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An improved virtualization layer to support distribution of multimedia contents in pervasive social applications

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ABSTRACT

Pervasive social computing is a new paradigm of computer science that aims to facilitate the realization of activities in whichever context, with the aid of information devices and considering social relations between users. This vision requires means to support the shared experiences by harnessing the communication and computing capabilities of the connected devices, relying on direct or hop-by-hop communications among people who happen to be close to each other. In this paper, we present an approach to turn mobile ad-hoc networks (MANETs) into stable communication environments for pervasive social applications. The proposal is based on an evolution of the VNLayer, a virtualization layer that defined procedures for mobile devices to collaboratively emulate an infrastructure of stationary virtual nodes. We refine the VNLayer procedures and introduce new ones to increase the reliability and the responsiveness of the virtual nodes, which serves to boost the performance of routing with a virtualized version of the well-known AODV algorithm. We prove the advantages of the resulting routing scheme by means of simulation experiments and measurements on a real deployment of an application for immersive and collective learning about History in museums and their surroundings.

1. Introduction

The steady advances in the realm of pervasive computing favored by the ever-growing popularity of smartphones, together with the new interaction patterns propelled by the social web, pave the way to a new era of information services tailored to the people's physical and social context (Drego et al., 2007; Zhou et al., 2012). Researchers in the area of *pervasive social computing* envisage many opportunities to enable meaningful interactions among groups of nearby people —either acquaintances or strangers— to help them make the most of their environment, ranging from the orchestration of activities in venues or events that attract people with potentially-related interests (e.g. museums, concert halls or campsites) to advances in the vision of *smart cities*, related to the planning of personal mobility or the celebration of location-based urban games (Schuster et al., 2013). As explained in Ben Mokhtar and Capra (2009), while *pervasive computing* aimed to facilitate the realization of users' daily tasks by changing the way they individually interact with the physical environment, pervasive social computing aims to facilitate the realization of those tasks that need to consider social relations between users. While the former placed a strong emphasis on the *self* component, the latter emphasises the social component. While web 2.0 websites enabled online interactions, pervasive social computing aims to change the way individuals interact with co-located people.

From the technological point of view, realizing the concept of pervasive social computing requires means to support the shared experiences by harnessing the communication and computing capabilities of the connected devices as an integrated whole. At the lowest level, due to physical proximity, the devices should be able to exchange data packets directly or within few hops in an ad-hoc network—rather than sending them out to remote Internet servers that would merely echo the same packets downlink—and harness the strengths of peer-to-peer (P2P), opportunistic networking (Sun, 2001; Conti and Giordano, 2013). The ad-hoc networks should serve as a channel to distribute a wealth of multmedia contents generated locally or downloaded from the Internet through any WiFi, DSRC, WiMAX, 3G or LTE connections

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available to the mobile devices. In doing so, it is necessary to deal with the challenges raised by the properties of the wireless medium, the varying topologies that emerge from the users' movements, and the fact that the devices may have limited memory, computational power and battery.

In this paper, we introduce an approach to support pervasive social applications by turning the mobile ad-hoc networks (MANETs) into more stable communication environments. Our proposal is based on an evolution of the virtualization layer presented in Dolev et al. (2004) and Brown et al. (2007) (called the *Virtual Node Layer*, VNLayer), which put forward procedures to create an infrastructure of stationary *virtual nodes* to ease the routing problem and the maintenance of persistent state information in the area covered by an ad-hoc network, notwithstanding the movements of the real nodes. Brown et al. (2007) discussed the advantages of the programming abstraction enabled by the VNLayer, whereas Wu et al. (2011) and Patil and Shah (2012) separately proved that a virtualized version of the AODV routing algorithm (Perkins et al., 2003) (called VNAODV) can outperform AODV itself in terms of route stability and packet delivery ratios. Later on, Wu proved the advantages of virtualization for another routing algorithm (RIP, Malkin, 2000) and ancillary protocols like DHCP (Wu, 2011). Here, we present a number of refinements to both the VNLayer and VNAODV, leading to new versions we have called VNLayer+ and VNAODV+. By means of simulation experiments and measurements on a real deployment, we prove that this solution achieves better performance than others in supporting a pervasive social application for History-related museums called REENACT (previously described in López-Nores et al., 2013a; Blanco-Fernández et al., 2014). Specifically, we have compared the performance achieved by the REENACT app in the distribution of multimedia contents with the five routing solutions shown in Fig. 1: plain AODV, VNAODV on top of the VNLayer, VNAODV+ on top of the VNLayer+, OLSR (Clausen et al., 2003) and ARA (Guenes et al., 2002). AODV, OLSR and ARA are the most representative examples of routing algorithms used for P2P distribution of contents in MANETs, along with DSDV (Perkins and Bhagwat, 1994) (an antecedent of OLSR) and Bee (Wedde and Farooq, 2005) (conceptually similar to ARA) (Gurumurthy, 2009; Tang et al., 2005; Sbai et al., 2010; Hwang and Hoh, 2009; Dhurandher et al., 2009; Castro et al., 2010; Barbeau, 2012; Wang et al., 2014).

