INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team distribcom

Distributed and Iterative Algorithms for the Management of Telecommunications Systems

Rennes - Bretagne-Atlantique

Theme : Networks and Telecommunications

Activity Report

2010

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1. Team

Research Scientists

Albert Benveniste [Team Leader, DR INRIA, part–time, HdR]
Éric Fabre [CR INRIA , HdR]
Loïc Hélouët [CR INRIA]
Blaise Genest [CR CNRS 15% with DistribCom, 85% with UMI IPAL, Singapore]

Faculty Members

Claude Jard [PROF. ENS CACHAN , HdR]
Anne Bouillard [ASSISTANT PROF. ENS CACHAN, until August 31st]

PhD Students

Bartosz Grabiec [INRIA grant]
Ajay Kattepur [INRIA grant]
Loig Jézéquel [ENS Cachan grant]
Rouwaida Abdallah [ENS Cachan grant, since March 1st]
Carole Hounkonnou [INRIA grant]
Aurore Junier [INRIA grant, since September 1st]

Post-Doctoral Fellow

Benoît Masson [Since October 15th]

Administrative Assistant

Laurence Dinh

2. Overall Objectives

2.1. Objectives of the team

The DistribCom team addresses models and algorithms for distributed network and service management, and the distributed management of Web services and business processes.

Today, research on network and service management as well as Web Services mainly focuses on issues of software architecture and infrastructure deployment. However, these areas also involve algorithmic problems such as fault diagnosis and alarm correlation, testing, QoS evaluation, negotiation, and monitoring. The DistribCom team develops the foundations supporting such algorithms. Our algorithms are model-based. Our research topics are therefore structured as follows:

1. *Fundamentals of distributed observation and supervision of concurrent systems*: this provides the foundations for deriving models and algorithms for the above mentioned tasks.
2. *Self-modeling*: for obvious reasons of complexity, our models cannot be built by hand. We thus address the new topic of self-modeling, i.e., the automatic construction of models, both structural and behavioral.
3. *Algorithms for distributed management of telecommunications systems and services.*
4. *Web Services orchestrations, functional and QoS aspects.*
5. *Active XML peers for Web scale data and workflow management.*

Our main industrial ties are with Alcatel-Lucent, on the topic of networks and service management.

2.2. Highlights

There is no highlight this year. An important event for the team, though, has been the launching of EU-IP Univerself project, headed by Alcatel-Lucent, in which we are heavily involved.

3. Scientific Foundations

3.1. Overview of the needed paradigms

Management of telecommunications networks and services, and Web services, involves the following algorithmic tasks:

Observing, monitoring, and testing large distributed systems: Alarm or message correlation is one of the five basic tasks in network and service management. It consists in causally relating the various alarms collected throughout the considered infrastructure—be it a network or a service sitting on top of a transport infrastructure. Fault management requires in particular reconstructing the set of all state histories that can explain a given log of observations. Testing amounts to understanding and analyzing the responses of a network or service to a given set of stimuli; stimuli are generally selected according to given test purposes. All these are variants of the general problem of *observing* a network or service. Networks and services are large distributed systems, and we aim at observing them in a distributed way as well, namely: logs are collected in a distributed way and observation is performed by a distributed set of supervising peers.

Quality of Service (QoS) evaluation, negotiation, and monitoring: QoS issues are a well established topic for single domain networks or services, for various protocols — e.g., Diffserv for IP. Performance evaluation techniques are used that follow a "closed world" point of view: the modeling involves the overall traffic, and resource characteristics are assumed known. These approaches extend to some telecommunication services as well, e.g., when considering (G)MPLS over an IP network layer.

However, for higher level applications, including composite Web services (also called *orchestrations*, this approach to QoS is no longer valid. For instance, an orchestration using other Web services has no knowledge of how many users are calling the same Web services. In addition, it has no knowledge of the transport resources it is using. Therefore, the well developed "closed world" approach can no longer be used. *Contract* based approaches are considered instead, in which a given orchestration offers promises to its users on the basis of promises it has from its subcontracting services. In this context, contract composition becomes a central issue. Monitoring is needed to check for possible breaching of the contract. Coutermeasures would consist in reconfigurating the orchestration by replacing the failed subcontracted services by alternative ones.

The DistribCom team focuses on the algorithms supporting the above tasks. Therefore models providing an adequate framework are fundamental. We focus on models of discrete systems, not models of streams or fluid types of models. And we address the distributed and asynchronous nature of the underlying systems by using models involving only local, not global, states, and local, not global, time. These models are reviewed in section 3.2. We use these mathematical models to support our algorithms and we use them also to study and develop formalisms of Web services orchestrations and workflow management in a more general setting.

3.2. Models of concurrency: nets, scenarios, event structures, and their variants

For Finite State Machines (FSM), a large body of theory has been developed to address problems such as: observation (the inference of hidden state trajectories from incomplete observations), control, diagnosis, and learning. These are difficult problems, even for simple models such as FSM's. One of the research tracks of DistribCom consists in extending such theories to distributed systems involving concurrency, i.e., systems in which both time and states are local, not global. For such systems, even very basic concepts such as "trajectories" or "executions" need to be deeply revisited. Computer scientists have for a long time recognized this topic of concurrent and distributed systems as a central one. In this section, we briefly introduce the reader to the models of scenarios, event structures, nets, languages of scenarios, graph grammars, and their variants.

