Location Management in Wireless ATM Networks

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The ATM Forum's View as of April 1998 towards location management in wireless ATM networks.

Abstract

The ITU's choice of ATM as a reference implementation of B-ISDN networks strengthened by the combination of legacy protocols over ATM as the foundation of the new very-high-performance Backbone Network Service (vBNS) show the significance of this particular network technology in the future. Besides, the international telecommunication industry tends more and more to integrate wireless and wireline services. This vision of seamless wireline/wireless services ongoing with a corresponding network infrastructure will help the providers to reduce administrative costs — a major market-driven aspect which most properly influenced the ATM Forum to speed up its work on a wireless ATM specification.

This paper will present the ATM Forum's view as of April 1998 towards location management in wireless ATM networks. After an abridged introduction to the area of "wireless" and "mobility", a general but brief overview of location management in wireless ATM networks will be given. The capital part of the paper will illustrate the two possible solutions to integrate location management services in wireless ATM networks: the mobile–PNNI scheme approach and the location register scheme approach.

Introduction

"WIRELESS" DOES NOT MEAN "MOBILITY"

Even though most of today's articles consider wireless computer equipment to automatically go along with the feature of being mobile, the ATM Forum does clearly differ between wired versus wireless and fixed versus mobile equipment.

A desktop computer, e.g., located within a building with a poor (wired) network infrastructure might be attached to the computer network using a *wireless* network adapter. It is very unlikely that the user of the desktop computer will move with it (frequently) to another building or even go with it to another room. The computer, i.e., the offered services, can be assumed to be *fixed* even though we have a wireless connection to the net.

On the other hand, a lecturer travelling around the world with his notebook might connect the latter with a (traditional) coax cable to the network of the company where he is giving his speech. If his notebook employs a mobile-IP protocol stack, he works as if he were located at his home office. Even though he is "wired", the notebook would be considered to be *mobile* as its user cannot tell a difference no matter wherever he is working.

For being both *mobile* and *wireless*, a mobile phone is properly the best known example. Therefore, the idea of a mobile, wireless terminal will be followed throughout this paper.

GENERAL REQUIREMENTS FOR SUPPORT OF MOBILE TERMINALS

If a communication partner has to be aware of the current location of a mobile user[1], the call set-up turns out to be a very unfavorable procedure. For simplicity, a *non–changing unique identification number (ID)* should be used for connection setup. Actually, it should make no difference for an interlocutor whether a mobile or fixed terminal is called. *The terminal's aspect of being mobile is invisible.*

WHAT COMPRISES LOCATION MANAGEMENT?

When a terminal is considered to be mobile, certain actions are essential in the context of location management. The terminal has to *register* itself whenever it moves from one network to another (i.e., from the network coverage of one provider to another) or *update* the information on its current position if moving within a constantly covered network area of one provider. Instead of actively updating its location information, the network can also keep track of the mobile's current position, i.e., *location tracking*.

The strict differentiation between location registration and location update/tracking derives from the fact that certain network policies have to be enforced depending on the provider. E.g., a provider might allow users who have a contract with him to use the NFS feature when accessing files on a server whereas foreigners (i.e., visiting users who booked in the net) might not be favored this privilege. This is done during the registration procedure whereas the update/tracking does only include the change of information leading to the mobile's current location.

LOCATION MANAGEMENT REQUIREMENTS AND FUNCTIONALITIES

Current documents on location management identify several requirements towards location management but only a few can be identified which do not directly deal with offered services by network providers.

As a mobile user might want to have network access even though the provider with whom he has a contract does not supply a network infrastructure at the users's current location, means of using someone else's infrastructure are essential. To be able

1. In the following, no difference is made between mobile users and mobile terminals as it is assumed that a one-to-one relationship between user and terminal exist. The previous example of a mobile phone shows that this is not always the case. If calling someone on his mobile phone, the dialled number identifies the person as it is stored on a chip card within the phone. This card can be seen as a "fingerprint" of the user whereas for the actual call-setup, the equipment's identification number (which in turn is associated with the phone number) is used. But to differ between terminal and user mobility in the context of location management is like splitting hairs and therefore not considered.

to utilize foreign networks (i.e., *roaming*) the latter has to be identified by a *(globally unique) network id*.

Besides all, the providers interest to *minimize the signaling load* in order to save bandwidth which can be sold is as clear as the fact that the network's infrastructure should be *scalable* to facilitate future expansions.

