PROGRAMMI DI RICERCA SCIENTIFICA DI RILEVANTE INTERESSE NAZIONALE
RICHIESTA DI COFINANZIAMENTO (D.M. 1152/ric del 27/12/2011)

PROGRAMMA DI RICERCA - MODELLO A
Anno 2010-2011 - prot. 2010LHT4KM

1 - Research Program Title

CINA: Compositionality, Interaction, Negotiation, Autonomicity for the future ICT society

2 - Area Scientifico-disciplinare

Research Area
01 Scienze matematiche e informatiche 100 *

3 - Scientific Subareas

INF/01 - INFORMATION TECHNOLOGY

3 bis Settori di ricerca ERC (European Research Council) interessati dal Progetto di Ricerca

4 - Key Words

5 - Principal Investigator

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6 - Scientific Curriculum

Education
* Ph.D. in Computer Science from Department of Computer Science of University of Edinburgh (UK) - May 1985.
* Laurea (magna cum laude) in Scienze dell'Informazione at Pisa University - December 1978.

Working Experiences
* July 2011- today. Full Professor of Computer Science at IMT - Institute for Advanced Studies, Lucca.
* November 1995 - June 2011. Full Professor of Computer Science at University of Florence.
* November 1990 - October 1995. Full Professor of Computer Science at University "La Sapienza" in Rome.
* October 1982 - October 1990. Researcher at Istituto di Elaborazione dell'Informazione of CNR in Pisa
* March 1981 - September 1983. PhD student at University of Edinburgh.
* May 1980 - February 1981. Researcher at ITALTEL in Milan.
* April 1978 - April 1980. Grant from Olivetti to work on a joint project with Istituto di Elaborazione dell'Informazione (IEI) at CNR in Pisa.

Research and its outcomes
De Nicola's research aims at understanding the foundations of distributed computing and at applying the formal techniques based on these foundational studies to the development and the analysis of concurrent distributed systems. Current research concentrates on:

* Models and Languages for Open Distributed Systems
* Network Aware Programming
* Service Oriented Computing
* Specification of Qualitative and Quantitative Properties of Distributed Systems
* Abstract Models for Security and Cryptographic Process Calculi

On this topics, De Nicola presently collaborates with researchers from many national and international institutions and is the author of around 130 publications in international refereed journals and conference proceedings. De Nicola has also edited books and special issues of journals.

De Nicola's research has also had three important recognitions:
* Patent: United States Patent 6751619 Methods and apparatus for tuple management in data processing system Issued on June 15, 2004 Inventors Antony Rowstron and Rocco De Nicola
* Citations De Nicola is among the 300 researchers in Computer SCience according to the rank of ISI-Thomson of highly cited researchers (http://isihighlycited.com).
* Titles: De Nicola has been honoured with the title of "Commendatore al Merito della Repubblica Italiana".

De Nicola is a member of IFIP Working Groups 2.2 , 1.6 and 1.8. He is also a member of Gruppo 2003 (an association of leading Italian scientists). In 2011, he has became a member of Academia Europaea.

Teaching

At Florence and Rome University, De Nicola has taught: Concurrent Programming, Specification and Analysis of Concurrent Systems, Computer Security, Operating Systems, Algorithms and Data Structures, Computer Architectures, Computability and Formal Languages, Foundations of Programming Languages.
De Nicola has supervised the PhD or Master work of a number of students. Some of them (Luca Aceto, Lorenzo Bettini, Michele Boreale, Flavio Corradini, Daniele Gorla, Michele Loreti, Rosario Pugliese, Roberto Segala, Emilio Tuosto) are currently playing an important active role in international research and in Italian or European Universities.

Professional Services and Activities

De Nicola has been "visiting professor" at Technical Univeritaet of Berlin in May 1996, at Ecole Normale Superiere de Paris in April 2004 and at Ludwig-Maximilians-Universitaet in Munich in July 2004; he has also been "visiting researcher" at Microsoft Research Laboratories in Cambridge (UK) for three months during 1999 and 2003.

De Nicola has been
* Coordinator of the PhD Program in Informatica ed Applicazioni at University of Florence.
* Director of Studies of the Bachelor (Diploma) and Master (laurea) curriculae in Informatics at University of Florence.
* Deputy Rector for the management of Information System of University of Florence.
* Vice-President of the board of (5) professors leading CSIAF. The center for information service of University of Florence.
* Deputy Director of Dipartimento di Sistemi ed Informatica at University of Florence.
* Vice-president (Coordinator of the Scientific Committee) of GRIN, the association of all researchers in Computer Science at Italian Universities.

De Nicola is currently
* Editor for Mathematical Structures in Computer Science (Cambridge University Press).
* Editor for Electronics Proceedings in Theoretical Computer Science.
* Chairman of the Steering Committee of the conference: International Symposium on Trustworthy Global Computing (TGC).
* Member of the Steering Committees of the International Federated Conferences on Distributed Computing Techniques (DISCOTEC) and of the International Conference on Coordination Models and Languages (COORDINATION) and MT-LAB: Modelling of Information Technology (Denmark).
* Coordinator of the PHD Program in Computer Science and Engineering at IMT.
* Director of the Research Area in Computer Science and Application at IMT.

Moreover, De Nicola has served as General Chair of PLI 2001, Conference Chair of PPDP 2001, Program Chair of COORDINATION 2004, TGC 2005 and ESOP 2007, member of the Steering Committee of ETAPS. He has also been a member of the program committee of important international conferences, such as AMAST, CAAP, CONCUR, COORDINATION, FCT, ICALP, LICS, MA, MFCS, PROCOMET, PPDP. De Nicola has also been invited speaker for many international conferences and schools among which IFIP World Congress 1986, COORDINATION 1999, CONCUR 2000, EXPRESS 2004, FMCO 2004, DAIS-FMOODS 2005, QAPL 2006.

Recent Research Project

* NAPOLI: Network Aware Programming: Objects Languages and Implementations 2002-2003 MIUR - Italy 200.000 Euro (National Coordinator)
* AGILE: Architectures for Mobility 2001-2004 IST FET Global Computing - EU 150.000 Euro (Site Coordinator)
* MIKADO: Models and Calculi for Mobility 2001-2004 IST FET Global Computing - EU 500.000 Euro (Site Coordinator)
* NAPI: Network Aware Programming in Italy 2001-2004 Microsoft Research Cambridge 100.000 Euro (Project Leader)
* SP4: Architetture Software ad Alta Qualita' di Servizio per Global Computing su Cooperative Wide Area Networks 2002-2005 Progetto SP4 - CNR 110.000 Euro (Site Coordinator)
* PaCo: Performability-Aware Computing: Logics, Models, and Languages 2008-2010 MIUR - Italy 20.000 Euro (Site Coordinator)
* SENSORIA: Software Engineering for Service-Oriented Overlay Computers 2005-2010 IST FET Global Computing Initiative II - EU 400.000 Euro (Site Coordinator)
* ASCENS: Autonomic Service-Component Ensembless 2010-2013 IST FET Self-Awareness in Autonomic Systems - EU 400.000 Euro (Site Coordinator)