3.2.1. Scenarios.

The simplest concept related to concurrency is that of a finite execution of a distributed machine. To this end, scenarios have been informally used by telecom engineers for a long time. In scenarios, so-called "instances" exchange asynchronous messages, thus creating events that are totally ordered on a given instance, and only partially ordered by causality on different instances (emission and reception of a message are causally related). The formalization of scenarios was introduced by the work done in the framework of ITU and OMG on High-level Message Sequence Charts and on UML Sequence Diagrams in the last ten years, see [35], [38]. This allowed in particular to formally define infinite scenarios, and to enhance them with variables, guards, etc [42], [40], [41]. Today, scenarios are routinely offered by UML and related software modeling tools.

3.2.2. Event structures.

The next step is to model sets of finite executions of a distributed machine. *Event structures* were invented by Glynn Winskel and co-authors in 1980 [37], [43]. Executions are sets of events that are partially ordered by a *causality* relation. Event structures collect all the executions by superimposing shared prefixes. Events not belonging to a same execution are said in *conflict*. Events that are neither causally related nor in conflict are called *concurrent.* Concurrent processes model the "parallel progress" of components.

Categories of event structures have been defined, with associated morphisms, products, and co-products, see [44]. Products and co-products formalize the concepts of parallel composition and "union" of event structures, respectively. This provides the needed apparatus for composing and projecting (or abstracting) systems. Event structures have been mostly used to give the semantics of various formalisms or languages, such as Petri nets, CCS, CSP, etc [37], [43]. We in DistribCom make a nonstandard use of these, e.g., we use them as a structure to compute and express the solutions of observation or diagnosis problems, for concurrent systems.

3.2.3. Nets and languages of scenarios.

The next step is to have finite representations of systems having possibly infinite executions. In DistribCom, we use two such formalisms: *Petri nets* [39], [31] and *languages of scenarios* such as High-level Message Sequence Charts (HMSC) [35], [41]. Petri nets are well known, at least in their basic form, we do not introduce them here. We use so-called *safe* Petri Nets, in which markings are boolean (tokens can be either 0 or 1); and we use also variants, see below.

3.2.4. Extensions and variants.

Two extensions of the basic concepts of nets or scenario languages are useful for us. Nets or scenario languages enriched with variables, actions, and guards, are useful to model general concurrent and distributed dynamical systems in which a certain discrete abstraction of the control is represented by means of a net or a scenario language. Manipulating such *symbolic nets* requires using abstraction techniques. Time Petri nets and network of timed automata are particular cases of symbolic nets. Probabilistic Nets or event structures: Whereas a huge literature exists on stochastic Petri nets or stochastic process algebras (in computer science), randomizing *concurrent models,* i.e., with ω's being concurrent trajectories, not sequential ones, has been addressed only since the 21st century. We have contributed to this new area of research.

3.2.5. Handling dynamic changes in the systems.

The last and perhaps most important issue, for our applications, is the handling of dynamic changes in the systems model. This is motivated by the constant use of dynamic reconfigurations in management systems. Extensions of net models have been proposed to capture this, for example the *dynamic nets* of Vladimiro Sassone [30] and *net systems* [32]. For the moment, such models lack a suitable theory of unfoldings.

4. Software

4.1. SOFAT: a scenario toolbox

Participants: Loïc Hélouët [correspondant], Rouwaida Abdallah.

The SOFAT toolbox is a scenario manipulation toolbox. Its aim is to implement all known formal manipulations on scenarios. The toolbox implements several formal models such as partial orders, graph grammars, graphs, and algorithm dedicated to these models (Tarjan, cycle detection for graphs, Caucal's normalization for graph grammars, etc.). The SOFAT toolbox is permanently updated to integrate new algorithms. It is freely available from Distribcom's website: http://www.irisa.fr/distribcom/Prototypes/SOFAT/index.html.

SOFAT is a demonstrator and a support for all our proposals in standardization committees at ITU. This involvement in standardization is also the occasion for numerous contacts with MSC users (France Telecom, Nokia, Motorola), but also with CASE tool designers at IBM.

The latest version of SOFAT (V3) has been released in 2008. Last year, SOFAT has been extended with new functionnalities such as scenario based diagnosis, and model checking of globally cooperative HMSCs. This year, we have extended our prototype with synthesis algorithms. These algorithms take as input High-level message sequence charts, and outputs a set of communicating automata. When a HMSC is local (a property that can be decided by our tool), the synthesized distributed behavior realizes exactly the input HMSC. A new version of SOFAT will be published as soon as all new functionalities are documented.

Time analysis of scenarios was developped this summer by G. Aggarwal, and is currently under integration in the tool. The principle of the analysis consists in unfolding an annotated HMSC, transform it into a colored stochastic Petri Net, and then run a simulation to obtain performance indicators.

5. New Results

5.1. Fundamentals results and algorithms: distributed unfoldings

Participant: Éric Fabre.

This is a joint work with our former PhD student Thomas Chatain, now assistant professor at the Ecole Normale Superieure in Cachan.

