From Ubiquitous Computing to Human Aware Networking: Exploiting the Know-how of Ubicomp Research for Improving Networked-User Experience

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ABSTRACT
This paper presents a series of reflections on the use of experiences gained in ubiquitous computing research to define their potential exploitation in the field of networking. On this regard, this paper presents preliminary ideas aiming at defining the concept of Human Aware Networking (HAN). The main idea behind HAN is to utilize the sensed context and the recognized human behaviors mostly based on the use of mobile devices in order to feed the network with the interaction patterns of users to better setup and optimize network parameters. With HAN, the goal is to maximize the relationship between provided Quality of Service (QoS) and perceived Quality of Experience (QoE)..

Keywords
human aware networking, quality of service, quality of experience, ubiquitous computing.

1. INTRODUCTION

In the past years, research in Ubiquitous Computing (ubicomp) [1] has focused on the design and evaluation of technologies and applications aiming to assist people in their daily life activities in the most natural and low intrusive possible way. The research on this field has focused on several complementary topics including the acquisition, analysis and interpretation of contextual data, the creation of required architectures, infrastructures and protocols for communication, the opportune presentation of processed information to users and the definition of adequate evaluation criteria for the resulting ubiquitous computing applications among others [2]. The research on ubiquitous computing has been enabled through a virtuous and synergic relationship between technology innovations and users research, providing advances in a long list of fields such as wearable computing, mobile technologies, human-computer interaction, pervasive monitoring and sensing, human behavior understanding, universal access, persuasive interfaces and many more. In most of these ubicomp applications the ultimate goal was to extract contextual information from different users scenarios and interpret it on the users benefit. In particular, advances in context awareness in the domain of ubiquitous computing has allowed to better model and interpret the state of the users and their environment, and to allow systems to react accordingly to contextual changes for improving different aspects of users life. The number of applications domain of ubicomp impacted by context awareness research is multiple, ranging from assisted living to entertainment, smart transportation and healthcare amongst others. A common denominator on such applications is that the availability of network services in previous ubicomp research was usually given for granted and the performance of systems was not always tested in real-life conditions regarding available connectivity [3].

The rest of the paper is organized as follows: Section 2 introduces Human Aware Networking as a result of a fusion between users research in ubicomp and applications research in networking for improving the user experience while interacting with the network. Section 3 describes the related work. In Section 4 some potential scenarios are presented. Section 5 describes challenges and opportunities for Human Aware Networking research and Section 6 presents the conclusions of this paper.

2. ACTIVITY, BEHAVIOR AND CONTEXT RECOGNITION FOR NETWORKING

2.1 Human Aware Networking

Today, with the proliferation of mobile devices and exponential grow of available applications, networks are being exposed in the present time to every time more and more demanding performance requirements in order to satisfy users' quality of experience (QoE) expectations. Moreover, with the increase of such applications migrating into the cloud the provisioning of network resources allocation in a best-effort Quality of Service (QoS) modality is no sufficient. On the network side, the challenge is now to provide allocation of network resources adaptable to users changing demands. On this regard we identify an opportunity on taking advantage of previous research on ubiquitous and context aware computing by exploiting the knowledge about users behaviors and contexts while interacting with the network. A possible approach for this would be to investigate the networked applications usage requirements from the primary source, namely the human interaction with the network, therefore identifying and predicting the users patterns on interacting with different networked applications in order to provide adequate resources settings and allocation in advance.

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The ability to change the network performance not only through usual routing, caching, or data replication means, but also through network-assisted human workload adaptation via tailored network feedbacks, calls for a rethinking of network optimization and traffic engineering approaches, either in terms of models and relevant formulations, as well as in terms of exploited methodologies, which should be made capable of capturing the human behavior. At the same time, a new research avenue consists in the network-aware rethinking of recommending and incentive/reward systems. We call this new research approach human-aware networking (HAN).

HAN research shall include knowledge of both, users and network contexts cooperating in a synergic way. In one hand the anticipation of users behaviors and needs will enable feeding the network with the actual requirements for resources allocation and in the other, the identification of network status should allow maximizing QoS for obtaining the desired QoE.

3. RELATED WORK

To the authors knowledge there is not previous work reported in the literature on utilizing user activity and behavior analysis detected from mobile devices for maximizing QoE in networking scenarios. However there is previous work in the fields of ubicomp and networking that if related together, may be used as foundations for setting up a path of convergence between these two research disciplines for developing the HAN paradigm. HAN may benefit from the experience of 1) ubicomp research on acquiring needs, contexts and identified behaviors from users domain and 2) networking research for estimating optimum connectivity parameters from networked applications domain.

