same agents on the neighboring access points (messages m4 and m5) in order to know the state of the neighboring cells. Each agent answers by a message which contains the state of the cell or the number of users in the cell with the location identifier of the cell (messages m6 and m7).

The State agent in the current cell makes a comparison between the numbers of users in the neighbouring cells or between their states. If there is at least a cell which is not filled, it sends the location identifier of the chosen cell to the Terminal agent (m8), and it sends an ACK message (m9) to the State agent in the chosen cell. At present, the Terminal agent sends a request to the server in order to download the application which will enable the user to know the place of the concerned cell in the room.

On the other hand, if all the cells are filled, the State agent contacts the Terminal agent (message m10) which will require the deployment of the UMTS.

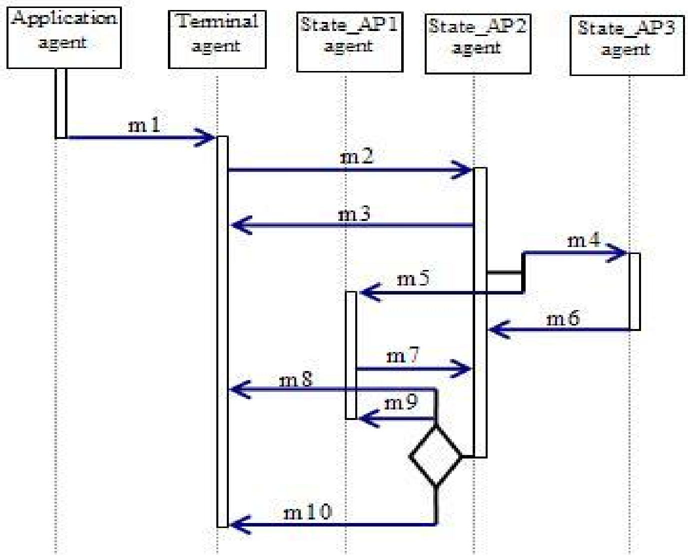


Fig. 4. The modelling of interactions between agents by the AUML model

4 Simulation

4.1 Validation of the Protocol Approach

The validation of the protocol approach is done on two stages; the first stage consists in seeking the good value of θ, for this, we use the MATLAB Mathematical Software. The second stage consists in comparing our approach of advance resources reservation with a model without resources reservation, for this, we use the OMNeT++ simulation tools.

For the second stage, we have chosen two parameters which are:

- The resources reservation time in the new cell.
- The packet loss before the resources reservation in the new cell.

The two parameters are based on the MSpec failure rate.

For the first stage, we suppose that the user's neighbourhood contains 10 cells and the value of **m** is 40 (the number of associations with the system).

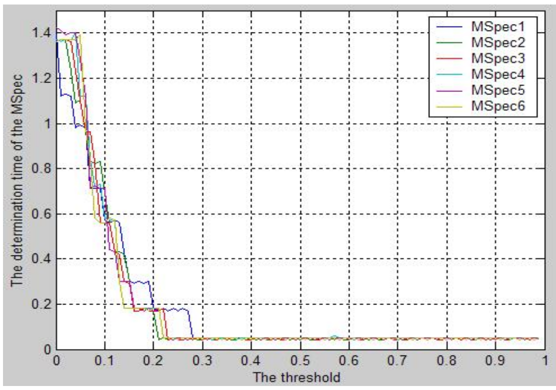
During theses 40 associations, we will follow the different locations of the mobile terminal in order to determine the M Matrix and the V Vector.

The system calculates the vector $V_1 = V * M$ in order to determine the MSpec1 for the 1st handover. For the second handover, the system calculates the vector $V_2 = V_1 * M$ in order to determine the MSpec2 and so on.