This works extends a long line of research in the team about the use of unfoldings to characterize the behaviors of distributed (concurrent) systems. Several monitoring algorithms have been based on variants of these structures, in particular distributed diagnosis algorithms. We have proposed a new notion of symbolic (or high-level) unfolding for a class of colored Petri nets [15]. These nets interact by shared places, which contrasts with the more usual way of defining component interactions, by synchronized transitions. Despite this novelty, we have proved that high-level unfoldings still enjoy nice algebraic properties, in particular they factorize: the high-level unfolding of a compound net is obtained as the product of the symbolic unfoldings of its components. This results in the possibility to perform modular diagnosis directly with symbolic branching processes.

5.2. Fundamentals results and algorithms: distributed planning

Participants: Éric Fabre, Loig Jézéquel, Blaise Genest.

A planning problem consists in organizing some actions in order to reach an objective. Formally, this is equivalent to finding a path from an initial state to a goal state in a huge automaton. The latter is specified by a collection of resources, that may be available or not (which defines a state), and actions that consume and produce resources (which defines a transition). In the case of optimal planning, actions have a cost, and the objective is to find a path of minimal cost to the goal.

Our interest in this problem is threefold. First, it is naturally an instance of a concurrent system, given that actions have local effects on resources. Secondly, it is a weak form of an optimal control problem for a concurrent/distributed system. Finally, we are interested in distributed solutions to such problems, which is a very hot topic in the planning community under the name of "factored planning."

Our contribution to this topic is the first optimal factored planning algorithm [33]. It is based on the observation that a planning problem can be translated into a network of components, modeled as weighted automata in our case. We have then designed a message passing procedure on this network, based on weighted automata calculus, where each component determines its part of the best global action plan using only local information: its local model, and messages received from neighbors about shared actions. This distributed solution resolves both a constraint solving problem, and an optimization problem. The optimal plan is given as a tuple of partially synchronized local plans, therefore as a partial order of actions.

In 2010, we have implemented these algorithms and have tested them on standard benchmarks of the planning community. Although benchmarks are not suited to factored planning (actions are generally strongly coupled), encouraging results were nevertheless obtained [18]. In particular, we can conclude with reasonable complexity that some problems have no solution, while some traditional planning methods can not conclude in such cases. We have also extended the approach to the case of networks automata with read arcs. They mimic the read arcs of Petri nets, and capture the fact that some actions in one component may be enabled by the state of another component, but do not change the latter. The formalism is close to the asynchronous automata introduced by Zielonka.

Another method we developped is the one to obtain directly a distributed implementation from a sequential specification. For that, we refined the celebrated theorem of Zielonka ('87). More precisely, we obtain an optimal network deterministic distributed automata, which translates into an optimal distributed algorithm from non stochastic specifications [19]. Plans are to extend this to stochastic specifications as well as to open systems, where an objective function is to be ensured.

5.3. Fundamentals and algorithms: communication with messages and senarios

Participants: Loïc Hélouët, Rouwaida Abdallah, Claude Jard.

In this paragraph, we collect our fundamental results regarding the models and algorithms we use for communicating systems, and in particular, scenarios.

A major challenge with models communicating with messages (e.g.: scenarios) is to *exhibit good classes of models* allowing users to *specify easily complex distributed systems* while *preserving the decidability* of some key problems, such as diagnosis, equality and intersection. Furthermore, when these problems are decidable for the designed models, the second challenge is to design algorithms to keep the *complexity low enough* to allow *implementation in real cases*.

This year, we have proposed several extensions and new techniques around scenarios. The first extension proposed is an extension of coregions [10]. A coregion is a part of a process description in which the ordering of events is relaxed. Usually, the ordering of events on a single process is a total order. The Z.120 standard [35] also allows for general orderings, that is a replacement of the total ordering imposed on a process by a partial ordering. However, coregions are limited to a finite set of events. We have extended the orginal formalism to allow for infinite coregions containing partial orderings. Within this context, we also have provided algorithms to detect discrepancies between the visual ordering of events and their actual ordering imposed by the semantics (this notion is usually called "race condition"). This work was done during a collaboration with Masaryk University (Czech Republic).

The second extension is called MSC grammars [12]. This formalism extends High-level message sequence charts to allow dynamic creation of an arbitrary number of processes. Rougly speaking, a context free grammar (instead of an automaton in the case of HMSCs) is used to compose partial orders. We have shown that this model can be implemented usind dynamic communicating automata (but with deadlocks) for a subclass of this model. We have also shown that MSO formulae verification and diagnosis are decidable problems for this formalism [12]. This last property is interesting as it is the first time that diagnosis is proposed for an infinite state space dynamic model with asynchronous communications.

The last part of our work is the study of realistic implementation of scenarios. The main idea is to propose distributed implementation of High-level MSCs that do not contain deadlocks, and behave exactly as the original specification. It is well known that a simple projection of a HMSC on each of its process to obtain communicating finite state machines results in an implementation with more behaviors than the original specification. We have studied how such projection with additional local controlers allows the distributed synthesized behavior to remain consistent with the original specification. This work has been implemented in our scenario prototype (see the Software section).

5.4. Fundamentals and algorithms: timed models

Participants: Claude Jard, Anne Bouillard, Bartosz Grabiec.

Our work on timed models was focused on the study and use of two different techniques: unfoldings of Time Petri nets and the network calculus. The goals are supervision with time and performance evaluation.

