HANDOVER SUPPORT IN RING BASED IP MICRO MOBILITY NETWORKS

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Abstract: *There is a high need for IP based micro mobility networks because of the convergence of the Internet and telecommunication networks. These micro mobility networks provide fast handovers in a well defined area. This paper elaborates various handover mechanisms in ring topology and hierarchy of rings topology IP micro mobility networks. In the ring topology network two different handover mechanisms are introduced, one of which can be extended to make it possible to use it in the hierarchy of rings topology network.*

KEYWORDS: Micro Mobility, Hierarchy of Rings, IP, handover

1 INTRODUCTION

The emerging IP technology requires that the Internet and IP backbones of 3rd and 4th generation mobile systems can be reached via IP based micro mobility access networks. In Mobile IP [1] communication is requires between the MN (Mobile Node) and the HA (Home Agent) every time a handover takes place, when the MN moves to a new BS (Base Station) in the active state, the communication terminates for a few seconds. Some applications (for example IP telephony) cannot tolerate this, hence micro mobility is gaining popularity nowadays. Another reason is that for example in a Bluetooth environment handovers can be as frequent as 20 seconds, so it would be inefficient to contact the home agent at every handover.

Micro mobility provides mobility within a well defined area, for example an access network. The HA is only notified when the MN leaves or enters the access network, but not at intra domain handovers. Intra-domain handovers are handled within the network, thus are very fast.

Almost all of the micro mobility protocol recommendations are based upon a tree topology network. We proposed a ring based micro mobility solution [5] and in this paper we focus on the various handover mechanisms that can be used in these types of micro mobility networks.

This paper is organized as follows: In Section 2 the basics of micro mobility are explained in brief. Section 3 gives a short survey on the two topologies introduced in [5]. Section 4 is the main section, its two subsections explain the various handover methods in the two topologies. In Section 5 the handovers of the classical tree topology and the two newly introduced topologies are compared.

2 MICRO MOBILITY

Micro mobility networks are connected to the IP backbone via gateways. Most of the IP micro mobility protocols [2,3] are based upon a tree topology network of routers. There is one gateway in the root of the tree. This architecture makes the network rather vulnerable to link or node errors.

There are base stations at the leaves of the tree. Intra domain handovers (when the MN moves from one BS to another) are handled completely internally. Router databases are updated, as few packets are lost as possible.

3 THE NEW TOPOLOGIES

3.1 Ring

This and the next subsections give a brief survey of the two micro mobility network topologies introduced in [5].

The ring used for the micro mobility network is a self healing ring, like the MSSP (Multiplex Section Shared Protection) in the SDH environment. This makes it possible to recover one node or link error below the IP level. We have two directional link with equal capacity in the two directions, and use the full capacity of one direction for normal traffic, and reserve the other direction for self healing. Fig. 1. shows an example how the ring can heal one node error.

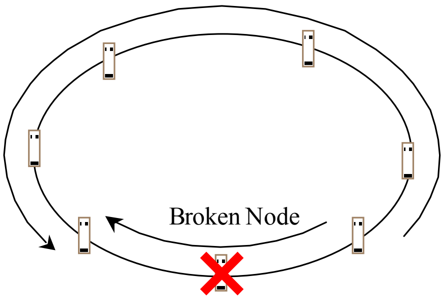

Figure 1 - The self healing ring corrects one error

The ring topology micro mobility network has the following types of nodes:

- gateway + router
- BS + router (SAP)
- router + special function

The gateway sends packets out to the IP backbone and receives packets from there. Gateways can be located anywhere in the network.

Fig. 2. shows the architecture of a ring topology micro mobility network.

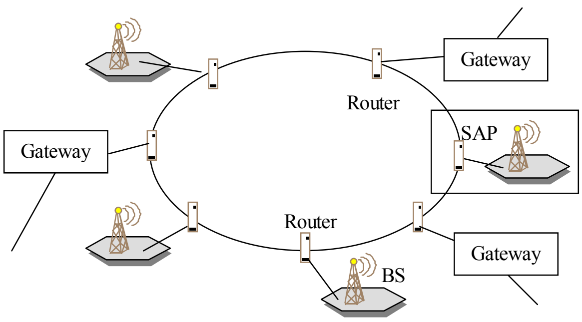

Figure 2 - Ring topology micro mobility network

The BS routers maintain a database that has an entry for all the MNs connected to that specific SAP. Gateway routers may have databases of all the MNs staying within the network. If they have this database, they are called enhanced database gateways. All these database entries are soft state, which means that they are timed out if not updated for a specified amount of time.

The database entries are set up at the time the MN registers to the micro mobility network, and they are updated during each handover.