7 - Most significant scientific publications of the Principal Investigator

1. Acciai L, Boreale M, DE NICOLA R. (2011). Linear-Time and May-Testing in a Probabilistic Reactive Setting. Formal Techniques for Distributed Systems: FMOODS/FORTE 2011. vol. 6722 - LNCS, p. 29-43, BERLIN: Springer, ISBN/ISSN: 978-3-642-21460-8
2. Caires L, DE NICOLA R., Pugliese R, Vasconcelos V T, Zavattaro G (2011). Core Calculi for Service-Oriented Computing. Rigorous Software Engineering for Service-Oriented Systems - Results of the SENSORIA Project on Software Engineering for Service-Oriented Computing. vol. 6582 - LNCS, p. 153-188, BERLIN: Springer, ISBN/ISSN: 978-3-642-20400-5
3. DE NICOLA R. (2011). Process Algebras. Encyclopedia of Parallel Computing. p. 1624-1636, NEW YORK: Springer, ISBN/ISSN: 978-0-387-09765-7
4. DE NICOLA R., Latella D, Loreti M, Massink M (2011). SoSL: A Service-Oriented Stochastic Logic. Rigorous Software Engineering for Service-Oriented Systems - Results of the SENSORIA Project on Software Engineering
for Service-Oriented Computing. vol. 6582 LNCS, p. 447-466, BERLIN: Springer, ISBN/ISSN: 978-3-642-20400-5
5. DE NICOLA R., D. GORLA, R.R. HANSEN, F. NIELSON, H. RIIS NIELSON, CHRISTIAN W. PROBST, PUGLIESE R (2010). From Flow Logic to static type systems for coordination languages. SCIENCE OF COMPUTER PROGRAMMING, vol. 75(6); p. 376-397, ISSN: 0167-6423, doi: 10.1016/j.scico.2009.07.009
6. DE NICOLA R., DANIELE GORLA, ANNA LABELLA (2010). Tree-functors, determinacy and bisimulations. MATHEMATICAL STRUCTURES IN COMPUTER SCIENCE, vol. 20(3); p. 319-358, ISSN: 0960-1295
7. MARCO BERNARDO, DE NICOLA R., MICHELE LORETI (2010). Uniform Labeled Transition Systems for Nondeterministic, Probabilistic and Stochastic Processes. Trustworthly Global Computing 5th International Symposium, TGC 2010, Munich, Germany, February 24-26, 2010, Revised Selected Papers. vol. 6084 - LNCS, p. 35-56, , ISBN/ISSN: 9783642156397
8. DE NICOLA R., D. LATELLA, M. LORETI, M. MASSINK (2009). Rate-Based Transition Systems for Stochastic Process Calculi. In: S. Albers, A. Marchetti-Spaccamela, Y. Matias, S.E. Nikoletseas, W.Thomas (Eds.). Automata, Languages and Programming, 36th Internatilonal Colloquium, ICALP 2009, Lecture Notes in Computer Science 5556. p. 435-446, BERLIN: Springer, ISBN/ISSN: 9783642029295, doi: 10.1007/978-3-642-02930-1_36
9. DE NICOLA R., D. LATELLA, M. LORETI, M. MASSINK: (2009). On a Uniform Framework for the Definition of Stochastic Process Languages. In: M. Alpuente, B. Cook, C. Joubert (Eds.. Formal Methods for Industrial Critical Systems, 14th International Workshop, FMICS 2009. p. 9-25, BERLIN: Springer, ISBN/ISSN: 9783642045691, doi: 10.1007/978-3-642-04570-7_2

10. DE NICOLA R., D. LATELLA, M. LORETI, MASSINK M (2009). MarCaSPiS: a Markovian Extension of a Calculus for Services. ELECTRONIC NOTES IN THEORETICAL COMPUTER SCIENCE, vol. 229; p. 11-26, ISSN: 1571-0661
11. R. BRUNI, DE NICOLA R., M. LORETI, L. MEZZINA (2009). Provably Correct Implementations of Services. In: Christos Kaklamanis, Flemming Nielson. Trustworthy Global Computing, 4th International Symposium, TGC 2008, Barcelona, Spain, November 3-4, 2008, Revised Selected Papers. Lecture Notes in Computer Science 5474. p. 69-86, , ISBN/ISSN: 9783642009440
12. BOREALE M, ROBERTO BRUNI, DE NICOLA R., MICHELE LORETI (2008). Sessions and Pipelines for Structured Service Programming. In: Gilles Barthe, Frank S. de Boer. Formal Methods for Open Object-Based Distributed Systems, 10th IFIP WG 6.1 International Conference, FMOODS 2008, Oslo, Norway, June 4-6, 2008, Proceedings. Lecture Notes in Computer Science 5051. p. 19-38, BERLIN: Springer, ISBN/ISSN: 9783540688624
13. CALZOLAI F, DE NICOLA R., LORETI M, TIEZZI F (2008). TAPAs: A Tool for the Analysis of Process Algebras. TRANSACTIONS ON PETRI NETS AND OTHER MODELS OF CONCURRENCY, vol. 5100; p. 54-70, ISSN: 1867-7193
14. DE NICOLA R., D. GORLA, R.R. HANSEN, F. NIELSON, H.R. NIELSON, C.W. PROBST, R. PUGLIESE (2008). From Flow Logic to Static Type Systems for Coordination Languages. In: Doug Lea, Gianluigi Zavattaro (Eds.).. Coordination Models and Languages, 10th International Conference, COORDINATION 2008. p. 100-116, BERLIN: Springer, ISBN/ISSN: 9783540682646
15. DE NICOLA R., LORETI M (2008). Modelling global computations with Klaim. PHILOSOPHICAL TRANSACTIONS - ROYAL SOCIETY. MATHEMATICAL, PHYSICAL AND ENGINEERING SCIENCES, vol. 366; p. 3737-3745, ISSN: 1471-2962
16. DE NICOLA R., LORETI M (2008). Multiple-Labelled Transition Systems for nominal calculi and their logics. MATHEMATICAL STRUCTURES IN COMPUTER SCIENCE, vol. 18; p. 107-143, ISSN: 0960-1295
17. DE NICOLA R., Loreti M (2008). Modelling global computations with Klaim. PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON SERIES A: MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES, vol. 336; p. 3737-3745, ISSN: 1364-503X
18. G. CASTAGNA, DE NICOLA R., D. VARACCA (2008). Semantic subtyping for the pi-calculus. THEORETICAL COMPUTER SCIENCE, vol. 398 (1-3); p. 217-242, ISSN: 0304-3975
19. LORENZO BETTINI, DE NICOLA R., MICHELE LORETI (2008). Implementing Session Centered Calculi. In: Doug Lea, Gianluigi Zavattaro. Coordination Models and Languages, 10th International Conference, COORDINATION 2008, Oslo, Norway, June 4-6, 2008. Proceedings. Lecture Notes in Computer Science 5052. p. 17-32, BERLIN: Springer, ISBN/ISSN: 9783540682646
20. DE NICOLA R., D. GORLA, PUGLIESE R (2007). Global computing in a dynamic network of tuple spaces. SCIENCE OF COMPUTER PROGRAMMING, vol. 64(2); p. 187-204, ISSN: 0167-6423
21. DE NICOLA R., D. GORLA, R. PUGLIESE (2007). Basic Observables for a Calculus for Global Computing. INFORMATION AND COMPUTATION, vol. 205(10); p. 1491-1525, ISSN: 0890-5401
22. DE NICOLA R., J.-P. KATOEN, D. LATELLA, LORETI M, M. MASSINK (2007). Model checking mobile stochastic logic. THEORETICAL COMPUTER SCIENCE, vol. 382(1); p. 42-70, ISSN: 0304-3975
23. DE NICOLA R., M. LORETI (2007). Multi Labelled Transition Systems: A Semantic Framework for Nominal Calculi. ELECTRONIC NOTES IN THEORETICAL COMPUTER SCIENCE, vol. 169; p. 133-146, ISSN: 1571-0661
24. L. BETTINI, DE NICOLA R., D. FALASSI, M. LORETI (2007). Implementing a Distributed Mobile Calculus Using the IMC Framework. ELECTRONIC NOTES IN THEORETICAL COMPUTER SCIENCE, vol. 382; p. 42-70, ISSN: 1571-0661
25. M.C. PALMERI, DE NICOLA R., M. MASSINK: (2007). Basic Observables for Probabilistic May Testing. In: Autori Vari. Fourth International Conference on the Quantitative Evaluaiton of Systems (QEST 2007). p. 189-200, WASHINGTON, DC: IEEE Computer Society, ISBN/ISSN: 076952883X
26. BOREALE M, ROBERTO BRUNI, LUIS CAIRES, DE NICOLA R., IVAN LANESE, MICHELE LORETI, FRANCISCO MARTINS, UGO MONTANARI, ANTONIO RAVARA, DAVIDE SANGIORGI, VASCO VASCONCELOS, GIANLUIGI ZAVATTARO (2006). SCC: a Service Centered Calculus. In: Mario Bravetti, Manuel Núñez, Gianluigi Zavattaro. Web Services and Formal Methods, Third International Workshop, WS-FM 2006 Vienna, Austria, September 8-9, 2006, Proceedings. Lecture Notes in Computer Science 4184. p. 38-57, , ISBN/ISSN: 3540388621
27. DE NICOLA R., D. GORLA, PUGLIESE R (2006). Confining data and processes in global computing applications. SCIENCE OF COMPUTER PROGRAMMING, vol. 63(1); p. 57-87, ISSN: 0167-6423
28. DE NICOLA R., D. GORLA, R. PUGLIESE (2006). On the Expressive Power of Klaim-based Calculi. THEORETICAL COMPUTER SCIENCE, vol. 356(3); p. 387-421, ISSN: 0304-3975
29. DE NICOLA R., J.-P. KATOEN, D. LATELLA, M. MASSINK (2006). Towards a Logic for Performance and Mobility. ELECTRONIC NOTES IN THEORETICAL COMPUTER SCIENCE, vol. 153(2); p. 161-175, ISSN: 1571-0661
30. L. BETTINI, DE NICOLA R., M. LORETI (2006). Implementing Mobile and Distributed Applications in X-Klaim. SCALABLE COMPUTING. PRACTICE AND EXPERIENCE, vol. 7; p. 13-35, ISSN: 1895-1767

8 - List of the Research Units

Unit	Associated Investigator of the Research Unit Program	Typology	Organisation	Affiliation	Disponibilità temporale indicativa prevista predicted months per person
Totale					**0**

9 - Research Program Abstract

This project deals with the issues related to the development and management of open-ended IT systems consisting of heterogeneous, highly parallel, massively distributed components with complex interactions and behaviours, and with autonomy in terms of individual behaviour, objectives and decision-making. We shall develop a coherent, integrated set of languages, methods and tools to build systems that can operate in open-ended, unpredictable environments while adapting to changing contexts or requirements, and that behave reliably and are able to cope with failures and attacks. The specific objectives of the project are outlined below.