Work on Petri Nets unfolding was conducted in collaboration with a group at IRCCyN in Nantes and also with a group at LSV in Cachan. In 2010, we focused on the introduction of parameters within the time constraints. This gives an interesting abstraction in the models and allows a model-checker or a supervisor to infer ranges of possible values for the parameters [26], [22]. Experiments with algorithms have been conducted and were implemented in the software Romeo of IRCCyN.

The other generalization made concerns the relationship between temporal and colored Petri Nets: the objective here is to transpose our symbolic approach of unfolding developed in the timed framework to a fairly general class of colored Nets in which the functions are linear [16].

Network Calculus is a quite recent theory developed to compute deterministic worst-case bounds in queuing networks. Computing such bounds is necessary when dealing with real-time and critical systems (that can be found for example in embedded systems of airplanes or cars). The Network Calculus is based on the (min,plus) algebra. It models constraints on arrival and output processes by means of arrival and service curves. Our work has focused on two main aspects:

1. First we focused on the different existing models: indeed, several definitions of service curves co-exist and several models (like real-tine calculus) have been defined as extensions of network calculus, and the difference between them may be confusing. We studied those different models and compared them in order to establish a hierarchy between them and point out the similarities that may exist. We prove that strict service curves cannot be built from simple service curves, but that in most of the cases, strict service curves and the minimal curves of RTC are equivalent [13].
2. Second, we derived efficient algorithms to compute the exact worst-case delays and backlogged in feed-forward networks under quite general assumptions and for arbitrary multiplexing (no service policy is fixed, so the worst-case performances are for the worst-case service policy) using linear programming techniques. The algorithm is polynomial for tandem (or tree) networks, whereas the problem is proved to be NP-hard for general networks [14]. This work has been extended during the Master internship of Aurore Junier, with the study of worst-case delay bounds for networks with fixed priorities. Using linear programming techniques combined with (min,plus) technique can drastically improve the bounds obtained by pure (min,plus) techniques.

5.5. Specific studies: Web services orchestrations

Participants: Ajay Kattepur, Albert Benveniste, Claude Jard.

Web services *orchestrations* and *choreographies* refer to the composition of several Web services to perform a co-ordinated, typically more complex task. We decided to base our study on a simple and clean formalism for WS orchestrations, namely the ORC formalism proposed by Jayadev Misra and William Cook [36].

Main challenges related to Web services QoS (Quality of Service) include: 1/ To model and quantify the QoS of a service. 2/ To establish a relation between the QoS of queried Web services and that of the orchestration (contract composition); 3/ To monitor and detect the breaching of a QoS contract, possibly leading to a reconfiguration of the orchestration. Typically, the QoS of a service is modeled by a *contract* (or Service Level Agreement, SLA) between the provider and consumer of a given service. To account for variability. In previous years, we proposed soft probabilistic contracts specified as probabilistic distributions involving the different QoS parameters; we studied *contract composition* for such contracts; we developed probabilistic QoS contract monitoring; and we studied the *monotonicity* of orchestrations; an orchestration is monotonic if a called service improves its performance, then so does the overall orchestration.

In 2009 and 2010, in the framework of the Associated Team FOSSA with the University of Texas at Austin (Jayadev Misra and William Cook), we have extended our approach to general QoS parameters, i.e., beyond response time. In particular, we now encompass composite parameters, which are thus only partially, not totally, ordered. We have developed a general algebra to capture how QoS parameters are transformed while traversing the orchestration and we have extended our study of monotonicity. Finally, we have developed corresponding contract composition procedures. This year, Sidney Rosario (post-doc at UT Austin) and Ajay Kattepur have started extending the Orc language and execution engine to support QoS according to our theory. This extension mainly consists in 1/ providing a rich type system to declare QoS domains and related algebra, and 2/ providing a new operator for Orc that allows for selecting competing returns from different sites on the basis of their QoS. A journal paper is in preparation.

A key task in extending Orc for QoS was to extend the Orc engine so that causalities between the different site calls are made explicit at run time while execution progresses. This benefits from our previous work on Orc semantics, but a new set of rules has been proposed to generate causalities in an efficient way, by covering new features of the language. This is joint work of Claude Jard, and Sidney Rosario and John Thywissen from Austin. A publication is in preparation.

Ajay Kattepur [25] has proposed an effective approach for QoS management of product lines of orchestrations, that is, families of variants of a given orchestration. Aim here is to avoid exploring all configurations exhaustively when performing QoS composition or other QoS-related tasks.

Ajay Kattepur has started a new research track for this thesis. The overall objective is to embed mathematical packages (such as optimization) within orchestration languages. By offering this, it will no longer be needed to shift paradigm when complex distributed service based applications need to rely on mathematical routines.

5.6. Specific studies: Active XML documents

Participants: Albert Benveniste, Loïc Hélouët, Blaise Genest.

The language *Active XML* or *AXML* is an extension of XML which allows to enrich documents with *service calls* or sc's for short. These sc's point to web services that, when triggered, access other documents; this materialization of sc's produces in turn AXML code that is included in the calling document. One therefore speaks of dynamic or intentional documents; note in particular that materialization can be *total* (inserting data in XML format) or *partial* (inserting AXML code containing further sc's). AXML has been developed by the GEMO team at INRIA Futurs, headed by Serge Abiteboul; it allows to set up P2P systems around repositories of AXML documents (one repository per peer).

