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A Gnutella-based P2P System Using Cross-Layer Design for MANET

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***Abstract*—**It is expected that ubiquitous era will come soon. A ubiquitous environment has features like peer-to-peer and nomadic environments. Such features can be represented by peer-to-peer systems and mobile ad-hoc networks (MANETs). The features of P2P systems and MANETs are similar, appealing for implementing P2P systems in MANET environment. It has been shown that, however, the performance of the P2P systems designed for wired networks do not perform satisfactorily in mobile ad-hoc environment. Subsequently, this paper proposes a method to improve P2P performance using cross-layer design and the goodness of a node as a peer. The proposed method uses routing metric as well as P2P metric to choose favorable peers to connect. It also utilizes proactive approach for distributing peer information. According to the simulation results, the proposed method provides higher query success rate, shorter query response time and less energy consumption by constructing an efficient overlay network.

***Keywords*—**Ad-hoc Networks, Cross-layer, Peer-to-Peer, Performance Analysis.

I. INTRODUCTION

TRADITIONAL Internet-based service paradigm based on the client-server environment is starting to shift to ubiquitous computing environment. A ubiquitous environment has features like peer-to-peer environment and nomadic environment. One of nomadic environment which is expected to be dominant in the future is the ad-hoc network. The concept of the ad-hoc network was first developed from DARPA packet radio network in 1970s. Peer-to-peer (P2P) systems were initiated in the middle of 1990s. P2P systems are widely used as resource sharing systems nowadays, generating significant traffics in the Internet backbone [1]. Among many P2P systems, Gnutella [2] is one of the most widely used one.

Ad-hoc networks and peer-to-peer networks share several common characteristics [3]. First common feature is self-configuration. Each entity in both networks can organize a network by itself. Second one is that network topology of both networks is changing dynamically. Also, operations are performed by issuing routing queries in a distributed environment. Such common characteristics raise a basic issue, that is how to communicate each other without a specific management entity. Because of the distributed, unstructured nature of both systems, they face a difficult task of delivering messages. Unlike wired Internet, an ad-hoc network is not reliable and has limited resources such as memory, processing power, bandwidth, and battery. Such characteristics of an ad-hoc network reduce the query success rate and the connectivity in the peer-to-peer system. It has been shown that the performance of Gnutella is not satisfactory when it is implemented straight-forward in the ad-hoc network under the point of view of the produced overhead and the average overlay connectivity [4].

Gnutella-based P2P systems on top of ad hoc networks have been studied in [4], [5], [6] and [7]. [4] applied cross-layer interaction between a P2P platform and the reactive routing agent at the network layer, producing simplified overlay management and improved the quality of the resulting overlay. [5] is one of the researches whose goal was more focused on the performance of ad-hoc routing protocols such as Destination-Sequenced Distance-Vector routing (DSDV), Dynamic Source Routing (DSR), and Ad hoc On-Demand Vector Routing (AODV) when Gnutella is operated over an ad-hoc network. [6] identified that Gnutella produced better performance when proactive ad-hoc routing protocol was used and hierarchical structure consisting of ultrapeers and leaves was introduced in Gnutella. In [7], an enhancement of Gnutella was proposed by using metric values in P2P system. Metric value was composed of the connectivity and remained energy ratio to enhance the lifetime of the P2P system.

In this paper, we propose a method for peer-to-peer systems to improve performance in the ad hoc networks. We are introducing cross-layer approach by incorporating routing table in selection of favorable ultrapeers to connect. The key idea to use routing table at the network layer for the P2P connection is to establish closer ultrapeer connections instead of having connections with far away ultrapeers, forming effective overlay network. To do that, we consider routing metric as well as P2P metric used in [7] for selecting ultrapeers to connect. The proposed method also incorporates proactive approach for delivering P2P metric values. According to the simulation results, the proposed method gives better performance than the system proposed in [7] in terms of query success rate and query

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response time.

The remainder of the paper is organized as follows. Section 2 overviews the Gnutella protocol. The proposed system is given in Section 3. Section 4 describes the simulation environment used and discusses the performance of the proposed system. Finally, Section 5 concludes this paper.

II. Overview of Gnutella Protocol

Gnutella is a fully distributed peer-to-peer resource locating protocol. With such characteristic, Gnutella network potentially has very good reliability and fault tolerance properties, but the search process is complex and costly.

