On Supporting Mobile Peer to Mobile Peer Communications

Tarik Taleb*, Eugène David Ngangue Ndih†, Soumaya Cherkaoui†
*NEC Europe Ltd., Heidelberg, Germany
†Department of Electrical and Computer Engineering
Université de Sherbrooke, Québec, Canada
Email: talebtarik@ieee.org, {eugene.ngangue, soumaya.cherkaoui}@usherbrooke.ca

***Abstract*—In this paper, we propose a new method for assessing the sociability scalar of a mobile peer by the network, most importantly with no involvement of the mobile peer. The sociability metric can help in the Application Layer Traffic Optimization (ALTO) guidance in Mobile Peer-to-Mobile Peer (MP2MP) scenario to scale up the database search of an ALTO server. The proposed method models encounters of mobile peers with predetermined areas, such as cells, tracking areas, gateway service areas, etc, depending on the targeted granularity. The obtained metrics, pertaining to inter-mobile peer relationship (i.e., sociability) and mobile peers mobility, are adopted to ALTO in a MP2MP scenario. In addition, metrics reflecting the energy budget of a mobile peer, the type of a mobile terminal, history of a mobile terminal in sharing contents with other mobile peers, etc, can be also taken into account by ALTO in the peer recommendation.**

I. Introduction

ALTO [1] is a fairly new approach for optimizing resource provider selection in distributed applications. Essentially, ALTO is a dedicated service, operated by a network operator or Internet service provider (ISP), which can provide useful network layer information to application layer clients about resource providers. In particular, in (Peer-to-Peer) P2P networking, upon a request from a peer interested in a particular content, an ALTO server uses information provided by the user's network operator (e.g. ISP) to determine the set of peers a requesting peer should be connecting to, i.e. to download/upload chunks of the requested content.

State-of-the-Art information provisioned by a network operator into an ALTO server refers to network topology and dynamics such as:

- operator's policies,
- geographical location information or network layer proximity,
- and transmission costs associated with sending/receiving a certain amount of data to/from a resource provider.

In the context of MP2MP networking, a topic recently attracting attention of major telecom operators (e.g., China Mobile), only network related metrics are not sufficient as both the requesting peer and the recommended peers may be on the move. Indeed, in the conventional approach of ALTO, the selection of peers is mainly based on IP addresses of the peers, which is assumed to be fixed. In case of mobile peer to mobile peer, such IP address based mobile peer selection is not efficient for the simple reason that IP addresses of mobile peers keep changing due to mobility. As a countermeasure, an ALTO server needs to get constant updates, about the IP addresses of mobile peers, from core network nodes such as Mobility Management Entity (MME) and Home Subscriber Server (HSS) in case of the Evolved Packet System (EPS) [2], or Home Location Register (HLR) and Gateway/Serving GPRS Support Node (G/S-GSN) in the case of General Packet Radio Service/Universal Mobile Telecommunications System (GPRS/UMTS). This clearly incurs significant overhead on these expensive and already loaded nodes, not to mention the additional delay that may be added to the peer guidance service (i.e., ALTO needs to request for information on IP addresses from the relevant nodes and await their responses before responding to a request from a peer interested in a particular content). For an efficient MP2MP networking, there is thus need to also reflect the peers' mobility patterns and their encounters with specific areas in the ALTO's peer recommendation.

As an operator would deploy one ALTO server, supposedly containing the database of all customers of the mobile operator, methods to scale up the database search of the ALTO server would be of vital importance. For this purpose, in this paper, we propose using a metric that indicates the sociability of a mobile peer. Peer sociability can be defined in terms of the frequency at which a peer is being in the vicinity of other peers. A straightforward method for assessing the sociability of a peer would be by having the mobile peer scanning the peers around it and constantly reporting it to the ALTO server. This is obviously not efficient from the energy consumption point of view as it may drain up the battery of the mobile peers. In this paper, we propose a method that assists in assessing the sociability of a mobile peer by the network and with no involvement from the mobile peers.

