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Simulation Study of Proposed Handoff Signaling in Wireless ATM Cellular Networks

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Abstract: - ATM protocols do not implement *Hand-off* functions that are required to support wireless users. *Complementary Signaling* solution is proposed to implement handoff functions in an ATM network context to support mobility of wireless users. *Complementary Signaling* uses switched ATM connections to encapsulate mobility related signaling messages between wireless-to-wire line inter-working nodes at the edges of the backbone ATM network and does not require any changes to the existing ATM protocols.

Key-Words: - Wireless Networks, Cellular Networks, Handoff, ATM

1 Introduction

Wireless and cellular today are seen as access and extension technologies of IP networks and, therefore, must be able to support guaranteed IP QoS parameters. The demand for mobile broad-band communication caused the European Telecommunications Standards Institute (ETSI) to create the Broadband Radio Access Networks (BRAN) Project. The project makes available various technologies for the access to wired networks in private as well as in public environments and offers bit rates up to 155 Mb/s

The project started with the goal of specifying a W-ATM-based air interface for applications and started close cooperation with the ATM Forum's WLAN group in June 1996. The W-ATM idea has been strictly followed and it was planned from the start that an ATM-based WLAN should be able to support any broad-band network-based service up to a WLAN's bandwidth limitations according to the service classes known from ATM networks.

2 Wireless ATM Network Architecture

Wireless ATM network architecture is based on the *location area* concept. An example of a location area in the wireless ATM network is depicted in Figure 1. A location area consists of radio stations, radio controllers and wireless ATM node equipments. The wireless ATM network is designed as a micro-cellular network according to literature [1], [2], [7]. The typical coverage of a radio station in a micro-cellular network varies between half a kilometer to one kilometer [l]; therefore, a fairly large number of radio stations are required in order to maintain full coverage of a given geographical area. Consequently, the radio stations in a micro-cellular network must be economical radio modems that are small enough to be placed on rooftops and utility poles. The radio controllers control the access to the shared radio resources of the wireless ATM network during call setup or handoff. Radio controllers are responsible for allocation of resources to wireless users and relaying signaling requests from the wireless users to the wireless ATM nodes

