An Efficient Query Scheme for Semantic Web on Mobile P2P Network

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***Abstract*—Service orientation and decentralization are characteristics in both semantic web and peer-to-peer (P2P) networks. In P2P networks, we can take the advantages of scalability and flexibility to improve semantic web services with lower cost. With IPv6, the P2P network can be extended to mobile network to support anycast delivery. This article proposes a novel semantic web service (SWS) integrated with mobile P2P network, called Mobile P2P Semantic Web, which combines extensibility of SWS, scalability of P2P, mobility of mobile network to enhance interactivity and interoperability of query service for semantic web. The simulation results demonstrated that our proposed scheme shortens the query response delay and reduces the number of duplications of query significantly.**

Index Terms—Semantic web; peer-to-peer; mobile network; IPv6; anycast.

I. INTRODUCTION

Semantic web has been proposed to provide comprehensive and triple-play web data. It enables users to create and share web content that features awareness and definition for computers or devices. Semantic Web Service (SWS) is gradually evolving into a worldwide network of semantic and statistical information, which can be accessed by users via hyperlink operations or database management [1]. SWS maintains the associations of meaningful content, which can be located and retrieved from any site of the Internet. SWS is also integrated with Service-Oriented Architectures (SOA) to create the web systems with high interactivity and interoperability. The meaningful content with high interoperability can be available via informative query that includes the queries of reasoning semantics, sentence parser, and string prefix.

SWS should be constructed with the decentralized scheme due to the high dynamics of information explosion and the high scalability of Internet development. Peer-to-peer (P2P) is a solution to cope with the characteristics of SWS. P2P systems can minimize server load and reduce bandwidth requirement of the servers by using forwarding query without flooding. A P2P system not only features the service-oriented cooperation but also utilizes the decentralized overlay. The integration of SWS and P2P provides the diversified sharing and querying solutions [2]. A P2P overlay can support a SWS framework, which allows data to be shared and reused across multiple applications.

With the development of Web 2.0 [27] and evolution of Web 3.0 [28], the novel vision of SWS has been created in the mobile network. An online semantic web not only needs the real-time management of rich semantic information about all digital resources (i.e., machine readability or content awareness), but also extends the management of dynamic location information (i.e., overlay locality and proximity) [3]. Both SWS and P2P have been developed in wired networks, so there are several challenges in the mobility extension.

In summary, SWS provides high flexibility, P2P offers high scalability, and mobile network supports high mobility. The mobile P2P environment can extend the applications of SWS for high accessibility and availability surely. Although P2P and mobile issues have been addressed in SWS individually, the combination of mobile network and P2P cooperative network has never been applied in SWS so far. The successful semantic query across mobile P2P network must bring rich and useful information and the importance of extended SWS, but the issue has never been discussed yet.

In this paper, we propose an extended query for semantic web and it can be applied to P2P and wireless mobile networks. The proposed Mobile P2P Semantic Web (MP2PSW) uses an informative query across IPv6-based network[22] to retrieve data from P2P system. The informative query is delivered via anycast forwarding. Due to the advantages of anycast and P2P, it can be shown that MP2PSW significantly reduces the traffic overhead and the response delay of query in the semantic web service.

The rest of this paper is organized as follows. Section II addresses the related works. In Section III, we discuss the proposed scheme. In Section IV, the simulation experiment and results are illustrated. Section V concludes the work.

II. RELATED WORKS

Since MP2PSW involves P2P overlay, mobile network, and anycast scheme, we discuss the terms one by one and survey the existed works.

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A. P2P

P2P [23] network is a popular and interesting development, it is widely used for file sharing, voice communications and video streaming nowadays. Distributed Hash Table (DHT) is commonly used in P2P network to hasten the query process and heighten the content availability. For example, Chord [4] uses DHT as its core algorithm that has been used successfully in P2P networks; such method has been proven to be an efficient overlay for a variety of scalable and robust distributed applications.

Chord uses a ring-based DHT to index files and peers. Every peer has a unique identification with *n* bits, so there are 2^n peers on Chord overlay with scalability. Every file can be identified and mapped via the hash key, which is derived from DHT to bind some peer. Every peer only maintains a finger table to forward any message or data to its successor, so the one-dimensional lookup in Chord is hop-by-hop and its complexity is $O(n)$. Other popular P2P systems can be found in [19 – 21].

