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Enhancements to Mobile IP

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I. INTERNET PROTOCOL-(IP)

The **INTERNET**- Never before has there been a more revolutionary achievement in known history of technology. From global communications to information archival and availability its impact is unprecedented and the world will never be the same place again. At the core of the Internet lies the now ubiquitous phenomenon IP – short for the layer 3 'Internet Protocol' which is responsible for host identification and packet delivery in this gargantuan network consisting of a seemingly infinite number of nodes.

How IP works:

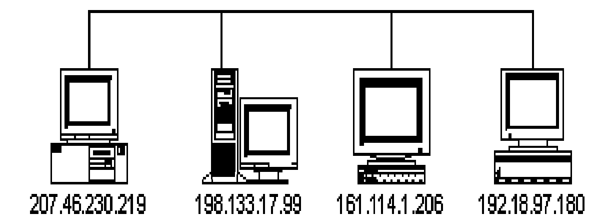


Figure 1: IP Addresses

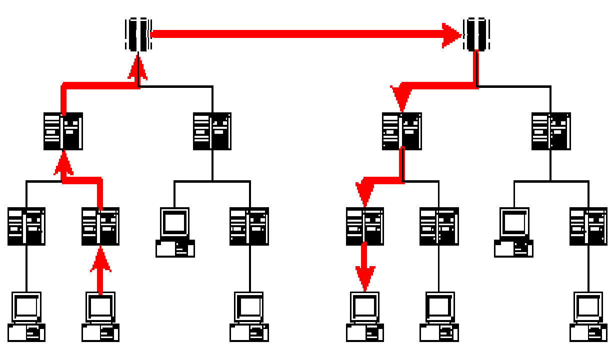


Figure 2: IP Terminals Connected through Routers

Machines connected to the Internet are recognized by their generic 4-byte identification number know as its IP address. Ex. 207.46.230.219 is the IP address of the first terminal in figure 1. The Internet is based on a 'packet' based data haul system, which works much like the prevalent mail delivery system.

Data to be transferred from one terminal is first *fragmented* into packets by the transport layer protocol (typically TCP). A header tag is attached to each such packet. The header contains information about source and destination IP address apart from other fields such as (TTL-Time To Live, Header Checksum – Coding to prevent data corruption). IP then *routs* each packet though a network of interconnected IP routers to the destination IP address. Once at the destination, the transport layer reassembles the fragmented data packets and delivers it to higher layers.

With rapid progress in the field of wireless communications, mobile phones have become extremely popular as a means of placing voice calls. Telecomm is fast progressing to realize the ultimate dream of anywhere-anytime connectivity. The next step for such services is to make available integrated voice-data access over portable devices. Wireless Internet accessibility to enable seamless data transfer between an existing IP backbone network and mobile terminals is an advancement in this direction.

II. MOBILE IP:

Traditional IP cannot support mobility, reason - the IP address of a host defines a fixed point in the network topology. Hence, once the device moves out of its home network, it is no longer accessible. Any new IP protocol designed to support mobility must meet the following objectives:

a) Compatibility: Should be congruous with the existing IP to allow data transfer between existing IP networks and mobile terminals.
b) Transparency: Mobility should remain 'invisible' to higher layer applications and all existing IP based features should run as before
c) Scalability: Should not disturb the stability of the Internet (Ex: Flooding the Internet with new messages)
d) Security: Should handle the security problems arising from mobility, esp. since the air-link is more susceptible to eavesdropping compared to a wired link.

The Basic Mobile IP is illustrated in figure 3. Its working can be described as follows.

1. Every Mobile Node (MN) has a home router known as a Home Agent (HA) when it is connected to its home network.
2. When MN moves to a foreign network, it attaches itself to a Foreign Agent (FA). The FA now acts as an interim router for MN.
3. Once the MN registers with the FA, the FA sends the temporary COA (Care-of Address) of the MN to the HA.
4. The packets with destination as MN are now

'tunneled' to the FA by the HA. This completes the mobile IP routing.

In principle, packets origination from the MN can be directly routed to the destination as in a normal IP based network. The problems arising out of this sort of a scheme will be discussed later.

