An Enhanced Hybrid Rerouting Scheme for Handoff in Wireless ATM Networks

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Abstract. For handoff in wireless ATM networks, a call might be rerouted because ATM basically provides connection-oriented service. We propose an enhanced hybrid rerouting scheme (EHRS) for handoff in wireless ATM networks, which combines the concepts of multicast rerouting, anchor rerouting, path extension and dynamic rerouting methods to effectively reduce handoff call dropping ratio, new call blocking ratio, and handoff delay. An analytical model and simulation experiments obtain performance measurements. According to the results, EHRS performs better than the different schemes.

Keywords: wireless ATM network, handoff, rerouting, dropping ratio, blocking ratio.

1 Introduction

Asynchronous transfer mode (ATM) network has several advantages, such as high transmission rate, large bandwidth, low delay, low cell loss rate (CLR), low bit error rate (BER) [1]. ATM network can dynamically allocate bandwidth and provide the quality of service (QoS) for different services; hence it is widely used as network backbone. Wireless ATM (WATM) emerges the advantages of the wired ATM [2] and the characteristics of wireless transmission to offer mobility and convenient communication.

Handoff mechanism is very important in mobile communications [3–5]. Lack of a good handoff mechanism may cause a call dropped when a mobile terminal (MT) is leaving a base station (BS) for a new BS. Because ATM basically provides connection-oriented service, a new route must first be found before setting up a new connection when handoff occurs, which is called rerouting. Some rerouting methods are proposed, such as connection reestablishment [6], path extension [7], anchor rerouting [8], dynamic rerouting [9], multicast based rerouting [10], hybrid rerouting, etc.

A new path may be an optimal route if it is setup by connection reestablishment method, but the setup time is longer and it does not used the original route. Path extension method can effectively reduce handoff delay and need not change the original route at all, but the required bandwidth may hugely increase if handoff frequently occurs. Anchor rerouting method changes the original path only from anchor switch to old BS and keeps the other parts, but the required bandwidth may hugely increase similar to path extension method. Dynamic rerouting method is more complicated, but its new path may be close to the optimal; it can effectively reduce the required bandwidth and the disruption delay, but it relatively takes longer while looking for the crossover switch (COS) and causes longer handoff delay. According to multicast rerouting method, an old BS first multicasts the information of the setup path to its neighboring BSs when handoff occurs. After an MT is moving to a new BS, it similarly sets up a new path to its neighboring BSs and remove the path disjoint to the new BS. Although this method is the fastest, the required bandwidth may be very huge. Hybrid rerouting mostly combines the above-mentioned methods; it generally combines two or more methods to satisfy different applications or environments, e.g., the idea of combining path extension and dynamic rerouting may yields a good rerouting method [10].

There are some factors to be considered while designing a rerouting method in wireless ATM network, such as the complexity of the protocol to send signals, the optimal path, and handoff delay. We propose an enhanced hybrid rerouting scheme (EHRS) for handoff in wireless ATM networks, which combines the concepts of multicast rerouting, anchor rerouting, path extension and dynamic rerouting methods to effectively meet the above-mentioned requirements.

2 The enhanced hybrid rerouting scheme (EHRS)

2.1 System Architecture

A WATM network includes three important components: ATM switch, base station (BS), and mobile terminal (MT) as shown in Fig. 1. The wired ATM network acts as a transmission backbone and operates with the cellular network; it can then connect to the other networks. BS provides an interface between the wired and wireless networks. MT is the moving device at the user end, such as notebook, cellular phone and so on. It is necessary to perform handoff procedure when MT moves from the coverage of a BS to the coverage of a new BS.