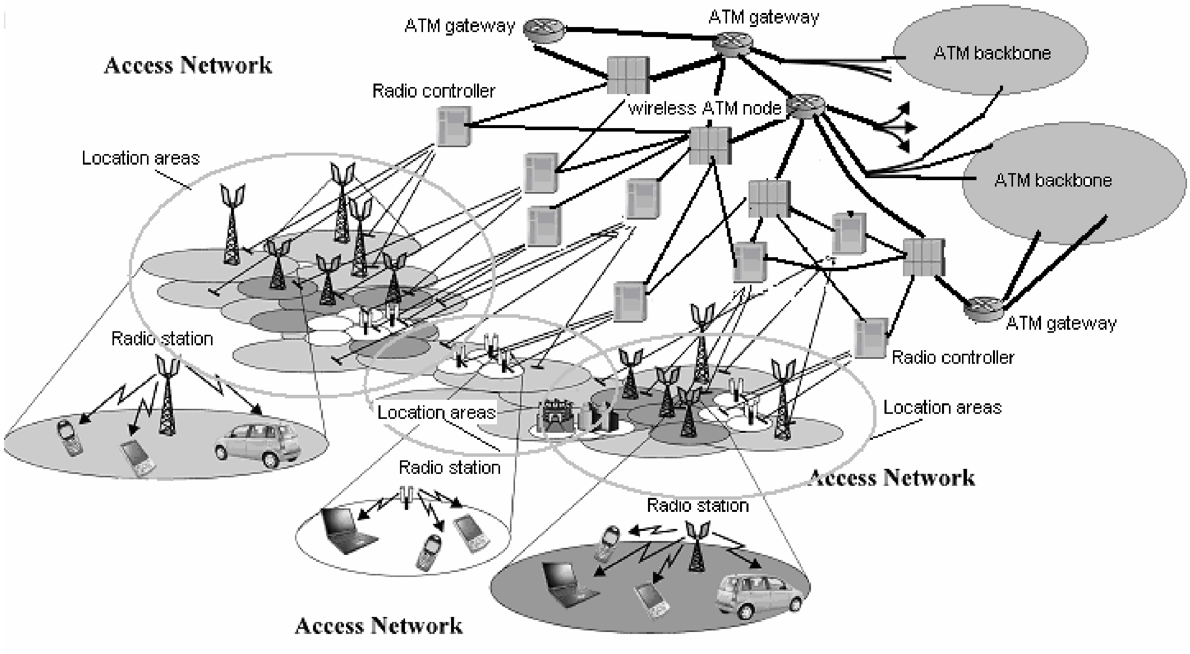

Figure 1: Location Area architecture of a Wireless ATM network

2.1 Location Area

Our wireless ATM network architecture consists of location areas [6], wireless ATM network backbone and gateways to the wire line ATM network (ATM gateway node) as depicted in Figure 1. Each location area incorporates the signaling functionality required to support mobile users. Via the use of location areas, the wireless ATM network architecture is a completely distributed network. Dividing the wireless ATM network into location areas, we also reduce the addressing granularity of the wireless ATM network. The radio stations and radio controllers have only local significance within the location area. In terms of locating and routing connections to wireless users, the wireless ATM network only considers the location area of the user and not the particular radio station. In the other direction, the location of the user needs to be updated only when the user moves between the location areas.

The ATM gateway manages the flow of information to and from the wireless ATM network to the wire line ATM networks, mostly during wire line to wireless calls or vice versa. The ATM gateway is necessary to support connections between the wire line ATM network users and wireless users and is responsible for performing location resolution functionality for wire line network users as described in [4]

3 Signaling Modifications

In order to support wireless users in the previously described ATM architecture, it is needed to adapt the handoff procedures used in existing wireless communication networks [1], [5] to function in a pre-existing wire line ATM network. The motivation for implementing a complementary overlay signaling network is to remain compatible with the existing ATM protocols [9]. Since there are no modifications to the ATM protocols, the complementary signaling approach does not require any modifications to existing wire line firmware ATM infrastructure. As the messages flow from the wireless ATM nodes to the wire line ATM network and vice versa, the necessary handover info is encapsulated in the standards ATM messages structure and can be interpreted from the ATM gateway nodes. Moreover in a more compact version the ATM gateway and the wireless ATM node can merge to a unified node.

3.1 Complementary Approach to Wireless ATM Signaling

In this section we discuss the network transactions that are related to supporting user mobility in a wireless ATM network and suggest how they can be implemented using the ATM User Network Interface (UNI) signaling protocol [3]. The network transaction under study, related to user mobility is Handoff. Location areas are interconnected by a wireless ATM network backbone using the ATM signaling in order to establish connections through the ATM network. The radio stations and portables belong to the wireless network exchanging wireless network signaling messages in order to support the needs among the users and the wireless ATM network. The wireless network signaling messages are encapsulated into ATM cells and transmitted through the wireless ATM backbone network to their destinations.

Handoff will be implemented, according to the ATM Connection Setup Procedure without any modification, using the complementary signaling approach. In the description of ATM Connection Setup Procedure, there are five messages involved. The *SETUP* message, between the calling party to the ATM network and the ATM network to the called party, includes the called party address info, the ATM user cell rate (ATM traffic descriptor), broadband bearer capability and QoS parameters. The *CALL PROCEEDING* message, between the ATM network and the calling user, after the authentication of the calling user to inform the calling user that the process is proceeding and waiting for the connection. The *CONNECT* message, send from the called user to the ATM network and from the ATM network forwarded to the calling user. The *CONNECT ACKNOWLEDGE* message, to inform the ATM network that the *CONNECTION* message has been received and the user is now in active mode, ready to receive ATM cells. Finally the *RELEASE* message, send from the user that terminates the call session to the ATM network

3.2 Handoff using Complementary Signaling

Handoff is the transfer of a user's radio link between radio stations in the network. The *inter-location area* handoff occurs between two radio stations that belong to two different location areas. The inter-location area handoff process depends on its implementation in the wireless network and it is portable initiated. The portables monitor the link quality in terms of received signal power to candidate radio stations and when the link to another port becomes better, that port is selected and handoff is initiated. The link quality is determined by the portables because only the portables can determine the quality of links to *multiple* radio stations and decide on the best link. In contrast, a radio station can only monitor the link between itself and the portable. Moreover handoff process may be initiated in two ways: The portable may tune into the control channel of the candidate radio station and initiate a handoff through the candidate port or the portable may use the existing link with the previous port to initiate the handoff. The latter method is used more frequently in present systems [2] since it does not need synchronization to the control channel of the candidate port and uses the existing radio link to the previous port for handoff related signaling. Figure 2 presents in flow chart the handoff process described below:

1. The portable realizes that a link of better quality exists to a candidate radio station. The portable records the identity of the candidate port (SETUP message)
2. The portable sends a message to the previous location area radio controller (PLA) desiring a handoff to the candidate radio station. The ATM address of the candidate location area is included in this message. Since we are considering inter-location area handoffs the candidate radio station is in a different location area (SETUP message).
3. The PLA establishes an ATM connection to the candidate location area radio controller (CLA) using the ATM connection setup procedure [3] (CALL PROCEEDING message).
4. The PLA transfers a copy of the user profile to the CLA; CLA assigns a channel to the user, relays the channel assignment information to the PLA (CONNECT message)
5. The PLA contacts the end point for the user connection and requests rerouting to the candidate location area (CONNECT message).
6. Once the re-routing is complete, the PLA contacts the portable and relays the channel assignment information (CONNECT ACK message).
7. . The portable tunes to the new channel and contacts the CLA (CONNECT message).
8. The CLA and the portable verify the connection. After verification the CLA notifies the PLA of the successful handoff. If the connection is not verified, the portable tunes to the previous channel and starts scanning for candidate ports. The CLA de-allocates the assigned channel. An alternative to this procedure is to verify the radio channel and then perform the rerouting in order to save resources. However, since the handoff is portable initiated and depends on power measurements to multiple radio stations, it is very likely to be successful (CONNECT ACK message).
9. If the handoff is successful, the PLA deletes user profile (RELEASE message).

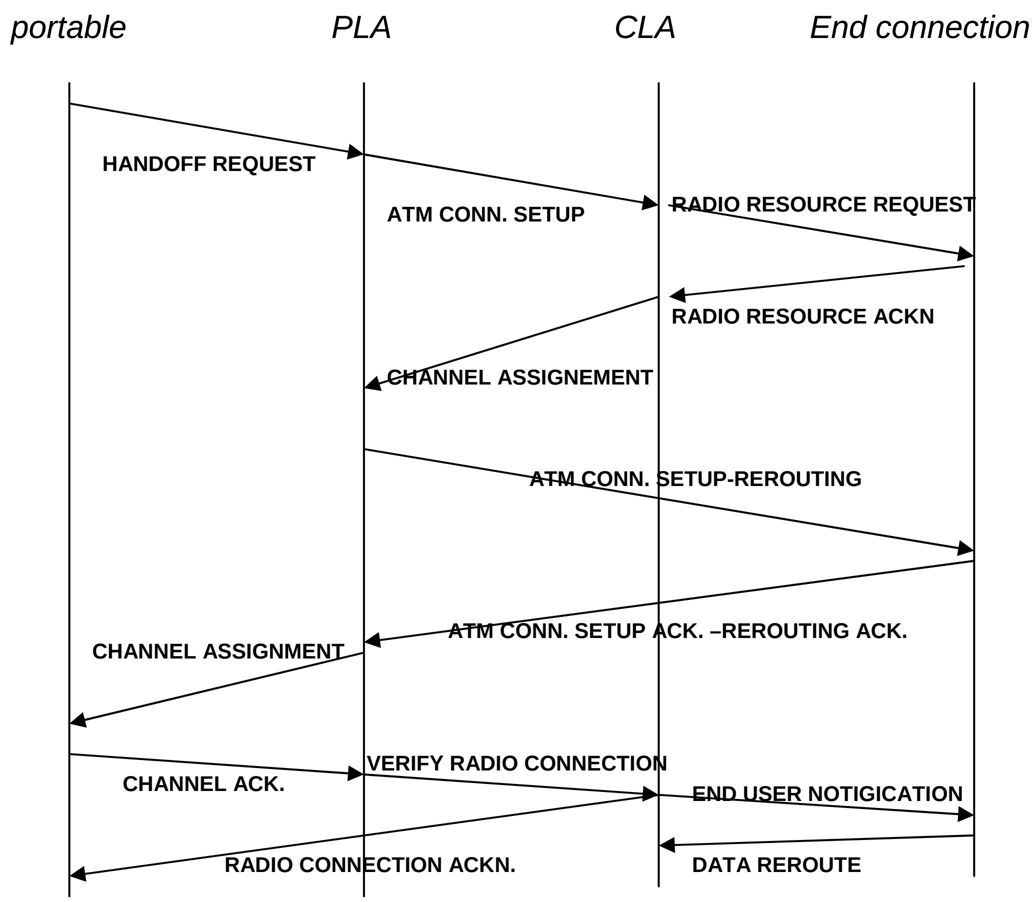

Figure 2: Signalling messages during handoff

4 Estimated Signaling Overhead

The overhead required for signaling is a good measure of the efficiency of the proposed protocol. We used the uniform fluid flow model for approximating wireless user motion, and Poisson call arrival and exponential call holding time distributions. The uniform fluid flow model approximates the wireless users as moving randomly in all directions between the location areas and on the average it is an acceptable representation of traffic [5]. The Poisson call arrival and exponential call holding times are standard models for modeling telephone calls in conventional telecommunications networks. Mean value for the handoff L_h has been used in a simulation.