The remainder of this paper is organized in the following fashion. Section II highlights the relevance of this work to the state of the art in the context of ALTO for fixed networks and the use of encounter models in different wireless/mobile networks. The key design philosophy and distinct features that were incorporated in the proposed scheme are described in Section III. Section IV portrays the simulation environment and discusses the simulations results. Concluding remarks and some future research directions are drawn in Section V.

978-1-4577-2053-6/12/$31.00

II. Related Work

ALTO is gaining interest of many operators within the Internet Engineering Task Force (IETF) [1]. The focus is currently on facilitating fixed P2P networking. MP2MP networking is a new topic that has not yet been widely addressed. Major operators, particularly China Mobile, are trying to promote it within IETF and 3rd Generation Partnership Project (3GPP). In order to facilitate the peer selection/guidance service of ALTO in the context of MP2MP, it is important to reflect peers' mobility in the service. Different approaches, using different mobility related metrics (e.g., cell residual time, session-to-mobility ratio (SMR)), cope with the selection of mobility anchor points (MAP) in mobility management schemes [3]−[6]. For example, users with low cell residual time simply register with higher levels of the MAPs hierarchies in Hierarchical Mobile IPv6 (HMIPv6). SMR is defined as the ratio of the session arrival rate to the handover frequency. In the SMR-based scheme, the highest MAP is selected for mobile nodes with small values of SMR [5]. In [6], the selection of anchor points is based on an estimation of MAP load transition using the exponential moving average method. MAPs with load decrease tendency are selected.

In the context of Ad Hoc networks, many Ad Hoc network routing protocols consider a metric, called Link Expiration Time, to select mobile nodes to connect to, to establish a stable end-to-end (E2E) route [7]. Mobility patterns are also used in delay tolerant networks (DTN). Indeed, the concept of encounter events between mobile nodes is heavily used to propagate packets in DTNs [8]−[10] and recently in Wireless Local Area Network (WLAN) traces [11], [12].

The authors in [13] proposed another peer selection scheme referred to as team-centric peer selection scheme. The selection protocol is based on fuzzy cognitive maps (FCM) theory [14] which describes the relationships among various factors such as transfer time, energy level, movement, and link quality of mobile peers. In [15], the authors combine network coding [16] and mobility assisted data propagation (single hop communication) to facilitate file sharing in mobile P2P systems and to deal with issues such as dynamic topology as well as intermittent connectivity.

III. Proposed Solution

Fig. 1 shows the state-of-the-art-ALTO provisioning, displaying the kinds of information currently considered by an ALTO server. The core idea of this paper is to use and adapt mechanism/proposals from the area of mobile network research and other fields such that they can be used as ALTO provisioning information in a mobile scenario. A mobile network operator would feed such information into its ALTO server. For instance, a) the sociability of peers b) the resemblance among mobility patterns of the peers, c) the residual time of peers in a particular area where the requesting peer is currently residing or will be visiting during the service time, are all metrics highly suitable for optimizing peer selection in MP2MP swarms because they consider the social and mobility patterns of users.

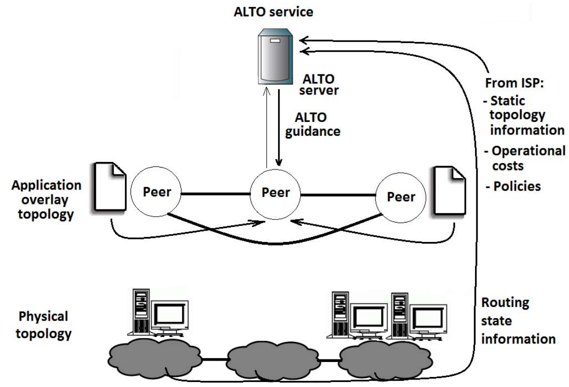

Fig. 1. State-of-the-art ALTO provisioning.

Other metrics that could assist an ALTO server in the peer selection could pertain to the overall energy budget of a mobile peer (e.g., available and harvestable from different sources in the environment), to the type of the peer/terminal, to the history of the peer in collaborating in the service (i.e. Deep Packet Inspection (DPI) can assist here should it be performed per application level), to the type of access the peer is currently connecting to or has the potential to connect to. The latter can be provided by nodes such as Access Network Discovery and Selection Function (ANDSF) in EPS [17].

