Route Optimization & Handoff Control in Wireless ATM Networks

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Abstract: A worldwide increasing demand for wireless communication services signals a new era for networks and their germane protocols. Wireless ATM is designed to provide high speed isochrous and asynchronous communications for users who may demand high-speed data communications along with audio and video conferencing capabilities is proposed as a solution for the provision of these services. This paper focuses on the evaluation of the impact of handoff and route optimization of such diverse traffic classes on network load, thus affecting performance and QoS. A simulation scheme of a WATM network is proposed, which in the implementation phase different handoff scenarios will be carried out and the results obtained will be reviewed to draw general conclusions.

Key-words: Wireless ATM, Handoff Control, Route Optimization, Mobility and QoS

1. Introduction

Recent advances in mobile devices' and networks' technology have set a challenging pace for all new proposals in the rapidly growing domain of mobile communications. The decade of the 90's brought a revolution in mobile computing. The explosion in sales of laptop PCs as well as personal digital assistants (PDAs) and cellular phones has marked the beginning of a new era in the users/consumers' needs and demands from the network providers [1]. Users of today opt not only for voice and multimedia applications but also for mobility. It is evident that high-speed wireless networks are becoming more than an in vitro area of research.

Wireless Asynchronous Transfer Mode (WATM), an extension to fixed ATM network aiming at adding mobility to ATM end users, appears to be a viable solution for broadband wireless networks [2]. The wired ATM network technology has already been tested and approved for high-speed digital integrated services [20]. Thus, it should be able to serve as the backbone network to support mobile wireless users. This choice is motivated by ATM's:

i) transport capabilities which allow different traffic types (voice, video, audio) to be carried through the network using different connection types (CBR, VBR, ABR) [14], [23]
ii) small and fixed cell size which permits multimedia applications to survive potential cell loss with reduced use of FEC schemes (due to relatively small amount of useful data per cell) and increases throughput [3]
iii) connection negotiation about quality of service (QoS) parameters [15], [16], [19]
iv) supple scaling from local area to wide or metropolitan area network
v) ability to provide seamless integration of wired and wireless end users [5].

However, the compatibility of several aspects of the ATM protocol and the wireless channel is in question. First, the radio channel is quite noisy and suffers severe interferences while ATM was designed for media with very low bit error (10^{-10}) and cell loss rate (10^{-6}). In addition, this multi access and time-varying medium may jeopardize ATM's smooth and unobstructed operation. Second, ATM is quite voracious for bandwidth, which cannot be available in plenty in the wireless channel. This paper focuses on the evaluation of the impact of handoff and route optimization of such diverse traffic classes on network load, thus affecting performance and QoS. A simulation scheme of a WATM network is proposed, which in the implementation phase different handoff scenarios will be carried out and the results obtained will be reviewed to draw general conclusions. Our paper is organized as follows: In section 2, a state of the art approach in WATM is taking place. The handoff procedure is discussed analytically. In the following section a reference model is presented and finally in section 4, the simulation schemes for handoff control are presented and discussed in detail.

2. State of the Art and Handoff Control in Wireless ATM Networks

2.1 From Wired to Wireless ATM

Two are the key elements to be addressed for the wireless ATM to emerge from the fixed ATM:

a) a radio access layer and
b) a set of operations to support user mobility.

The RAL comprises several new protocol sub-layers to extend ATM services over the wireless channel [21]. The major functions of RAL will be Medium Access Control (MAC) for channel sharing by multiple terminals, radio resource control to determine radio frequencies, modulation schemes and channel coding for a high-speed physical layer reception-transmission, data link control to cope with errors of the radio channel and to ensure proper and error free release of ATM cells to the ATM network layer and wireless control to provide control plane functions such as radio resource management, terminal migration and handoff control. Coming to the set of operations to support mobility, which is expected to be independent of the specific radio access technology used, they will be location management for mapping user IDs to their current locations, handoff control to support dynamic terminal migration and routing and QoS control to deal with route changes and optimizations through the entire connection while maintaining QoS parameters agreed on during call setup [18], [22]. Although this last issue is the most complicated one, it is the characteristic that makes WATM to stand out from other proposals for wireless broadband networks.

