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MOBILITY, MOBILITY MANAGEMENT MECHANISMS AND A MOBILE P2P ARCHITECTURE

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Summary

Mobility management mechanisms are used to provide mobility. Different kinds of mobility require different mobility management mechanisms. Common P2P applications are designed for fixed networks. Applying mobility to P2P applications is still a research issue. There are some approaches to improve P2P overlay networks in order to support the mobility of users.

1. Introduction

Definitions of Mobility: In this section different definitions of mobility from different sources are presented.

1.1. Various degrees of mobility from "Computer Networking"

In „Computer Networking" [1] the degrees of mobility from the networks point of view are defined.

• ***No mobility:*** If a user moves around with his terminal within the reachability of one point of attachment of the network, e.g. a wireless LAN accesspoint, no mobility is experienced from the networks point of view.

• ***Medium mobility:*** If a user shuts down his terminal, moves to a new point of attachment of the network and reconnects, medium mobility is experienced from the networks point of view.

• ***High mobility:*** If a user moves to a new point of attachment of the network with his terminal, while maintaining an ongoing connection, high mobility is experienced from the networks point of view.

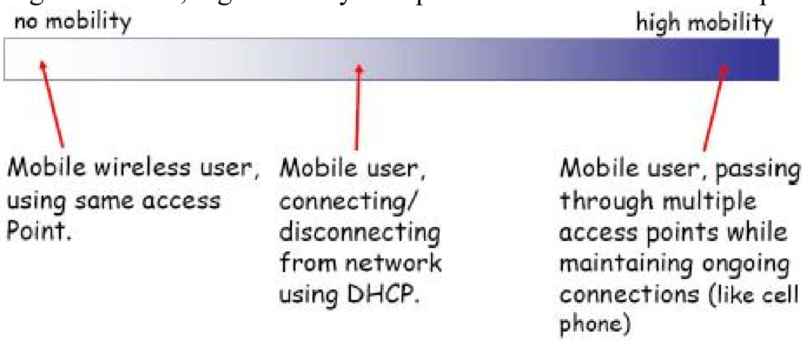

Figure 1: Various degrees of mobility from the networks point of view.

1.2. Definitions of Mobility from "IP for 3G"

In „IP for 3G" [2] different kinds of mobility are defined.

• ***Portability:*** If a user shuts down his terminal, moves to a new point of attachment of the network and reconnects, the terminal is considered as portable.

• ***Terminal mobility:*** If a user moves to a new point of attachment of the network with his terminal, while maintaining an ongoing connection, this is called terminal mobility. Terminal mobility can be broken into two different parts that require different solutions.

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o ***Terminal macromobility:*** Mobility in a large area, e.g. mobility in between administrative domains, is called terminal macromobility. This kind of mobility is also called global mobility.

o ***Terminal micromobility:*** Mobility in a small area, e.g. mobility within one administrative domain, is called terminal micromobility. In this case the mobility information of the mobile terminal is kept local. This kind of mobility is also called local mobility.

• ***Personal mobility:*** If a user moves to a different terminal while maintaining an ongoing session, this is called personal mobility. For example a user transfers a phone call from his mobile to a terminal in order to extend it to a videoconference.

1.3. Definitions of Mobility from "Application-Layer Mobility Using SIP"

In the paper "Application-Layer Mobility Using SIP" [3] mobility is defined as follows:

Terminal mobility allows a device to move between IP subnets, while continuing to be reachable for incoming requests and maintaining sessions across subnet changes. A subset of terminal mobility, being able to be reached for new sessions after subnet changes, requires only DHCP and dynamic DNS.

Personal mobility allows addressing a single user located at different terminals by the same logical address. Both 1- to-n (one address, many potential terminals) and m-to-1 (many addresses reaching one terminal) mappings are useful.