B. Mobile Network

Wireless network provides Internet accessibility for mobile devices. Nowadays, popular WiFi [29], WiMax [30], 3G [31] and LTE [32] can support network access with or without infrastructure. Both WiFi and WiMax have access-point mode with infrastructure and ad-hoc mode without infrastructure, and the latter mode is generally known as Mobile Ad hoc NETwork (MANET). The performance of ad hoc routing protocols is similar with P2P forwarding process; so, the integration of MANET and P2P is efficient for mobile SWS [5].

There is a large amount of personal information and potential knowledge, including geographical features, topological information, and social relationships, in WiFi and MANET. Through informative query, the personal and potential knowledge is searchable via SWS, and knowledge data such as files and streams is available via P2P content sharing.

C. Anycast

Anycast is an addressing/routing mechanism based on IP network [6]. In essence, data or packets can be delivered through any network via one-to-one unicast, one-to-all broadcast, or one-to-many multicast. In unicast, a sender clearly queries or sends data to only one receiver; in broadcast, a sender floods data to all nodes, and some nodes drop such data that is not interested by the node; in multicast, a sender queries or sends data to multiple receivers, which forms a multicast group in advance. However, anycast is a new concept; it adopts the one-to-one-of-many delivery. A sender queries or sends data to an unspecified receiver, which forwards such data to other receivers in the anycast group.

Anycast originates from IPv6 [22] for service-orientated applications to reduce the network traffic and shorten the response delay. An anycast address can be assigned to an anycast group, in which the receivers with the same anycast address should receive the same packets. For example, MP2PSW sends an informative query through anycast to a group providing service-oriented application in semantic web, such that the nodes in the group should receive the same query.

Although the source should send a query to the nearest destination among an anycast group of multiple receivers, the nearest destination is not consistent with different routing principles and arbitrary routing paths. Therefore, anycast is suitable for connectionless protocols, generally built on UDP [24].

D. Query Service

The query service is a function of SWS; it provides a solution to the search engine or social network. The combination of Web Service Description Language (WSDL) [25] and Web Ontology Language (OWL) [26] provides a standard to develop the query service. The query can be developed from the string manipulation to the informative query with reasoning ontology. The informative query can integrate with SOA to improve interactivity and interoperability, Figure 1 illustrates the general module of informative query and the components of semantic web query service.

Enhanced-Chord Web Service [7] also uses P2P overlay with Chord to efficiently discover web services in a fully decentralized network. Chord is modified to a two-level hierarchy overlay, which is built by single super ring and multiple sub rings. Enhanced-Chord Web Service uses WSDL and OWL in semantic web, and it uses the super-peer solution in P2P overlay. A convergence of semantic web also uses the super-peer solution to achieve the P2P groupware [8], and the hierarchical overlay uses the computational model and distributed replication model to manage P2P framework. P2P Model for Semantic Web Service (PM4SWS) [9] is based on P2P network to discover SWS for the high scalability and avoid single point of failure. PM4SWS clearly defines the maintenance of P2P network and the process of WSDL and OWL. Semantic Overlay Network (SON) [10] presents a distributed and semantic matching-based approach for SWS publication and discovery by leveraging P2P technology. SON not only sorts the relevant concepts for service matching but also publishes ontology mapping on P2P network.

Context-Aware Semantic-Based Access Control (CASBAC) [11] follows OWL to build a model for mobile web services. Semantic COntext-aware Ubiquitous scouT (SCOUT) [12] is a mobile application framework, which supports online semantic sources to improve personalization. It not only provides the mobile query but also manages the detection and location of user profile. Semantic Mobile Service Discovery (SeMoSD) [13] is a mechanism to discover mobile web services. It can query, reason, and make result for the accurate search. Semantic Web mobile Learning Object Repository (SWmLOR) [14] develops a

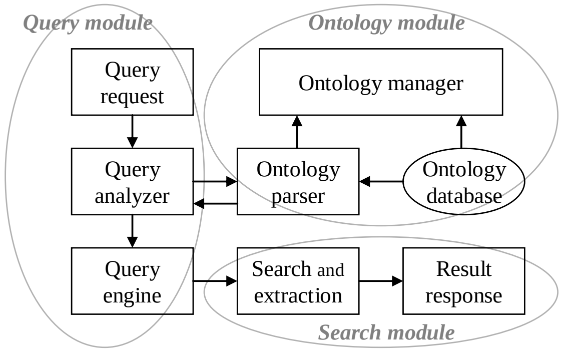


Figure 1. The components of semantic web query service.

mobile e-learning repository via semantic web technology and ontology.