2.2 Handoff overview in WATM

One of the fundamental procedures supported by WATM is handoff. Handoff permits a wireless mobile user to move freely throughout the network. It ensures that a user's radio link is seamlessly transferred between radio ports (RPs) without interruption of the user connection and usually, without significant loss of data [10]. In WATM, it is often the case that a user may simultaneously hold several different connections of different QoS requirements which all need to be handed over and perhaps rerouted quite a few times during the whole period of communication [4]. Thus, the complexity of handoff in WATM grows, when compared to other best-effort networks, by means not only of path rerouting but also of sufficient resource reservation at all new switches comprising the new path in order to offer the previously agreed on QoS parameters [8], [9]. A handoff may be initiated due to a mobile terminal's moving away of the RP's coverage area or due to significant deterioration of the radio signal received. There are basically two types of handoff:

a) a backward handoff where the mobile terminal notices a fading signal and informs the network that it needs to connect to a new RP, and
b) a forward handoff where the mobile terminal suddenly arrives at a new RP without previous notice [1].

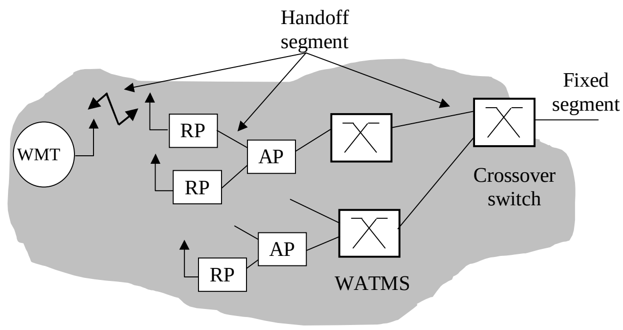

Fig. 1: The Handoff Scenarios Schemes in WATM Networks

In the backward handoff the network controls the whole procedure and decides which is the most suitable RP for the mobile terminal to connect to, whereas in the forward handoff the mobile terminal impulsively chooses a RP and the network merely has to try to conform to the mobile terminal's requirements. But, whatever the case, there are three basic handoff scenarios (Fig. 1) depending on the old and new RPs' relative position in the network [11]. The most basic form of handoff is when the user moves from one RP to another and both are attached to the same access point (AP). In this case only an internal update of the AP's routing table is required and the wireless ATM switch is not even aware that a handoff has occurred. The second handoff scenario involves two RPs that are attached to different APs but these APs belong to the same WATMS [12], [13]. This event is not complicated from the network point of view. The entire procedure is controlled by this specific WATMS which, when informed by one AP that a new user has been acquired, only updates its internal routing table since no path rerouting is necessary. The third scenario however is the most complex. It involves two RPs attached to different APs who themselves belong to different WATMSs. This case involves the wATM network, which has to scan its topology to locate a WATMS that is the first common (a parent) to both other WATMSs. This crossover switch will control the handoff procedure and ensure proper path rerouting and cell sequence preservation.

3. WATM Reference Model

A system reference model for WATM consists of a fixed ATM network infrastructure and a radio access segment. Radio links are established between the Wireless Mobile Terminals (WMT) and the Radio Ports (RP), which are connected to an Access Point (AP) via wires (Fig. 2).

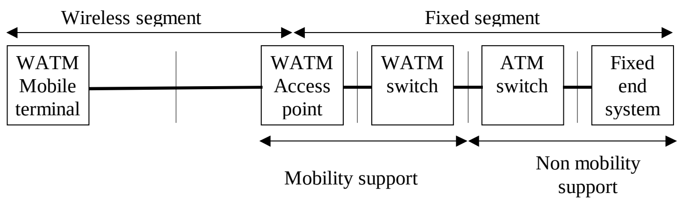

Fig. 2: WATM Reference Model

The AP, which usually controls a small number of RPs, performs the operations required for the wireless communication such as radio medium access control and radio resource management [6], [7]. Several APs are connected to a mobility-enhanced ATM switch (WATMS). These switches differentiate from common ATM switches in that they offer mobility functions to enable users to roam among them. In addition, they serve as the "entrance" to the infrastructure wired ATM networks. The other ATM switching elements in the wired ATM networks remain unchanged.

