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(71) Applicant *(for all designated States except US)*: **DOCOMO COMMUNICATIONS LABORATORIES EUROPE GMBH** [DE/DE]; Landsberger Strasse 308-312, 80687 München (DE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **KELLERER, Wolfgang** [DE/DE]; c/o Technische Universität München, Arcisstrasse 21, 80333 München (DE). **SCHOLLMEIER, Rüdiger** [DE/DE]; c/o Technische Universtität München, Arcisstrasse 21, 80333 München (DE). **GRUBER, Ingo** [DE/DE]; c/o Technische Universität München, Arcisstrasse 33, 80333 München (DE). **NIETHAMMER, Florian** [DE/DE]; c/o Technische Universität München, Arcisstrasse 21, 80333 München (DE).

(74) Agents: **HOFFMANN.EITLE** et al.; Arabellastrasse 4, 81925 München (DE).

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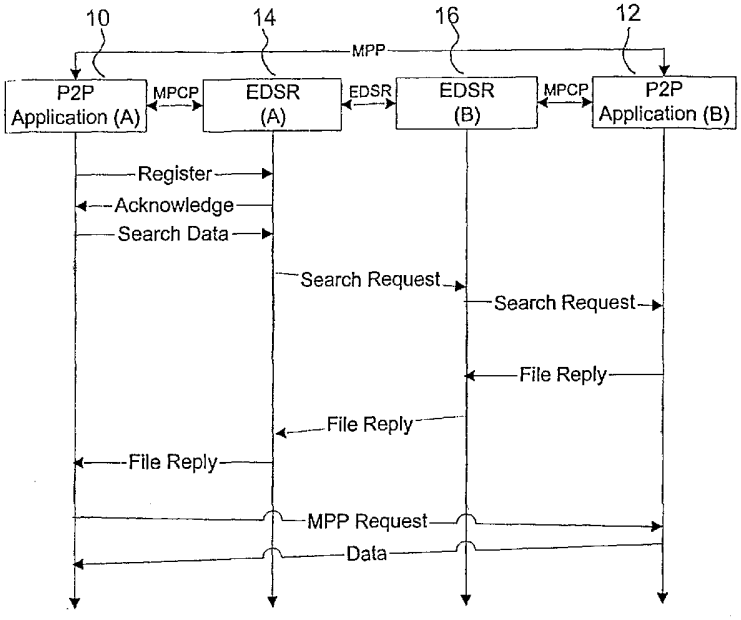
(54) Title: MOBILE PEER-TO-PEER NETWORKING



(57) Abstract: The present invention relates to mobile peer-to-peer networking over mobile wireless communication networks. In particular, there is introduced a mobile peer-to-peer protocol suite spanning from the network layer to the application layer, where the upper peer-to-peer network protocol layer specifies search criteria for retrieval of shared services resources in the mobile communication network extending beyond address information, e.g., proximity. These criteria are signalled to a lower layer network protocol to perform extended routing. This allows to enhance performance of retrieval of service-related resources in the network, e.g., according to proximity of nodes and/or service types.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Mobile Peer-to-Peer Networking

FIELD OF INVENTION

The present invention relates to a protocol stack for mobile peer-to-peer networking in a mobile communication environment, and in particular to a protocol suite supporting peer-to-peer overlay networking over mobile wireless networks for the introduction of new services and options on the application layer and for better performance.

BACKGROUND ART

Generally, peer-to-peer applications have an optimised algorithm to find information within an overlay network, while they generally rely on a network layer protocol, e.g., TCP and assumed stable connections. Nevertheless, in wireless communication networks, in particular with respect to ad-hoc wireless communication networks, connection breaks are common, as all mobile nodes are in motion.

Whenever two adjacent mobile nodes currently forwarding data packets move out of each other's proximity, the connection between both mobile nodes will break. Here, the network layer protocol not being aware of the peer-to-peer application being on top of the network layer protocol will

try to re-establish a new route to the same destination node, independent of the necessary effort.

Nevertheless, instead of trying to create a new route to the same source of information, other sources could provide the information at lower costs after change of network topology.

In other words, mobile nodes will report connection break to the peer-to-peer protocol level and related applications which then decide whether the old source of information is still utilizable or different sources of information are more appropriate.

Further, as peer-to-peer networks usually operate on top of fixed network structures, peer-to-peer network nodes mostly do not distinguish between communication participants in close proximity and network participants being located far away. As distance between mobile nodes does generally not affect the stability and error-free operation of communications in fixed networks, usual peer-to-peer protocols can create connections to a distant node, although the searched information is available more closely as well.

In more detail and as an example, Fig. 1 shows a simple peer-to-peer file sharing application running on top of a mobile ad-hoc network having four nodes. On the peer-to-peer overlay network level, node A maintains a static connection to node D, so that when node A wants to search for a file in the network, it sends out a query message to node D. Should the requested file not be available at node D, it will then forward the message to node B via the connection to this node B, i.e. connection No. 2.

According to the example shown in Fig. 1, this message will again be forwarded to node C for the same reason, so that one could assume that the requested file may be unveiled at this node C. Therefore, on the physical network layer, six wireless connections will be used to find the node C which is only two hops away.

In conclusion, the maintenance of static overlay connections is the major performance bottleneck for applying peer-to-peer network protocols over wireless communication networks like a mobile ad-hoc network, where bandwidth and battery power are very scarce resources.

While in the prior art some investigations on a combination of peer-to-peer applications and ad-hoc wireless communication networks have been explained, nevertheless, they still lack sufficient consideration of ad-hoc networking capabilities on the peer-to-peer network protocol level. E.g., while JXME, A. Arora, `JXTA for J2ME$_{TM}$-Extending the Reach of Wireless With JXTA Technology', White Paper, 2002, adapts JXTA to mobile environments, it still does not consider a mobile ad-hoc scenario. Further, the proposal of Lawrence, `LEAP into Ad-Hoc Networks', Proceedings of the Workshop on Ubiquitous Agents on Embedded, Wearable, and Mobile Devices, Bologna, Italy, 2002, does not ask the question of routing, and 7DS, M. Papadopouli, H. Schulzrinne, `Effects of Power Conservation, Wireless Coverage and Cooperation on Data Dissemination among Mobile Devices', Proceedings of the ACM Symposium on Mobile Ad-Hoc Networking (MOBIHOC 2001), Long Beach, CA, 2001, does not consider location information. Further, PROEM, G. Kortuem, J. Schneider, `An Application Platform for Mobile Ad-hoc Networks', Proceedings of the Workshop on Application Models and Programming Tools for Ubiquitous Computing (UBICOMP 2001), Atlanta, Georgia,

2001, has deficiencies in scaling for larger mobile ad-hoc scenarios, while ORION, A Klemm, C. Lindemann, O.P. Waldhorst, `A Special-Purpose Peer-to-Peer File Sharing System for Mobile Ad-Hoc Networks', Proceedings of the Workshop on Mobile Ad-Hoc Networking and Computing (MADNET 2003), Sophia-Antipolis, France, 2003, concentrates on file sharing applications only, lacking location awareness and having a large routing overhead. Still further, while the Bluetooth standard allows for peer-to-peer applications in an ad-hoc communication environment, nevertheless, it does not support routing but only communication via very short distances.

To summarize, the introduction of peer-to-peer computing n wireless ad-hoc communication networks without consideration of particular requirements of these ad-hoc networks has a poor performance, as peer-to-peer protocols are designed to serve for completely independent overlay networking without any knowledge and information of underlying protocols, e.g., location information of requested content or participants. This lack of knowledge of the proximity in peer-to-peer networks may cause distant connections, whereas the same contents could be available more closely. Also, while mobile ad-hoc networks employ hop-by-hop routing where the number of hops increases the routing overhead, peer-to-peer networks are currently unaware of the underlying route and thus unable to judge on the optimal route. In other words, peer-to-peer protocols are designed for fixed networks and thus are not able to cope with varying channels conditions in mobile communication environments, where in particular connection losses are interpreted as if the participant would have left the peer-to-peer network thus causing immediate re-routing.

SUMMARY OF INVENTION

In view of the above, the object of the present invention is to optimize peer-to-peer networking over mobile wireless communication networks.

Overall, the present invention introduces a mobile peer-to-peer protocol suite expanding from the network layer to the application layer and vice versa, where the upper peer-to-peer network protocol layer not only specifies suitable search criteria, but also receives appropriate responses so that it is well aware of the wireless network to minimize the traffic wherein it may cope with frequent route breaks. In addition, the network layer routing level receives information about the peer-to-peer application to establish routes only to appropriate communication nodes. Therefore, the present invention forms the necessary framework for creation of involved variety of different services over wireless communication network, e.g., ad-hoc wireless networks.

Therefore, the optimization of peer-to-peer applications over mobile wireless networks supports a higher degree of acceptance at the user, a decrease of costs for service providers, and for the provision of location-based services and applications without the use of any fixed or centralized infra-structure.

According to the present invention, there is provided a protocol stack for optimized peer-to-peer communication over a mobile wireless communication network, e.g., an ad-hoc network, relying on a method and apparatus of implementing a network layer routing protocol according to claims 1 and 31, further, a method of implementing a mobile

peer-to-peer network protocol according to independent claims 19 and 59, and a method of implementing a cross-layer communication channel protocol between the mobile peer-to-peer protocol level and the network layer routing protocol level according to independent claims 37 and 77.

In other words, the protocol stack according to the present invention includes an enhanced network layer protocol allowing for dynamic source routing and to find service hosting peers, e.g., based on proximity, further, a mobile peer-to-peer protocol for data exchange on the application layer and a synchronous protocol for interlayer communication between these formal two protocols.

According to the present invention, it is particularly proposed to enhance the functionality of the network layer protocol such that query messages applied to retrieve application resources in the wireless communication network allow for search criteria extending beyond address information, e.g., according to proximity of a mobile node in the mobile communication network providing the query response, or service capabilities. Therefore, according to the present invention, it is proposed to improve the search criteria on the network layer protocol where actually information on the topology of the wireless communication network is available. The information on the type of search criteria to be used on the network layer routing protocol level is provided by a superior peer-to-peer communication layer protocol supporting applications and services.

According to the present invention, the change of the search criteria between the upper peer-to-peer layer protocol and the network layer protocol is achieved by a cross-layer communication channel protocol and particularly adapted to exchange of search-relevant messages between

different hierarchy levels in the peer-to-peer protocol stack.

