Project-Team CASA

Disruption-Tolerant Networking and Computing

Vannes

Activity Report

2014

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2 Overall Objectives

2.1 Overview

Keywords: ambient, pervasive, ubiquitous, computing, delay-tolerant, disruption-tolerant, opportunistic, networking.

The research activity of team CASA aims at supporting communication and service provision in challenged environments, and most notably in partially or intermittently connected networks. A network can become disconnected when, for example, the nodes that compose this network are not always up and running, or when transmission links between these nodes are not always available. The whole network can then appear as a non-connected dynamic graph, whose topology changes continuously as nodes and links get up and down. Communication between nodes that belong to a connected fragment (a.k.a. an "island") of the network is possible, but no temporaneous end-to-end communication is possible between nodes that reside on distinct islands.

Delay/Disruption-Tolerant Networking (DTN) is an approach that can help in such conditions [Fal04]. With this approach a message can be stored temporarily on a node, in order to be forwarded later by this node when circumstances permit. This *store-and-forward* mechanism is actually the foundation of DTN.

[1] UBS: Université de Bretagne-Sud

[Fal04] K. FALL, "Messaging in Difficult Environments", *research report*, Intel Research Berkeley, 2004.

In team CASA we mostly focus on mobile ad hoc networks (MANETs), and investigate how the DTN approach can help support communication and services when such networks are disconnected. Indeed, in a disconnected mobile network, mobility can be considered as an advantage as it makes it possible for messages to propagate network-wide, using mobile nodes as carriers that can move between remote fragments of the network. In the literature the term *Opportunistic Networking* is often used to denote solutions that apply this *store-carry-and-forward* principle in disconnected MANETs (or D-MANETs), for radio contacts between mobiles nodes are often non-predictable and must thus be exploited opportunistically [PPC06b].

Part of our activity in team CASA consists in designing opportunistic routing protocols for D-MANETs, and implementing these protocols in communication middleware so they can be tested in real conditions. We also investigate how distributed applications can be designed and implemented for networks whose characteristics keep changing spontaneously and unpredictably. Indeed, designing distributed applications that require network-wide communication and coordination in an opportunistic network is quite a challenge, when communication and coordination depend on unpredicted pairwise contacts between neighbor nodes. The term *Opportunistic Computing* has been introduced recently in the literature in order to refer to a new computing paradigm that relies exclusively on such pairwise contacts [CGMP10]. Team CASA strives to contribute to the development of this computing paradigm by designing methods, models, and middleware tools that make it easier for programmers to tackle the challenges presented by opportunistic networks.

3 Scientific Foundations

3.1 Opportunistic Communication in Disconnected Mobile Ad hoc Networks

A Mobile Ad hoc NETwork (or MANET for short) is a network that is composed of a number of mobile digital devices featuring interfaces for short-range wireless transmissions (such as Wi-Fi, Bluetooth, or ZigBee interfaces). Each device can communicate directly with other devices, provided these devices are within its transmission range.

During the last two decades the mainstream research activity on mobile ad hoc networking has mostly aimed at achieving dynamic routing between mobile devices [BKP02,RT99]. Most of the proposals designed along this line rely on the assumption that communication between two devices in a network is possible only if a temporaneous end-to-end transmission route can be established (using multi-hop forwarding if necessary) between them whenever needed. Yet it is now widely admitted that this hypothesis about continuous end-to-end connectivity in a MANET is somewhat contrived. Many real MANETs are actually either partially or intermittently connected, and routing protocols that as-

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[PPC06b] L. PELUSI, A. PASSARELLA, M. CONTI, "Opportunistic Networking: Data Forwarding in Disconnected Mobile Ad Hoc Networks", *IEEE Communications Magazine*, nov 2006.

[CGMP10] M. CONTI, S. GIORDANO, M. MAY, A. PASSARELLA, "From Opportunistic Networks to Opportunistic Computing", *IEEE Communications Magazine 48*, 9, September 2010, p. 126–139.

[BKP02] C. BASILE, M.-O. KILLIJIAN, D. POWELL, "A Survey of Dependability Issues in Mobile Wireless Networks", *Technical report number 02637*, LAAS CNRS Toulouse, France, oct 2002.

[RT99] E. M. ROYER, C.-K. TOH, "A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks", *IEEE Personal Communications*, April 1999, p. 46–55.

sume continuous connectivity cannot perform satisfactorily in such conditions [NG09,PPC06a]. Specific protocols must thus be designed for disconnected MANETs (a.k.a. D-MANETs), and these protocols must opportunistically exploit transient unpredicted contacts between mobile nodes.

Team CASA has thus designed and tested several opportunistic protocols over the last years, exploring different kinds of forwarding algorithms in these protocols (content-based epidemic forwarding, location-based routing, service-oriented routing, etc.). The last results obtained by the team are presented in Section 6.

