Title: Wireless Mobile Terminal/Network Anchor Switch Handover Model

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Abstract: This contribution details the handover strategy and signalling requirements for an anchor switch handover model. We propose that the anchor switch model should be supported as a WATM release 1.0 specification handover architecture.

1 Introduction

The handover protocol should allow a wireless mobile ATM terminal (WMT) or mobile ATM network (MN) to seamlessly move between wired network access points (APs) while maintaining the negotiated Quality of Service (QoS) of its active connections. This can be achieved by using efficient signalling protocols combined with the efficient rerouting and switching of the WMTs/MNs virtual connections (VCs) to the appropriate AP.

This contribution details the handover strategy and user plane signalling for a handover protocol currently being developed at the Olivetti Research Laboratory (ORL). A lightweight version of this protocol has been implemented and is currently being used to allow a prototype wireless ATM terminal to handover between APs that are directly connected to the ORL ATM network infrastructure. The performance of this handover protocol is being evaluated by marking cells with a GPS time stamp and sequence number thereby allowing the measurement of cell delay, cell delay variation, cell ordering and cell loss during handover for a variety of wired and wireless network conditions.

The location management, security, wireless call admission control, local connection ID and buffer management aspects of the anchor switch handover protocol are not discussed in this contribution but will be the subject of future contributions to the ATM Forum.

The simplicity of the anchor switch model combined with the use of user plane signalling lends itself to an early practical implementation. We propose that an anchor switch model, as outlined in this contribution, is supported and defined as a handover model for the WATM Release 1.0 specification.

2 Handover Model

The anchor switch (AS) handover model uses a selected network switch (AS) to route the WMTs connections for the attachment lifetime of the WMT to a given network. This type of model uses the concept of VC grouping to provide collective management of a WMTs active VCs at the selected AS. The AS could be assigned to the WMT at start of day registration by the registering AP or by some external management entity.

User plane signalling over AAL5 is used for all handover protocol messages. Switched user plane channels are used to link software entities located in the AS, AP and WMT. Rather than using a reliable transport protocol, which is not designed to work over a radio channel, the signalling software incorporates acknowledgement messages and timers to counter any possible message corruption or loss – this gives the state machines full control over retransmission policies during handover. The use of user plane signalling connections in the wired network also reduces the handover latency by avoiding the switch by switch processing delay associated with UNI/NNI signalling.

The software used to support the user plane handover signalling protocol need only be located in the AS, AP and WMT. There will be no requirement for any other network switches to support this software and there will be no modifications to UNI and NNI signalling.

The handover model is very simple, supporting two types of handover procedure. The handover is said to be either a connected or disconnected handover. As the WMT roams into a new AP radio coverage area then the WMT must register with the new AP before initiating either a connected or disconnected handover.

- *Connected Handover*: This occurs when the WMT is still in contact with the current AP before it initiates the move to the target AP. (The complete definition for this type of handover as defined in ATMF/96-989 is a connected hard backward handover.)

- *Disconnected Handover*: This occurs when the WMT has lost contact with the current or target AP and reconnects with the network but not necessarily via the AP used before disconnection occurred. (A disconnected hard forward handover.)

- *Registration*: Every time a WMT attaches to a new AP it must register with that AP. The registration phase is also used to assign an AS to the WMT at start of day operation and to complete security and authentication checks.

A simple example network will be used to illustrate the registration and disconnected/connected handover procedures. This network includes a number of end-user mobility-supporting ATM switches. These switches, known as anchor switches (AS) in this protocol model, simply carry the signalling and management software stacks that support communication between AS, AP and WMT. A visitor location management (VLM) service, that can be located in either switch, AP or external servers, caches security, local network location and home/foreign address binding information of all visiting WMTs. Communication with the VLM is also carried out over switched user plane connections.

3 Handover Procedure

3.1 Registration

Registration occurs at the start of day for a WMT or at handover whether it be connected or disconnected. If the network has no knowledge of the WMT at registration then the WMT could be registering for the first time or may be performing a disconnected handover where the disconnection time was such that local cached information had timed out and the network resources reclaimed. In this situation a new AS will be allocated. If the network has prior knowledge of the WMT then the WMT is probably performing a connected or disconnected handover and an AS may not have to be allocated. The start of day registration procedure is as follows. Referring to Figure 1:

Step 1) WMT1 monitors the AP ID information transmitted by AP1, AP2 and APxxx. This information is used to generate a table of available AP IDs based on a performance metric associated with the radio channel between the WMT and APs.