Therefore, during the search for appropriate service resources the maintenance of an appropriate link in a wireless communication network and the operation of the cross-layer communication protocol achieves a higher degree of acceptance of peer-to-peer services over wireless communication networks by the user due to an increase in quality and a decrease of costs, and further a decrease of costs for the provider of the peer-to-peer services. They are perfectly suited for providing routing functionalities in highly dynamic fast changing wireless communication networks, in particular in an un-managed and un-controlled ad-hoc wireless communication environment.

According to another preferred embodiment of the present invention there are provided a computer program products directly loadable into the internal memory of a processing devices in mobile communication environments comprising software code portions for performing the inventive protocol implementations when the product is run on a processing devices of mobile communication environments.

Therefore, the present invention is also provided to achieve an implementation of the different protocols outlined above on computer or processor systems. In conclusion, such implementation leads to the provision of computer program products for use with a computer system or more specifically a processor comprised in e.g., an ad hoc network.

This programs defining the functions of the present invention can be delivered to a computer/processor in many forms, including, but not limited to information

permanently stored on non-writable storage media, e.g., read only memory devices such as ROM or CD ROM discs readable by processors or computer I/O attachments; information stored on writable storage media, i.e. floppy discs and harddrives; or information convey to a computer/processor through communication media such as network and/or Internet and/or telephone networks via modems or other interface devices. It should be understood that such media, when carrying processor readable instructions implementing the inventive concept represent alternate embodiments of the present invention.

DESCRIPTION OF DRAWING

Fig. 1 shows an example of a peer-to-peer application on top of a wireless network at motivation for the present invention;

Fig. 2 shows a protocol suite for peer-to-peer operation on top of a wireless communication network according to the present invention;

Fig. 3 shows a message sequence chart for data search and download in a mobile peer-to-peer network according to the present invention;

Fig. 4 shows a schematic diagram illustrating functionalities on the level of the network layer routing protocol;

Fig. 5 shows a schematic diagram illustrating functionalities on the level of the mobile peer-to-peer protocol;

Fig. 6 shows a directory structure underlying the search of service resources according to the present invention; and

Fig. 7 shows a schematic diagram illustrating functionalities on the level of the mobile peer control protocol.

BEST MODE AND PREFERRED EMBODIMENTS OF INVENTION

In the following, the best mode and different aspects and preferred embodiments of the present invention will be described with reference to the drawing. Insofar as different functionalities are described in the following, they may either be implemented software and/or hardware and/or a combination thereof. Further, insofar as the different aspects of protocol implementation on different levels of abstractions will be discussed, it should be noted that each single protocol and related implementation as explained in the following may either be operated on its own, or in combination with further related protocols and corresponding implementation within the overall framework of peer-to-peer protocol stack implementation according to the present invention.

Fig. 2 shows a protocol suite for peer-to-peer operation on top of a wireless communication network according to the present invention.

As shown in Fig. 2, the present invention relates to the provision and implementation of a mobile peer-to-peer protocol MPP, an extended dynamic source routing protocol EDSR, and a mobile peer communication channel control protocol MPCP, respectively.

As shown in Fig. 2, the extended dynamic source routing protocol EDSR runs on tops of the link and physical layer according to the OSI protocol stack, which - without being considered as binding for scope of the present invention - is referred to as mobile ad-hoc communication network or equivalently MANET in the following. However, generally it should be noted that the present invention is also applicable to any other different type of wireless communication network as long as it supports a routing protocol on the network layer as outlined in the following.

As shown in Fig. 2, peer-to-peer mobile ad-hoc networks have two challenges in common: peer detection and packet routing. To meet these challenges, synergies between peer-to-peer networks and mobile ad-hoc communication networks reduce the administrational effort and increase performance and reliability of the mobile peer-to-peer protocol.

As shown in Fig. 2, in more detail the peer-to-peer protocol allows peers to directly exchange data and therefore this protocol is responsible of service-related data, e.g., files, in the peer-to-peer network. The mobile peer-to-peer protocol has capability to perform data uploads and downloads, e.g., on the basis of HTTP. In the case of interrupted transmissions due to broken links, a content range header provides the ability to resume the file transfer. According to the present invention, HTTP is applied as one example of its rich set of features and numerous standard implementations available in different computer languages. However, any other protocol of the same functionality may be applied as well.

Further, the extended dynamic source routing protocol has new request and reply types to existing network layer

protocols, e.g., the DSR protocol. Therefore, the extended dynamic source routing protocol provides means to find peers by other criteria than simply an IP address. Nevertheless, the extended network layer routing protocol EDSR does not change the basic behavior of previously known dynamic source routing protocols, so that EDSR nodes can be an integral part of old existing DSR networks.

Further, the mobile peer control protocol links the extended dynamic source routing protocol and the network layer with the peer-to-peer application in the application layer. Using the mobile peer control protocol, the application may register in the extended dynamic source routing layer to initialize search requests and to process incoming search requests from other nodes in the wireless communication networks, as will be explained in detail in the following. In other words, the mobile peer control protocol is the cross- or interlayer-communication channel between the application and the network layer. It communicates all incoming and outgoing requests and responses to the corresponding protocol, except the file exchange itself.

Fig. 3 shows a message sequence chart for data search and download/upload in a mobile peer-to-peer network according to the present invention.

The units peer-to-peer application (A) 10 and peer-to-peer application (B) 12 shown in Fig. 3 relate to peer-to-peer applications A and B running in the mobile communication environment, which applications actuate a communication channel for exchange of data, as will be explained in the following. Further, the additional units EDSR (A) and EDSR (B) 14 and 16 relate to functionalities implemented on the network communication protocol layer, with respect to the

peer-to-peer application (A) and the peer-to-peer application (B), respectively.

As shown in Fig. 3, exchange, either of control-related data or payload data, is represented by error lines in the form of a sequence chart.

In the following, the detailed aspects of the network protocol layer implementations and functionalities will be explained with respect to Figs. 4 to 6.

Extended Dynamic Source Routing Protocol

Fig. 4 shows a schematic diagram of the EDSR (A) and (B). According to the present invention, it may be assumed that each such unit is operated at a node in a wireless communication network for implementation of related extended dynamic source routing protocol functionality at each such node.

As shown in Fig. 4, each such extended dynamic source routing protocol unit (A) divides into a receiving unit 18, a transforming unit 19, and a forwarding unit 20.

Operatively, the first Interface unit 18 is adapted to receive search-related data in relation to a service request initiated through a service running on top of the mobile peer-to-peer layer protocol, i.e. the peer-to-peer application (A). Further, the transforming unit 20 is adapted to transform the submitted search-related data into a query message in accordance with the network layer routing protocol EDSR. As outlined previously, according to

the present invention it is proposed that the query message comprises search criteria extending beyond simple address information, i.e. criteria specifying aspects of proximity to the node initiating a search for service resources or type of such service resources, i.e. type of data or type of service. Further, operatively the forwarding unit 22 is adapted to output the query term to the lower layers for spread-out through the wireless communication network in search of service resources.

Typical examples of search criteria in the sense of the present invention would be that services are located to the nearest extent in, e.g., a wireless ad-hoc communication network for minimization of subsequent data transfer traffic, or indication of type of service, e.g., restaurant, banking, parking, etc. Examples given in more detail for the query message are related to the search request SREQ, to a Hash request HREQ, to a file reply FREP, to a push request PREQ, and to a declaration reply DREP and are explained in detail in the following.

As shown in Fig. 3 in combination with Fig. 4, operatively the extended dynamic source routing protocol will receive a registration of a peer-to-peer application and then acknowledge receipt of such registration. Operatively, this is achieved by the registration unit 24 shown in Fig. 4.

Further, subsequent hereto and after set-up of the query message, the forwarding unit 22 is also adapted to receive a response to the query message initiated from the further node (B) in the wireless communication network. Heretofore, in each implementation of the extended dynamic source routing protocol (A) and (B), the receiving unit 18 and the forwarding unit 22 are adapted for exchange of query messages flowing in the wireless network infra-structure

from the network protocol layer to the peer-to-peer application level for evaluation of the different query messages on the application level. Depending on the outcome of the evaluation, i.e. whether the search criteria are met by a service operated at the related node or not, there may be generated a search response which is subsequently forwarded down from the peer-to-peer application level to the extended dynamic source routing level for forwarding to the node which initiated the search request, referred to as the sending node in the following.

The related different search responses are file reply, push request, and declaration reply.

A further aspect being related to the search and being achieved by the evaluation unit 26 shown in Fig. 4 is the evaluation of different search requests when a plurality of search responses are received at a node initiating a search. Here, the evaluation unit 26 is adapted to process at least one predetermined cost function, e.g., characteristics of at least one node in a path of the wireless network connecting the sending node and the responding node. Typical examples of the characteristics are number of nodes in the path, transmission power of a node, moving speed of a node, or transfer of a node, respectively.

In the following, different instantiations of the query messages referred to above will be explained. Heretofore, there will be differentiated between an IP field implementing standard functionality, an the fields being related to the search criteria according to the present invention.

Search Request (SREQ):

To search for data, EDSR offers a similar message like the Gnutella QUERY-message, namely the *Search Request* (SREQ). SREQ is the initial option for data searches in the mobile P2P network. SREQ is based on the DSR option Route Request (RREQ). A SREQ expects as an answer an option of the type REPLY (xREP). What kind of REPLY EDSR expects depends on the service and the data-type originally requested.

Table 2-1 shows SREQ in its bit structure, and the SREQ field are explained below.

Table 2-1: EDSR-SREQ option

Byte 1	Byte 2	Byte 3	Byte
Option Type	Option Data Length	Identification	
Service Type		Klen	Reserved
Keyword [1]			
Keyword [2]			
...			
Keyword [k]			
Address [1]			
Address [2]			
. . .			
Address [n]			

IP Field

Source Address	The IP address of the node originates this packet. Intermediate nodes that retransmit the packet to propagate the SREQ must not change this field.
Destination Address	IP limited broadcast address (255.255.255.255)
Hop Limit	8-bit unsigned integer, which indicates the time-to-live (TTL) for the packet

SREQ Field

Option Type	32
Option Data Length	8-bit unsigned integer, length of the option in octets, excluding the Option Type and Option Data Length fields.
Identification	16-bit, a unique value generated by the initiator (original sender) of the Search Request. This value allows a receiving node to determine whether it has recently seen a copy of this Search Request: If this Identification value is found by this receiving node in its Search Request Table, this receiving node must discard the Search Request to avoid loops during the forwarding of the SREQ packet.
Service Type	16-bit Hash-value of the Service that we want to look for. It

	can be, e.g., 'Audio', 'Video ', 'Taxi ' or something similar.
Klen	4-bit value, which indicates the number of Keywords in this option. The maximum number of Keywords is therefore 15.
Keyword	Keyword [i] is 32-bit Hash-value of the string, which specifies a search criterion for a previously selected Service Type. The following keywords restrict the criteria further. Thus, it is AND operator.
Address	Address [i] is the IP address of the i^{th} node recorded in the Search Request option. This field is used to determine the route in the wireless communication network.