Service mobility allows users to maintain access to their services even while moving or changing devices and network service providers. In a voice-over-IP environment, simple services that users will likely want to maintain include their speed dial lists, address books, call logs, media preferences, buddy lists and incoming call handling instructions.

Session mobility allows a user to maintain a media session even while changing terminals. For example, a caller may want continue a session begun on a mobile device on the desktop PC when entering her office. A user may also want to move parts of a session, e.g., if he has specialized devices for audio and video, such as a video projector, video wall or speakerphone.

2. Mobility Management Mechanisms

Mobility management mechanisms are used to provide mobility. Different kinds of mobility require different mobility management mechanisms.

2.1. Layers where Mobility Management Mechanisms can be applied

Mobility management mechanisms can be applied on different layers. If a mobility problem is solved on a certain layer, usually the mobility is transparent to all layers above it. There are solutions for mobility management mechanisms for the following layers:

• ***Link layer**:* Mobility can be provided with special layer 2 protocols. Therefore a mapping of an IP address to a link layer address has to be provided, e.g. by a special dynamic address resolution protocol (ARP). This approach is taken by wireless local area network protocols like the inter-access point protocol (IAPP).

Such protocols can be fast but do not scale to large numbers of terminals. Another problem of these protocols is that the solutions have to be specific for a particular link-layer technology and so inter-technology handovers are hard to provide. Layer 2 solutions can provide terminal mobility.

• ***Network layer:*** The layer 3 seems to be the natural place to provide IP-mobility management mechanisms because it handles the delivering of IP packets. Layer 3 solutions have fewer limitations than the link layer approach. Mobile IP is an example of a protocol that provides mobility on the network layer. Layer 3
solutions can provide terminal mobility.

• ***Application layer:*** The session initiation protocol (SIP) is an example of a protocol that applies mobility management mechanisms in the application layer. Application layer solutions can provide terminal mobility and personal mobility.

2.2. Indirect Routing and Direct Routing

Indirect routing and direct routing are mobility management mechanisms, solving the terminal macromobility problem for a mobile node. In order to illustrate the routing towards a mobile node the following terminology is introduced:

***Home network**:* The home network is the home of a mobile node. This is the place, where the mobile node usually resides.

***Permanent address**:* The address of the mobile node in its home network is called its permanent address.

Home agent: The home agent is located in the home network of a mobile node and provides mobility management functions for the mobile node.

***Visited network**:* The network in which the mobile node is currently residing is called the visited network or the foreign network.

***Foreign agent**:* The entity that is located in the visited network, supporting the mobile node with mobility management functions is called foreign agent.

Care-of-address: This is the IP address of the mobile node in the visited network. The address is assigned by the foreign agent to the mobile node.

Correspondent: The correspondent is the entity that wants to communicate with the mobile node.

2.2.1. Registration

When a mobile node leaves its home network and visits another network it registers at the foreign agent in the visited network, this is shown in Figure 2.

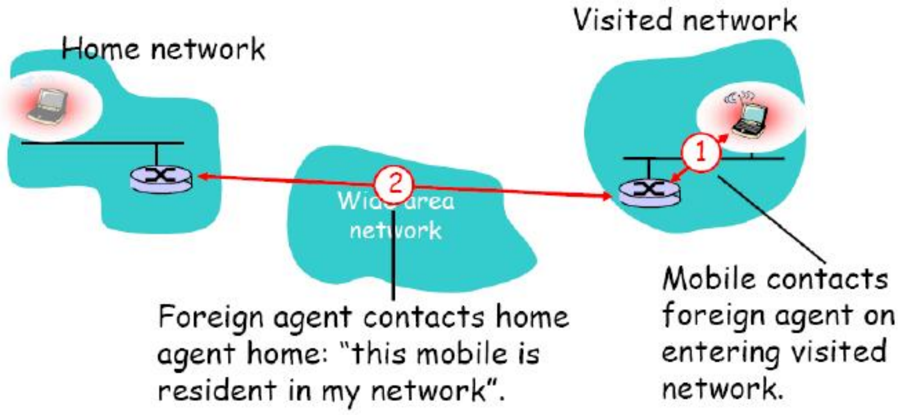

Figure 2: Registration of a mobile host

After that, the foreign agent contacts the home agent, in order to make the home agent aware of the current location of the mobile node. The foreign agent therefore submits the current care-of-address of the mobile node to the home agent.