Uplink traffic is routed as follows:

When the MN sends a packet to the BS via the air interface, it is passed to the SAP router. As we have a one directional ring, the packet is launched onto the ring, where all the SAP routers forward it until it reaches one of the gateway routers. As the gateway router identifies the packet as an uplink packet, it sends it out to the IP backbone instead of forwarding it.

Downlink traffic is routed as follows:

One of the gateway routers receives an IP packet. If it is an enhanced database gateway, it can check for the destination MN in the database. If it finds it or it does not have a database, it launches the packet onto the ring. The ring travels along the ring until a router finds the destination address in its database. This is the router of the SAP where the MN accesses the network. This router passes the IP packet to the BS instead of forwarding it along the ring. If the packet gets back to the gateway that launched it, it means that the MN can not be found in the network.

The ring topology micro mobility network is much more reliable than the classical tree topology one.

3.2 Scalable Hierarchy of Rings

The ring topology has a drawback: it does not scale very well with network size. To combine the reliability of the ring and the scalability of the tree we proposed a new topology, called the *scalable hierarchy of rings*.

This topology is basically a tree having rings instead of its nodes. The tree has a root node (the gateway), the hierarchy has a *root ring*. In place of the routers there are *transport rings*, in place of the base stations there are *access rings*. Fig. 3. shows the architecture of the scalable hierarchy of rings.

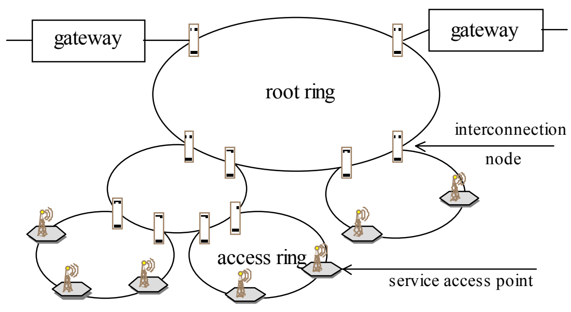

Figure 3 - Hierarchy of rings topology micro mobility network

This topology has the following node types:

- gateway + router
- BS + router (SAP)
- interconnection node
- router + special function
- combined

Our hierarchical network has gateways only in the root ring, and SAPs only in the access rings. A transport ring has child rings, an access ring has SAPs. Interconnection nodes are the routers that connect two rings.

The root ring, the transport rings and the access rings are all very similar to the simple ring. For example the interconnection nodes that connect a transport ring to its child rings act like SAP routers in a single ring, and the interconnection nodes that connect the transport ring to its parent are similar to the gateways of a single ring. The root ring has real gateways instead of interconnection nodes to the parent ring, and the access rings have real SAPs instead of interconnection nodes to the children. All the rings have uplink and downlink traffic just like a single ring topology network.

All the routers maintain enhanced databases. This means that an interconnection node has information about all the MNs that access the network below them.

When a MN sends a packet to a BS, the BS forwards it to the SAP router. The SAP router launches the packet on the access ring. It travels along the ring until it reaches an interconnection node. The interconnection node launches the packet on the parent ring instead of forwarding it. The packet travels step by step up to the root ring. In the root ring the first gateway it reaches sends it out to the Internet or the IP backbone.

Downlink packets travel down similarly from ring to ring to the access ring where the MN stays.

In this hierarchical network the MNs can switch to idle state to prolong battery life. Idle state MNs only notify the network when they move from one access ring to another. The network knows only the access ring that the MN is connected to but not the exact location. When an idle MN receives a packet, it is pages by all the BSs of the access ring, and it has to switch to active mode and notify the network about its location.

4 THE HANDOVER

4.1 Handover in the Ring Topology Network

4.1.1 Databases

If the ring is not an enhanced gateway database ring, only the SAP routers maintain databases. There is a database entry for each MN that accesses the network at that SAP. The database entry contains the *IP address* of the MN, a *packet timer* field and a *handover timer* field.

When a downlink packet arrives to the router it looks up the destination address in the database. If it is not found, it forwards the packet along the ring, if it is found, it sends the packet to the appropriate BS.

The packet timer is set up at registration, and is reset every time the MN sends a packet or registration update message. If the packet timer expires, the database entry is removed. This is because in a micro mobility environment the MNs may leave the network without notification.

The handover timer is used for handover purposes and will be discussed later.

If the ring is an enhanced gateway database ring, the gateway routers have a list of all the MNs staying in the network.

4.1.2 Registration

If there are no gateway databases, the registration is very simple. The MN sends the registration message to a BS. The BS forwards it to the SAP router, and the SAP router adds an entry to the database, and sets up the timer for it.

If it is an enhanced gateway database ring, then after adding the entry to the database, the registration message is launched on the ring. As it travels around, the gateway routers can update their databases, and all other SAP routers can delete any entries with the same IP address to prevent multiple registrations. When the registration message returns to the SAP router that has sent it out, it simply discards it.