Although P2P issues [7 – 10] or mobility issues [11 – 14] have been taken account in SWS, we must emphasize again that, to our best knowledge, there is no functional combination of SWS with P2P and mobile networks so far; MP2PSW is the first trial to integrate SWS with P2P and mobile networks.

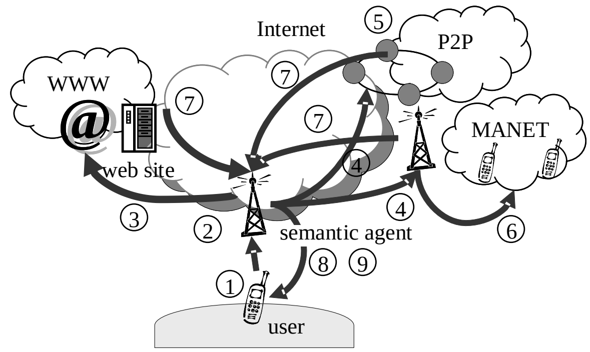
III. Proposed Scheme

The proposed MP2PSW focuses on informative query rather than semantic design or analysis. The proposed design focuses on network performance rather than web or database design. We focus on the promotion of P2P scheme for SWS, and the anycast delivery is adopted for mobility improvement.

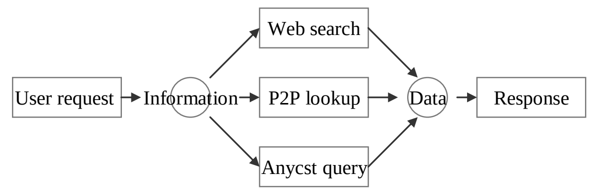
A. System Overview

A user may use a wired personal computer or a wireless handheld device to request or access the SWS by initiating an informative query, which should be forwarded to a semantic agent through the Internet. The agent handles the basic ontology extraction, data mining, or reasoning management to parse the query to the semantic web site, or a P2P overlay which can be formed either on a social network or on a mobile network. The query arrives at the semantic web site or P2P overlay and the returned result contains the information that is very likely a list of hyperlinks for real data. If the query is matched, the real data will be downloaded or responded via P2P file sharing or live streaming. The query process is summarized and illustrated in Figure 2 (a).

1. A user sends a query for a file.
2. The query is parsed by a semantic agent.
3. The query is sent to web site, which may be a search engine.
4. The query is sent to P2P network and mobile network simultaneously.
5. The query is forwarded via DHT lookup in P2P network.
6. The query is forwarded via anycast in mobile network.
7. The semantic agent receives the results of query from multiple networks as Figure 2 (b) illustrated.
8. The semantic agent ranks the results and sends them back to the user.
9. The result indicates a document or multimedia content, and the user can download it via P2P network.



(a) The network architecture and query process.



(b) Informative query

Figure 2. The system overview and query process.

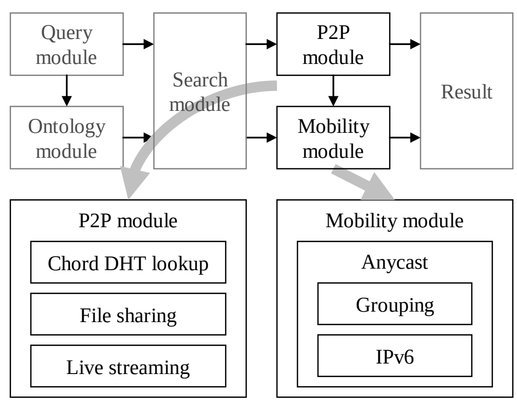


Figure 3. The proposed system modules.

The system overview is illustrated in Figure 3. Compared to Figure 1, besides the general query service, MP2PSW proposes two special modules, P2P module and mobility module.

In P2P module, DHT locates the peers and indexes the files. An informative query is looked up via Chord protocol. If a lookup is matched with returned content, which then can be available for file sharing or live streaming. For example, a movie on PPLive [15, 19] is responded, such that it can be delivered via live streaming on demand through P2P network.

