Adaptive Data Distribution for Collaboration

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Abstract: This paper presents an adaptive data distribution model for mobile collaborative applications called *ADDOCO*. Its goal is to adapt the way data is disseminated in environments where Internet is not always available to create a collaboration network. In this kind of environments, ADDOCO allows to send and retrieve information that otherwise would be unavailable. The dynamic information dissemination model of *ADDOCO* was tested in a collaboration application using smartphones proving its utility to enhance the distribution of the required information.

1 INTRODUCTION

The increasing number of Internet-capable devices makes remote collaboration and data storage possible by enhancing the interaction with constant communication and the possibility of sharing resources and information. Storage services like iCloud, Dropbox, Box, Ubuntu One, etc. are internet based storage services that rely on the network to handle the information and the resources they manage. This kind of services allows the user the possibility of accessing his information and resources in any place at any time.

With the increase of mobile devices, these on-line services are an adequate solution for data storage and processing, overcoming some of the limitations mobile devices have. However, all of these services require an Internet connection to work properly. In a scenario where no Internet connection is available, a lot of the above mentioned services would be immediately affected by not being able to work correctly and most of them will need to wait for a new Internet connection available in order to work at all. Lack of Internet can be found in developing countries where Internet coverage is not as widespread as in other countries; even in developed countries in some conditions (e.g. high mountain roads, isolated places, etc.) might have no Internet connection whatsoever, diminishing the possibility of remote collaboration, even when the devices have technologies that make them capable of making a network of their own and collaborate. For example if there is a landslide in a mountain road where no mobile Internet is available, a network can be created with nearby smarthphone users in order to send information on the landslide, e.g. photos, location, number of injured people if any, etc. and get adequate help from nearby entities. There are tools that allow people to interact while being on a mobile environment and allow users to share information between them. However, these services rely on having an active Internet connection in order to be able to spread notifications among the users.

The requirement of having Internet independent collaborative networks motivates the creation of this work. This paper presents *ADDOCO*: an adaptive data distribution framework that supports collaborative mobile environments making a dynamic transition on the data dissemination method they use to communicate and allowing to change dynamically the entity that plays a role in a collaborative task. These dynamic properties are based on the context of the entities, taking into account their abilities, location, collaboration phases and other relevant contextual information. The structure of this paper is as follows: Section 2 describes some of the basic concepts around data dissemination; then Section 3 shows *ADDOCO*, a framework that considers user context and collaboration phase in order to dynamically disseminate data. Section 4 shows related works and their contribution to this work, afterwards Section 5 shows a prototype of *ADDOCO* and its functional evaluation. Finally, Section 6 shows the conclusions and future works.

2 PRELIMINARY CONCEPTS

In order to have an appropriate understanding of the problem context, the key elements involved in this

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work are introduced in this section.

Contextual information is the information that considers environmental elements, location description and interaction of people, among other characteristics, that help defining a complete scenario (Bellavista et al., 2013). Contextual information can be very wide and may take into account a lot of elements in order to correctly describe the particular scenario in which some action is taken. In this particular case, we restrain contextual information as a series of elements that are relevant to the scenarios in which the presented framework will be used, such as medical contexts, emergency management contexts, etc. There are mainly two contexts that are considered in this work: the Collaborative Context and the Mobile context.

The **Collaborative context** determines in a logical way the elements involved in a scenario. It includes the elements that will determine whether a person is available to collaborate and the different roles, which that particular person could assume during a collaborative scenario. For example, if a person is a medical doctor and its willing to collaborate during an accident, the collaboration context for that person will include that he is willing to assume the role of a doctor if it is required.

The **Mobile context** determines the involved elements in a physical way, this is, considering elements that can be interpreted as physical signals or data; for example, if there is any Internet connection available, the speed at which the user is moving, etc. Location is an important contextual element that is present in both Collaboration Context and Mobile Context. However, location is expressed differently in each context. In the Collaboration Context location will be represented as a Hierarchical Location, which describes location as a topology or symbolic place, e.g. a room X inside building Y (Prayogi et al., 2007)(Zhang et al., 2006). In the Mobile Context location is represented as a Cartesian Location which describes locations as a set of coordinates or GPS assisted geometric calculations e.g. 04 degrees 00' N and 63 degrees 00' W. Other important elements are Participants, which collaborate sending and receiving information and executing actions according to their knowledge and role.

It is important to notice that Participants are the main elements in the model because they are mobile entities that share and store information. Additionally, a Participant is able to act as a bridge between two participants. Each participant will have a set of roles that he is willing to assume.