Hash Request (HREQ):

The *Hash Request* (HREQ) is a special variant of the SREQ. However, HREQ is using as search criteria only the file size and the *Fingerprint* of the requested data. This Fingerprint is 128 bits long and is created with the MD5 hashing procedure. With this specific attribute, HREQ can be used to find alternative data sources in case of route breaks. Like SREQ, HREQ is also based on the DSR-option RREQ.

Table 2-2 shows HREQ in its bit structure, and the HREQ fields are explained below.

Table 2-2: EDSR-HREQ option

Byte 1	Byte 2	Byte 3	Byte
Option Type	Option Data Length	Identification	
Service Type		Reserved	
File Size			
. MD5 Hash .			
Address [1]			
Address [2]			
. . .			
Address [n]			

IP Field

Source Address	The IP address of the node originates this packet. Intermediate nodes that retransmit the packet to propagate the HREQ must not change this field.
Destination Address	IP limited broadcast address (255.255.255.255)
Hop Limit	8-bit unsigned integer, which indicates the time-to-live (TTL) for the packet.

HREQP Field

Option Type	33
Option Data Length	8-bit unsigned integer. Length of the option in octets, excluding the Option Type and Option Data Length fields.
Identification	16-bit, a unique value generated by the initiator (original sender) of the Search Request. This value allows a receiving node to determine whether it has recently seen a copy of this Search Request: If this Identification value is found by this receiving node in its Search Request Table, this receiving node must discard the Hash Request to avoid a loops during the forwarding of the HREQ packet.
Service Type	16-bit Hash-value of the Service that we want to look for. It can be, for example, 'Audio ', 'Video', 'Taxi ' or something similar.
File Size	32-bit value, which indicates the size of data in octets.
MD5 Hash	128-bit Hash value, which is created with the MD5 procedure. This value together with the File Size identify the file clearly in the peer-to-peer Network.
Address	Address [i] is the IP address of the i^{th} node which received this message. This field is used to determine the route in the MANET.

File Reply (FREP):

The option *File Reply* (FREP) is the answer of a peer on a received of a search request. The search request can be therefore a SREQ or HREQ, which matches the metadata of the object shared by the peer. A FREP implies that the requested data is a file and therefore includes all necessary information about that shared file. Based on this information, the requesting peer can initialise a transmission of the file, which the help of mobile peer-to-peer protocol. As in the case of SREQ, the structure of a FREP is based on the structure of a *Route Reply* (RREP) option of the network layer protocol DSR.

Table 2-3 shows FREP in its bit structure, and the FREP fields are explained below.

Table 2-3: EDSR-FREP option

Byte 1	Byte 2	Byte 3	Byte	
Option Type	Option Data Length		L	Reserved
File Size				
TCP Port		U	Reserved	
Keywords Sum				
. MD5 Hash .				
File Name Length	File Name			
. . .				
Address [1]				

Address [2]
. . .
Address [n]

IP Field

Source Address	The IP address of the node originates this packet.
Destination Address	Contains the address of the node that originates the SREQ/HREQ. This address can be copied from the Source Address field of the SREQ/HREQ.

FREP Field

Option Type	48
Option Data Length	16-bit unsigned integer, length of the option in octets, excluding the Option Type and Option Data Length fields.
L	1-bit flag, states whether the last hop is out of the EDSR network, to enable interaction with other networks.
File Size	32-bit value, which indicates the size of the found file.
TCP Port	TCP port (1-65535), through which the service of the peer is reachable. Over this port, an MPP communication with this peer is possible.

U	1-bit flag, specifies whether the providing peer also allows uploads.
Keywords Sum	Bit-wise addition of all the Keywords in SREQ. This sum can be used as a match code of the request and the response.
MD5 Hash	128-bit Hash value, which is created with the MD5 hashing procedure. This value together with the File Size identify the file clearly in the peer-to-peer Network.
File Name Length	8-bit value, indicates the length of the following File Name. The File Name therefore can contain up to 255 characters.
File Name	Name of the file.
Address	Address [i] is the IP address of the i^{th} node which received this message. The FREP therefore contains the full path, from the sending node S to the receiving node R.

Push Request (PREQ):

The option *Push Request* (PREQ) is sent from the responding node to the sending node for subsequent data upload from the sending node to the responding node.

Table 2-4 shows PREQ in its bit structure, and the PREQ fields are explained below.

Table 2-4: EDSR-PREQ option

Byte 1	Byte 2	Byte 3	Byte	
Option Type	Option Data Length		L	Reserved
TCP Port		Reserved		
File Size				
MD5 Hash				
Address [1]				
Address [2]				
. . .				
Address [n]				

IP Field

Option Type	49
Source Address	The IP address of the node, which generates the PREQ.
Destination Address	Contains the IP address of the node that originates the FREP. This address can be copied from the Source Address field of the FREP.

PREQ Field

Option Type	49
Option Data Length	16-bit unsigned integer, length of the option in octets, excluding

	the Option Type and Option Data Length fields.
L	1-bit flag, states whether the last hop is out of the EDSR network, to enable interaction with other networks.
TCP Port	TCP port (1-65535), through which the service of the peer is reachable. Over this port, an MPP communication with this peer is possible.
File Size	32-bit value, which indicates the size of the found file.
MD5 Hash	128-bit Hash value, which is created with the MD5 hashing procedure. This value together with the File Size identify the file clearly in the peer-to-peer Network.
Address	Address [i] is the IP address of the i^{th} node which received this message. The PREQ therefore contains the full path, from the sending node S to the receiving node R. This path should be the same path that carried the FREP.

Declaration Reply (DREP):

The option *Declaration Reply* (DREP) is the answer of the peer upon receiving a search request. The search request can be SREQ or HREQ. DREP is a general option of network layer protocol EDSR and offers application developers the

possibility to implement protocols beyond MPP to satisfy the requirement of their specific application. DREP therefore does not transmit specific information about the offered service, but information about the profile of the service. Thus, mobile peer-to-peer protocol MPP can transmit the profile, which holds all necessary information to establish a communication channel between two Peers. DREP is a special mode of a FREP and does not differ in its bit structure. The data information in the DREP refers to the service profile.

IP Field

Source Address	The IP address of the node, which generates the DREP
Destination Address	Contains the address of the node that originates the SREQ/HREQ. This address can be copied from the Source Address field of the SREQ/HREQ.

DREQ Field

Option Type	50
Option Data Length	16-bit unsigned integer, length of the option in octets, excluding the Option Type and Option Data Length fields.
L	1-bit flag, states whether the last hop is out of the EDSR network, to enable interaction with other networks.

File Size	32-bit value, specify the size of the profile in octets.
TCP Port	TCP port (1-65535), through which the service of the peer is reachable. Over this port, an MPP communication with this peer is possible.
Keywords Sum	Bit-wise addition of all the Keywords in SREQ. This sum can be used as a match code of the request and the response.
MD5 Hash	128-bit Hash value, which is created with the MD5 procedure. This value together with the File Size identify the file clearly in the P2P Network.
File Name Length	8-bit value, indicates the length of the following profile name. The profile name therefore can obtain up to 255 characters.
File Name	Name of the data.
Address	Address [i] is the IP address of the i^{th} node which received this message. The FREP therefore contains the full path, from the sending node S to the receiving node R.

Mobile Peer-to-Peer Protocol

Fig. 5 shows a schematic diagram illustrating functionalities on the level of the mobile peer-to-peer layer protocol.

As shown in Fig. 5, on this layer protocol layer, functionality is related and implemented by a first interface unit 28, an evaluation unit 30, a memory unit 32, a search response generation unit 34, a data exchange unit 36, a registration unit 38, and a second interface unit 40.

Operatively, the first interface unit is adapted to receive a service request comprising search criteria extending beyond node address information. Here, it should be noted that the service request is generated in a service operated on top of the mobile peer-to-peer network protocol.

Further, operatively the second interface unit is adapted to exchange the service request with the network layer routing protocol operated under the mobile peer-to-peer network protocol for identification of shared service resources in the wireless network. The second interface unit 40 is also adapted to receive a service request from the network layer routing protocol that may be initiated at a remote node for forwarding this service request up to the service running on top of the mobile peer-to-peer protocol for evaluation thereof.

Further, operatively the evaluation unit 30 is adapted to evaluate the search request on the level of the mobile peer-to-peer network protocol. Heretofore, there is also provided a memory unit 33 storing a classification of peer-to-peer services into different types as basis of evaluation. Heretofore, the evaluation unit is adapted to classify mobile peer-to-peer services into different types by using a directory structure for the search of services resources as shown in Fig. 6.

Operatively, the search response generation unit 34 shown in Fig. 6 generates a search response for subsequent forwarding through the second interface unit 40 when the evaluation of the search request on the level of the mobile peer-to-peer network protocol identifies fulfillment of search criteria.

Further aspects of functionality on the mobile peer-to-peer protocol level are related to the operation after successful search.

Heretofore, the data exchange unit 36 is adapted to direct exchange on the mobile peer-to-peer protocol layer after exchange of a search request and search response having identified a path/route in the wireless mobile communication network for exchange of data. Also, operatively the data exchange unit 36 is adapted to connection recovery after connection breakdown, should it occur. Preferably, the direct data exchange according to the present invention is achieved through data download and/or data upload, preferably on the basis of HTTP.

Another unit being directly related to the search is a registration unit 38 shown in Fig. 6 which allows to register a mobile peer-to-peer service at the network layer routing protocol and to receive a combination of registration subsequent to submission of a registration request for subsequent exchange of search-related messages, as outlined above.

Mobile Peer-to-Peer Control Protocol

A further aspect of the present invention is related to the exchange of information between the mobile peer-to-peer

protocol level and the network layer routing protocol. Heretofore, and as shown in Fig. 5, the mobile peer control protocol has an upper layer implementing functionality on the mobile peer-to-peer protocol layer level and a lower layer level implementing mobile peer control protocol functionality at the level of the network layer routing protocol. In the following, the upper layer will also be referred as MPCP7, and the lower layer will be referred to as MPCP3.