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while an informative query is received do          while a P2P query is received do
    let q = informative query;                          let key = hashChord(P2P query);
    let req = getRequest(q);                            let peer = forwardChord(key);
    let sem[ ] = parseSemantics(req);                   let result[ ] = Φ;
    while sem[ ] ≠ Φ do                                 while peer ≠ null do
        sends sem as a data query;                          if peer is a mobile node then
        delete sem;                                           sends such P2P query as a mobility
    end while                                                 query to peer;
end while                                                   else
while a data query is received do                             result[ ] = result[ ] + searchResult(peer);
    let q = data query;                                         peer = peer → next;
    let meta = extractData(q);                          end while
    sends meta as a web query;                          let link[ ] = getHyperlink(result);
    sends meta as a P2P query;                          sends link;
end while                                           end while
while a web query is received do                    while a mobility query is received do
    let result[ ] = searchResult(web                    let peer = anycastDelivery(mobile query);
query);                                                 let result[ ] = Φ;
    let link[ ] = getHyperlink(result);                 while peer ≠ null do
    sends link;                                             result[ ] = result[ ] + searchResult(peer);
end while                                                   peer = peer → next;
while a link is received do                             end while
    let response = shareP2P(link);                      let link[ ] = getHyperlink(result);
    sends response;                                     sends link;
end while                                           end while
```

Figure 4. The algorithm of MP2PSW.

In MP2PSW, Chord not only indexes peers, but also forwards informative query for P2P overlay (called P2P query). Therefore, Chord is modified to forward query efficiently. Every P2P network owns an individual P2P ID, which is linked to a unique ring-based DHT inherited from Chord. Every peer is identified by a peer ID, which is ranging from 0 to $2^n - 1$ like Chord, but a peer can own multiple peer IDs unlike Chord due to the consideration for multidimensional query. When a peer has higher availability and its files have higher level of ontology, its peer ID will be smaller to reduce the forward steps.

In mobility module, anycast protocol is used to deliver an informative query. The anycast address of IPv6 is defined as the ID of P2P group to integrate P2P solution, such that every mobile node is seen as a peer in WLAN or MANET. We adopt IPv6 to implement anycast delivery, because IPv6 features higher extensibility, scalability, and mobility than that in IPv4 .

Since the cooperative network is formed in WLAN or MANET, the communication between mobile nodes is similar to the communication between peers. However, anycast delivery is forwarded in IP layer, while P2P delivery is forwarded in application layer. In order to allow informative queries for mobile network, anycast address in IPv6 is set to a P2P ID. Therefore, an informative query can be translated to a P2P query and mobility query for an integration of P2P and mobile network.

B. Algorithm

In MP2PSW, SWS must handle the messages of query process, as illustrated in Figure 4. Every informative query should be parsed to generate multiple data queries via either the query module or ontology module. Such data query is translated to P2P query or mobility query, which is forwarded via Chord forwarding or anycast routing, respectively. Through P2P and mobile network, the results are responded with hyperlinks. We discuss the steps necessary to implement MP2PSW as followings:

1. The query module is implemented in the semantic agent, which supports the network socket.
2. The socket may need multiple network interfaces to support some relay nodes.
3. The relay node is bound to single or multiple P2P network or mobile network to handle query.
4. The result of query may be generic. The ontology principle let the result specific.
5. Because every mobile node need a public IP to route informative query through Internet and supports anycast query, IPv6 is required.

C. Advantages