In this work, we first form a model for the distribution of encounters between a mobile node and areas over time. Areas may refer to the cell of an Evolved Node B (eNB), a Tracking Area, or a Gateway Service Area, depending on the envisaged granularity. Fig. 2 shows an example of a "Mobile Peer"-"Access Point" encounter model for a mobile peer X. The figure shows the access point (AP) residual times of a mobile peer X for n days. Using different time-series models, the encounter model of the mobile peer X with the different APs can be formed. It should be noted that in case of idle mobility, the network does not always know which AP a mobile peer is connected to. In this case, the encounter model could be formed between the mobile peer and a wider area, such as Tracking Area or Gateway Service Area. In Fig. 2, the mobile peer X is assumed to reside at AP_1 during time interval $[t_6; t_1]$, at AP_3 during $[t_1; t_2]$, etc.

Similarly, we also form a model of the distribution of the number of mobile peers per area (e.g., Tracking Area, Service Area) or connecting to an AP over time. Fig. 3 depicts the time distribution of mobile peers connecting to AP Y. For example, between time instants 0 and t_1, an estimate of 1000 mobile peers are connected to AP Y.

One of the objectives of the proposed approach is to assess the sociability of a mobile peer. The sociability of a mobile peer indicates how often the mobile peer is encountering other mobile peers and (if possible) for how long. As stated earlier, a mobile peer could assess its sociability by scanning the other mobile peers that are around it. In case of ALTO, this assessment of sociability needs to be constantly sent to the ALTO server. Intuitively, this operation shall have a significant

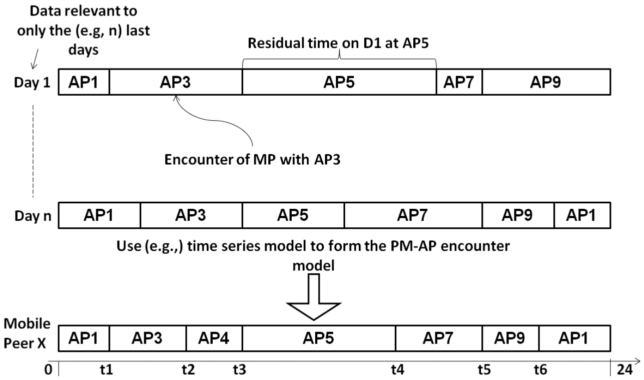

Fig. 2. Example of a "Mobile Peer"-"Access Point" (MP-AP) encounter model.

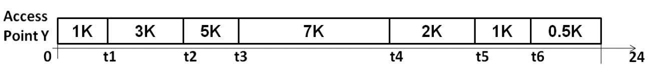

Fig. 3. Time distribution of the number of connecting mobile peers for an AP.

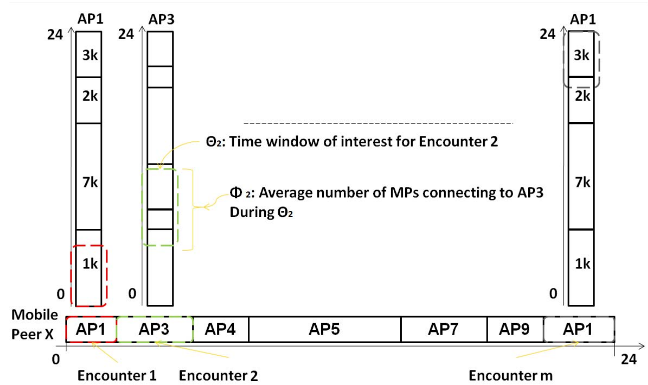

Fig. 4. Envisioned matrix for assessing mobile peer sociability by ALTO server (or network) with no involvement from mobile terminals.