We are cooperating with the GEMO team (Serge Abiteboul) and the LABRI laboratory in Bordeaux (Anca Muscholl) to explore the behavioral semantics of AXML in the framework of the former ASAX INRIA-ARC (see the 2006 activity report), and to analyze such systems in the frameword of the Docflow and Activedoc projects, see 6.5, 6.6 below.

This year, we have addressed the problem of distribution and composition of AXML systems [23]. In the usual AXML framework, the locality of active documents is not considered, and guards can be evaluated over documents that are located at any place. However, in a real implementation, it is not possible to evaluate a guard over a part of a document owned by a distant site without some additional communication. We have proposed a distributed version of Active XML, in which guards can only be evaluated locally to a given site, and agents of the system interact using calls to external services. From a site, the interactions with the environment are only seen as interfaces, that depict the relation between the parameters sent to an implementation of an interface, and the expected results. Intuitively, interfaces describe the needed functionnalities of a site in terms of legal inputs/outputs. Then, a service implements an interface if it accepts all allowed parameters, and returns only results described by the interface. This implementation relation builds on the well-known notion of query containment, and can rapidly become undecidable if the considered data is infinite. We have shown sufficient conditions for decidability. Distributed AXML compose, just by providing in one system some implementations needed by the other one. They can also be abstracted (a part of the system is replaced by interfaces for it) to allow modular model checking.

We also have considered a different formalism for active document [20]. In this work, we consider a tree-rewriting framework for modeling documents evolving through service calls. We focus on the automatic verification of properties of documents that may contain data from an infinite domain. We establish the boundaries of decidability: while verifying documents with recursive calls is undecidable, we obtain decidability as soon as either documents are in the positive-bounded fragment (while calls are unrestricted), or when there is a bound on the number of service calls (bounded model-checking of unrestricted documents). In the latter case, the complexity is NexpTime-complete. Our data tree-rewriting framework resembles Guarded Active XML, extended with node renaming and subtree deletion.

Within the context of the DST associated team, we have also started a study of a promising model, that combines arbitrary numbers of finite workflows. This formalism can be seen as a mix of BPEL and ORC elements, but we have designed the formalism to keep it decidable. This is still an unachieved work, that will be continued next year.

5.7. Specific studies: security

Participant: Loïc Hélouët.

We have performed some work on security issues in the context of the DOTS project, and within a collaboration with the VERTECS team. In DOTS, we are involved in a working group on non-interference. This year, we have mainly focused on discovery of covert channels using information theory.

Covert channels discovery using information theory: In the DOTS project, we have studied covert channels with the help of information theory. Roughly speaking, a covert channel is an obfuscated use of a system to create hidden communication between agents that are not allowed to exchange information. We have adapted work on channel capacities to discover covert flows of information. Namely, if we represent a distributed system with agents $u_1, \cdots, u_n$ as a transition system, a covert channel exists if the channel with input action of u_i and output observation of u_j has a non-zero capacity. We have generalized the finite state communication channel capacity to the case where the input alphabet depends on the state. With this new channel model, we have shown how to bring back the search for covert channels to the computation of a capacity [28].

So far, our solution applies only if the considered automaton meets some syntactic criteria. The next stage is to characterize covert information flows for arbitrary automata models. This problem is difficult, as it brings back to information theory issues (capacity of an intersymbol interference Markov channel: the state has memory and is input dependent) that are open for more than 50 years.

5.8. Specific studies: Distributed optimization in network management

Participant: Éric Fabre.

This work represents part of our activities within the research group "High Manageability," supported by the common lab of Alcatel-Lucent Bell Labs (ALBLF) and INRIA. It concerns a key issue for the autonomic management of photonic networks, i.e. optically routed networks. The problem concerns the fine tuning of wavelength reamplification gains at the input of each fiber, in order to optimize the optical signal to noise ratio (OSNR) at egress of the connection, and to equalize all connections. The tuning of these gains directly influences the reach of a connection, that is the distance over which the signal can be transported optically, without necessity of an electronic regeneration. This in turn has a direct financial impact since less equipment is needed.

The problem is made complex by several phenomena. First of all, the total amount of power allowed in a fiber is limited (or equivalently each optical cross-connect has a bounded power budget). This implies that each node must select which wavelengths will be reamplified, and by how much. Secondly, the per-wavelength amplification gains are themselves limited, so an important loss on some connection in a link may have to be compensated for by several consecutive reamplifications along this connection. These two phenomena, combined with other non-linear effects, make this optimal tuning of gains a huge and complex network-scale optimization problem under constraints. The objective function is of course to maximize the OSNR of all connections in the network, and at the same time equalize these OSNR, so that long-range connections have the same quality as short range ones. For the moment, all these gains are manually adjusted, one by one, which is extremely difficult and suboptimal.

We have designed and tested an iterative and distributed solution to solve this problem: each optical cross-connect in the network tunes its own reamplification gains, based on information provided by its neighbors. No global topology information is necessary, and convergence is guaranteed. The algorithm is adaptive to network changes: it redistributes optimally the power left by closed connections, and symmetrically pumps power in the less important connections to feed a newly created one.

Two patents have been derived from this work, jointly registered by ALBLF and INRIA. In 2010, these ideas have been experimented by Alcatel in a more realistic environment, simulating accurately the properties of optical fibers. Compared to existing dimensioning tools, interesting gains have been obtained that demonstrate the relevance of the idea. Refinements of the distributed tuning algorithm are ongoing.