The WMT may have to use software ID filters to stop channel measurements being made on APs that are in radio adjacent networks or in networks that the WMT has no desire to connect with. In this example, AP1 has been selected as the target AP for WMT1 to register with. APxxx belongs to another network and is ignored.

Step 2) Meta-signalling uses a single cell to establish a communication channel across the air interface between the WMT and AP. WMT1 meta-signals the target AP, AP1, with a **HandoverRequest( )** which contains an ID for WMT1. AP1 binds this ID with a VPI and passes back the allocated VPI that will be used for all signalling and data transfer to and from WMT1 with **HandoverRqReply( )**. Each WMT registered with the AP has a unique VPI.

The ID used to identify the WMT could be the ESI MAC address of the WMT or for security reasons a random 48bit number. The ID stored at AP1 will then be replaced by the WMT1 home address after security keys have been exchanged and a secure encrypted communication channel established between the WMT and AP.

Public key security models have been considered, but not implemented, for this handover protocol. Details of these security models will not be discussed in this contribution.

Step 3) WMT1 sends AP1 its full (encrypted) home address with **NameResponse( )**. AP1 can now replace the WMT1 ID used at the meta-signalling stage with WMT1s home address.

Step 4) AP1 now tries to register WMT1 with the VLM using **RegisterMobile( )**. If no information is cached about WMT1 then the VLM contacts the home register of WMT1 to obtain security and authentication information.

Step 5) If the WMT is not registered then an AS is allocated by the VLM, in this case AS1. All call connections for WMT1 will now pass through AS1. The VLM generates a foreign address for WMT1 and sends AS1 details of WMT1s home/foreign address binding and current AP with **AllocateAS( )**.

Step 6) If the registration was successful then the VLM signals AP1 with details of the allocated AS with **RegisterMobileReply( )**.

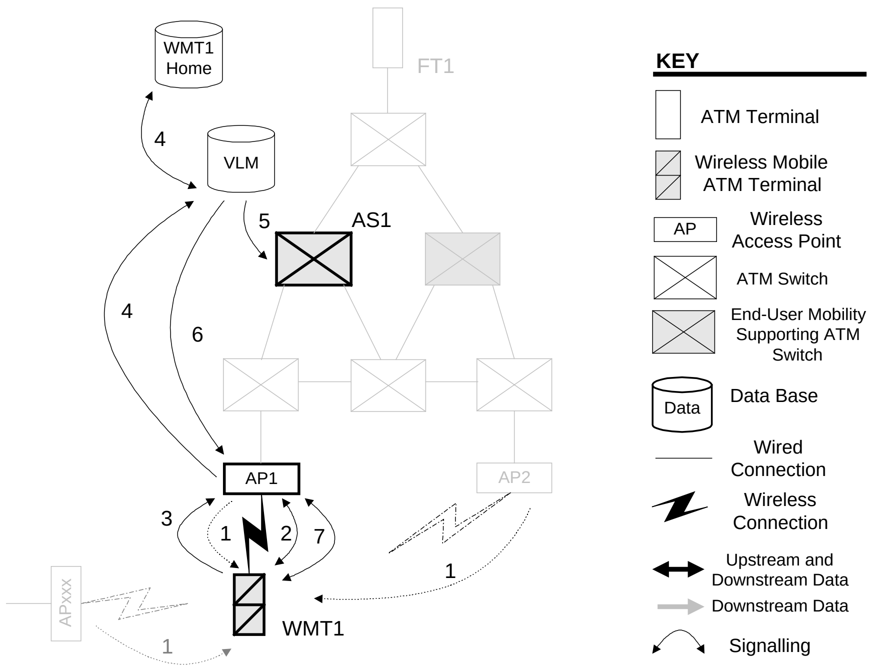

Figure 1. Start of Day Registration of WMT1 with AP1.

Step 7) If all security and authentication procedures are complete and WMT1 was successfully allocated an AS then AP1 signals **HandoverComplete( )** to WMT1, otherwise it signals a **HandoverFail( )**. WMT1 responds with **HandoverCompleteAck( )** or **HandoverFailAck( )**.

