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# Two birds, one stone: Using mobility behavioral profiles both as destinations and as a routing tool

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ABSTRACT

We present *HabCast*, a profile-cast communication paradigm that learns about the mobility habits of the location-aware nodes of the network and uses this information both to route the messages, and to deliver them only to the nodes that match the target behavioral profile. *HabCast* substitutes destination's identifier by a mobility profile model called habitat, meaning that allows users to send messages "to any nodes who usually roams around this area" instead of sending messages intended to a node. *HabCast* is designed to operate without network infrastructure, using Opportunistic Networking strategies and operates in three phases: approximation, floating and delivery phase. *HabCast* enables new services and applications on Opportunistic Networking by automatically inferring the nodes' behavioral profiles and using them to define the messages' destinations. The overhead introduced by *HabCast* is evaluated using a proof-of-concept implementation, and its performance and feasibility is studied, through simulation, under the scope of a real *carsharing* application.

## 1. Introduction and motivation

Opportunistic Networking (OppNet) is designed to operate in challenged scenarios where the communication networks are unavailable or spotty and the resources are scarce (Borrego et al., 2014; Martín-Campillo et al., 2013). Due to its design, based on the store-carry-and-forward strategy, OppNet is able to deal with the absence of simultaneous end-to-end paths through the usage of mobile devices that opportunistically establish contact and exchange messages between them. For this reason, OppNet is usually used as a communication solution in developing countries (Sánchez-Carmona et al., 2015)...

... but it should not be limited to these kind of scenarios. During the recent Hong Kong's protests, *Firechat* has proven the utility of OppNet in a well-connected, highly-populated, urban scenario (Bland, 2014). OppNet could take advantage of the high density of mobile devices in urban regions of industrialized countries. Besides, its capability of operating without the infrastructure of Internet Service Providers (ISP) can help fighting problems as the lack of Net Neutrality,[1] the censorship[2] or the need of privacy of the users.[3]

We envision a future where many applications will be using Opportunistic Networking technology, as *Firechat* does. A future where mobile users carry ultra portable devices delivering highly personalized, context-aware services without endangering their privacy through the dependence on the ISP. A future that is not impossible. However, there are applications whose specific needs make difficult to port them from an Internet environment to OppNet. For this reason, this future will only be feasible if OppNet researchers are able to find ways to overcome these limitations and to provide new features.

Conventional communication paradigms face important limitations in the context of highly dynamic mobile opportunistic networks. Unicast requires explicit identification of the destination node, but it may be hard to know the identities of all the other nodes. On the other hand, multicast requires the maintenance of group membership, and needs to know if they maintain their interests even after being disconnected for a while. The profile-cast paradigm aims to solve these issues by inferring membership in interest groups based on the past behavioral of nodes, removing the need of being explicitly expressed. But even when a message can be sent to the nodes matching a target profile, instead of to a node's identifier, there is still needed to route the message towards them. In this paper, we address a very complex task: to route a message towards an unknown number of destinations that will not be recognized until reaching them.

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[1] Although Net Neutrality in the U.S.A. is granted thanks to a rule voted in February of 2015, it is still in discussion in other regions, as the European Union: https://savetheinternet.eu/.

[2] The reader can find a ranking of the most censured countries on: https://cpj.org/2015/04/10-most-censored-countries.php.

[3] This topic has been drawing increasing attention among the population since the NSA scandal broke in early June 2013.

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Our proposal consists in a profile-cast paradigm of communication for OppNet called *HabCast*. *HabCast* leverages the existence of life-cycles of the users to learn about their whereabouts and uses this information not only to define the profile of the messages' destinations, but also to route the messages towards the area where there will be more likely to find nodes matching the target profile. This way, both the routing and the delivery of every message are made in the basis of the nodes's usual behaviours. We propose the very first system that takes history-based decisions both to route the messages towards their receivers and to decide which to which nodes deliver them.

Our main contributions are summarized below:

- We present *HabCast*, a profile-cast paradigm of communication. *HabCast* benefits from our previous work in Sánchez-Carmona et al. (2015) to learn about users' whereabouts, and uses this information to route the messages towards the area where the destinations are more likely to be found, then, it delivers the messages to the nodes matching the target behavioral profile.
- We discuss the limitations of traditional unicast, multicast and manycast communications in OppNet, and suggest a set of real applications that could benefit from our *HabCast* proposal.

The outline of the rest of the paper is as follows. We state the problem we aim to solve and list some of the potential applications that could benefit from the proposed solution in Section 2. We discuss the state of the art in Section 3. We summarize the key concepts of our previous work in Section 4. Then, we present our habitat-based profile-cast paradigm of communication, called *HabCast*, in Section 5. This is followed by the description of a proof-of-concept implementation in Section 6. Next, we study the feasibility of our proposal through simulation in Section 7. Finally, Section 8 conclude this paper.