Originally Gnutella network consists of a number of equal nodes, called peers or servents. These peers are connected by an application level overlay network [8] that provides routing and forwarding of Gnutella messages. A newly participating servent can connect to Gnutella network by handshaking with the already connected node whose address is learned somehow out-of-band [9]. Once a servent has connected successfully to the network, it communicates with the other servents by sending and receiving Gnutella protocol messages.

Ping, pong, query, and query hit are the crucial messages for Gnutella operation. Ping is used to discover servents on the network. A peer receiving a ping message sends one or more pong messages. A pong message contains information on a peer. When a peer receives a pong message, it stores the obtained peer information in its pong cache and tries to make connection to the peer. Each entry in the pong cache corresponds to one pong message. The number of pong messages generated in response to a ping message is the number of entries in the pong cache of the responding peer. Query is used as a primary mechanism for searching the distributed network. When a servent receives a query message, it searches its local files for matches to the query and returns a query hit message containing all the matches it finds [10]. The actual download of files is executed via the HTTP protocol and bypasses the Gnutella network. Ping and query messages are broadcasted over the network. Pong and query hit messages are routed back to the originator of the ping and query messages.

Having random connections with the other servents results in routing inefficiency. To address this problem, the ultrapeer system has been introduced by organizing nodes into hierarchical fashion with ultrapeers and leaves. A leaf keeps only a small number of connections with ultrapeers. On the other hand, an ultrapeer maintains many leaf connections as well as a small number of connections to the other ultrapeers [11, 12]. It acts as a proxy to the Gnutella network for the leaves connected to it and shields leaves from the majority of message traffic. An ultrapeer forwards a query to a leaf only if it believes the leaf can answer it [11]. Leaves never relay queries to ultrapeers.

In Gnutella, the ping and pong messages between a leaf and an ultrapeer as well as between ultrapeers are used to find out a new peer for maintaining connectivity. Although the message lengths of ping and pong messages are only 23 bytes and 37 bytes respectively, the traffics generated by these messages are fairly huge because ping messages are flooded up to hop count defined in the time to live (TTL) field and pong messages are generated as many as the number of entries in each node's pong cache. An example is shown in Fig. 1. If Gnutella is applied to an ad-hoc network, bandwidth occupied by such messages would not be negligible.

Another concern in Gnutella is that a peer may make a connection with another peer which would not provide good service to it. Information contained in a pong message is the address and port number of a peer collected by other peers in the system. So, there is no measure to decide which node is good to connect or which pong message contains better information. Since it is plausible to make inefficient connections, a new measure is necessary to differentiate the goodness of peers.

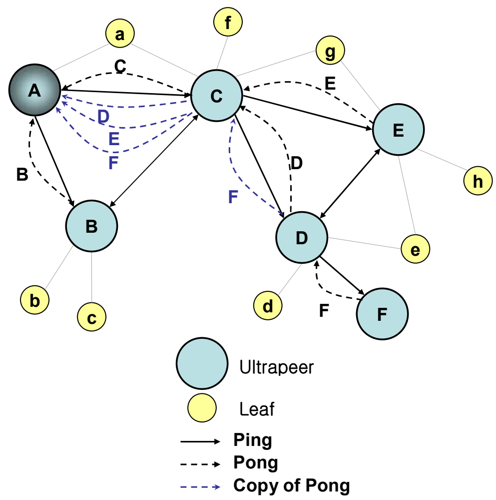

Fig. 1 Gnutella operation

III. The Proposed Method

The proposed method is based on the Gnutella with hierarchy and incorporates the operation of P2P system used in [7]. As a measure to decide the goodness of ultrapeers to form effective overlay network, following metrics are used.

- Routing metric
- P2P metric

Using of a routing metric in P2P system is the key approach of cross-layer design. The explanation of P2P metric, peer selection process and overall operation procedure of the proposed P2P system is described in this section.

