

Research Activities in Distributed Systems
Computer Science Department
Institut National des Télécommunications, Evry, France

Guy Bernard

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Abstract

The Institut National des Télécommunications, Evry, France, includes a school of engineering and a school of management and is part of the Groupe des Ecoles des Télécommunications (GET), a public institution funded by the french Ministry of Telecommunications. It has about one thousand students and 150 academic staff people belonging to 10 Teaching/Research Departments.

The Computer Science Department itself is divided into 3 teams: Databases, Parallelism, and Distributed Systems. It groups 21 permanent people and 10 Ph.D. students. This memo describes research activities for the Distributed Systems team only – activities of other teams are described in companion memos.

Execution environments of distributed services and applications are characterized today by an increasing variability in terms of types of devices, underlying network technologies and user mobility. The challenge is to design software infrastructures enabling application developers to focus on functional code design, while being insulated from the variability of the environments in which the applications will be deployed and executed.

Our research activities in the distributed systems domain are done in a global project, MARGE (*M*iddleware *p*our *A*pplications *D*istribuées avec *G*estion de l'*E*nvironnement - Middleware for distributed applications with context management). The goals of the project are to design, implement and evaluate tools for building object- or component-based middlewares aimed at supporting the execution of distributed applications in environments of any scale, involving devices of any kind (including mobile terminals) and mobile users. We focus on tools allowing dynamic adaptation (at application startup or during application execution) to context characteristics.

The MARGE project is part of the UMR (Unité Mixte de Recherche - Joint research unit) "SAMOVAR"¹ of CNRS (French National Center for Scientific Research), together with other research projects at Institut National des Télécommunications. We contributed to the output of a specific action of CNRS about research problems raised by data access in mobile environments [Bern03, Bern04].

1 Staff

The team is managed by Pr. Guy Bernard.

It includes six associate professors:

- Christian Bac
- Djamel Belaïd
- Sophie Chabridon
- Denis Conan
- Michel Simatic
- Chantal Taconet

and five Ph.D. candidates :

- Dhouha Ayed
- Nabih Belhanafi
- Lydialle Chateigner
- Mohamed Cherouati
- Nabil Kouici

¹<http://www.int-evry.fr/samovar/>

2 Background

Research in distributed systems started at INT in 1989. The group got experience in the following topics:

- distributed programming [Duda87, Bern89, Bern91a],
- object-oriented DBMS systems [Bern92],
- UNIX and interprocess communications [Boui88, Boui90, Boui92, Boui94, Boui97],
- load balancing [Bern91b, Bern91c, Bern93b, Bern95, Bern96],
- process migration [Alar92],
- Chorus and MacIntosh [Garn91, Bac93, Bac94, Bac95a, Bac95b],
- remote memory paging [Bern94b],
- fault tolerance [Bern93a, Bern94a, Cona95, Bac95b, Cona96, Cona97, Cona98],
- mobile code [Bern99a, Bern99b, Bern99c, Putr99b, Putr99a, Bern02], and
- support for distributed multimedia applications [Nguy95, Bac95b, Nguy97a, Nguy97c, Nguy97b, Bac99, LT99a, LT99b, Vill99, LT00, Vill00, Vill01].

3 Ongoing Research Activities : MARGE project

The MARGE project is divided into four subprojects.

3.1 Context-aware dynamic deployment tool for distributed applications

Dynamic deployment of component-based distributed applications consists in determining which component instances to instantiate, and where to instantiate them, for building an application session suited to the current execution context (eg., terminal type, terminal location, user preferences, server loads). Our goal is to design a dynamic deployment mechanism that would be generic, i.e. independent from applications and from the underlying middleware.