The Mobile Peer Control Protocol is a synchronous protocol to provide a communication channel between the service layer and network layer. MPCP must be implemented therefore on the one hand in OSI layer 3 and on the other hand by the respective service in OSI layer 7. Thus, MPCP3 and MPCP7 are defined respectively.

The necessity for the development of the mobile peer control protocol MPCP results from the functions offered by a service. Services do not only offer data, but they also have to decide, whether to answer a search request positively or not, i.e. whether the service shares a requested file. In case of a positive answer, the service has to communicate the necessary information to the EDSR, so that a FREP can be sent to the requesting peer accordingly. MPCP therefore has to fulfil the following tasks:

- **Registration:** As one Peer can implement several services, every service has to register at the network layer, so that the network layer can notify the service about the incoming search request accordingly. When a user removes the services, the service has to deregister at the network layer.

- **Search:** If a service offers its user the possibility to search for data in the wireless communication network, MPCP has to forward the search parameters to the network layer protocol EDSR via MPCP3.

- **Request:** MPCP3 transmits incoming request to MPCP7 and then to the services. MPCP also transmits the suitable responses to the network layer protocol EDSR.

- **Response:** MPCP3 informs the MPCP7 about incoming responses and then initiates actions at the network layer protocol EDSR accordingly.

For these tasks, according to the present invention, there are defined several messages with their specific parameters, like confirmation messages, registration messages, request messages and response messages.

In the following, the MPCP messages with their parameters and the expected answers are specified as follows:

Confirmation Message - ACK (Acknowledgement)

The message ACK acknowledges the message that it successfully receives.

Message format:	ACK([Id])
Sender:	MPCP3/MPCP7

Id:	Unique identifier of the service, which was used to register with MPCP3 before. This parameter is only used for messages from MPCP3, in order to specify which MPCP7 service is the receiver of this message
Answer:	N/A

Confirmation Message - NAK (Negative Acknowledgement)

The message NAK acknowledges the message, which produces no errors, but cannot be successfully executed. Reasons for this can be, e.g., user rights, timeouts or something similar. The reason of failure is returned to the sender as number (Code) and as text (Reason) in NAK.

Message format:	NAC ([Id], Code, Reason)
Sender:	MPCP3/MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before. This parameter is only used for messages from MPCP3, in order to specify which MPCP7 service is the receiver of this message
Code:	Number, which specifies clearly the failure reason
Reason:	Reason of failure, readable by user

Answer:	N/A

Confirmation Message - ERR (Error)

The message ERR acknowledges the message, which has error in its format. Reasons for this can be, e.g., conflicts with the registered services, or an incorrect format of a Search Request. The reason of the error will be returned to the sender as number (ErrorCode) and as text (Description).

Message format:	ERR ([Id], ErrorCode, Description)
Sender:	MPCP3/MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before. This parameter is only used for messages from MPCP3, in order to specify which MPCP7 service is the receiver of this message
ErrorCode:	Number, which specifies clearly the failure reason
Description:	Reason of error, readable by user
Answer:	N/A

Registration Message - REG (Register)

With the message REG, a service can register itself with MPCP3. This is necessary and usually accomplished when

starting services. Registered services can receive, for example, an ISREQ for further processing.

Message format:	REG (Id, IP, Port, (Services))
Sender:	MPCP7
Id:	Unique identifier of the service. It can be, e.g., its process ID, random number, which is generated for instance from the system time and a random function, or a combination of an IP address and Port, which are currently used by services
IP:	The IP address of the service. This is necessary, in case the equipment supports several Network component/IP address
Port:	The TCP port, under this, the service is available through the IP address
Services:	List of service types. For example, after receiving a search request, only those that are corresponding to the registered service will be forwarded
Answer:	ACK, NAK, ERR

Registration Message - DREG (Deregister)

By means of the message DREG, a service can deregister itself with MPCP3 and therefore it will no longer receive any message from MPCP3.

Message format:	DREG (Id)
Sender:	MPCP3/MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before
Answer:	ACK, NAK, ERR

Search Message - SEQ (Search Request)

Through SREQ, MPCP7 can initiate a search request based on keywords with MPCP3. The MPCP SREQ is transformed into the corresponding SREQ of the EDSR protocol and then it is dropped.

Message format:	SREQ (Id, Service, (Keywords))
Sender:	MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before
Service:	16-bit Hash value of the string, which specifies a requested service
Keywords:	List of 32-bit Hash values, which is used as keywords for the search in the specified service. The Hash

	value is created from the strings of the search words
Answer:	ACK, NAK, ERR

Search Message - ISREQ (Incoming Search Request)

ISREQ is the counterpart of a SREQ. MPCP3 sends an ISREQ message with a detailed EDSR SREQ option to the MPCP7. The respective service can then verify whether it can respond positively to this search request.

Message format:	ISREQ (Id, Service, (Keywords))
Sender:	MPCP3
Id:	Unique identifier of the service, which was used to register with MPCP3 before
Service:	16-bit Hash value of the string, which specifies a requested service
Keywords:	List of 32-bit Hash values, which is used as keywords for the search in the specified Service. The Hash value is created before sending out the EDSR SREQs, from the strings of the search words
Answer:	ACK, NAK, ERR

Search Message - HREQ (Hash Request)

By means of a HREQ, a service can initiate an EDSR HREQ, in order to search an alternative source for downloading of the data.

Message format:	HREQ (Id, Service, FileSize, Hash)
Sender:	MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before
Service:	16-bit Hash value of the string, which specifies a requested service. This service corresponds to the Service Type field of the EDSR HREQ option
FileSize:	Size of data in Octets
Hash:	128-bit MD5 Hash value over the whole data
Answer:	ACK, NAK, ERR

Search Message - IHREQ (Incoming Hash Request):

MPCP3 sends the message IHREQ to MPCP7 as soon as it receives an EDSR HREQ. Then the respective service can react accordingly.

Message format:	IHREQ (Id, Service, FileHash, FileSize)
Sender:	MPCP3

Id:	Unique identifier of the service, which was used to register with MPCP3 before
Service:	16-bit Hash value of the string, which specifies a requested service. Copy from the Service Type field of the EDSR HREQ option
FileHash:	128-bit MD5 Hash value over the whole data
FileSize:	Size of data in Octets
Answer:	ACK, NAK, ERR

Response Message - FREP (File Reply)

FREP is the positive answer of services on receiving a search request of the form ISREQ or IHREQ, if the corresponding data as files are available. MPCP3 can create an EDSR FREP based on the information of the data of the registered service, such as IP address and TCP port.

Message format:	(Id, FileHash, FileName, FileSize, Upload)
Sender:	MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before
FileHash:	128-bit MD5 Hash value over the whole file
FileName:	Name of the file

FileSize:	Size of the file in Octets
Upload:	Bool value, which indicates whether upload on the MPP servers is possible
Answer:	ACK, NAK, ERR

Response Message - IFREP (Incoming File Reply)

IFREP is the counterpart of FREP. IFREP is sent with a detailed information of EDSR FREP option by MPCP3 to MPCP7. Based on this information, the service can initialise a data transfer over MMP.

Message format:	IFREP (Id, IP, Port, FileHash, FileName, FileSize, Upload)
Sender:	MPCP3
Id:	Unique identifier of the service, which was used to register with MPCP3 before
IP:	IP address of the offered service
Port:	TCP port, over this the service can be obtained
FileHash:	128-bit MD5 Hash value over the whole file
FileName:	Name of the file
FileSize:	Size of the file in Octets
Upload:	Bool value, which indicates whether upload on the MPP servers is possible
Answer:	ACK, NAK, ERR

Response Message - PREQ (Push Request):

After receiving a FREP, mobile peer-to-peer protocol MPP will try to set up a direct connection to the provided Peer over the given TCP port. If it is not possible, as the case of the providing Peer is behind a Firewall, and the providing Peer allows upload (U-flag in FREP), MPCP7 will send a PREQ message to MPCP3 to initiate an EDSR PREQ. The PREQ informs the providing Peer that it cannot initiate an MPP download over the provided port, so please upload the file instead. With PREQ all necessary data are provided, which is necessary for an upload.

Message format:	PREQ (Id, FileHash, FileSize)
Sender:	MPCP7
Id:	Unique identifier of the service, which was used to register with MPCP3 before
FileHash:	128-bit MD5 Hash. This value together with FileSize specifies the file clearly in the P2P network
FileSize:	Size of the file in Octets
Answer:	ACK, NAK, ERR

Response Message - IPREQ (Incoming Push Request)

The IPREQ is the counterpart of the PREQ. It contains information about the requested file that need to be

uploaded. It is sent by MPCP3 to MPCP7 on receiving of an EDSR PREQ. Then the service can initiate an upload over mobile peer-to-peer protocol MPP.

Message format:	IPREP (Id, IP, Port, FileHash, FileSize)
Sender:	MPCP3
Id:	Unique identifier of the service, which was used to register with MPCP3 before
IP:	IP address of the requesting service
Port:	TCP port, over which the service can be uploaded
FileHash:	128-bit MD5 Hash value over the whole file
FileSize:	Size of the file in Octets
Answer:	ACK, NAK, ERR

Response Message - DREP (Description Reply)

DREP requests to send out an EDSR DREP message. It is sent from MPCP7 to MPCP3 and it is the positive answer to a received ISREQ or IHREQ. MPCP3 provides necessary information about the registered service, such as IP address and TCP port to create an EDSR DREP.

Message format:	PREP (Id, ProfileHash, ProfileName, ProfileSize)
Sender:	PCP7

Id:	Unique identifier of the service, which was used to register with MPCP3 before
ProfileHash:	128-bit MD5 Hash value over the profile data
ProfileName:	Name of the profile
ProfileSize:	Size of the profile in Octets
Answer:	ACK, NAK, ERR

Further to the above, the proposed protocol stack according to the present invention was also simulated in SDL to prove its function. In particular, simulation with five nodes was performed. These investigations and related comparisons to pre-existing solutions, in particular Gnutella show a significant improvement in performance of the protocol stack according to the present invention over traditional peer-to-peer protocols used over ad-hoc networks. In more detail, the overhead per successful file search was 4850 bytes for Gnutella and 1966 bytes for MPP, and further the background traffic was 2,43 kbit/s for Gnutella and 0,029 kbit/s for MPP.

C l a i m s

I.