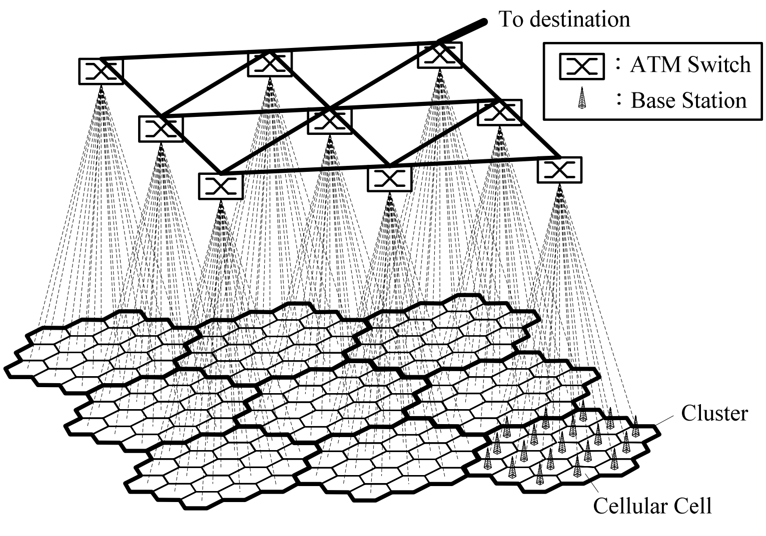

Fig. 1. An example of WATM network infrastructure

Generally in WATM network infrastructure, several BSs are grouped into a cluster administered by an ATM switch. Handoff may occur in two ways: intracluster and intercluster handoffs. It is simpler to process intracluster handoff, because the rerouting scheme does not need to process the intervention of a switch in the backbone network. Conversely, intercluster handoff procedure needs to process the intervention of a switch because it needs to find a proper COS in the backbone ATM network. Generally, the probability of intracluster handoffs is greater than that of intercluster handoff; it is cited if a cluster contains more than three rings [11]. However, the loading of an ATM switch may be too heavy if a cluster contains too many BSs. Therefore we adopt a cluster with three rings (i.e., 19 cells in a cluster) for further analysis.

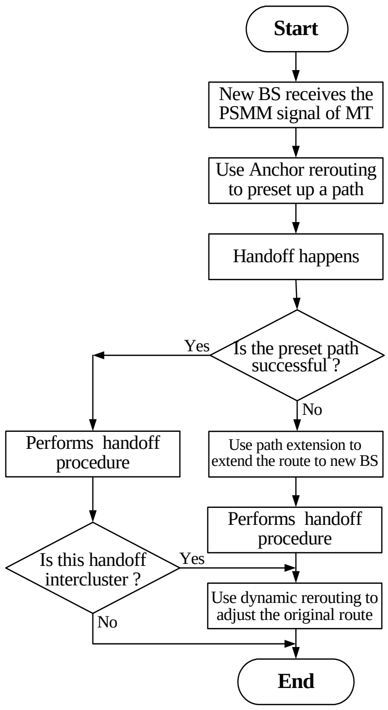

Fig. 2. Flowchart of performing EHRS

2.2 The enhanced hybrid rerouting scheme (EHRS)

EHRS combines the concepts of multicast rerouting, anchor rerouting, path extension and dynamic rerouting methods. The following steps show how EHRS works, while the related flowchart is shown in Fig.2.

(1) Preset paths: The concepts of multicast and anchor rerouting methods are used to preset routes. When BS receives the signal of pilot strength measurement message (PSMM), the BS adopts the anchor rerouting method to build a route in advance. If the cell contains the preset route and MT belongs to the same cluster, the route is built directly from anchor switch to this cell, otherwise the route is built from anchor switch to COS and then from COS to this cell.

(2) Perform handoff procedure: MT can quickly finish handoff procedure if the cell of handoff region has already had a preset route; or the path extension method is used to set up the route.
(3) Adopt path extension: When the preset route fails, this route is directly extended to the entering cell of MT to save handoff time.
(4) Adjust path dynamically: When this handoff is intercluster handoff or adopts path extension to set up the route, dynamical adjustment is needed by choosing the switch closest to COS to get the optimal path to reduce bandwidth.

3 Analysis of the handoff signaling messages using EHRS

EHRS combines suitable handoff procedures and dynamical path adjustments to obtain better performance. Handoff may succeed or fail and occur in either intracluster or intercluster, hence EHRS considers four different situations, i.e., the successful or failure preset path for intracluster and intercluster handoffs. Different handoff procedures may need different handoff signaling messages and processing time. However, by the limited paper length, we only show the analysis of the successful preset path for intracluster handoff in this paper.

3.1 Analysis of the successful preset path for intracluster handoff

In order to successfully preset path for intracluster handoff, the related handoff procedure may need eighteen steps as shown in Fig. 3, while Tables 1 and 2 collect some parameters for performance analysis [12] and Table 3 shows the meanings of the signaling messages [13].

