A Signaling and Control Architecture for Mobility Support in Wireless ATM Networks

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Abstract

This paper presents a signaling and control architecture for mobility support in a "wireless ATM" network that provides integrated broadband services to mobile terminals. ATM signaling and wireless control capabilities required for mobility services are discussed, and preliminary solutions are given for selected major functions. Potential extensions to standard Q.2931 ATM signaling are proposed to support mobility related functions such as handoff and service parameter/QOS renegotiation. A custom wireless control protocol for supporting terminal migration, resource allocation, handoff, etc. is outlined for a wireless ATM network. Preliminary experimental results validating the proposed handoff control protocol on an ATM network testbed are briefly outlined.

1 Introduction

Wireless personal communication services (PCS) and broadband networking for delivery of multimedia information represent two well established trends in telecommunications. While technologies for PCS and broadband communications have historically been developed somewhat independently, harmonization into a single architectural framework is motivated by an emerging need to extend multimedia services to portable terminals, as well as by service integration and operational efficiency considerations. Given that ATM is now viewed as a universal base technology for broadband networks, it is reasonable to consider extension of standard ATM services into next-generation microcellular wireless/PCS scenarios. In [1,2], the authors propose an architecture for "wireless ATM" in which broadband services are extended over shared radio channels via incorporation of suitable medium access control (MAC) and data link control (DLC) layers [3] into the standard ATM protocol stack. In this paper, we focus on the related signaling and control functions required to support mobility in such a wireless ATM system. While some early theoretical work on the handoff aspects has been reported [4,5], there is no concrete proposal on the actual signaling support for handoff in an ATM network. Further conceptual development is required to define a complete framework for mobility management in ATM.

In this paper, we present a signaling and control architecture for mobility in wireless ATM networks. Section two gives a general discussion on the issue of mobility support in an ATM network. An outline of our "mobile ATM" protocol architecture is provided in section three. Specific handoff procedures and their signaling support is presented in section four. A wireless control protocol for terminal migration, handoff and radio resource management is described in section five. Some early implementation results and their implications are discussed in section six. Section seven concludes the paper. It should be noted that the specific signaling and control architecture presented here represents a preliminary design, and is intended as an early architectural contribution to a topic that will eventually require standardization. We refer readers to earlier papers [1-3] for background information on wireless ATM architecture and user plane protocols.

2 Mobility in ATM Network

In a typical multimedia application scenario, a user will have multiple active connections at the same time. In an ATM network environment, these virtual circuits (VC) will have different QOS requirements. Furthermore, for distributed applications, these VCs may be connected to different end systems. During user migration, the application program should be able to maintain the same connections as the terminal moves from one location to another. The corresponding parties associated with the VCs should not be required to keep track of terminal mobility. Moreover, it should be possible to establish new connections to and from the mobile terminal regardless of location changes. In short, mobility management should be supported by the network, and applications should function transparently during terminal migration[1].

In order to support mobility in an ATM network as discussed above, the network infrastructure needs to have a set of network entities and functions, that, when functioning together, are able to provide the necessary services for the application. First, a wireless access with ATM capability is needed to extend the same type of transport service to the mobile terminals. Second, an ATM signaling protocol that is capable of supporting connection establishments and seamless handoffs when the mobile terminal is migrating across the cell boundaries is required. Third, a scalable addressing and location management scheme that is efficient and able to support both connectionless and connection-oriented traffic in a micro cellular network needs to be established. Finally, a wireless control mechanism is needed for management of radio resources, handoff, etc. among base stations and mobile terminals.

In an ATM network, mobility poses a significant new challenge for network control and management. Handoff of heterogeneous, multi-rate ATM connections must be supported with low cell-loss, latency and control overhead. The QOS constraints for each individual connection need to be satisfied during and after the terminal migration. At the network level, this translates into various issues such as dynamic resource allocation, QOS provisioning and rapid handoff control, etc. It is anticipated that a mobile ATM terminal can experience varying radio/network environments during migration, so that QOS renegotiation

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[1] Optionally, certain location-aware applications may choose to receive location information from the network.