For example, in the landslide scenario, if there were injured people and a doctor is quickly required, *Participant A* could look for the Doctor role in participants nearby. If a nearby *Participant B* has in his set of roles the Doctor role, then he will be asked to assume that role in healing the injured.

Each participant has relevant data that must be distributed; to achieve this different variables must be taken into account, such as, the availability of Internet connection and the location, both physical and logical. For example, in our landslide scenario, information about the time when the landslide occurred, the location where it happened and the number of injured people must be distributed to Participants to whom that information is relevant (e.g Firemen, Doctors, Road Safety Department, etc.)

Since these two variables are dynamic, this is, are prone to change rapidly, the data distribution method must also by dynamic. In order to address this issue, different data dissemination methods have been selected and are the basis of the dynamic transition of data distribution according to the context of the participants. For example, if in the landslide scenario, the accident occurred in a road and the people who are driving through that road do not know each other, the first step in the dissemination of data would be to ask if a required role is nearby. If, on the contrary, people already know each other along with role information, a communication protocol can be established and a dynamic communication protocol with a basic structure will be generated according to the scenario needs. There are different data dissemination models (Bellavista et al., 2013) that are used differently according to the requirements of the environment that uses them. Since a highly-dynamic environment is being evaluated, then dissemination methods must also be highly-dynamic.

Some of the data dissemination models are: i) Sensor Direct Access dissemination: Distributing the data directly to a specific place, ii) Flooding-Based dissemination: Distributing the data to a specific group, iii) Gossip-Based dissemination: Distributing data randomly among available nodes and iv) Selection Based dissemination: Distributing data creating a backbone of nodes.

The next section will present ADDOCO, a framework that dynamically changes data dissemination methods in mobile environments according to contextual information and available participants.

3 ADDOCO

Due to the requirements of data sharing in highly- dynamic environments, this is, mobile and distributed environments; ADDOCO is created as a framework that aids in the distribution of data between partici-

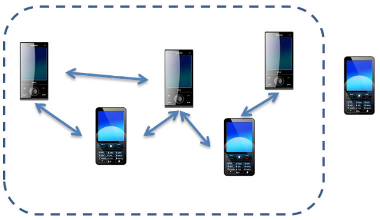

Figure 1: Smartphones creating a smartphone-network.

pants among a collaborative process. To achieve this, ADDOCO adapts, according to the context, the model used for data distribution between the participants involved in a collaboration.

3.1 Distribution Principle

When mobile devices are connected to the internet they can access on-line services that allow them to communicate, obtain and even process information. Some mobile devices nowadays are smartphones, defined as *"a mobile phone that can be used as a small computer"* by the Cambridge dictionary and are capable of doing a lot of data processing. Smartphones take more advantage of on-line services, by having synchronized contacts, configuration files, etc. Most of them have the ability to create networks between them in order to share information and communicate. It is possible to think in a smartphone network that would act like a small scale Internet, with smartphones providing services to other smartphones while communicating and sharing data. This capacity of making a network between them can be very useful when collaboration is required, but there is no Internet connection that allows smartphones to do so. In a scenario where no Internet is available the smartphones could create a network between them, with no guarantee that all of the smartphones connected to the internet will be inside the smartphone network due to technical restrictions like location, i.e. too far to be included in the network, or permissions, i.e. the device has not allowed smartphone networking, as seen in Figure 1. Within the smartphone network there may be smartphones that act as a bridge connecting two smartphones that are within its range, but not within the range of each other. For example, if three devices A,B and C are making a network and the device A needs to send some data to C, but C is out of range, then B, who is in range of both A and C will act as a bridge transmitting information between both A and C. This scenario is illustrated in Figure 2. Taking advantage of this possibility, different dissemination methods can be dynamically selected according to the context. For example, if a landslide occurs in a road where no internet access or mobile

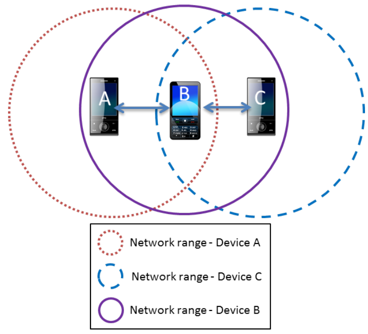

Figure 2: Smartphone Network Bridge.

network is available, someone affected by the landslide could start making a network with nearby drivers in order to send information on the landslide like pictures, location, if there were accidents, etc. In this scenario the device of the user will look for other devices and send information, either randomly to a group of those nearby users using gossip-based dissemination, or selecting a range to send to all users within that range using flooding-based dissemination. When a pattern has been established, the dissemination method changes to a selection based method, creating a backbone based on the interactions of each participant.