4. Description of the Simulation Scheme

This work focuses on developing a simulation tool to evaluate WATM's ability to deliver QoS to the users with regard to handoff. We will approach this issue through the use of a terrain mobility model. In particular, there will be entities representing all the WATM elements involved such as radio ports, access points, wireless ATM switches and mobile terminals. There will be a specific yet extendible network topology and users traveling throughout this area. We will assume that each user has an active connection with one RP. While moving, his connections will have to be handed over several times. The decision for the handoff will be triggered by the user's position in the coverage area of the specific cell and will be made by the network through a process of evaluating the user's priority and reserving sufficient resources. The WATM network will always seek to perform lossless handoffs while preserving cell sequence. We will work using coordinates (a pair of x and y values) that will be attributed to all entities. WATMSs, APs and RPs will have fixed coordinates while WMT's coordinates will change dynamically through the duration of the simulation process. The WMT's coordinates will enable the network (the RPs) to track down its customers, thus understanding when they move away from their coverage, which means that a handoff is required. It is clear that judging by the user's position, a WATMS will know whether it is one of its RPs that should serve this user or not.

The actual movement of all users will be emulated by a process capable of producing random variation to the user's coordinates [24]. Depending on the actual size of the network, we will allow a certain portion (a pace) by which the coordinates will be updated. In addition, we will have the ability to change the time interval between these updates. Therefore, the simulation will explore network performance not only to pedestrian users (velocity of 4-5km/h), but also to cars moving for example 50 or 80km/h. All users should belong to one of three priority groups: lowest, medium and maximum priority. Users of the lowest priority will be the first to lose their connection not only in case of the new WATMSs failing to provide the resources necessary to meet their QoS requirements, but also in case of a user of maximum priority requesting handoff to a WATMS that is temporarily short on resources [17]. This means that the network will be releasing all connections with lowest priority up to the point where it will have acquired the means to satisfy the customer with the highest priority. Furthermore, all WATMSs will be equipped with buffers to store data every time it is needed. Though buffering the network will try to preserve some connections despite temporal shortage of resources. In an attempt to emulate actual conditions, we will simulate different user behaviors in terms of QoS, connection type and mobility. A critical issue will be the metrics used to evaluate the network's performance. The number of dropped calls will be considered but in order to achieve a multilateral perception of the QoS delivered to the user some additional parameters will be thoroughly examined. For example, the amount of time a user does not get his desired bandwidth, thus resulting in slower data delivery by or to the network, is a critical factor in determining the network's overall QoS.

5. Conclusions

The simulation scheme described above is expected to supply us with some helpful information that will contribute in an in depth evaluation of WATM's performance. The metrics used and the obtained results should provide the means that will lead to a classification of the various WATM network topologies of such kind that will be proved to be valuable in terms of future planning and implementation. In other words, the simulation is expected to shed light on the issues that will enable us to decide on which type of user specific network topology and configuration should perform more efficiently and predict network behavior according to different traffic scenarios. In particular, different user velocities, QoS requirements and traffic loads will be considered in an attempt to classify the effect they have on QoS perception by the user. We will conclude on the efficiency of several handoff schemes implemented. Therefore, a significant contribution of our approach to handoff is the simulation of different schemes. In this paper a different approach on route optimization and handoff control in Wireless ATM networks is presented, which are a key prerequisite for the successful deployment of this networking technology. Several research initiatives aim at enabling researchers and engineers to understand the route and handoff characteristics and their impact on control mechanisms through measurement, simulation and analytical studies. Further research work should be done and evaluated in the future, as management and control are still open and important issues for the successful development of wireless communications and especially for the wATM networks.

References:

[1] J. Schiller, "Mobile Communications", Addison-Wesley, 2000.