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may also be required when the existing constraints can no longer be met.

3 Architecture Overview

A wireless ATM network is intended to support integrated broadband service to the mobile terminals. Fig. 1 shows a network diagram that illustrates the various network entities and the functions that may comprise such an ATM network that supports mobility.

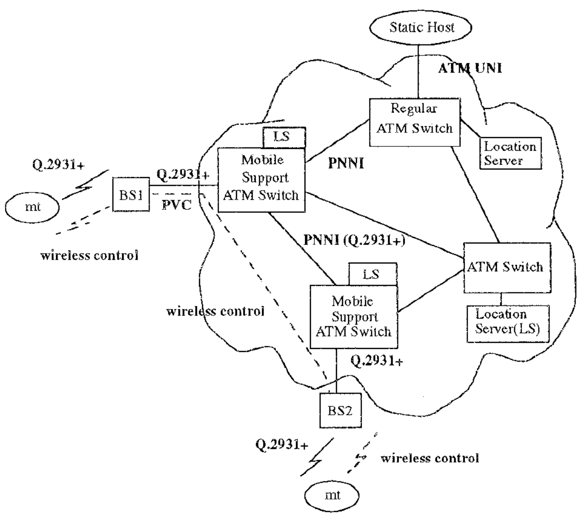

Figure 1: Network elements and associated functions for mobility support in an ATM network

As shown in the figure, the mobile terminal is a full-fledged ATM end system that can support multimedia applications. It will use the standard ATM signaling protocol [6,7](Q.2931, ATM forum UNI3.1) for connection establishment between end systems. The wireless link between the MT and base station provides the desired ATM transport services to the mobile terminal. A mobility enhanced signaling protocol based on the ITU recommendation Q.2931 (termed Q.2931+) is used by the MT, BS, and MSS (mobility support switches) to support handoff related functions. In addition, a wireless control protocol is used between base stations to facilitate wireless resource management and sequential cell delivery during handoffs. This custom protocol is supported via permanent virtual circuits (PVC) between neighboring base stations.

The location registration and resolution functions are performed by the location servers (LS) and database (DB) systems coexists with the network hierarchy. We propose to decouple the location management from the connection management system. Such decoupling permits the independent operation and optimization of location update schemes. It also enables us to efficiently support the connectionless data service in the network.

Our protocol architecture is based on an integration of the wireless and mobility specific functions into the standard ATM protocol stack. The user and control planes are shown in Fig. 2, where the shaded areas represents new layers added for wireless ATM support. The function of wireless MAC and DLC layers is to provide a standard ATM transport service across the shared/unreliable radio channel. The wireless control protocol supports management functions at these layer, while interfacing with higher layer (ATM) control functions. These control plane functions are the primary focus of the following two sections.

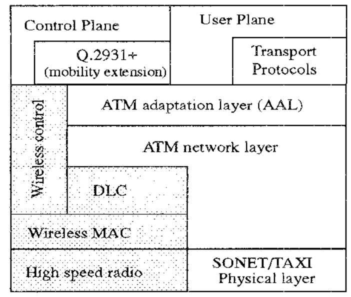

Figure 2: Protocol stack for wireless ATM

4 ATM Signaling Support for Mobility

4.1 VC Segmentation and Rerouting

We observe that in an ATM network, an end-to-end virtual connection is constructed by link-by-link VCs connected through different network switches. In essence, the handoff of a mobile terminal between different base stations is the dynamic re-configuration of the end-to-end VCs under the constraint of QOS requirements of the connections. To simplify the approach, we separate the end-to-end VC into two segments: the static and dynamic segments (note that in the case of connection between two MTs, the end-to-end VC may be separated into three segments, but from the perspective of one MT during re-configuration, the two segments scenario still applies). This is illustrated in Fig. 3, where an MT has three active connections from two remote terminals (RT), one from RT1 and two from RT2. When the MT migrates from the coverage area of BS1 into BS2, these connections are re-configured by creating three new segments from the hand-off switch (HOS) to BS2, and changing the VC routing table at the HOS. This approach introduces the concept of VC grouping, where active connections of the MT are grouped and re-configured collectively.

