

Mobile IP Working Group

Internet Draft

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**Mobile IP Regional Paging**  
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Abstract

This document specifies Mobile IP Regional Paging (MIRP), a small and link-layer independent extension to Mobile IP [2] with regional registrations [3], to support power-constrained operation in the mobile nodes and to reduce routing state information in the visited domain. The extension allows a mobile node to enter a power saving idle mode during which its location is known with the coarse accuracy defined by a paging area. Downlink routes to idle mobile nodes terminate in a paging foreign agent, which re-establishes them on demand by means of paging. This does not require snooping of data packets but is a natural extension to network-level routing. Optionally, the mobile node and the visited domain can agree on

communication time slots used for Agent Advertisements and paging,  
to restrict link interface power-on time in the mobile node.

Haverinen and Malinen Expires December 2000

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**[1](#). Introduction**

This document specifies an extension to Mobile IP [[2](#)] with regional registrations [[3](#)] in order to support power-constrained operation and to reduce routing state information in the visited domain. The extension allows a mobile node to enter a power saving idle mode. The visited domain does not know the location of idle mobile nodes with the accuracy of an IP subnetwork but with a more coarse accuracy of a paging area.

Foreign agents advertise paging support by including a Paging Area ID extension in the Agent Advertisements. A mobile node that wishes to enter the idle mode sends either a Registration Request or a Regional Registration Request with an Idle Mode Request extension to the paging foreign agent of the current paging area. The paging foreign agent includes an Idle Mode Reply extension to the corresponding Registration Reply or Regional Registration Reply. In the idle mode, the mobile node does not need to perform subsequent registrations when it moves between the IP subnetworks of the paging area.

The mobile node enters the active mode by performing a normal home registration or a normal regional registration. The network may trigger this by paging the mobile node. The network pages the mobile node by sending an Agent Advertisement with a Paged Mobile Node Address extension to a paging multicast address.

When entering the idle mode, the mobile may optionally negotiate time slot based paging to be used. In this case, the mobile node and the network agree on the time slots used for Agent Advertisement and paging within the paging area.

## 2. Terms

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [4].

This document uses the same terminology as [2]. In addition, this document frequently uses the following terms:

### Active Mode

When a mobile node is in the active mode, it operates as normally with regional registrations. In order to send or receive packets, the mobile node must be in the active mode.

### Advertisement Interval

The time between two successive unsolicited Agent Advertisements, in milliseconds.

### Advertisement Slot

A time slot during which an idle mobile node activates its receiver to be able to receive the periodical unsolicited Agent Advertisements sent by the leaf foreign agents in the paging area.

### Crossover Foreign Agent

When a mobile node is performing a Regional Registration, the crossover foreign agent is the foreign agent where the old path of tunnels leading to a mobile node and the new path cross, i.e. the foreign agent in the hierarchy where a change in the tunneling or routing information is needed in order to keep the communication path to the mobile node up-to-date.

### Idle Mode

When a mobile node is in the idle mode, the network knows its location with a smaller precision than usual, in a granularity defined by the paging area. In the idle mode, the mobile node may be able to deactivate some of its components for energy-saving purposes.

## Idle Mobile Node

A mobile node that is in the idle mode.

### Idle Mode Registration

A home registration or regional registration performed by a mobile node in order to enter the idle mode or to extend the lifetime of a previous idle mode registration. A mobile node performs an idle mode registration by sending either a Registration Request or a Regional Registration Request with an Idle Mode Request extension.

### Leaf Foreign Agent

A foreign agent in a regional mobility hierarchy closest to the mobile node. This is usually a leaf of a tree structure of foreign agents within the visited domain.

### Paging Agent Advertisement

An Agent Advertisement which is sent to a paging multicast address and which contains a Paged Mobile Mode Address extension.

### Paging Area

An area containing possibly multiple foreign agents where an idle mobile node can be without the visited domain knowing anything more precise about the location of the idle mobile node. The foreign agent at the root of the paging area is called a paging foreign agent.

### Paging Foreign Agent

The foreign agent that maintains the paging state in a paging area. The downlink communication paths to idle mobile nodes within this paging area terminate in this foreign agent. In the foreign agents closer to the mobile node in the hierarchy, that is, below this node, there is no need to maintain any communication state information for idle mobile nodes.