Extended Dynamic Source Routing Protocol

Method Claims

1. Method of implementing a network layer routing protocol being operated in support of a mobile peer-to-peer layer protocol for communication in a wireless network, comprising the steps:

   - receiving search-related data in relation to a service request initiated through a service running on top of the mobile peer-to-peer layer protocol;

   - transforming the search related-data into a query message in accordance with the network layer routing protocol; wherein

   - the query message allows comprises search criteria extending beyond address information.

2. Method according to claim 1, ***characterized in that*** the query message (SREQ, HREQ) is related to search of data.

3. Method according to claim 2, ***characterized in that*** the query message (HREQ) specifies file size and fingerprint information with respect to searched data.

4. Method according to one of the claims 1 to 3, ***characterized in that*** it comprises the step of forwarding the query message for identification of a responding node responding to the service request.

5. Method according to claim 4, ***characterized in that*** a query message is forwarded between mobile nodes of the wireless network.

6. Method according to one of the claims 1 to 5, ***characterized in that*** it further comprises the steps of:

- receiving the query message at a node of the wireless network infrastructure;
- forwarding the query message to at least one peer-to-peer application registered at the node according to the network layer routing protocol;
- receiving an evaluation from the peer-to-peer application whether search criteria are fulfilled or not; and
- sending a search response to the sending node in the wireless network where the search was initiated when at least one search criteria are fulfilled.

7. Method according to claim 6, ***characterized in that*** it further comprises a step of receiving the search response at the sending node.

8. Method according to claim 6 or 7, ***characterized in that*** the search response (FREP) comprises path information with respect to a path in the wireless network connecting the sending node and a corresponding node sending the search response.

9. Method according to claim 6 or 7, ***characterized in that*** the search response (PREQ) comprises path information with respect to a path in the wireless network connecting a sending node and a corresponding node sending the search response for subsequent data upload from the sending node to the responding node.

10. Method according to claim 6 or 7, ***characterized in that*** the search response (DREP) comprises profile information with respect to a searched service.

11. Method according to one of the claims 6 to 10, ***characterized in that*** it further comprises a step of forwarding the search response to the peer-to-peer layer protocol.

12. Method according to one of the claims 6 to 11, ***characterized in that*** it further comprises the step of evaluating different search results when a plurality of the search responses are received.

13. Method according to claim 12, ***characterized in that*** the evaluation is achieved according to at least one pre-determined cost function.

14. Method according to step 13, ***characterized in that*** the pre-determined cost function evaluates characteristics of at least one node in a path of the wireless network connecting the sending node and the responding node.

15. Method according to step 14, ***characterized in that*** the characteristics are number of nodes in the path, transmission power of a node, moving speed of a node or transfer rate of a node.

16. Method according to one of the claims 1 to 15, ***characterized in that*** it further comprises a step of registering a service running on top of the mobile peer-to-peer layer protocol at the network layer routing protocol level.

17. Method according to one of the claim 16, ***characterized in that*** it further comprises a step of confirming registration of a service running on top of the mobile peer-to-peer layer protocol to the network layer routing protocol level.

18. Method according to one of the claims 1 to 17, ***characterized in that*** the wireless network is an ad hoc wireless network.

II.

Mobile Peer-to-Peer Protocol

Method Claims

19. Method of implementing a mobile peer-to-peer network protocol in support of mobile peer-to-peer services, wherein the mobile peer-to-peer network protocol is operated on top of a network layer routing protocol provided for routing nodes of a wireless network, comprising the steps:

    - receiving a service request comprising search criteria extending beyond node address information; and

    - exchanging the service request with the network layer routing protocol for identification of shared service resources in the wireless network.

20. Method according to claim 19, ***characterized in that*** the service request is received from a mobile peer-to-peer service running on top of the mobile peer-to-peer network protocol.

21. Method according to claim 19, ***characterized in that*** the service request is received from the network layer routing protocol.

22. Method according to one of the claims 19 to 21, ***characterized in that*** it further comprises a step of receiving a search response to the service request on the level of the mobile peer-to-peer network protocol.

23. Method according to claim 22, ***characterized in that*** the search response is forwarded to the mobile peer-

to-peer network protocol from the network layer routing protocol.

24. Method according to claim 22 or 23, ***characterized in that*** the search response comprises path information with respect to a path in the wireless network, the path connecting a sending node where the mobile peer-to-peer service initiating the search request is running and a responding node sending the search response.

25. Method according to one of the claims 19 to 24, ***characterized in that*** it further comprises the step of evaluating the search request on the level of the mobile peer-to-peer network protocol.

26. Method according to claim 25, ***characterized in that*** the evaluation is based on classifying mobile peer-to-peer services into different types.

27. Method according to claim 26, ***characterized in that*** the step of classifying mobile peer-to-peer services into different types is achieved using hash values.

28. Method according to one of the claims 25 to 27, ***characterized in that*** it further comprises the step of describing mobile peer-to-peer services on the basis of service profiles.

29. Method according to claim 28, ***characterized in that*** service profiles comprise information with respect to service characteristics and service providers.

30. Method according to one of the claims 25 to 29, ***characterized in that*** it further comprises the step of generating a search response and a step of forwarding the service response when the evaluation of the search request on the level of the mobile peer-to-peer network protocol indicates fulfilment of search criteria.

31. Method according to one of the claims 19 to 30, ***characterized in that*** it comprises a step of connection recovery after connection breakdown.

32. Method according to one of the claims 19 to 31, ***characterized in that*** it further comprises the step of direct exchange of data being related to the service request between the sending node and the responding node on the basis of the mobile peer-to-peer network protocol.

33. Method according to claim 32, ***characterized in that*** the step of direct data exchange is achieved through data download and/or data upload.

34. Method according to claim 33, ***characterized in that*** the step of direct data exchange is achieved through HTTP data download and/or HTTP data upload.

35. Method according to one of the claims 19 to 34, ***characterized in that*** it further comprises a step of registering a mobile peer-to-peer service at the network layer routing protocol.

36. Method according to claim 35, ***characterized in that*** it further comprises the step of acknowledging registration of a mobile peer-to-peer service at the network layer routing protocol.

III.

Mobile Peer-to-Peer Control Protocol

Method Claims

37. Method of implementing an cross-layer communication channel protocol (MPCP) between a mobile peer-to-peer application and a network layer routing protocol, comprising the step:

exchanging all incoming and outgoing messages between the mobile peer-to-peer application and the network layer routing protocol, except file exchange.

38. Method according to claim 37, ***characterized in that*** implementation of the cross-layer communication channel protocol divides into a first part (MPCP7) operated on the level of the mobile peer-to-peer application and a second part (MPCP3) operated on the level of the network layer routing protocol.

39. Method according to claim 38, ***characterized in that*** messages are exchanged between the first part and the second part of the cross-layer communication channel protocol.

40. Method according to one of the claims 37 to 39, ***characterized in that*** messages are related at least to service confirmation, service registration, data search, service request, service response.

IV.

Extended Dynamic Source Routing Protocol

Apparatus Claims

41. Apparatus for implementing a network layer routing protocol being operated in support of a mobile peer-to-peer layer protocol for communication in a wireless network, comprising:

- a first interface unit adapted to receive search-related data in relation to a service request initiated through a service running on top of the mobile peer-to-peer layer protocol;

- a transforming unit adapted to transform the search related-data into a query message in accordance with the network layer routing protocol; wherein

- the query message comprises search criteria extending beyond address information.

42. Apparatus according to claim 41, ***characterized in that*** the transforming unit is adapted to transform the search related-data into a query message (SREQ, HREQ) being related to search of data.

43. Apparatus according to claim 42, ***characterized in that*** the transforming unit is adapted to transform the search related-data into a query message (HREQ) specifies file size and fingerprint information with respect to searched data.

44. Apparatus according to one of the claims 41 to 43, ***characterized in that*** it further a second interface unit adapted to forward the query message for identification of a responding node responding to the service request.

45. Apparatus according to claim 44, ***characterized in that*** the second interface unit is adapted to forward the query message between mobile nodes of the wireless network.

46. Apparatus according to one of the claims 41 to 45, ***characterized in that***

- the second interface unit is adapted to exchange query messages with nodes of the wireless network infrastructure;

- the first interface unit is adapted to forward the query message to at least one peer-to-peer application registered at the node according to the network layer routing protocol;

- the first interface unit is adapted to receive an evaluation from the peer-to-peer application whether search criteria are fulfilled or not; and

- the second interface unit is adapted to send a search response to the sending node in the wireless network where the search was initiated when search criteria are fulfilled.

47. Apparatus according to claim 46, ***characterized in that*** the second interface unit is adapted to receive a search response.

48. Apparatus according to claim 46 or 47, ***characterized in that*** the search response (FREP) comprises path information with respect to a path in the wireless network connecting the sending node and a responding node sending the search response, which path information is used by the second interface unit during data exchange following search.

49. Apparatus according to claim 46 or 47, ***characterized in that*** the search response (PREQ) comprises path information with respect to a path in the wireless network connecting a sending node and a responding node sending the search response for subsequent data upload from the sending node to the responding node via the second interface unit.

50. Apparatus according to claim 45 or 46, ***characterized in that*** the search response (DREP) comprises profile information with respect to a searched service, forwarded via the second interface unit and the first interface unit to the service running on top of the mobile peer-to-peer layer protocol.

51. Apparatus according to one of the claims 46 to 50, ***characterized in that*** the first interface unit is adapted to forward the search response to the peer-to-peer layer protocol.

52. Apparatus according to one of the claims 46 to 51, ***characterized in that*** it further comprises an evaluation unit adapted to evaluate different search results when a plurality of the search responses are received.

53. Apparatus according to claim 52, ***characterized in that*** the evaluation unit is adapted to process at least one pre-determined cost function.

54. Apparatus according to step 53, ***characterized in that*** the evaluation unit is adapted to evaluate characteristics of at least one node in a path of the wireless network connecting the sending node and the responding node.

55. Apparatus according to step 54, ***characterized in that*** the characteristics are number of nodes in the path, transmission power of a node, moving speed of a node or transfer rate of a node.

56. Apparatus according to one of the claims 41 to 55, ***characterized in that*** it comprises a registration unit adapted to register a service running on top of the mobile peer-to-peer layer protocol at the network layer routing protocol level.

57. Apparatus according to one of the claim 56, ***characterized in that*** the registration unit is adapted to confirm registration of a service running on top of the mobile peer-to-peer layer protocol to the network layer routing protocol level.