2.2.2. Indirect Routing

In the indirect routing approach the home agent of the mobile node tunnels messages of the correspondent to the mobile node. This is shown in Figure 3. If the correspondent wants to communicate with the mobile node, it sends messages to the node as if the node would reside in its home network. This means the
correspondent sends its messages to the permanent address of the mobile node. The home agent knows the current position of the mobile node, intercepts the messages, and tunnels them to the mobile node in the visited network. To do this, the home agent packs the original messages of the correspondent in new IP packets with
the care-of-address as recipient. The foreign agent unpacks the packets and sends them to the mobile node. The mobile node sends its responses directly to the correspondent. One big advantage of this mobility management mechanism is that ongoing connections can be maintained while the mobile node changes the network. If the
mobile node moves to another network, it registers at the new foreign agent which informs the home agent. The home agent updates the care-of-address of the mobile node and tunnels packets to the new location of the mobile node. In the indirect routing approach the mobility of the mobile node is transparent for the correspondent.

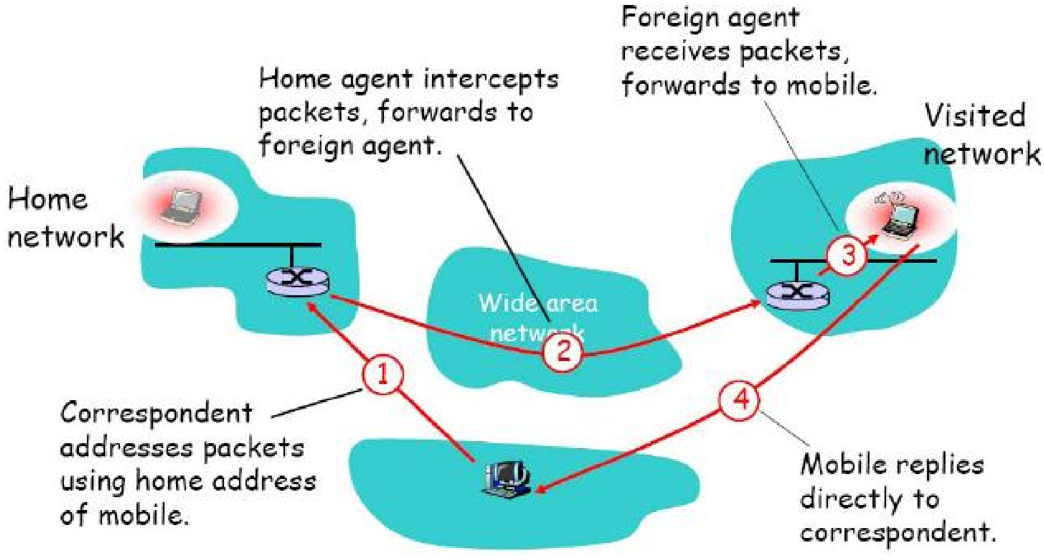

Figure 3: Mobility via indirect routing

A disadvantage of the indirect routing approach is the ***triangle routing*** problem. If the correspondent and the mobile node are residing in the same network for example, the routing is still done via the home agent of the mobile node. This scenario is shown in Figure 4.

The Mobile IP protocol is an example of a mobility management protocol that uses indirect routing as mobility management mechanism.