4.1.3 Simple Handover

Simple handover is a soft handover type that can be used in rings where there are no gateway databases. The MN has to be able to communicate to two BSs simultaneously.

Simple handover is initiated by the MN. The BS that the MN leaves is called the old BS, the BS that the MN moves to is called the new BS.

First the MN notifies the new BS, and the new BS adds a database entry for the MN, then the old BS is notified. The old BS sets up the handover timer for a fixed time. When the handover timer expires, it removes the entry of the MN from the database and notifies the MN about it. Until that time if it receives a packet that is sent to the MN, it forwards it to the BS.

There are basically two topological variations of the simple handover in the ring. As the ring is one directional, the new BS can be "before" the old one, as in Fig. 4., or "after" it, as in Fig. 5.

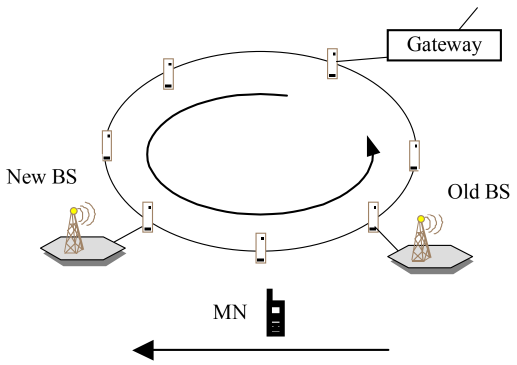

Figure 4 - New BS "before" the old one

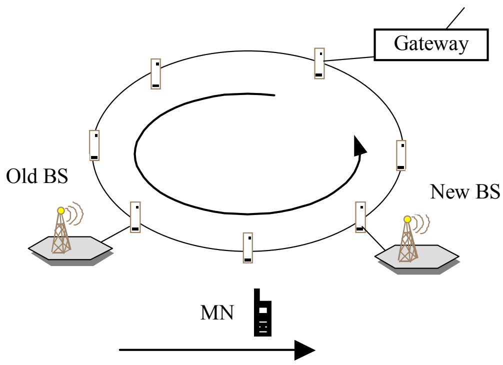

Figure 5 - New BS "after" the old one

The arrows indicate the working direction of the self healing rings.

Uplink traffic is simple during the handover. The MN can send packets to both the old and the new BS, they will be routed correctly. Sending packets to the new BS is recommended.

Actually, the MN can receive packets from more than one gateway, but for each of the gateways the situation is similar to one of the two mentioned here.

If the new BS is before the old BS (Fig. 4.), after the MN has notified the new BS, it will receive packets from the new BS. Some of the packets, that were already on their way from the new BS to the old BS, will be received from the old BS. This is why the handover timer is required. When the handover timer expires at the old BS, it sends a message to the MN, so the MN can know that it will not receive any further packets from the old BS.

The handover timer has to be set up carefully, because if it expires before one of the packets gets to the old BS, the router will forward it along the ring, it will get back to the gateway router that has sent it out, and the gateway router will falsely imply that the MN can not be found in the network.

Packet tagging can solve this problem, and at the same time makes it possible to use hard handovers. The old BS router sets up the handover timer, and until it expires it does not send packets to the BS, but tags packets (sets a bit in the header), and forwards them along the ring. These are handover tagged packets. When the gateway that has sent out the packet receives it with a handover tag, it launches it again without the handover tag. So the packet will travel around the ring once, but will not be lost. When using handover tags, the handover timer can be set up to a longer fixed time.

With handover tags a hard handover can be used by mobile equipments that can communicate to only one BS at a time. The MN notifies the old BS about its leaving, then switches to the new BS, notifies it about its arrival, and the MN will receive all its packets from the new BS. When using this solution, the packet header has to contain a roundtrip counter to prevent it from travel around the ring endlessly.

4.1.4 Advertised Handover

In this handover type it is not the MN but the new BS is that notifies the old BS. The MN sends the handover request to the new BS. If it is accepted, the router of the new BS starts routing packets sent to the MN to the BS instead of forwarding them, and at the same time launches a handover message on the ring. As this message travels around the ring, all the gateway routers have information about the handover. When it reaches the old BS, it simply deletes the entry of the MN from its database, and notifies the MN that it will not send any more packets.

This solution works, because if the new BS is "before" the old one, as in Fig.4., then the old BS will not receive any packets after the handover message, because the new BS will not forward any after launching the handover message. Note that this solution assumes FIFO processing at the routers.

If the new BS is "after" the old one, as in Fig. 5., then the packets will arrive from the old BS until it gets the handover message. After that the old BS forwards packets along the ring, and as the new BS is "after" it, no packets will be lost.