58. Apparatus according to one of the claims 41 to 57, ***characterized in that*** it is adapted to operate in an ad hoc wireless network.

V.

Mobile Peer-to-Peer Protocol

Apparatus Claims

59. Apparatus for implementing a mobile peer-to-peer network protocol in support of mobile peer-to-peer services, wherein the mobile peer-to-peer network protocol is operated on top of a network layer routing protocol provided for routing nodes of a wireless network, comprising:

- a first interface unit adapted to receive a service request comprising search criteria extending beyond node address information; and

- a second interface unit adapted to exchange the service request with the network layer routing protocol for identification of shared service resources in the wireless network.

60. Apparatus according to claim 59, ***characterized in that*** the first interface unit is adapted to receive the service request from a mobile peer-to-peer service

running on top of the mobile peer-to-peer network protocol.

61. Apparatus according to claim 59, ***characterized in that*** the second interface unit is adapted to receive the service request from the network layer routing protocol.

62. Apparatus according to one of the claims 59 to 61, ***characterized in that*** the second interface unit is adapted to receive a search response to the service request on the level of the mobile peer-to-peer network protocol.

63. Apparatus according to claim 62, ***characterized in that*** the first interface unit and the second interface unit are adapted to forward the search response to the mobile peer-to-peer network protocol from the network layer routing protocol.

64. Apparatus according to claim 62 or 63, ***characterized in that*** the search response comprises path information with respect to a path in the wireless network, the path connecting a sending node where the mobile peer-to-peer service initiating the search request is running and a responding node sending the search response.

65. Apparatus according to one of the claims 59 to 64, ***characterized in that*** it comprises an evaluation unit adapted to evaluate the search request on the level of the mobile peer-to-peer network protocol.

66. Apparatus according to claim 65, ***characterized in that*** it comprises a memory unit storing a classification of mobile peer-to-peer services into different types as basis of evaluation.

67. Apparatus according to claim 66, ***characterized in that*** the evaluation unit is adapted to classify mobile peer-to-peer services into different types by using hash values.

68. Apparatus according to one of the claims 65 to 67, ***characterized in that*** the memory unit is adapted to store service profiles with respect to mobile peer-to-peer services.

69. Apparatus according to claim 68, ***characterized in that*** service profiles comprise information with respect to service characteristics and service providers.

70. Apparatus according to one of the claims 65 to 69, ***characterized in that*** it a search response generation unit adapted to generate a search response and that the second interface unit is adapted to forward the service response when the evaluation of the search request on the level of the mobile peer-to-peer network protocol indicates fulfilment of search criteria.

71. Apparatus according to one of the claims 59 to 70, ***characterized in that*** it comprises a connection recovery unit adapted to achieve connection recovery after connection breakdown.

72. Apparatus according to one of the claims 59 to 71, ***characterized in that*** it comprises a data exchange unit adapted to direct exchange of data being related to the service request between the sending node and the responding node on the basis of the mobile peer-to-peer network protocol.

73. Apparatus according to claim 72, ***characterized in that*** the data exchange unit is adapted to achieve direct data exchange through data download and/or data upload.

74. Apparatus according to claim 73, ***characterized in that*** the data exchange unit is adapted to achieve direct data exchange through HTTP data download and/or HTTP data upload.

75. Apparatus according to one of the claims 59 to 74, ***characterized in that*** it comprises a registration unit adapted to register a mobile peer-to-peer service at the network layer routing protocol.

76. Apparatus according to claim 75, ***characterized in that*** it the registration unit is adapted to receive an acknowledgement registration for a mobile peer-to-peer service at the network layer routing protocol.

VI.

Mobile Peer-to-Peer Control Protocol

Apparatus Claim

77. Apparatus for implementing an cross-layer communication channel protocol (MPCP) between a mobile peer-to-peer application and a network layer routing protocol, comprising:

an exchange unit adapted to exchange all incoming and outgoing messages between the mobile peer-to-peer application and the network layer routing protocol, except file exchange.

78. Apparatus according to claim 77, ***characterized in that*** exchange unit comprises an upper layer unit (MPCP7) operated on the level of the mobile peer-to-peer application and a lower layer unit (MPCP3) operated on the level of the network layer routing protocol.

79. Apparatus according to claim 77 or 78, ***characterized in that*** messages are related at least to service confirmation, service registration, data search, service request, service response.

80. A computer program product directly loadable into the internal memory of a mobile communication unit, comprising software code portions for performing the steps of one of the claims 1 to 18 or claims 19 to 36 or claims 37 to 40, when the product is run on a processor of the mobile communication unit.

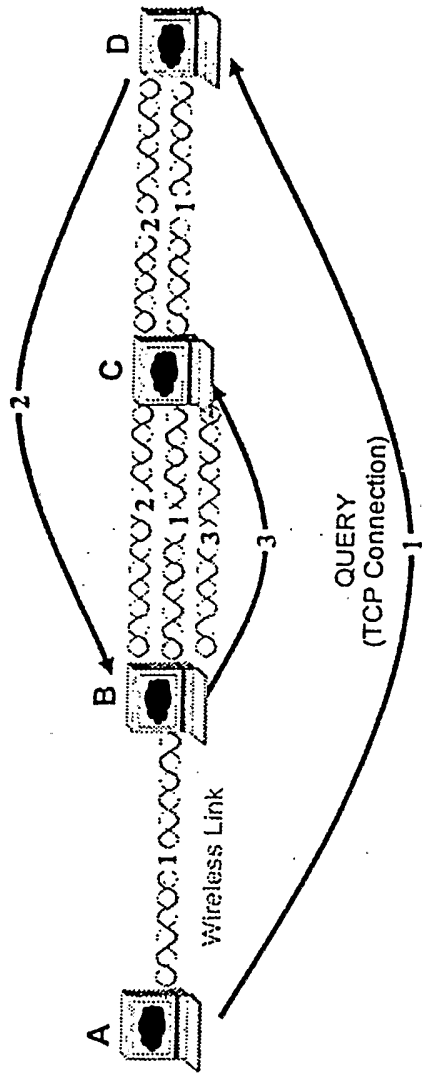

FIG. 1

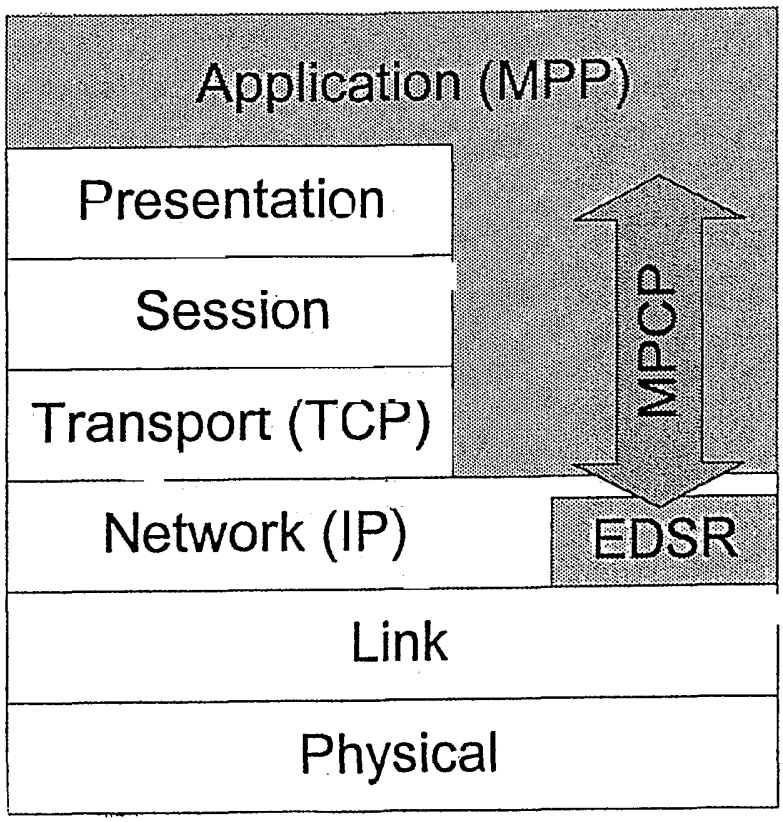
Application (MPP)
Presentation
Session
Transport (TCP)
Network (IP)
Link
Physical
MPCP
EDSR

FIG. 2

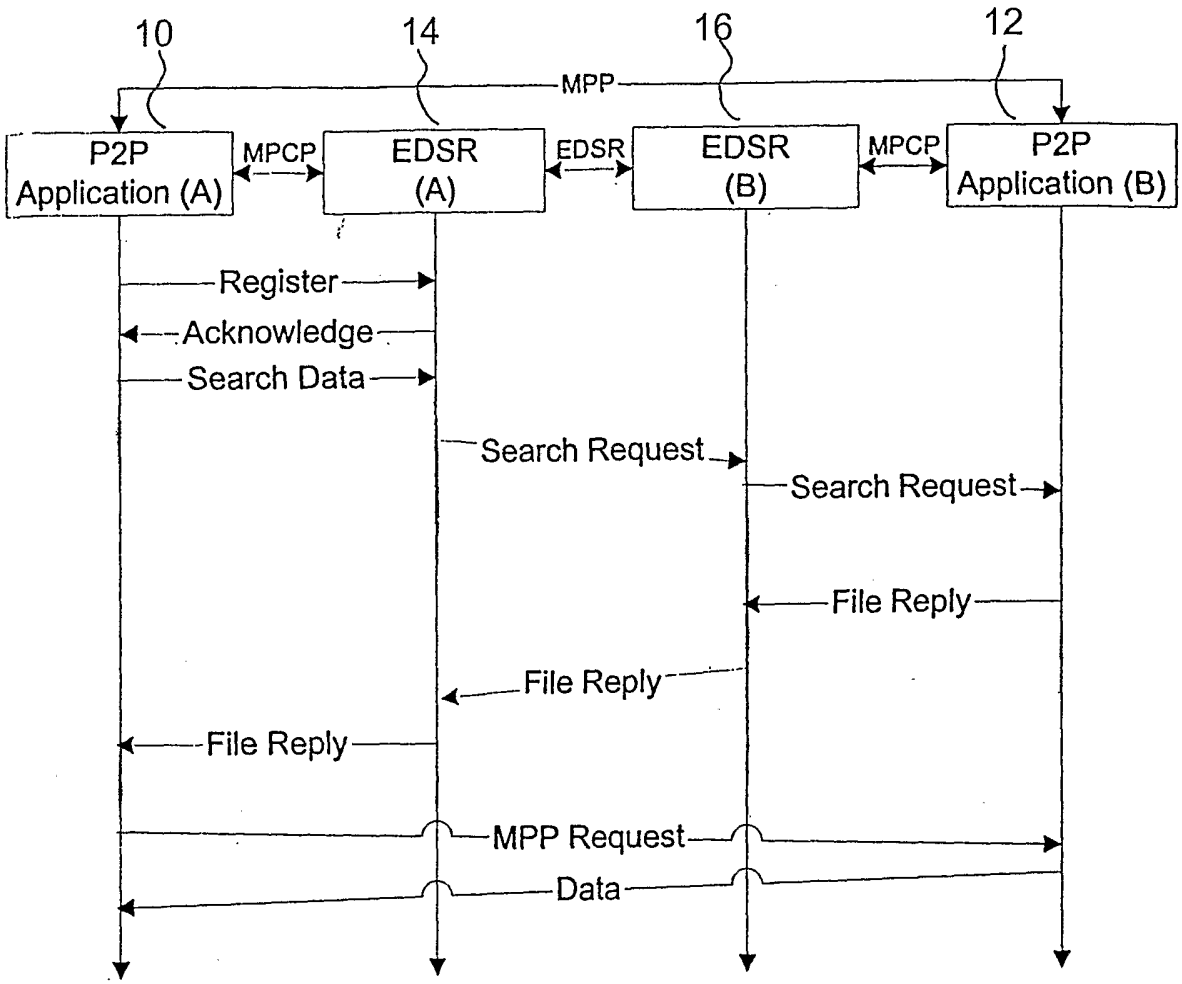
10
14
16
12
MPP
P2P Application (A)
MPCP
EDSR (A)
EDSR
EDSR (B)
MPCP
P2P Application (B)
Register
Acknowledge
Search Data
Search Request
Search Request
File Reply
File Reply
File Reply
MPP Request
Data

