

# Implementation of CAMEO: a Context-Aware MiddleWare for Opportunistic Mobile Social Networks

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**Abstract**—**Opportunistic Mobile Social Networks** represent the emerging trend in mobile applications combining the novel paradigm of opportunistic networking with the need of users to generate and share contents anywhere and anytime. In this demo we present a real implementation of a context-aware middleware for the development of optimized opportunistic Mobile Social Networks. To highlight the advantages of this platform we present also an innovative application for tourists aimed at enriching the touristic experience with useful information and virtual social interactions with other users.

**Keywords**—**opportunistic networks, Mobile Social Networks, context-awareness, user-generated content, content sharing**

## I. INTRODUCTION

Due to the join of emerging trends like opportunistic communications and the generation of multiple contents by users in a participatory way, a new class of mobile applications has born in order to create new and on-demand virtual networks among users. This class of applications, identified as opportunistic Mobile Social Networks (MSN) [1], exploits opportunistic communications to establish new social interactions among users characterized by common interests, making them able to share content, experiences, and open discussions on several topics.

Currently the attractiveness of an application domain is identified by its potential impact on the final users and on the entire society, creating smart services able to support users in everyday activities, to improve their social interactions, and to provide customized useful information. Opportunistic MSN address all these requirements in several application domains, from personal healthcare to environmental monitoring and urban sensing by implementing the main concepts of *context- and social-awareness*. The core of this scenario is represented by the ensemble of a user and her mobile devices and all the context information that characterize them. Specifically, the notion of context consists of the set of information characterizing the user (e.g., in terms of user's profile, interests, mobility patterns), her devices (e.g., information related to device's internal resources like sensors), the applications running on the devices (content produced and shared by an application), and the surrounding

environment (e.g., collected by external sources like fixed sensor stations). To correctly exploit context information, opportunistic MSN applications are characterized by a set of basic functionalities, independent of their application domain: (i) the collection and management of the local context of each node, (ii) the creation of a social context of each node obtained through the exchange of context information among physical neighbors, (iii) the maintenance of a historical profile of the social context, in terms of information of previous encountered neighbors, (iv) the elaboration of all the context components to optimize application's features in opportunistic networks. In order to provide a common platform for the development of this kind of applications we propose CAMEO, a Context-Aware MiddleWare for Opportunistic MSN, that provides the basic functionalities for context management in addition to a set of optimized services and protocols for opportunistic networks (e.g., context-aware forwarding protocols). In this demo, we present the implementation of CAMEO and an example of opportunistic MSN application designed mainly for tourists, aimed at improving their experience visiting a touristic location exploiting opportunistic communications. Both CAMEO and the application, called Tourist-MSN, have been implemented on Android 2.2 smartphones.

## II. CAMEO: CONTEXT-AWARE MIDDLEWARE FOR OPPORTUNISTIC MSN

CAMEO is a middleware platform focused on the management and elaboration of context information both to implement a set of optimized services for opportunistic networks (like forwarding protocols) and to support the optimized development of context-aware applications. As shown in Figure 1, CAMEO is represented by two packages: Local Resource Management Framework (LRM-Fw), aimed at implementing features related strictly to the interaction with the local resources of the device, both hardware (e.g., embedded sensors, capacity, battery, wireless interfaces) and software (e.g., communication primitives and programming libraries); Context-Aware Framework (CA-Fw), aimed at storing, elaborating and disseminating all the context information in addition to the definition of optimized forwarding protocols.

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The first step in CAMEO is the collection and management of the local and social context of each node. To this aim, CAMEO CA-Fw implements a beaconing procedure for the dissemination of context information among 1-hop neighbors. In order to avoid the periodical dissemination of a huge amount of information, CAMEO implements an optimized procedure based on the identification of context components through hash values. The Beaconing module periodically sends on the network the hash values of the context components of the local node (related mainly to the user profile and the applications' context) and receives those of the neighbors. If there is no correspondence between the received hash value and the current version of the context of the same node stored by CAMEO, the current version of the context will be directly required to the source node. Therefore, through the beaconing procedure each node becomes aware of its neighbors and their context.