3.2 Opportunistic Computing in Disconnected Mobile Ad hoc Networks

Opportunistic computing is an emerging paradigm that builds on the results of several research areas (including autonomic computing and social networking), moving forward from simple communication to develop a framework to enable collaborative computing tasks in networking environments where long disconnections and network partitions are the rule [CGMP10].

Service-oriented applications seem well suited for ambient computing environments in general, and for MANETs –and especially disconnected MANETs– in particular. Building applications based on software services is now well mastered and supported by many techniques and tools, among which the most popular Web Services. Moreover this approach fosters decoupling between interacting applicative entities. It should therefore accommodate well with the connectivity constraints of disconnected MANETs. Indeed, a significant amount of research work has been produced in recent years on middleware solutions for service provision in MANETs. Nevertheless, most of them consider only connected MANETs and focus on the performance of service discovery. Providing support for service-oriented applications poses specific problems in disconnected MANETs. The main challenge is to cope with the absence of end-to-end connectivity guaranty brought upon by the continuous fragmentation of the network into several communication islands, which impacts not only on service discovery but also on service invocation.

Beside service-oriented computing, other computing paradigms have long proved useful for designing distributed applications. Group communication, publish-subscribe systems, message queues, tuple spaces, are thus abstractions or systems for which efficient implementations are available in software development kits. Yet most of these implementations have been realized for traditional, connected environments. They cannot operate satisfactorily in partially or intermittently connected environments, and must be completely revised in order to tolerate network partitions, transmission disruptions, or long transmission delays.

4 Application Domains

4.1 Overview

The research work carried out in team CASA is focused on the design and the implementation of middleware support for applications targeting challenged networking environments. We are particulary

[NG09] H. A. NGUYEN, S. GIORDANO, "Routing in Opportunistic Networks", *International Journal of Ambient Computing and Intelligence (IJACI) 1*, 3, 2009, p. 19–38.

[PPC06a] L. PELUSI, A. PASSARELLA, M. CONTI, "Beyond MANETs: dissertation on Opportunistic Networking", *research report*, IIT-CNR, aug 2006.

interested in providing support for mobility and continuity of service, even in the absence of any stable communication infrastructure. This applies to multiple environments where adaptive and cooperative applications are required, but where cost or technical constraints preclude the deployment of stable computing and communication resources. Possible application domains are:

- Collaborative computing in crisis operation fields (e.g., military operations, disaster relief situations);
- Sensor and actuator networking, as part of the Web of Things[2] (e.g., environment monitoring, robot/drone control);
- Automotive computing (e.g., vehicle-to-vehicle and vehicle-to-roadside communication);
- Home automation (e.g., pervasive multimedia, general purpose applications);
- Nomadic computing (e.g., coordination and data sharing in remote areas);
- Personal communication systems (e.g., group communication, social interactions);
- Mobile health (e.g., ambulatory patient monitoring).

To date the activities conducted in team CASA already cover most of these application domains. For example the communication among vehicles in challenged conditions is currently addressed in project Ship2Ship (see Section 7.1), though in that case the "vehicles" are racing sailboats. The problem of controlling mobile robots remotely through intermittent transmission links is considered in project ASAWoO (see Section 7.2). Data sharing among people during social events such as cultural or sports events is addressed in project C3PO (see Section 7.3). The development of a service architecture for tactical (i.e. military) networks is the main goal of project TACTICS (see Section 7.4). Monitoring the health status of people wearing biometric sensors during their daily activities is addressed in project SHERPAM (see Section 7.5).

The middleware systems developed in team CASA in the recent years can also be considered as enablers for the above-mentioned application domains. For example the DoDWAN platform can support the communications in opportunistic networks, while middleware systems such as JOMS, JION, and ADAM can help develop distributed applications for such networks (see Section 5).

5 Software

5.1 DoDWAN

Keywords: opportunistic, content-based, epidemic, networking, middleware.

DoDWAN[3] is a flexible Java-based middleware platform that has been developed in team CASA in order to support content-based, disruption-tolerant communication in disconnected MANETs. It is distributed under the GNU General Public License (GPL)[4].

[2] Or, more generally, the Internet of Things (IoT).
[3] DoDWAN stands for "Document Dissemination in Wireless Ad hoc Networks".
[4] http://www.irisa.fr/casa/dodwan

In content-based networking, information flows towards interested receivers rather than towards specifically set destinations. This approach notably fits the needs of applications and services dedicated to information sharing or event distribution. It can also be used for destination-driven message forwarding, though, considering that destination-driven forwarding is simply a particular case of content-driven forwarding where the only significant parameter for message processing is the identifier of the destination host (or user).