Autonomicity
To provide programmers with the appropriate linguistic abstractions for modelling and manipulating knowledge, behaviour, aggregation, and interactions, we shall design and implement programming/specification languages that offer the possibility of integrating behavioural description and knowledge management and that are based on solid mathematical ground to permit formal reasoning and property verification.

Negotiation
To handle collaborative scenarios with a high dynamicity of participants, we shall design interaction models adhering to the Negotiate, Commit, and Execute (NCE) schema. Moreover, to deal with unexpected events and deviations from the expected behaviours we shall develop techniques based on reversibility, allowing components to return to globally safe states, and techniques based on compensations, to remedy the effects of aborted long-running transactional activities.

Glocality
Global design is often more feasible for systems with complex interactions than bottom-up component-wise assembly. For passing from global to local specifications, we will define engineering principles and operational guidelines for the design and analysis of collective adaptive systems. These will be based on general formal models that will lay the basis for projection algorithms to automatically derive not only components' descriptions starting from global specifications but also to deal with resource-aware middleware and for computing emergent collective behaviour from interacting autonomous entities.

Performability

To take uncertainty and partial knowledge into account and model "partial truth", we will investigate quantitative extensions of models, languages and logics that permit the consideration of quantities such as event probabilities and execution rates. We will thus develop a framework for modelling and analysing both qualitative and quantitative characteristics of interacting systems, for supporting decision making and dynamic system reconfiguration and for resolving conflicting goals.

Trustworthiness
Formal correctness and security guarantees will play an important role in helping users to gain confidence in the developed systems. We shall deal with the enforcement of functional properties, like safety and progress, at a global level, and the prevention of misuse by either outsiders or insiders. We shall propose both linguistic primitives and quantitative models to manage access control, trust and privacy at an appropriate level of abstraction. We shall envisage domain-dependent methodologies, ranging from static to run-time techniques, for the enforcement of global correctness.

Validation
To provide the project with a context of real-life applications, a substantial effort in the project will be invested in work on use cases covering a representative range of the challenges posed in the Horizon 2020 program. The purpose of the use cases is many-fold:
feed and challenge the foundational research on models, assist the design of our programming abstractions, help structure and fine-tune the different techniques for qualitative and quantitative modelling and analysis throughout the project duration, and provide the basis for future exploitation of the project results.

10 - Research Program Aim

Today, distributed computing has become a ubiquitous technology, mainly thanks to the infrastructure of the global Internet. This phenomenon will grow bigger: open-ended, heterogeneous, highly parallel, massively distributed systems will soon span millions of nodes with complex interactions and behaviours. In addition, single components might have autonomy in terms of individual properties, objectives and decision-making while interaction between components may lead to the emergence of new and/or unexpected behaviours.
Prominent examples of such systems are cloud systems, power grids, social networks, systems relying on swarm intelligence, models for the handling of emergencies. The central challenge they pose is that of the decentralized coordination of distributed systems agents, processes, computers, ``things", ... that guarantees that expected behaviours are exhibited, services are offered according to the agreed quality of service, unexpected behaviours or security attacks are properly faced. Moreover, properties and constraints cannot have a rigid meaning (“either it is safe or it is not”) but should have a less absolute nature (“in 99.7% of the cases, safety can be ensured”).
This project deals with the formalisation of the concepts and behaviours outlined above. We shall develop a coherent, integrated set of languages, methods and tools to build systems that can operate in open-ended, changing environments while adapting to changing conditions or requirements, and that behave reliably and predictably being able to cope with failures and attacks. The more specific objectives are outlined below.

1. Languages Coordination and Autonomicity
We shall design and implement programming/specification languages that offer the possibility of integrating behavioural description and knowledge management and are equipped with specific abstractions or linguistic primitives for key concepts like knowledge, behaviour, aggregation, and interactions. The languages will be based on solid mathematical theory (like multi-agent models or process calculi) which will support the development of a comprehensive framework for the development, verification and analysis of the above mentioned classes of systems. For such languages, behavioural type systems dealing with the greater levels of openness and dynamicity of autonomic and self-adaptive systems will be designed, analysed and implemented. Behavioural, polymorphic, dependent, modal and self-adaptive types will be considered for a wide range of application scenarios, possibly considering a mixture of static and dynamic type checking techniques.

2. Models for Long-Running Reliable Interactions
The model we shall define will adhere to the NCE schema, which includes three phases: negotiation, commit, and execution. The participants negotiate their behaviours and, if an agreement is reached, they commit and begin executing according to the assigned duties and rights. Type systems will be used to specify the negotiation protocols of the participants, and investigate automated verification of conformance to the protocols. For handling unexpected events or deviations from the prescribed protocol both techniques based on reversibility (allowing the system to return to a past safe state) and techniques based on compensation activities (to remedy the effect of aborted transactions) will be investigated.

3. Global and Local Models of Adaptivity
We shall define general models of adaptivity that will be framed into conceptual categories, including black-box, white-box and reflective architectures. These models will be studied together with adaptation patterns at system level emerging from local changes at components' level and will pave the way to the definition of engineering principles and operational guidelines for the design and analysis of collective adaptive systems. The model will rely on the integration of declarative and procedural programming techniques and on a general theory of knowledge propagation (from local to global) and multilevel abstraction. We shall define flexible projection algorithms to automatically derive component descriptions starting from global specifications and for computing the emergent collective behaviour starting from the models of autonomous entities. In order to guarantee proper handling of the available resources we shall also consider introducing resource-aware networking middleware that account for non-functional aspects of interaction, while for guaranteeing correctness we will study symbolic verification techniques for open-ended systems.

4. Models and Logics for Quantitative Evaluation
To deal with uncertainty and partial knowledge, we shall investigate quantitative extensions of models, languages, and logics to consider quantities such as event probabilities and execution rates of highly dynamic and reconfigurable systems. The analysis of the resulting models will also be addressed, so that relevant performability indices can be computed algorithmically. This will allow us to represent and study e.g. quantitative contract-based choreographical and orchestrational systems. Inparticular, we shall consider, extend, and compare two alternative/complementary approaches to quantitative modeling and analysis: an operational one (based on enriched automata) and a declarative one (based on behavioral types). We shall define general automata-based models and observational semantics that encompass nondeterministic, probabilistic, and stochastic behaviors as well as combinations thereof to develop expressive frameworks for modeling both qualitative and quantitative descriptions of interacting systems. We shall extend behavioral types with quantitative information about alternative options and develop techniques and tools to support dynamic system reconfiguration and conflicting management goals while guaranteeing the satisfaction of requirements on the whole system.

5. Tools and Methods for Trustworthy Systems
The trustworthiness of a system encompasses two main properties: correctness and security. Within the project, we target selective aspects of such properties, namely: safety and liveness, related to (global) functional correctness; trust, integrity and privacy, related to security. Specifically, we shall propose models for the quantitative analysis of data and identity privacy and devise techniques to measure trust, and to find appropriate trade-offs between conflicting requirements such as trust and anonymity. Moreover, by resorting to language-based security techniques, we shall provide support for flexible access control policies drawing on behaviour tracking mechanisms to build dynamic notions of roles and on reputation-relevant events to build trust for principals and roles. Concerning the enforcement of global correctness, we will have to necessarily rely on a variety of approaches, also depending on the chosen application domain. This will result in a framework integrating static techniques (type theories), as well as dynamic (symbolic execution and model checking) and run-time (monitoring) ones.

6. Case Studies
To provide the project with a context of real-life applications, a substantial effort in the project will be invested in work on use cases. The use cases will feed and challenge the foundational research on models, assist the design of our programming abstractions, help structure and fine-tune the different techniques for qualitative and quantitative modelling and analysis throughout the project duration. Finally, they will provide the basis for future exploitation of the project results. The case studies are centered on a few, well identified, Horizon's 2020 challenges with the purpose of demonstrating the project's contribution and impact on the development of effective and fully reliable platforms for green traffic and transport support systems, for citizen-centric delivery of services and for emergency management.

11 - Scientific Background

Compositionality and the related methods of separation of concerns and *divide et impera* are fundamental concepts in science and engineering: large, critical systems, either in terms of size or structure, can be tackled only by breaking them into pieces and by recombining the pieces as needed. Often, the additional dimension of *abstraction* is essential: when studying a natural phenomenon, the details in the model depend on its purpose, and moving from one level of description to another is a key issue.