Each application or CAMEO internal service that wants to exploit this data to optimize its features will specify the type of information it is interested in and a customized evaluation algorithm defined as *context-based utility function* [2]. For example, in case of a context-aware forwarding protocol, the Forwarding Manager requires to the Context Manager to analyse context information of the current neighbors to evaluate the probability of each node to deliver a message to its final destination selecting the best next hop for that message.

To support an easy and optimized development of context- and social-aware opportunistic MSN applications, CAMEO defines an API through which it interacts with each application developed on top of it. Specifically, it establishes an interprocess communication (IPC) channel with each application in order to collect its context information and send its messages on the network when required. It defines also a callback interface with each application to notify it when specific events occur following a publish/subscribe protocol. In addition, in order to collect information related to the local user (information that does not depend on the execution of specific applications), CAMEO interacts with the User Profile Module, which requires the user to initialize her profile with some (optional) information and to authorize their distribution on the network<sup>1</sup>. Finally CAMEO interacts with the Android platform in order to collect information related to internal resources for a local elaboration and to establish communication channels on the network. Since CAMEO must support multiple concurrent applications, we decided to implement it as an Android Service. Then, opportunistic MSN applications, developed on top of CAMEO, have been implemented as Android applications. A single instance of CAMEO, running on a separate process, is shared among

<sup>1</sup>In this work we do not address privacy and security issues related to users' personal information. In the demo we require to the user to insert non-sensitive information and we inform them of the limited dissemination of their data.

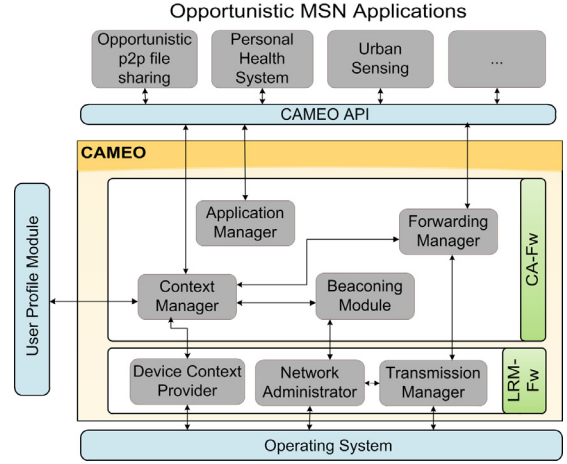


Figure 1. CAMEO software architecture.

all the applications. To support the communication between CAMEO and the applications, we exploited an Android Java proxy class implementing the transfer of Parcelable objects between processes as IPC paradigm. In addition, AIDL (Android Interface Definition Language) has been used to define the callback interface to each application for the event notification. As far as the management of context information we decided to model each context data as a  $\langle key, value \rangle$  pair. This requires an a priori definition of context information involved and their possible values but, at the same time, it simplifies the elaboration of those data and the implementation of context-based utility functions. To better understand the impact of CAMEO on real application scenarios, we describe in the next section an example of opportunistic MSN dedicated to tourists.

### III. TOURIST-MSN APPLICATION FOR OPPORTUNISTIC NETWORKS

In the era of Internet and Online Social Networks, tourists are even more autonomous in planning their trip and sharing their experiences on the Web after their visit. Tourist-MSN is designed to improve the touristic experience *during* the visit, anywhere and anytime, collecting and sharing useful information and content without requiring a stable Internet connection but simply establishing opportunistic communications with other users and their devices, both tourists or not. Let us consider a couple of people (Alice and Bob) visiting Rome; before leaving they planned to visit several attractions in few days trying to optimize their time. While they are moving around the city they encounter several people and other tourists that have just visited some of those attractions and with interesting and useful information (e.g., "At 3PM there was 2 hours queue to visit the Colosseum"). A context-aware dissemination of this kind of information can help Alice and Bob to re-schedule their visit, further optimizing their time. The same principle can be applied to other information like restaurants, museums, public transportations. For example, Charles had a dinner in a famous restaurant yesterday evening but the food was not very good and he decided to post that information