6. Other Grants and Activities

6.1. Associated team DST

Participants: Loïc Hélouët, Blaise Genest, Anne Bouillard.

DST : Distributed systems, Supervision and Time.

Associated Team INRIA-NUS-Chennai — 2009-2011

This associated team is a collaboration with the National University of Singapore, Chennai Mathematical Institute and Institute for Mathematical Science in Chennai, and also involves members of the S4 team. The main research theme is to study supervision and time issues in distributed systems with the help of concurrency models, which follows and extend the work done in the former associated team CASDS. Two application areas are targeted: real-time embedded systems and telecommunications systems and services. Although very different in nature, both areas make fundamental use of models of concurrency. Several types of formal models are considered: scenario languages, communicating automata and Petri-nets. More specifically, we work together on the following problems:

- Distributed Control of Concurrent Systems and the problem of synthesizing small controllers;
- Quantitative aspects of timed distributed systems;
- Qualitative Verification of timed constraints concurrent models.

Two long versions of papers we wrote two and three years ago have been accepted then published to top journals this year [34] and [8], one considering the minimal control. On quantitative aspects of time, [29] has been published in a conference. Loïc Hélouët and Philippe Darondeau visited Chennai in January for 10 days, spending time at a Indo French Workshop. Blaise Genest visited Singapore for 2 weeks in February, spending time at SinFra (Singapore-French) conference. Loïc Hélouët and Blaise Genest are going to visit NUS in early december. We received the visit of several PhD students from Chennai, S. Akshay in July for a week and Paul Soumya in November for 2 weeks. We also hired an intern from India in the summer working on implementing a tool to compute mean throughput of probabilistic and timed distributed system through simulation.

6.2. Associated team FOSSA

Participants: Claude Jard, Albert Benveniste, Ajay Kattepur.

FOSSA: Formalizing Orchestration & Secure Services Analysis

Associated Team INRIA-University of Texas at Austin, 2010-2011

The widespread deployment of networked applications and adoption of the internet has fostered an environment in which many distributed services are available. There is great demand to automate business processes and workflows among organizations and individuals. Solutions to such problems require orchestration or choreography of concurrent and distributed services in the face of arbitrary delays and failures of components and communication. The Orc team, led by Jayadev Misra at the University of Texas at Austin, has developed the Orc language to support orchestrations. The DistribCom team has developed studies regarding the Quality of Services of orchestrations and choreographies, with emphasis on Orc. Finally, from the newly created (2009) MExICo team in Saclay (), Stefan Haar is a former member of DistribCom and has participated in the above research, and Serge Haddad has been working on client synthesis and aspects of orchestration, in particular adaptation. The teams cooperate since 2006 and have decided to join their efforts in lauching the associated team FOSSA, with the following objectives:

- To contribute to the development of Orc as a support for Structured Application Development over Wide-Area Networks;
- To develop a comprehensive theory of QoS for composite Web services, supporting: SLA contracts, contract composition, contract monitoring, and reconfiguration;
- To experiment on real orchestrations or choreographies;
- To develop studies on security (Authorization and Information flow);
- To develop studies on the functional synthesis and design of composite services, including mashups and synthesis of adaptors for services inside a composition;
- To develop the synthesis of clients supporting the interaction protocol of a composite service;
- To benchmark different styles of formalisms: Orc, a graphical formalism for workflow specifications by Gero Decker (Signavio), and Active XML document based formalism developed by Serge Abiteboul ().

As a general umbrella for all the above objectives, distributed aspects are central. This year cooperation events included a visit of A. Benveniste and C. Jard in Austin in February, a visit of Jayadev Misra in Rennes in April, and a visit of Ajay Kattepur in Austin in July. Our former PhD student Sidney Rosario was postdoc at Austin until August 2010. Main results consisted of 1/ causality analysis of Orc programs and the on-the-fly construction of causality between events in an execution (this is essential for studies on QoS), and 2/ studies on how Orc can be upgraded to manage QoS.

6.3. DISC

Participants: Éric Fabre, Loig Jézéquel.

European STREP project - Call FP7-ICT September 2008 - September 2011

Distributed Supervisory Control of Large and Complex Plants. This project involves as well team S4 (Ph. Darondeau), and a starting collaboration with Serge Haddad (LSV, ENS Cachan) will also be hosted by DISC. The main collaborations of DistribCom will be with the LSV, the University of Cagliari (Italy), the CWI (Amsterdam, NL), Ghent University (Belgium), the Czech Academy of Sciences (Czech Republic), and with Canadian and US partners that will soon be attached to DISC. Distribcom is involved in three workpackages, on the following topics 1/ the distributed optimal control of coupled MDP (Markov Decision Processes), 2/ distributed planning algorithms, and in particular distributed reachability tests, and 3/ the existence of distributed observers for a distributed system.

6.4. UniverSelf

Participants: Éric Fabre, Albert Benveniste, Claude Jard, Loïc Hélouët.