Considering these basic requirements, functionalities to be employed are directly derived: A mobile terminal must be able to *recognize its Point of Attachment (POA)*, i.e., to see if it is located in its home or foreign (visiting) network. As for call-setup purposes, a globally unique ID is preferred which does not represent the mobile's current location and is therefore not usable for routing, a *temporary address (TA) must be assigned to the mobile terminal*. Additionally, procedures to *propagate the mobile's reachability information*, i.e., basically the relation between the mobile's unique id (which can be considered as its "home address") and its assigned temporary address revealing its current location, have to be implemented.

The mobile–PNNI Scheme Approach

The mobile–PNNI scheme approach can be seen as the solution of the "network society" to the question of how to achieve mobility in ATM based networks.[1]

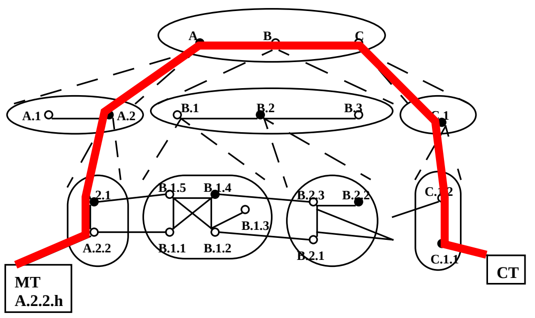
The best way to illustrate how the mobile–PNNI scheme works is to illustrate four central situation:

- a mobile located in its home network,
- how a mobile moves (and registers) in a foreign (visiting) network,
- a calling terminal which is "within scope" of the mobile, and
- a calling terminal which is "out of scope" of the mobile.

MOBILE LOCATED IN HOME NETWORK

The mobile terminal (MT) with its home address A.2.2.h is located in its home network; it is connected to node A.2.2 (see Figure 1). Any calling terminal (CT) will employ the mobile's home address in order to set-up a connection. As the mobile is connected to its home node, the routing information within the mobile's home address are valid and the call is directly forwarded to the mobile. This scenario holds also for every connection set-up to a terminal being "fixed" and is the same in networks not supporting mobility.

FIGURE 1. Mobile located in Home Network



1. If the reader is not familiar with the PNNI concept, it is recommended to have a look at section "How does PNNI comprise Reachability Information?" on page 13 first.

MOBILE MOVES IN FOREIGN NETWORK

FIGURE 2. **Mobile Registers in Foreign Network**

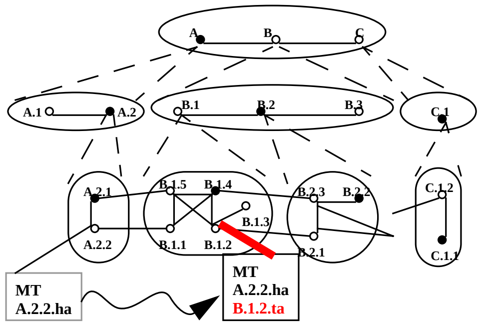
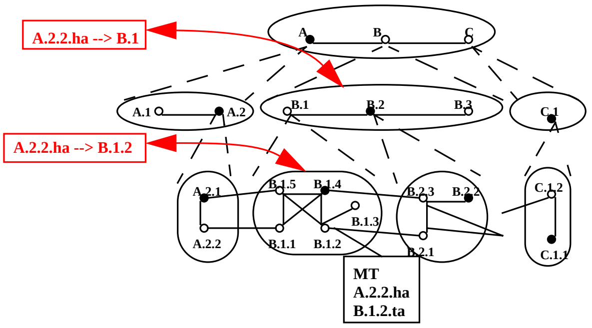


Illustration 2 shows a mobile terminal moving from its home network to a foreign network. As soon as the mobile recognizes its new point of attachment, i.e. B.1.2, the registration procedure is started and a temporary address (TA), i.e. B.1.2.ta, is assigned to the mobile. As the TA's structure shows, the assigned address represents the MT's current position, i.e., any call set up to B.1.2.ta will automatically be routed to the mobile employing the existing PNNI routing mechanisms.