DoDWAN implements a selective version of the epidemic routing model proposed in [VB00]. It provides application services with a publish/subscribe API. When a message is published on a host, it is simply put in the local cache maintained on this host. Afterwards each radio contact with another host is an opportunity for the DoDWAN system to transfer a copy of the message to that host. In order to receive messages an application service must subscribe with DoDWAN and provide a *selection pattern* that characterizes the kind of messages it would like to receive. The selection patterns specified by all local application services running on the same host define this host's *interest profile*. DoDWAN uses this profile to determine which messages should be exchanged whenever a radio contact is established between two hosts. As a general rule, a mobile host that defines a specific interest profile is expected to serve as a mobile carrier for all messages that match this profile. Yet a host can also be configured so as to serve as an altruistic carrier for messages that present no interest to the application services it runs locally. This behavior is optional, though, and it must be enabled explicitly by setting DoDWAN's configuration parameters accordingly. Details about this interaction scheme and about how it performs in real conditions can be found in [11].

A suite of applications suitable for disconnected MANETs has been developed on top of the DoDWAN middleware system. This suite is called DoDWAN-Apps, and it is available for laptops and netbooks running Linux or Windows, as well as for Android smartphones. DoDWAN-Apps is meant to be a fully-functional demonstrator of the concept of opportunistic ad hoc networking. With a mobile device running DoDWAN-Apps a user can for example locate other users in the neighborhood and exchange text messages, voice messages, or files with any other user or group of users.

DoDWAN and DoDWAN-Apps have been tested and demonstrated on several occasions during the past years. They have notably been used in a military tactical network, using VHF battlefield radios with built-in modems, and proved very robust and reliable in such harsh conditions [10]. Field experiments have also been conducted during the 4th and 5th occurrences of the Extreme Conference on Communication, which took place in the Swiss Alps[5] and in Iceland[6] respectively. During these experiments volunteers were equipped with Android smartphones running DoDWAN-Apps, which allowed them to communicate together while trekking in remote areas not covered by GSM/UMTS cell networks.

Recent developments concerning the DoDWAN platform are discussed in Section 5.1.

5.2 JOMS

Keywords: opportunistic, computing, message, service, middleware.

[5]http://www.extremecom.org/2012
[6]http://www.extremecom.org/2013

[VB00] A. VAHDAT, D. BECKER, "Epidemic Routing for Partially Connected Ad Hoc Networks", *research report*, Duke University, April 2000.

JOMS (Java Opportunistic Message Service) is an opportunisitc message-oriented middleware system that has been designed in order to operate in partially or intermittently connected ad hoc networks [1, 2]. JOMS is actually a provider for the standard Java Message Service (JMS), so distributed applications using JMS message queues and topics can be deployed and executed in challenged networking environments. An opportunistic, content-driven communication model (based on DoDWAN) is used to enable message forwarding in such networks, using mobile hosts as carriers that allow messages to propagate network-wide.

JOMS is distributed under the terms of the GNU General Public License[7].

5.3 JION

Keywords: opportunistic, computing, tuple-space, JavaSpace, middleware.

The concept of tuple space is interesting for both communication and coordination in distributed applications, and the JavaSpaces technology provides a functional implementation of this concept for Java applications. Yet most current JavaSpaces implementations are server-based systems. Since no host in an opportunistic network can be considered as stable and accessible enough to play the role of a server for all other hosts, a server-less implementation of the JavaSpaces specification is required for applications targeting opportunistic networks.

JION (JavaSpaces Implementation for Opportunistic Networks) has been designed and implemented along that line. It provides a fully-distributed, peer-to-peer JavaSpaces implementation, while tolerating transmission disruptions and delays [3, 4]. It is distributed under the terms of the GNU General Public License[8].

5.4 ADAM

Keywords: opportunistic, computing, distributed consensus, One-Third Rule algorithm.

The One-Third Rule (OTR) algorithm is an elegant solution to solve consensus in networks where message loss can occur [CBS09]. Being based on the Heard-Of (HO) model, it is well suited to support transient process and link faults, which makes it an ideal solution to solve consensus in opportunistic networks.

ADAM is a middleware system that combines an implementation of the One-Third Rule (OTR) algorithm with our communication system DoDWAN, which supports network-wide, content-driven message dissemination based on controlled epidemic routing. Experimental results obtained with a small flotilla of smartphones have confirmed that this system is effective at solving consensus problems in an opportunistic network [4]. ADAM is distributed under the terms of the GNU General Public License[9]. Further details about ADAM are available in Section 6.3.

[7]http://www.irisa.fr/casa/joms
[8]http://www.irisa.fr/casa/jion
[9]http://www.irisa.fr/casa/adam

[CBS09] B. Charron-Bost, A. Schiper, "The Heard-Of Model: Computing in Distributed Systems with Benign Faults", *Distributed Computing 22*, 1, 2009, p. 49–71.

