Integrating IP-based Micro-Mobility in Future Cellular Multimedia Networks

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Introduction

- Future mobile users shall have the ability to retain everywhere seamless access to a rich set of information and communication services driven by IP-based multimedia applications.
- Applying a global approach for providing IP-based mobility management over various access technologies (WLAN, 3G mobile systems) will permit to provide seamless mobile services and applications over both public and private networks.
- Mobile IP offers a flexible mechanism for the management of macro-mobility over the Internet but is non optimized to provide real-time high speed micro-mobility within one site or one domain.

The requirements for a new micro-mobility protocol (1/5)

- Micro-mobility is characterized by frequent and fast movements.
- The use of Mobile IP implicates:
  - An overload of the network core.
  - An important delay in the diffusion of the new location.
  - A long interruption of communications.
  - An enormous loss of packets.
  - A degradation of the quality of services.
  - Non-support of real time applications.
- From which the necessity of a new protocol able to manage micro-mobility and to fill Mobile IP limits.

The requirements for a new micro-mobility protocol (2/5)

- This new micro-mobility will have to:
  - Manage local movements without informing the core network.
    - Therefore, it will send update messages outside the access network only at the time of inter-network movements.This will avoid overloading Internet core backbones with important control traffic induced by the frequent local intra-network movements.
  - Decrease the update traffic of the new location.
    - The mobile node must not have the obligation to transmit update messages to its home agent and to its direct correspondents independently of the movement nature. Otherwise, this will generate enormous control traffic and a bad use of radio resources.
  - Limit the diffusion of update messages.
    - The limitation of the update diffusion the most locally than possible could reduce the diffusion time of the new location.

The requirements for a new micro-mobility protocol (3/5)

- Minimize the delay in the new location update.
  - It must not generates an update message at each movement which will have to go through the entire network to the home agent, and thereafter requires to wait until the message response.
- Eliminate the packet losses during handovers.
  - The minimization of delay in the update diffusion will certainly reduce packet losses. But will it be possible to eliminate it completely?
- Provide superior QoS and support real time services.
  - It will have to ensure a good quality of service and be able to maintain it during all the mobile node communication.
  - By minimizing the diffusion delay of the new location, it will facilitate the support of real time applications. But it shall be careful to avoid favoring elimination of packet losses to the detriment of the operation of real time service.

The requirements for a new micro-mobility protocol (4/5)

- Define an optimal use of radio resources.
  - The reduction of update traffic initiated by the mobile node will contribute to avoid the saturation of radio resources.
  - In order to minimize the battery power consumption, it would be beneficial to avoid the mobile node emitting update messages when it's not communicating. The introduction of a stand-by mode as defined in GPRS could be a good alternative.
- Support paging.
  - When the mobile node will not be in the course of communication and therefore it will be in stand-by mode, its exact location will not be known because it won't be updated. We'll then have to define a paging mechanism, which will have the capability to inform the mobile nodes in stand-by mode that they'll be receiving packets.
- Interact with Mobile IP.
  - The macro-mobility will always be managed by Mobile IP. It will then be necessary to define a good interaction between the two protocols in order to ensure the end to end mobility management.

The requirements for a new micro-mobility protocol (5/5)

- Be independent of the radio technology.
  - We'll have to render this protocol as independent as possible from access networks. Otherwise it will not be able to be supported by the maximum of public and private mobile/wireless networks.
- Insure the robustness.
  - We'll have to take in consideration the tolerance to failures of the home agent and other entities used in the micro-mobility management.
- Be scalable.
  - The new protocol will have to remedy to Mobile IP limits without complexing the mechanism of mobility management.