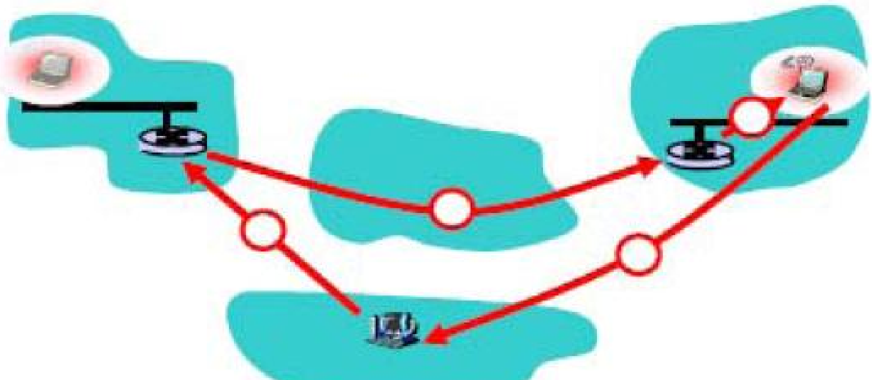

Figure 4: The triangle routing problem

2.2.3. Direct Routing

In the direct routing approach the home agent of the mobile node transmits the current care-of-address of the mobile node to the correspondent. So the burden of redirecting messages to the location of the mobile node is put on the correspondent. This is shown in Figure 5.

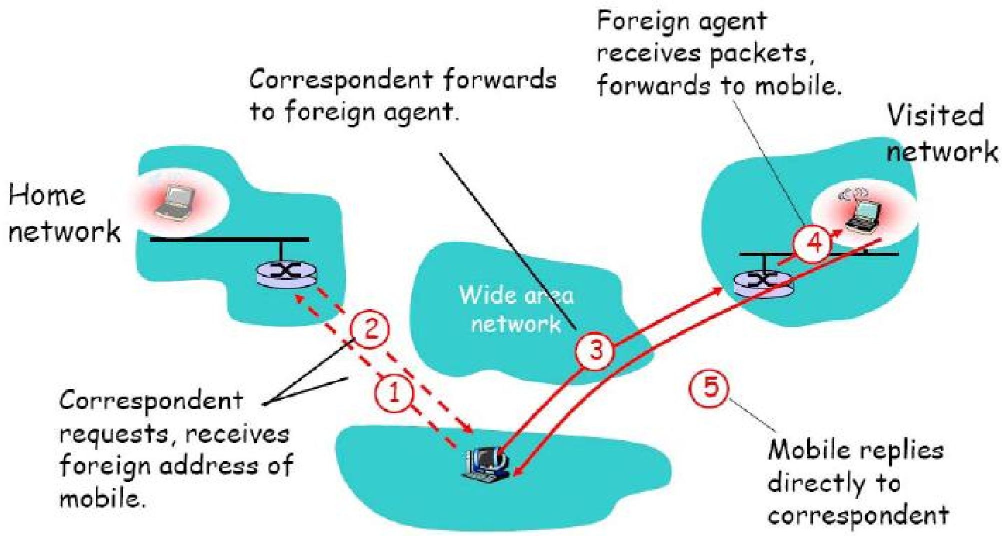

Figure 5: Mobility via direct routing

If a correspondent wants to communicate with a mobile node, it first contacts the home agent by sending a request to the permanent address of the node. The home agent then responds with the current care-of-address of the mobile node. After that the correspondent directly addresses the mobile node via the foreign agent. In this scenario the triangle routing problem is avoided. On the other hand the mobility of the mobile node is no longer transparent to the correspondent. Therefore the correspondent has to modify its protocols to provide the mobility of the node.

Furthermore another problem occurs when the mobile node moves to another network while communicating with the correspondent. Without modification of the protocol the communication can not be maintained. There are two solutions for this problem:

A new protocol has to be introduced that updates the address of the mobile node at the correspondent during the conversation.

The first foreign agent used during the conversation can be considered as an ***anchor foreign agent***, as shown in Figure 6. When the mobile node moves to another network it registers at the new foreign agent.