5.5 FelixDroid

Keywords: service-oriented, computing, OSGi, Android.

FelixDroid is an Android-embedded version of Felix OSGi Felix Apache framework, an open-source implementation of the OSGi specification. FelixDroid is also a framework dedicated to the development and the execution of OSGi graphical applications in Android. It provides graphical tools in order to manage the OSGi Felix framework (management of the bundle repositories, deployment and management of bundles, etc.). FelixDroid is distributed under the terms of the CeCiLL licence[10]. It is currently used by several companies (Bull, Orange Business Services, SOGETI High Tech, Proxym-it, DEV1.0...) and academic teams (Université de Valenciennes, École des Mines d'Ales, Carnegie Mellon University, ETH Zürich, TU-Berlin...).

5.6 Ship2Ship

Keywords: disruption-tolerant, wireless transmission, navigation data, sailboat.

Ship2Ship is a Java-based application dedicated to professional sailing teams during training sessions. It enables the real-time visualization of navigational data from neighbor ships. Its helps sailors to compare quantitatively their tuning choices, and coaches to apply pertinent judgement. It aims at replacing post-mortem analysis tools used during debriefing sessions, when navigational data of competing sailboats are replayed and synchronized. Ship2Ship ensures that the data stream received from the local navigation central is broadcast wirelessly to other ships. Conversely, data received from other ships are relayed to the skipper's laptop. The transmission protocol is fully disruption-tolerant, as the distance between ships varies continuously and transmission links depend on sea state. The graphical user interface allows a skipper to select the neighbor ship from which data should be received and displayed on the navigational software. Ship2Ship can operate over the 868 MHz or 2.4 GHz ISM bands.

6 New Results

6.1 Protocols for Intermittenly Connected Hybrid Networks

Keywords: opportunistic, disruption-tolerant, protocols.

Participants: M. Auzias (PhD student), A. Esnault (PhD student), A. Makke (PhD student), Y. Mahéo, N. Le Sommer, F. Guidec.

Team CASA develops opportunistic protocols for different kinds of partially and intermittently connected networks.

Besides disconnected MANETs, that are only composed of mobile nodes, an interesting class of networks is one that combines fixed infostations and mobile nodes. In such an ICHN (Intermittently Connected Hybrid Network), infostations may be directly connected with one another, although that is not an obligation. An ICHN can actually be viewed as an extension of an already existing infrastructure

[10] http://www.irisa.fr/casa/felixdroid

network, including mobile nodes that are not always in range of an infostation but that can however benefit from services deployed on this infostation thanks to opportunistic networking techniques.

Team CASA worked on a middleware system called TAO, dedicated to service provisioning in ICHNs. This system includes protocols for service discovery and service invocation whose originality lies in the fact that their design strives to exploit the request-response pattern of communication induced by invocations, as well as the fact that an ICHN includes not only intermittently connected mobile clients but also fixed infostations that host service providers. This is achieved mainly thanks to a simple heuristic that exploits the last date of contact between a mobile device and an infostation. Simulation experiments based in particular on real mobility traces data showed that TAO is able to guarantee good performance with limited overhead [14, 15].

For billions of people, mobile phones have become essential communication means to produce and share multimedia contents (photos, videos, texts). Most current sharing solutions rely on centralized online solutions, requiring a permanent Internet connectivity, with the consequence of increasing –and sometimes of overloading– the networks of mobile operators. In order to relieve these networks and to provide end-users with a better quality of service, we have defined and implemented a middleware platform, called Nephila, which supports communications and data offloading in wide intermittently-connected hybrid networks, using a peer-to-peer approach [5, 6]. Such networks combine of an infrastructure part that relies on fixed equipments with intermittently or partially connected parts formed by mobile devices. Nephila performs a proactive discovery of fixed and mobile nodes. . Based on this neighbor discovery process, Nephila creates and maintains logical links between fixed devices so as to form a backbone. This backbone helps cover a wide area and support communications between remote mobile devices. The scalability of our system results from the existence of this backbone. Nephila allows each node to compute a list of so-called ”trail values” and to share these values with its neighbors. A trail value computed by a node for a given destination reflects its capacity to forward a message to this destination, either directly or through intermediate nodes. Trail values are meant to be used by a forwarding algorithm in order to select, for each message, the most relevant next forwarder(s). The trail values are efficiently stored and disseminated the trail values of each node in the overlay system using a modified version of the Exponential Decay Bloom Filter, we called Trail Bloom Filter (TBF). Nephila implements a message forwarding algorithm called BTSA (for Best Trail Selection Algorithm). This algorithm uses the transitive property of the TBFs and promotes, while forwarding a message, the nodes that met the destination of the message the most recently. Nephila also implements an anycast communication model and a network healing mechanism in order to improve data exchange with remote hosts accessible through standard access points.

