Optimization for Reducing Handoff Latency and Utilization of Bandwidth in ATM Networks

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***Abstract*—**To support mobility in ATM networks, a number of technical challenges need to be resolved. The impact of handoff schemes in terms of service disruption, handoff latency, cost implications and excess resources required during handoffs needs to be addressed. In this paper, a one phase handoff and route optimization solution using reserved PVCs between adjacent ATM switches to reroute connections during inter-switch handoff is studied. In the second phase, a distributed optimization process is initiated to optimally reroute handoff connections. The main objective is to find the optimal operating point at which to perform optimization subject to cost constraint with the purpose of reducing blocking probability of inter-switch handoff calls for delay tolerant traffic. We examine the relation between the required bandwidth resources and optimization rate. Also we calculate and study the handoff blocking probability due to lack of bandwidth for resources reserved to facilitate the rapid rerouting.

***Keywords*—**Wireless ATM, Mobility, Latency, Optimization rate and Blocking Probability.

I. Introduction

WIRELESS Asynchronous Transfer Mode (WATM) technology combines two of the hottest technologies in communication these days: wireless and ATM. WATM will provide multimedia traffic for mobile terminals with high quality of service .However, WATM faces many technical challenges. One of the most important is supporting mobility of the user while maintaining communication. This requires the implementation of handoff. In WATM handoff, connections need to be modified as users move from one radio cell to another. The rerouting of connections must be done quickly with minimal disruption to traffic. Also the resulting routes must be optimal [1]. Handoff occurs when a mobile terminal moves from one base station to another. ATM handoff differs from traditional voice handoff in that a mobile user may have several active connections with different bandwidth requirements and quality-of-service (QoS) constraints[2]. The handoff function ensures that all these ongoing connections are rerouted to another access point in a seamless manner. In other words, the design goal is to prevent service disruptions and degradation during and after the handoff process. There are two types of handoff; intra-switch handoff and inter-switch handoff [3]. In intra-switch handoff, the mobile terminal moves from one access point (AP) to another, and both APs are connected to the same ATM switch. While in the inter-switch handoff, the mobile terminal moves to a new AP that belongs to another ATM switch. In the first type the handoff process doesn't involve any ATM network switching. A number of schemes to reroute connections during WATM handoff has been proposed in literature. Two well-known schemes are path extension [4] and route optimization [5].In path extension, the connection is extended from the old AP (Access Point) to the new AP. Pre-provisioned connections are typically established between APs in order to reduce connection setup time. While this scheme promises low rerouting latency, the resulting route is often not optimal. Also, it increases the complexity of the AP.

The AP must be capable of managing preprovisioned connections, and it must have buffering and switching capabilities to all adjacent AP links. Increasing complexity of the AP will lead to increase in the total system cost as the AP will be one of the most widely deployed nodes. In this approach, inter-switch handoff calls are rapidly routed using reserved channels between switches or by just extending the original path to the new base station (BS). In other schemes, this has been done by establishing in advance the routes to different switches where the mobile might go in future.

However, in this handoff scheme, there is no path optimization and it is likely to misuse bandwidth during the time the path is not rerouted. The efficient way to do this is by reserving permanent virtual channels which can be used for handoff calls. In the scheme presented in [6], permanent virtual paths are reserved between adjacent MES for handoff calls. The reserved paths are used to rapidly reroute connections with the second part of the handoff scheme being route optimization [7]. However, in most of these works, cost associated with route optimization in terms of signaling load and the cost of extending the path is not considered. In this paper, we propose a method of signaling and optimization cost reduction during handoff/route optimization in wireless ATM networks using the Bernoulli route optimization scheme. With the aim of reducing inter-switch handoff dropped calls. We consider an ATM architecture in which adjacent ATM switches are interconnected by reserved Handover Permanent Virtual Channels (HO PVC) [8][9] for rerouting inter-switch handoff calls. In the new scheme, Handoff Permanent Virtual Paths (HO PVPs) are provisioned between adjacent MESs to rapidly reroute user VCs during inter-switch handoffs eliminating the connection processing overhead and delays at intermediate switches. Therefore, the handoff latency is minimal. The rapid reroute of user VCs is followed by a

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nonreal time second phase in which a distributed route optimization procedure is initiated to find optimal paths. This scheme keeps AP complexity and cost low. We also consider a one phase handoff in which at ATM switch level, before the connection is established, the anchor switch will be able to compute the optimized route during the handoff process. The way this is done is similar to the Nearest Common Node Rerouting (NCNR) presented in and also the scheme. This means that due to the added delay in performing this process, there will be need to buffer cells during the handoff/optimization. Also provisioning HO PVPs between adjacent MESs is more efficient in terms of bandwidth and management resources. The rest of this paper is organized as follows: in section II, the route optimization scheme is presented, section III gives the traffic model and section IV gives the simulation details. Results and performance discussions are presented in section V, and section VI concludes this paper.