### Paging Multicast Address

An IP multicast address used for paging a mobile node by leaf foreign agents. When a mobile node is paged, each leaf foreign agent sends an Agent Advertisement to this address with the Paged Mobile Node Address extension indicating which mobile node is being paged. Such advertisements are called paging Agent Advertisements. A paging multicast address can be used for paging one or more mobile nodes.

### Paging Slot

A time slot during which an idle mobile node activates its receiver to be able to receive the possible paging Agent Advertisements sent by the leaf foreign agents in the paging area.

## Visited Domain

The domain defined by a hierarchy of regional-aware foreign agents. This domain is usually administered by a single entity and can have secure localized signaling between the foreign agents in the domain. When the mobile node stays inside one visited domain (and the home registration does not expire), the mobile node does not need to do home registrations but can use the regional registrations to get a fast response from the localized location management.

## **3. Protocol Operation**

### **3.1. Paging Area Discovery**

A leaf foreign agent advertises paging support with the Paging Area ID extension in the Agent Advertisement. The mobile node detects its current paging area based on the paging area ID. If the Agent Advertisement contains an FA NAI extension [3], the mobile node uses the pair (paging area ID, the realm part of the FA NAI) as an identifier for the paging area. A mobile node considers two foreign agents to belong to the same paging area only if the foreign agents advertise the same paging area ID, and either both the foreign agents advertise the FA NAI with the same realm part or neither of the foreign agents advertise the FA NAI.

When an idle mobile node detects that it has moved to a new paging area, it MUST perform either a normal home registration, a normal regional registration or an idle mode registration.

The visited domain can contain anything from zero to as many paging areas as there are foreign agents in a visited domain. However, the subtree of a paging foreign agent MUST belong to the same paging area.

The advertisement MAY also contain an Advertisement Interval extension which specifies the time interval between subsequent advertisements. An Advertisement Interval extension with non-zero slot length field indicates support for time slot based paging within the paging area. In the time slot based paging case, the leaf foreign agents of the paging area send Agent Advertisements simultaneously with the same advertisement interval.

A new field in the Advertisement Interval extension indicates the length of the advertisement slot in milliseconds. The advertisement slot is the time during which idle mobile nodes power on their receivers in order to receive unsolicited Agent Advertisements. This allows foreign agents with overlapping cells to send their advertisements at slightly different times in order to avoid

interference. Because foreign agents may send their advertisements at slightly different times, mobile nodes cannot determine the exact instant of the advertisement slot. Therefore, foreign agents do not

send unsolicited Agent Advertisements during first and the last quarter of the advertisement slot.

Slot sequence number is another new field in the Advertisement Interval extension that is used for determining the mobile node's paging slot as described in [Section 3.2](#).

If time-slot based paging is used, the paging area is assumed to have a mechanism for synchronizing the clocks of the foreign agents. Such a mechanism is beyond the scope of this document.

If time slot based paging is used, a mobile node that is in the idle mode MAY power on its receiver when an unsolicited Agent Advertisement or a paging Agent Advertisement is expected and keep its receiver powered off at other times. The mobile node doesn't have to power on its receiver for every advertisement slot, but it MAY power on its receiver only for every Nth advertisement slot, where N can be freely picked by the mobile node. If the mobile node does not receive an Agent Advertisement during the advertisement slot, whether due to leaving the paging area or due to clock skew, it SHOULD send an Agent Solicitation and keep its receiver powered on until it receives an Agent Advertisement.

### **[3.2. Entering Idle Mode](#)**

When the mobile node is sending or receiving data packets, it is in the active mode. When the mobile node is in the active mode, the operation is exactly the same as in Mobile IP with regional registrations. When the mobile node is not actively communicating, it can enter the idle mode. When the mobile node is in the idle mode, the visited domain does not know the exact location of the mobile node. The visited domain only knows the paging area of the idle mobile node.

When the mobile node wishes to enter the idle mode, it performs an idle mode registration by sending either a Registration Request or a Regional Registration Request with an Idle Mode Request extension. If time slot based paging is used, the Idle Mode Request extension contains the paging slot interval expressed as a multiple of advertisement intervals.