impact on the battery lifetime of mobile peers and also involve significant signaling and impose significant load on the ALTO server, as updates take place frequently for each mobile peer. In this paper, we use the models depicted in Fig. 2 and Fig. 3 to assess the sociability of a mobile peer by the ALTO server (or by the network) with no involvement from the mobile terminals, following the matrix shown in Fig. 4. Denoting by m the total number of encounters a mobile peer X has with different areas, the sociability scalar of the mobile peer X, denoted by S_X, can be computed using the following equation:

$$S_X = \sum_{i=1}^{m} \Phi_i \Theta_i \tag{1}$$

where Θ_i denotes the duration of the ith encounter, and Φ_i denotes the average number of mobile peers connecting to the area respective to the ith encounter during Θ_i. Alternatively, this computation can be performed over only a predetermined period of time (e.g., from when content is requested till the expected completion time of its download) and/or for only specific areas (e.g., APs) satisfying specific conditions (e.g., APs covering specific areas, with an average number of connecting mobile peers exceeding a specific threshold, etc). The above summation can be replaced by any other function that takes Φ_i and Θ_i as input values.

It should be mentioned that the sociability metric assists in sorting mobile peers that have "high exposure" to other mobile peers; i.e., being connected for sufficiently long periods of times to APs with "populated" coverage areas. As mentioned earlier, this is highly beneficial for a centralized ALTO server servicing and maintaining information about a potential number of mobile peers (i.e., subscribers of the whole country) and that is for the purpose to reduce the search table size. Additionally, using the envisioned sociability metric, ALTO may focus on only mobile peers with high sociability scalar (i.e., exceeding a certain threshold) in its mobile peers recommendation. Indeed, the sociability metric is useful to estimate how helpful a peer will be in distributing content to other peers, e.g. whether the peer will be moving to key areas with many participants of the P2P swarm or not. In the following, we explain how an ALTO server may use the sociability scalar of mobile peers and their encounter model with areas (e.g., APs, tracking areas, and service areas) in the peer recommendation. It should be noted that how to precisely combine the different kinds of ALTO metrics into an overall ALTO recommendation and how to combine them with other ALTO information is outside the scope of this paper. Fig. 5 gives a high-level overview on the core rationale of the approach. A conventional ALTO would likely recommend peers in the same access network of the requesting peer without considering how long these peers are likely to stay online, within the same cell, or how likely they are to meet other peers in the future. With the proposed approach, the conventional ALTO metrics are still used. However, the above mentioned social and mobility patterns of nodes/users are also considered, thus taking into account estimations about node behavior based on observations the mobile network has done of the node in the past. In Fig. 6, we assume that ALTO (or a collocated function

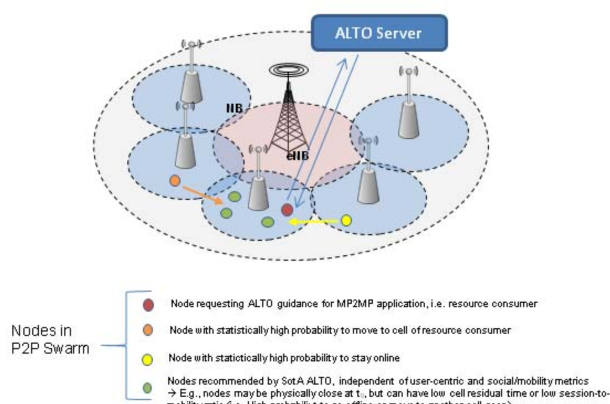

Fig. 5. Simplified, high-level view of the rationale behind the proposed approach.

