Performance evaluation of OnehopMANET

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Abstract: **When used together, Peer-to-Peer overlays and MANET complement each other well. While MANET provides wireless connectivity without depending on any pre-existing infrastructure, P2P overlays provide data storage/retrieval functionality. However, both systems face common challenges: maintaining connectivity in dynamic and decentralized networks. In this paper we evaluate the performance of OnehopMANET[1] as a structured P2P over MANET system that uses cross-layering with a proactive underlay. We compare the performance of OnehopMANET with two recent structured P2P over MANET systems (MA-SP2P and E-SP2P) that use the same underlay protocol (OLSR) and that have been shown to outperform other proposals. Through simulation we show that OnehopMANET achieves a better performance in terms of file discovery delay, lookup fail rate and total traffic load for all the simulated scenarios.**

Keywords: OnehopMANET; P2P; MANET; P2P over MANET; Cross layering.

I. INTRODUCTION

Peer-to-Peer (P2P) overlay networks support a wide variety of applications without the need for centralised servers. They are typically implemented as an overlay on a physical underlay network and allow higher-layer communication among participating peers. The established connections between peers in the overlay are usually independent of the structure in the underlay. The architecture of P2P is primarily designed to operate in infrastructure (wired) networks. However, the rapid development in wireless technology has brought a need for the adoption of P2P network systems into the mobile field [2].

Mobile ad hoc networks (MANET) on the other hand consist of a set of autonomous mobile nodes that communicate with each other using wireless connections without relying on pre-existing infrastructure. As in P2P overlays, in MANET each node is regarded as a client and a server at the same time. In addition, the participating nodes collaborate and forward messages towards other nodes.

There are many common characteristics between P2P overlays and MANET. Self-organization, decentralization, dynamicity and changing topology are key shared features. Consequently, they also face common challenges, most notably to maintain connectivity in dynamic and decentralized networks. However, the challenges are seen to be stronger when P2P deployed over MANET. This is a result of the lack of rich services provided in the IP routing infrastructure.

OnehopMANET employs a structured, DHT-based, overlay. Earlier unstructured systems do not offer guarantees that data stored in the overlay is actually found. Furthermore, such approaches often rely on some flavour of random walk or flooding approaches which are inefficient.

One key issue when combining MANET with a structured overlay network is that each single logical hop in the overlay maps to a path in the underlay. As a consequence, each logical hop results in multiple physical hops. Often peers which are neighbours in the overlay are separated by many hops in the physical network. When using multi-hop P2P overlays in such a setting, each overlay hop results in multiple hops in the underlay. Progressing through the overlay path to the destination may well mean contacting some underlay nodes repeatedly and passing underlay nodes which are very close to the final destination node. Consequently, multi-hop overlays are not well suited to such systems. However, one-hop overlays avoid such inefficient routing paths. OnehopMANET is proposed to reach the destination in a one logical hop.

OnehopMANET, our proposed architecture in [1], is a combination of a proactive MANET routing protocol Optimized Link State Routing protocol (OLSR) [3] with a structured P2P overlay system similar to Chord [4] and EpiChord[5]. EpiChord is a Distributed Hash Table (DHT) based P2P overlay network which can achieve lookups in a single hop. This is a novel approach as previous work focused on pairing multi-hop overlays with MANET. The resulting system, OnehopMANET employs a cross-layer approach to exchange information between the MANET underlay and the P2P overlay. The contribution of this paper is to evaluate the performance of OnehopMANET against two recent structured P2P over MANET systems (MA-SP2P [6] and E-SP2P [7]). MA-SP2P and E-SP2P deploy the P2P overlay over OLSR. The authors of MA-SP2P and E-SP2P have previously shown that their proposal outperforms two other approaches, Modified Chord [8] and P2P-WANT[9]. Through simulation we show that OnehopMANET outperforms MA-SP2P and ESP2P based on data lookup latency, network load and lookup failure. Thus our system also outperforms Modified Chord and P2P-WANT.

The rest of this paper is structured as follow: Section II presents a review of related work. In section III, OnehopMANET is introduced. The three systems are then compared in section IV. Finally, the conclusion and future work are presented in section V.