The new foreign agent transmits the new care-of-address to the anchor foreign agent which then tunnels the packets from the correspondent to the new location of the mobile node. This solution is adopted for example in GSM networks.

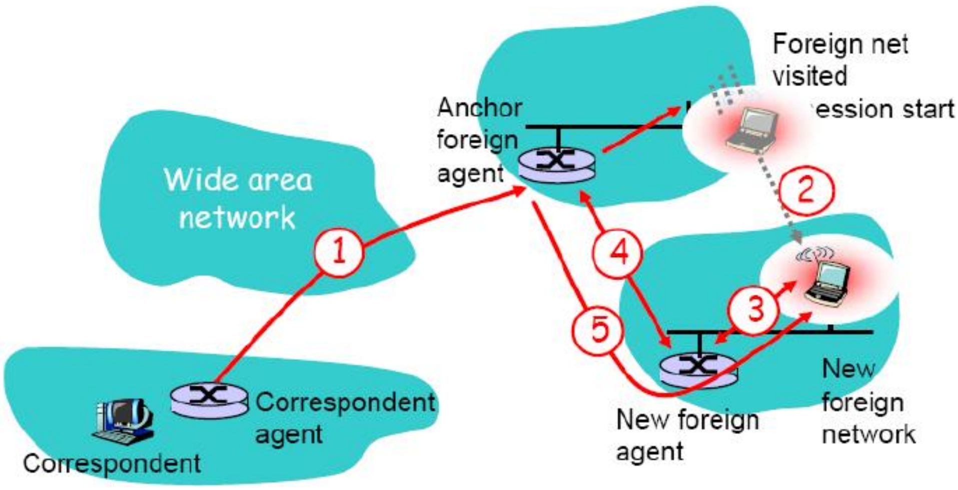

Figure 6: Direct routing using an anchor foreign agent

2.3. Mobile IP based Schemes and Per Host Forwarding Schemes

Mobile IP based schemes and per host forwarding schemes are mobility management mechanisms used to provide terminal micromobility. Mobile IP is a protocol building up on the indirect routing mobility management mechanism.

To provide terminal micromobility direct routing and indirect routing approaches could also be used. But these solutions suffer from a few disadvantages:
• Handovers may be slow if the home agent is located far away, e.g. in a different country.
• The signalling overhead is high for the core internet if the home agent is located far away.
• The protocols may interact with QoS protocols. For example if the home agent tunnels packets to the mobile node the headers with QoS information are also tunnelled and become invisible while transported in another IP packet.

2.3.1. Mobile IP based Schemes

In the mobile IP based schemes the mobile IP protocol (which builds up on indirect routing, see 2.2.2) is modified in a way to be more appropriate for providing terminal micromobility. Mainly two extensions are made to the indirect routing approach.
• ***Local mobility agents:*** Local agents are added to the network in order to reduce signalling overhead to the home agent, if it is far located. If the mobile node changes its care of address, the new foreign agent registers locally at a gateway foreign agent (GFA) and not at the home agent to avoid signalling overhead. The movement information of the mobile node is kept local.
• ***Fast and smooth schemes:*** These extensions refer to providing a seamless handover when the mobile node moves within a network.

2.3.2. Per Host Forwarding Schemes

Per host forwarding protocols are introduced to provide terminal micromobility. The basic idea of the per host forwarding schemes is, that the information about the current location of the mobile node is stored in various routers that are spread through the access network. Like this, the mobility information of the mobile node is kept local in the access network.

If a packed arrives at the access networks gateway, the gateway determines which port is the best to use, to route the packet towards the mobile node. This is repeated by every router on the way from the gateway node to the mobile node. So the location information of the mobile node is distributed locally within the access network and packets are forwarded without tunnelling or any address translation.

To implement a per host forwarding protocol three main problems have to be solved:
• The forwarding information has to be distributed throughout the various routers of the access network.
• The forwarding information has to be maintained.
• When the mobile node moves the forwarding information has to be updated.