with ALTO server) knows the AP (alternatively tracking area, gateway service area, etc) a mobile peer, requesting for ALTO guidance, is currently connecting to and can predict from the proposed encounter model the other APs the mobile terminal will be connecting to in the future, during a time window of interest (e.g., predetermined period of time, duration of requested content playback, etc). In Fig. 6, the requesting mobile peer is expected to connect to $AP_1, AP_2, ..., AP_k$, for durations $\Delta_1, \Delta_2, ..., \Delta_k$, respectively, during the time window of interest. ALTO server can consider different mechanisms for recommending adequate mobile peers (i.e., with the required content, focusing on those with high sociability scalar, with optimal paths to requesting mobile peer) and forming different groups of them. These groups could be, for example, Group 1 consisting of mobile peers connecting to AP_1 for at least Δ_1, Group 2 consisting of mobile peers connecting to AP_2 for at least $\Delta_1 + \Delta_2$ and/or will connect to AP_2 for at least Δ_2 from time instant $t + \Delta_1$, etc. The ALTO server recommends mobile peers of Group 1 for the Δ_1 (worth) first chunks and mobile peers of Group 2 for the upcoming Δ_2 chunks to be played after the Δ_1 first chunks, and so forth. If the prediction of the next APs a requesting mobile peer is likely going to connect to, is not possible, ALTO would recommend, for example, a list of MPs (with the requested content) being in k-hops neighborhood of the current AP, or being in the same tracking area or service area prioritizing the mobile peers in the nearest APs. Loads of APs, anchor points (e.g., P/S-GWs, G/S-GSNs) associated with the APs can be also taken into account.

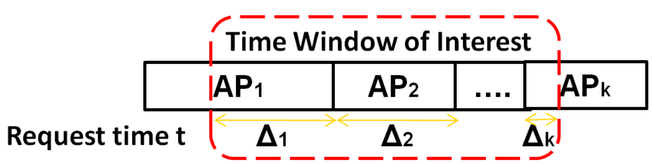

Fig. 6. Example of a mobile peer, requesting for ALTO guidance at time instant t, currently connecting to AP_1, and expected to connect later to $AP_2, ...AP_k$.

IV. Analysis and Simulations

In this section, we present some simulation results comparing the proposed sociability-based ALTO protocol with both the standard ALTO protocol and a random peer selection protocol. We consider a network with a varying average number of peers. According to a random waypoint mobility model, the peers move all around a network divided into 10 disjoint APs; the times each peer spends in a specific AP are random and independent to each other. We consider a scenario whereby a mobile peer is requesting a specific content. Upon receiving a request, the server selects from its database some peers having the requested content. The choice of the group of peers depends on the protocol used. In case of the random peer selection protocol, the peers are randomly selected among those having the requested content. For the standard ALTO protocol case, the server dynamically and randomly chooses peers having the requested content and located in the vicinity of the current location of the requesting peer. In case of our proposed sociability-based ALTO protocol, the selected peers are those with a sociability scalar above a given threshold. With no specific purpose in mind, the threshold considered for the conducted simulations is set to the average sociability scalar for the overall network. For each protocol, each time an encounter between a group of selected volunteering peers and the requesting peer is possible, we assume that the selected peers are synchronized with each other and with the requesting peer such that the transmission for each selected group is optimal. We further assume that all selected peers enjoy the same bandwidth availability and we consider only direct communication between the requesting peer and the selected peers.

We consider two main simulation scenarios. In the first scenario, we fix the average number of peers having the requested content and determine the average ratio of the received requested content with regard to the average number of peers in the network. The results are shown in Fig. 7. As one may observe, the sociability-based protocol outperforms both the standard ALTO protocol and the random peer selection protocol. The determination of the average ratio of the received content for all different numbers of peers in the network considered, shows an improvement of 50% and 100% compared to the standard ALTO protocol and the random peer selection protocol, respectively. In addition to the proximity criteria as in the standard ALTO protocol, the peers selection in the sociability-based ALTO protocol also takes into consideration the probability that the selected peer will encounter the requesting peer. Indeed, peers with high sociability scalar are peers with high probability of presence in the network, that is, high probability of encounter with the requesting peer. The results shown in Fig. 7 confirm the necessity of predicting, with high probability, encounters in dynamic networks such as mobile networks. Indeed, considering the case of the random peer selection protocol, we notice that its performance drastically downgrades as the size of the network increases compared to the number of peers having the requested content.

In the second scenario, we fix the network size and vary the average number of peers having the requested content. The obtained results are plotted in Fig. 8. The results show that the average ratio of the received requested content at the requesting peer increases with the average number of peers having the requested content. These results confirm that, regardless the number of peers in the network or the number of peers having the requested content, the proposed sociability-based ALTO protocol exhibits the best performance, in comparison to the other two protocols. In addition, it is worth mentioning that accurate encounter models guarantee low database search time and good performance of the sociability-based ALTO protocol.