Existing proposals (1/11)

- We will restrain ourselves to the two following approaches: Cellular IP from the University of Columbia and HAWAII from Lucent Bell Labs.
- These two protocols are based on the same base principles:
  - A network architecture on two levels.
    - The highest level is classic Internet with mobile IP.
    - Access networks constitute the lowest level.
  - The router linking the two levels masks the local movements to the rest of the network and avoids the diffusion of internal update messages in the Internet core.
  - All the nodes of access network have routing tables with entries, which map the mobile node address to the neighbor from which the update packet arrived to the node.
  - These entries are updated at each movement so that they point continuously on the new location.

Existing proposals (2/11)

- The entries must be refreshed periodically otherwise they are automatically erased.
- They distinguish between a mobile node in active mode receiving or transmitting data with a mobile node in stand-by mode. In the second case, the mobile node needs neither to update nor to refresh its routing entries which are then destroyed at the end of the route-timeout.
- In order to ensure the delivery of the packets destined to these mobile nodes, they defined paging entries able to find the mobile in a location area rather broad and they will thus make it possible to forward to him a paging request.
- By receiving this paging request, the mobile node passes in active mode thanks to the emission of an update packet of routing entries so that they point on its current location.

Existing proposals (3/11)

- On top of these common base principles, each of the two protocols Cellular IP and HAWAII tries to bring its own solutions to mobile IP limits.
  - Manage local movements without informing the core network.
    - The access networks are named “domains” in HAWAII and “Cellular IP networks” in Cellular IP.
    - The routers, linking the two levels, are named “domain root routers” in HAWAII and “gateways Cellular IP” in Cellular IP.
    - In a visited Cellular IP network, a mobile node is addressed by its home address and it uses the gateway as foreign agent. The packets destined to the mobile reach at first the gateway where they are decapsulated and after they're routed to their home address. So until the mobile remains in this network, it doesn't have to inform the home agent of its movements.
    - In a visited HAWAII domain, a mobile node is being addressed by a dynamically configured address, which it keeps all the remaining time in this domain. The packets are then directly addressed to this address and decapsulated by the mobile node.

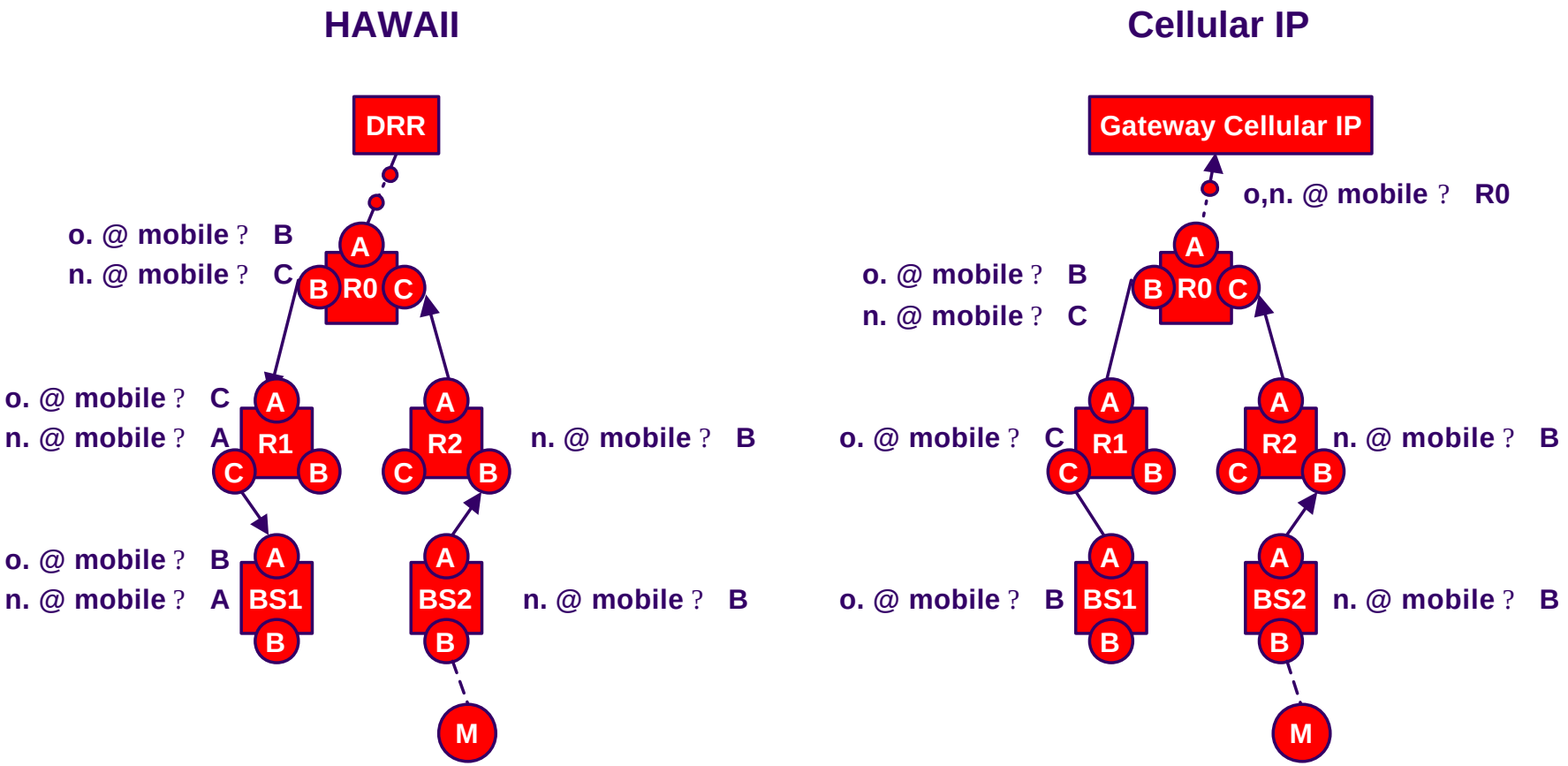
Existing proposals (4/11)