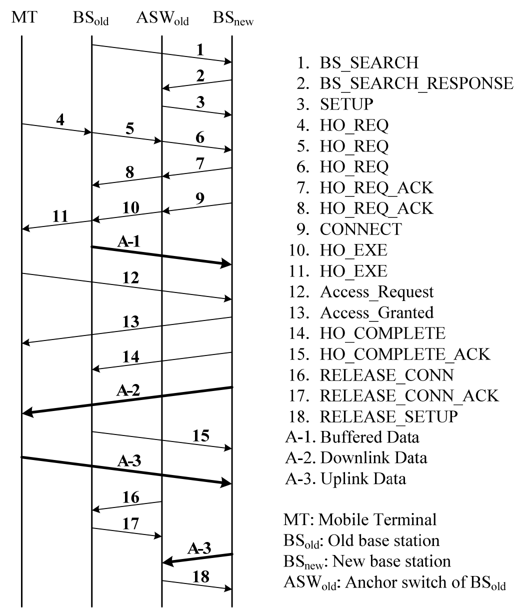

Fig. 3. The timing sequence for the successful preset path for intracluster handoff

Table 1. Message transmission times.

Parameters	Message Type	Transmitted on	Value
T_w	Signaling	Wireless links	S_s / BW_s + T_{PW}
T_{sw}	Signaling	Switch-to-switch links	S_s / BW_s + TP_{SW}
$T_{d(w)}$	Data	Wireless links	S_d / BW_d + T_{PW}
$T_{d(sw)}$	Data	Switch-to-switch links	S_d / BW_d + T_{PSW}

Table 2. Input parameters

Parameters	Description	Value
S_s	Signaling message size	56 bytes
S_d	Data packet size	8 k bytes
BW_s	Signaling channel bandwidth	450 kbps
BW_d	Data channel bandwidth	9 Mbps
T_{Pw}	Propagation delay on the wireless link	50 µs
T_{PSW}	Propagation delay on the inter-switch link	50 µs
T_{PBS}	Propagation delay on the BS-to-BS link	20 µs
T_{STP}	Processing time in nodes only Signal Transfer Point (STP) function required	0.3 ms
T_{PSS} T_{PSB}	Processing time of SETUP message in a switch or a BS, respectively	8 ms 16 ms
T_{COS}	Processing time of signaling message that execute COS discovery function in a switch	4 ms
T_{SWr} T_{BSr}	Processing time of RELEASE_CONN and RELEASE SETUP messages in a switch or a BS, respectively	4 ms 8 ms
T_{PS} T_{PB}	Processing times for switching an ATM cell in a switch or a BS, respectively	10 µs 20 µs
T_{ASW} T_{BS}	Processing time of signaling messages (other than SETUP and RELEASE_CONN) in a switch or a BS, respectively	3 ms 6 ms
T_{SM}	Signaling message processing time at the mobile	5 ms

Table 3. Signaling messages for handoff

Signaling Messages	Description
BS_search	Search for a new BS to preset path
BS_ search _reply	Response from the BS having the preset path
HO_req	Handoff request
HO_req_ack	Acknowledgement for handoff request
SETUP	Setup a path
CONNECT	Connect
HO_exe	Handoff execution
Access_request	Access request
Access_granted	Access granted
HO_complete	Handoff complete
HO_complete_ack	Acknowledgement for handoff complete
CONN_rel	Connection release
CONN_rel_ack	Acknowledgement for connection release
SETUP_rel	Release the path

The signaling procedure in Fig. 3 is explained and summarized in Table 4.

Table 4. Meanings of the signaling messages in Fig. 3

Steps	Meaning of signaling messages	Time for the step
1	Initially MT locates at the coverage of the old base station BS_{old}. According to the moving direction of MT, BS_{old} looks for three new base stations (BS_{new}) most possibly for the MT to handoff, then it presets the new path to BS_{new} by sending the message BS_search.	T_{S1}
2	BS_{new} notices anchor switch (ASW_{old}) to preset the route by sending the BS_search_reply message.	T_{S2}
3	ASW_{old} sets up a path to BS_{new}.	T_{S3}
4	MT asks BS_{new} for handoff but it first sends the handoff request to BS_{old}.	T_{S4}
5	BS_{old} forwards the handoff request to ASW_{old}.	T_{S5}
6	ASW_{old} forwards the handoff request to BS_{new}.	T_{S6}
7	BS_{new} replies the acknowledgement through ASW_{old} first after receiving the handoff request message.	T_{S7}
8	ASW_{old} forwards the acknowledgement of the handoff request to BS_{old}.	T_{S8}
9	BS_{new} asks to connect to ASW_{old} by sending the CONNECT message.	T_{S9}
10	ASW_{old} notices MT to execute handoff procedure, but this message will be sent to BS_{old} first.	T_{S10}
11	ASW_{old} forwards the acknowledgement of the handoff request to indicate MT.	T_{S11}
12	MT begins the handoff procedure and sends the Access_request message to BS_{new} to request the wireless channel.	T_{S12}
13	BS_{new} sends the Access_granted message to MT and provides MT enough bandwidth, because a connection has been successfully setup.	T_{S13}
14	BS_{new} will notice BS_{old} that the handoff procedure has been completed, but this message will send to ASW_{old} first, then to the BS_{old}.	T_{S14}
15	BS_{old} sends the acknowledge message to ASW_{old} and BS_{new}.	T_{S15}
16	ASW_{old} sends the message to releases the BS_{old}'s connection after ASW_{old} knows that BS_{old} has sent the HO_complete_ack message to BS_{new}.	T_{S16}
17	BS_{old} sends the acknowledgement message to ASW_{old}.	T_{S17}
18	ASW_{old} releases the other two preset paths.	T_{S18}