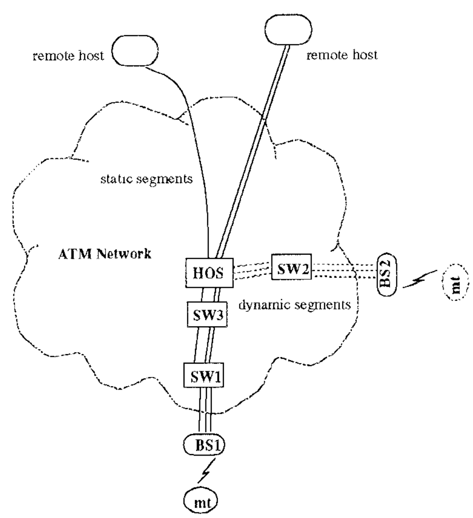

Figure 3: VC segmentation and re-routing during handoff

The Hand-Off Switch (HOS) is the mobility supporting switch that anchors the entire handoff process. By cooperating with BS1 and BS2, the HOS establishes a group of new dynamic segments and then connects them with the original static segments.

4.2 Handoff Procedures

A generic inter-switch handoff scenario is illustrated in Fig. 4. As the mobile terminal migrates away from BS1 and towards the cell coverage area of BS2, it listens to the beacon signals from both base stations. The mobile terminal can suggest when to initiate a handoff from BS1 to BS2 based on its measurements of the BS beacons. The mobile terminal sends an HO_INDICATION signal to the base station using the wireless control protocol (to be discussed later in Sec. 5) between MT and BS. The HO_INDICATION includes multiple potential handoff candidates.

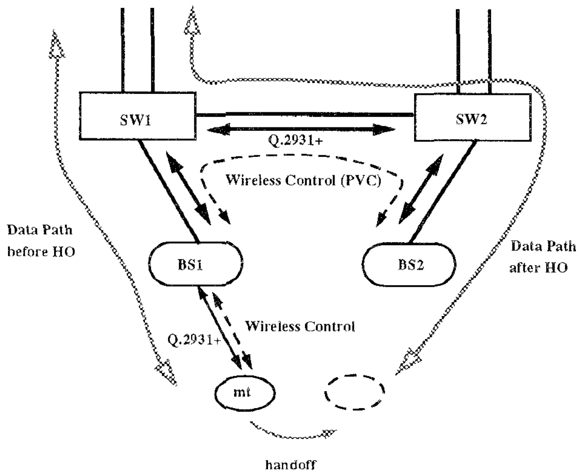

Figure 4: An example of inter-switch handoff

Upon receiving the HO_INDICATION from the mobile terminal, BS1 uses the wireless control protocol between base stations to contact the handoff candidate base stations through the PVC established between base stations. In this case, the primary candidate BS2 acknowledges the availability of resource.

After receiving the acknowledgement from BS2, BS1 sends a "HANDOFF_REQ" message to the handoff switch (selection of the HOS can be based on route optimization for the multiple connections and a series of QOS requirements. It is also possible to have multiple HOSs handle multiple connections. However, for implementation simplicity, we shall assume there is only one HOS). The HOS then establishes a data path to the targeted base station via the fixed network signaling scheme (Q.2931+). After the alternate data path was established, the HOS sends a "HANDOFF_ACK" message to BS1.

Assured of the establishment of an alternate datapath, BS1 sends a HO_START message to the mobile terminal through the wireless control channel. In the meantime, it sends a RT_CHANGE signal to the switch to instruct the switch to change the datapath from the original to the newly established connections. After receiving the HO_START from BS1, the mobile terminal changes its operating frequency and starts communicating through BS2.