II. RELATED WORK

Structured P2P overlays typically employ a Distributed Hash Table (DHT) based approach. A review and analysis of such systems can be found in [10], [11] and [12]. Most DHT based overlays require multiple hops, however, some systems such as OneHop [13], D1HT [14] and EpiChord [5] can achieve lookups in a single hop. The approach in this paper employs structure similar to EpiChord, which is a DHT algorithm where peers maintain a full routing table and ideally approach O(1) hop lookup performance compared to the O(logN) hop performance offered in many multi-hop networks. It is organized as a one-dimensional circular space where each node is assigned a unique node identifier. The node responsible for a key is the node whose identifier most closely follows the key. In addition to maintaining a list of the k succeeding nodes, EpiChord also maintains a list of the k preceding nodes and a cache of nodes. Nodes update their cache by observing lookup traffic. Therefore nodes add an entry anytime they learn of a node not already in the cache and remove stale entries.

MANET routing protocols can be divided into unicast, multicast and geocast approaches. For this paper, the unicast approaches are of interest. These can be divided into proactive, reactive and hybrid routing protocols [15]. Reactive routing protocols discover a path to the destination node as required. Once discovered, the route is maintained until no longer required or being unavailable. The disadvantage of reactive routing is the relatively long delay during route discovery. On the other hand, in proactive routing protocols each node holds routing information to all other nodes. OLSR Optimized Link State Routing protocol [3] is an example of proactive routing protocols. Proactive routing approaches exhibit lower routing latency than reactive systems; however they incur increased overhead traffic. When combining P2P overlays with MANET, the lower overhead of reactive systems is offset by the frequent route requests by overlay nodes. Thus the additional cost of proactive systems is minimal in this context. Hence our approach employs proactive MANET routing.

A number of systems combining P2P overlays with MANETs have been proposed [16]. Scalable Source Routing SSR [17]builds a Chord-like ring at the network layer. SSR nodes maintain physical neighbours, virtual successors and predecessors lists, and cached information. Virtual Ring Routing VRR [18] organizes nodes into a virtual ring similar to Chord at the network layer. It supports traditional point to point and DHT routing. MADPastry [19] integrates Pastry with the reactive MANET protocol AODV. It uses random land-marking, where a set of nodes in the same physical cluster share a common overlay ID. CrossROAD [20] adopted Pastry over OLSR. Each CrossROAD node maintains a global services table that stores all the services provided in the network. Ekta [21] also integrates Pastry with DSR [22] at the network layer. It overhears the underlay control messages to reduce network traffic. Some proposed systems adopt building minimum spanning trees to recognize the physical topology [6] and [7]. MANETChordGNP [23] considers the physical locality through using GNP global network positioning system. It integrates modified Chord that uses GNP with AODV. Enhanced Backtracking Chord [24] modified Chord to perform better in MANET. It modified Chord to use retransmission and path selection.

This paper compares the performance of OnehopMANET with the performance of two very recent systems: E-SP2P [7] builds an identifier space ranging from 0 to 2^m -1. Each peer maintains a disjoint portion of the ID space. A root peer organizes the relationship between neighbouring peers. It is the reference point to nominate one of the neighbouring peers to be in charge of maintaining the relationship. A peer which is closer to the root peer will send probe messages to its neighbouring peer. When a peer joins the network, it constructs a graph that consists of itself, its direct neighbours and peers which are 2 logical hops away. The graph will then be used to execute a minimum spanning tree. The range of the ID space of the direct neighbour peer will be split between itself and the joining peers.

E-SP2P was extended to MA-SP2P [6]. MA-SP2P is similar to its predecessor but does not use root peers. It distributes the ID space in a way that the portion of an ID space at peer P (which can be non-contiguous) has to be consecutive with each P's directly connected neighbour peers. The upper end of ID space portion at peer P points at the neighbour that has the portion of the ID space with greater IDs. The lower end of P's ID space points to P's neighbour that stores the ID space portion with the next lower IDs. Both systems try to push the overlay to match the physical underlay to avoid the crisscrossing problem. E-SP2P can be criticized by the use of the root peer. All peers in the network contact the root peer resulting in collisions and lost packets. The root peer may become a bottleneck when the number of peers gets larger. Moreover, the accuracy of the routing is affected by the way the ID space portions are exchanged. Due to node mobility, peers will have to exchange ID space portions and build new relationships with new neighbours. This can result in inaccurate routing table information and hence poor lookup performance.