FIG. 3

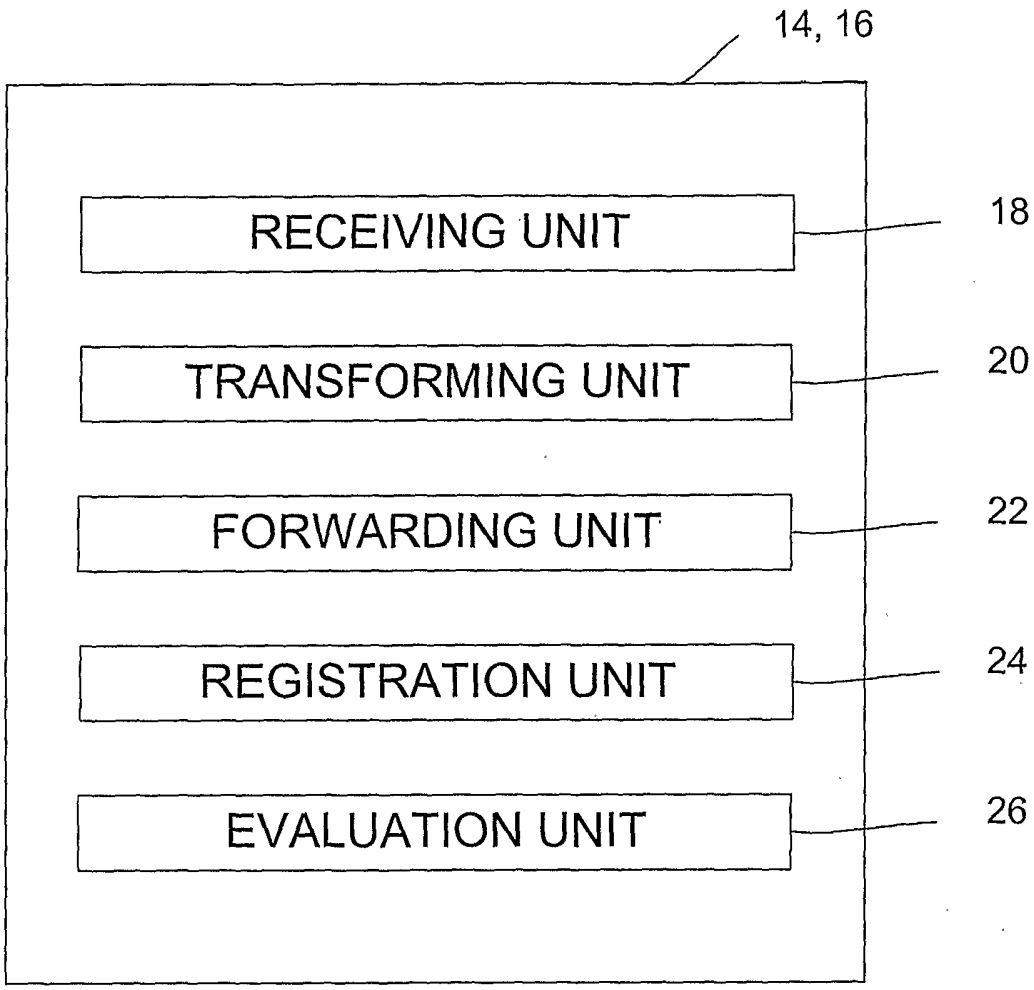
14, 16
RECEIVING UNIT
18
TRANSFORMING UNIT
20
FORWARDING UNIT
22
REGISTRATION UNIT
24
EVALUATION UNIT
26

FIG. 4

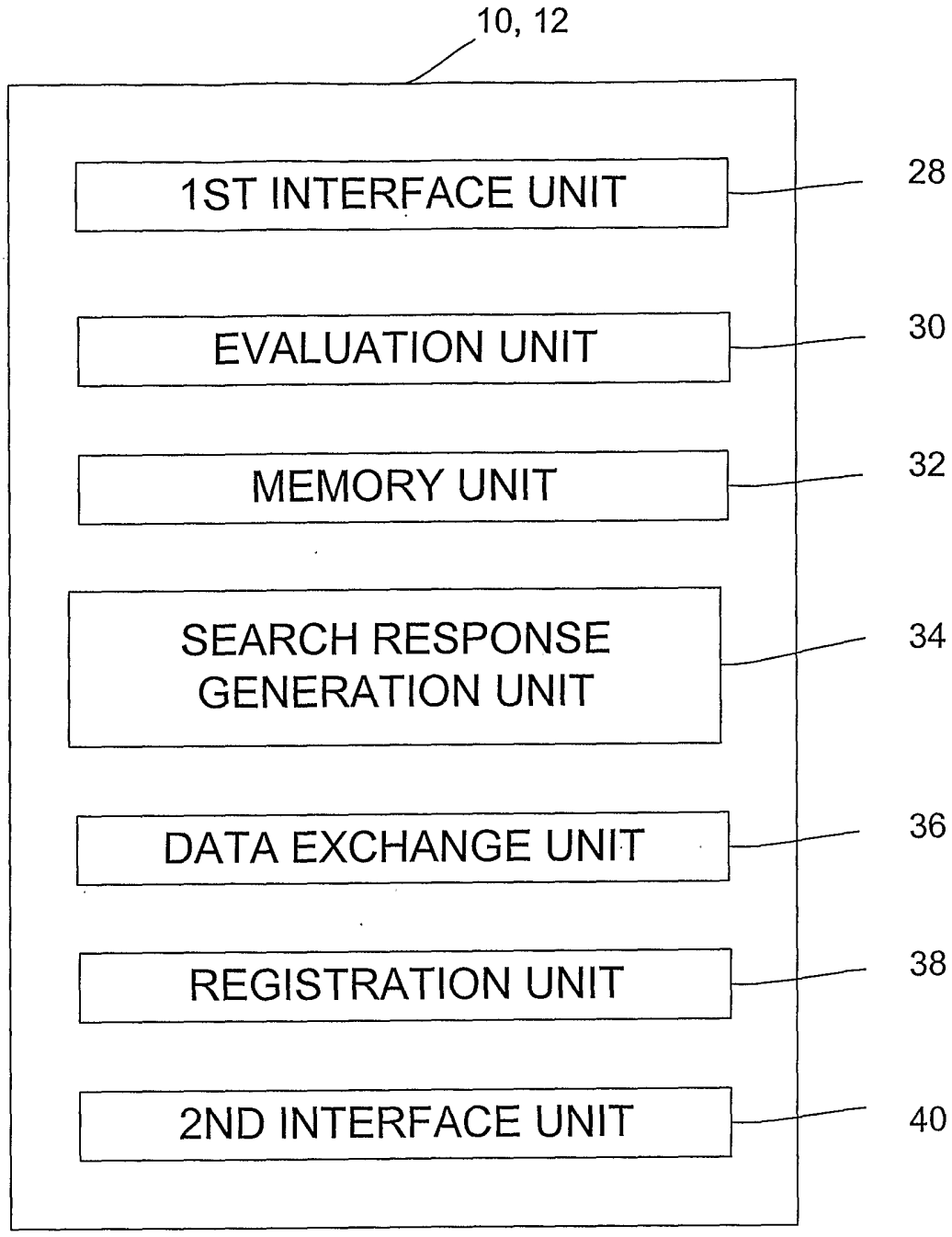
10, 12
1ST INTERFACE UNIT
28
EVALUATION UNIT
30
MEMORY UNIT
32
SEARCH RESPONSE GENERATION UNIT
34
DATA EXCHANGE UNIT
36
REGISTRATION UNIT
38
2ND INTERFACE UNIT
40