Fig. 1 below shows the ATM architecture under consideration. In this scheme, there will be no route extension in the case of intra-switch handoff. We will only make use of route re-establishment of a switched virtual circuit (SVC) between the ATM Switch and the BS involved. Referring to the figure below, when the mobile terminal (MT) moves from BS1 to BS2, SVC1 will be released and a new SVC2 will be established between ATM-SW1 and the BS2. This route is already optimal and does not require any optimization. Optimization is therefore required only for inter-switch handoff in which route extension is applied. This is the case when the MT moves from BS2 to BS3 which is connected to the ATM-SW2. We adopt a Route Optimization in which the probability to perform route optimization will be based on the expected cost associated with route optimization and traffic arrival rate.

Each inter-switch handoff will result into a path extension from the serving ATM switch to the new ATM switch. This means that after each inter-switch handoff, there will be a probability q (calculated such that $0 \leq q \leq 1$) for which we have to perform route optimization [5]. In this optimization scheme, during every inter-switch handoff, the probability q is calculated and compared to some random number r. Optimization is performed only if the value of q is greater than the number r, otherwise we assign a PVC for this call. The probability q will be calculated by the ATM switch based on the expected signaling and optimization cost and handoff arrival rate with the aim of minimizing the cost to be incurred while at the same time minimizing dropped call probability. The optimization process will involve path rerouting in which the path between wire line network and ATM switch 1 will be rerouted to a new route between the wire line network and ATM switch 2, which will now be the anchor switch. Figure 2 below shows the scenario for handoff, the extended route and the scenario after optimization. In this diagram, we consider a call from the wire line network to a mobile terminal. As the MT moves from BS1 to BS2, traffic can be routed either by using the optimized route or using the suboptimal route depending on the result of the calculation of the optimization probability.

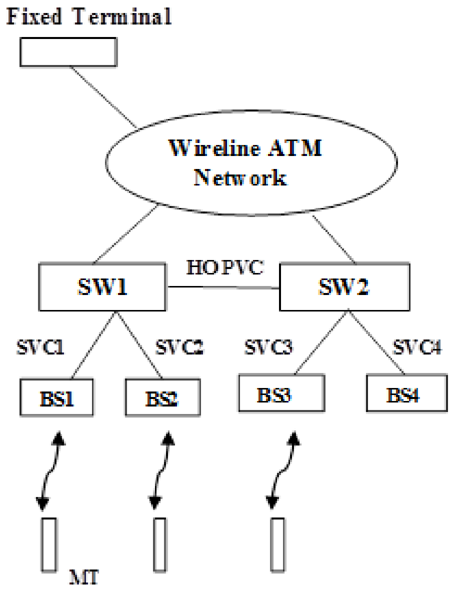

Fig. 1 The ATM network architecture

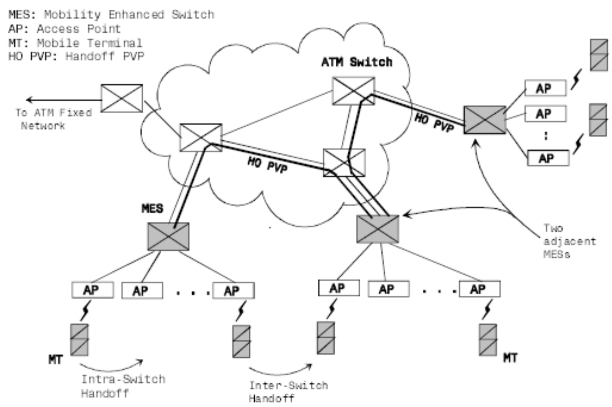

Fig. 2 WATM network architecture

II. A Two-Phase Handoff

In this section, we briefly describe the two-phase handoff scheme proposed. We describe how the two-phase handoff scheme can be applied to Intra-Switch handoff as well as Inter-Switch. Intra-Switch handoff occurs when an MT (Mobile Terminal) moves from an AP connected to an MES to another AP connected to the same MES. Inter-Switch handoff occurs when an MT moves from an AP connected to an MES to another AP connected to a different MES. Intra-Switch handoff requires only one new connection to be established between the MES and the new AP, and the resulting route is optimal, assuming the original path to the MES was optimal.