When the paging foreign agent receives the Registration Request or the Regional Registration Request with an Idle Mode Request extension, it adds the mobile node to the visitor list and marks its mode as idle. The entry in the visitor list is otherwise maintained as normal entries in regional registrations, but the paging foreign agent does not have any tunnels or other routing information for the mobile node in its routing table. As any registration, the idle mode

registration has a lifetime. A mobile node that wishes to stay in the idle mode longer than this lifetime must extend the lifetime by performing another idle mode registration. The mobile node may also extend the lifetime of its home registration and yet stay in the

idle mode by performing a home registration with the Idle Mode Request extension.

The operation of the paging foreign agent upon receipt of a data packet destined to an idle mobile node is specified in [Section 3.3](#). The foreign agents closer to the mobile node in the hierarchy do not need to maintain any state specific to the mobile node. That is, after forwarding the message containing the Idle Mode Reply extension to the mobile node, these foreign agents delete the mobile node from their visitor lists. If the idle mode registration is a regional registration and the crossover foreign agent is above the paging foreign agent in the hierarchy, it also receives the Regional Registration Request and updates its state as normally in regional registrations.

The paging foreign agent includes an Idle Mode Reply extension to the Registration Reply or the Regional Registration Reply. The reply contains a paging multicast address. The leaf foreign agents of the paging area use this address for paging the mobile node when they receive a Paging Request from a paging foreign agent.

If the optional time slot based paging mechanism is used, the Idle Mode Reply extension contains a paging slot index (an integer) and a paging slot offset (milliseconds). The paging slot instant is determined as follows. The paging slot is  $N$  milliseconds later than the advertisement slot for which the slot sequence number of the Agent Advertisement modulo the paging slot interval is equal to zero. The delay  $N$  equals paging slot index times advertisement interval plus paging slot offset. In other words, the paging slot interval specifies how often a paging slot occurs, and the paging slot index and the paging slot offset specify when the paging slots occur in relation to unsolicited Agent Advertisements. For example, if paging slot interval is four, paging slot index is two and paging slot offset is 100 ms, then there is a paging slot 100 ms after every fourth advertisement slot. More specifically, the paging slot is 100 ms after the advertisement slots for which slot sequence number modulo four equals two.

The length of the paging slot is equal to the length of the advertisement slot. Since mobile nodes cannot determine the exact instant of the paging slot, foreign agents do not send paging Agent Advertisements during first and the last quarter of the paging slot.

The sequence number field in the Agent Advertisement cannot be used in determining the paging slot because the foreign agent increments the sequence number also in solicited Agent Advertisements. Thus the new slot sequence number field is required.

### **3.3. Paging**

When the paging foreign agent receives a packet from a correspondent node destined to a mobile node that has the idle flag set, the paging foreign agent does not forward the packet to any lower

foreign agent. Instead, the paging foreign agent sends a Paging Request to its child foreign agents which forward the message to their child foreign agents recursively. The leaf foreign agents send a paging Agent Advertisement to the mobile node using the paging multicast address. This advertisement contains a Paged Mobile Node Address extension which identifies the target among the mobile nodes listening to this paging multicast address. When time slot based paging is supported, the Paging Request contains the paging slot interval, the paging slot index, and the paging slot offset.

The leaf foreign agents send the paging Agent Advertisement with a Paged Mobile Node Address extension to the mobile node's paging multicast address. Besides the Paged Mobile Node Address extension, the leaf foreign agent includes the same extensions that it normally includes in solicited Agent Advertisements.

If time slot based paging is used, the leaf foreign agents send the paging Agent Advertisement during the second or the third quarter of the mobile node's paging slot.

The mobile node is expected to perform an ordinary home registration or an ordinary regional registration in response to a paging Agent Advertisement. The paging foreign agent MAY retransmit the Paging Request after a timeout. If the mobile node has not performed a regional registration after a small number of retransmissions, the paging foreign agent SHOULD send a Destination Unreachable ICMP message to the correspondent node.

While waiting for the response of the mobile node, the paging foreign agent MAY buffer the data destined to the mobile node. When the mobile node has entered the active mode, the paging foreign agent can stop buffering and forward the buffered packets to the mobile node. The paging foreign agent discards buffered packets after a timeout.

### **3.4. Entering Active Mode**

When the mobile node receives an Agent Advertisement to its paging multicast address and the advertisement contains the address of the mobile node in the Idle Mobile Node Address extension, the mobile node enters the active mode. The mobile node can also enter the active mode if it needs to send a packet.