III. ONEHOPMANET

Unlike previous approaches, OnehopMANET combines a one-hop structured P2P overlay with a proactive MANET protocol (OLSR [3]). Fig. 1 depicts the architecture of the proposed system.

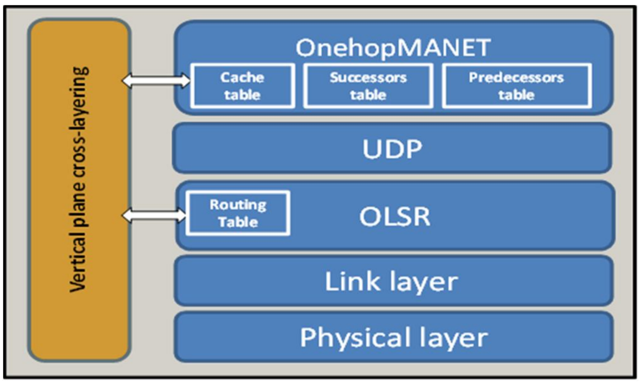

Fig. 1: OnehopMANET

Each node in OnehopMANET assigns itself a unique identifier by hashing its own IP address. OnehopMANET builds a one dimensional circular address space as in EpiChord and Chord. Similar to EpiChord and Chord, OnehopMANET maintains lists of key nodes that succeed and precede a node. In addition, it also maintains a cache table. Each node updates its cache table largely by using information from the proactive underlay. OnehopMANET inherits from EpiChord the O (log N) performance, in the worst case, and also the potential of O (1) performance if up to date routing information is available.

OnehopMANET uses cross-layering to exchange information between the underlay and overlay to reach one hop performance. This approach reduces the typical overhead from employing one hop overlay systems as routing updates from the underlay are forwarded to the overlay which in turn can scale down its own update mechanisms. OnehopMANET follows the manager method of cross-layering [25] to optimize the network layer's routing information transfer.

A notification board is used as a vertical plane managing the information sharing between the application and the network layers. OLSR provides updated information to the overlay whenever changes occur in any of its routing tables. The overlay then uses this to update its view of the network.

Using the underlay information significantly reduces the need for overlay maintenance traffic. OnehopMANET nodes do not initiate any joining messages. Once a peer gets information through the cross layer channel, it calculates the logical IDs of other peers by hashing their IP addresses and then populates its routing and cache tables.

Besides the updates from the underlay, OnehopMANET can also use additional lookup queries to update its routing tables. Each lookup query response contains some information from the queried peer. However, the need to use additional lookup messages to update routing tables is much reduced when compared with standard EpiChord.

Like EpiChord, OnehopMANET uses an iterative lookup algorithm where the queried peer will respond with its best knowledge of the queried key without forwarding the lookup to other nodes. EpiChord supports parallel lookups to increase its chance of finding the key with the first hop reducing lookup latency. However, OnehopMANET does not need to make use of this technique and only sends lookup requests to single destinations reducing the bandwidth usage. To locate a file, an OnehopMANET peer hashes the value of the file and then consults its own routing table to find the best logical Id that follows this key. As a result of having highly accurate logical routing tables that get updated from the underlay, OnehopMANET can contact the peer that is responsible for the queried key with the first logical hop.

If a query cannot be resolved in the first hop, i.e. the queried peer has no information about the data item, it replies to the originator with its best knowledge about the queried object. This will be a node closer to the destination peer. After receiving the reply, the originator sends a further query until it finds the peer which is in charge of the queried object. However, as is shown in the experimentation, this approach is not often needed as the data can be located in the first hop.

IV. PERFORMANCE EVALUATION

To evaluate the performance of OnehopMANET, we implemented the system in a network simulator which includes a packet level simulator together with an implementation of the MANET protocol (OLSR). We used the discrete event simulation system OMNet++ [26], the communication network simulation package INET-MANET[27] together with Oversim [28] for the P2P model.