3.2 Connected Handover (WMT Initiated)

As WMT1 roams through the network a different AP may be required in order to continue the established call connections. In this example the WMT initiates the handover to the new AP by measuring the performance of the radio channel between the WMT and available APs. The WMT could then interrogate the candidate AP to see if the QoS of the WMTs established VCs can be supported. Indeed the network may wish to initiate the handover of a WMT in order to load balance the radio channel resources between APs. Referring to Figure 2:

Step 1) WMT1 monitors the AP ID information transmitted by AP1 and AP2. WMT1 selects AP2 as the target AP to handover to. WMT1 is still connected to AP1 so it can initiate a connected handover.

Step 2) WMT1 signals AP1 with a **HandoverInitiate( )** indicating the target AP, AP2, that it wishes to handover to. AP1 acknowledges the handover initiation with **HandoverInitiateAck( )**. AP1 then signals AS1 with **HandoverIntiate( )**, AS1 acknowledges. AS1 then signals AP2 and AP2 acknowledges. Information about the call connections and the WMT1 registration information can be transferred in the **HandoverIntiate( )** messages. If the handover cannot be supported then a **HandoverFail( )** message is propagated back to WMT1.

Step 3) After AS1 receives the AP2 **HandoverInitiateAck( )** then the new handover segment to AP2 is created using standard SETUP messages creating a duplicate set of VCs from AS1 to AP2.

Step 4) As soon as all the VCs are complete to AP2, then AS1 signals AP2 with **PathComplete( )**, AP2 acknowledges. Once AS1 receives the acknowledgement, then all downstream traffic is switched from AP1 to AP2 by AS1.

Step 5) AS1 signals AP1 with **HandoverReady( )**. AP1 acknowledges.

Step 6) AP1 then signals WMT1 **HandoverReady( )** and after WMT1 acknowledges then WMT1 changes channel to AP2.

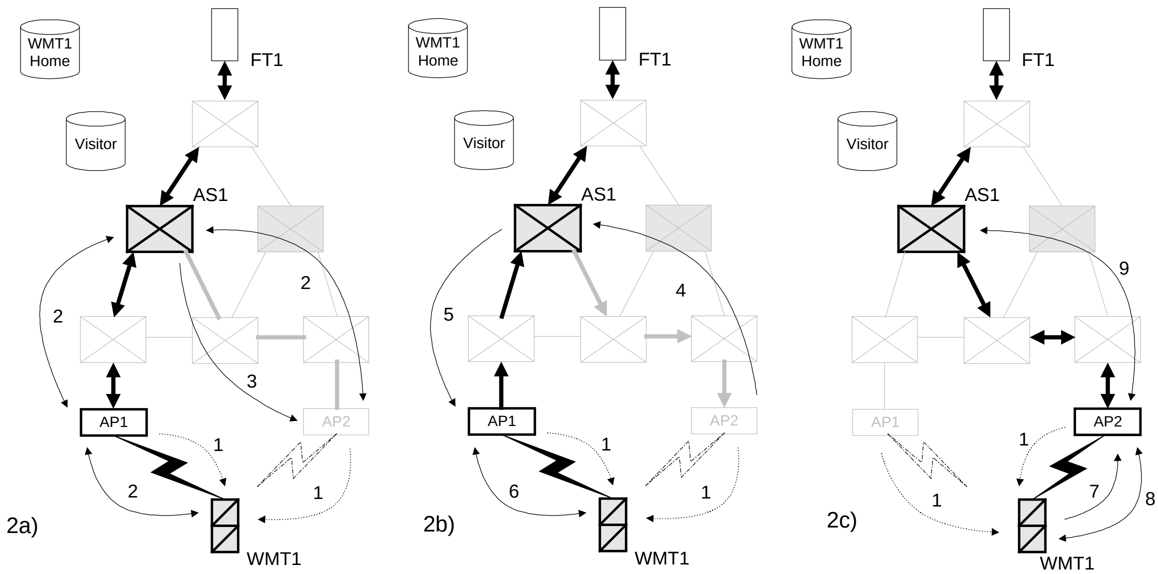

Figure 2. WMT1 Initiated Connected Handover to AP2.

Step 7) WMT1 starts the registration process with AP2. Information about WMT1 has been passed to AP2 in the **HandoverInitiate( )** message and so after a VPI is established only WMT authentication checks need to be completed.

Step 8) If the registration process was successful then AP2 will signal WMT1 with **HandoverComplete( )**. WMT1 acknowledges.