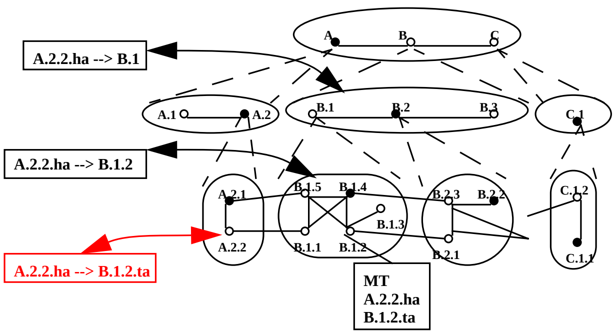
FIGURE 3. **Propagation of Reachability Information**



Now that the MT has registered within the foreign network, the reachability information has to be flooded in order to allow calls to be set up to the MT. (Note that any calling terminal will use the MT's HA for a connection set-up causing the call to reach the MT's home node, i.e. A.2.2, where the MT is no longer.)

Within pear group B1, an entry in the routing table of the mobile-enhanced PNNI protocol showing the relation between the MT's HA and TA is made. This information is well-know to all nodes within this pear group whereas a summarized version is distributed "upwards" by the pear group leader. In pear group B, only the information that the MT with the HA A.2.2.ha can be reached via the pear group B.1.

FIGURE 4. **Setting Forwarding Pointers at MT's Home Switch**



As the correlation between the MT's HA and TA is not indefinitely flooded due to constrains to any additional signaling load caused by mobility enhancements, a pointer at the MT's home node indicating the current POA of the MT has to be set. The flooding of reachability information is illustrated in figures 3 and 4 correspondingly.

CALLING TERMINAL WITHIN SCOPE OF MOBILE

FIGURE 5. Calling Terminal within Scope of Mobile

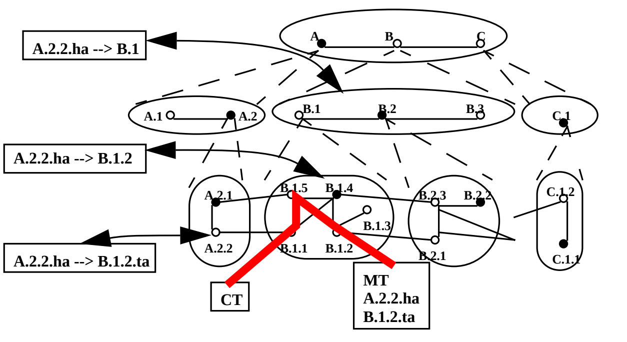
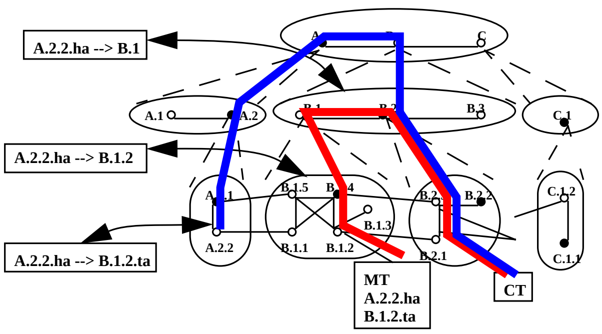


Figure 5 depicts the situation where a calling terminal (CT) sets up a call to the MT. As both, the CT's and MT's POA is within the same pear group, this situation is commonly referred to as "within scope".[1] The CT would utilize the MT's HA for connection set-up. As soon as the call request reaches node B.1.1, the latter's routing table has an entry resolving the MT's HA to its current TA. Based on that TA, the call can be directly routed to the MT's current POA (i.e., B.1.2).

CALLING TERMINAL OUT OF SCOPE OF MOBILE

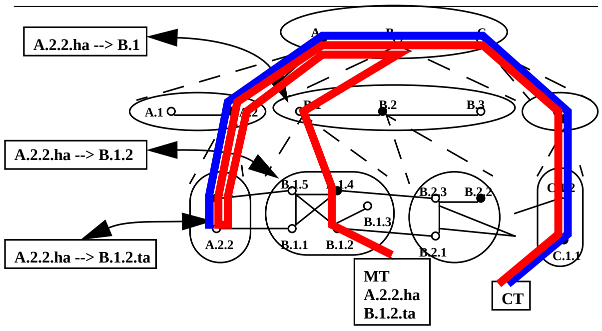
FIGURE 6. Calling Terminal Out of Scope of Mobile (I)