A. Simulation Setup

Table 1 shows the used parameters for the simulated scenarios. All the simulated scenarios were repeated ten times and the result is the average of the repetitions. Peers randomly join or leave the network. The used mobility model is Random Way Point model which is commonly used for simulating ad hoc networks. For each of the simulated scenarios, the network is given about 60 seconds to stabilize. After the 60 seconds, the measurements of the metrics begin. Lookups for shared files are randomly initiated for about 100 random files in the network. We compare the performance of our system to MA-SP2P [5] and E-SP2P [6].we looked at the file discovery delay, fail ratio and traffic load. The previous metrics were monitored with different scenarios of the network. We change the ratio of peers in the network from 10% up to 50% of the network size. We simulate network with 10%, 20% 30%, 40% and 50% as the peer rate to 100 mobile nodes. Node mobility also varied for the simulated scenario from 0.4 m/s to 1.6 m/s.

TABLE I. SIMULATION CONFIGURATION

Simulator	OMNeT++
Underlay protocol	OLSR
Topology size	1000m x 1000m
Propagation model	Two ray ground
Number of nodes	100
Peer ratio	10%, 20%, 30%, 40%, 50%.
Mobility model	Random way point
Node speed	0.4m/s, 0.8m/s, 1.2m/s, 1.6m/s
Measurement time	1000 seconds
Transmission range	250 m
Network stabilization	60 seconds
Simulation repetitions	10
MAC Layer	IEEE 802.11
Bandwidth OLSR Hello Interval	2MB 3 seconds
OLSR Topology Control Interval	6 seconds.

B. Performance Metrics

The following performance metrics are evaluated from the conducted simulations:

- Average File discovery delay: the average amount of time that was required in order to solve a lookup query. It starts from sending the key lookup until the time when a peer received the answer of that lookup. This reflects the ability of the system to retrieve a shared key on the network.
- Network Traffic Load: The total number of packets transmitted at the routing layer in the network.
- Fail rate: the ratio of the number of unanswered file lookup queries for files that exist in the network to the total initiated file lookup queries in the network.

C. Experimintal Result

We compare the performance of OnehopMANET to MASP2P and E-SP2P. The authors of MA-SP2P and E-SP2P have previously shown that their proposal outperforms Modified Chord and P2P-WANT. For clarity in the graphs we do not reproduce these results here. Table 1 provides an overview of the key simulation parameters. These parameters were chosen because they match the ones used in the E-SP2P and MA-SP2P papers and thus our results are comparable.

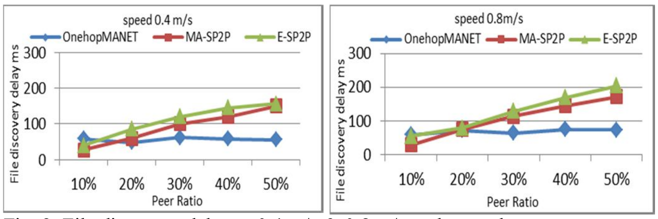

Fig. 2: File discovery delay at 0.4 m/s & 0.8 m/s node speed.

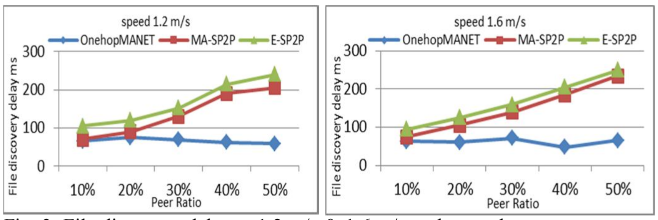

Fig. 3: File discovery delay at 1.2 m/s & 1.6 m/s node speed.