An important concept in these schemes is the so called **cross-over router**. This is the router in which the paths of the new location and the old location of a mobile node converge when the mobile node moves. When the handover is done for the mobile node, the cross-over router has to change its forwarding entry.

There are three different approaches to provide per host forwarding mobility management mechanisms:

• ***New protocols:*** Cellular IP and Hawaii are examples of new protocols providing per host forwarding schemes. The main idea is the reverse forwarding of packets on a known path. When a mobile node enters the access network it sends a packet on the default route to the gateway. Each router on the way caches an entry that maps the permanent address of the mobile node to the reverse path of this route. These forwarding entries are soft state that means they have to be updated periodically.

• ***Manet-based protocols:*** One protocol of this category is called MER-TORA which bases on the TORA ad hoc routing protocol used in mobile ad-hoc networks (Manet). In TORA each router has a “height” and the routing is done downhill from a source to a destination. TORA assigns every node an appropriate “height” and reacts to changes in the routing topology. A “height” is assigned for every destination, so there is a downhill route for every destination. In a static network the “height” is mainly the hop count to the destination. To use TORA for per host forwarding a few changes are necessary, e.g. the protocol has to act proactively instead of on demand.

• ***Multicast-based protocols:*** Multicast protocols are designed to provide point to multipoint connections. The basic principle to use this technique to provide a per host forwarding scheme is to assign a multicast address to the mobile node. When the mobile node moves a new access router is added as a leaf to the multicast tree and the old access router is removed.

2.4. Mobility, Mobility Management Mechanisms and Protocols

The following table shows different kinds of mobility management mechanisms providing mobility. Furthermore an example protocol implementing the mobility management mechanism is given and the layer is shown where the protocol is applied.

Mobility	Mobility management mechanism	Example Protocol	Layer
terminal macro	indirect routing	Mobile IP	network
terminal micro	per host forwarding	Cellular IP	network
personal	direct / indirect routing	SIP	application
session	direct / indirect routing	SIP	application

3. Mobility in P2P Applications

Common P2P applications are designed for fixed networks. Applying mobility to P2P applications is still a research issue. There are some approaches to improve P2P overlay networks in order to support the mobility of users.

As an example for supporting mobility in P2P applications the MoPi architecture [4][5][6][7][8] is presented in this section. The MoPi architecture enables mobile phones to do file-sharing over the eDonkey protocol [9].

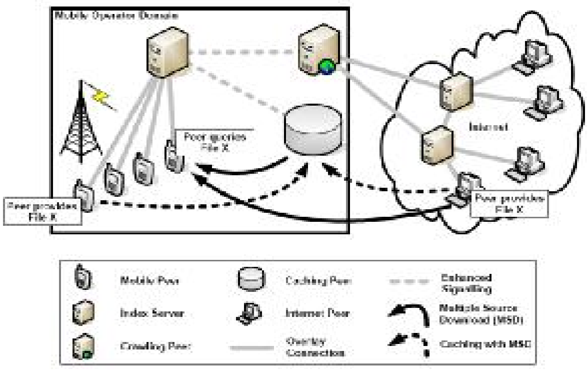

Figure 7: The MoPi architecture

3.1. eDonkey File-Sharing Protocol

eDonkey is a popular, second generation P2P file sharing protocol. It relies on specialized index servers for file location and the principle of multiple source download (MSD). The MSD concept is enabled by a fragmentation of files to logical parts, e.g. blocks of fixed size. A requesting peer can download different blocks from multiple providing peers.

eDonkey peers publish and look up shared files using the index servers. Hence, eDonkey deviates significantly from the pure P2P concept where all entities are similar peers. In the eDonkey protocol the mediation is handled by centralized index servers. This means the index servers handle all queries in order to relieve normal peers from query traffic. On the other hand the data exchange is done decentrally between the peers. eDonkey is therefore denoted as hybrid P2P architecture.