From the description above, we summarize the handoff procedure as follows:

- New base station (BS2) identification: Both the mobile terminal and the base stations can coordinate the selection. Usually, a BS beacon serves the purpose of base station identification and SIR/BER measurement.
- HOS selection: The handoff switch can be selected based on the route optimization from multiple connections, and a series of QOS considerations. The easiest selection is the current switch serving the mobile terminal. This is the switch where all the connection to the mobile terminal transit. We thus exclude the possibility that another mobile terminal within the same base station coverage can establish a connection to the MT directly through the base station without involving the switch.
- New mobile segments establishment: A group of new mobile segments are established together between the HOS and BS2, and BS2 can allocate the wireless resources for the mobile terminal before actual handoff.
- VC re-routing: The HOS re-routes the connections by connecting the original static segments with the new mobile segments. At the same time, the BS1 instructs the mobile terminal to switch to the new base station.
- Cell re-sequencing: The old base station transfers the wireless datalink state information to the new base station. This guarantees the in-sequence delivery of ATM cells.
- Route optimization: Optionally, the route optimization can be treated separately from the handoff process, as long as the HOS provides reasonable robustness to avoid obvious loops.

4.3 Signaling Sequence

In our inter-switch handoff example, SW1 acts as the HOS, the signaling flow during the handoff process is shown in Fig. 5. Several signal messages are used to achieve the MT handoff between the two base stations. Since the current ATM signaling protocol standard does not have any mobility support functions, we propose several extensions to the ATM signaling protocols to facilitate mobility support in an ATM network. We are currently implementing these extensions on an experimental ATM prototype. We list the extension signals, their functionalities and the information elements (IE) in Table 1.

The preliminary implementation of the signal extensions listed in Table 1 should be straightforward. Compared with existing Q.2931 and ATM forum UNI 3.1 standards, these new signals merely add additional information elements into the message contents, with little modification of the syntax. A signal extension for point-to-point multiconnection call control, similar to the M_OPEN_REQ, is also being studied in the ITU Study Group 11 [8].

The issue of backward compatibility arises when communication links between HOS and the base station transit through other regular ATM network switches. In the example of Fig. 3, the HANDOFF_REQ message transits through SW3. If SW3 is a regular network switch that doesn't support mobility extensions, it is difficult for the HANDOFF_REQ to function transparently across SW3. If SW3 has mobility support extensions, it can interpret the message and issue a similar HANDOFF_REQ to HOS with different connection identifier and call reference values. This is a general question concerning NNI signaling, where signal encapsulation might be employed as a possible solution and is beyond the scope of this paper. Here we assume that the HOS communicate directly with BS1, and all network switches support mobility.

4.4 QOS Renegotiation and Provisioning

Another signaling function of importance in the mobile scenario is that of service parameter and QOS spec-

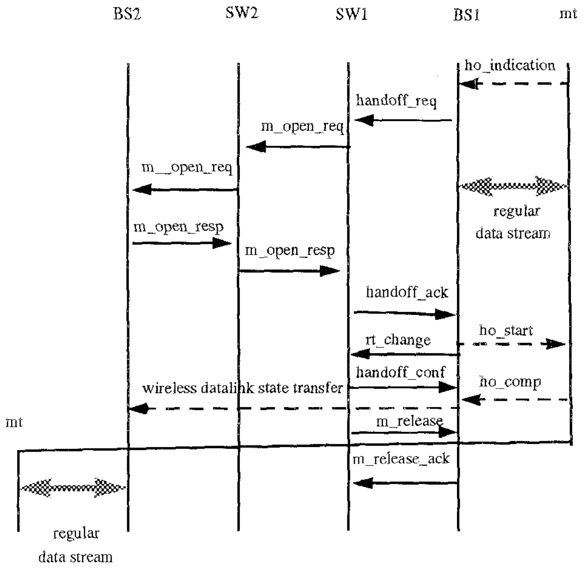

Figure 5: Signaling sequence during a mobile handoff

ification and renegotiation in the presence of heterogeneous/variable radio channel bandwidth. When an ATM call is established to a mobile terminal, the available service parameters may be lower than that requested in the connection message, most often due to radio channel limitations. In this case, a suitable "fallback" mechanism which sets up a connection with the highest available bandwidth parameters will be needed. This type of fallback function is useful in conventional fixed network scenarios as well, although it is not specified in the current ATM Forum UNI specification. For mobile terminals which operate in highly variable environments, we are considering provision of a CONNECT (..,new service parameters,..) message in response to a SETUP (..,service parameters,..) message.