V. Conclusion and Future Work

In this work, we have presented a sociability-based ALTO protocol for selecting adequate mobile peers in a mobile P2P

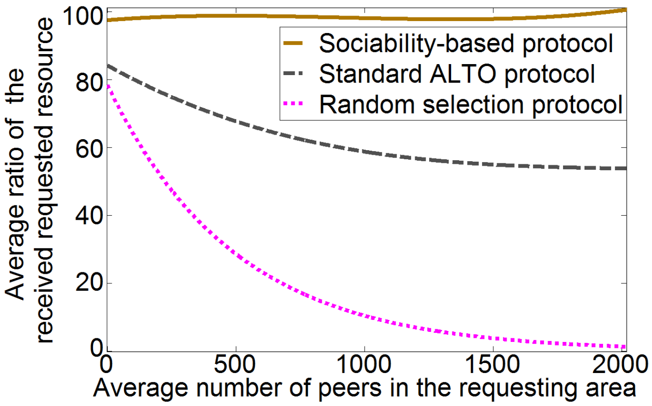

Fig. 7. Average ratio (in %) of the received requested content with regard to the average number of peers in the requesting zones. The average number of peers having the requested content is set to 20.

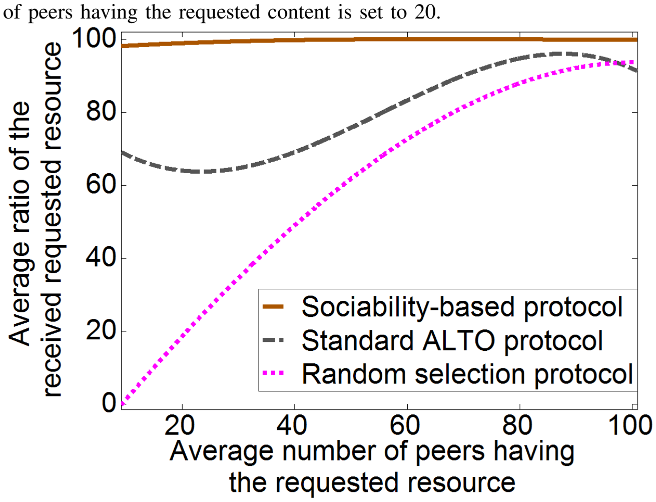

Fig. 8. Average ratio (in %) of the received requested content with regard to the average number of peers having the requested content. The average number of peers in the requesting areas is set to 1000.

network. The envisioned sociability metric improves the ALTO guidance in MP2MP scenarios and shall scale up the database search of an ALTO server. The simulation results show that with accurate encounter models, the prediction performed for future encounters between the requesting peer and the peers with the requested content ensure optimal resource sharing. The results further show that the selection of sharing group of peers based on the sociability scalar can improve the resource sharing approach in MP2MP, in comparison to the standard ALTO protocol, by up to 50%.

For simplicity of presentation, we have assumed equal available bandwidths and have considered only direct communications between the involved peers. As immediate extension, the authors will consider the case of multihop transmissions with different mobility models, and will investigate the tradeoff between sociability and bandwidth availability of the selected peers. Since scaling up the database search of a sociability-based ALTO server depends on a given threshold of the sociability scalars of the peers, the authors will address the question of finding the threshold which guarantees low database search time while providing high ratio of the received requested content. In addition, another objective of the authors will be to investigate how our mobility management scheme, recently proposed for highly mobile users and vehicular networks, presented in [18], can be efficiently integrated with the proposed sociability-based ALTO protocol to allow efficient file sharing in vehicular networks.

References

[1] J. Seedorf and E. Burger, "Application-Layer Traffic Optimization (ALTO) Problem Statement," RFC 5693, October 2009.

[2] 3rd Generation Partnership Project, "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access," 3GPP TS 23.401 V10.0.0, June 2010.