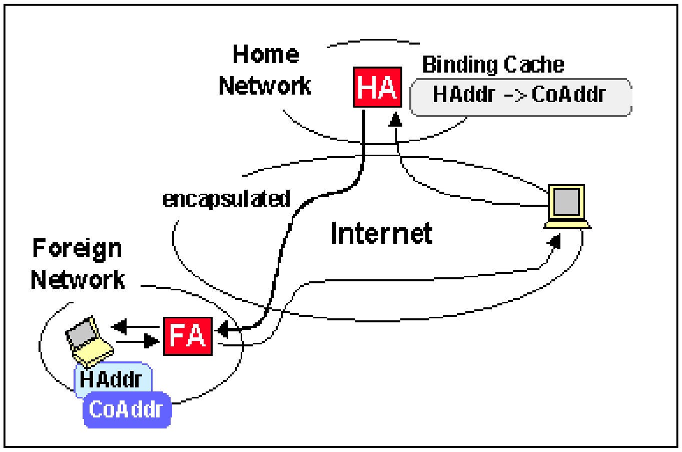


Figure 3: Mobile IP Packet Routing.

> Tunneling: The virtual pipe between the packet entry and packet end-point through the HA is referred to as the 'tunnel' and the process of routing packets is called tunneling.
> Encapsulation: Upon receiving a packet, the HA puts the packet into the data part of its packet and re-routs it to the FA. Such packet modification is called 'encapsulation'.

Agent advertisement and discovery:

A very critical part in step 2 above is to answer the question, how does the MN discover that it has moved? This is the problem of agent discovery. For this purpose, foreign as well as home agents advertise their presence periodically through special messages. These messages use ICMP (Internet Control Message Protocol). These advertisements contain information about the available COA s. Thus the MN acquires a temporary COA.

If the MN does not receive a COA, it can send out agent solicitations. Care must be taken how ever not to flood the network with solicitation messages. A Typical problem associated with agent messages is that they use the RFC 1256 standard, which requires a minimum delay of three seconds between consecutive advertisements. While this is fine for wired environments, it is too large for mobile environments.

Registration:

After receiving the COA the MN has to inform the HA about its new COA. This process is known as registration. For this purpose, the MN sends a registration request to the FA. The FA forwards the request to the HA. The HA now sets up what is called a **mobility binding** containing the MN's IP address and the current COA. It then sends registration ack to FA which forwards it to the HA.

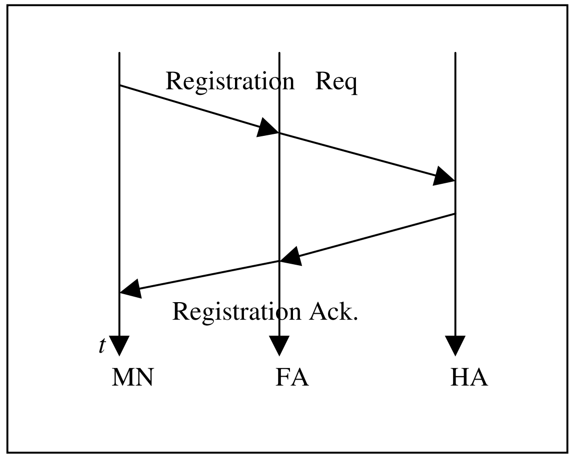


Figure 4: Registration

Reverse Tunneling:

The return path from the MN to the correspondent Node (CN) looks simple. MN can directly send packets with destination address CN, but there are several problems such as,

1. All companies have **firewalls** to secure their network. These only allow packets with valid IP addresses to pass through. However, the MN still continues to transmit with its fixed IP address, which is topologically incorrect when in a foreign network.
2. TTL (Time To Live): If the MN moves to a foreign network, the TTL of the packets it generates might be low to reach the same nodes as before. So the TTL has to be modified according to location, which is not transparent anymore.
3. Without a reverse tunnel, multicast packets cannot be generated by an MN in a way they would emanate from its home network.

These considerations led to the development of **RFC 2344** to define reverse tunneling as an extension to Mobile IP. This is backwards-compatible with Mobile IP and defines topologically correct reverse tunneling as necessary to handle the problems above.