3.1 Ubicomp Assets for Networking

Advances in ubicomp research allow to perform human activity and context recognition through wearable and mobile devices with reasonably high accuracy defined under non-ambiguous and measurable performance criteria [4]. Several application domains such as wellbeing, fitness, assisted living, smart transportation, logistics, healthcare, energy saving, self-management, entertainment and marketing amongst others have found a benefit on the use of context and activity recognition through the usage of mobile devices [5]. Moreover these researches focus mainly on impacting aspects of daily living of users and still haven't exploited their potential to contribute to networking domain. In addition, research on automatic mobile monitoring has achieved to estimate not only objective data representing specific activities such as walking, running, sleeping, etc. but to provide the basis for understanding more sophisticated human behaviors from automatically captured behavioral cues (like in honest signals research) such as sociability, mood, and human intentions [6]. In particular referring to estimation of human intentions, the prediction of activities and behaviors using mobile phones sensors in past ubicomp research has demonstrated to be feasible [7].

Other recent work in ubicomp community relevant for HAN paradigm development consists in predicting mobile applications usage accordingly to previous behavior patterns and users intentions [8]. On their research the main motivation was to understand and predict applications usage in different locations and contexts for providing users with simplified access through adaptive user interfaces in the mobile phone screen depending on most frequently used applications. Other related research, defined new applications usage models for producing robust app predictions for enabling in one hand significant smartphone system optimizations at the interface level and in the other to proposed possible future developments on pre-loading apps when potentially needed for giving a perception of being virtually instantaneous and to cache network content potentially providing the appearance to the user of much higher network speeds [9].

3.2 Networking Related Research

Ongoing research on Applications Aware Networking (AAN) is related to HAN in the sense that it focuses on defining the network resources based on customer demand. In these cases, application awareness is related to the different tools that service providers use to optimize network resources accordingly to the required performance of overlay applications in terms of bandwidth, delay and jitter among others. In AAN the focus is on understanding the requirements from the different applications in order to define resources allocation through a Software-Defined-Networking (SDN) approach. An example of this is the provisioning of prioritized Service Levels Agreements (SLAs) depending on the requirements of different types of applications. Differently to HAN, in AAN, the focus is on applications while the user behavior and intentions are not considered to establish possible network consumption demands.

Other research considers content consumption patterns of users and connected objects that are located in proximity in order to identify frequently used content and position it in nodes nearby [10]. This is done by establishing relational metrics among objects in the real world (e.g. people, locations, things) and the content itself to establish closeness relationships and similarity patterns on content consumption relating users through a social-distance criteria [11]. With this approach the intention is to reduce traffic congestion by moving and storing the frequently used content by a series of users in nearby nodes to provide better content delivery.

More recent approaches are focusing on the concept and theoretical foundation of Anticipatory Networks [12] to exploit network predictability and adaptability to upcoming events in a way to anticipate requirements to improve operation quality and efficiency. This approach is well in-line with potential future scenarios enabled by 5G technologies and the upcoming next wave of the digital society.

4. HAN SCENARIOS EMPOWERED BY UBICOMP AND NETWORKING TECHNOLOGIES

The hypothesis formulated here is that it would be of high relevance for networking domain to predict the human usage patterns prior to interacting with the different networked applications and consequently to adjust the network parameters to maximize service delivery in an opportune way. This would mean to dynamically establish the required bandwidth, tolerable latency and in general to propose a suitable QoS in advance to its actual usage given a predicted context.

On this regard, previous ubicomp research on context and activity recognition can support anticipating human intentions and

behaviors that may be relevant for adequately configuring the network parameters in advance to increase QoE. Some examples of potential scenarios where anticipating users behaviors and expectations for dynamic network services may turn useful are listed below:

Handover improvement in mobile scenarios – Understanding situations from behavior forecast in which users may be commuting in public transportation for example the expected destinations, their frequent routes and their travel preferences.

Bandwidth allocation depending on expected applications usage – By estimating users behaviors, it may be possible to anticipate the expected applications usage in different contexts including highly bandwidth demanding audiovisual applications with the corresponding setting of network parameters in advance.

Latency management for real-time gaming / collaborative working – Activity and context recognition through mobile devices may turn useful to detect the users context while executing tasks and facing interaction constraints in collaborative environments such as in working or gaming applications needing fast response and low latency.

Immersive and Augmented environments – Predicting users behaviors while interacting with immersive and augmented environments may support efficiently setting of QoS parameters to maximize users QoE.

Intensively and dynamic mobile data collection requirements – In monitoring human activities and behaviors it is necessary very often to use different sampling rates accordingly to the quality required on the necessary parameters that are monitored at different times. Estimating in advance the possible monitoring requirements could allow to optimize bandwidth allocation to communicate the different data in an efficient way while saving other resources as battery consumption.