3.2. eDonkey and the Limitations of Mobile Phones

eDonkey is widely used protocol in the fixed network. However, users of mobile phones encounter several problems while using this file-sharing protocol. eDonkey requires the peers to be connected a period of time before a download succeeds (peers are queued and have to wait before they are allowed to download). The following attributes of mobile phones are in conflict with the protocol.

• ***Air interface:*** With its lossy channels, limited bandwidth, asynchronous transfer rates and lost connections the air interface of mobile phones restricts the usability of the eDonkey protocol.

• ***Limited battery capacity:*** Mobile phones can not stay too long online while being queued because of the limited battery capacity.

• ***Expensive online time:*** For a mobile phone the up and download has to be as fast as possible because of the expensive online time.

3.3. The MoPi Architecture

The MoPi architecture, shown in Figure 7, enhances the eDonkey file-sharing protocol with two components, the ***caching peer*** and the ***crawling peer.*** The operator of a mobile domain places three operator controlled entities in his domain:

• ***Index server:*** All peers inside the mobile domain are served from one or more central index servers. The architecture provides additional information to the index server, e.g. presence information, from the mobile network domain.

o The index Server mediates resources inside the mobile infrastructure.
o The mobile peers are forced to connect to only these index servers.
o Local resources are favoured by the index server and outside sources are hidden as far as possible.
o The advantage for the operator is that the traffic is kept inside the operator's network.
o The index server collects access statistics to support the caching of popular files.

• ***Cache peer:*** Popular contents are cached by the cache peer. As end-to-end communications between mobile devices utilize twice the air interface, caching P2P content in the core of the network decreases cost for transmitting popular files. Resource access control is partly shifted from the network-edge towards the network-core. The number of traversals of the air interface must be minimized in order to reduce the traffic and the transmission delay.

o The cache peer stores popular files at the network core to reduce the amount of expensive air-interface usage.
o The cache peer is an ordinary peer that has a special relationship with the index server.
o If the access characteristic measured at the index servers signals multiple downloads of a popular file, caching is initiated.
o For the downloading of files, the cache peer uses the same mechanism as an arbitrary peer.
o The completion of the download is signalled to the index server, which informs the requesting peers.

• The **crawling peers** support the index server with resources that are unknown in the operator domain.

o Mobile peers can only reach the index servers within the operator domain.
o The central index servers can locate any resource in the global P2P community by utilizing the crawling peers to request unknown resources from internet index servers.

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МОБИЛЬНОСТЬ, МЕХАНИЗМЫ УПРАВЛЕНИЯ МОБИЛЬНОСТИ И МОБИЛЬНАЯ P2P АРХИТЕКТУРА

Резюме

Механизмы управления мобильностью используются, чтобы обеспечить мобильность. Различные виды мобильности требуют разных механизмов управления мобильностью. Общие P2P приложения разработаны для фиксированных сетей. Применение мобильности к P2P - приложениям все еще проблема исследования. Есть некоторые подходы улучшить оверлейные сети P2P, чтобы поддержать мобильность пользователей.

ა. ბერლი, ჰ. დე მეერი (გერმანია)

მობილურობა, მობილურობის მართვის მექანიზმები და მობილური P2P არქიტექტურა

რეზიუმე

მობილურობის მართვის მექანიზმები გამოიყენება მობილურობის უზრუნველსაყოფად. მობილურობის სხვადასხვა სახეები თხოულობს განსხვავებულ მართვის მექანიზმებს. ზოგადი P2P დანართები დამუშავებულია ფიქსირებული ქსელებისათვის. მობილურობის გამოყენება P2P დანართებისათვის ჯერაც კვლევის ობიექტია. არსებობს მიდგომები, რომელთაც შეუძლია გადაფარვის (overlay) P2P ქსელების გაუმჯობესება, რათა უზრუნველყოს მომხმარებელთა მობილურობა.