6.2 Content-based data dissemination in opportunistic networks

Keywords: content-based, disruption-tolerant, opportunistic.

Participants: F. Guidec, Y. Mahéo, P. Launay.

DoDWAN is a flexible Java-based middleware platform that supports content-based, disruption-tolerant communication in opportunistic networks (see also Section 5.1). Although this platform has been developed a few years ago, it has been improved continuously since then. Recent improvements include the ability for mobile devices running DoDWAN to switch between several modes of operation depending on their context and on user preferences. A mobile device that belongs to a Wi-Fi ad hoc network can thus operate in "direct" mode in order to interact directly with its neighbors. This mode is also operational when a mobile device is associated with a Wi-Fi access point, since all other devices that are associated with the same access point are then considered as being "neighbors". Another possible mode of operation is to rely on a "hub", which is a software system running on a server whose role is to help mobile devices get in touch with one another. The "hub" can operate either as a simple directory or as a full repeater. In the first case, the mobile devices rely on the hub to locate each other, but the gossiping between mobile devices still relies on direct pair-wise links between them. In the second case all transmissions between mobile devices go through the "hub". Communications in "direct" mode allows mobile devices to share data withouth depending on any server whatsovever, but to do so they have to be located in the same area. Conversely, mobile devices running in "hub" mode can share data even if they are far from one another, but connectivity (at least intermittent connectivity) to the "hub" is required.

In order to complement the DoDWAN platform, the development of a mobility simulator has been initiated in 2014. This simulator is called MobSim. It has been specifically designed to run as a back-end of the above-mentioned "hub" software. Upon receiving a message from a DoDWAN node, the "hub" then relies on the simulator to decide which other DoDWAN nodes are in a position to receive this message. This combination of the "hub" with MobSim makes it possible to demonstrate DoDWAN and DoDWAN-Apps, even when all the devices used for the demonstration are not moving for real (typically when a dozen of smartphones or tablets are used in a demonstration room). It also makes it possible to check the scalability of distributed algorithms using DoDWAN, since hundreds or thousands of programs based on DoDWAN can be started on the same workstation, while the simulator orchestrates the transmissions between these programs according to a given mobility model.

To date the DoDWAN platform can use Wi-Fi transmissions (in ad hoc or in managed mode), as well as 3G/4G transmissions. In the near future it shall also be able to use Bluetooth and XBee transmissions, and the support for Wi-Fi transmissions shall be extended so DoDWAN-enabled devices can share data in piconets based on Soft AP or Wi-Fi Direct.

6.3 Middleware Support for Opportunistic Computing

Keywords: middleware, opportunistic, computing.

Participants: A. Benchi (PhD student), P. Launay, F. Guidec.

Designing and implementing distributed applications capable of running satisfactorily in opportunistic networks is quite a challenge. The peer-to-peer model should generally be preferred over the client-server model, because in many opportunistic networks no host can be considered as stable and accessible enough to play the role of a server for all other hosts. Additionally, any distributed application running in an opportunistic network must obviously be able to tolerate long transmission delays, and occasional transmission failures as well.

The concept of middleware has long proved efficient in easing the development of distributed applications for traditional wired networks. It can be expected that carefully designed middleware systems might bring similar benefits for opportunistic networks.

Developers need to be able to rely on well-known distributed computing abstractions when designing applications for challenged networks. Yet standard implementations for message queues, tuple spaces, etc. can hardly run satisfactorily in opportunistic networks, as they have originally been designed to operate in resilient connected networks. Members of team CASA are thus revisiting these "standards" in order to provide new implementations that can tolerate network partitions, long transmission delays, and transmission failures.

An opportunistic middleware system called JOMS (Java Opportunistic Message Service) has been designed in order to support message queues and topics in opportunistic networks [1]. Likewise, JION (JavaSpaces Implementation for Opportunistic Networks) is a middleware system that implements the concept of tuple space in opportunistic networks [3, 4].

Solving consensus is a key requirement in many distributed applications. Yet most traditional consensus protocols implicitly assume continuous network-wide end-to-end connectivity, and the absence of crash failures. Such assumptions hardly hold in an opportunistic network, so solving consensus becomes a real challenge in such conditions. ADAM (Agreement in Disconnected Ad hoc Mobile networks) is a middleware system we designed and implemented in order to support consensus solving in an opportunistic network. This system combines an implementation of the One-Third Rule (OTR) algorithm [CBS09] with an opportunistic communication layer that relies on DoDWAN. Experiments have been conducted with a small flotilla of smartphones in order to validate the system [4]. Further experiments are now under way using a simulator in order to check the scalability of the OTR algorithm when running in an opportunistic network involving hundreds of mobile nodes.