$$T_{S1} = T_{PBS} + T_{BS} \quad (1)$$

$$T_{S2} = T_{SW} + T_{ASW} \quad (2)$$

$$T_{S3} = T_{SW} + T_{PSB} \quad (3)$$

$$T_{S4} = T_{PW} + T_{BS} \quad (4)$$

Similarly, the times for the other steps can be easily obtained.

3.2 Analysis of dynamic path adjustment

Before performing the dynamic path adjustment, we need to find a new COS on the original path, where the COS is closest to the switch connecting to the new BS. If two or more switches satisfy the above-mentioned condition, the farther COS from the old BS is chosen. The procedure of dynamic path adjustment completes, if the new COS has set up a new route to the new BS.

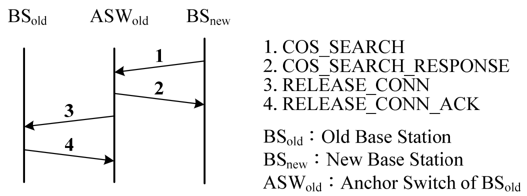

Fig. 4. The signaling procedure of dynamic path adjustment after intracluster handoff

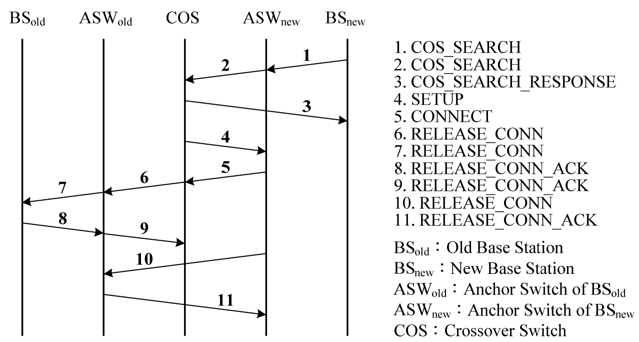

Fig. 5. The signaling procedure of dynamic path adjustment after intercluster handoff

Figure 4 shows the signaling procedure of dynamic path adjustment when path reservation fails for intracluster handoff. Figure 5 shows the signaling procedure of dynamic path adjustment for intercluster handoff, which consists of 11 steps and are needed whatever path reservation succeeds or not.

3.3 Performance Measurements

In order to analyze the proposed method, the performance measurements, such as handoff call dropping ratio, new call blocking ratio, and handoff delay, are defined and shown as follows.

(1) Handoff call dropping ratio (R_{hd})

$$R_{hd} = \frac{N_{hd}}{N_h} \times 100\ \% \tag{5}$$

Where N_{hd} is the total number of handoff calls being dropped, while N_h is the total number of handoff calls in the total observation time.

(2) New call blocking ratio (R_{nb})

$$R_{nb} = \frac{N_{nb}}{N_n} \times 100\ \% \qquad \textbf{(6)}$$

Where N_{nb} is the total number of new calls being blocked, while N_n is the total number of new calls in the total observation time.

(3) Handoff delay

The handoff delay T_{HD} is the time interval between when an MT sends a handoff request message (HO_REQ) and when the MT receives a handoff execution message (HO_EXE). Therefore, T_{HD} can be obtained by summing the times of all signaling messages between HO_REQ and HO_EXE. The handoff delay for the Intracluster handoff with successful preset path is shown in (7).

$$T_{HD} = T_{S4} + T_{S5} + T_{S6} + T_{S7} + T_{S8} + T_{S9} + T_{S10} + T_{S11} \qquad \textbf{(7)}$$

4. Simulation results

4.1 The parameters of the simulated system

Without loss generality, we assume that the simulated system consists 9 clusters, where a cluster has 19 cells and is managed by an ATM switch; a cell has a radius of 500 m. A BS and a switch have the maximum transmission rates of 9 Mbps and 622 Mbps, respectively. We also assume that the network traffic mainly includes voice, video, and data flows with the percentages of 19%, 4%, and 77%, respectively. For voice and video traffics, we assume that the call holding times are exponentially distributed with the means of 3 and 10 minutes, respectively [14], while the transmission rate of data is also exponentially distributed with a mean of 128kbps [15]. The related parameters are listed in Table 5 [14], [15].