FIG. 5

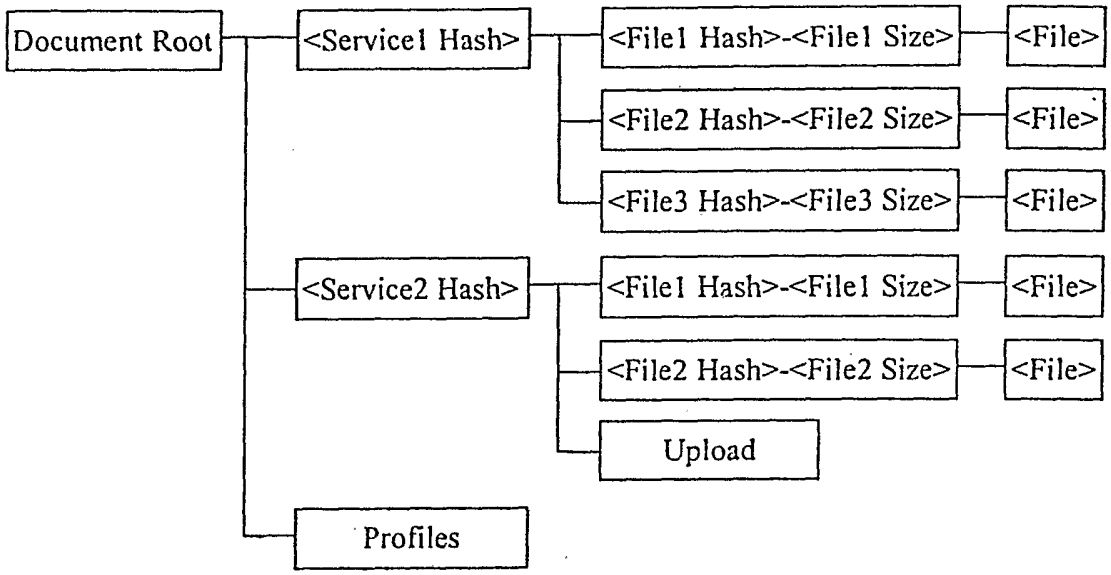
Document Root
<Service1 Hash>
<File1 Hash>-<File1 Size>
<File>
<File2 Hash>-<File2 Size>
<File>
<File3 Hash>-<File3 Size>
<File>
<Service2 Hash>
<File1 Hash>-<File1 Size>
<File>
<File2 Hash>-<File2 Size>
<File>
Upload
Profiles

FIG. 6

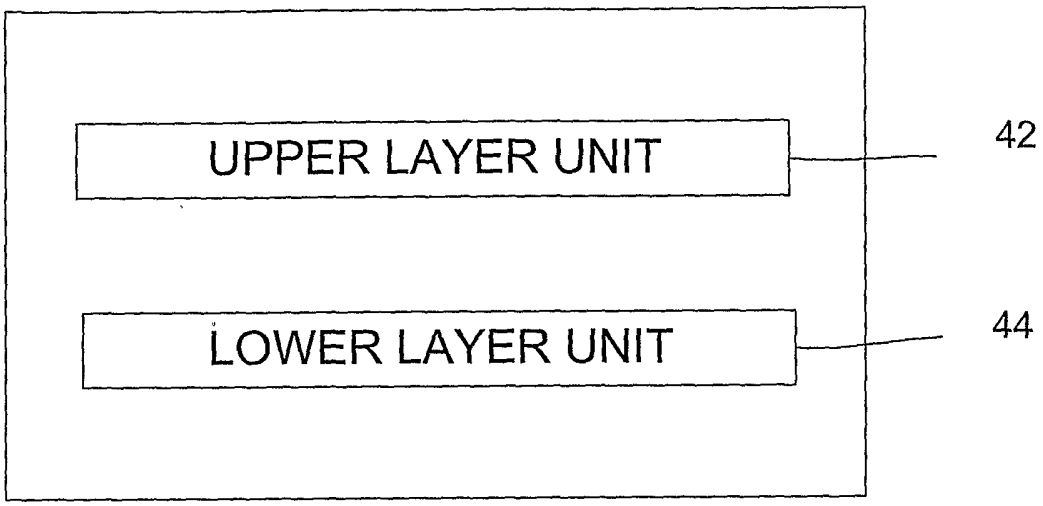

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/11472

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L29/08 H04L12/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/125063 A1 (SVENSSON BO ET AL) 3 July 2003 (2003-07-03) abstract paragraph '0006! paragraph '0028! - paragraph '0029! -/--	1-18, 41-58

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 August 2004	24.08.04

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bertolissi, E

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/11472

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	A. KLEMM, C. LINDEMANN, AND O. WALDHORST: "A Special-Purpose Peer-to-Peer File Sharing System for Mobile Ad Hoc Networks" IEEE SEMIANNUAL VEHICULAR TECHNOLOGY CONFERENCE (VTC2003-FALL), 'Online! 4 October 2003 (2003-10-04), - 9 October 2003 (2003-10-09) pages 41-49, XP002282779 ORLANDO, FL Retrieved from the Internet: URL:http://rul-www.cs.uni-dortmund.de/MobileP2P/publications/vtc03.pdf> 'retrieved on 2004-05-24! Abstract I. Introduction III. The ORION search algorithm	1-18, 41-58
X	M. KHAMBATTI AND S. AKKINENI: "Location Management in Peer-to-Peer Mobile Ad Hoc Networks " TECHNICAL REPORT COMPUTER SCIENCE AND ENGINEERING DEPARTMENT UNIVERSITY OF ARIZONA, 'Online! May 2002 (2002-05), XP002282780 Retrieved from the Internet: URL:http://www.public.asu.edu/{mujtaba/Articles%20and%20Papers/TR-05-02-a.pdf> 'retrieved on 2004-05-24! Abstract 1.1 Mobile peer-to-peer computing 4. Hierarchical location management	1-18, 41-58
X	RÜDIGER SCHOLLMEIER AND INGO GRUBER: "Routing in Peer-to-Peer and Mobile Ad Hoc Networks. A Comparison" INTERNATIONAL WORKSHOP ON PEER-TO-PEER COMPUTING, 'Online! 19 May 2002 (2002-05-19), - 24 May 2002 (2002-05-24) XP002282781 Pisa, Italy Retrieved from the Internet: URL:http://www.elet.polimi.it/p2p/papers/1.pdf> 'retrieved on 2004-05-25! Abstract 4. Routing in Ad Hoc Networks 5. Routing in Peer-to-Peer Networks	19-40, 59-80
A	US 2002/178260 A1 (CHANG HSIN-WANG WAYNE) 28 November 2002 (2002-11-28) abstract paragraph '0010! - paragraph '0012!	1-18, 41-58

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/11472

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ORAM ANDY (ED): "Peer-to-peer: Harnessing the Benefits of a Disruptive Technology passage" PEER-TO-PEER: HARNESSING THE BENEFITS OF A DISRUPTIVE TECHNOLOGY, XX, XX, 15 March 2001 (2001-03-15), pages 94-122, XP002259974 the whole document	1-18, 41-58
T	RÜDIGER SCHOLLMEIER, INGO GRUBER, FLORIAN NIETHAMMER: "Protocol for Peer-to-Peer Networking in Mobile Environments" IN PROCEEDINGS OF IEEE12TH INTERNATIONAL CONFERENCE ON COMPUTER COMMUNICATIONS AND NETWORKS, ICCCN'03, 'Online! 20 October 2003 (2003-10-20), XP002291690 DALLAS, TEXAS, USA Retrieved from the Internet: URL:http://www.lkn.ei.tum.de/lkn/mitarbeiter/hrs/Komponenten/paper/EDSR.pdf> 'retrieved on 2004-08-05! the whole document	
T	INGO GRUBER, RÜDIGER SCHOLLMEIER, WOLFGANG KELLERER: "Performance Evaluation of the Mobile Peer-to-Peer Protocol" IN PROCEEDINGS OF THE FOURTH INTERNATIONAL WORKSHOP ON GLOBAL AND PEER-TO-PEER COMPUTING, GP2PC'2004, 'Online! 19 April 2004 (2004-04-19), XP002291691 CHICAGO, USA Retrieved from the Internet: URL:http://www.lkn.ei.tum.de/lkn/mitarbeiter/hrs/Komponenten/paper/MPP_camera.pdf> 'retrieved on 2004-08-04! the whole document	
A	JAKOB ERIKSSON ET ALT.: "PeerNet: Pushing Peer-to-peer down the stack" 2ND INTERNATIONAL WORKSHOP ON PEER-TO-PEER SYSTEMS (IPTPS '03), 'Online! 20 February 2003 (2003-02-20), - 21 February 2003 (2003-02-21) XP002282783 Berkeley, CA, USA Retrieved from the Internet: URL:http://iptps03.cs.berkeley.edu/final-papers/peernet.pdf> 'retrieved on 2004-05-24! Abstract 3 The PeerNet Network Layer 3.2 Routing	19-40, 59-80

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/11472

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ANWITAMAN DATTA: "MobiGrid: Peer-to-Peer Overlay and Mobile Ad-Hoc Network Rendezvous - a Data Management Perspective" CAISE 2003 DOCTORAL SYMPOSIUM, IN CONJUNCTION WITH THE 15TH CONFERENCE ON ADVANCED INFORMATION SYSTEMS ENGINEERING, 'Online! 16 June 2003 (2003-06-16), XP002291692 KLAGENFURT,VELDEN, AUSTRIA Retrieved from the Internet: URL:http://www.mics.ch/getDoc.php?docid=518&docnum=1> 'retrieved on 2003-08-05! Abstract 4 MobiGrid: Intergating ... -----	19-40, 59-80
A	FOX HARRELL, YUANFANG HU, GUILIAN WANG, HUAXIA XIA: "Survey of Locating & Routing in Peer-to-Peer Systems"'Online! 3 December 2001 (2001-12-03), XP002291693 Retrieved from the Internet: URL:http://www.cse.ucsd.edu/classes/fa01/cse221/projects/group15.pdf> 'retrieved on 2004-08-04! the whole document -----	19-40, 59-80
A	Y. CHARLIE HU, SAUMITRA M. DAS, AND HIMABINDU PUCHA: "Exploiting the Synergy between Peer-to-Peer and Mobile Ad Hoc Networks" IN PROCEEDINGS OF HOTOS-IX, NINTH WORKSHOP ON HOT TOPICS IN OPERATING SYSTEMS, 'Online! 18 March 2003 (2003-03-18), XP002291694 KAUAI, HAWAII Retrieved from the Internet: URL:http://dynamo.ecn.purdue.edu/{ychu/publications/hotos03_dpsr.pdf> 'retrieved on 2004-08-05! Abstract 3 Key Concepts 4 DPSR Design -----	19-40, 59-80

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP 03/11472

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. [X] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[X] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18, 41-58

   Method and apparatus for implementing a network layer routing protocol

   ---

2. claims: 19-36, 59-76

   Method and apparatus for implementing a mobile peer-to-peer network protocol

   ---

3. claims: 37-40, 77-80

   Method and apparatus for implementing a cross-layer communication channel protocol

   ---

INTERNATIONAL SEARCH REPORT

[redacted]ternational Application No
PCT/EP 03/11472

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003125063 A1	03-07-2003	WO 03058923 A2	17-07-2003
US 2002178260 A1	28-11-2002	NONE	