Handoff:

When the MN moves from the subnet of FA_{old} to the subnet of FA_{new}, handoff is achieved through the following steps:

1. The MN registers with FA_{new}
2. FA_{new} informs the HA about the new COA of MN.

3. The HA now tunnels packets to FA_{new}
4. Also, HA informs FA_{old} about the new COA. Thus any undelivered packets will be delivered to FA_{new}.

III. Triangular Routing Problem and ROMIP

Consider this scenario: Two businessmen, an American and a Japanese meet in France and want to exchange data on their laptops. Both of them run Mobile IP on their devices. Now because of the typical way mobile IP routs packets, the data to the Japanese has to first pass through his HA in Japan and same is true for the American. Thus even though they are seated a few feet apart, the data packets have to almost travel all around the world!! This is the problem of "**Triangular Routing**" which arises in traditional Mobile IP.

Triangular routing in MIP results in the following concerns.

1. **Increased Delay:** The destination HA is a fixed redirection point for every IP packet even if there is a shorter routing path available between the two nodes. This results in a large end-to-end delay.
2. **Home Agent Overloading:** The network links connecting a HA to the network are overloaded. All session paths sharing the subnet field of their DA converge into that HA even if the adjacent network links are idle.

ROMIP

A possible solution to avert his problem is the "**ROMIP**" (Route Optimization Mobile IP) protocol. The ROMIP packet routing goes through the following three phases.

1. **Binding Acquisition:** The initial packets are routed to the MN through the HA. Meanwhile the HA sends a 'binding warning message' to the source. The source responds with a binding request message. HA replies with a binding update message containing the COA.
2. **Direct Routing:** The source receives the COA and uses it to tunnel the packets directly to the FA. This is done as long as the MN is in the given foreign subnet.
3. **Handover:** The MN moves to a different foreign subnet of FA_{new}. The MN sends an update to FA_{old} and the HA. Once FA_{old} gets the update, it sends a warning to the source and forwards incoming packets to FA_{new}. The handover phase ends when the source receives the current binding. It then updates its registry and enters a direct routing phase.

Steps 2 and 3 are repeated in a cycle. Further care has to be taken to stabilize the algorithm. For example, the periodic binding warning messages issued by the agents might flood the network. Hence an appropriate **back-off** algorithm has to be used to limit the frequency of these messages. Also, control messages are always triangle routed. This ensures safe delivery of control messages and avoids sending further control messages to be issued for ensuring delivery of a control message. Otherwise, it might possibly give rise to positive feedback and result in flooding the network.

The primary disadvantage of ROMIP is the necessity of the additional binding update and warning messages, which increases the transmission overheads. Such messages might be very taxing on the available bandwidth, especially in situations when the mobile device is moving at a high velocity from one subnet to other, thus causing frequent transmission overheads. The ROMIP can work efficiently, only if the mobile agent does not change subnet too often.

Simulation Studies

Elaborate studies comparing the ROMIP to the MIP are made in [3]. The traffic descriptors chosen in the work are the average session length (S, expressed in kbit) and the average offered load (L, expressed in kbit/s). L = S/T, where T is the arrival time delay between groups or in other words, the mean idle time for each generator. The mobility process is modeled as a continuous time random walk and its descriptor is the average mobility rate (inverse stay time). Their observations can be summarized as follows:

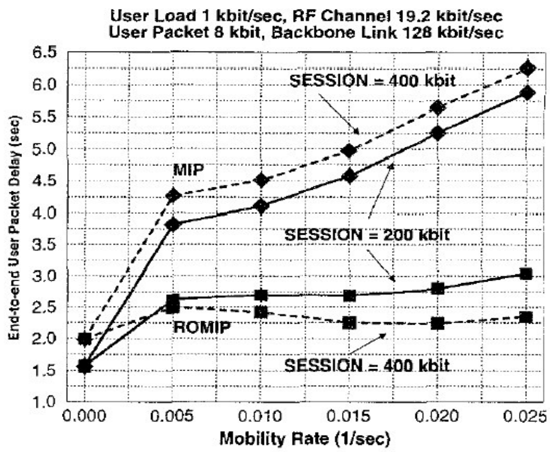
1. At null mobility rate, end-to-end delay increases as session duration increases. The optimal session length is around 100kbit.
2. At higher mobility, the end-to-end delay depends on the session length.
a) At lower session lengths, the overheads involved in ROMIP become significantly higher. In fact short session lengths hardly enter the direct routing phase. This results in the MIP dominating the ROMIP. Fig. (5)
b) At high session length, the ROMIP outperforms the MIP because of faster binding. Fig (5). Long session lengths give a more homogeneous traffic distribution and result in a saturation effect to traffic burstiness. So even for the longest sessions, delivering packets tends to an asymptotic value.
3. ROMIP has a slightly higher packet loss rate, which can be attributed to the increase in binding update time.
4. Finally the effect of the binding cache is studied in for the ROMIP. The study indicates that a large cache size results in shorter delay and greater packet loss (since a lot of binding addresses may be invalid). A small cache size results in lower loss but increases packet delay.

IV. MOBILE IP^2:

As the Internet becomes more and more popular, the lives of people are becoming increasing intertwined with it. The ability to remain always connected with the Internet no matter where is increasingly desired in a mobile environment. Mobile IP^2 (MIP2) suggested in [4] is one such enhancement, which introduces the concept of Multiple Interface/Multiple

Connection improves handoff ability and support seamless roaming between different networks.

Figure 5: Delay- MIP Vs ROMIP



Advantage: The salient feature of this architecture is that rather than viewing the wireless aspect as a "hassle" which needs to be merged with the existing IP network, this uses the same concept to its advantage. One such advantage of a wireless device is its ability to connect to multiple service points and hence simultaneously be a part of different networks, which are entirely different.

MIP2 Network Architecture:

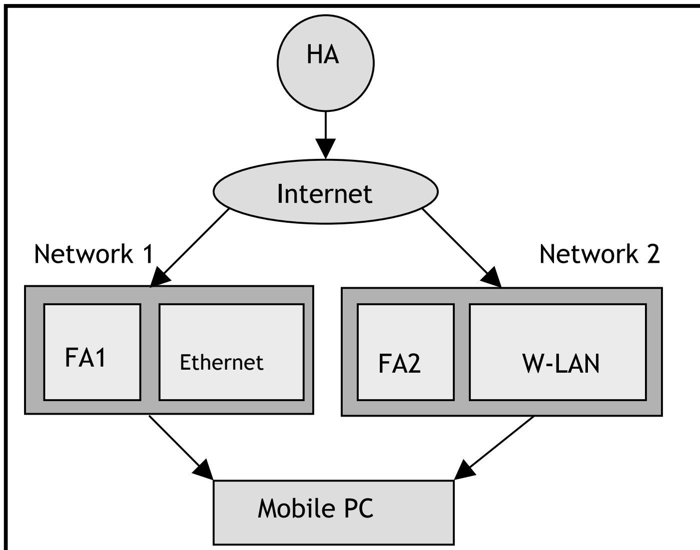


Figure 6: Mobile IP^2

The central idea is to establish a multiple interface so that frequent switching between systems becomes possible. Moreover, the user can then select the network that is best for him. A typical network topology under such a scheme is shown in Fig. (6). The mobile nodes now need to perform routing based on user profile. The user profile can be stored as a table in the HA. (As shown in Table 1. below)

Network Type	Priority	COA
Ethernet W- LAN Cellular	1 2 3	1.1.1.x 2.2.2.x Not Available

Table 1: User Profile in Mobile IP^2

Description of key steps:

1. Mobile scans network as soon as it powers up. The mobile registers through all the networks it can access. It receives a COA and updates its user profile.
2. These connections are checked regularly and their status is updated.
3. When the MN moves from one system to another, the mobile updates the HA and the undelivered packets from one system are automatically delivered from another by setting up of proper control messages.
4. IP session should be transferred to a second option seamlessly. This requires setting up of two additional enhancements. The **ARP** (Address Resolution Protocol) for controls routing through multi-physical connections and the **CMIP** (Current Mobile IP) effectively controls the mobile IP tunneling between different systems.