First, MP2PSW can avoid the single-point-of-failure problem because MP2PSW is based on P2P scheme. Although the semantic agent is used in MP2PSW, it is still

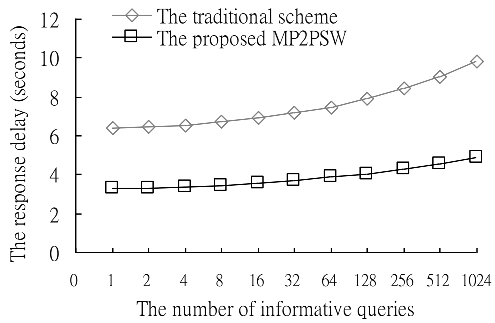

Figure 5. The response delay of informative query.

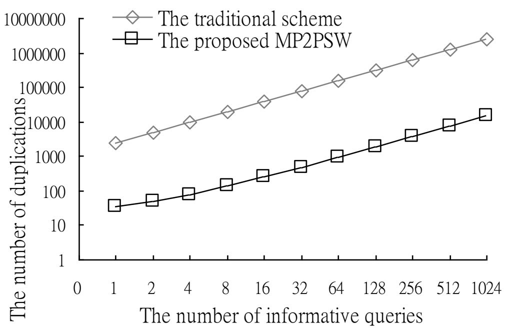

Figure 6. The duplications of informative query.

workable even if a semantic agent is failed. An information query is still forwarded to P2P and mobile network without a semantic agent, but the query results will be multifarious and the response delay will be long due to the lack of ontology parser and extraction.

Second, the combination of P2P and wireless mobile network heightens the interoperability of SWS, because such combination extends the scalability and heterogeneity of the network. The advantage of interoperability brings the rich information. In addition, P2P solution provides file streaming and video streaming services, and mobility solution provides geographic information in SWS.

Third, the network overhead can be reduced. P2P minimizes server load and anycast reduces traffic load when processing informative query. P2P solution also balances network overhead when downloading or sharing content.

IV. Performance Evaluation

We focus on the network performance of MP2PSW, which is evaluated through system simulation. We use OMNet++ [16] to construct a simulation environment as Fig. 2 illustrates. Under OMNet++, OverSim [17] is used for P2P core, i.e., Chord, and INET/ xMIPV6 [18] is used for anycast delivery. The simulation is based on IPv6, with 10000 peers given in a P2P network, in which there are 20 WLANs, with 100 mobile nodes in each WiFi. We compare MP2PSW with the traditional scheme, which adopts the server-client model. Every user as a client sends the query to the server, and waits for the response from server. The server uses the flooding query to all network nodes. The experiment repeats 20 simulations and the result represents an average.

During a given interval, a user continuously sends a large number of informative queries to the semantic agent. More queries lead to longer response delay and higher overhead. As Figure 5 illustrated, MP2PSW outperforms the traditional scheme. Based on the DHT query of Chord, the response delay is slightly long with the increasing queries. Since MP2PSW handles the variants of informative query (i.e., web query, P2P query, and mobile query) in parallel, the search process can be fastened. Via the proposed P2P module and mobility module, the modified Chord can perform query for the peers with high level of ontology, so the steps can be reduced with hop-by-hop query.

The number of duplications is used to measure the network overhead. The more the duplications are, the higher the overhead will be. As Figure 6 illustrated, MP2PSW adopts DHT-based P2P search to forward informative query in P2P network, such that the number of duplications of MP2PSW is much smaller than that of the server-client model. Although the number of duplications increases exponentially, unlike the traditional scheme, the network overhead is limited within a reasonable bound in MP2PSW. Since the anycast delivery is more efficient than the flooding delivery, the query duplications are not only reduced in wired P2P network but also minimized in wireless mobile network. However, the admission of multiple peer IDs for multidimensional query cannot alleviate the duplicated load.

V. Conclusions

In this paper, we proposed a novel scheme, which not only enables the informative query across P2P and mobile networks for SWS, but also retrieves the responded context via P2P file sharing or live streaming. The proposed MP2PSW orientates SWS to the cooperative and wireless network to obtain the potential demand and information. The proposed P2P module and mobility module parallelize the informative query via Chord and anycast protocols individually. We modified Chord and anycast to support SWS. MP2PSW not only accomplishes the pioneer and practicable design, but also considers the network performance. Therefore, MP2PSW can be demonstrated to achieve the high interoperability, scalability, and flexibility. Although MP2PSW must work in IPv6 with low popularity now, MP2PSW follows the current trend and takes advantage of P2P socialization and mobile personalization.

References

[1] V. Ermolayev, N. Keberle, S. Plaksin, O. Kononenko, and V. Terziyan, "Towards a framework for agent-enabled semantic web service composition," International Journal of Web Services Research, vol. 1, iss. 3, July–September 2004, pp. 63-87.