A terminal located in pear group B.2 would on the other hand to be considered "out of scope" as shown in figure 6. Again, the CT would try to set up a connection to the mobile based upon the HA. As no relation between the HA and TA can be found within the pear group's routing tables, the call will be forwarded based upon the mobile's HA (and would eventually reach the mobile's home node A.2.2). As the call follows the regular setup path, it passes pear group B which has an entry within its routing table about the MT's HA. It can be resolved to the (summarized) address B.1 and the call is routed based upon this new location information. As soon as the call reaches the pear group B.1, the exact POA can be determined due to the routing table entry resolving the MT's HA to the address of its current POA. This example shows that a call does not necessarily has to reach the mobile's home network as it might passe any level in the PNNI hierarchy that holds information about the MT's current location in its routing tables. Just to complete the picture, figure 7 illustrates the "worst case" where a call would reach the mobile's home node before a relation between HA and TA can be resolved. The call is forwarded from the MT's home node to the mobile's current POA. (Please note that this will result in a sub-optimal path. Nevertheless, optimization is possible as indicated in the section "Route Optimization" on page 11).

1. The terminus scope is used in the PNNI contents to refer to the "number of levels" where reachability information is distributed to. As the nodes (i.e., POAs) the MT and CT are attached to have a common set of reachability information, i.e., the relation between the MT's HA and TA, both terminals are within scope.

FIGURE 7. Calling Terminal Out of Scope of Mobile (II)



ADVANTAGES AND NEGATIVE ASPECTS

One of the most apparent advantages is that PNNI does already allow the exchange of reachability information. Additionally, an explicit location phase for MTs is not necessary; the information about the mobile's current location is integrated within the network's routing information. Locating the mobile can basically be done "on the fly". One aspect of the mobile–PNNI scheme and a major difference to the location register scheme presented in the following is the fact that the current address space can be kept. (Later on, the need to separate the address space to define a terminal to be mobile due to its distinguishable ATM address will be shown.[1]) The obvious and most counting negative aspect of the discussed mobile–PNNI scheme is the need for a new (changed or enhanced) PNNI protocol.

The Location Register Scheme Approach

The location register scheme approach is a solution of the challenge to integrate location management in ATM networks from another point of view. Even though, at a first glimpse, it looks very much the same as the mobile–PNNI scheme (which is obvious, as both tackle the same problem), the location register approach represents the perspective of the (mobile) telephone society which is trying to adapt its current technical solutions, e.g., used in GSM telephone networks, to the needs of an ATM based network.

WHAT COMPRISES A LOCATION REGISTER?

Basically, a location register is a database storing information on a MT's current POA. For simplicity, they are referenced by the node's address they are located at even though a location register is a *separate entity* and could theoretically be located somewhere besides a node within a peer group.[2] Its primarily task is to track mobiles within the peer group the location register is located at. Additionally, location registers can be hierachically organized. (Usually, one location register would be used for each pear group which allows a similar summarization of data as in the mobile–PNNI scheme.) With respect to one specific MT, location registers are commonly

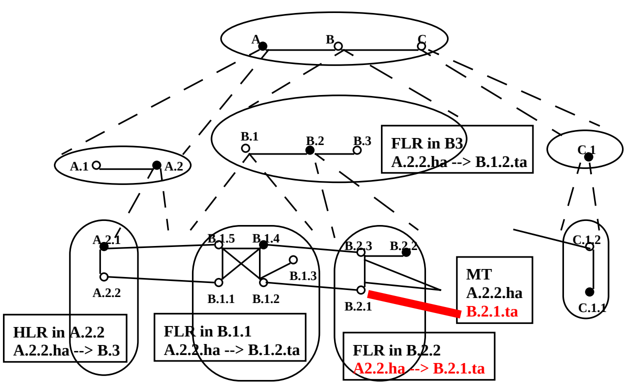
1. The ATM Forum does not consider address space separation to be a problem.
2. Of course, this is an academic view as the database has to be accessed via the computer storing the information and the latter is usually the node itself. The situation is comparable to, e.g., the Xwebster program. Even though the computer (node) running the program is not important at all when talking about the functionalities of Xwebster, the program cannot be accessed or used without "knowing" the computer at which it is running.

referred to as home location registers (HLR), i.e., the one located within the mobile's home network / peer group, and foreign location register (FLR) which are responsible for other peer groups.

