QoS Implementation For MPLS Based Wireless Networks

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Abstract : Voice has been the primary application in wireless networks to date. However, packet based applications and higher bandwidth requirements to sustain these applications are ever emerging. As in wireline packet based networks, while IP routing is well understood, IP networking by itself is still not achieved and is dependent on the backbones that can offer quality of service gurantees. Mulitprotocol Label Switching (MPLS) is a newer technology that offers service integration, layer 2 switching and connection orientedness, that allows traffic engineering control traffic flows in the network. The purpose of this paper is to show how MPLS QoS architecture can be employed to provide traffic engineering in broadband wireless networks.

1 Introduction

Today's land based networks transport voice and data traffic on predominantly separate networks, each with its own switching/routing architecture, network management platform, and support staff. With emergence of VoIP technology there is a growing trend towards the integration of voice and video into one single network. With the imminent evolution to the next generation **wireless** network, **wireless** service providers are striving to converge these separate infrastructures to a single network **over** a common packet core, that will help reduce both operational expenditure (OPEX) and capital expenditure (CAPEX).

One of the primary goals of this emerging wireless networks will be to enable bandwidth on demand, based on different traffic types (Conversational, Streaming, Interactive, and Background). To meet the demands of the different traffic types carried across 3G networks, service providers need to ensure that their networks are reliable, flexible, and will evolve to support the high bandwidth requirements of the future. Current 3G standards are based on Asynchronous Transfer Mode (ATM).

ATM has been used to a large extent as a switching technology for the backbone data networks today to support integrated services with QoS control. Considerable research has been carried out to extend ATM services to mobile terminals mostly with the assumption that ATM connections terminate at the wireless users. For example, Wireless-ATM (WATM), extends the ATM signaling and control framework to support mobility. On the other hand, with the widespread use of Internet protocols, many schemes have been proposed to support mobility for IP wireless terminals within a connection-oriented framework of ATM networks, as in the case of the wireline networks. However, the need to integrate the best of both IP based networking and traditional voice service like quality of service, has made many in the technology world rethink on ATM for both wireline and wireless networks. IP, by its very connectionless nature can't offer quality of service, except when the networks are extremely overprovisioned.

MPLS is a technology that delivers a unified control mechanism with its multiprotocol capabilities for running over mixed media infrastructures. MPLS defines signaling mechanisms to support both Class of Service (CoS) and QoS. It provides the means to relate this to the IP DiffServ markings of the originating IP traffic. Also QoS mappings to ATM also exists (if an evolution from a ATM based wireless netowork backbone is needed). MPLS's ability to support constraint-based routing and traffic engineering delivers the QoS that is required to support Conversational, Streaming, and Interactive traffic, something only previously possible only with ATM. Hence, Multi-Protocol Label Switching (MPLS) is emerging as the technology of choice to facilitate traffic engineering and internetworking.

This paper explains how the MPLS hierarchical architecture for label-switched networks can be used for supporting wireless users. This architecture involves requirements at the mobile terminal for initiating label switched paths at the air interface, and allowing end to end interconnection to the backbone network. Subsequently, we present mechanisms for location and handoff management. This paper explains the basic signaling mechanism involved and an over view of how traffic engineering in the network can be used using constrained based packet routing in the wireless network.

2 MPLS System Architecture for Mobile Networks

MPLS architecture needs to be specified for label maintenance and distribution that supports unicast, multicast, a hierarchy of routing knowledge and explicit paths. The basic architectural issues lie in defining procedures and protocols for label distribution, encapsulation, reservation and QoS mechanisms, and definition of mobile host behaviors.

The basic network architecture comprises of mobile hosts (terminals) capable of initiating traffic flows towards the base stations. The base stations aggregate traffic flows towards the Mobile Label Switching Nodes (MLSN) and terminate label switched paths. MLSNs provide support for fast handoff and location management mechanisms. MLSNs can perform the function of both a Label Switch Router (LSR) or a Label Edge Router (LER), as in a classical MPLS network.

Figure 1. shows a simplified model of a mobile network with labels distributed between a correspondent node and the destination mobile node in a foreign network. This shows an instance where the mobile hosts are directly participating in the label switched network. Host participation in label switching is a little easier in data driven approach, where the mobile initiates label request based on traffic flows, rather than on a control driven approach, where routing protocols are involved.