Fig. 2 and Fig. 3 show the file discovery delay for all the three systems with different peer ratio for 0.4 and 0.8 as well as 1.2 and 1.6 m/s speeds. Looking at each individual graph, it can be seen that the latency for a lookup in OnehopMANET stays constant at about 70ms as the number of nodes in the network increases. This is in contrast to the other two systems where the latency for 50% peer ratio increases markedly to about 3 or 4 times the latency experienced at 10% peer ratio. For all the simulated scenarios across the four node speeds and peer ratios, OnehopMANET maintains a latency which equal or less than both other systems. Albeit to a lesser extent than the peer ratio, the performance of E-SP2P and MA-SP2P is affected by the node speed. As can be seen in the figures, the file discovery delay of about 150ms for 50% peer ratio at 0.4m/s node speed increases to about 250ms for 50 peer ratio at 1.6 m/s node speed.

Fig. 2 and Fig. 3 show that OnehopMANET outperforms MA-SP2P and E-SP2P. The reason for the improved latency behavior is that OnehopMANET resolves most lookups in a single hop. Clearly, this helps to keep the latency down. MA-SP2P and E-SP2P require multiple overlay hops with a queried node forwarding the lookup to other peers in the network until the lookup is resolved.

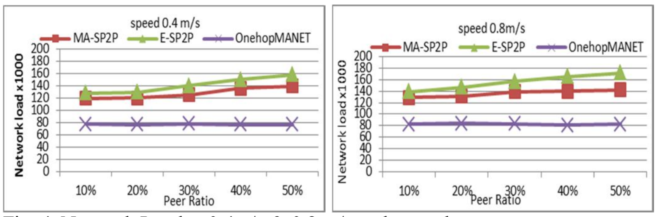

Fig. 4: Network Load at 0.4m/s & 0.8 m/s node speed.

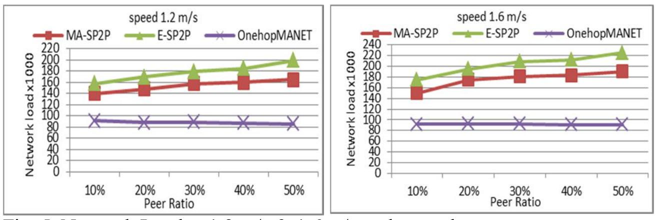

Fig. 5: Network Load at 1.2 m/s & 1.6 m/s node speed.

Fig. 4 and Fig. 5 show the generated traffic in the network. As a result of optimizing the underlay (OLSR) routing behavior, OnehopMANET generates the least amount of traffic in all the simulated scenarios. Across all node speeds the amount of traffic generated various only slightly, with about 75k packets at 0.4m/s up to about 90k packets at 1.6m/s being required. This is a result of exploiting the synergies between the underlay and overlay. OnehopMANET uses the underlay routing tables to populate the overlay routing tables without incurring additional traffic in the network. As Fig. 4 and 5 present, MA-SP2P and E-SP2P loads increase with the peer ratio. A reason for this is that when introducing new peers in the network, more traffic is required to maintain the links. In addition, when the node speed increases, all the three systems incur more traffic in the network. However, the resulting extra traffic required by OnehopMANET is at a much lower level than the additional traffic needed by MA-SP2P and E-AP2P. MA-SP2P and E-SP2P produce more than 140k packets (at 50% ratio and 0.4 m/s node speed) compared to about 200k packets (at 50% node ratio and 1.6 m/s). This is about twice what OnehopMANET uses. Clearly, OnehopMANET can handle the required routing table updates which are required due to increased node mobility much better than the other two systems. This is because of that with MA-SP2P and E-SP2P peers may move away from their connected neighbor peers. Consequently, peers are required to operate the procedure of minimum spanning tree and create new relationships with new neighbor peers. Hence, more traffic will be introduced.

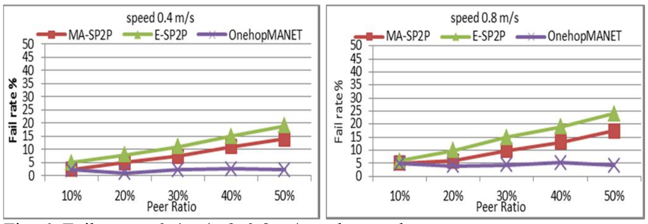

Fig. 6: Fail rate at 0.4 m/s & 0.8 m/s node speed.