MOBILE MOVES IN FOREIGN NETWORK

Figure 8 shows the situation where the MT has just moved into another foreign (visiting) network. It registers within network B.2 via its POA (i.e., B.2.1). During this procedure, the FLR is asked to assign a TA to the MT which will also be stored in the FLR itself. (A closer look at the picture also reveals the MT's former POA: The FLR responsible for peer group B.1 still holds reachability information about the mobile's former POA, i.e., B.1.2. The HLR and the FLR in B.3 do also hold the "old" reachability information.)

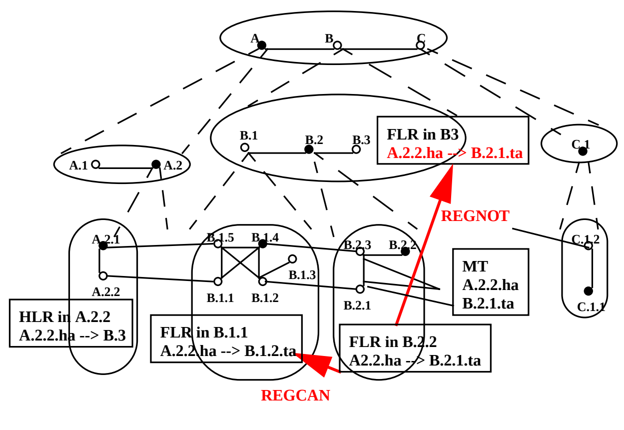
FIGURE 8. Mobile Registers within Peer Group



Now, the FLR in B.2.2 has to actively inform the other LRs about the change of the MT's location. Therefore, a *registration cancel* request is send to the LR of the peer group the mobile came from, i.e., the FLR in B.1.1, which in turn flushes its entry and forwards the registration cancel request upwards. All entries in FLRs will consecutively be removed unless the request reaches a FLR which is common ancestor to the mobile's old and new position.

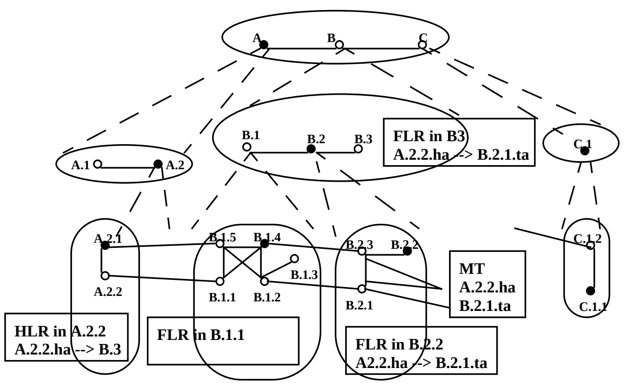
In addition, a *registration notification* is send upward to the LR that is the common ancestor of the MT's former peer group and its current, i.e., the FLR in B.3. This request "updates" the entry associated with the mobiles HA. This procedure is illustrated in figure 9.

FIGURE 9. Update of Reachability Information in Foreign Location Registers



Also note that an update of the mobile's HLR would only be necessary if the registration cancel request would finally reach a FLR which is not a common ancestor (which corresponds to the registration notification request reaching an upper most FLR which does not hold reachability information about the MT), as the HLR of the mobile does only track the upper most FLR storing location information. This procedure results in a minimized signaling load. Illustration 10 shows the contents of all LRs after all necessary updates have been performed.

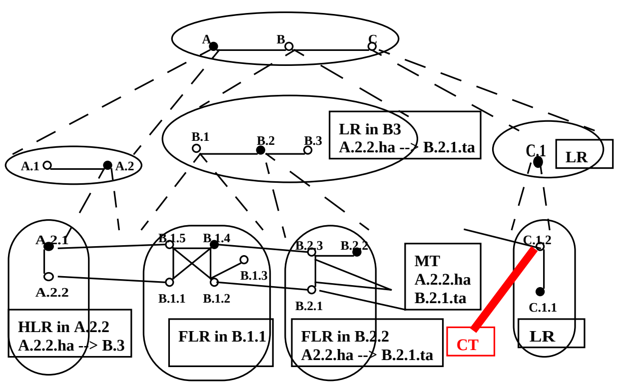
FIGURE 10. Location Registers after Update Procedures



CALL-SETUP TO MOBILE TERMINAL

If a connection is requested to a MT in the location register paradigm, a CT (which is as in figure 11 attached to node C.1.2) will start with a regular connection-setup request. The first node being "mobile enhanced" (i.e. being able to recognize the terminal's address to which a connection is requested to be the one of a mobile[1]) interrupts the regular PNNI-supported connection-setup phase. Afterwards, LRs are probed to find out about the MT's current location.