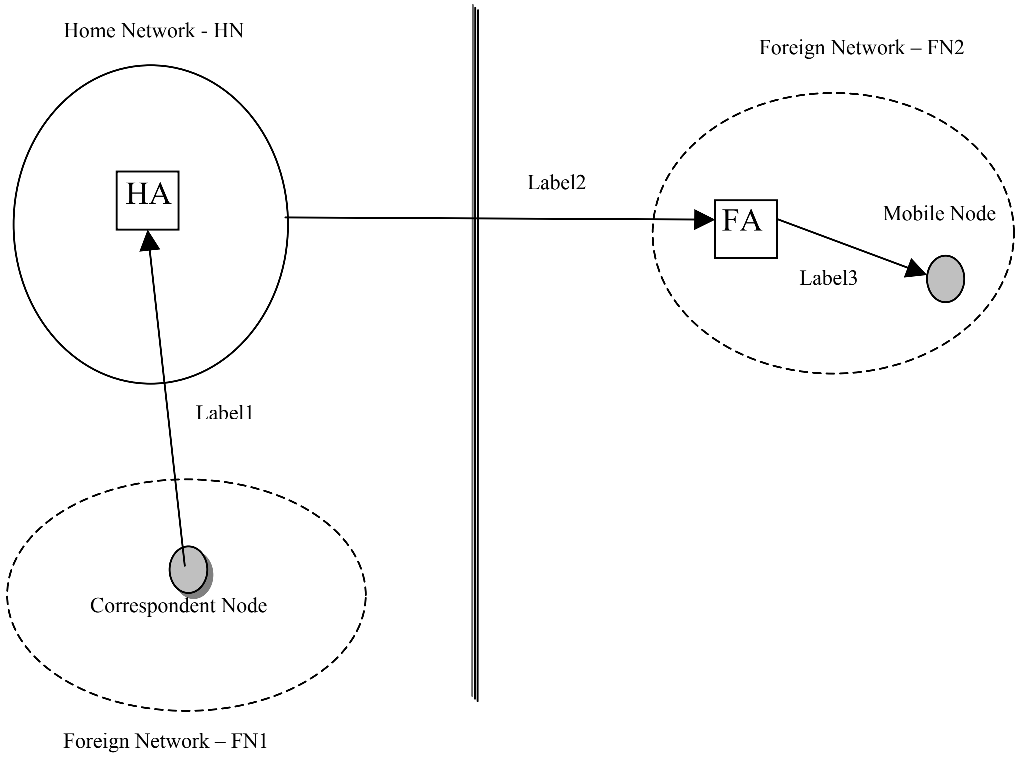

Figure 2-1 : MPLS Labelled Mobile Network

Also when the mobile initiates a path establishment process, in a control driven approach, each mobile will need to have the complete topology of the network and need to run a OSPF like routing protocol. This will not be an optimum solution, since this will require huge resources for each mobile and each mobile need not learn the topology information of the network where ever they are currently operating. However, it is necessary to utilize all the advantages provided by the routing protocols. Hence routing protocols are run across the MLSNs and across the interworking interfaces (between mobile and non mobile networks).

Considering IP forwarding operation, label switched paths can be setup between two edge switches/ nodes of a mobile network and use this path to tunnel the IP packets across. IP packets can be assigned to different label switched paths based on their destination IP address and other criteria, like the QoS attributes.

Whenever a mobile node wants to establish a label switched path a participating mobile switching node in the home area can provide the explicit routing information to the mobile, so that the mobile can initiate signaling with an explicit route specification.

IP forwarding in a mobile node typically involves two distinct operations, namely, aggregate IP packets to a Forwarding Equivalence Class (FEC) and map the FEC to the next hop in the path. This will be done by every mobile node. End-to-end MPLS will let the mobile map packets to the FEC and encode this FEC as a label. Once the path is established, the intermediate mobile nodes (that includes the base transceiver nodes, and mobile switching centers) need to just perform only the second operation, mapping the label to the next hop and performing appropriate label translations.

2.1 MPLS Protocol Layer Architecture

Figure 2 explains the MPLS end-to-end layered architecture proposed for wireless networks. The proposed architecture is such that the air interface and the mobile terminal are basically the same as in a traditional mobile packet network. Mobile terminals need to aggregate traffic flows (traffic classes) towards the network over the radio link. Base stations termiate radio links on the user side and label paths on the network side. Base stations forward all packets to the MLSNs, which provide switching, control and routing mechanisms.