JOMS, JION, and ADAM have all been tested experimentally in real mobile networks, and they are all distributed under the GNU General Public License (see Section 5).

6.4 Disruption-Tolerant Biometric Sensors for Health Monitoring

Keywords: mHealth, mobile, health, disruption-tolerant, biometric, wireless sensors.

Participants: D. Benferhat (PhD student), M. Bagot (engineer), P. Launay, F. Guidec.

The concept of Wireless Biomedical Sensor Network (WBSN) opens up new opportunities for biomedical monitoring, such as the long-term, continuous monitoring of patients in a clinical environment or at home. In team CASA we investigate the possibility of using the DTN (Delay/Disruption Tolerant Networking) approach as a means to tolerate transmission disruptions between sensors worn by highly mobile people in outdoor conditions, and a remote monitoring center.

In recent work we investigated the possibility of monitoring the cardiac activity of runners during a marathon race, using a limited number of base stations deployed along the marathon route. In such a scenario base stations provide a sparse coverage of the route, so cardiac sensors worn by runners must record data continuously during the race, and use episodic contacts with roadside base stations to upload data to the monitoring center. This work was conducted as part of Djamel Benferhat's PhD thesis, which was defended in October 2013 [7]. Besides marathon runners, we also considered the problem of monitoring the health of non-hospitalized subjects during their daily activity. Preliminary field experiments were conducted in order to demonstrate that this kind of monitoring can indeed be performed using Wi-Fi community hotspots for opportunistic data uploading [2]. This option for data

[CBS09] B. CHARRON-BOST, A. SCHIPER, "The Heard-Of Model: Computing in Distributed Systems with Benign Faults", *Distributed Computing 22*, 1, 2009, p. 49–71.

transmission is now investigated further in the framework of project SHERPAM (see Section 7.5), whose goal is to design, implement, and evaluate a full-featured monitoring system for biophysical data acquisition and transmission in e-Health applications.

6.5 Disruption-Tolerant Transmission of Navigation Data between Racing Sailboats

Keywords: disruption-tolerant, wireless transmission, navigation data, sailboat, ship.

Participants: F. Raimbault, N. Le Sommer, F. Guidec.

In project Ship2Ship (see Section 7.1) we investigate the possibilities offered by disruption-tolerant ad hoc networking to support the transmission of navigation data between racing sailboats during training sessions.

A prototype system has been developed by team CASA, and it has been tested in 2013 on one-design IMOCA and Figaro class sailboats [11]. This first prototype was implemented as a sealed box connected to a marine Wi-Fi antenna. The box contained a Raspberry-Pi, credit-card sized computer with a Wi-Fi dongle. The marine antenna was used for ship-to-ship transmissions, and the dongle for inboard transmissions between the micro-PC and the skipper's laptop.

Several options have been investigated during the past year, among others different radio technologies. The results of our experiments at sea led us to replace our embedded system by a fully software system, and to use Xbee transmissions (in the 868 MHz ISM band) rather than Wi-Fi transmissions (in the 2.4 GHz ISM band). This new version of Ship2Ship runs on the in-board laptop, which is connected to the antenna mast thanks to a USB XBee radio module. This solution allows transmissions on a longer range, and it eases the installation on board.

6.6 Middleware Support for the Web of Things

Keywords: Internet of Things, Web of Things, opportunistic computing, disruption-tolerant networking.

Participants: M. Auzias (PhD student), N. Le Sommer, Y.Mahéo, F. Raimbault.

The number and types of connected objects increases quickly. These objects are heterogeneous and are rarely able to communicate with each other as they do not share the same communication protocols, same business model representations (aka interfaces) or abstraction levels. Moreover, objects are usually designed to process basic requests using their sensors and actuators. The "Web of Things" (WoT) extends the Internet of Things so that physical objects can be accessed and controlled using Web standards. To do so, objects are expected to expose logical interfaces through Web services, to describe Web contents and services using semantic Web languages and annotations, and to communicate together through standard protocols in order to provide software interoperability between objects.

In project ASAWoO (see Section 7.2), we promote the concept of avatar as a new virtual abstraction to extend physical objects on the Web **[3, 8]**. Avatars rely on Web languages and protocols, and perform reasoning on semantic annotations, in order to dynamically drive connected objects, exploit

[11] IMOCA Class sailboats are 60-foot open mono-hulls used in ocean races. Figaro class is the famous one-design 33 footer designed for the "Solitaire du Figaro" race.

their capabilities and expose user-understandable functionalities as Web services. Avatars are also able to collaborate together in order to achieve complex tasks. We have developed an avatar platform as an extensible and distributed runtime environment endowed with an autonomous behaviour. It is currently implemented as an OSGi service-oriented architecture, that partially rely on the OM2M open-source platform[12]. OM2M is a RESTful implementation of the ETSI M2M standard [13]. According to the resources offered by the physical objects, this avatar platform can either be fully deployed on the object itself, or be distributed both on the object and a cloud infrastructure. The avatar platform allows to expose the functionalities and the capacities of the object dynamically using Web standards. These functionalities and capacities can be used by other avatars for collaboration purposes or by end-users in order to interact with the physical object.