Scenario:

A typical such scenario is described by the following steps:

1. User powers up his mobile PC. The PC is connected to the corporate LAN through Ethernet. Also during this time the user profile is downloaded from the HA. Potential system links will also be established and maintained based on the user profile.
2. The user sends/receives packets from the LAN at work.
3. User unplugs Ethernet and walks towards the garage.
4. User is driving home and a seamless transfer occurs from wireless LAN to his cellular service provider.
5. User reaches home and connects either to a WLAN or back into the MMDS system.

V. Internetworking for efficiency - DECT

One innovative technique to solve the mobility problem in IP is to use internetworking. By internetworking we mean to integrate a network which supports mobility with the Internet. **DECT** (Digital Enhanced Cordless Telephony) which supports short-range local host mobility seems very attractive for such a purpose. As mentioned in [5], using DECT, which is more suited for handling mobility, the mobile IP handover latency can be improved.

DECT is a second-generation pico-cellular system standardized by The European Standards Institute (ETSI). It is a short-range wireless technology so that it can be interfaced to a large number of local and public networks such as the Internet, PSTN etc. However, DECT does not support wide area mobility due to the lack of a dedicated backbone.

DECT can possibly be fused with the Internet to serve two purposes.
1. To provide wide area mobility in DECT networks
2. To provide mobility support in IP based networks.

Network Architecture:

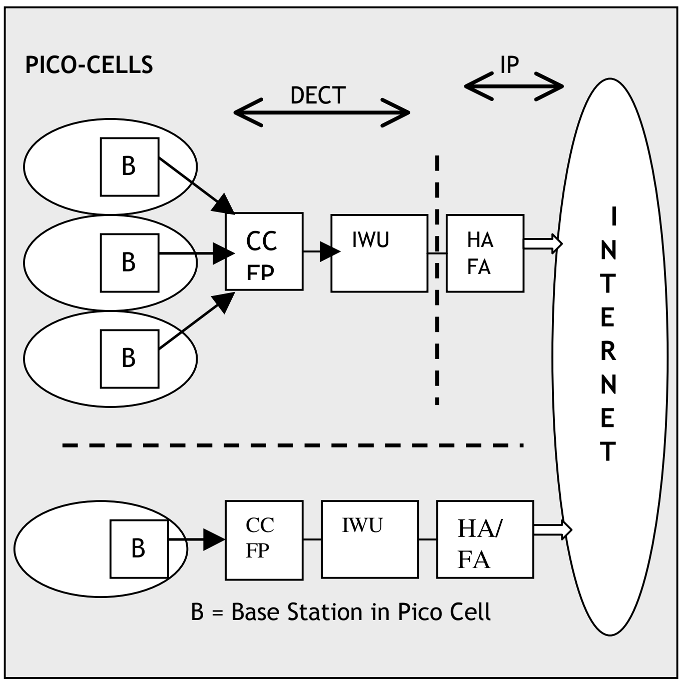


Figure 7: DECT-Internet Internetworking

Figure above shows the DECT-IP internetworking. Each of the DECT pico-cell contains a Fixed Part (FP) and several Portable Parts (PP). The FP in turn comprises of the Common Control Fixed Part (CCFP), Internetworking Unit (IWU) and several RFPs (Radio Fixed Parts- Base Stations). The cell sizes typically range from 50-300m. The RFPs handle physical and MAC layer aspects in a given pico-cell. The CCFP handles the network layer for a cluster of RFPs via the conventional data-networking infrastructure. The CCFP is connected to the Internet via the IWU. The IWU is realized as a sublayer in an SNDCF (Subnetwork Dependent Convergence Function) which is used to bridge the gap between MIP and the DECT protocols.

Several pico-cells are then connected to a Home or Foreign Agent (HA/FA). The PP is identified by two addresses: a home IP address and a DECT International Portable User Identity (DPUI). The binding between these addresses is static. The IP address is used for routing on the Internet, while the DPUI is used for the PP to identify itself in the DECT network.

Mobility Management in DECT-IP

Location Management: The movement detection capabilities of DECT are used because it offers much faster convergence than MIP. MIP advertisement messages are large and it is rather inefficient to broadcast them periodically. The SNDCF can be used to intercept and store the latest advertisement of the HA/FA. The SNDCF then forwards a copy of this advertisement to any PP which has successfully registered with the FP in the DECT subnet. It works as follows.