In computer science, compositionality and abstraction are important for maintenance and reusability: a component should depend as little as possible on application details and on other components, so that it can be reconfigured easily. Reusability is an essential property for hardware and software, both in terms of production and maintenance costs and of security and social acceptance. Object-oriented programming has been a key achievement for encapsulating implementation details. More recently, model driven architecture has promoted the use of compositionality and abstraction from the programming level to the intermediate levels of requirement, specification and design. Thus, functional and quantitative analysis of a design can be performed on a plurality of models, covering different key aspects and making easier, and to some extent automatic, the programming phases. Besides reusability, this guarantees platform independence and the possibility of discovering design flaws at an early stage of the development.

Within these approaches, analysis and design often take advantage of well-studied models of data and computation, like conceptual data models, labelled transition systems, Petri nets, message sequence charts. In other cases they are based on well-known mathematical theories, like those of Markov processes, linear algebras, ordinary differential equations, mathematical programming. However in most cases the quest for compositionality and abstraction, together with requirements for computability and computational efficiency, has required a fresh reconsideration of the various models and of the convenience of their applications.

The models actually used in practice are widely different according to: (i) their application domains; (ii) the historical period they were introduced; (iii) the amount of synchrony vs. asynchrony in their behavior; (iv) the criteria of correctness they are supposed to satisfy; and (v) the flexibility expected in the systems' lifetime. Here we examine three scenarios: centralized systems (CS), service-oriented architectures (SOA) and autonomic systems and social networks (AS). The evolution from CS to SOA can be understood in terms of the dimensions (i)-(v) above. In the project we focus mainly on issues particularly relevant for SOA and AS, but the three of them are currently present.

Centralized systems embody the most localized form we consider. They are possibly large, dedicated computation centers, supporting critical, strategic installations, or heavily protected data centers but also microcontrollers or digital signal processors within larger systems. After the APOLLO and military applications in the sixties, this kind of CS became widespread with the fall of microprocessor cost. They are ubiquitous and their number is continuously growing. They contribute to the impression that computers are disappearing. They are often synchronous and timed, and their concurrency is determined by a scheduler exploiting the available parallelism. CS also communicate via the Internet, as anticipated by the *Internet of things* scenario. From the composition point of view, they are usually represented as networks of finite state automata interacting via connectors, verified via model checking of temporal logic properties. A design problem is state explosion, which is limited via BDDs, context dependency restrictions, priority-based behavior restrictions or probabilistic Monte Carlo methods. Networks of connectors with convenient algebraic properties in terms of canonical representations, synthesis algorithms and abstract observational semantics are also actively studied [Arb04,BLM06,BS10]. The evolution of these CS in their lifetime is usually quite limited: their behavior is verified statically and never changes.

Service oriented software architectures aim at establishing dynamic connections on the web between heterogeneous costumer-and-service applications, typically within a business process [CPPR10]. Emphasis is on flexibility, negotiation, service contracts, business process management, shared sessions with guaranteed functional and quality of service properties. Also security aspects are essential, as trustworthy services must provide guarantees of authentication and authorization among the involved parties [BCEM11], trust in their behavior [XL04] and protection against unintended release of sensitive data [CR07]. SOA were introduced with relatively simple data base oriented applications in mind, but soon many software products were offered as services, and now other computer resources are offered on the web as virtualized clouds. Behavior is essentially asynchronous, but contracts have a transactional flavor.

Compositionality, in the full sense of service discovery, binding, negotiation, guaranteed execution, takes place at run time, so compositionality is ensured by definition. Service composition can be hierarchical, with different connectors for parent and sibling relationships [BGL10]. When possible, the modular and hierarchical nature of such systems is exploited also in systems analysis [BHM10]. Ad hoc networks are another example of highly dynamical system. They consist of collections of wireless hosts that communicate by broadcasting messages according to protocols working independently from specific network configurations.

Autonomic computing still considers distributed computing resources, but introduces additional self-managing characteristics with the aim of adapting systems to unpredictable changes in the environment. Self-* features include self configuration, healing, optimization and protection. Autonomic architectures include sensing capabilities and control loops and goal-oriented reasoning abilities. *Black box* autonomicity concerns the ability to adapt exploiting only the owned resources, while *white box* autonomicity [BCGLV12] allows for the intervention of external agents to modify behaviors. Due to the intrinsic reflexive meaning of actions modifying the behavior, compositionality is now more complex.
Particularly interesting is the case of autonomic systems consisting of a large number of similar agents, swarms, which together exhibit an *emergent* complex behavior, while alone have a simple behavior. Abstracting emergent behavior and knowledge from a large amount of data describing the local behavior is very important when analyzing the different aspects of networked communities.
Combining autonomic and swarm behavior raises a number of interesting questions about the propagation of knowledge among neighbors and about awareness of local and global behavior among agents [AMHB04,ZV11].
Several works on complex systems propose a multi-level approach to cope with the issue of emergent behaviors. This approach has been also conceived for software systems [CIW2006]. Thus, a multi-level approach seems to be a fundamental ingredient in this field: the emergent behavior can be observed at a ``higher" level w.r.t. a basic level in which components interacts.
The composition and abstraction needs of the three scenarios above are diverse and could require significantly different approaches. However, it is important to establish a transversal, common foundation which tries to unify the phenomena as much as possible, in order to factorize concepts, results and tools. Thus, we will focus on a few theories which are both well understood and promising in many application contexts.

One option is *process algebras* [BPS01]. Compositionality is built-in in the algebraic structure and abstraction is based on a number of behavioral equivalences.
Among the many process calculi for SOA we have [CDPV11,PT12].
Other extensions deal with probability-related and time-related aspects, possibly in combination with nondeterminism [BPS01]. Also several specification languages [ABC10,BDHK06,DKLLM07] have been introduced to enhance the modeling capabilities for systems exhibiting stochastic behavior. At the same time, various formal tools mainly based on stochastic temporal logics have been developed to deal with quantitative properties [DHS09,CHKM11].
Different extensions have also been devised to cover quantitative aspects of security, such as access control [MPT12], to measure information leakage, based on tools for performance evaluation [AB07] as well as information theory [CHM01,Bor09]. Another security aspect concerning business processes is the need of keeping private the sensitive information that they may contain. This is achieved through abstract processes that hide private information.
Techniques for reasoning on components acting in a partially specified or open-ended environment [BBB07] will be also pivotal. In the project, building on all the above, we will study extensions dealing with reconfiguration capabilities due to a flexible name and resource structure, as well as the ability to interact with declarative knowledge.

Another option we will study and apply to our scenarios is *type theory*: it is an expressive, but still computationally feasible form of verification which covers both modal and behavioral aspects, as shown in [KS11], and which enforces safe interactions among partners. In this field, [BCDGV08] shows how session types can be integrated into object-oriented languages, and [AL09] how static type analysis can be combined with symbolic execution and compiler technology. We will study and develop expressive type systems able to deal with the greater levels of openness and dynamicity of autonomic systems, introducing, as in [DGZ11], mixed (static/dynamic) strategies of type-checking. Regarding declarative approaches to knowledge representation, we plan to build on [CGMS06] to design a static type system for a graph query language, targeting SPARQL [PS08].

A third option is *constraint theory*: constraints can represent quality of service and behavioral properties, and well-understood primitives are available for matching the control flow with the constraint conditions [BMRS10]. General notions of constraint propagation can model the evolution of local to global emergent behavior and its projection back [CDP11]. We shall extend constraint systems to cope with knowledge representation and exploit it for modeling control loops in autonomic computing.

Last but not least, we will devote some efforts in the integration of the above three options to combine and enhance their features. In particular, we plan to encode types as constraints and develop process algebras tailored to their manipulation, following the line of [BCDM12].

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12 - Project development and schedule

The project will be structured into six work packages that, in turn, contain more specific tasks. Some of the proposed tasks will exploit results obtained in ongoing EU projects in which some of the partners are involved.The names of the six work packages are reported below together with the name of the partner unit that will coordinate their activity:
* WP1: Autonomicity: Adaptivity and Self-Awareness (UNIGE)
* WP2: Negotiation: Transactions, Reversibility and Compensations (UNIBO)
* WP3: Glocality: Connecting Global and Local Views (UNIPI)
* WP4: Performability: Evaluating for Deciding (IMT)
* WP5: Trustworthiness: Correctness and Security (UNIFI)
* WP6: Validation: Case Studies (UNIVE)

Although the different WPs focus on fundamental and orthogonal aspects of the systems of interest, the interrelation among them will be strong. Indeed, the foundational basis for these WPs is the same, relying on process calculi for modeling and designing programming constructs, type systems and operational techniques

for analysis, contracts for reasoning on interaction dialogues. Therefore, the success of a construct or a technique proposed within a certain task will be also measured by the possibility of applying it to the issues examined in related tasks of other WPs.