The paper is organized as follows. First of all, Section 2 includes an overview of routing protocols for MANETs. Then, we present the main procedures of the VNLayer (Section 3) and details of how AODV was adapted to work on top of it (Section 4). The refinements we have included in the VNLayer+ and in VNAODV+ are presented in Sections 5 and 6, respectively. Section 7 presents the REENACT application, the scenarios of our measurements and simulations and the comparison results. Finally, conclusions are given in Section 8 along with the motivation of our ongoing work.

2. Overview of MANET routing protocols

During the last fifteen years, the wireless networking community has come up with a large number of routing protocols for ad-hoc networks of mobile devices, going from early proposals that would fit a wide range of scenarios to more recent algorithms focused on specific constraints (in terms of mobility parameters, energy limitations, knowledge of the physical location of the nodes, etc). Accordingly, whereas the first surveys would only consider centralized/distributed and proactive/reactive/hybrid categories, the most recent ones (e.g. see Alotaibi and Mukherjee, 2012; Boukerche et al., 2011) cover new families like hierarchical, multicasting, geographical, multipath and power-aware. The following are some comments about these categories:

- *Proactive (or table-driven) routing* is an approach where each node maintains information on how to reach every other node in the network by exchanging topology update messages with the others on a regular basis. This way, the nodes can decide on the next hop for any outgoing packet with minimal delay, but the maintenance of the routing tables implies significant overhead and bandwidth consumption (even when there is no data traffic flowing). Some examples of proactive algorithms are DSDV, OLSR and FSR (Gerla et al., 2002), among others.
- *Reactive (aka on-demand or source-initiated) routing* is an approach where the nodes do not attempt to find routes to every other node, but only to the ones they actually have to send data packets to. Reactive algorithms typically flood the network with request messages when it is necessary to discover a route to a new node, which implies a certain latency before the packets start arriving at the destination. However, reactive algorithms usually have lower overhead and demand much less memory than proactive ones, which increases their scalability. AODV, LAR (Ko and Vaidya, 2000a) and DSR (Johnson et al., 2001) are reactive algorithms.
- *Hybrid routing* combines features from both proactive and reactive routing, typically following the intuition that table-driven routing is more convenient in areas where the connections change relatively slowly, whereas source-initiated routing is better in areas with frequent topology changes. Some protocols, like DST (Radhakrishnan et al., 1999) and DDR (Nikaein et al., 2000), explicitly build a *backbone* of nodes which have more stable connections, so that nodes in the backbone use table-driven routing, while nodes outside are reached with source-initiated routing. Other protocols classify nodes into *zones* defined from the perspective of the source node, either based on hop count as in ZRP (Beijar, 2002), FSR (Gerla et al., 2002) and RDMAR (Aggelou and Tafazolli, 1999) or based on physical location as in SLURP (Woo and Singh, 2001) and ZHLS (Joa-Ng and I-Tai, 1999).
- *Hierarchical routing* may be seen as a particular case of hybrid routing, in which the nodes form clusters so that the exchange of messages can be managed differently within the same cluster (e.g. with a proactive algorithm) and between different ones (e.g. with a reactive approach). One or more *cluster heads* are responsible for transmitting packets on behalf of the nodes in each cluster, which makes the inter-cluster routing mechanisms deal with a significantly reduced number of nodes (thus favouring scalability). In turn, it is of utmost importance to deal properly with the nodes' movements from one region to

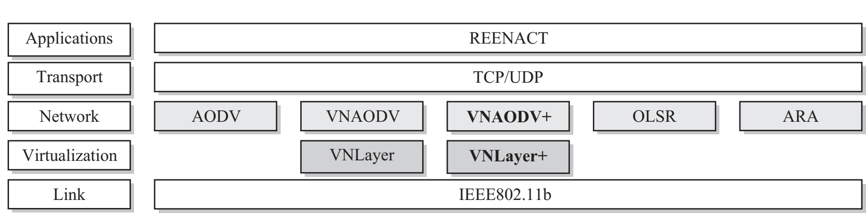

Fig. 1. The five configurations compared in our experiments.