Table 5. Numerical values for the different traffic models

Traffic Type	CBR (voice)	VBR (video)	ABR (data)
Percentage	19 %	4 %	77 %
Minimum Transmission Rate	64 kbps	64 kbps	64 kbps
Mean Transmission Rate	64 kbps	256 kbps	128 kbps
Maximum Transmission Rate	64 kbps	512 kbps	512 kbps
Mean Holding Time	3 min	10 min	-
Mean Data Size	-	-	3 Mbytes

4.2 Simulation results

In this section, the performance of EHRS is evaluated and compared with the path extension, anchor rerouting, and dynamic rerouting by simulation.

Figure 6(a) shows for handoff call dropping ratio that EHRS is the best and the path extension scheme is the worst, while the other two schemes perform little better. The path extension scheme simply extends the original connection to the switch connecting the new BS. The original BS will not release the bandwidth after handoff procedure until the connection finishes, hence the path extension scheme occupies more bandwidth and results in greatest handoff call dropping ratio. EHRS presets path and reserves bandwidth for MT in advance, and dynamically adjusts the path to make it optimal after handoff procedure, hence it has least handoff call dropping ratio. Similarly for the new call blocking ratio, EHRS still is the best and the path extension scheme is the worst, while the other two schemes perform little better as shown in Fig. 6(b). The path extension scheme occupies too much bandwidth during handoff and causes new calls having less bandwidth, but the others do not waste so much bandwidth especially for EHRS.

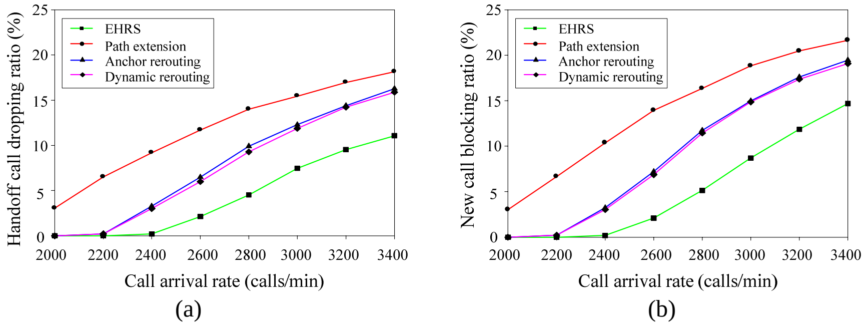

Fig. 6. (a) Handoff call dropping ratio versus call arrival rate. (b) New call blocking ratio versus call arrival rate

Figure 7 shows for handoff delay that EHRS is the best; the anchor rerouting and path extension schemes are the next, but the dynamic rerouting scheme is the worst. The dynamic rerouting scheme has the longest handoff delay, because it has to find out a COS before setting up the path and spends a lot of searching time. EHRS may achieves fast handoff, because EHRS performs the COS discovery and path setup procedures in advance and the new BS simply allocates the required bandwidth for the MT.

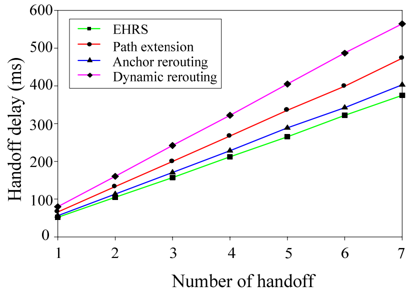

Fig. 7. Handoff delay versus number of handoff

5 Conclusion

In this paper, an enhanced hybrid rerouting scheme (EHRS) is proposed for handoff in wireless ATM networks, which combines the concepts of multicast based rerouting, anchor rerouting, path extension and dynamic rerouting. Basically EHRS uses path reservation before handoff and dynamically adjusts the path to make it optimal after handoff. According to the previous shown results, EHRS has the best performance in handoff call dropping ratio, new call blocking ratio, and handoff delay. Actually, EHRS still is good in other performance issues. In other words, EHRS achieves low handoff call dropping ratio, new call blocking ratio, and handoff delay.

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