When entering the active mode, the mobile node sends a Registration Request or a Regional Registration Request. This changes the state of the visited domain as defined in the regional registrations [3]. This registration clears the idle mode in the paging foreign agent and allows all subsequent data to reach the mobile node.



The slot length also specifies the length of the paging slot within the paging area.



The Idle Mode Request extension is defined as follows:



```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |      (Paging Slot Interval)      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Type

TBD (non-skippable)

Length

The length of the fields excluding the Type and the Length fields, in octets. If the mobile node requests time slot based paging, the length equals to 2, else the length equals to zero.

Paging Slot Interval

An optional field that contains a 16-bit unsigned integer. If the mobile node requests time slot based paging, the paging slot interval is used for determining the mobile node's paging slot, as specified in [Section 3.2](#).

#### [4.4. Idle Mode Reply Extension](#)

The Idle Mode Reply extension is defined as follows:

```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |      Reserved      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Paging Multicast Address                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      (Paging Slot Index)      |      (Paging Slot Offset)      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Type

TBD (non-skippable)

Length

The length of the fields excluding the Type and the Length fields, in octets. If time slot based paging is used, the length equals to 10, else the length equals to 6.

Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

### Paging Multicast Address

An IP address used for paging the mobile node. If a correspondent node sends a datagram to the mobile node while the mobile node is in the idle mode, the network pages the mobile node by sending a paging Agent Advertisement to this multicast address. The paging foreign agent can decide how to assign these addresses.

### Paging Slot Index

An optional field that contains a 16-bit unsigned integer. If time slot based paging is supported, the paging slot index is used for determining the mobile node's paging slot, as specified in [Section 3.2](#).

### Paging Slot Offset

An optional field that contains a 16-bit unsigned integer. If time slot based paging is supported, the paging slot offset is used for determining the mobile node's paging slot, as specified in [Section 3.2](#).

## **[4.5. Paging Request Message](#)**

When paging a mobile node, the paging foreign agent sends a Paging Request Message to its descendants in the paging area. The recipients of this message that have active interfaces capable of serving mobile nodes then send a paging Agent Advertisement to those interfaces in order to page the mobile node.

The Paging Request message is an UDP packet sent to the UDP Port 434. The Paging Request message contains the addresses of the paged mobile nodes and optionally parameters for calculating the point of time when to page the mobile node.

#### IP fields:

Source Address: Typically the interface address from which the message is sent.

Destination Address: The address of lower foreign agent.

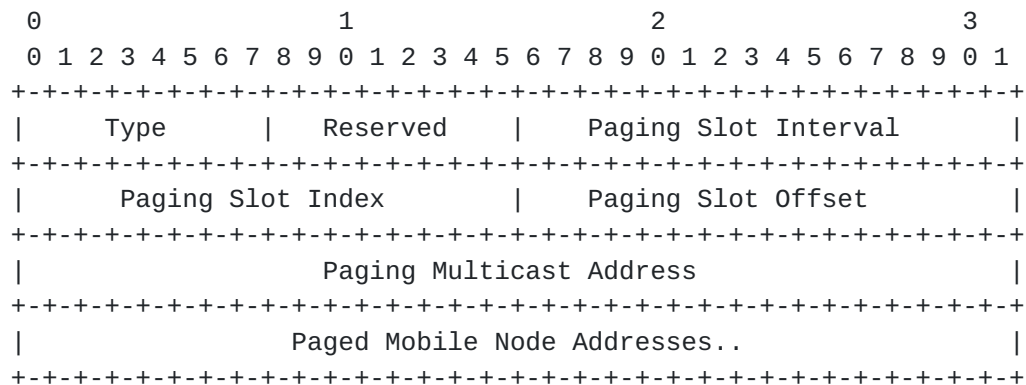
#### UDP fields:

Source Port: variable

Destination Port: 434

The UDP header is followed by Paging Request fields shown below:





The Paging Request fields can be followed by a Foreign-Foreign Authentication extension.

#### Type

TBD

#### Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

#### Paging Slot Interval

16-bit unsigned integer. The interval between two successive paging slots, in multiples of advertisement intervals. If time slot based paging is not used, this field must be set to zero.