Advertised handover also has a hard variation with some packet losses. The MN simply moves to the new BS and packets sent by the old BS are lost.

When advertised handover is used, no handover timer is needed, but it generates signaling overhead on the ring.

4.2 Handover in the Hierarchy of Rings

4.2.1 Databases

In the hierarchy of rings topology network (Fig. 3.), all the interconnection nodes maintain a database. In that database there is an entry for every MN that is connected to the network in the subtree under the interconnection node. These entries are soft state too.

Downlink routing is based on these databases. When a downlink packet arrives to the interconnection node on the upper ring, it checks its database, and if there is a match, it launches the packet on the child ring instead of forwarding it along the parent ring.

4.2.2 Registration

When the MN registers the registration message travels around the access ring where it registers. The first interconnection node that it reaches tags the packet as "passed up", forwards it and at the same time launches an untagged instance of the packet on the parent ring. It travels around the parent ring and all the rings on its way up to the root ring. This way it reaches all the routers that have to have information about the MN, so they can set up they databases. The MN has to keep sending registration update messages to prevent the database entries from timing out.

4.2.3 Handover

The advertised handover mechanism can be adapted to the scalable hierarchy of rings topology. The MN initiates the handover as in the single ring topology network. The MN sends the handover message to the new BS. The new BS can be of course in a different ring than the old BS. The handover message contains the address of the MN. The handover message travels up from ring to ring as the registration message. All the routers can set up the databases. It travels up to the root ring and travels around all the rings on the way. It also travels around the crossover ring. The crossover ring is the first ring that the paths from the old and the new BSs to the root ring have in common.

The interconnection nodes that connect the crossover ring to its child ring towards the old BS know that they are in the crossover ring, because they have database entries for the MN. They delete the database entries for the MN.

The old path is the path from the crossover ring to the old BS. The database entries on the old path will time out anyway, but a direct tear down message can be sent down. This increases the traffic in the network but has the advantage that when it reaches the old BS, the MN can be notified that it will not receive any more packets from the old BS. If a direct tear down message is not used, timers have to be used as in the previous example.

During the time of the handover packets can arrive from both the old and the new BS. If the MN can not communicate to more than one BSs at a time, it can simply be connected to the new BS. The packets that were on their way from the crossover ring to the old BS will be lost, but the connection will not be terminated.

4.2.4 Idle State Handover

In [5] it was proposed that the MNs can switch to idle state to prolong battery life. The access rings are the paging areas. In the idle state the MN only has to notify the network when it moves from one paging area to another, but not when it moves from one BS to another. The interconnection nodes that connect the access ring to its parent ring has an idle field in their databases, so when a packet arrives to the MN the interconnection nodes launch a paging message on the access ring before launching the packet. As a reply to the paging message the MN switches to active state and sends a registration message to the network.

Idle state handover takes place when the MN moves from one access ring to another in the idle state. It is very similar to active state handover. The new access ring is where the MN moves to, the old access ring is the ring where the MN moves away from. The idle state handover message travels around the new access ring, all the interconnection nodes set up their database entries, they put the MN is, and mark it as an idle state MN. The idle handover message then travels up to the crossover ring as a normal handover message. If a tear down message is sent down, all the databases entries are deleted on the old path, but as there is no active communication is possible in the idle state, the MN is not notified by any of the BSs, actually the idle state tear down message does not even have to travel around the old access ring.

5 COMPARISON

In this chapter the explained handover mechanisms are compared to handover mechanisms of CellularIP [2] and HAWAII [3]. Both Cellular IP and HAWAII are based upon a tree topology.

Cellular IP provides a hard and a semi-soft handover. They are both for MNs that can maintain connection to only one BS at a time. HAWAII provides a soft and a hard handover mechanism. In a ring topology both simple and advertised handover have a soft and a hard variation. In the hierarchy of network topologies there is also a hard and a soft variation, but the hard variation might cause high packet loss rates.

One important advantage of the simple handover is that it does not require any traffic in the network.

The handover mechanisms of tree topology networks can be used in the hierarchy of rings with slight modifications, because the hierarchy of rings is actually a tree of rings.

In a single ring it is difficult to handle idle state, because it is difficult to define paging areas. In the tree subtrees can be defined as paging areas. Defining the paging areas as access rings in the hierarchy is straightforward and efficient.

6 CONCLUSIONS

In this paper various handover mechanisms of ring and hierarchy of rings topology micro mobility networks were examined. Two different handover types were introduced that can be used in ring based network: simple handover and advertised handover. They both have a soft and a hard variation. The advertised handover was then extended so that it can be used in hierarchy of rings topology networks. In the hierarchy of rings idle state handovers were discussed too.

Then the new handover types were compared to the standard handover mechanisms of tree topology micro mobility networks.

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