The project development will be organised in three phases, corresponding to the three years of duration. We plan to have a kick-off meeting at month 1, and to put online the website of the project at month 2. Then, for each phase/year, we plan an internal check point at month 6 and a project workshop at month 12. In the kick-off meeting we will discuss the state of the art and choose an Advisory Board built of international experts. In the internal check points we will have (possibly virtual) meetings among the WP leaders to verify that the research activities are going as expected. In the project workshops we will present and compare the obtained results before the Advisory Board.

Below we provide a description of the activities within each WP, structured in terms of specific tasks.

WP1: Autonomicity: Adaptivity and Self-Awareness
The first work package will address both the foundations of autonomic and self-adaptive systems and the design and prototypical implementation of programming/specification languages and tools which will provide a comprehensive framework for the development, testing and analysis of such systems. The activities within this workpackage will be organised in three themes, namely Models, Languages and Types, detailed as follows.

T1.1: Models
We will develop a theory of adaptivity based on reflective architectures, evaluating the impact of stream feedback patterns on such notions. We shall develop and analyse several models of adaptive systems exhibiting a variety of dependency patterns between local changes and adaptation at the global level. For example, adaptation might be triggered by a modification of a meta-level (choreographical) description of the system, causing replacement or modification of the affected components.

T1.2: Languages
We shall investigate the foundational aspects of agent-based computing models for autonomic systems and will continue the development and the implementation of two languages simpAL and SCEL, based on the agent paradigm and on process calculi, respectively. Such languages will support formal reasoning on the behaviours of such systems, and will offer programming abstractions to represent directly aggregations, behaviours and knowledge according to specific policies. Logics and linguistic primitives for modelling variability, evolvability and adaptability in product family engineering will be proposed and evaluated.

T1.3: Types
We will study and develop type systems to deal with openness and dynamicity of autonomic systems. We will consider behavioural types and modal type systems for interacting participants which can adapt their behaviour dynamically. Modalities will also be used to annotate open code, representing the requests that the run-time environment makes on the code. Also other kinds of type systems will be considered possibly considering a mixture of static and dynamic type checking techniques.

WP2: Negotiation: Transactions, Reversibility and Compensations
To handle unexpected events and to deal with deviations from the expected behaviours we shall develop an interaction model adhering to the Negotiate, Commit, and Execute (NCE) schema and will use techniques based on reversibility, allowing the system to return to a past safe state, and techniques based on compensations to remedy aborted transactions. Type systems will be used to specify the negotiation protocols and support automated verification.

T2.1: Negotiate, Commit, Execute
We will study models for the NCE schema: negotiate, commit, execute. A starting point for the negotiation phase is a recent proposal that makes use of forms of constraints. We will experiment the possibility of viewing constraints as types and apply to them techniques developed for type systems. In general, we will look for suitable representations of contracts and constraints and for appropriate primitives for their manipulation.

T2.2: Long Running Transactions
We will develop a coherent framework for the specification, verification and analysis of long running transactions and will study notions of long running transactions where the transaction scope is not statically defined, but determined dynamically by the actual interactions. This allows to deal with systems where components are driven by their goals and do not follow a pre-defined schema.

T2.3: Reversibility and Fault-Recovery
We will study fault-recovery mechanisms based on reversibility. In particular, we will consider behavioural equivalences for reversible systems, allowing to compare different reversibility schema. We will also analyse mechanisms for controlling reversibility, to specify when and where execution should be reversed. Finally, we will combine reversibility and compensations, to keep track of past errors.

T2.4: Contracts and Compliance
We will study types for sessions and contracts. This includes techniques and tools for ensuring various behavioural properties, and the integration of session types within multi-agent languages, in which notions of subtyping will be used to allow agents to check the intentions of other communication parties.

WP3: Glocality: Connecting Global and Local Views
This work package will be concerned wit the design and analysis of collective adaptive systems and their emergent behaviour. We shall define engineering principles and operational guidelines based on general models of adaptivity that will lay the basis for defining projection algorithms to derive components' descriptions from global specifications and for computing the emergent collective behaviour from the models of autonomous entities.

T3.1: Global Descriptions
This task consider the description of global activity of systems by means of constraint-based contracts, choreography languages and global types. We will develop techniques to deal with systems where participants may enter and exit on request and will generalise the notion of global type to consider mutual dependencies. Also we shall be concerned with the projection of a global specification to local descriptions, thus from choreography (describing expected global behaviour of systems) to orchestration (describing system components).

T3.2: Emergent Behaviours
We will study techniques for programming single components by which the resulting behaviour of a dense ensemble can be understood in terms of space-time abstractions. This will throw light on the connections between local components' code and global emergent patterns. The activity concerned with emergent behaviour will build on constraint propagation and closure operators, taking into account probabilities and choices.

T3.3: Resource-Aware Middleware
We will exploit and enhance operational models of dynamic connectors based on Reo, BIP, Petri nets and Tile model and will introduce suitable extensions of process calculi where the communication infrastructure is explicit and programmable. Category theory will be helpful to account for resource-aware models in terms of suitable pre-sheaves.

T3.4: Open-Ended Systems
The activity concerned with open-ended systems will exploit process algebra, symbolic semantics and modal logics, suitably extended to deal with systems that are not entirely known or only partially specified. This will enable studying computational properties and verification methods in situations in which individual processes have only partial information about the entire system.

WP4: Performability: Evaluating for Deciding
This work package is concerned with stochastic models and quantitative analysis to deal with uncertainty and partial knowledge. We shall investigate quantitative extensions of models, languages, and logics to consider event probabilities and execution rates. We will thus develop expressive frameworks for qualitative and quantitative modelling of interacting systems that will be instrumental for establishing functional and non-functional properties, for supporting dynamic reconfiguration, and for resolving conflicting goals.

T4.1: Unifying Quantitative and Nondeterministic Models
We plan to define an extension of labeled transition systems that encompass nondeterministic processes, probabilistic processes, stochastic processes, and combinations thereof. The resulting unifying model will be used to provide general definitions of behavioural equivalences (bisimulation, testing, trace) and to study their general properties in a process algebraic setting.

T4.2: Revisiting Quantitative Formalisms

We intend to revisit existing quantitative formalisms, such as stochastic Petri nets and stochastic process algebras, in order to model in a compact and modular way autonomic systems. We will also address the problem of the specification of novel reward structures and stochastic temporal logics supporting enhanced methodologies for the computation of quantitative indices.

T4.3: Quantitative Types and Adaptation Support
We will extend behavioural types with quantitative information about alternative options and will develop techniques and tools, based on stochastic model checking and self-learning spatial strategies, to support dynamic system reconfiguration and conflicting management goals while guaranteeing satisfaction of the general requirements.

T4.4: Business Process Efficiency
We will develop formal analysis techniques and prototypical tools for monitoring and evaluating business processes deployed as services of the public administration. Moreover, we will investigate quantitative extensions of contract-based choreographical and orchestrational descriptions and the related notions of projection, conformance, and refinement.

WP5: Trustworthiness: Correctness and Security
For gaining confidence in the developed systems, we shall consider both formal correctness and security guarantees. We shall put forward both linguistic primitives and quantitative models to manage access control, trust and privacy at an appropriate level of abstraction and consider a range of techniques for the enforcement of global correctness.

T5.1: Foundations for Privacy, Trust and Access Control
In open systems where security infrastructures (PKI and the like) may not be available, the only form of trust for users might rest upon forms of reputation, computed on the basis of past behaviors. We intend to devise a solid foundational framework for computational trust-based and use quantitative information flow techniques to assess the tradeoff between seemingly conflicting requirements, like privacy/anonymity and trust.

T5.2: Programming Abstractions for Privacy and Trust in Authorization Systems
We will propose programming abstractions based on powerful theories of types for authorization, privacy and trust, to lift security foundations to the programmer level. Our abstractions will support information gathering about behavioral patterns of services, to build "trust groups", and define messaging techniques that ensure satisfactory degrees of anonymity. Languages for expressing efficient policy and decision making mechanisms (cf. XACML) will play an important role here.

T5.3: Global Correctness
We plan to employ a mix of domain-dependent approaches to enforce global correctness, ranging from static (types), to dynamic (model checking and symbolic execution), to run-time (monitoring) techniques for the enforcement of desirable properties. We will study static analysis techniques for the enforcement of desirable properties at both local and global level. We will then investigate techniques for run-time monitoring and checking of highly dynamic interconnected systems and for modifying at run-time the behavior of the various entities, or of their coordination.