The CoAP protocol is one of the current major protocols that support the WoT. It advocates a REST architectural style and is tailored for small devices and lossy communication links. CoAP exploits a compact message format, allows multicast communication, and provides a thin control layer for reliability and message deduplication. The intended underlying transport layer is UDP, and the main implementations of CoAP are indeed based on UDP. Although CoAP/UDP can bear long disruptions between clients and servers, it still assumes end-to-end communication links and is therefore not suited for DTN and opportunistic networks. We investigate the necessary adaptations of this protocol to the context of opportunistic computing. We perfomed several modifications to an existing CoAP implementation (Californium) and developed a new partial implementation in order to leverage on DTN protocols (IBR-DTN and DoDWAN).

6.7 Spontaneous and Ephemeral Social Networking

Keywords: opportunistic computing, social networking, multimedia content sharing, participatory and spontaneous micro-journalism.

Participants: F. Baklouti (PhD student), M.-A. Ghorbali (engineer), F. Guidec, P. Launay, N. Le Sommer, Y. Mahéo.

Online social networks have been adopted by a large part of the population, and have become in few years essential communication means and a source of information for journalists. Nevertheless, these networks have some drawbacks that make people reluctant to use them, such as the impossibility to claim for ownership of data and to avoid commercial analysis of them, or the absence of collaborative tools to produce multimedia contents with a real editorial value. To address these issues, we have defined a new kind of social networks, namely spontaneous and ephemeral social networks (SESNs) [7]. This work is conducted in the framework of project C3PO (see Section 7.3).

SESNs rely on a peer-to-peer distributed architecture formed spontaneously by mobile devices carried by people and by devices deployed for a particular occasion to support such networks. In these networks, devices opportunistically communicate with each others thanks to wireless interfaces such as Wi-Fi or Bluetooth. Due to their spontaneous and ephemeral nature, SESNs are suited to produce multimedia reports on sport or cultural events in a collaborative way. SESNs are expected to favor the emergence of a participatory micro-journalism. To do so, people are linked together for the duration

[12] `http://eclipse.org/om2m/`

[13] `http://www.etsi.org/technologies-clusters/technologies/m2m`

of the event, and each member of a SESN is expected to offer a set of resources and services (e.g., data sharing service, bib recognition service) to the other members. Members are provided with tools exploiting these data and services, and allowing them to collaborate on the production of multimedia reports. These data and reports are replicated on remote servers in order to ensure their lasting and their large diffusion after the end of the event. The multimedia contents produced by the SESN members are exchanged opportunistically and can be recommended by these members in order to ease the filtering and the retrieving of relevant contents. A SESN also provides mechanisms to incite users to share their own productions.

A prototype dedicated to the reporting and the promotion of sport events is currently under development. The objective is to experiment this prototype in real situations, and to have a feedback in order to improve it, and to show how SESNs can contribute to support the micro journalism of the future.

7 Contracts and Grants with Industry

7.1 Project Ship2Ship (2013-*)

Project Ship2Ship involves the "Pôle Finistère Course au Large" (PFCL), the Adrena company, and team CASA. The objective is to design, implement and validate a data transmission system allowing navigation data to be exchanged between racing sail-boats during training sessions, so skippers can compare their tactical choices and the settings of their riggings. In 2013 a prototype system has been developed by team CASA and tested on IMOCA sailboats and Figaro Class sailboats. During year 2014, several software and hardware solutions have been investigated, and the last version of Ship2Ship is currently in a technology transfer phase.

7.2 Project ASAWoO (2014-2017)

Project ASAWoO *(Adaptive Supervision of Avatar/Object Links for the Web of Objects)* has been accepted by ANR in the framework of programme INFRA 2013, to be funded from 2014 to 2017. Besides team CASA this project involves team AVALON at LIP (Lyon 1), teams DRIM and SOC at LIRIS (Lyon 1), team COSY at LCIS (Univ. Pierre Mendès-France), and company Génération Robots (Lyon). This project addresses the domain of the Web of objects. The objective is to improve the integration of connected objects in the Web. A software platform shall be developped, that will facilitate the communication and control of connected objects, as well as the cooperation of several such objects. This platform will benefit from advances in complementary disciplines, such as semantic Web for knowledge processing, service-oriented architectures for interoperability and scalability, context-aware computing for situation-driven multi-level decision making, multi-agent systems for autonomous cooperation between objects, delay/disruption-tolerant networking for communication, and cloud technology for reduced power consumption.