- Decrease the update traffic of the new location.
  - The transparent management of local movements permits to decrease the control traffic but it induces others kinds of messages initiated by the mobile node and necessary for the update and the refreshment of the routing entries.
  - In Cellular IP, they use routing update messages called route-update packets. They are emitted from the mobile node to the gateway Cellular IP.
  - The refreshment of routing entries is insured by amount data packets. Otherwise by route-update packets generated periodically in absence of data emission.
  - In HAWAII, update messages are called path setup power-up messages and they're sent from the new base station to the domain root router in the case of power-up or they are called path setup update messages and they're sent from the new base station to the old one during handovers.
  - The refreshment is done by messages periodically sent by a base station or a router to its neighbors.
  - The number of control messages generated in HAWAII is equal to the 1/3 of the number of control messages generated in Mobile IP.

Existing proposals (5/11)

- Limit the diffusion of update messages.
  - The diffusion stops at the gateway in Cellular IP and at the first common router between the old base station and the new one in HAWAII. This router is called the cross-over router.
- Minimize the delay in the new location update.
  - The new location diffusion is completed once the route-update packet or the path setup message reaches the cross-over router.
- Eliminate the packet losses during handovers.
  - The loss of packets is considerably reduced by the minimization of the diffusion delay of the new location.
  - Moreover, Cellular IP defines a handover called semi-soft handover able to completely eliminate the losses of packets.
  - HAWAII proposes two update schemes. In the first, data packets are forwarded from the old base station to the new one before they're diverted at the cross-over router. Whereas in the second, packets are diverted at the cross-over router to the new base station resulting in non forwarding of packets from the old base station.

