Application-oriented Approaches to Context-aware Mobile Crowdsensing in Vehicular Social Networks

Xiping Hu, Victor C.M. Leung

Dept. Electrical and Computer Engineering, The University of British Columbia, Vancouver, Canada V6T 1Z4

{xipingh, vleung}@ece.ubc.ca

1. MOTIVATION

Mobile crowdsensing aims to provide a mechanism to involve participants from the general public to efficiently and effectively contribute and utilize context-related sensing data from their mobile devices in solving specific problems in collaborations. Also, a remarkable trend in mobile computing is the increasing use of mobile devices to access social networking services. The wide availability of sensing modules in mobile devices enables social networking services to be extended to incorporate location based services, media tag services, etc. Therefore, there is growing interest in fusing social networking services with real-world sensing, such as crowdsensing [1]. Mobile social networks (MSNs) [2] not only can provide an ideal and ubiquitous platform to enable mobile users to participate in crowdsensing, but can also help to improve the context-awareness of mobile applications and better assist users in mobile crowdsensing by analyzing and utilizing their social contexts. Vehicular social networks (VSNs) are an emerging kind of MSN for transportation applications, and a number of research works have identified that crowdsensing in VSN can be effectively used for many purposes and bring huge economic benefits, e.g., safety improvement and traffic management [3].

2. CHALLENGES AND RELATED WORKS

Nevertheless, there are still several key research problems that currently exist, which may significantly limit the applications of mobile crowdsensing in VSNs. To address such problems, systematic solutions are needed to achieve context-awareness of ubiquitous mobile crowdsensing applications in VSNs.

In VSNs, the network connectivity of the underlying VANET is dynamic and frequently changes as mobile nodes like vehicles can move at high speeds; consequently the wireless links may be unreliable and have short lifetimes. The dynamic network connectivity may cause failures of mobile crowdsensing applications during their executions. To enable the adaptation of mobile crowdsensing applications to such dynamic network conditions, beyond many challenges already addressed in network protocol designs in all layers of the protocol stack [4], in the application layer, its major challenge is the applications need to handle possible disconnections and reconnections [4,5]. However, in the application layer, existing solutions on self-adaptive mobile applications in dynamic networks still have several constrains and could not address this challenge effectively over VANETs. First, traditional approaches like JADE [6] and SPRINGS [7] adopt a centralized approach to track and update the network status for mobile applications. These approaches may not be suitable for VANETs, where centralized nodes may not exist and direct communications are not always possible [5]. Second, several solutions such as [8] strictly constrains the behaviors of mobile applications in finishing some simple tasks and is not scalable for extension to finish more complicated tasks. In addition, some solutions depend on specific hardwares and have only been designed for specific applications [9]. Thus, they do not give a paradigm that can be used for different mobile crowdsensing applications that self-adapt to dynamic network connectivity status in VSNs, and a new programming framework with features of automatic and decentralized network management, scalability, and universality (i.e., platform/hardware independence) still needs be investigated.

Furthermore, in VSNs, because of the dynamism of VANETs discussed above and the opportunism of user connections in VSNs, the changing contexts of the users involved in the VSNs may also result in users' dynamic contexts (which may vary with changing VSN context, such as user location, time periods, identities of neighbors and objects, etc.). Thus, in users' dynamic contexts of VSNs, beyond adaptation to dynamic network connectivity status, the mobile crowdsensing applications also need the capabilities to autonomously adapt their behaviors to match appropriate service and information with different users in crowdsensing during run-time [10]. This is important, as such capabilities could maximize the data quality for the requesters of crowdsensing by delivering them with appropriate services relevant to their application context. Also, for participants of crowdsensing, such capacities enable them to contribute sensing data that are relevant and valuable to their activities, interests in VSNs. However, in the traditional approaches in mobile computing, the descriptive information of the service requester (i.e., crowdsensing requester) is compared to that of the service provider (i.e., crowdsensing participant), and their similarity is measured using traditional service matching by simple string or key-word matching, e.g., location based [8], identities based [11] methods. Such approaches cannot work well as it is not realistic to require two entities to use exactly the same contexts (i.e., words about the vehicle users' destinations/preferences) in open and dynamically changing environments of VSNs. Also, most of the existing high level service matching approaches like [12] are based on complex system, and may cause much redundancy in information representations that can hardly be processed in mobile devices, thus is not necessarily suitable in the context of VSNs. Therefore, in users' dynamic contexts of VSNs, a systematic approach is needed to enable mobile crowdsensing applications to autonomously adapt their behaviors to match appropriate service and information with different users in crowdsensing.

3. TARGETS AND METHODOLOGIES

In order to address the challenges discussed above, which are not addressed by existing solutions of mobile crowds, in our research work, we plan to design and develop a mobile distributed system that meets the following four goals:

A. Construct a mobile service-oriented architecture (SOA), which could provide a service-oriented programming model and run-time environment for mobile platform, and work with the customized cloud computing with standard and universal service interactions for different mobile crowdsensing applications across Internet and VANETs. Moreover, inside this architecture, develop a multi-agent framework, which consists of both the language approach and middleware approach, to simplify and hide the complexity of handling different connectivity status of VANETs, to provide a modeling paradigm for different mobile crowdsensing applications self-adaptation in dynamic network connectivity status of VSNs.

B. Design a novel mobile social context-aware resource optimization mechanism, which could aggregate and analyzes the application related context information and social context of human factor. Based on such context information, this mechanism mainly contemplated to incorporate two algorithms, one is used to calculate the similarities of application services, and another one is used to quantify the distance of social relationship between mobile users, so as to effectively matching and allocate the diverse inter-related computing tasks and human based tasks of different mobile crowdsourcing applications simultaneously during run-time of mobile devices.