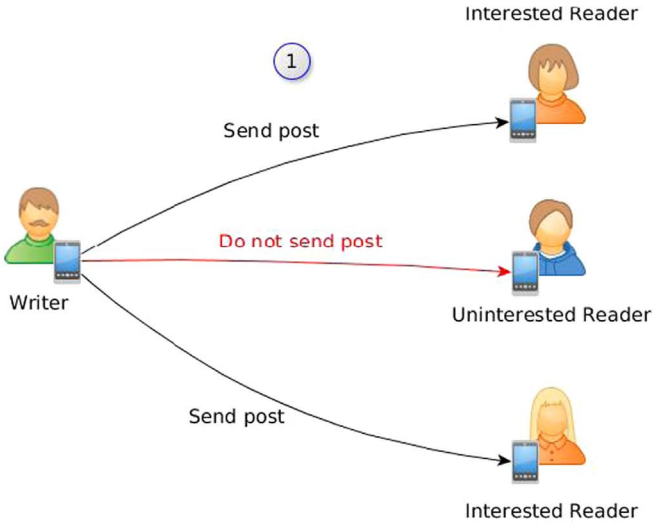
## 2. Definition of the problem

In this section, we explain why sending messages to a bunch of unidentified nodes based on their mobility profile would allow OppNet to support new applications and services. Firstly, we explain the issues and limitations derived from the current communication's paradigms, and we provide examples of actual Internet applications that do not need it although they use it. Then, we select a set of emergent applications that could be ported to OppNet thanks to our proposal.

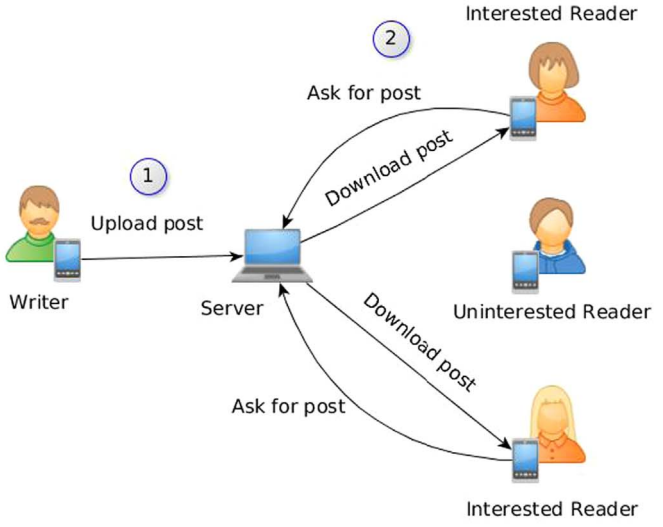
### 2.1. The problem of matching destinations in OppNet

Most previous works in the OppNet field (Abraham and Jebapriya, 2012; Cao and Sun, 2013; Liu et al., 2011) consider one-to-one communications based on nodes identities (IDs). Usually, their main objective is to deliver messages efficiently and promptly, given a destination node ID chosen by the sender, so, they assume that every sender knows the destination's ID of every message. The multicast approach only moves this problem from the sender to the receivers: they are expected to know that *somewhere* on the network, there are *someone* sending messages they want to receive using a certain ID. The manycast paradigm (Carter et al., 2003), designed to enable communication with an arbitrary number of group members, provides some flexibility but forces the sender to know the ID of the destination group. The publish-subscribe approach allows nodes to communicate without knowing other's ID, but it is usually based on filtering the received messages (A dtn routing scheme based on publish,), or on the willingness of nodes to make their interests public (Zhou et al., 2013).

These communication schemes limit the potential usages of the network. To better illustrate this, the reader may think on the services he or she uses on the Internet. The e-mail, the chat and the RSS are examples of communications directed to a destination. But there are other popular services, as blog posts (see Fig. 1), the news web pages or the forums that are different in essence. A message post in a blog is not directly sent to its readers, instead, it "keeps waiting" until someone interested reads it. It is not the writer of the message who decides who is its destination, because he or she cannot know it. The readers are who, while accessing their favourite blogsite, become the destinations of the message. So, the participants perceive the illusion of a profile-cast functionality. Fig. 1 illustrates how this process is perceived by the users in contrast with how this process is actually conducted.




(a) The users perceive a profile-cast communication




(b) The communication is conducted through a third party

**Fig. 1.** The blog post example. The logic flow of the application is shown in a): a direct communication (1) between the writer of the post and any number of interested readers. However, the actual communication flow is shown in b): two separate communications using a third party, the first (1) between the writer and the server, and the other (2) between the server and every interested reader.

Blogs would never have become so popular if the writers would been forced to specify the ID of all the readers of their posts. Besides, the usage of third parties to build this illusion is not always feasible in OppNet, because there is no guarantee of the existence of a simultaneous end-to-end path. Therefore, we propose a profile-cast flow of communication using users' behavioral profiles as the messages' destination. Instead of explicitly expressing membership in interest groups or receiving and filtering lots of messages, our proposal allows senders to intend messages to any nodes matching a certain behavioral