In addition to service parameter fallback at call setup, mobile terminals encounter variable service availability due to handoff migrations. For example, a mobile operating a CBR connection at 2 Mbps might find that only 1.5 Mbps is available in the new microcell after handoff. In this case, a suitable RENEGOTIATE (..,service parameters,..) syntax is required to provide for in-call adjustment of service parameters. Once again, this type of capability is useful in fixed networks as well as a robust mechanism for dealing with congestions, outage, etc. For the wireless ATM scenario, this renegotiation capability is viewed as extremely important since frequent handoff events will otherwise result in relatively high call termination rates. Of course, not all applications will be able to operate over a range of bit-rates, but it is anticipated that well-designed mobile software applications will incorporate such capabilities.

QOS specification is another important aspect to be considered in mobile ATM. Current ATM signaling provides for QOS specification in the standard SETUP message, but does not specify how this QOS budget is to be allocated between each segment of the route (some discussion is currently in progress in the PNNI working group at the ATM Forum). In the wireless scenario, a larger QOS degradation budget (i.e. CDV, CLR and delay) needs to be allocated to the wireless link in view of intrinsic radio channel characteristics, and performance implications of MAC and DLC protocols used on the access link. For example, if a total delay budget of 30 ms is specified, it might be appropriate to allocate 20 ms to the radio link and 10 ms to the fixed network segment, thus permitting the use of relatively powerful DLC modes [3] for low CLR. Thus, it may be useful to augment current ATM syntax to specify a partition of QOS between wired and wireless network segments. Once again, this type of capability is needed in fixed ATM as well, particularly when dealing with heterogeneous link speeds and switch buffer sizes. A possible mechanism is to extend current SETUP syntax to include both total and next hop QOS values. Note that as discussed earlier for service parameters, renegotiation of QOS during handoff is also an important feature for the mobile ATM scenario.

5 Wireless Control Protocols

In addition to the network layer signals, described in Section 5, a separate set of wireless control messages are necessary for supporting mobility related functions at the lower layers of the protocol stack (see Fig. 2). Primary functions of the wireless control protocol include terminal migration, handoff and other wireless resource management related operations.

A functional classification and behavioral descriptions of the wireless control messages are outlined in this section. Also, a summary of the used messages can be found in Table 2. Note that the wireless control message syntaxes may need further modifications as the design evolves.

5.1 Between Base and Remote

Wireless control message exchange between the base and remote terminals is necessary in the following situations. These control messages are sent in a connection-less fashion where the remote terminals use a set of random access slots and the base stations use the control slots allocated at the beginning of each MAC layer frame [2].

5.1.1 Power-Up Sequence

On power-up, a remote terminal scans its audible frequencies and finds out the base stations which it can hear with acceptable signal to interference ratio (SIR). After it chooses the best audible base unit, the remote and its chosen base follow a message exchange sequence in order to complete the authentication, registration and signaling channel setup procedure.

The message REGISTER_REQUEST is sent with a globally unique identifier of the remote terminal. On reception of this message the base station consults with a suitable authentication server in order to decide about the entry of the remore terminal in the network. An additional pair of messages, namely, REGISTER_CHALLENGE and REGISTER_PASSWORD, provide another level of security[2] from illegal network access of a personal terminal.

On successful completion of the authentication procedure the base sends a REGISTERED message indicating the temporary terminal ID. of the remote. Note that this terminal ID. is used as a part of the wireless VCI[3] and is valid only within the present wireless cell. If the base station refuses to register the terminal or the authentication procedure fails at any stage, a REGISTER_FAILED message is sent back to the remote entity. Also, if the base station malfunctions, the remote can timeout and try to get registered with some other base unit. Upon reception of a

[2] The authentication operation, however, can be optionally carried out through signaling channel after the terminal registration procedure is completed.