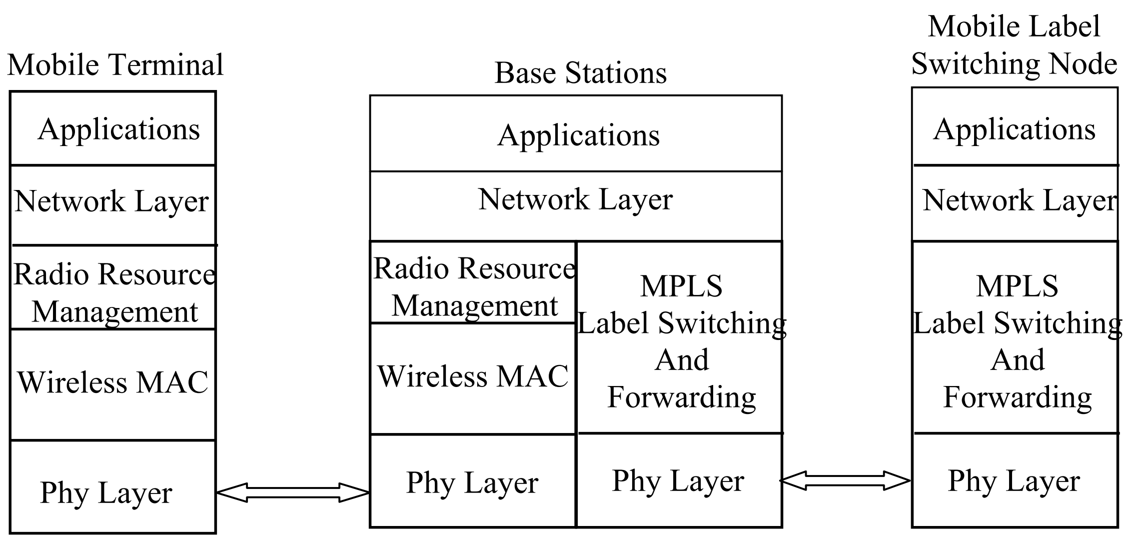

Figure 2 : Mobile MPLS end-to-end protocol layer architecture

2.2 MPLS call setup in Wireless Networks

This section shows how different MPLS components interact during setup, modification and teardown of an LSP. Mobility issue handling is done in the next section. We consider the case of a mobile establishing an MPLS path to another mobile in the network. The signaling protocol used can be RSVP or LDP. Considering the prominence of RSVP in today's environment, we use RSVP as the signaling protocol for path setups.

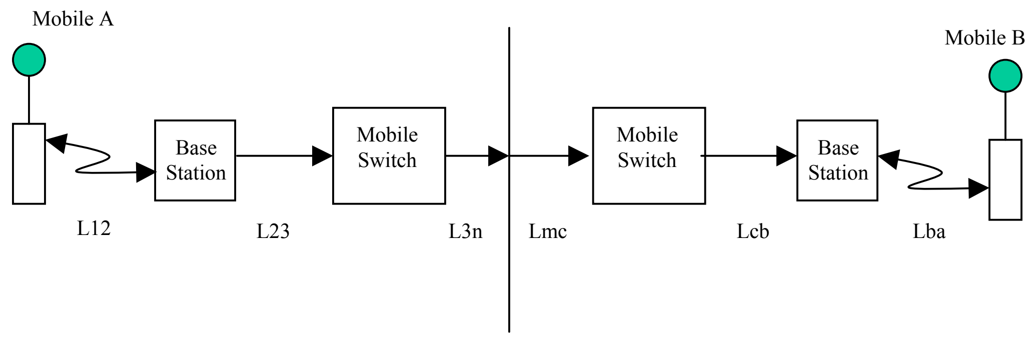

Figure 3 : Label Switched Path setup in a mobile network

Figure 3 shows a mobile network with LSPs setup end-to-end. As a part of the call setup, mobile A sends a UNI signaling request to its local base station. Local base station registers this request and forwards it to the Mobile switch. Mobile switch which is running the routing protocol maintains the topology of the network and has enough intelligence to determine the path to the destination node, based on the destination nodes, current foreign home location, Quality of Service requested, total bandwidth needed, load balancing to be handled in the network etc. This information is used by the mobile switch to signal the upstream nodes in the path for label setup, upto the destination node B.