A. P2P Metric

P2P metric is used for judgment of a goodness of a peer in peer-to-peer system perspective. The used P2P metric value is as follows:

$$W_i = f\left(\beta \frac{E_{cur_i}}{E_{\max_i}} + (1-\beta)\frac{U_i}{U_{\max}}\right) \quad (1)$$

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In this equation, f is an indicator whether node i is a freeloader or not. f is set to one only if node i is not a freeloader. As a result, if node i is a freeloader, its P2P metric becomes zero. E_{cur_i} is the remained energy level of node i and $E_{\max}$ is the maximum energy level. Subsequently, the term $E_{cur_i} / E_{\max}$ represents the remained energy ratio in node i. U_i is the number of ultrapeers connected and $U_{\max}$ is the maximum number of ultrapeers that node i can make connections. Thus, $U_i / U_{\max}$ represents the connectivity of node i. As the connectivity gets higher, it is possible to deliver ping or query messages to more nodes by flooding. Therefore, if a node connects to an ultrapeer with higher value of connectivity, it is easier to have better connectivity and is probable to get more query hits. β is used as a weighting factor for the remained energy ratio and the connectivity.

B. Bootstrapping

Bootstrapping operation is executed when a peer joins the P2P system for the first time. The peer informs its address and P2P metric value to the bootstrap server. The address of the bootstrap server is usually obtained out-of-band. If the joining peer wishes to act as a leaf, it sets its P2P metric value to zero during the bootstrapping. When a bootstrap server receives the peer information, it saves the received information in its cache if the P2P metric value is not zero. When the bootstrap server sends the information of currently active peer to a newly joined peer, it provides the peer's address with non-zero P2P metric values.

C. Connection to Ultrapeers

In the proposed system, the selection of ultrapeers to connect is performed in two stages. In the first stage, P2P system looks up its local routing table to find the routing metric values from itself to the ultrapeers in the pong cache. Then the found routing metric values are sorted in ascending order. An ultrapeer with least routing metric value is selected first, if the peer does not have reached the maximum number of connections and it does not have connection to the corresponding ultrapeer. Then the P2P system tries to make a connection with the selected ultrapeer. If there are multiple ultrapeers with same routing metric value, selection process goes to the second stage. In the second stage, P2P metric value is used to determine to which ultrapeer connection request should be delivered. An ultrapeer with higher P2P metric value is selected for connection.

D. Ultrapeer Advertisement

As discussed in Section 2, ping-pong operation in Gnutella may generate a lot of traffics. In order to reduce the ping and pong messages, we introduce ultrapeer advertisement operation. Ultrapeer advertisement is used by an ultrapeer to inform other ultrapeers its presence proactively using UADV messages. In UADV operation, an ultrapeer which needs to make connections informs its information to other ultrapeers using UADV messages, rather than request information of other ultrapeers by broadcasting ping messages as shown in Fig. 2. Upon receiving an UADV message, an ultrapeer behaves as if it receives a pong message in Gnutella. In other words, if a node receives an UADV message, it tries to make a connection with the node which sent the UADV message.

Since UADV operation requires to deliver only a node's information, it introduces much less overhead than ping-pong operation. UADV operation eliminates flooding of ping messages among ultrapeers. For the operation between a leaf and an ultrapeer, ping-pong operation is used.

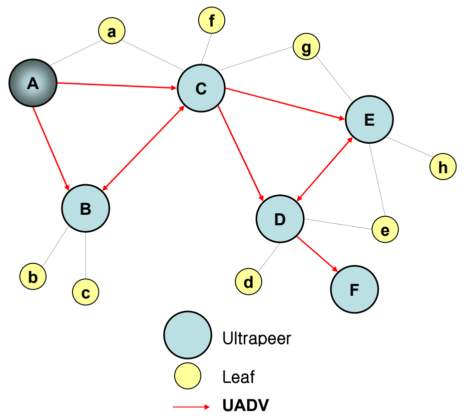

Fig. 2 Ultrapeer advertisement

E. Delivery of P2P Metric Values

Each node maintains its own P2P metric value. It also needs to know the up-to-date P2P metric values of other peers in order to operate properly. To inform the P2P metric values among ultrapeers, Ultrapeer Advertisement (UADV) message is used. UADV message is a modified version of a pong message. It carries information on the advertising ultrapeer, including P2P metric value. Between an ultrapeer and a leaf, the P2P metric value is basically informed using pong messages. For that purpose, we extend the format of a pong message to include the P2P metric value. In addition to UADV and pong messages, bootcache updating, and handshaking are used for the delivery of metric values.

IV. Performance Analysis

A. Simulation Environment

In this section, we describe the simulation environment on which simulations are executed. The Network Simulator (ns-2 version 2.26) [13] is chosen as a simulation tool.