7.3 Project C3PO (2014-2016)

Project C3PO *(Collaborative Creation of Contents and Publishing using Opportunistic networks)* has been accepted by ANR in the framework of programme CONTINT 2013, to be funded from 2014 to 2016. Besides team CASA this project involves team INRIA/DICE (Lyon), team SATIN at LT2C

(Saint-Étienne), team SSG at LEMNA (Nantes), and company ChronoCourse (Vannes). The objective of this project is to support so-called "Spontaneous and Ephemeral Social Networks" (SESNs), based on a peer-to-peer distributed architecture and on mobile ad hoc networks. A SESN is meant to allow nomadic people to interact according to their affinities and centers of interest, so they can cooperate to perform specific tasks within a SESN. Several application domains are considered for SESNs, such as the collection of data and the production of digital content during cultural or sports events. The contents thus produced shall be accessible from the users' mobile terminals, and be replicated on dedicated servers or in traditional social networks so they can also be accessed by remote users, and remain accessible beyond the lifetime of a SESN.

7.4 Project TACTICS (2014-2017)

Project TACTICS *(TACTICal Service oriented architecture)* is a project of the European Defence Agency (EDA), whose objective is to define and validate a service infrastructure to be used by armed forces for tactical communication. This infrastrucure shall be efficient, safe, and tolerate connectivity disruptions. This project has been approved by EDA in the framework of the "ad hoc B" programme, to be funded from 2014 to 2017. It involves six countries: France (Thales Communications France and team IRISA/CASA at Université de Bretagne-Sud), Finland (Patria), Germany (Thales Defence & Security Systems and Fraunhofer FKIE), Italy (Selex ES, Thales Italia, and Università degli Studi dell'Aquila), Norway (Gjøvik University College), and Poland (ITTI Sp., Military Communication Institute, Military University of Technology).

7.5 Project SHERPAM (2014-2017)

Project SHERPAM *(Sensors for HEalth Recording and Physical Activity Monitoring)* has been approved by LabEx CominLabs, to be funded from 2014 to 2017. The objective is to design, implement, and validate experimentally a system based on biophysical sensors to monitor people during their daily life. Two application domains are considered specifically in this project: the evaluation of the functional limitations of arteriopathic patients, and the recognition and quantization of physical activity for a given population. Besides team IRISA/CASA this project involves laboratories LTSI (Rennes 1), M2S (Rennes 2, ENS Rennes), LAUREPS (Rennes 2), and the CIC-IT 804-CHU Rennes.

8 Dissemination

8.1 Involvement in the Scientific Community

- Frédéric Guidec is a member of the editorial board and/or program committee of the International Journal on Advances in Internet Technology, IEEE Transactions on Computers, the International Symposium on Wireless Personal Multimedia Communications (WPMC), the International Conference on Body Area Networks (BODYNETS), and the International Workshop on Sensor Networks for Intelligence Gathering and Monitoring (SNIGM). As such he has reviewed several papers for these journals and conferences in 2014. He served as the president of the jury for the PhD thesis of Hanane El Abdellaoui ("*Optimization of routing mechanisms for green home networks*", Telecom Bretagne / Orange Labs, Jan. 2015). From September 2012 to

September 2014, he served as a member of the Scientific Committee of the “Images & Réseaux” Cluster.

- Nicolas Le Sommer is a member of the editorial board and/or program committee of the International Journal on Advances in Internet Technology, International Journal of Handheld Computing Research (IJHCR) and the International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies (UbiComm). As such he has reviewed several papers for these journal and conferences in 2014. He also served as session chair in conferences WWIC 2014 and MoWNet 2014.
- Yves Mahéo is a member of the reviewing committee of the 12th IEEE Consumer Communications and Networking Conference (CCNC).

8.2 Teaching

- Frédéric Guidec teaches computer networking at different levels, from Licence 3 to Master 2, and he serves as an academic director for Licence 3 in Computer Science at UBS.
- Pascale Launay teaches object programming, computer networking and middleware at ENSIBS (École Nationale Supérieure d'Ingénieurs de Bretagne Sud). She is the academic director for the Computer Science Departement of ENSIBS.
- Frédéric Raimbault teaches programming language theory and compiler construction, computer architecture and distributed systems at different levels, from Licence 1 to Master 1. He serves as an academic director for the first year of Master WMR (Web, Multimédia, Réseaux) at UBS.
- Nicolas Le Sommer teaches database theory, Web application programming and the programming, the supervision and the management of distributed applications at the Computer Science department of the IUT de Vannes. He manages and supervises the student projects in the Computer Science department.
- Yves Mahéo teaches computer systems, distributed systems and middleware, at different levels at UBS, from Licence 1 to Master 2.

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