FIGURE 11. Initiation of Connection Set-Up



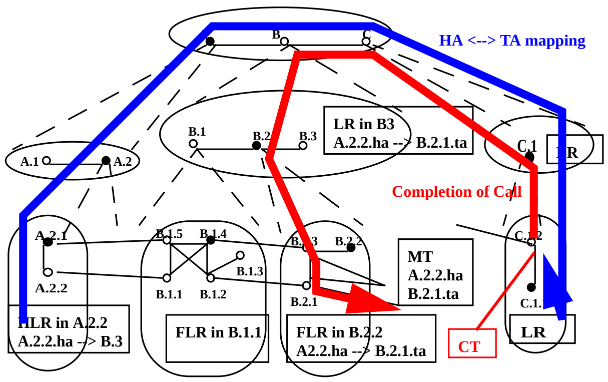
First, the node sends a location request to its own LR. If the latter one, as in our example, does not have a valid entry, the request is consecutively forwarded to the next upper hierarchy of LRs. Finally, if the most upper LR cannot answer the request either, it is passed to the mobile's HLR which will definitely points to a valid entry.

The first LR to have a valid entry in its look-up table returns the mobile's TA to the CT's POA. Now, the call can be completed as shown in figure 12 based on the current PNNI protocol's routing mechanisms using the MT's TA.

1. Here it becomes obvious that an address separation is needed in order to differ between "regular" and "mobile" addresses as a connection-setup request to a fixed mobile does not need to result in an location request.

It is worth noting that even the CT is fixed (and does therefore not necessarily be attached to a peer group with a LR), the connection request to any mobile terminal does eventually pass a node which is able to identify the address to be a mobile's and consecutively prompt its LR. In the worst case, this node is the MT's POA itself.

FIGURE 12. **Call Completion after Prior Localization Phase**



Additionally, the fact of having an explicit prior location phase before a routeable address is actually returned to the MT's POA should be noted.

MOBILE LOCATED IN HOME NETWORK

The scenario describing the MT being located in its home network is comparable with a connection setup to a fixed terminal even though a prior location phase does still exist.

ADVANTAGES AND NEGATIVE ASPECTS

Obviously, the location register scheme approach isolates the effects on current PNNI implementations. Mobility support can be achieved by simply adding additional functional entities (i.e. the LRs) to dedicated "mobile-enhanced" nodes which need to be able to identify a terminal's address to be mobile. For simplicity, the LR database might be placed within peer group structures.

The side-effect of an address space separation coming along with the location register scheme approach is not considered to be a problem by the ATM Forum's working group responsible for ATM addresses.

Route Optimization

Even though route optimization is necessary in order to avoid wasting network resources, it is not primarily subject of location management. Nevertheless, a short look at it might prevent some questions arising during the lecture of papers related to location management.[1]

FORWARDING AND COMPLETE RELEASE

As seen before in the mobile-PNNI scheme approach, a connection setup request that reaches the mobile's home network before a valid entry resulting in a routeable TA's can be found will lead to "worst case" paths as the call will simply be forwarded. On the other hand, the best possible path to the mobile's current location could be obtained if a "complete release" would be performed; this is comparable to the explicit location phase in the location register scheme approach as the mobile's TA would be returned to the CT's POA which in turn results in the best possible path

1. For a deeper understanding of routeoptimization, the reader needs be get familiar with the designated transit list concept (DTLs) of the PNNI protocol.

to the MT due to regular PNNI routing algorithms. Most of the time, after “re-establishing” the route from the CT’s POA, parts of the path that were previously torn down are used again. Therefore, finding a way to identify the point from which on the (worst) path differs from the best one due to the complete release concept is the challenge.

PARTIAL RELEASE

Today’s PNNI does already support a such called crank-back mechanism, i.e., identifying alternative paths to the target address. This is actually used to bypass defect nodes but can also be used for routeoptimization during the setup phase to mobiles.

If the first node where the address resolution between the mobile’s HA and TA takes place performs a crank-back to its prior node, the latter one can identify which path it would choose based on the (just obtained) TA. If the next hop in this new path is the node which the crank-back request derived from, the (local) decision based upon the old address, i.e. the HA, was optimal. The call is returned to the same node.