Our evaluations are based on the simulation of 100 wireless nodes forming an ad-hoc network, moving over a 3000 meter × 600 meter rectangular flat space. A rectangular space was chosen to force the use of longer routes between nodes than those would occur in a square space with equal node density [14]. Total simulation time was set to 300 seconds. The link layer used in the simulation is IEEE 802.11 standard. The bandwidth was set to 2 Mbps and the transmission range was set to 250 m. These values are default values of ns simulator.

For the routing protocol of the ad-hoc network, we used DSDV based on the observation made in [6]. For DSDV, routing update interval was set to 15 seconds and the minimum time interval for the triggered update was set to 1 second.

Nodes in the simulation moved according to random waypoint model [15]. Random waypoint model defines the mobility pattern of nodes by pause time and the maximum node speed. Each node began the simulation by remaining stationary for the specified pause time. It then selected a random destination in the given space and moved to that destination at a speed distributed uniformly between 0 and some maximum node speed. Upon reaching the destination, the node paused again for the pause time, selected another destination, and proceeded from there as previously described. Each node repeated this behavior for the simulation time. Each run of the simulator accepted a scenario file as an input that describes the initial location and mobility pattern of each node in the network. We ran our simulations with movement patterns generated for 5 different pause times; 0, 30, 60, 120 and 300 seconds. A pause time of 0 second corresponds to continuous motion. On the other hand, a pause time of 300 seconds corresponds to no motion since the length of the simulation was set to 300 seconds. We experimented with two different maximum speeds of node movement, 1 m/sec and 20 m/sec.

For the energy model, initial energy for a node was randomly selected from U[80, 100] Joule. The amount of energy consumption for packet transmission was set to 0.66 Joule. For packet reception, it was assumed that 0.395 Joule was consumed. A mobile node was set to consume 0.035 Joule during idle state.

For P2P systems, we set the number of P2P nodes to 60 among 100 mobile nodes. Non-P2P nodes were used just to form an ad-hoc network. We set the ratio of ultrapeers to leaf nodes to 1:3 among the P2P nodes. One third of the leaf nodes were set to freeloaders. For each P2P node, PING TIMEOUT was set to 30 seconds. GnutellaSim [16] was used for Gnutella. For each Gnutella messages, initial TTL value was set to 7 as recommended in [10]. For the proposed system, the minimum interval to generate UADV messages was set to 30 seconds. $U_{\max}$ was set to 4. The value of β in Eq. 1 was set to be 0.7.

B. Performance Evaluation

In this section, we present the results of simulations that were conducted accordingly as described in the previous subsection, and evaluate the obtained results to see the performance of the proposed system over Gnutella and P2P system using only P2P metric [7]. As measures for the performance, we investigated followings:

- Average query success rate: the ratio of queries that are replied by one or more query hits over the total initiated queries.
- Average query response time: the time duration from the time when query is sent to the time when the corresponding query hit is received at the query initiator.
- Average consumed energy: the amount of consumed battery power during the simulation time.
- Average path stretch: the number of hops between two peers that had connections to each other in the P2P system.

The query success rate obtained from the simulation is shown in Fig. 3 for the various pause times and the maximum node speeds. When the maximum node speed was 1 m/sec, the proposed system gave about 32% higher query success rate than Gnutella on average. Also, it provided about 21% higher query success rate than the system proposed in [7]. When the maximum node speed was 20 m/sec, the proposed system provided about 33% and 16% better query success rates than Gnutella and the P2P system using P2P metric value. Such improvements can be obtained because leaves tried to make connections with the nearby ultrapeers with higher connectivity. For all the P2P system considered, higher query success rates were obtained when the maximum node speed was set to 20 m/sec. Such results are due to overcome network partition when high mobility. So, although the maximum node speed was same, the success rate was higher according to decrease pause time.