[3] A wireless VCI comprises of the hop destination terminal ID. and a VC number, assigned by the remote entity [3].

REGISTERED message, a remote terminal confirms it by sending a REGISTRATION_CONFIRM message. These also act as a set of meta-signaling messages. By the end of this registration procedure, a signaling channel with a pre-defined VCI number is setup both ways for exchanging the network layer signaling messages, outlined in Section 4.

5.1.2 Remote Migration

During migration, when a remote terminal starts noticing a very low SIR value, it initiates an SIR measurement cycle for all the frequencies of the neighbor cells[4]. After the measurement is done the remote sends an HO_INDICATION message to the base, specifying all its audible frequencies and their corresponding SIR status. The base entity uses an inter-base protocol to find out the best possible new base station for the migrating remote terminal. Once decided, an HO_START message is sent back to the mobile unit with the new base station identifier and a terminal ID. assigned by the new base station. The remote then sends back an HO_COMPLETE to confirm the reception of HO_START.

Note that these HO_INDICATION and HO_START messages are necessary for a terminal migration even if there are no virtual circuits to be handed over. Once migrated, both the remote terminal and the new base station start using the newly established signaling channels for other signaling purposes.

In cases where the remote terminal is equipped with only one receiver, while scanning the local frequencies it has to stop communicating with the host base station. In order to handle this situation, another pair of control messages, namely, MEASURE_START and MEASURE_DONE, are used by the remote to instruct the host base station to stop downlink data transmission during the measurement period.

5.1.3 Disconnection

Disconnection occurs when a remote terminal leaves a wireless cell without following the proper exit manners. This usually happens during a power failure or a sudden uncontrollable degradation of signal quality. Such situations require to be detected reliably so that the base can release all the resources tied with the disconnected mobile unit. The option of providing *keep alive* mobile beacons has been dropped on the ground of its excessive requirement of the scarce remote battery power.

Under the present scheme, the host base unit queries (with the message CONNECT_QUERY) about a registered remote terminal's presence only if it notices no activity of the mobile for a specific period of time. Message CONNECT_REPLY is used by the remote as a reply to the above query. Since the present MAC layer protocol [2] requires a base station to periodically transmit MAC frame headers, a mobile terminal can easily detect base station malfunction by listening to those periodic frames.

5.1.4 Power Control

A power control message ADJUST_POWER is provided for enabling a base entity to control the transmission power of its registered mobiles. Note that a base station can also use these messages for informing the remote terminals about the frequencies of the neighboring wireless cells.

[4] A list of neighbor cell frequencies are passed on to the remote by the host base.

5.2 Between Base Stations

Wireless control messages between the base stations are necessary for handling the following situations.

5.2.1 Selection of New Base

During migration of a remote terminal the host base entity needs to consult the relevant neighbor bases for choosing an appropriate wireless cell to transfer registration of the migrating mobile. Once received an HO_INDICATION from the remote, the base sends REGISTRATION_TRANSFER_REQUEST message sequentially to all those base stations whose frequencies are sent down from the remote through the HO_INDICATION request. A REGISTRATION_TRANSFER_REQUEST contains the details of all the connections to be handed over, with their QOS specifications. If the recipient base station is willing to accept the remote's registration, it replies with a REGISTRATION_TRANSFER_ACCEPT message; otherwise a REGISTRATION_TRANSFER_REJECT is sent back to the host base station. REGISTRATION_TRANSFER_ACCEPT message contains the new terminal ID. assigned for the remote terminal. If no reply is received by the host base within a specific time period then it sends a REGISTRATION_TRANSFER_REQUEST to the next neighbor base from the HO_INDICATION frequency list.