Step 9) As soon as AP2 receives the WMT1 acknowledgement then it signals AS1 with **HandoverComplete( )**. AS1 acknowledges this and switches the upstream traffic from AP1 to AP2.

Step 10) AS1 then RELEASES the old handover segment to AP1. As the foreign address of the WMT1 is topologically significant to AS1, no location management update information has to be sent to the home location register.

3.3 Disconnected Handover

The disconnected handover will occur when the WMT loses contact with the current AP. There will be time out period after which all call connections will be lost. A number of procedures can be implemented to try and recover the original call connections after the WMT has re-attached with the network. In this example we assume that the VLM still contains cached information about WMT1. Referring to Figure 3:

Step 1) WMT1 has become disconnected from the AP it was registered with. AP2 is an alternative AP that WMT1 has detected.

Step 2) WMT1 registers with AP2. A VPI is established in the normal way and WMT1 sends AP2 its full home address using the signalling outlined in the registration phase.

Step 3) AP2 checks to see whether the WMT1 has been assigned an AS by interrogating the VLM. If no cached information exists then the registration process continues as for a start of day registration.

Step 4) If cached information does exist in the VLM for WMT1 then WMT1 is probably in a disconnected handover state. AP2 obtains the allocated AS, AS1, and signals AS1 to SETUP a new handover segment to AP2.

Step 5) AS1 signals a **PathComplete( )** and AP2 returns a **PathCompleteAck( )**.

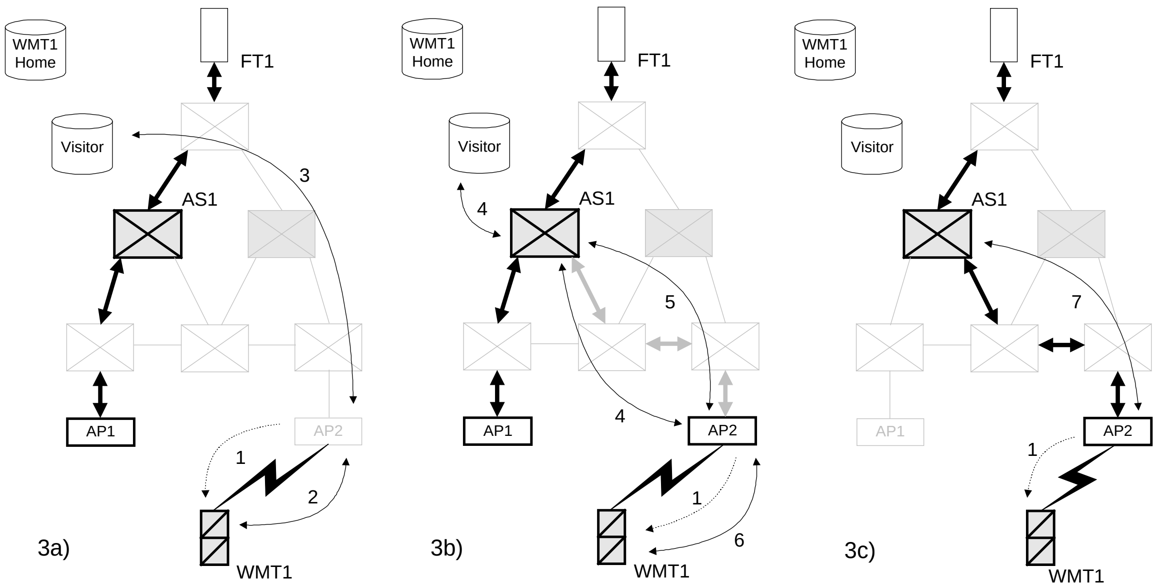

Figure 3. Disconnected Handover to AP2.

Step 6) If the new segment SETUP was successful then a **HandoverComplete( )** is sent to WMT1. WMT1 acknowledges.

Step 7) AP2 signals AS1 with a **HandoverComplete( )**. AS1 acknowledges and RELEASES the connections to AP1. The connections are switched in AS1 to AP2 and the WMT1 calls are reconnected.

There is the possibility that the disconnected handover could re-attach to the original AP that WMT1 was connected to. In this case WMT1 still has to register with the AP and be authenticated but obviously an AS does not have to be allocated and a new handover segment does not have to be created. The original call connections can be maintained with only a VPI update being required at the AP.