1. Locate request is sent by PP to SNDCF
2. CCFP -SNDCF replies with location registration accept.
3. SNDCF sends an agent advertisement message to PP.
4. PP sends an MIP registration request to FA via the CCFP.
5. FA determines PP's HA and relays request to HA.
6. If request if valid, HA updates PP's binding entry.
7. The physical connection with the RFP is released.

Handover

Two types of handover are defined: Internal and External. Internal handover occurs when a PP switches between RFPs in the same subnet. This involves only a change in the RPN (Radio Fixed Part Number).

External handover between two different subnets is more complicated and for this purpose, MIP can be used to re-route IP Packets. It takes place in the following step-wise manner.

1. PP requests handover to a target CCFP by sending a NWK layer message, CC_SETUP
2. CCFP replies with a CC_CONNECT message
3. PP acknowledges with a CC_CONNECT_ACK message.
4. This triggers the SNDCF to send the advertisement message to the PP.
5. MIP registration is carried out as in Mobility Management (described above).

Thus the mobility support of DECT can be efficiently fused with the existing Internet backbone to provide wide area mobility.

VII. QoS - Mobile IP Reservation Protocol (MIR)

In this final section we discuss the QoS aspects of mobile networks. In wired environments, protocols like the CLEP (Control Load Ethernet Protocol) address the problem of bandwidth allocation and reservation in order to provide the users of shared media with a guaranteed band-width. The MIR protocol discussed in [6] is an extension of the CLEP for mobile environments and reserves resources in cells where the mobile is likely to go.

CLEP - Description

Load control in CLEP is done using 'token bucket filters'. A token bucket is a particular form of a Traffic Specification (T_{spec}). Different packets are organized into different privileged flows according to their T_{spec}. Traffic without guaranteed QoS is 'Best Effort Traffic'. Both privileged and best-effort flows use the CLEP to control network admission. Packets are admitted only if there is enough band-width for them.

Four parameters are continuously updated at each network element to monitor network traffic. They are

1. R_{be} (Best Effort Traffic Rate)
2. R_{min}(Min R_{be})
3. R_{priv}(Privileged Flow Rate)
4. R_{max} (Max rate for the Link).

When ever a new element appears or a new reservation is needed, R_{be} is decreased if it is greater than R_{min} . The new available bandwidth R_{free} is computed and if it is greater than needed, the new reservation is allowed, else rejected. Other more optimized update rules allow for better QoS guarantees.

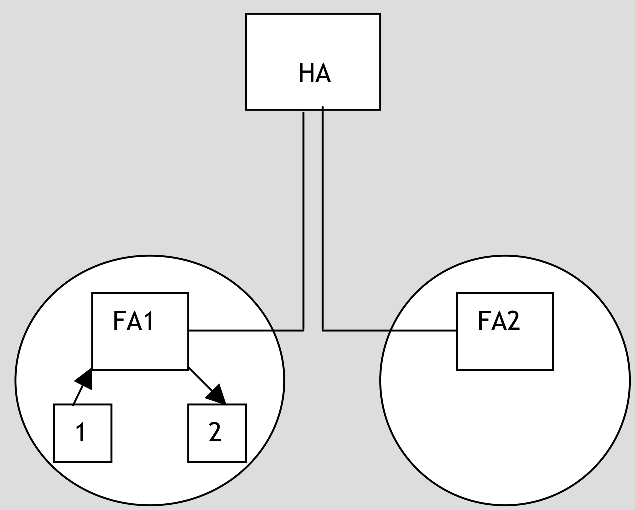
MIR (Mobile IP Reservation Protocol):

In a mobile environment, the number of tokens allocated to a particular queue should be determined according to two factors.

1. Traffic in the cell.
2. Mobility of cell members.

Adapting CLEP would mean taking into account resource reservation during handoffs and adapting the size of buffers. If the wired network offers a much greater bandwidth, essentially implying that it is not a bottle neck, then only the wireless cells need to run the MIR. Consider a handoff situation involving 2 Foreign Agents FA1, FA2 and 2 mobile nodes MN1, MN2. Assume also that MN 1 is transmitting data while MN2 is receiving data. Initially, both MN1 and MN2 are attached to FA1. One of the following two scenarios possibly arise.