If the comparison identifies another path to be optimal based on the new TA, the node will initiate a crank-back request to the next upper node consecutively.

Finally, the crank-back request will reach a node that had already chosen (based on the HA) a local optimal path and will reject the crank-back. Now all other nodes that are passed to find the way to the mobile will base its routing decisions on the TA which results in an optimal path.

Summary

Even though on the first glimpse, the mobile-PNNI scheme and the location register scheme seem to be the same (both utilize local look-up tables for entries describing the relation between HAs and TAs) they do slightly differ as the two approaches derive from the computer networking perspective and the cellular telecommunication’s point of view.

The mobile-PNNI scheme integrates information about the mobile’s current location in its routing information. This leads to an extremely low setup-delay; suboptimal paths are easily resolved applying the existent crank-back mechanisms. Nevertheless, this approach results in a new (enhanced) version of the PNNI protocol which is less likely to be favored as a smooth transition towards mobility support.

Despite the mobile–PNNI scheme, the location register scheme requests the separation of the ATM address space into “mobile” and “fixed” addresses which is not considered to be a problem by the responsible ATM Forums’s working group. By far more counting is the fact of an explicit (prior) localization phase resulting in high set-up delays. Nevertheless, this side effect might be accepted as the current PNNI protocol does not to be changed as the location management functionalities are integrated in separate entities.

Current contributions seem to be slightly in favor for the location register approach to coexist with current PNNI implementations.

Appendix

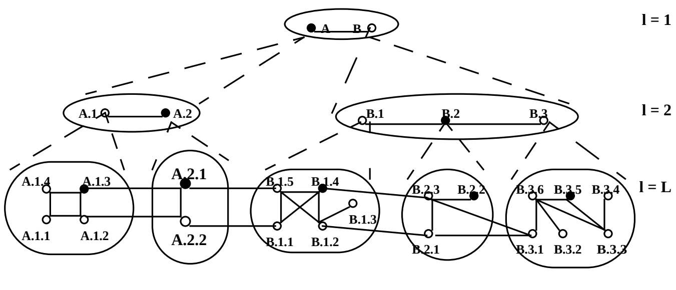
LIST OF ABBREVIATIONS

CT	Calling Terminal
FLR	Foreign Location Register
HA	Home Address
HLR	Home Location Register
LM	Location Management
LR	Location Register
MT	Mobile Terminal
POA	Point of Attachment
REGCAN	Registration cancel
REGNOT	Registration Notification
TA	Temporary Address
WATM	Wireless ATM

HOW DOES PNNI COMPRISE REACHABILITY INFORMATION?

PNNI is the routing protocol applied in private ATM networks. It allows the distribution of topology information which are hierarchical grouped and enforces source routing mechanisms (using such called designated transit lists) in addition to its ability to bypass point-of-failures using alternative routes by its crank-back mechanism.[1]

FIGURE 13. Hierarchy of PNNI–based Network



PNNI summarizes network nodes within pear groups which can be compared to logical subnets in IP. Reachability information is accumulated by one special node, i.e., the pear group leader. The latter in turn represents its pear group in higher hierachical levels as it “knows” everything about its pear group. Again, representatives in higher levels may again form pear groups in which pear group leaders aggregate information about their particular group. An example of a hierachical ATM network is illustrated in figure 13. Node A.1.3, e.g., is the pear group leader and collects reachability (routing) information about all nodes in group A.1; therefore, it can represent the entire group in the next higher level, i.e., pear group A, as (the virtual) node A.1. Again a pear group leader is elected (A.2) representing pear group A.

As shown before, pear group leaders summarize reachability information about all its descend pear groups. This compressed information is afterwards flooded to other

1. For a more detailed introduction into PNNI concepts, please refer to [14], especially as some comparisons found in the following may not hold proof but are nevertheless used for simplicity and illustrational purposes.

pear groups. If, e.g., node B.2.1 wants to reach node A.1.1, it has the information that this can be done via the most upper pear group (level l=1). Therefore a call-setup will be forwarded to the (virtual) node B which in turn knows to reach A.1.1 via node A. Finally the node passes A.2, A.1, and finally A.1.1. During this procedure, the so called designated transit list is built which holds afterwards the "physical" way the call will follow (i.e., B.2.1, B.1.2, B.1.5, A.2.1, A.1.3, A.1.4, A.1.1).

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