WP6: Validation: Case Studies
The following case studies, used to experiment and integrate the provided theoretical results and analytical methods, represent the projects contributions towards the Horizon 2020 objectives ”Smart, green and integrated transport” and ”Inclusive, Innovative and Secure Societies” for promoting " smart mobility systems" and ”innovation to foster efficient, open, and citizen-centric public service (eGovernment)”.
T6.1: Citizen-Centric Platform
This task exploits a platform deployed in the Trento region, which captures existing systems available in the region, enriches them in order to support their interoperability, and reuses them to deliver context-aware, adaptable citizen-centric services. We will use the platform to experiment the integration of systems dealing with different aspects of our life (health, work, mobility, lodging...) typically fragmented, heterogeneous, and non-interoperable. Languages and models of WP1 will improve adaptivity and compositionality aspects, while results of WP5 will increase dependability and trustworthiness.

T6.2: Emergency Management
This task deals with the definition of PA inter-organizational Business Processes for emergency management. We will define decision and coordination logic for orchestration and choreography based paradigms, mechanisms for evaluating their consistency, and for adaptability to continuously changing environments. The task will start from T6.1 defined methodology.

T6.3: Traffic Monitoring for Low Environmental Impact
Urban traffic systems will be modelled with the proposed formal calculi, then relative analytical techniques will derive a set of performance indices providing measures of environmental impact, such as the spatial distribution, or the concentration of the fine PM10 and PM2.5 particulate. The results of such analyses will be instrumental to the development of traffic design systems, based on a coordinated control of traffic actuators to shape an optimal traffic distribution with respect to e.g., minimization of acoustic emissions, or uniform distribution of particulate polluting agents.

Tasks dependence
Below we provide an indication of the temporal dependencies between the different tasks.
T1.1 (7-30) - T1.2 (1-18) T1.3 (19-36)
T2.1 (1-24) - T2.2 (1-24) - T2.3 (13-36) - T2.4 (13-36)
T3.1 (1-30) - T3.2 (7-30) - T3.3 (1-24) - T3.4 (1-30)
T4.1 (1-18) - T4.2 (7-24) - T4.3 (19-36) - T4.4 (19-36)
T5.1 (7-30) - T5.2 (1-24) - T5.3 (13-36)
T6.1 (1-36) - T6.2 (19-36) - T6.3 (19-36)

13 - Role of each research unit with regards to expected targets and related modalities of integration and collaboration.

All the CINA units have a rather large common knowledge base. This is witnessed by several long-standing collaborations among participants from different units that have led to joint scientific publications on themes related to CINA topics. We believe this offers good possibilities w.r.t. the foreseen inter-unit collaborations. On the other hand, the involvement of the units is justified by their complementary expertise on different methodologies and techniques that will play a main role in the project, as detailed below. Each unit will consider specific (parts of the) the case studies to evaluate the impact of the developed techniques and tools.

IMT
IMT is a freshly formed research institute with expertise on the design and analysis of concurrent, distributed and mobile systems, stochastic and probabilistic models and logics and associated tools for property checking, contracts based on abstract processes and constraints, service-oriented computing and adaptation. The IMT unit also includes leading researchers from the University of Urbino with expertise on models for quantitative analysis. The contribution of IMT to the different WPs is as follows:
* WP1 (in collaboration with ISTI, UNICAM, UNIFI and UNIPI): definition of linguistic primitives and methodologies to design autonomic systems, where interacting components can dynamically self-adapt in response to environmental changes;
* WP2 (in collaboration with UNIPI and UNITO): development of the NCE schema and constraint-based contracts;
* WP3 (in collaboration with ISTI and UNIPI): definition of convenient mechanisms for dealing with the distributed knowledge governing the emergent behaviour of systems;
* WP4 (in collaboration with ISTI, UNIFI, UNITO and UNIVE): definition of operational models that can be used to describe the semantics of a number of variants of quantitative process algebras;
* WP5 (in collaboration with UNIFI, UNIPI and UNITO): development of a comprehensive quantitative model for contrasting trust and privacy requirements, as well as to the definition of a framework for managing access control and trust at a linguistic level.
IMT will lead WP4.

ISTI
The Formal Methods and Tools (FM&T) group of CNR/ISTI has a long-standing expertise in the area of design and application of formal methods, logics and languages for the specification and analysis of the behaviour of complex, distributed systems, including global computers, and their requirements. Expertise has also

been built in the area of semantic models, notations and techniques for the integrated modelling and analysis of qualitative and quantitative aspects of system behaviour, modelling/analysing variability; addressing scalability and emergent behaviour. In particular ISTI will play a major role in addressing the following Project Objectives:
* WP1 (in collaboration with IMT, UNIFI and UNITO): study of models and languages to support design of software product lines;
* WP3 (in collaboration with IMT and UNIPI): development of techniques for modelling and analysing emergent behaviour of massively populated systems (macroscopic level) using agent process-algebraic specifications (microscopic level);
* WP4 (in collaboration with IMT, UNIFI, UNIPI, UNITO and UNIVE): definition of models and logics for quantitative evaluation as well as development of uniform approaches for their definition;
* WP6 (in collaboration with all the research units): modelling and analysing crowd dynamics and emergency management systems.

Bologna
The Bologna Unit (UNIBO) has internationally well-known expertise on: concurrent models and languages involving mobility and coordination; agents and multi-agent systems; behavioural equivalences; type systems for processes; quantitative models; operational techniques for modelling dialogues and reversibility; application of techniques of self-adaptivity and self-organisation in the context of emerging pervasive computing scenarios as well as in the context of distributed business processes. The unit includes researchers from Fondazione Bruno Kessler (Trento). The contribution of UNIBO to the different WPs is detailed below.
* WP1 (in collaboration with UNIGE and UNITO): design and implementation of a new agent-based language for autonomic interacting components, with run-time adaptivity of components;
* WP2 (in collaboration with UNIGE and UNIPI): development of a framework for specification, verification and analysis of long running transactions and will study the foundations of reversibility of computations;
* WP3 (in collaboration with UNIGE and UNITO): investigate the application of process calculi to describe the collective behaviour of mobile and ad-hoc networks modelling pervasive computing scenarios, and techniques of projection from global choreographies to local orchestrations;
* WP4 (in collaboration with UNIFI): study of the integration of probabilities into the contracts for choreographies and orchestrations;
* WP6 (in collaboration with all the research units): use of a platform developed with Provincia di Trento, to experiment the approaches developed in the project and their suitability for citizen-centric service delivery.
UNIBO will lead WP2.

Camerino
The Camerino research unit (UNICAM) has worked on the design and analysis of concurrent and distributed systems with particular attention to the analysis of non-functional aspects of such systems. Interesting results of the unit have been concerned with the evaluation of efficiency in the worst-case and with a study of relationships among timing, fairness and liveness properties. Recently, the group has been interested in models, simulation and analysis of spatial aspects of evolving systems and developed a spatial process algebra and an associated simulation and verification framework. The group encompasses also expertise in the area of eGovernment and services for public administration. UNICAM will contribute to the project's objectives as detailed below per work-package:
* WP1 (in collaboration with IMT and UNIFI): definition of modelling languages for specification and analysis of collective adaptive systems with a special attention to their spatial and multilevel features;
* WP3 (in collaboration with UNITO): study of analysis methods for verification of emerging collective behaviour;
* WP4 (in collaboration with UNIFI, UNIPI and UNITO): development of strategies to devise adaptation support;
* WP5 (in collaboration with UNIFI): analysis of run-time monitoring approaches to state global correctness of dynamically evolving systems;
* WP6 (in collaboration with all the research units): coordination of activities on modelling, analysis, development and validation of emergency management.

Firenze
The members of the Firenze Unit have worked extensively on languages and models for the analysis of concurrent and mobile systems. Important outcomes of this work include calculi for programming tuple-based interactive systems and for service oriented computing. The group is also well known for work on security, (stochastic) behavioural equivalences and logics, and type theories, focused on process calculi. In particular, UNIFI will contribute to:
* WP1 (in collaboration with IMT, ISTI, UNICAM, UNIGE, UNIPI, and UNITO): study of linguistic primitives and self-adapting types for the design of autonomic systems, also taking advantage of the experience acquired within the ASCENS project;
* WP4 (in collaboration with ISTI, IMT, UNIBO, UNICAM, UNIPI and UNITO): devising (a) tools based on stochastic model-checking, supporting quantitative analysis
of partially specified systems; (b) behavioural types to be employed in the semantics of quantitative process calculi, in order to account for non-functional aspects of system behaviour;
* WP5 (in collaboration with IMT, UNICAM, UNITO and UNIVE): development of a comprehensive quantitative model
to contrast Trust and Privacy requirements, as well as a framework for
managing Access Control and Trust at a linguistic level; study of language-based access-control mechanisms, by designing mechanisms for compactly storing policies, akin to the XACML language.
UNIFI will lead WP5.