Content-critical applications requiring high reliability – Constant monitoring of users contexts and behaviors may allow to predict situations in which they require high reliability in connections (e.g. online shopping, tele-medicine scenarios, etc.) that can be satisfied anticipating proper network parameters.

Preventing connectivity in crowded locations – Estimating proximity and in general location of a number of users concurrently based on their contexts and behaviors can anticipate allocation of enough network resources for satisfying properly their connectivity needs.

5. HAN CHALLENGES AND OPPORTUNITIES

In networking, the current assumed paradigm is that the user demand has an "a-priori" nature. However, we believe that current, real-time human behaviour plays an important role in network performance. When brought down to networking, this calls for a foundational, "human-Iayer-aware" re-thinking of networks and networked services, which need to embed a thorough quantitative understanding of the human behavior, as well as new modeling and design methodologies for capturing and exploiting such human-network interaction. Two major and tightly intertwined challenges do emerge.

First, user interests should be matched with network-related aspects (cost, performance, quality of the expected access/delivery conditions, predictions on resource availability, etc). Since network load is ultimately determined by the free choice of the user among alternatives, a thorough understanding is required on how network feedbacks should be devised and presented, and how humans react to network feedbacks in taking alternative decisions. As such, methodologies and insights adapted from human sciences, as well as cognitive models of decision-making, become now essential and integral aspects in networking.

Second, human adaptability becomes a novel key instrument for controlling network performance and providing improved quality of experience and better end user services. The exploitation of the human dimension in the network operation indeed calls for solutions able to discover, predict and rank "best fitting" opportunistically available resources and services, along with new algorithms able to integrate human adaptability in the network operation, and means to devise the most effective and convenient feedbacks to the users.

6. CONCLUSIONS

The ability to change the network performance not only through usual routing, caching, or data replication means, but also through network-assisted human workload adaptation via tailored network feedbacks, calls for a rethinking of network optimization and traffic engineering approaches, either in terms of models and relevant formulations, as well as in terms of exploited methodologies, which should be made capable of capturing the human behavior. At the same time, a new research avenue consists in the network-aware rethinking of recommending and incentive/reward systems. We believe that the experience of previous work in ubicomp and networking can exploit their synergies to constitute the basis for the required research agenda leading to Human-Aware Networking as a possible approach to address predictability of users needs and the consequent adaptation of network provisioning.

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8. REFERENCES

[1] Weiser, M. The computer for the 21st century. Scientific American, 265:3 (1991), 66-75

[2] Abowd, G.D., and E.D. Mynatt: Charting past, present, and future research in ubiquitous computing. ACM Trans. Comput.-Hum. Interact. 7(1): 29-58 (2000)

[3] Scott D. Mainwaring, Michele F. Chang, and Ken Anderson Infrastructures and Their Discontents: Implications for Ubicomp. Ubicomp, volume 3205 of LNCS, page 418-432. Springer, (2004)

[4] Jamie A. Ward, Paul Lukowicz, Hans-Werner Gellersen: Performance metrics for activity recognition. ACM TIST 2(1): 6 (2011)

[5] Choujaa D, Dulay N, Activity Recognition from Mobile Phone Data: State of the Art, Prospects and Open Problems. *To appear*

[6] Alex Pentland, Tracy Heibeck. Honest Signals – How They Shape Our World. MIT Press 2008.

[7] J. Song, E. Y. Tang, L. Liu. User behavior pattern analysis and prediction based on mobile phone sensors. NPC'10 Proceedings of the 2010 IFIP international conference on Network and parallel computing. Pages 177-189. Springer 2010.

[8] C. Shin, J. Hong, A. K. Dey. Understanding and prediction of mobile application usage for smart phones. UbiComp '12: Proceedings of the 2012 ACM Conference on Ubiquitous Computing. September 2012

[9] Y. Xe, M. Lin, H. Lu, G. Cardone, N. D. Lane, Z. Chen, A. Campbell, T. Choudhury. Preference, Context and Communities: A Multi-faceted Approach to Predicting Smartphone App Usage Patterns, 17th International Symposium on Wearable Computers (ISWC'13), September 2013

[10] N. Maki, T. Nishio, R. Shinkuma, T. Mori, N. Kamiyama, R. Kawahara, T. Takahashi. Traffic Engineering of Peer-Assisted Content Delivery Network with Content-Oriented Incentive Mechanism. IEICE Transactions, 2012

[11] R. Shinkuma, H. Kasai, K. Yamaguchi, O. Mayora. Relational metric: A new metric for network service and in-network resource control. Proceedings of CCNC, 2012

[12] Skulimowski, A. M. J. Exploring the future with anticipatory networks. Physics, Computation and the Mind. Advances and challenges at interfaces: Proceedings of the 12th Granada Seminar on Computational and Statistical Physics. AIP Conference Proceedings, Volume 1510, pp. 224-233 (2013).