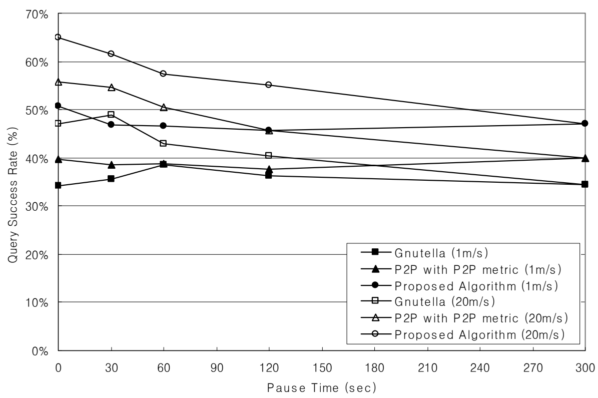

Fig. 3 Query success rate

Next, we investigated the query response time. Fig. 4 shows the average query response time. The proposed system resulted about 42% and 59% faster query response times than Gnutella when the maximum node speed was 1 m/sec and 20 m/sec respectively. Also, the average improvement of the query response time of the proposed system over P2P system with peer metric was 26% for the maximum speed of 1 m/sec and 33% for the maximum speed of 20 m/sec. Based on the observation made on the simulation results, it can be claimed that the effectiveness of incorporating routing metric value in choosing ultrapeers to connect was clearly shown. Because, each connected peer in the overlay was located nearly in the physical network in the proposed system, such result could be obtained.

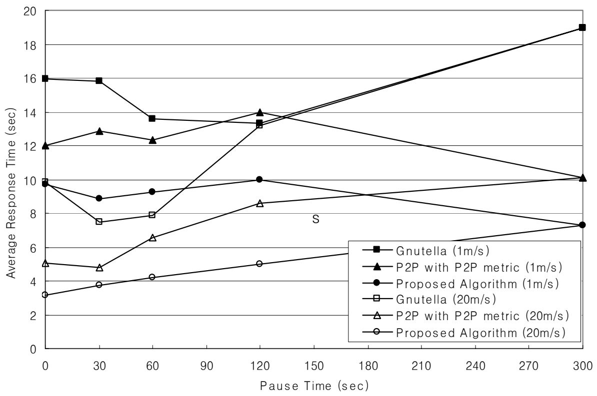

Fig. 4 Average response time

The average consumed energy of peers in the P2P systme during simulation time is shown in Fig. 5. It was represented by Joule. The proposed system resulted about 18% and 26% better energy efficiency than Gnutella when the maximum node speed was 1 m/sec and 20 m/sec respectively. Also, it saved about 16% and 18% energy consumption than P2P system with P2P metric when the maximum speed of 1 m/sec and 20 m/sec. The reason of this result is due to the proximity of connected peers. Because peers chose closer ultrappers, less mobile nodes were required for the routing of messages exchanged between the corresponding peers. That means the transmission and reception of packets in each node were reduced. The reasons of energy consumption for the maximum node speed was 20m/s lower than for the maximum node speed was 1m/s is that each peer doesn't need to generate a lot of ping and pong messages because ping timer was already reset before expired when connection was successfully established. It leads to reduce average consumed energy.

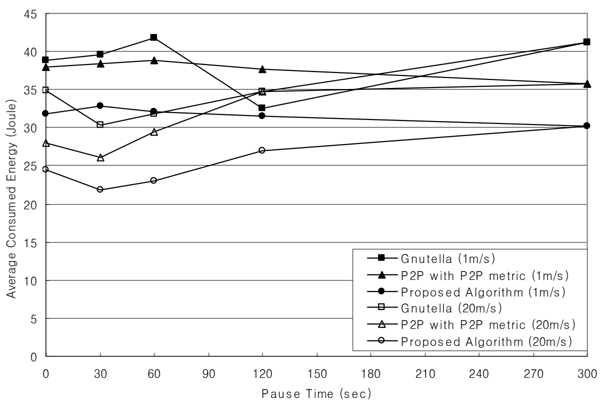

Fig. 5 Average consumed energy

Lastly, we measured path stretch of each connection in the overlay network. Fig. 6 shows the average path stretch. The proposed system gave about 15% and 19% shorter number of hops than Gnutella when the maximum speed of 1m/s and 20m/sec respectively. Also, the proposed system provided 16% and 12% shorter number of hops than P2P system with P2P metric. Clearly, it shows the benefit for using routing metric for the P2P connections. For the proposed system, each peer used routing metric to connect peer that are located nearly from them. As a result, the proposed system indicates shorter number of hops than other P2P system.