It is important to note that L12 and Lba in Figure 3 actually represent the radio links that represent individual traffic classes from the mobile hosts. The UNI signaling request here actually represents the request for radio link assignment, though based on traffic flows. Label paths are terminated in the network at the base stations.

Once the destination node responds with the RSVP RESV message every down stream node in the path register this label and create a label forwarding entry. When the origination mobile switch receives this RESV message it signals the orgination base station and mobile A.

Origination base station might ideally combine multiple streams from different mobile station and send them towards a mobile switch. This will then form a label stack hierarchy, with 2 layer of labels, one between the mobiles and base station and the other between the base station and mobile switch.

Once the end to end path is setup the mobiles can then start transmitting packets with the assigned labels which are then routed deterministically to the destination node. Path tear down might once again be initiated by source mobile, the destination or the network itself. In the first two cases, a path TEAR message is sent to every node in the path, which then clears the forwarding entries for the labels. In the third case, the routing protocol takes the responsibility of distributing the stale labels and thus providing information to start the path tear down, upstream or downstream.

3 Mobility handling Wireless MPLS networks

3.1 Location Management

The location management allows the network to keep track of mobile user's current location and thus simplifies the forwarding of the incoming calls to the mobile. It also brings user's profile and quality of service requirements near to its current location and allows the network to provide the user with the subscribed services.

OSPF or IS-IS Interior Gateway Protocols (IGP) can be used to support thewireless MPLS architecture. These in an MPLS domain broadcast the network state to compute the path through the network topology. Paths are computed on a call setup request form the mobile end user to the MLSN via the base station. Once the path has been computed, signaling protocols are used to establish an LSP, and the traffic that satisfies the forwarding equivalence class relationship is sent down the LSP. These paths are computed based on the topology state information database existing in each LSR and shared among its neighbors.

To compute the path, reachability information is shared among label switch routers in the network. In order to limit the traffic due to the distribution of the reachability information among the LSRs, LSRs are divided into manageable mobile router areas (MRA) in a particular area and in the complete autonomous system. The area's topology is invisible to the entities outside the area. There are area border routers in OSPF and level 2 routers in IS-IS, which are responsible for inter-area routing.

Location databases in the network maintain the information of the current RA of the mobile host, instead of tracing the base station to which the mobile is connected. This is done by updating the changes in the mobile's RA.

Base stations with the supporting MLSN will belong to a certain router area for example, which will limit the network changes and failure information to be distributed to just within this area. Similarly some of the LSRs and MLSNs will form another RA to further reduce routing updates. This constitutes the next higher level in the MPLS network hierarchy. The RAs will effectively limit the registration traffic and routing updates arising due to roaming by mobiles. This is indicated in figure 4.

There is a trade-off between the propagation of the information to the higher layers and the amount of routing updates needed for the location management. The highest level in which the location information is distributed defines the reachability region. The topological state updates are propagated within the reachability region to indicate where the mobiles are located and to enable the LSRs to have exact location information about the mobiles.