[2] D. Skoutas, D. Sacharidis, V. Kantere, and T. Sellis, "Efficient semantic web service discovery in centralized and

P2P environments," ISWC '08 Proceedings of the 7th International Conference on the Semantic Web, October 2008, pp. 583-598.

[3] J. Veijalainen, S. Nikitin, and V. Tormala, "Ontology-based semantic web service platform in mobile environments," Proc. 7th International Conference on Mobile Data Management, Nara, Japan, May 2006.

[4] I. Stoica, R. Morris, D. Karger, M.F. Kaashoek, and H. Balakrishnan, "Chord: A scalable peer-to-peer lookup service for internet applications," ACM Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications, August 2001, pp. 149-160.

[5] J. L. Kuo, C. H. Shih, C. Y. Ho, and Y. C. Chen, "A cross-layer approach for real-time multimedia streaming on wireless peer-to-peer ad hoc network," Ad Hoc Networks, vol. 11, iss. 1, January 2013, pp. 339-354.

[6] S. Weber and L. Cheng, "A survey of anycast in IPv6 networks," IEEE Communications Magazine, vol. 42, iss. 1, August 2004, pp. 127-142.

[7] A. Adala and N. Tabbane, "Discovery of semantic Web Services with an enhanced-Chord-based P2P network," International Journal of Communication Systems, vol. 23, iss. 11, November 2010, pp. 1353-1365.

[8] F. Xhafa and A. Poulovassilis, "Awareness in P2P groupware systems: a convergence of contextual computing, social media and semantic web," Proc. International Conference on Emerging Intelligent Data and Web Technologies, September 2011, pp. 14-21.

[9] M. Gharzouli and M. Boufaida. "PM4SWS: a P2P model for semantic web services discovery and composition," Journal of Advances in Information Technology, vol. 2, no. 1, February 2011, pp. 15-26.

[10] H. Si, Z. Chen, Y. Deng, and L. Yu, "Semantic web services publication and OCT-based discovery in structured P2P network," Service Oriented Computing and Applications, January 2012, DOI 10.1007/s11761-011-0097-4.

[11] H. B. Shen and Y. Cheng, "A context-aware semantic-based access control model for mobile web services," Advanced Research on Computer Science and Information Engineering, 2011, pp. 132-139.

[12] W. V. Woensel, S. Casteleyn, E. Paret, and O.D. Troyer, "Mobile querying of online semantic web data for context-aware applications," IEEE Internet Computing, vol. 15, iss. 6, November–December 2011, pp. 32-39.

[13] R. Besen and F. Siqueira, "A mechanism for semantic web services discovery in mobile environments," Proc. 10th International Conference on Networks, January 2011, pp. 329-334.

[14] R. Pathmeswaran and V. Ahmed, "SWmLOR: technologies for developing Semantic Web based mobile Learning Object Repository," The Built & Human Environment Review, vol. 2, special iss. 1, 2009.

[15] X. Hei, C. Liang, J. Liang, Y. Liu, and K. W. Ross, "A measurement study of a large-scale P2P IPTV system," IEEE Transaction on Multimedia, vol. 9, iss. 8, December 2007, pp. 1672-1687.

[16] A. Varga, "Using the OMNeT++ discrete event simulation system in education," IEEE Transactions on Education, vol. 42, iss. 4, November 1999.

[17] I. Baumgart, B. Heep, and S. Krause, "OverSim: a flexible overlay network simulation framework," Proc. IEEE Global Internet Symposium, May 2007, pp. 79-84.

[18] F. Z. Yousaf, C. Bauer, and C. Wietfeld, "An accurate and extensible mobile IPv6 (xMIPV6) simulation model for OMNeT++," Proc. International Conference on Simulation Tools and Techniques for Communications, Networks and Systems & Workshops, March 2008, Article No. 88.

[19] "PPLive," http://www.pplive.com/ [Retrieved: April, 2013]

[20] "PPStream,"http://www.ppstream.com/[Retrieved:April, 2013]

[21] "BitTorrent,"http://www.bittorrent.com/[Retrieved:May, 2013]

[22] http://ipv6.com/articles/general/Next-Generation-Networking. Htm[Retrived: May, 2013]

[23] https://www.hpl.hp.com/techreports/2002/HPL- 2002-57R1.pdf [Retrieved: March, 2013]

[24] http://www.ietf.org/rfc/rfc768.txt [Retrieved: March, 2013]

[25] http://www.w3.org/TR/wsdl [Retrieved: March, 2013]

[26] G. Antoniou and F. van Harmelen, "Web Ontology Language: OWL," International Handbooks on Information Systems 2004, pp. 67-92.

[27] http://oreilly.com/web2/archive/what-is-web-20.html [Retrieved: May, 2013]

[28] Victoria Shannon, "A 'more revolutionary' Web," International Herald Tribune [Retrieved: May, 2013]

[29] http://www.wi-fi.org/ [Retrieved: May, 2013]

[30] http://www.wimaxforum.org/[Retrieved: May, 2013]

[31] ITU (4 July 2002), "IMT-2000 Project - ITU" [Retrieved: April, 2013]

[32] E. Dahlman, H. Ekström, A. Furuskär, J. Karlsson, M. Meyer, S. Parkvall, J. Torsner and M. Wahlqvist, "The long-term evolution of 3G," Ericsson Review, no. 02, 2005.