Existing proposals (6/11)



Existing proposals (7/11)

- Provide superior QoS and support real time services.
  - With the reduction of packet losses, the quality of services is considerably upgraded.
  - In Cellular IP, they foresee delaying the packets at the cross-over router.
  - HAWAII is easier to adapt to the resources reservation protocol because it avoids starting again all the reservation after a handover.
- Define an optimal use of radio resources.
  - The diminution of signal traffic permits to save radio resources.
  - In order to better manage the consumption of the battery power, Cellular IP defines two modes for mobile nodes: active mode where the mobile node is communicating or idle mode instead.
  - HAWAII defines three states: the “active state” where the node is receiving or transmitting data, the “stand-by state” where the mobile is listening to only broadcast channels and the “null state” where the mobile is power down.
  - In the two approaches, the mobile node must update and refresh its entries only if it's in active mode.

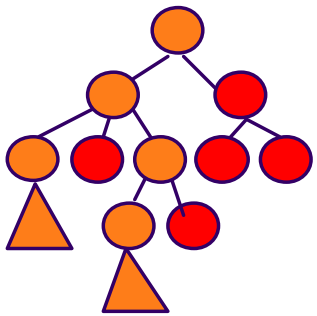
Existing proposals (8/11)

- Support paging.
  - In Cellular IP, paging entries are implanted in paging caches, which are placed in well chosen nodes.
  - The location of these caches allows to define paging areas which are a group of base stations where the mobile node is subject to be found.
  - The paging entries are created and updated by route-update packets when the mobile is in active mode and by paging-update packets periodically sent or generated following a paging area change when the mobile is in stand-by mode.
  - When a packet destined to a mobile node in idle mode reaches the Cellular IP network, it is then routed by the paging entries and when it meets a node without paging cache, it's diffused towards all neighbors.
  - Finally, the packet is broadcasted in the paging area of the mobile node that receives it and emits a route-update message so it can create these routing entries.

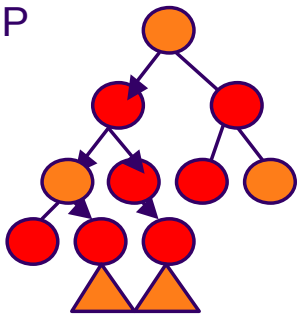
Existing proposals (9/11)

- In HAWAII, the paging entries are located in routing tables and are dynamically created like in the case of routing entry on the path between the mobile node and the domain root router.
- They are created by path setup messages after a powering up or after handover and by paging update messages sent by a mobile node to its domain root router when it changes of paging area.
- The paging area in HAWAII is defined by Multicast groups addresses. To belong to a paging area, a base station must join this area address.
- When a packet destined to a mobile node in idle mode reaches the HAWAII domain, a paging request is iniated.

HAWAII



Cellular IP



Existing proposals (10/11)

- Interact with Mobile IP.
  - In HAWAII, when a mobile node detects a location change, it sends a registration request to its new base station. This last one verifies if it's an intra-network or inter-network movement. In the first case, it generates a path setup update message to the old base station and in the second case it relays the request to the mobile node's home agent. Finally and independently from movement, the new station must receive acknowledgement and by consequence it generates a registration response to the mobile node.
  - In Cellular IP, when a mobile node connects to a new Cellular IP network, it sends towards the gateway a router-update packet or paging-update, according to its mode, which contains authentication parameters. The gateway realizes its admission control and then sends its response to the mobile node. If the response is positive, the mobile will be able to emit its registration request towards its home agent throughout the gateway which plays the foreign agent role.

Existing proposals (11/11)

- Be independent of the radio technology.
  - These two protocols act mainly at layer 3. Therefore they are rather independent of the access networks. However, there are certain assumptions which can question this independence. For example: the need for the paging support on level 2 in HAWAII or the quick switch between two base stations in the semi-soft handover of Cellular IP.
- Insure the robustness.
  - If the home agent breaks down, the mobile node will be able to communicate with its direct correspondents as long as it does not change its Cellular IP network or its HAWAII domain.
  - The failures of routers and links are treated thanks to periodic refreshment of the routing entries.
- Be scalable.
  - The local management of the intra-network movements reduces enormously the signaling traffic. And even if this management induced the generation of new types of update messages, the new micro-mobility traffic remains less important and more local than that of Mobile IP.