4. INITIAL RESULTS

A. An agent based multi-layer framework with context-aware semantic service has been designed and implemented [13, 14]. It provides a hierarchical multi-agent based programming model with sufficient generic services, to enable different agent based mobile crowdsensing applications to self-adapt to dynamic connectivity status of VANETs.

B. A service-oriented mobile social network platform (consists of a mobile SOA framework) has been developed. It is the first solution that fully supports SOA based mobile applications working independently on mobile platform in an ad-hoc manner, with low resource overhead on mobile devices. Also, a prototype version of a customized cloud computing platform is implemented, it can work with the mobile SOA framework to support effective matching and allocation of mobile crowdsensing tasks [15,16].

5. REFERENCES

[1] R. K. Ganti, F. Ye, and H. Lei. Mobile crowdsensing: current state and future challenges. *IEEE Communication Magazine*, vol.49, no.11, Nov. 2011, pp.32-39.

[2] **X. Hu**, T.H.S. Chu, V.C.M. Leung, E. C.-H. Ngai, P. Kruchten, and H.C.B. Chan. A Survey on Mobile Social Networks: Applications, Platforms, System Architectures, and Future Research Directions. *IEEE Communications Surveys & Tutorials*, under second round review.

[3] M. Gerla, and L. Kleinrock. Vehicular networks and the future of the mobile internet. *Elsevier Computer Networks*, vol. 55, no. 2, 2011, pp. 457-469.

[4] J. Hoebeke, I.Moerman, B. Dhoedt, and P. Demeester. An Overview of Mobile Ad Hoc Networks: Applications and Challenges. *Journal of the communication networks*, vol.3, no. 3, 2004, pp. 60-66.

[5] O. Urra, S. Ilarri, T. Delot, and E. Mena. Mobile agents in vehicular networks: Taking a first ride. *In Proc. PAAMS*, 2010, pp. 118–124.

[6] F. Bellifemine, F. Bergenti, G. Caire, and A. Poggi. JADE -a java agent development framework. *Multi-Agent Programming, Multiagent Systems, Artificial Societies, and Simulated Organizations*, vol. 15, 125-147, 2005.

[7] S. Ilarri, R. Trillo, and E. Mena. SPRINGS: A scalable platform for highly mobile agents in distributed computing environments. *In Proc. IEEE WoWMoM*, 2006.

[8] C. L. Fok, G. C. Roman, and C. Lu. Agilla: A Mobile Agent Middleware for Sensor Networks. *ACM Trans. Autonomous and Adaptive Systems*, vol. 4, no. 3, 2009.

[9] N. Liu, M. Liu, J. Cao, G. Chen, and W. Lou. When Transportation Meets Communication: V2P over VANETs. *In Proc. IEEE ICDCS*, 2010, pp. 567-576.

[10] N.D. Lane et al. Urban Sensing Systems: Opportunistic or Participatory? *In Proc. ACM WMCSA*, 2008.

[11] L. Capra, and D. Quercia. Middleware for social computing: a roadmap. *Journal of Internet Services and Applications*, vol. 3, no. 1, 2012, pp. 117-125.

[12] K. Fujii, and T. Suda. Semantics-based context-aware dynamic service composition. *ACM Trans. Autonomous and Adaptive Systems*, vol. 4, no. 2, Article 12, 2009.

[13] **X. Hu**, V.C.M. Leung, and W. Wang. VSSA: A Service-oriented Vehicular Social-Networking Platform for Transportation Efficiency. *In Proc. ACM MSWiM-DIVANet*, 2012, pp. 31-38.

[14] **X. Hu**, X. Li, E. C.-H. Ngai, V.C.M Leung, and P. Kruchten. Multi-dimensional context-aware social network architecture for mobile crowdsensing. *IEEE Communications Magazine*, 2014, vol. 52, no. 6, pp. 78-87.

[15] **X. Hu**, T.H.S. Chu, H.C.B. Chan, and V.C.M. Leung. Vita: A Crowdsensing-oriented Mobile Cyber Physical System. *IEEE Trans. Emerging Topics in Computing*, 2013, vol.1, no. 1, pp. 148-165.

[16] **X. Hu**, J. Deng, W. Hu, G. Fotopoulos, E.C.-H. Ngai, Z. Sheng, M. Liang, X. Li, V.C.M. Leung, and S. Fels. SAfeDJ Community: Situation-Aware In-Car Music Delivery for Safe Driving. *To appear in Proc. ACM MobiCom*, 2014

Biography: Xiping Hu joined UBC in September 2011, and he is now working towards his PhD under the supervision of Prof. **Victor C.M. Leung** in the Electrical and Computer Engineering Department of UBC. He is the winner of silver prizes in national Olympic competitions in mathematics and physics in China, and a Microsoft certified specialist in web applications, .NET Framework and SQL server. Also, he participated as a key member in several research projects, like web service security identification at Tsinghua University in China, SAVOIR project at National Research Council of Canada, and NSERC DIVA strategy research network at UBC. His research contributions have been published and presented in various of international conferences and journals, such as IEEE HICSS, IEEE Transactions on Emerging Topics in Computing (TETC), and ACM MobiCom. His current research areas at UBC are mobile social networks, mobile computing, and crowdsourced-sensing, and expected to finish his PhD thesis by the summer of 2015.