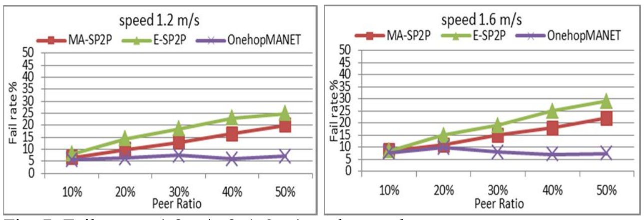

Fig. 7: Fail rate at 1.2 m/s & 1.6 m/s node speed.

Fig. 6 and Fig. 7 show the ratio of failed lookups for keys to the total initiated lookups. They indicate that MA-SP2P and E-SP2P performance decrease when the peer ratio increases. In other words, the fail rate of both systems goes up as a result of having more peers in the network. One possible reason for this is that as the number of participating peers increases, more traffic at the MANET layer is created resulting in collisions and lost packets. Hence, the performance of the overlay routing is compromised. Moreover, the performance of both systems is influenced by the movement speed of the mobile nodes. With a node speed of 1.6 m/s the success rate drops to fewer than 80% (fail rate more than 20%). A likely reason for this drop is the frequent topology changes which cause the peers to incur more maintenance traffic to keep the entries in the overlay routing tables up-to-date. These require peers to rebuilding minimum spanning trees and build new relationships with new neighbors. On the other hand, OnehopMANET outperforms both systems especially with higher peer numbers. The main reason for this is that the increase of the number of peers will not cause a noticeable increase in the traffic since each peer in OnehopMANET uses the underlay routing information to populate the overlay. Even with higher node speeds, OnehopMANET manages to maintain accurate routing tables and keep the fail rate at less than 10%.

V. CONCLUSION

This paper presented an evaluation of OnehopMANET which uses cross-layering to exploit proactive underlay (OLSR) to build structured one hop P2P system over mobile ad hoc networks. Through simulation we compared OnehopMANET to two recent structured P2P systems for MANET (MA-SP2P and E-SP2P) which have separately been shown to outperform Modified Chord and P2P-WANT. OnehopMANET as well as MA-SP2P and E-SP2P adopt the same underlay (OLSR) protocol. OnehopMANET achieves better performance in term of lookup latency, network traffic load and lookup fail rate.