The limits (1/5)

- The movement detection.
  - The detection can be accomplished at layer 3 by the network prefix. The base stations periodically send agent advertisement containing their address on their beacon signal. If the mobile node detects an address change it concludes then that it moved and executes the handover.
  - This render the access protocol easy to integrate and independent of the radio technology. However, there's a considerable delay between the real change of attachment point and the detection of this change. So it produces a loss of packets and in such conditions the support of real time services is mostly impossible.
  - Movement detection can be made also in layer 2. In fact, the mobile node chooses permanently the base station with the most powerful signal. And as soon as it notices a more suitable station, it executes the handover. This method is fast but requires to manage some parameters and thresholds of change in order to control phenomena such as temporary signal weakening and also movement to frontiers of two cells.

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The limits (2/5)

- The management of the constraints can turn out to be difficult for a mobile node and we can ask ourselves if it wouldn't be more interesting to manage the handover execution decision at the network level. Especially, that we'll be able to control the traffic load in the cells.
- But in this case we'll have to define the entities implicated in the decision charge and insure the independence of the solution to access networks.

- The paging support.
  - In HAWAII.
    - The paging packet is a paging request and it can be initiated by all routers of the HAWAII domain.
    - The paging entries are dynamically created.
    - However, HAWAII paging supposes that the layer two of the radio link supports the paging. This isn't verified in wireless networks such as IEEE802.11 and HIPERLAN.
    - Routers must support multicasting..

The limits (3/5)

- In Cellular IP.
  - There is no paging packet, it is the data packets themselves which are routed via paging entries.
  - When such a packet reaches a node without paging cache, it's broadcasted to all neighbors.
- The placement of paging caches is very complex because we have to find a compromise with the number of nodes where they are placed. This number must be small to insure the scalability of the solution and must also be big to avoid overloading the network with paging broadcasting.
- As long as the new routing entries are not created, data packets will be broadcasted in paging areas and they'll overload the access network.

The limits (4/5)

- The Cellular IP semi-soft handover.
  - When a mobile node in active mode moves, it sends a route-update packet which updates its routing entries so that they can point on the new location. Therefore, during all this procedure, the packets are delivered to the old base station and they are lost.
  - During a semi-soft handover, the mobile node sends a route-update packet with selected S bit towards the new base station and continues to listen to the old one.
  - This update packet creates new routing entries pointing towards the new base station and when it arrives at the cross-over router, it adds a new entry without erasing the old one. Therefore packets will be delivered to the two base stations.
  - When the mobile makes the move then the packets will already be underway to the new base station and the handover can be performed with minimal packet loss.
  - After migration the mobile node sends a route-update packet with S bit cleared. This packet will remove all routing entries except for the ones pointing to the new base station.

The limits (5/5)

- However, if a radio handover isn't instantly made, there will be still packet losses. Therefore Cellular IP introduced the possibility to delay data packets and to buffer them at the cross-over router.
- In the case of applications that are sensitive to delay variations more than to loss, Cellular IP suggests not to use this delay.
- This handover is very interesting but it requires that the mobile is able to switch quickly between two base stations and that the handover time is faster than the route-update diffusion.

Conclusion

- Cellular IP and HAWAII offer very interesting solutions for micro-mobility management.
- However, some mechanisms such as HAWAII paging and Cellular IP semi-soft handover remain dependant of radio technology and it will be beneficial to develop them so they will be supported by the maximum of public and private Mobile/wireless networks.
- Thereafter, we will have to better define the movement detection procedure and the handover execution decision. A layer two triggering seems fundamental to optimize the procedure speed whereas the network layer management is necessary for the repartition of traffic load between adjacent cells and for the control of the movement parameters.

Acknowledgements: *This work has been performed in the framework of the IST project IST-1999-10050 BRAIN, which is partly funded by the European Union. The authors would like to acknowledge the contributions of their colleagues, although the views expressed are those of the authors and do not necessarily represent the project.*