on his profile. Alice and Bob can declare their interest in collecting information about restaurants in the city to plan their dinner and while they are moving they encounter Charles. Even without a direct interaction among users, their devices exchange information related to interests and shared posts so that Alice and Bob can decide not to include that restaurant in their plan. In addition, a user could need to ask more information about a specific topic to other users even without directly knowing them. In this case the application can allow users to create a chat on a specific subject or to join an existing chat in order to obtain more detailed information in a quasi real-time fashion. Due to the nature of opportunistic networks, the management of a real-time chat can be developed only among 1-hop neighbors, while in case there are no strict delay constraints in the recovery of specific information, we can exploit the mechanism of asynchronous posts on the same topic to extend the request to all the interested users or those who can have that information. Therefore, Tourist-MSN is an opportunistic MSN application characterized by multiple contents: textual posts of users related to a specific location, attraction, service or topic; posts enhanced with pictures and/or videos to improve the user visualization of a content; chat discussions and related topics. These contents and their attributes, in addition to user's preferences and interests for this specific application, represent the Tourist-MSN context, which is further enriched with other information collected by CAMEO and related mainly to the user's profile (i.e., general information about the local user, her interests and habits) and the local device and its resources. In this specific application the elaboration of context information can provide the following optimized features: (i) identify users in the social context interested in a specific content, post or discussion; (ii) disseminate selected contents to interested users; (iii) generate ratings of available contents depending on the local user's interests; (iv) establish discussion forums with other users. In addition to these features, Tourist-MSN can evaluate through CAMEO the historical profile of the social context of each node to identify interesting contents for users that are not in the current physical neighborhood of the local node. In this way, in case the local device has enough resources, the application can implement a preventive download procedure by hosting on the local device some content, making them available to other nodes that could be encountered again in the next future. This represents an example of implementation of social-oriented policies for content dissemination in opportunistic networks [2].

#### IV. RELATED WORKS

Several context-aware frameworks have been proposed in literature but only few of them are designed for pervasive opportunistic environments and they do not provide a general architecture for the management and elaboration of multiple context components. In a previous work the authors proposed the implementation of the main concepts of context-

and social-awareness in the framework of FET-SAC Hagggle project, based on the definition of a data-centric event-driven architecture to support multiple services for opportunistic networks (from forwarding to resource management and heterogeneous connectivity) and applications. This architecture was completely layer-less. Each protocol exploited a Publish/Subscribe mechanism to register their interests in a specific event and to be notified when it occurs (e.g., new neighbor event, new resource available, application message request). In order to guarantee as much generality as possible in the definition of protocols, services and applications, Hagggle architecture provided general interactions among all its components. However, the excessive modularity of the software design resulted in a overload of internal messages that affected the scalability of the system in terms of number of involved nodes and number of concurrent services active inside Hagggle [2]. Another example of mobile system architecture for opportunistic networks is provided by [3] defining a middleware for opportunistic applications developed on top of Android 1.6. It is a preliminary solution implementing basic opportunistic networking services such as epidemic routing to allow multi-hop communication between nodes, not addressing context management issues.

Based on the lessons learned from previous works [4], [2], we decided to design and implement CAMEO as a light-weight and modular software architecture able to manage a multidimensional notion of context and addressing the requirements for an optimized and easy development of Mobile Social Networks applications.

#### V. DEMO HIGHLIGHTS

During this demo attendees will be able to run CAMEO and Tourist-MSN on Google Nexus One smartphones. The application will show the exchange of context information among neighbors, visualizing the list of neighbors and shared contents; users can create and disseminate posts, comments on pictures and create or join a chat to discuss about a specific topic. From the technical point of view, the demo will show the reliability of the system in case of intermittent connectivity and the implementation of multiple functionalities of both CAMEO and Tourist-MSN application.

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