REFERENCES

[1] M. Al Mojamed and M. Kolberg, “OnehopMANET: One-hop Structured P2P over Mobile ad hoc Networks,” *Next Gener. Mob. Apps, Serv. Technol. IEEE(NGMAST), 2014*, pp. 159–163, 2014.
[2] F. Chowdhury and M. Kolberg, “A Survey of Peer-to-Peer Solutions in Mobile and Cellular Networks,” in *PGNet*, 2012.
[3] T. Clausen and P. Jacquet, “Optimized link state routing protocol (OLSR),” *RFC:3626-http://www.ietf.org/rfc/rfc3626.txt*, 2003.
[4] I. Stoica, R. Morris, D. Karger, M. F. Kaashoek, and H. B. Ý, “Chord : A Scalable Peer-to-peer Lookup Service for Internet,” in *SIGCOMM*, 2001, pp. 149–160.
[5] B. Leong, B. Liskov, and E. D. Demaine, “EpiChord: parallelizing the chord lookup algorithm with reactive routing state management,” *12th IEEE Int. Conf. Networks (ICON 2004)*, pp. 270–276, 2004.
[6] N. Shah, D. Qian, and R. Wang, “MANET adaptive structured P2P overlay,” *Peer-to-Peer Netw. Appl.*, Vol. 5(2), pp. 143–160, Nov. 2012.
[7] N. Shah and D. Qian, “An efficient structured P2P overlay over MANET,” *ACM International Workshop on Data Engineering for Wireless and Mobile Access - MobiDE '10*, 2010, pp. 57–64.
[8] D. N. da Hora, D. F. Macedo, L. B. Oliveira, I. G. Siqueira, A. a. F. Loureiro, J. M. Nogueira, and G. Pujolle, “Enhancing peer-to-peer content discovery techniques over mobile ad hoc networks,” *Comput. Commun.*, vol. 32, no. 13–14, pp. 1445–1459, Aug. 2009.
[9] H. Sözer, M. Tekkalmaz, and I. Korpeoglu, “A peer-to-peer file search and download protocol for wireless ad-hoc networks,” *Comput. Commun.*, vol. 32, no. 1, pp. 41–50, Elsevier, Jan. 2009.
[10] J. Li and J. Stribling, “A performance vs. cost framework for evaluating DHT design tradeoffs under churn,” *INFOCOM 2005*.
[11] I. Baumgart and B. Heep, “Fast but economical: A simulative comparison of structured peer-to-peer systems,” *Proc. 8th Euro-NF Conf. Next Gener. Internet NGI 2012*, pp. 87–94, Jun. 2012.
[12] F. Chowdhury and M. Kolberg, “Performance evaluation of structured Peer-to-Peer Overlays for Use on Mobile Networks,” in *6th IEEE conference on Developments in eSystems Engineering (DESE)*, 2013.
[13] A. Gupta, B. Liskov, and R. Rodrigues, “Efficient Routing for Peer-to-Peer Overlays.,” *IEEE NSDI*, 2004.
[14] L. R. Monnerat and C. L. Amorim, “D1HT : A Distributed One Hop Hash Table” in *Parallel and Distributed Processing Symposium*, 2006.
[15] R. R. Roy, *Handbook of mobile ad hoc networks for mobility models*. Boston, MA: Springer US, 2011, pp. 3–22.
[16] M. C. Castro, A. J. Kassler, C.-F. Chiasserini, C. Casetti, and I. Korpeoglu, “Peer-to-Peer Overlay in Mobile Ad-hoc Networks,” in *Handbook of Peer-to-Peer Networking*, X. Shen, H. Yu, J. Buford, and M. Akon, Eds. Boston, MA: Springer US, 2010.
[17] T. Fuhrmann, P. Di, K. Kutzner, and C. Cramer, *Pushing chord into the underlay: Scalable routing for hybrid manets*. 2006.
[18] M. Caesar, M. Castro, E. Nightingale, G. O'Shea, and A. Rowstron, “Virtual ring routing: network routing inspired by DHTs,” *2006 Conf. Appl. Technol. Archit. Protoc. Comput. Commun.*, pp. 351–362, 2006.
[19] T. Zahn and J. Schiller, “MADPastry: A DHT substrate for practicably sized MANETs,” *Proc. ASWN*, 2005.
[20] F. Delmastro, “From Pastry to CrossROAD: CROSS-layer Ring Overlay for AD hoc networks,” *IEEE Conference on Pervasive Computing and Communications Workshops*, 2005.
[21] H. Pucha, S. Das, and Y. Hu, “Ekta: An efficient dht substrate for distributed applications in mobile ad hoc networks,” *IEEE Workshop on mobile computing systems and applications (WMCSA)*, 2004.
[22] D. Johnson, D. Maltz, and J. Broch, “DSR: The dynamic source routing protocol for multi-hop wireless ad hoc networks,” *Ad hoc Netw.*, 2001.
[23] S. G. Fantar and H. Youssef, “Locality-aware Chord over Mobile Ad Hoc Networks,” *2009 Glob. Inf. Infrastruct. Symp.*, pp. 1–6, Jun. 2009.
[24] M. Thaalbi, N. Tabbane, T. Bejaoui, and A. Meddahi, “Enhanced Backtracking Chord protocol for mobile Ad hoc networks,” *Int. Conf. Commun. Inf. Technol.*, pp. 191–195, Jun. 2012.
[25] B. Fu, Y. Xiao, H. Deng, and H. Zeng, “A Survey of Cross-Layer Designs in Wireless Networks,” *IEEE Commun. Surv. Tutorials*, vol. 16, no. 1, pp. 110–126, 2014.
[26] “OMNET++ network simulator.” [Online]. Available: http://www.omnetpp.org/.
[27] “INET FRAMEWORK.” [Online]. Available: http://inet.omnetpp.org/.
[28] “OverSim.” [Online]. Available: http://www.oversim.org/