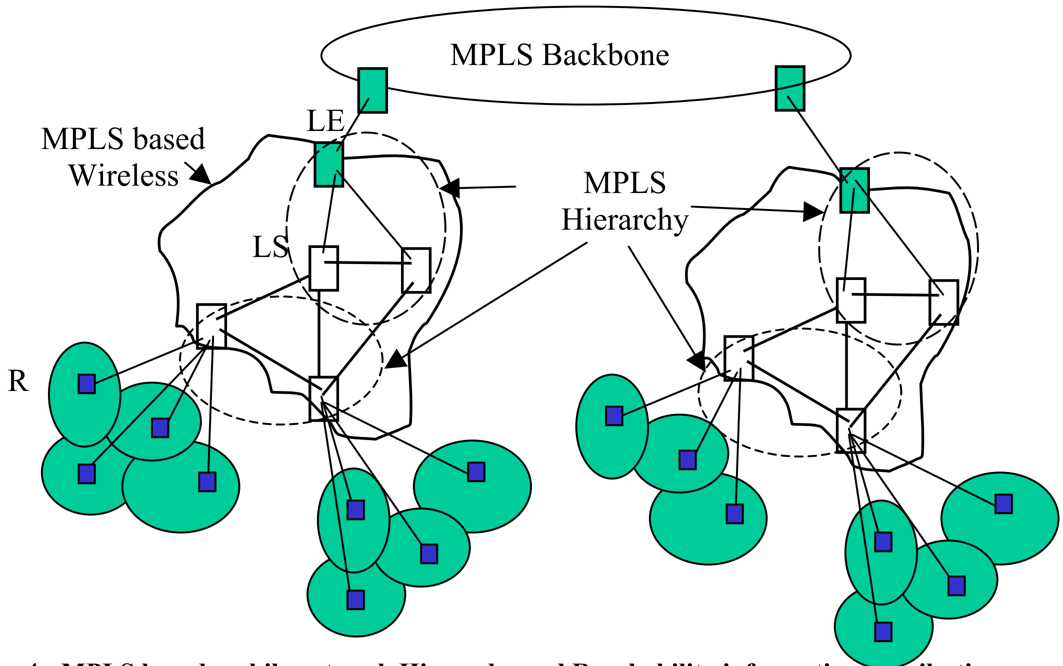

Figure 4 : MPLS based mobile network Hierarchy and Reachability information distribution

3.2 Mobility Management

As can be expected in a mobile network both the source and destination nodes can be on the move, moving from (1) one transceiver station to the other, (2) one base station to the other, (3) from one mobile switch to the other, or (4) from one network to the other.

In case 1, the base station can still retain the labels already established between the mobile and base station, and hence there can be very little loss of packets. In case 2, while the path established beyond the originating (destination) mobile switch remains the same, paths need to re-establised between the mobile switch and the mobile through the new base station. In the third case, the old mobile switch can provide the information about the current state of the LSP, but these need to modified and reestablished between the next for router and the new mobile switch, in addition to establishing the path to the mobile. In the last case, it will be a similar case of the old base station providing LSP info, enabling the establishment of the new path to the mobile.

In case the destination mobile moves, all the above transactions need to happen only at the destination side. When the mobile moves from one foreign agent to another foreign agent, the mobile should be able to provide information about the old foreign agent. Based on this information the new foreign agent, can try and establish the downstream broken path and restore the end to end path, between the mobiles.

Thus unlike the classical mobile IP, the source node, need not know the current foreign IP address of the destination mobile, or send all IP packets to the home agent of the mobile for rerouting. This has tremendous advantages to both maintaining a deterministic quality of service and also burdening the network with almost no rerouted traffic flow.

4 Traffic Engineering in Mobile Networks using MPLS

Traffic engineering in the MPLS based wireless network actually start from the mobile itself, which regulates traffic flows in the network based on the traffic classes it serves. While the base stations merely aggregates this traffic towards the MLSNs, MLSNs decide the label switched path through the entire network.

Classical IP routing produces a shortest path tree rooted at the current destination mobile switch for a forwarding equivalence class. Shortest path criterion avoids loops and provides a common forwarding criteria. A tree topology results from the optimality of shortest paths.

However as mobile paths get setup using the shortest path, more paths get merged near the far end into common branches of the tree and can cause congestion. Equal Cost multipath (ECMP) technique has been attempted in the past to divide IP flow among equal cost path, though not the shortest. Though this helps in distributing the traffic, it is hard to find ECMPs. Attempts have also been made to relax the shortest path criterion. This can increase the cost dramatically.

MPLS explicit routed paths can be setup to bypass congested areas and take advantage of under utilized network resources without having to modify IGP link metrics. Constraint based routing used by MPLS helps in identifying paths that are constrained by the Quality of Service requirements needed for the user. This makes MPLS role very significant in traffic engineering. Hence, as long as the mobile switching nodes can run the routing protocols and run efficient algorithms to find the most optimal path for connection setup, based on the current location information of the destination mobile, MPLS in mobile networks can perform traffic engineering. This helps avoiding congestion on LSP tunnels, allowing traffic rerouting.There can also multiple LSP tunnels between two mobile nodes, corresponding to a local QoS or cost policy.

5 Conclusion

Wireless packet core networks which are in the infancy must evolve to support future IP/PPP transport. By deploying **MPLS** in the core of the network, voice and data can be converged onto the common packet core network and also provide QoS and CoS features. The packet core could simultaneously support multiple services, including 3G **wireless** applications/traditional data services/traditional voice services. Also standardization bodies are working on developing standards towards using G**MPLS** for end-to-end services. This will ensure not only a consistent control plane across many electrical-based protocols (ATM, PPP, Ethernet, etc) but will extend this same control plane across optical and wireless networks as well.

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