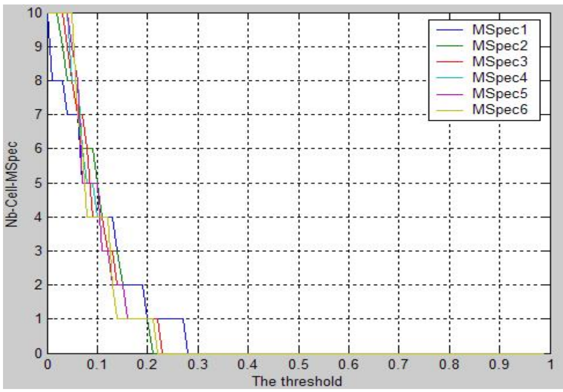
After 6 handover, we have the following results:

V_1= [0.2712 0.0700 0.1350 0.0665 0.1900 0 0.1440 0 0.0920 0.0313].
V_2= [0.2015 0.1193 0.1089 0.1558 0.0504 0.1404 0.0271 0.0940 0.0343 0.0683].
V_3= [0.2217 0.1119 0.1531 0.0873 0.1308 0.0406 0.0876 0.0331 0.0791 0.0548].
V_4= [0.2147 0.1275 0.1263 0.1350 0.0689 0.0941 0.0433 0.0693 0.0500 0.0709].
V_5= [0.2176 0.1225 0.1509 0.1022 0.1064 0.0543 0.0684 0.0446 0.0696 0.0635].
V_6= [0.2159 0.1296 0.1361 0.1250 0.0792 0.0777 0.0501 0.0597 0.0569 0.0698].

The following graph shows the impact of θ on the determination time of the MSpec (The time is calculated in millisecond).



The second graph shows the impact of θ on the MSpec size.



If θ ≥ 0.28, the MSpec is empty, we remark that θ = 0.1 is a good value for the simulation.

With θ = 0.1, we have the following results: MSpec 1 = {C_1, C_3, C_5, C_7}, MSpec 2 = {C_1, C_2, C_3, C_4, C_6}, MSpec 3 = {C_1, C_2, C_3, C_5}, MSpec 4 = {C_1, C_2, C_3, C_4}, MSpec 5 = {C_1, C_2, C_3, C_4, C_5}, MSpec 6 = {C_1, C_2, C_3, C_4}.

Currently, we simulate the system with OMNet++ in order to validate the second stage.

4.2 Validation of the Agent approach by Petri nets tools

Implementing Agent technology in a wireless environment is a heavy task. So, for the validation of the Agent approach, we use Petri nets tools.

The following figure represents the modelling of interactions between agents by Petri nets tools.

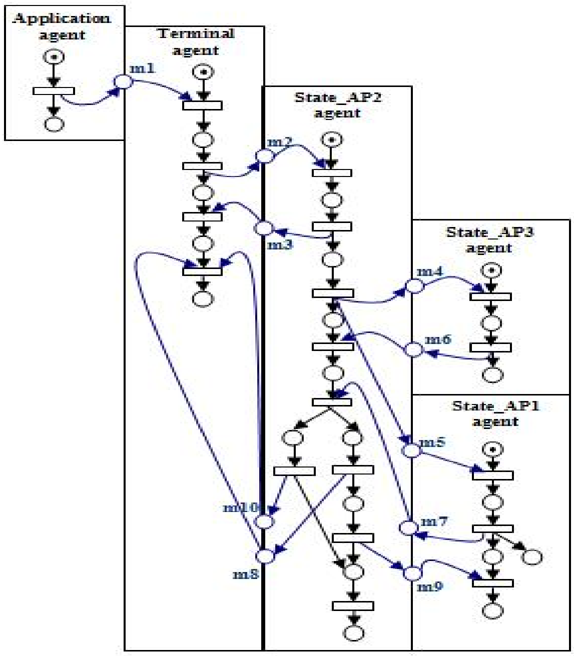


Fig. 5. The modelling of interactions between agents by Petri nets tools

A simple manual verification is sufficient to verify the Petri net describes previously, it is necessary to launch the token corresponding to the Application agent and to cross successive transitions according to each event in the system. We can verify that the Petri net contains neither the blockage situation nor the conflict situation.

5 Conclusion

We have presented in this paper a mobility profile management based approach for advance resource reservation in wireless networks.

This reservation is made according to the MSpec object which determines the future locations of the mobile terminal. Our objective through this approach is to minimize the degradation of services during the handover. The determination of the

MSpec is made after an observation phase during which the user is new and his mobility profile is unknown for the system. During the observation phase, the system can't make advance resources reservation for the user. In this case, we use Agent technology in order to improve the QoS for this user. The validation of the Agent approach is based on the Petri nets tools. Currently, we simulate the system with OMNet++ in order to validate the protocol approach.

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