Since the new AP is directly connected to the MES, the HO PVP is not involved. Hence, for the Intra-Switch handoff, there will be no need to execute a second phase. However, Inter-Switch handoff becomes more involved as more new connections need to be set up. The number of new connections is dependent on the network topology and may span number of ATM switches. With the use of HO PVP between adjacent MES, the management and establishment of new connections are simplified. Only two new connections need to be established and managed: one is within the HO PVP and the other is between the new MES and the new AP.

III. Route Optimization

The following are the various route optimization techniques:

A. Bernoulli route optimization

In this optimization scheme, the most important parameter (the design problem) is to find an optimal value q at which to perform route optimization. This value should be able to minimize handoff blocking probability p_h and the expected average cost per call during optimization. The expected average cost per call during optimization is given in [10]. This is the amount of network resources used and the processing and the signaling load of the network and is given by the equation:

$$Cost_{(Expected)} = Cost_{(link)} + Cost_{(Signalling)} \quad (1)$$

In the Bernoulli route optimization scheme in Wireless ATM networks the main Objective of this technique was to maintain the handoff dropping probability to a minimum while maintaining route optimization costs to a fixed value. This can be done through adjusting the rate at which optimization should occur. This technique does not give optimal results. We observed that further increase in the optimization probability will not result into any further significant drop in handoff blocking probability.

B. Non-Adaptive optimization

In this scheme optimization periodic rate is constant and doesn't adapt to network condition. In particular, we studied the relation between the optimization rate and the reserved HO PVP bandwidth utilization. The bandwidth utilization is the percentage of the total bandwidth currently being used by connections/calls, i.e. the current number of connections within the HO PVP. According to the two-phase scheme, the bandwidth for a single HO PVP is affected by two factors: 1) allocation of connections due to inter-switch handoff arrival of λ_s and 2) release of connections due to one of the followings:

- Route optimization
- Call termination
- Handoff blocking as a result of MT journey

First we find λ_s, the total inter-switch handoff request rate. In [10], the handoff call arrival rate in a radio cell is given as follows:

$$\lambda_h = \frac{\mu_R(1-P_O)\lambda_o}{\mu_M + \mu_R P_f} \quad (2)$$

P_O : The originating call Blocking Probability
P_f : The handoff Blocking Probability
λ_o : The originating call arrival rate in a cell
$1/\mu_M$: The mean of holding time of a call
$1/\mu_R$: The mean residual or sojourn time of a call in a cell.

C. Adaptive optimization

In order to maximize utilization of the reserved bandwidth and minimize the signaling and processing load at the ATM switches due to the non-adaptive optimization rate, it would be more appropriate to have the optimization rate adapt to changes in network conditions. In real life the optimization rate is dependent on several network parameters: optimality of the current path, reserved bandwidth utilization of HO PVP, handoff blocking, connection QoS, connection lifetime (being old or new), number of hops, loop detection, etc. However, it would be difficult to model such a system based on all of these parameters. Also from implementation point of view, additional processing load and computation complexity would be imposed on the MES as it needs to monitor and compute all of these parameters. A simple parameter would be the reserved bandwidth utilization. To have the optimization rate adapt to changes in the bandwidth utilization, we must allow the optimization rate to decrease when the utilization decreases. Also, when the utilization increases, the optimization rate should increase. Hence, the route optimization service time for any handoff is given as:

$$1/\mu_n = \tau + 1/\mu \quad (3)$$

Where, τ represents the route optimization urgency (i.e. how aggressive the optimization rate should be) and is dependent on the current bandwidth utilization.

IV. Conclusion

In this paper, we have presented three optimization schemes. This schemes was maintain the handoff dropping probability to minimum while maintaining route optimization costs to a fixed value and adaptive route optimization was shown to minimize signaling and processing load while maximizing utilization of reserved resources. This scheme gave the optimal result but we have also seen that increasing the optimization probability from the optimal operating point results into a small drop in handoff blocking probability. But my work focuses on that rapidly reroute user connections during inter-switch handoffs eliminating the connection processing load and delays at intermediate switches. Therefore, the handoff latency is minimal and keeps AP (access point) complexity and cost low. Examine the relation between the required bandwidth resources and optimization rate. Also we calculate and study the handoff blocking probability due to lack of bandwidth for resources reserved to facilitate the rapid rerouting.

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