5.2.2 Datalink State Transfer

In order to efficiently handle the ATM cell out-of-ordering problem during a connection handoff, it is necessary to transfer the wireless datalink state[5] of the connection from the old base to the new one. For implementing the present group connection handoff scheme, state information of all the connections of a remote are marshalled together and sent as a single RPC message, SEND_DATALINK_STATE, through a preset permanent virtual circuit between the old and the new base stations. Exact timing of the SEND_DATALINK_STATE message is indicated in the handoff signaling sequence, shown in Fig. 5.

6 Handoff Control Implementation

In order to test the practicality of our handoff procedures and evaluate its performance, we have implemented a preliminary version of the handoff signaling in a test network environment. The network configuration is shown in Fig. 6. Two Sparc 10 workstation emulating the base stations are connected to a Fore ASX-100 switch using TAXI interfaces. One Sparc 2 workstation is used as a static host. The operating systems on all the workstation and the ASX-100 switch are SunOS 4.1.x.

The experiment involves a round-trip transfer of data packet of fixed size (it is similar to the standard 'ping' utility program, but using native ATM transport rather than IP, thus termed 'ATMping'). The 'ATMping' resides on the "host" and periodically sends packet through ATM transport (AAL3/4) to the 'echo' client that resides in the base stations. When the connections are handed over from one base station to another, the 'ATMping' data packets will be lost if the cell stream of the data packet is broken by the VC routing table change on the switch, or the received packet cannot be returned to the server after the routing change. The sequence of events during the handoff experiment is depicted in Fig. 7.

[5] A typical datalink state [3] includes VCI, traffic class information, transmission and reception tables, outstanding cell sequence numbers and datalink cell buffers.

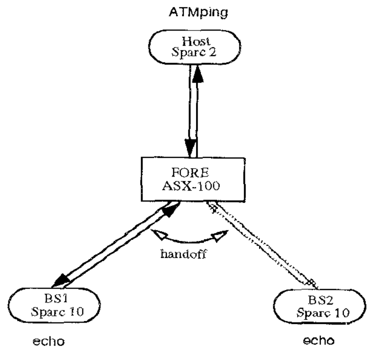

Figure 6: Network configuration for intra-switch handoff

Both the ATM device driver on the workstation and the signaling software on the ATM switch signaling software were modified to realize the handoff scheme proposed in section 4. During the experiment, the 'echo' clients were started at both base stations, and the "host" established two unidirectional VCs with one base station for the 'ATMping' program. The handoff is triggered by a software signal generated with a random time interval. The experiment showed that the 'ATMping' application continues to operate when the VCs are handed over from one base station to another. This successfully demonstrated that handoff in an ATM based cell-relay network can be achieved with relatively simple modification of the switch control software and addition of new signal messages.

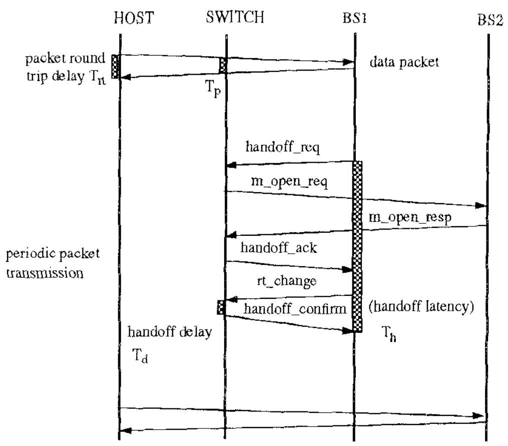

Figure 7: Sequence of events during handoff operation

Our preliminary experiments focused on two performance parameters. First, the time delay from the start of HANDOFF_REQ to the receipt of HANDOFF_CONFIRM. This is the handoff latency T_h in Fig. 7. Second, the time delay T_d for changing the VC routing table on the switch for multiple VCs (in the case of the experiment, two VCs).

The handoff latency T_h is the time taken for the wired network operation during the handoff process. Although this number does not directly affect the cell loss and delay for the mobile terminal, the longer the wired network delay, the earlier the mobile terminal should start handoff before the wireless channel deteriorate. T_h depends on the amount of signaling messages, their propagation delay and processing delay in the wired networks. In our experiment, under light traffic conditions but with the overhead of UNIX OSs, T_h is measured to be 10ms $\sim$ 20ms.