The work in this field started on the topic of extending the internal mechanisms of microkernels used for resource location in order to cope with wide area/high speed networks. We have designed an extended location service that can be integrated in the communication part of the Chorus microkernel [Taco94, Bac95b, Taco96, Taco97b]. The second step consisted in extending the CORBA Trading Service in order to dynamically manage a federation of traders, while being compliant to the OMG's Trading Service Specification [Taco97a, Bela98]. This work has been extended to the federation of any kind of servers in wide area networks, through a generic tool [Sabr01]. Then, we considered just-in-time component-based application deployment, by designing a portable dynamic load-balancing service which can select the

appropriate hosts on which instantiating the application components according to the current state of the environment [Putr00b, Putr00c, Putr00a]. We shown how the CORBA Trading Service could be extended to store both static and dynamic data in a uniform way [Kebb01], and we have implemented a first prototype of the deployment infrastructure using standard CORBA tools. A sample banking application has been used to demonstrate the flexibility of the deployment process, which can adapt both to terminal capabilities and to current state of the environment by selecting the less loaded machine in a set of replicated server hosts [Putr01a]. Moreover, once an application is deployed, the configuration can evolve in order to balance the load among replicated servers [Putr01b, Putr03]. This work has been mainly carried out within the CESURE² project, funded by the French Ministry of Research under the *Réseau National de Recherche en Télécommunications* (RNRT) program. This global *Smart Deployment Infrastructure* is described in [Taco03].

This work is now extended in several directions. First, we are investigating the characteristics of a property-based lookup service that are needed for adaptive application deployment [Ayed03a]. Second, we are designing the deployment process itself as a context-sensitive component-based distributed application [Ayed03b, Ayed04b]. Third, we aim the automation of component registration on component registries, through the component container code [Belh04]. We are defining descriptors for context-aware deployment, and the global architecture and API of the CADeComp (Context-Aware Deployment of Component-based applications) tool [Ayed05a]. The data model of CADeComp is defined in order to be independent from the target platform [Ayed04a, Ayed04d]. We have proposed a Platform Independent Model designed as an extension of the data model of the OMG's "Deployment and Configuration" specification. A first implementation has been made, on the basis of the Corba Component Model deployer [Ayed05b]. A case study of context-aware deployment for crisis management is described in [Ayed04c], and the special case of dynamic deployment on mobile terminals is addressed in [Belo05].

Whereas our goal is to design generic solutions (independent of the middleware instance), the validation (proof of concept) of our proposals is done through the Corba Component Model. This work is being developed within the french-finnish AMPROS³ project, in which we design a middleware platform for emergency services [Cona04b], and the European ITEA OSMOSE⁴ project.

3.2 Adaptation to the variability of wireless network connections

The goal is to enforce the continuity of execution of distributed applications when voluntary or involuntary network disconnections occur. To this end, we are designing a design pattern and a framework for partitioning application components between mobile terminals and remote computers so as to support disconnections as transparently as possible.

We have started by focusing on the adaptation of legacy CORBA-based applications in order to support network disconnections. We have shown how in the CORBA context "Objects by Value" and "Any" types can be used for achieving the local copy of remote objects, and that "Portable Interceptors" can be used for transparent switching between modes

²<http://www.gemplus.fr/cesure/>

³<http://www-inf.int-evry.fr/AMPROS/>

⁴<http://www.itea-osmose.org>

[Cona01a, Cona02a]. In order to validate and evaluate the design choices, a sample application (wireless email browser) has been implemented on a Compaq iPAQ running Orbacus4.1 over WindowsCE2.0, with a IEEE 802.11b wireless network connection to a remote server [Cona01b, Cona02b]. We have evaluated the impact of using Portable Interceptors over application performance [Cona02c]. Moreover, a generic architecture for coupling disconnected mode management with roaming between several wireless networks (eg., Bluetooth, WLAN and GPRS) has been designed [Cona02d]. This work has been achieved within the European ITEA VIVIAN⁵ project.

Whereas our recent work was targeted to application-transparent adaptation of CORBA-based legacy applications to network disconnections, we are now focusing on more general application-aware adaptation of component-based applications [Cona00] to wireless environments. We will handle non-functional properties such as bandwidth variability or fault tolerance. In the case of component-based applications, non-functional properties are handled by the container [Cona01c], so that some negotiation between application components and containers is required in order to support application-aware adaptation. We are designing a middleware platform called *DOMINT (Disconnected Operation for Mobile INternetworking Terminals)* that hides as much as possible the details of the hardware, the operating system, and the communication protocols to application developers and users [Cona04a].