4 Handover Model Discussion

The handover model described in this contribution uses an anchor switch to re-route all of the WMTs call connections in the wired network. Another VC re-routing handover model, described in ATMF/97-0125, is the dynamic cross-over switch (COS) model that uses a search to find an anchor switch for each active connection that a WMT/MN has open.

There are a number of requirements set out by the ATM Forum that the handover model should satisfy. These handover requirements are proposed in ATMF/96-989 and further detailed in ATMF/97-0153. The first requirement in ATMF/97-0153 is that of handover latency. For the sake of brevity, handover latency will be the only performance metric used to discuss the handover models in this contribution.

Requirement: *Handover Latency ATMF/97-0153.*

a) *The total time for the completion of the handover should be appropriate for the rate of mobility of the WMT or MN.*
b) *The handover period should be such that that the handover decision is still valid for the new WMT/MN position after the handover process is complete.*
c) *The switching of data paths in the selected network switch should also be as efficient as possible in order to minimise disruption to cell transport.*

In order to achieve the above requirements the handover latency must be kept to a minimum and must not be significantly affected by the number of active VCs that a WMT is using. The time taken to handover a WMT/MNs VCs can be broken down into three distinct time periods:

T1) Time taken to search for a switch that can be used to set up the new segment of the VC to the new AP. This period is highly dependent on the switch search algorithm used.

T2) Time taken to create the new VC segment from the selected network switch. Each new VC segment will be created using standard signalling. The time taken to complete the set up of the segment will be highly variable and will depend on the number of switches and the processing load at each switch in the new path.

T3) Time taken to break the old data path and re-make the new data path establishing data flow to the WMT/MN via the new AP.

The advantages and disadvantages of the anchor switch handover model described in this contribution are compared with the dynamic COS switch model for each time period T1, T2 and T3.

Period T1) Switch selection.

Anchor Switch: The anchor switch has already been selected at registration. All VCs are being routed through this switch.

+ No switch search time at handover.
+ Wired network does not have to be completely mobile enabled (ME).
- Possible sub-optimal path of the VCs at connection set up due to anchor switch position. (Dependant on anchor switch selection and availability.)

Dynamic COS: The path of each VC must be traced back to an “appropriate” switch in the network. This is achieved by performing a COS selection function in each switch on the VC path.

+ Does not require a management entity to select an anchor switch on WMT/MN registration.
+ No network constraints placed on VCs at connection set up.
- Possible high degree of latency dependant on the number of VCs and number of switches in search.
- Implications for backward compatibility.
- COS selection algorithm likely to produce sub-optimum routes.

Period T2) Establishment of VC segments from selected switch to new AP.

Anchor Switch: The anchor switch will receive a command via the old AP to start establishing connections to the new AP. The switch will then signal the old AP when these connections are complete.

+ One command can be used to signal and acknowledge the establishment of all VCs ready for handover.
- Possible sub-optimum routing of new segments dependant on selected anchor switch position in network.

Dynamic COS: The establishment of new VC segments from the selected COS switch will probably take place as soon as the COS switch is discovered. Acknowledgements must be passed back to the old AP when all the segments have been established for all VCs.

+ A more optimum route for each new VC segment may be created.
- High signalling overhead and increased latency as each VC is controlled independently.

Period T3) Switch data paths in selected switch. With all VC segments established the data paths can be switched at the selected switch to start data flowing to the WMT/MN via the new AP.

Anchor Switch:
+ Low signalling overhead as only one signal sent to switch.
+ Efficient group switching of VCs in anchor switch leading to lower handover latency.

Dynamic COS:
- High latency and signalling overhead due to independent signalling to each COS for data path switching.

5 Conclusion

There are a number of performance advantages and disadvantages associated with the use of an anchor switch handover model. This contribution has discussed the relative merits, in terms of handover latency, for the anchor switch model over that of a dynamic COS handover model.

The simplicity of the anchor switch model combined with the use of user plane signalling lends itself to an early practical implementation and we believe that it should form the basis of the handover model in WATM Release 1.0 Specification. A lightweight version of this model has already been implemented on a prototype wireless ATM network and is currently being used to obtain performance measurements in terms of cell transport and switch processing overheads. Results from these performance tests will be the subject of future ATM Forum contributions.

6 Motion

6.1 Support the use of an anchor switch as discussed in this contribution in the WATM Release 1.0 Specification.

6.2 Support the use of user plane signalling over AAL5 for handover messages in the WATM Release 1.0 Specification.