[2] B.H. Walke, "Mobile Radio Networks", Wiley, 1999.

[3] D. Raychaudhuri and D. Wilson, "ATM-Based Transport Architecture for Multiservices Wireless Personal Communication Networks ", IEEE JSAC, Vol. 12, No 8, Oct. 1994, pp 1401 - 1413.

[4] Anthony Acampora, "Wireless ATM: A Perspective on Issues and Prospects," IEEE Pers. Comm., pp. 8-17, August 1996.

[5] Ender Ayanoglu, Kai Y. Eng and Mark J. Karol, "Wireless ATM: Limits, Challenges, and Proposals," IEEE Pers. Comm., Oct 1996 pp. 18-34.

[6] I. F. Akyildiz, et al., "Mobility Management in Current and Future Communications Networks", *IEEE Network, July/August 1998*, pp. 39-49.

[7] D. Raychaudhuri, "Wireless ATM Networks: Architecture, System Design and Prototyping", *IEEE Personal Communications*, Vol.X, No.X, August 1996, pp. 42-49.

[8] Bora Akyol, and Donal C. Cox, "Signaling Alternatives in a Wireless ATM Network, "IEEE JSAC, Vol. 15, No. 1, pp. 35-49, Jan. 1997.

[9] L. Fernandes, " Developing a System Concept and Technologies for Mobile Broadband Communications", IEEE Personal Comm., Feb. 1995, pp 54 - 59.

[10] Jun Li, Roy Yates and D. Raychaudhuri, "Performance Analysis of Path Rerouting Algorithms for Handoff Control in Mobile ATM Networks", *IEEE JSAC*, Vol.18, No.3, Mar. 2000, pp. 496-509.

[11] B. A. Akyol, D. Cox, "Rerouting for Handoff in a Wireless ATM Network", *IEEE Pers. Comm.*, Oct. 1996.

[12] A. Acharya,, J. Li, and D. Raychaudhuri, "Primitives for Location Management and Handoff in Mobile ATM Networks", ATM Forum Contribution 96-1121, Aug. 1996.

[13] Hiroshi Saito, "Dynamic Resource Allocation in ATM Networks", *IEEE Comm. Mag.*, May 1997, pp. 42-49.

[14] A. Lombardo, S. Palazzo and G. Schembra, "An Admission Mechanism for ABR Traffic in an ATM Wireless Network", Nec Research Institute, 1999.

[15] C. Chao and W. Chen, "Connection admission control for mobile multiple class personal communications networks," IEEE JSAC, vol. 15, Oct. 1997, pp. 1618–1626.

[16] M. Bracha Epsteinand Mischa Schwartz, "Predictive QoS-Based Admission Control for Multiclass Traffic in Cellular Wireless Networks", IEEE JSAC, Vol. 18, No. 3, Mar. 2000, p. 523.

[17] B. Epstein and M. Schwartz, "QoS-based predictive admission control for multimedia traffic in Broadband Wireless Communications", Luise &. Pupolin, Eds. Berlin: Springer-Verlag, 1998, pp. 213.

[18] M. R. Sherif, et al., "Adaptive Allocation of Resources and Call Admission Control for Wireless ATM Using Genetic Algorithms", IEEE JSAC, Vol. 18, No. 2, Feb. 2000.

[19] D. Zhao, et al., "Efficient "Call Admission Control for Heterogeneous Services in Wireless ATM Networks", IEEE Com. Mag., Oct. 2000.

[20] ATM Forum, "ATM Traffic Management Specification", Version 4.0, Feb. 1996.

[21] D. McDysan and D. Spohn, "ATM Theory and Applications", McGraw-Hill, 1998.

[22] D. McDysan, "QoS and Traffic Management in IP & ATM Networks", McGraw-Hill, 2000.

[23] Harry G. Perros, "Call Admission Control Schemes: A Review", IEEE Comm. Magazine, Nov. 1996.

[24] A. Acharya et al., "Mobility Management in Wireless ATM Networks", *IEEE Com. Mag.*, Nov. 1997, pp. 100-109.