We address the issue of determining which objects are mandatory, and which ones are optional, for an application to run in disconnected mode. To this end, we have introduced the notion of “disconnection metadata” [Koui03a] and proposed a design pattern for its integration into the CORBA Component Model [Koui03b, Koui04a]. A global software architecture aimed at supporting disconnections has been designed, which includes dedicated containers and four services (connectivity detection, logging, disconnected components management and reconciliation management) [Koui04b]. Following a model driven architecture approach, the UML profile of CCM can be extended to support this architecture [Koui04d]. The issue of managing the cache of software components on the mobile terminal is addressed through application profiles, which specify the dependencies between components and application services [Koui04c].

This work is being developed within the french-finnish AMPROS and the European ITEA OSMOSE projects.

We are also addressing the issue of disconnection detection. We have shown how disconnection detection and failure detection are related [Tema04]. We are studying how legacy middlewares can be enriched with three detectors: failure, connectivity (local detection) and disconnection (distributed detection) [Bhat04]. These three detector types can be used jointly for extending disconnection management and enhancing fault tolerance.

In the same area, we have also investigated how transparent disconnection management can be handled in the Web Services environment [MdC04b, MdC04a, MdC05].

3.3 Handling replication in mobile environments

Network disconnections inherent to wireless networks can lead to divergences between multiple copies of the same data, both in client-server and in collaborative environments. We are

⁵<http://www-nrc.nokia.com/Vivian/>

designing algorithms and software infrastructure, suited to mobile environments, for solving this problem. Reconciliation algorithms are based on operational transformation paradigm.

Previous work in this area started by the design of a flexible software infrastructure able to support both eager (synchronous) consistency and lazy (asynchronous) consistency, with the same programming interface. In order to do so, we have been designing a generic software switch that can be interposed on the path between a sender entity and one or more receiver entities. This switch may be particularly useful for handling mobile devices, by transparently switching from synchronous communication to asynchronous communication when the target device is unreachable [Buda02a, Buda02c]. A prototype of the synchronous/asynchronous switch has been developed in order to evaluate the benefits of this mechanism [Buda02b, Buda02d, Buda03b, Buda03a].

We are investigating the potential contribution of the operational transformations for designing reconciliation algorithms adapted to the characteristics of mobile wireless computing [Deba03]. To this end, we have been adapting an algorithm used in synchronous mode for collaborative work (the SOCT4 algorithm) to mobile contexts, where network connectivity is not permanently available. The challenge is to behave according to multi-synchronous mode, in which connection phases altern with disconnection phases. We take benefit of connectivity periods for broadcasting local modifications to reachable peers, and to receive from these peers the journal of their modifications. Through operational transforms, the modifications are inserted in the right place in a suitable form, in order to achieve eventually the convergence of the replicas [Chat04c, Chat04a]. This algorithm is fully decentralized, for stamp management as well as for dynamic group management. Moreover, the several logical blocks of the algorithm have been gathered in a Fractal composite component, in order to be integrated in a middleware as a non-functional service, allowing application developers to easily use this service if the application needs it [Chat05]. An implementation in the OpenCCM middleware is ongoing [Chat04d], and a sample demonstrator in the emergency services area is being set up [Chat04b, BA05].

This work is being developed within the french-finnish AMPROS project.

3.4 Multi-players networked games

Multi-players networked games, especially from mobile terminals, are expected to see a huge development in the coming years. Their execution relies on distributed software architectures which have to fulfill very specific constraints. We contribute to these architectures by designing algorithms suited to content-based publish-subscribe, and algorithms for consistency management between the views of the several players.

The first issue that we are considering is the architecture of middlewares dedicated to gaming support. Starting from the analysis of the Open Mobile Alliance specifications, we are implementing these specifications in the Java language.

The second issue is the high latency delay implied by mobile networks, which is a handicap for real-time gaming. We are investigating original software architectures aiming at accommodating this high latency.

The third issue is consistency management. Different players can experiment very different latencies, according to their location and the network they use. This discrepancy can lead to unfairness. We are designing algorithms aiming at satisfying the need of equity between players, by compensating the variable latency effect.

Contact

Prof. Guy Bernard
Head, Computer Science Department
INT
9 rue Charles Fourier
91011 EVRY Cedex
France

Phone: +33 1 60 76 45 67
Fax: +33 1 60 76 47 80
Email: Guy.Bernard@int-evry.fr
<http://www-int.int-evry.fr>

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