1.The sender is roaming. MN1 moves to FA2. Then, the reservation made by MN1 in cell 1 should be cancelled and resources should be reserved in cell 2 (with FA2). However, FA1's resources should not be cancelled as it is still transmitting to MN2.
2.The receiver is roaming. After MN2 moves to FA2, MN1 should keep its reservation in cell1 as it is transmitting. However, since FA1 is no longer transmitting, its reservation in cell 1 needs be cancelled and new resources need to be allocated to FA2.



1 = MN1 = Mobile Node1, 2 = MN2
Figure 8: Scenario Described in MIR

Other key considerations for QoS enhancement could be to consider certain key factors such as speed of the terminal (fast or slow), the type of connection (degradable or non-degradable). An audio stream is a degradable privileged flow in the sense that it can still be understood if a random part of it is removed. However, some compressed video streams will make no sense if a part of the information is lost and hence are classified as non-degradable flows. Different such aspects can be considered.

Three states are identified according to the nature to traffic in these networks. In the first state, all connections are accepted. In the second state, all handoffs are accepted and finally in the last state, only fast non-degradable handoffs are accepted. Fast connections are chosen because of two reasons.

1. Slow connections utilize the local BW for a long time

2. Slow passive reservations are likely to be unused for a longer period of time.

Thus the MIR and proposals like it can be used to improve QoS guarantees in mobile networks.

VIII. CONCLUSION

In this term paper, firstly, we briefly described IP and its counterpart for mobile environments – Mobile IP. An in-depth literature survey was made and articles discussing several aspects of MIP were researched. Several enhancements to the basic Mobile Internet Protocol have been presented. QoS and other aspects have also been discussed.

IX. REFERENCES:

[1] Jochen Schiller – "Mobile Communications", Addison Wesley Publishing Co., 2000 (Chapter 9, 'Mobile Network Layer'), Pg 255-289.
[2] Sam Makki, Niki Pissinou, Philippe Daroux and Emmanuelle Sardaby, "On Fundamental Issues in Mobile and Wireless Internet" – Wireless Communications and Networking Conference 2000, Pg.1297-1302.
[3] Maurizio Dell'Abate, Martino De Marco, Vittorio Trecordi, "Performance Evaluation of Mobile IP Protocols in a Wireless Environment", IEEE International Conference on Communications, ICC 98, Pg. 1810-1816.
[4] David J.Y. Lee and William C.Y.Lee, "Mobile IP^2 ",IEEE International Conference On Microwave and Millimeter Wave Technology, 2000, Pg. 403 – 407.
[5] Anthony Lo, Winston Seah and Edwin Schreuder, "An Efficient DECT-Mobile IP" Internetworking for Mobile Computing, IEEE Vehicular Technology Conference,2000. Pg. 274-278.
[6] Gwendal Le Grand, Jalel Ben-Othman, Eric Horlait, "Providing Quality of Service in Mobile Environments with MIR (Mobile IP reservation Protocol)",IEEE International Conference on Networks, 2000, Pg24-29.
[7] http://www.xoc.net/works/jigsaw/internetbasics.asp
[8] http://carmen.cselt.it/papers/iss2000-ip_role_mobile/paper/IP-Role-Mobile.html

Introduction:

In this term-paper, the current issues in **Mobile IP** and strategies to enhance its performance are presented. Mobile IP is a relatively new concept. It aims to make IP based services and more specifically the Internet, accessible over mobile devices.

In the first section, the basic concept of IP is introduced briefly for the sake of completeness. The next section describes the key features and aspects of Mobile IP. The sections following it are devoted to describing various enhancements to the basic MIP to improve performance. Section III discusses the ROMIP (Route Optimization MIP) while Mobile IP^2 and a DECT-MIP internetworking scheme are presented in the following sections. These sections give new ideas and bring into light innovative concepts, which rather than blindly extending the concept of IP to mobile devices, make fullest use of the available mobility dimension. Finally, to conclude the work, QoS aspects of Mobile IP networks are discussed.

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