3.2 Dynamic Dissemination Process

In order to describe the dynamic dissemination process some basic concepts must be formally defined. A *Participant* has a physical *Location*. Note that the location here is represented as a Cartesian coordinate in order to be interpreted appropriately by the device. The *Participant* also has a set of *Permission* that allows him to request, obtain and manipulate *Data* within the device. It is important to remember that *Data* will be stored as closely as possible to the node that generated it. Therefore the *Data* modelled in this context is not a replicated copy of *Data* available someplace else, but represents the *Data* that a mobile device is responsible for creating, updating and disseminating. Note that the Mobile context also has a *Connection Status* component. This component has information regarding its environment, for example if the *Participant* is connected to a network, it must search within near devices in order to perform a collaborative task, and will aid in selecting the best dissemination method that a requested *Data* needs to follow in order to arrive at its destination.This contextual information is a key element used to dynamically adapt the dissemination method. The "dissemination service" algorithm is described in Algorithm 1. In this algorithm a directory is first used in order to obtain the *dataHolder*, this is, the entity responsible for hand-

Algorithm 1: *ADDOCO* Dissemination Process.

Require: Data requirements, Access Permissions specified, Max number of jumps.
Ensure: Data obtained or stored
1: nJump ⇐ Max number of jumps
2: **if** Directory is active **then**
3: dataHolder ⇐ **call** retrieveDataHolder **with** Task,Location,Role
4: **else**
5: **for all** Entity in nearEntities **do**
6: **if** Entity $\neq$ dataHolder and nJump > 0 **then**
7: dataHolder ⇐ **call** Dissemination Process **with** Entity,Task,Location,Role, (nJumps-1)
8: **end if**
9: **end for**
10: **end if**
11: **return** dataHolder

ling the data requested. A number of jumps are specified (1) in order to know how many neighbours must be queried to try to obtain the requested data. If there is an active *Directory* with the information of the data handler (2) the *dataHolder* is then acquired. If the Directory is not available then the query is made to near entities. If a near entity does not have the data, it will recursively ask its neighbours for the *dataHolder*, having one jump less than the original caller (7) until it reaches zero (6). The element *nearEntities* are dynamically located according to both contextual and collaborative information according to the messaging protocol if: a) the collaboration model relies on a centralized role and someone who plays that role is nearby, most likely a sensor direct access will be used. b) the collaboration model relies mainly on message or event interchange in a publisher-subscriber way, the selected dissemination method would be selection based. c) the collaborative model relies on roles, but there are not many entities that play the role in range a flooding based dissemination may be adequate, and d) There are some of the required roles nearby a gossip based dissemination could obtain the data.

3.3 ADDOCO Architecture

The main components of the architecture are described in Figure 3. The **BPMN parser** component is in charge of obtaining a BPMN model described in XPDL (XML Process Definition Language) and interpreting them so that both; the mobile context and the collaboration context obtain the data in their own terms in order to correctly execute the tasks described. The **Mobile Context Manager** component handles the data, location and connectivity capabilities and status of the mobile device. The Collaboration Context Manager manages all the elements related to the collaborative process such as the sequence of the tasks

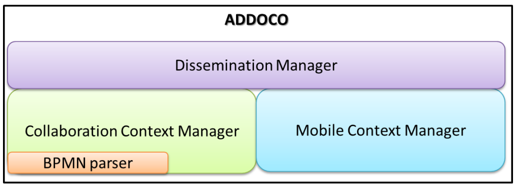

Figure 3: ADDOCO Architecture.

to be executed, the role that will perform each task, the abilities of each user, etc. This manager handles the dynamic role assignment in *ADDOCO*. The **Dissemination Manager** will take into account the information provided by both (the Mobile and Collaboration context managers) in order to determine the right dissemination model. This manager handles the dynamic dissemination in *ADDOCO*. A collaborative process using *ADDOCO* will start by defining the collaborative services involved in collaboration. This involves the definition of roles, their required abilities and the contextual elements that are going to be considered. After these basic components have been defined, a BPMN model is made in order to link those services and determine which role will execute them. The translation of a BPMN model into a collaborative service is not detailed due to the scope of this paper.