Genova
The Genova research unit (UNIGE) has consolidated and specific experience in the following areas: programming foundations, languages and techniques for composition and adaptivity of object and component systems; type systems for compositional analysis, notably of Java-like languages; computational models for dynamic linking and reconfiguration. These results have been partly achieved within three past PRIN projects (EOS, EOS2 and DISCO) coordinated by the unit of Genova, and including research groups in Bologna, Firenze and Torino which are now involved in CINA. These projects have significantly extended object systems beyond the traditional ingredients of the object paradigm, incorporating more powerful and flexible features. This expertise of the unit of UNIGE, together with the well-established collaborations with other units, will play a key role in the following project's objectives:
* WP1 (in collaboration with UNIBO, UNITO and UNIFI): definition of languages for coordination and autonomicity by developing constructs and techniques for composition and adaptation which can be integrated with primitives for interaction, including sessions and conversations, and with the agent-based computing model;
* WP2 (in collaboration with UNIBO, UNIPI and UNITO): study reliable interactions by expressing and checking appropriate requirements on composition and adaptation, often in form of sophisticated types;
* WP3 (in collaboration with UNIBO, UNIPI and UNITO): definition of models of adaptivity, by relying of symbolic verification procedures for open-ended systems.
UNIGE will lead WP1.

Pisa
The Pisa research unit (UNIPI) has internationally known expertise on process calculi and other models of concurrency for the specification, analysis and verification of open ended and distributed systems. In particular, UNIPI has provided significant contributions to constraint theory, foundational models for transactions, service-oriented and session-oriented process calculi, the integration of process calculi with constraints and types, symbolic semantics for open systems, logics and type systems for accessing distributed data and more recently on white-box adaptation, emerging behaviour and business process analysis. The UNIPI unit also includes leading researchers from the University of Udine with expertise on type-theory based logical frameworks, bigraphic reactive systems, categorical models of quantitative aspects and on anomaly behaviour detection. The role of UNIPI in the WPs is detailed below.
* WP1 (in collaboration with IMT, UNIFI and UNITO): definition of adaptive architectures, languages and models;
* WP2 (in collaboration with IMT, UNIBO, UNIGE and UNITO): definition of fault-handling mechanisms in largely distributed and dynamic transactional systems;
* WP3 (in collaboration with IMT, ISTI, UNIGE, UNITO and UNIVE): design and analysis of collective adaptive systems with emergent behaviour;
* WP4 (in collaboration with IMT, ISTI, UNICAM and UNIFI): definition of categorical models of continuous state systems and formal analysis of business processes;
* WP4 (in collaboration with IMT, ISTI, UNICAM and UNIFI): definition of mixed static+dynamic analysis techniques and patterns for guaranteeing global correctness.
UNIPI will lead WP3.

Torino
The Torino research unit (UNITO) has a wide research tradition on formal methods, in particular on type theories. This is key for the project, since types play a central role in all work packages. More specifically UNITO has a solid background on: type systems, semantics of programming languages, design of linguistic constructs oriented to reuse and reconfiguration of software, static and dynamic software composition, semantics of concurrency, analysis and verification of distributed systems; probabilistic model checking and stochastic model checking.
UNITO will contribute to:
* WP1 (in collaboration with ISTI, UNIBO, UNIFI, UNIGE and UNIPI): definition of types for linguistic constructs supporting dynamic adaptation of system components;
* WP2 (in collaboration with IMT, UNIGE and UNIPI): development of types for process calculi augmented with suitable constraints;
* WP3 (in collaboration with UNIBO, UNICAM, UNIGE and UNIPI): use of theories of global and local types and their semantics to support analysis of emerging

collective behaviour;
* WP4 (in collaboration with IMT, ISTI, UNICAM, UNIFI and UNIVE): use of probabilistic timed automata, stochastic Petri nets and their equivalences to support quantitative analysis of stochastic systems;
* WP5 (in collaboration with IMT, UNIFI, UNIPI and UNIVE): development of types which contain partially specified parts.

Venezia
Venice's research unit (UNIVE) has a well-known expertise in process algebraic models of concurrent and distributed systems, security analysis of mobile and wireless networks based on behavioral techniques, logical and type-theoretic frameworks, as well as performance and reliability models based on a variety of Markovian stochastic models. Recent results in the areas of interest to CINA include powerful theories of logic and types for access control, bisimulation-based analysis of connectivity in wireless networks, efficient algorithms for the exact or approximated computation of steady-state performance indices. UNIVE includes researchers from the Univ. of Padova who seamlessly integrate in the group while bringing specific expertise on true concurrent models and logics for the analysis of causal properties of distributed and mobile systems, andon logics and algorithms for probabilistic behavioural equivalences. UNIVE contributes to CINA its expertise on security analysis and language-based techniques as detailed below per work package:
* WP3 (in collaboration with UNIPI): modular specification and analysis of qualitative and quantitative models;
* WP4 (in collaboration with IMT, ISTI, UNITO and the Dept. of Computing at Imperial College): quantitative modelling and computation of performance indices;
* WP5 (in collaboration with UNIFI, UNIPI, UNITO as well as with CISPA at Saarland University): study of security and privacy for distributed authorization systems;
* WP6 (in collaboration with all the research units): development of a use case on pollution monitoring for traffic-generated fine particulate (pm2.5 / pm10) conducted in collaboration with the research group of Analytical Chemistry at Ca' Foscari.
UNIVE will lead WP6.

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14 - Predicted Results

Autonomicity

* Design and implementation of programming/specification languages that offer dynamic updating and the possibility of integrating behavioural description and knowledge management and are based on solid mathematical ground to permit formal reasoning and property verification. Within these languages we shall define complex interactions mechanisms that are controlled also by a flexible type discipline, using self-adapting types to ensure safety properties.

* A specification methodology, based on Modal Transition Systems for modelling and analysing variability, evolvability and adaptability. A rigorous semantics of variability over behavioural models will can support a number of design- and run-time analysis techniques. This will contribute to the possibility of identifying variability points that can be triggered at run time to increase adaptability and optimise the (re)use of resources.

* Type inference for dynamic OO languages (as Python and JavaScript) using abstract compilation, a promising technique for integrating precise type analysis and compiler technology.

* Stream-based feedback patterns for black-box adaptivity, bigraphic models of adaptive systems and reflective architectures, models and tools for white-box adaptivity.

* Calculi supporting a variety of binding primitives and coercion/cast constructs with flexible type systems containing modalities expressing properties of the run-time environment.

The results of the project will provide programmers with the appropriate linguistic abstractions for modelling and manipulating knowledge, behaviour, aggregation, and interactions. The primitives will be based on solid mathematical background to guarantee systems verification.

Negotiations

* Models for long-running transactions adhering to the Negotiate, Commit, and Execute (NCE) schema where the transaction scope is not statically defined, but determined by the actual interactions.

* Agent-based languages equipped with session types, supporting both dynamic checking of agent conversations, and a priori checking of the agents' implementation compliance. Integration of session types with multi-agent systems, allowing automated verification of negotiation protocol conformance and notions of subtyping for those session types obtained via projections on single participants of a global type.

* Definition of a calculus of contracts enriched with semi-ring based constraints, which allow clients to choose services and to interact with them in a safe way. Moreover, we will represent session and contract types in suitable extensions of the constructive type theory of the Logical Framework LF, featuring "lock" types. This will allow to refine the contract types as a specific logic for ensuring properties of contracts.

* Fault-recovery schemes for distributed systems based on notions of reversibility of concurrent computations, with integrated mechanisms for compensations of aborted activities.

The results of the project will allow the design of systems that provide reliable services even in unreliable environments, by allowing the management of runtime errors using compensation and rollback mechanisms. The engineering process of advanced systems will benefit from those results since the time needed to cope with error handling will be shortened.

Glocality

* Engineering principles and operational guidelines for the design and analysis of collective adaptive systems based on general formal models that will lay the basis for projection algorithms to automatically derive not only components' descriptions starting from global specifications but also to deal with resource-aware middleware and for computing emergent collective behaviour from interacting autonomous entities.

* Generation techniques based on choreography representation and automatic orchestration to deal with systems where (a potentially unbound number of) participants may enter and exit on request.

* Process-algebraic languages and dialects also with spatial features for the effective agent-based modelling of (large) collections of agents equipped with several, coherent, semantic interpretations in the stochastic as well as the highly scalable fluid flow domains and with associated analysis techniques, possibly supported by appropriate logics.

This work is expected to impact, in the medium term, on the design of collective adaptive systems (possibly consisting of huge populations), making it possible to more easily predict and control the emergent behaviour in future and emerging ICT scenarios, like adaptive traffic control, socially-aware content provisioning, and energy allocation in smart grids.

Performability

* A unified operational format, focussing mainly on the framework of labelled state-to-function transition systems, to be employed to provide uniform characterisations of the major approaches to behavioural equivalences (bisimulation, testing, trace,...) and to study their general properties in a process algebraic setting (congruence, axiomatisation, logical characterisation). Further insight on behavioural relations will be guaranteed by a general co-algebraic framework.