European IP project - FP7 Sept. 2010 - Sept. 2013

UniverSelf is led by ALU-Bell Labs, in particular the people involved in our joint team HiMa. It gathers 18 of the most significant teams in Europe dealing with autonomic networking. Its objective is to bring to maturity some selected autonomic functions, covering configuration, optimization, diagnosis, healing, control, security, etc. The work is organized around an evolving set of use-cases, and will aim at designing a universal management framework for autonomic functions. INRIA is involved with three teams: DistribCom, Madynes (Nancy) and Mexico(Saclay), and will address use-cases related to self-diagnosis and self-healing for networks and services, and to secure policy-based network configuration.

6.5. ANR Docflow

Participants: Albert Benveniste, Éric Fabre, Loïc Hélouët, Blaise Genest, Benoît Masson.

Contract INRIA *ANR-06-MDCA-005 January 2007 - April 2010*

Docflow (http://www.labri.fr/perso/anca/docflow/main.html) is a national research project where Distribcom cooperates with INRIA's GEMO team, and the LABRI/Bordeaux. It started in January 2007 and is scheduled to end in April 2010. It is a follow-up of the ARC Asax (see below). The aim of the docflow project is to model, analyze and monitor real life composite services, as tour operators (Opodo) or supply chains (DELL). It builds on the understanding between the Database community (data centric views) and the Discrete Event community (control centric), brought by the past ASAX meetings. The main tool is Active XML, see URL http://activexml.net on Active XML and Web services. So far, only a fragment of AXML was considered. It is called "positive AXML", and have simplistic control (no move or deletion of data, only copy of nodes are possible at some given nodes, and every copy is possible in parallel). We try to develop a model where control can simulate worflow, and structured data (XML) can be used in the same formalism. This starting point will allow us to develop algorithms to analyse, monitor and optimize worflows with rich data.

6.6. CREATE ActiveDoc

Participants: Albert Benveniste, Éric Fabre, Loïc Hélouët, Blaise Genest, Ajay Kattepur, Benoît Masson.

Contract INRIA *CREATE February 2007 - August 2011*

Activedoc is funded by Région Bretagne, supporting the ANR Docflow project. It started in February 2007, for 18 months, and can be extended twice for 18 months. In addition to the Docflow program, it grants funding to study composite web services in a quantitative way. The fundamental models proposed in Docflow will be a starting point. For instance, developing methods to compose the Quality of Service of different web services is a difficult problem if one wants realistic values which are not too imprecise. Methods to elaborate and use contracts between heterogeneous services would thus be simplified.

6.7. ANR Dots

Participants: Claude Jard, Loïc Hélouët, Blaise Genest, Bartosz Grabiec.

Contract INRIA *ANR-06-SETI January 2007 - December 2011*

Dots (http://www.lsv.ens-cachan.fr/anr-dots/) is a national research project where Distribcom cooperates with the LSV/ENS Cachan, the LABRI/Bordeaux, the LAMSADE/Paris Dauphine and the IRCCyN/Nantes. It started in January 2007 and is scheduled to end in December 2010. The ambitious goal of the project is to consider open systems (that is interacting with other undefined systems) which are distributed and require timing information, in order to analyze concrete systems without abstracting one of these aspects. For instance, the interference between several systems require a combination of opened, distributed and timed information. Distribcom is in charge of the interaction of distributed systems with timing aspect (as timed Petri nets) or openness (as distributed controllers and distributed games).

6.8. Joint Bell Labs INRIA Laboratory

Participants: Éric Fabre, Albert Benveniste.

Started January 2008.

The *Joint Bell Labs INRIA Laboratory* is the ongoing framework for the overall research cooperation between Alcatel-Lucent Bell Labs and INRIA. This joint Laboratory was launched in January 2008. It is a virtual lab, meaning that researchers remain hosted by their home institutions. The lab has the general area of *self-organizing networks* in its central focus. It is organized into three *Actions de Recherche (ADR)*:

- SelfNets (Self-Organizing networks), headed by Olivier Marcé (BellLabs) and Bruno Gaujal (INRIA);
- Semantic Networking, headed by Ludovic Noirie (BellLabs) and Pascale Vicat-Blanc (INRIA);
- High Manageability, HiMa, headed by Pierre Peloso (BellLabs) and Éric Fabre (INRIA, DistribCom).

Overall, the joint lab involves about 50 people. It is jointly headed by Olivier Audouin (BellLabs, president), and Albert Benveniste (INRIA, president of the Scientific Committee). The lab organizes bi-yearly seminars with progress reports and keynotes by key engineers from Alcatel-Lucent — the first one was about LTE (Long Term Evolution) by Denis Rouffet and the second one was about optical networks, by Paolo Fogliata, both from business divisions.

6.9. ADR HiMa

Participants: Éric Fabre, Albert Benveniste, Claude Jard, Anne Bouillard, Carole Hounkonnou, Aurore Junier.

Research Action "High Manageability", hosted by the common research laboratory of Alcatel-Lucent-Bell Labs and INRIA. June 2008 - June 2011.

This research group involves three INRIA teams, DistribCom, Madynes (O. Festor, INRIA Lorraine), and Mascotte (J.-C. Bermond) who joined the group recently in 2009. On the Alcatel-Lucent side, 5 persons of the PTI group (Packet Transport Infrastructure) are involved. It is jointly headed by P. Peloso (ALU, in replacement of M. Vigoureux) and E. Fabre (INRIA). The objective is to contribute to the autonomic networking trend, that is to design telecommunication networks that would be programmed by objectives, with minimal human operations, and that would then adapt themselves in order to reach these objectives. More specifically, this covers both the architectural and the algorithmic aspects of self-management methodologies. The activity is organised around several case-studies and working groups. In 2010, the mature results about the optimal power allocation to wavelengths in photonic (i.e. optically routed) networks was experimented on realistic simulators. The other activities where DistribCom is involved concern the maintenance of networks and services with minimal service disruption (Carole Hounkonnou's PhD, started in 2009), and the analysis of network stability under different tunings of protocol parameters (Aurore Junier's PhD, started in 2010).