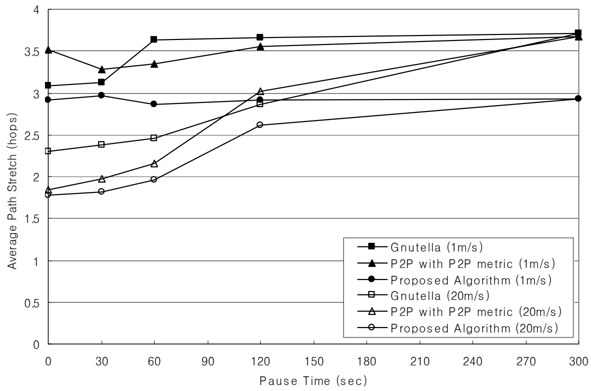

Fig. 6 Average path stretch

V. Conclusion

In this paper, we proposed an enhanced version of Gnutella system that can efficiently operate in the ad-hoc networks. The objective of our proposal is to increase the performance of the P2P system by choosing ultrapeers using routing metric value, the commitment level of the participating peers, the connectivity and the remained battery power. Also, proactive approach is used to provide up-to-date information on the ultrapeers by delivering ultrapeer advertisements periodically. Based on the analysis of the results obtained through extensive simulations, the proposed P2P system proved that it can form the P2P overlay network effectively, resulting superior performance in average query hit ratio and the query response time.

References

[1] C. Fraleigh, S. Moon, B. Lyles, C. Cotton, M. Khan, D. Moll, R. Rockell, T. Seely and C. Diot, "Packet-level traffic measurements from the sprint IP backbone," IEEE Network, vol. 17, no. 6, pp. 6–16, Nov. 2003.

[2] Gnutella, http://www.gnutella.com/

[3] R. Schollmeier, I. Gruber and M. Finkenzeller, "Routing in Mobile Ad Hoc and Peer-to-Peer Networks. A Comparison," in Workshop on Peer-to-Peer Computing, held in conjunction with IFIP Networking 2002, May 2002.

[4] M. Conti, E. Gregori and G. Turi, "A Cross-Layer Optimization of Gnutella for Mobile Ad hoc Networks," in Proc. MobiHoc '05, May 2005.

[5] L. B. Oliveira, I. G. Siqueira and A. A. F. Loureiro, "Evaluation of Ad-hoc Routing Protocols under a Peer-to-Peer Application," in Proc.WCNC 2003, pp. 1143–1148, 2003.

[6] H. Choi, H. Park and M. Woo, "Performance Analysis of Peer-to-Peer Application in Ad-Hoc Networks," in Proc. ITST 2005, pp. 49–52, June 2005.

[7] Hyun-Duk Choi and Miae Woo, "A Power-Aware Peer-to-Peer System for Ad-Hoc Networks," in proceedings of MSN 2006, LNCS 4325, pp. 861-872, December 2006.

[8] D. Diego and O'Mahony Donal, "Overlay Networks - A Scalable Alternative for P2P," IEEE Internet Computing, Vol. 7, No. 3, pp 2–5, June/Junly 2003.
[9] M. Portmann, P. Sookavatana, S. Ardon and A. Seneviratne, "The Cost of Peer Discovery and Searching in the Gnutella Peer-to-peer File Sharing Protocol," in Proc. IEEE ICON 2001, Sep. 2001.
[10] T. Klingberg and R. Manfredi, "Gnutella 0.6," available from http://rfc-gnutella.sourceforge.net/src/rfc-0_6-draft.html, Jun. 2002.
[11] A. Singla, C. Rohrs and Lime Wire LLC, "Ultrapeers: Another Step Towards Gnutella Scalability," available from http://rfcgnutella. sourceforge.net/src/Ultrapeers 1.0.html, Nov. 2002.
[12] Limwire: http://www.limewire.com/
[13] K. Fall, K. Varadhan, editors. ns notes and documentation. The VINT Project, UC Berkeley, LBL, USC/ISI, and Xerox PARC, available from http://www.isi.edu/nsnam/ns/, Nov. 1997.
[14] J. Broch, D. A. Maltz, D. B. Johnson, Y. Hu and J. Jetcheva, "A Performance Comparison of Multi-Hop Ad Hoc Network Routing Protocols," in Proc. MobiCom'98, Oct. 1998.
[15] D. B. Johnson and D. A. Maltz, "Dynamic source routing in ad hoc wireless networks," in Mobile Computing, edited by T. Imielinski and H. Korth, Kluwer Academic Publishers, pp. 153–181, 1996.
[16] Packet-level Peer-to-Peer Simulation Framework and GnutellaSim version 1.1, http://www.cc.gatech.edu/computing/compass/gnutella, Sep. 2003.