4 RELATED WORKS

This section presents an analysis of the main limitations of the architectures and frameworks related to the intention of *ADDOCOM*. MoCA (Sacramento et al., 2004) is an architecture oriented towards mobile collaboration, by communicating each node with another directly and obtaining information through a proxy. This architecture models effective collaboration architecture, but it does not define how data is managed and highly depends on the availability of the proxy for new interactions. Other solutions are distribution applications as Solar, (Chen et al., 2008) a middleware that aids in the creation of data-centred applications, by letting the program request data to the middleware and handles the data distribution for the application, storing and retrieving it using different distribution models. However, once a distribution model has been selected it distributes data in a specific way and it does not adapt according to the changing context of the application. There are also frameworks and middlewares for building collaborative applications that take into account the above mentioned concepts and act as a guideline for new or existing programs and determine how they distribute data. SALES (Corradi et al., 2010) is a middleware that aims to distribute information in a context-oriented mobile based application. The SALES model takes into account the individual context in each node and notifies others of the contextual information it handles. SALES aids in data distribution by reducing the weight of data transferred and the amount of data transmitted while at the same time increasing the relevance of the disseminated information. However, an algorithm for intelligently distributing data is yet to be done. Another work establishes a publisher - subscriber dissemination, which is a selection based dissemination method (Wu et al., 2010), between Vehicular Ad-Hoc Networks (VANETs). This project proposes the transmission of real time information on the traffic to surrounding vehicles while taking into account their behaviour order to predict their future location and whether the information is relevant or not. This work aids in disseminating traffic data but only as information to other vehicles and it cannot be applied to a complex collaboration scenario. Zimbra (Zimbra, 2011) is another collaborative application that provides real time information and aids in the management of schedules, tasks and calendars. Mobile collaboration in these applications is well managed, however, it depends on a server-side to obtain and manage the data required in order to function properly, being highly dependent on an Internet connection. The *ADDOCOM* framework considers dynamic roles of the users, their location and context information, takes into account collaboration models and has a Dynamic Data Dissemination method that adapts to the environment, addressing the data management requirements of a distributed mobile collaboration environment.

5 PROTOTYPE

In order to make tests of the *ADDOCO* model, a mobile prototype was made. This prototype aims to validate the usefulness of the collaboration model and how dynamic data dissemination may aid in obtaining the information required to collaborate in different environments and contexts. The selected devices for the test were Android powered devices running 2.3.3 version of the OS (Gingerbread) with no cellular data internet plan, with an initially active Wi-Fi connection to connect to an initial directory, and Bluetooth in order to make a collaboration network that tests the data dissemination model. The prototype first attempts a connection with a pre-established server in order to obtain the data and begins downloading it. If that server is unreachable, whether at the beginning of the process or the connection fails in the middle of the process, an alternate dissemination method will be selected using Bluetooth networks. If the connection with the directory fails the user will be notified that the connection has been lost and that nearby users are being queried for the information. A list of nearby users who have the requested information is displayed and the user selects one of the available devices.

Once a user selects a data source who will provide the information, the provider user's device will display a message with the request of information and additional data on the user who wants to obtain it. The provider user may accept or reject the request. If the request is accepted then the information will be provided to the user that requested it, if the request is rejected a message will show up in the requester's device informing that the connection could not be established.

6 CONCLUSIONS AND FUTURE WORK

The implementation of the *ADDOCO* model aims to take full advantage of Ad-Hoc networks in collaborative environments. Functional tests proved that collaboration is enhanced with *ADDOCO* by having dynamic methods for obtaining the data while being aware of the context, thus reducing the time of a potentially non-executable task. Bluetooth technology was used in order to make closed-range networks to adequately test the dissemination model; however, we found that this technology is not the best choice for making effective data dissemination and collaborative networks due to its restrictions and characteristics. However, it shed light in how the functionality of a smartphone network could work and the effectiveness of the collaboration and data distribution model of *ADDOCO*. As a future work the prototype is going to be enhanced in order to work in more complex collaborative tasks, taking into account not only the connection status but also the specific location of the user and making possible the execution of parallel tasks. Additionally, *ADDOCO* will make use of an emerging technology called Wi-Fi Direct™(WiFi, 2011) in order to overcome technical drawbacks seen during the use of Bluetooth technology in this context. The Wi-Fi Direct technology will be supported by Android 4.0 (Ice Cream Sandwich) and due to the implementation of the prototype using the Android SDK *ADDOCO*'s prototype will most likely adopt this technology in a near future for further tests and improved functionality.

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