The other measurement: handoff delay T_d gives the minimum time the switch takes to change the VC routing table. This number is directly related to the cell loss rate cause by the handoff in our experiment. Our measurement gives T_d to be 1ms $\sim$ 3ms.

It should be noted that the present handoff measurement did not include the factors related to the wireless link. Further implementation using wireless ATM access links with an 8Mbps radio [9] modem in the 2.4GHz band will be reported in the future.

7 Conclusion

With ATM technology playing an increasing important role in the future broadband network, it is natural to expect the emergence of "wireless ATM" networks enabling multimedia access for mobile end systems. Consequently, mobility support in an ATM network assumes an increasing importance. In this paper, we have presented a signaling and control framework for supporting mobility in a wireless ATM network. Our preliminary design calls for several mobility extensions in the current Q.2931 signaling protocol to support handoff and service parameter/QOS selection. A wireless control protocol for management of radio resources and handoff between base stations and terminals has been outlined. Experimental implementation indicates that handoff support in a wireline ATM network can be achieved with relatively small interruption in the application (i.e. handoff latency in the range of 10ms to 20 ms and handoff delay in the range of 1ms to 3ms). It is recognized that further work on design and validation of mobility signaling and control functions will be required before a viable specification emerges. We believe that standardization discussions on this topic should be initiated in the near future by applicable ATM Forum and ITU committees.

8 References

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Signal Message	Functions	Arguments
HANDOFF_REQ	Request HOS to initiate handoff	MT address, new BS address, multiple connection identifier
HANDOFF_ACK	Acknowledgement of HANDOFF_REQ	MT address, new MT ID, new BS address, new connection identifiers
M_OPEN_REQ	Establish multiple connections	MT address, new BS address, multiple connection identifier and QoS parameters
M_OPEN_RESP	Acknowledgement of M_OPEN_REQ	MT address, new MT ID, multiple connection identifier and QoS parameters
RT_CHANGE	Request changing routing table at HOS	MT address, multiple connection identifier
HANDOFF_CONFIRM	Acknowledge of RT_CHANGE	MT address
M_RELEASE	Releases multiple connection from BS to HOS	MT address, multiple connection identifiers
M_RELEASE_ACK	Acknowledgement of M_RELEASE	MT address, multiple connection identifiers

Table 1: Extended signal messages, their usage and information elements

Control Message	Function	Arguments
REGISTER_REQUEST	Registration initiation	Unique hardware Id.
REGISTER_CHALLENGE	Authentication query	MT name/addr., secret code
REGISTER_PASSWSD	Authentication reply	Password
REGISTERED	Registration acceptance	Temporary terminal Id.
REGISTER_FAILED	Registration rejection	Reason
REGISTER_CONFIRM	Registration confirmation	Temporary terminal Id.
HO_INDICATION	MT migration initiation	List of audible bases, SIR measurements
HO_START	Instruct MT to switch base station	New base Id,. new terminal id., VCIs
HO_COMPLETE	Confirmation of migration	New base station Id.
MEASURE_START	MT strats power measurement	-
MEASURE_DONE	MT compl. power measurement	-
CONNECT_QUERY	MT disconnection detection	Temporary terminal Id.
CONNECT_REPLY	Reply to the above	
ADJUST_POWER	Power control	Temporary terminal Id. and power info.
REGISTRATION _TRANSFER_REQUEST	Request for terminal registration transfer	MT address, UPC and QoS for all connections
REGISTRATION _TRANSFER_ACCEPT	Acceptance of registration transfer request	MT address, new terminal id.
REGISTRATION _TRANSFER_REJECT	Rejection of registration transfer request	MT address
SEND_DATALINK_STATE	Datalink states transfer from old to new base	MT address, All relevant datalink state info.

Table 2: Wireless control messages and their usage