According to [8] the formula for L_h, prior to small corrections, is given by

$$L_h = (1 - s_1)(1 - s_2)4NP_B \frac{1}{\pi T} \quad (1)$$

where s_1 is the percentage of stationary users in the location area, s_2 is the ratio of mobile subscribers that do not leave the location area, N is the number subscribers in the location area, P_B is the probability of busy subscriber

$$P_B = t \times \lambda \quad (2)$$

where t is the average call holding time and λ is the call arrival rate.

T is the average location area crossing time

$$T = \frac{D}{u} \quad (3)$$

where D is the edge of a square area (modeling the location area with a square) and u is the mean subscriber velocity. Typical values for the above parameters are

- $S_1 = 0.5$
- $S_2 = 0.5$
- λ = 6 calls per hour
- t = 180 s
- D = 1000 m
- u = 50 Kmph

In the simulation the following assumptions are considered:

- Population density remains constant; all of the above transaction rates vary proportional to the square of the location area size.

- The rate of connection attempts is not affected by the user velocities.

Moreover in the simulation results the complementary messages, encapsulated in the ATM UNI [3], have the following lengths according to [3]:

- SETUP 180 bytes
- CALL PROCEEDING 20 bytes
- CONNECT 40 bytes
- CONNECT ACK 9 bytes
- RELEASE 30 bytes

These are the mean values between the minimum and maximum proposed lengths.

Finally the ATM signaling connections for the handoff case are one per step, so totally 13 signaling messages.

In figure 3, when varying the call arrival rate it results in immediate increase of the byte transactions among the network elements. Keeping the population number unchanged the available bandwidth increases significantly with small changes in call arrival rate. Hence, it is concluded that the call arrival rate is a very important parameter for ATM signaling bandwidth.

By varying the call holding time by a factor of three, it results in only one percent change on the estimated ATM bandwidth required for signaling, as shown in Figure 4. Hence, we conclude that the call holding time does not have significant effect on the ATM signaling bandwidth. Of course, it has a very marked effect on the bandwidth required to support user connections

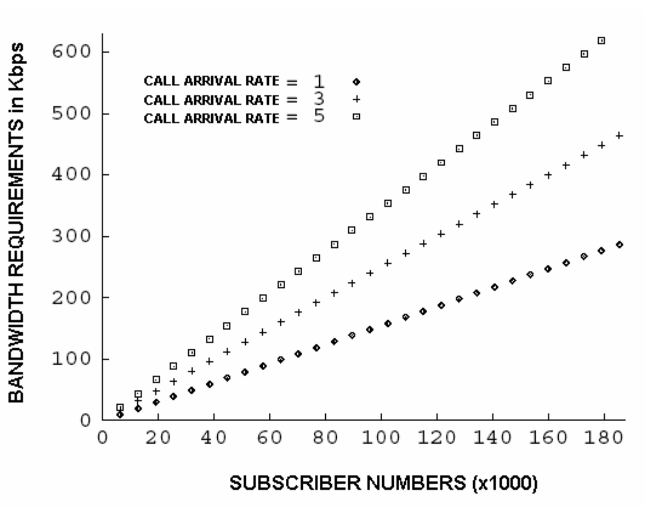

Figure 3: Complementary signalling bandwidth vs subscriber numbers with the Call arrival rate as parameter

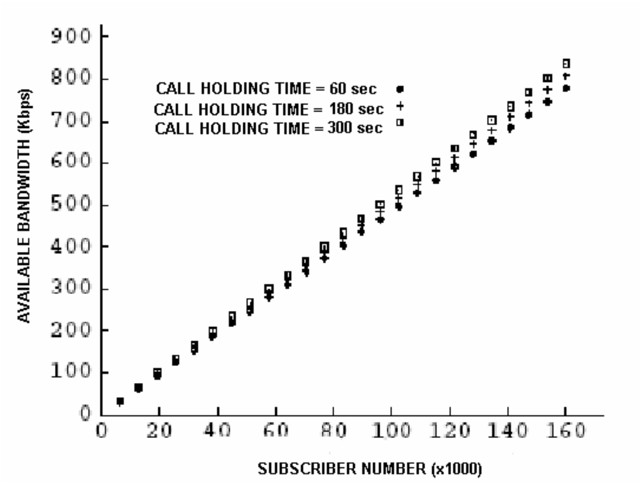

Figure 4: Complementary signalling bandwidth vs subscriber numbers with the channel holding time as parameter

5 Conclusions

In this paper a different signaling protocol has been described, resulting in a possible integration of the wire line ATM network with the personal wireless networks towards a wireless ATM network. Complementary signaling is crucial in order to integrate mobility into the existing ATM protocol stack. There is actually no need to change existing firmware of wire line ATM, but only include in the network service gateways to support the mobility messages from the wireless to the wire line networks and vice-versa

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