[3] E. Natalizio, A. Scicchitano, and S. Marano, "Mobility Anchor Point Selection Based on User Mobility in HMIPv6 Integrated with Fast Handover Mechanism," in *Proc. of IEEE WCNC*, New Orleans, USA, Mar. 2006.

[4] S. Pack, T. Kwon, and Y. Choi, "A Performance Comparison of Mobility Anchor Point Selection Schemes in Hierarchical Mobile IPv6 Networks," *in Elsevier J. Computer Networks*, Vol. 51, No. 6, pp. 1630–1642, Apr. 2007.

[5] ——, "An adaptive mobility anchor point selection scheme in hierarchical Mobile IPv6 networks," *Computer Communications*, Vol. 29, No. 16, pp. 3066–3078, Oct. 2006.

[6] T. Taleb, A. Jamalipour, Y. Nemoto, and N. Kato, "DEMAPS: A Load-Transition Based Mobility Management Scheme for an Efficient Selection of MAP in Mobile IPv6 Networks," *in IEEE Trans. on Vehicular Technology journal*, Vol. 58, No. 2, pp. 954–965, Mar. 2009.

[7] T. Taleb, E. Sakhaee, K. Hashimoto, A. Jamalipour, N. Kato, and Y. Nemoto, "A Stable Routing Protocol to Support ITS Services in VANET Networks," *in IEEE Trans. on Vehicular Technology journal*, Vol. 56, No. 6, pp. 3337–3347, Nov. 2007.

[8] K. Fall, "A Delay-Tolerant Network Architecture for Challenged Internets," in *Proceedings of ACM SIGCOMM*, Karlsruhe, Germany, Aug. 2003.

[9] M. Grossglauser and M. Vetterli, "Locating Nodes with EASE: Last Encounter Routing in Ad Hoc Networks through Mobility Diffusion," in *Proceeding of IEEE INFOCOM*, San Franscisco, USA, Apr. 2003.

[10] F. Bai and A. Helmy, "Impact of Mobility on Last Encounter Routing Protocols," in *Proceedings of the Fourth Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON 2007)*, San Diego, California, USA, June 2007.

[11] W. Hsu and A. Helmy, "On Nodal Encounter Patterns in Wireless LAN Traces," *in IEEE Transactions on Mobile Computing (TMC)*, Accepted, to appear.

[12] W. Hsu, T. Spyropoulos, K. Psounis, and A. Helmy, "Modeling Spatial and Temporal Dependencies of User Mobility in Wireless Mobile Networks," *in IEEE/ACM Transactions on Networking*, Vol. 17, No. 5, pp. 1564–1577, Oct. 2009.

[13] L. Xi, J. Hong, Z. Ruiming, L. Yi, and F. R. Yu, "A Novel Team-Centric Peer Selection Scheme for Distributed Wireless P2P Networks," in *Proc. of Wireless Communications and Networking Conference (WCNC)*, Budapest, Hungary, Apr. 2009.

[14] B. Kosko, "Fuzz cognitive maps," *International Journal of Man-Machines Studies*, Vol. 24, pp. 65–75, 1986.

[15] U. Lee, J.-S. Park, S.-H. Lee, W. W. Ro, G. Pau, and M. Gerla, "Efficient Peer-to-peer File Sharing using Network Coding in MANET," *Journal of Communications and Networks (JCN), Special Issue on Network Coding*, Vol. 10, pp. 422–429, 2008.

[16] R. Ahlswede, N. Cai, S. yen Robert Li, R. W. Yeung, S. Member, and S. Member, "Network information flow," *IEEE Transactions on Information Theory*, Vol. 46, pp. 1204–1216, 2000.

[17] 3rd Generation Partnership Project, "Access Network Discovery and Selection Function (ANDSF) Management Object (MO)," 3GPP TS 24.312 V9.1.0, Mar. 2010.

[18] S. Cherkaoui, T. Taleb, and E. D. Ngangue Ndih, "Improved Inter-Network Handover for Highly Mobile Users and Vehicular Networks," in *Proc. of IEEE VTC*, Budapest, Hungary, May 2011.