#### Paging Slot Index

16-bit unsigned integer. A parameter used for determining the mobile node's paging slot, as specified in [Section 3.2](#). If time slot based paging is not used, this field must be set to zero.

#### Paging Slot Offset

16-bit unsigned integer. A parameter used for determining the mobile node's paging slot, as specified in [Section 3.2](#). If time slot based paging is not used, this field must be set to zero.

#### Paging Multicast Address

An IP multicast address used for paging the mobile node. In the idle mode the mobile node listens to this address for the agent advertisements which indicate paging of the mobile node by the network.



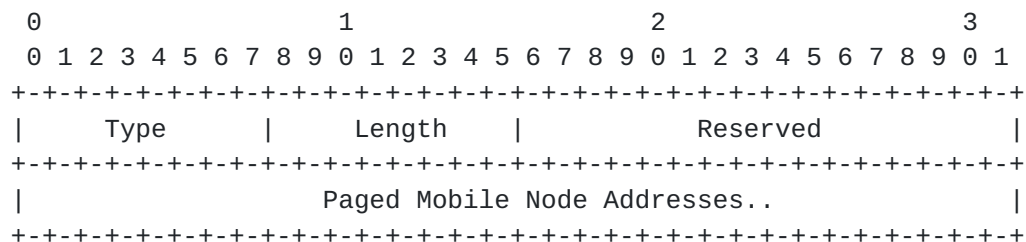
#### Paged Mobile Node Addresses

The IP home address of the mobile node that is the target of paging. For efficiency reasons, there MAY be more than one mobile node addresses listed in this field.

#### **4.6. Paged Mobile Node Address Extension**

The Paged Mobile Node Address extension is used for the identifying the mobile node that is paged with the paging Agent Advertisement. This allows several mobile nodes to share a paging multicast address. The motivation for using an Agent advertisement for paging is that in order to return to the active mode by performing a home registration or a regional registration, the mobile node needs an Agent Advertisement anyway.

The Paged Mobile Node Address extension is defined as follows:



#### Type

TBD (skippable)

#### Length

The length of the fields excluding the Type and the Length fields, in octets.

#### Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

#### Paged Mobile Node Addresses

The IP home address of the mobile node that is the target of paging. For efficiency reasons, there MAY be more than one mobile node addresses listed in this field.

### **5. IANA Considerations**

MIRP requires a new Mobile IP Message type to be used for sending the Paging Request message to the UDP port 434 ([Section 4.5](#)).

MIRP requires three new extension types to be used in combination with the Agent Advertisement: a skippable type for Advertisement Interval extension ([Section 4.1](#)), a skippable type for the Paging Area ID extension ([Section 4.2](#)), and a skippable type for the Paged Mobile Node Address extension ([Section 4.6](#)).

MIRP requires two new extension types to be used in combination with the Registration Request or Reply: a non-skippable type for the Idle Mode Request extension and a non-skippable type for Idle Mode Reply extension ([Sections 4.3](#) and [4.4](#), respectively).

## **[6. Security Considerations](#)**

MIRP uses the same security mechanisms as regional registrations [[3](#)]. More specifically, the Idle Mode registration is protected by the Mobile-Foreign Authentication extension using the same key distribution and replay protection mechanisms as specified for the regional registrations. The Paging Request message is protected by the FA-FA Authentication extension [[3](#)].

## **[7. IPv6 Considerations](#)**

Several proposals with regional registrations support for IPv6 are currently under development. The mechanisms are likely to be similar to regional registrations for IPv4. The mechanisms specified here for Mobile IPv4 should be easily applicable to IPv6.

## **[8. Intellectual Property Right Notice](#)**

Nokia may or may not have patents or patent applications that are applicable for this contribution. In case such patents exist or are subsequently granted, Nokia is willing to grant licenses on these patents on terms according to [RFC 2026, section 10](#).

## **[9. References](#)**

- [1] Bradner, S., "The Internet Standards Process -- Revision 3", [BCP 9](#), [RFC 2026](#), October 1996.
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Requirement Levels". [RFC 2119](#), March 1997.

- [5] C. Perkins and D. B. Johnson. "Mobility Support in IPv6", [draft-ietf-mobileip-ipv6-13.txt](#), May 2000. (work in progress).
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