The activities of HiMa also cover security issues for VOIP (studied by Madynes), and network defragmentation issues (studied by Mascotte).

6.10. ANR Pegase

Participant: Anne Bouillard.

Contract INRIA *ANR-09-SEGI-009 October 2009 - October 2012*

Pegase (Perfomances garanties dans les systèmes embarqués) is a national research project where DistribCom interacts both with academical partners (ENS Lyon and INRIA Rhône-Alpes) and with industrial partners (Thalès, ONERA and RT@W). It started in October 2009 and is scheduled to end in October 2012. The aim of Pegase is to develop the theory of Network Calculus and study the applicability to embedded networks (SpaceWire, AFDX). A prototype is planed to be developed.

7. Dissemination

7.1. Scientific animation

A. Benveniste is member of the Steering Committee of the International Journal of Discrete Event Systems and its Applications (JDEDS). He is member of the Strategic Advisory Council of the Institute for Systems Research, Univ. of Maryland, College Park, USA. A. Benveniste is president of the Scientific Committee of the *Joint Bell Labs INRIA Laboratory*. A. Benveniste is member of the Scientific Council of France Telecom.[1]

E. Fabre is associate editor (AE) for the journal *IEEE Trans. on Automatic Control*.

B. Genest is an elected member of the Comité National de la Rercherche Scientifique for 2008-2012.

C. Jard has been in 2010 member of the Program Committee of the following international conferences: NOTERE, FMOODS/FORTE, CONCUR/WDOTS, MOVEP. He is also member of the editorial board of the *Annales des Télécommunications* and the steering committee of MSR series of conferences. C. Jard supervises a CNRS national transverse program on formal approaches for embedded systems (AFSEC). C. Jard is the director of the research of the Brittany extension of the ENS Cachan (director of the pluridisciplinary institute called the Hubert Curien Research College). He is member of the scientific council of the European University of Brittany. He is expert of the AERES, the national evaluation agency and expert for the French ministry of research, he has also served as an expert in several programs of the ANR. In 2010, C. Jard was president of the PhD thesis jurys of S. Sen, F. Bonnet, N. Le Scouarnec (University of Rennes 1) and J. Haillot (University of Bretagne Sud).

Loïc Hélouët is co-reporter at ITU for the question 17 on MSC language. Loïc is also the co-organizer (together with S. Pinchinat (S4), D. Cachera (Celtique) and N. Bertrand (Vertecs)) of the 68NQRT, a weekly seminar of IRISA on software, theory of computing, discrete mathematics in relation to computer science and artificial intelligence. He is the coordinator for the DST associated team between Rennes, the National University of Singapore, and two computer science institutes in Chennai. He is also a member of the working group for international relations in the scientific orientation council of INRIA. He has been member of the program committee of the DOTS workshop, affiliated to CONCUR, and of the SAM (System Analysis and Modeling) 2010 conference.

7.2. Teaching

E. Fabre teaches "information theory and coding" at École Normale Supérieure de Cachan, Ker Lann campus, in the computer science and telecommunications Master program. He also teaches "numerical and combinatorial optimization," and "distributed algorithms and systems" in the computer science Master program at the University of Rennes 1.

C. Jard is a full-time professor at the ENS Cachan and teaches mainly at the Master level, in Computer Science and Telecom, and in Maths. He supervises the third year of the cursus (the research master's degree). He is also in charge of the competitive examination for the entry of new students in computer science in the French ENS schools.

A. Bouillard is an Assistant Professor at the ENS Cachan and teaches at the last year of Bachelor and at Master level in computer science. She is also the responsible for the computer science option of the Agrégation of Mathematics (highest competitive examination for teachers in France), where she is involved in the training of the candidates.

7.3. Visits and invitations

Albert Benveniste and Claude Jard spent one week in February 2010 in Austin to work with J. Misra and W. Cook about some QoS aspects in ORC and its partial order instrumented semantics.

[1]Only facts related to the activities of DistribCom team are mentioned. Other roles or duties concern the S4 team, to which A. Benveniste also belongs.

Ajay Kattepur spent one week in July 2010 in Austin to work with J. Misra and W. Cook about some QoS aspects in ORC.

Albert Benveniste spent one week in September 2010 in Singapore to work with Thiagarajan and Blaise Genest about probabilistic models.

L. Hélouët spent one week in Singapore in december 2010 to work with S.Yang, P.S. Thiagarajan, and B. Genest on timed scenarios, within the context of the DST associated team. He was also invited to give a talk in the ACST workshop in Chennai in February 2010. He also gave a talk on the differences between interferences and covert channels during the GIPSY seminar (Workshop on games and security issues) held in Rennes in November 2010.

Éric Fabre visited Stephane Lafortune's team (Mich. Univ.) in May 2010, and gave a seminar about distributed optimal planning.

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