* New formal methods, based on model checking and behavioural types, for the development and verification of systems in which quantitative information is inherent. Quantitative behavioural types will allow one to lift the outcomes of quantitative analysis (use of resources, timing and probabilistic behaviour,...) from abstract types to the corresponding processes.

* Extensions of choreographical descriptions and of projection/conformance theories, to represent probabilistic choices and time. This will make it possible to design and implement autonomic systems where subsystems are replaced according to adaptation needs related to efficiency of interaction (responsiveness) or to other quantitative measures, e.g., to service level agreement.

* A formal spatial framework based on probabilistic timed automata and multi-agent systems suitable for modelling, simulating and analysing eco/geographical/emergency-management systems also relying on self-learning and goal-driven strategies aiming at regulating the environment behaviour in order to support the achievement of desired spatial properties.

* Formal analysis techniques and supporting tools for the classification and automatic evaluation of the efficiency of business processes within complex organisations, in particular public administrations.

All this will enable taking uncertainty and partial knowledge into account and model "partial truth", and the development of a framework for modelling and analysing both qualitative and quantitative characteristics of interacting systems, for supporting dynamic system reconfiguration and for resolving conflicting goals.

Trustworthiness

* Quantitative models to manage access control, trust and privacy at an appropriate level of abstraction. In particular, by relying upon a model that combines elements of reputation and information flow, we expect to establish general, quantitative results about the trade-off between the seemingly conflicting requirements of privacy and trust. Moreover, we will devise policy managing mechanisms that permit compact storing of policies and efficient decision-making.

* Programming abstractions and security policy based on powerful static theories of types for authorisation, privacy and trust, to lift the project's security foundations to the programmer level. Techniques based on true concurrent semantics for proving desirable global properties like absence of deadlocks, liveness, absence of interferences or undesired information flows. These will be supported by corresponding behavioural logics for expressing causal and history dependent properties of concurrent computations and by self-adaptive types, collecting information on the trustworthiness of the participants in open, global environments.

* Domain-dependent methodologies, ranging from static to run-time techniques, for the enforcement of global correctness that will be addressed both in the context of variability analysis and in that of the analysis of probabilistic behaviour and will be accompanied by model checking algorithms to support variability analysis and OTF algorithms for probabilistic model-checking.

* Run-time failure prediction approaches for dynamically evolving software systems able to predict if erroneous states can be reached in the near future; techniques and tools for the automatic derivation and deployment of additional behaviour aiming at avoiding reaching the foreseen erroneous conditions will be proposed.

The above mentioned results will help lifting security foundations to the programmer level and provide models for qualitative and quantitative analysis of systems guaranteeing formal correctness and provide techniques to measure trust, and to find appropriate trade-offs between conflicting requirements such as trust and anonymity.

Validation

We will provide three case studies with a two-fold purpose: i) to provide challenging validation tests for the project's formal models, programming abstractions and analytical methods and ii) to demonstrate how the project's contribution can be used for the development of fully reliable automated services with organizational, socio-economic, and environmental impact. The expected results on the three scenarios are summarized in the following:

Citizen Centric Services:
Citizen-centric service delivery is an ideal case for experimenting with the design and provision of trustworthy, adaptive services. The expected results of the task come from the application of the project results to this case:
- models and languages for the specification of trustworthy, adaptive citizen-centric services
- techniques and tools for context-aware adaptation of citizen-centric services
- a methodology for trustworthy citizen-centric service delivery
- artifacts (services, requirements, context properties) and collected data (user logs, recommendations, usage and adaptation traces)

In addition to this, this case will offer to CINA a permanent showcase which is based on a territorial platform that will keep running also after the conclusion of the project.

Emergency Management
Emergency management is certainly one of the most complex tasks for the Public Administration. It provides a proper scenario for testing run-time model checking, adaptivity and learning methods for predicting an emerging behavior.
In particular the work on this case-study will deliver a demonstrator in which a disaster scenario is simulated and where the expected results are tested:
- algorithms and methodologies to handle run-time dinamicity, uncertainity and emerging behaviors.
- mechanisms for optimize the intervention at run-time via automated negotiation
- definition and evaluation of Business Processes for emergency management.

The Emergency Management service will be developed in synergy with the Citizen Centric Platform.

Traffic Monitoring for Low Environmental Impact
Traffic monitoring is an ideal case for experimenting with quantitative analysis of performance indices and with techniques to ensure the trustworthiness of the data sources (while preserving their privacy). The work on this case-study will deliver:
- a reusable methodology for a modular construction of urban traffic models encompassing qualitative indices, and quantitative metrics;
- algorithms and methodologies for extracting, accurate, time-efficient and numerically stable evaluations of the performance indices of those models, while preserving the privacy of the data sources whenever needed;
- a framework supporting timely "what-if" analysis in response to changes to the underlying traffic model.

Collectively, these results will enable framework to establish correlations of various indices based on which to informed decision can be made about sustainable traffic design plans.

15 - Proposed elements and criteria for ex-post review of the reached results

We propose below some criteria that we consider useful and significant in order to assess the achievements of the CINA project:

Scientific results

We will measure the quality of scientific results by the following elements.

Progress w.r.t. the scientific objectives described in the proposal.
To this end, the project will be monitored by the Coordination Board, consisting of the coordinator and the WP leaders. The Coordination Board will, at each planned checkpoint, verify if (partial and final) achievements are as expected and possibly undertake correcting actions.

External evaluation.
To this end, we will choose an Advisory Board built of two/three international experts. The project workshops at the end of each project phase will be useful both for the project itself and as an evaluation method. The participation to the workshops will be open to external researchers and to the Advisory Board experts. After the project workshops at month 12 and 24, the Advisory Board will be asked to provide evaluation reports on the state of the project, indicating points in favour and against the presented results, in order to suggest possible modifications and/or improvements. Correspondingly, after the checkpoints at month 18 and 30, the Coordination Board will write a brief document for answering the Advisory Board observations and for describing the possible correction actions we have engaged. After the final project workshop the Advisory Board will write a document with a global judgment on the research developed by the project.

Evaluation of the scientific quality.
We will evaluate the scientific quality according to the number of publications, the reputation of the journals, conferences and workshops where the scientific papers describing the project results will have been published or presented, and the diffusion of the results in the international scientific communities (e.g., citations in publications of other research groups).

Coordination among partners

The information exchange among partners will be easily and quickly handled through electronic mailing lists and the web site, where a private section will be used for sharing the relevant information between all the project researchers. A repository for concurrent, distributed editing of documents (which is already in place) will be used for information and document deposit and retrieval, thus also improving cooperation among the groups and making coordination easier. Coordination and information flow among project partners will also take place via the workshops to be held at the end of each phase.

We will evaluate the coordination and knowledge transfer among partners on the basis of the participation to the project workshops, the number and quality of joint papers between authors belonging to different units, and the development of techniques able to integrate different skills.

Dissemination
The results of the project will be disseminated through publications in journals and proceedings of conferences, and talks at conferences and workshops. The prototype implementations will become open-source software.

Reports, publications and prototype implementations will be also published in the (public section of) the project web site, in order to make them available quickly.
The web site will also be used to timely maintain and publicise to the researchers of related scientific communities other relevant information on the state of the project, such as short descriptions of results, and general information relevant to the project activity

The project workshops at the end of the three phases will be used for dissemination, and project's partners may organize thematic workshops, also aimed at dissemination.

We will evaluate the degree of dissemination on the basis of the quality of all the above mentioned aspects.

Moreover, we will evaluate the interest of project themes for teaching purposes, on the basis of the courses given by project participants on themes and results of the project, of the visiting periods of the youngest researchers at units different from their one, and of the number and quality of publications by young researchers.

Finally, we will evaluate the possible development/improvements of related software tools and the possible interest manifested by national and international industries.

16 - Sintesi delle collaborazioni con altri organismi di ricerca pubblici e privati, nazionali e internazionali, e indicazione degli eventuali collegamenti con gli obiettivi di Horizon 2020

Relations with "Horizon 2020"
The planned outcomes of the research pursued in the project CINA are relevant for the aims of the Horizon 2020 project (see references [A,B] at the end of this part). The individual Research Units not only complement each other with respect to their scientific and technical expertise, but also several of them have matured specific experiences in different scenarios connected with Horizon 2020 objectives.

The focus of the CINA project is in the ICT area. ICT acts as a major enabling technology inside Horizon 2020, and in the ICT field CINA concentrates on topics which are relevant inside Horizon 2020. In order to show how CINA advancements in the ICT field will actually impact on relevant societal challenges, we have planned to apply CINA's methods, languages and tools to 3 carefully chosen scenarios, also detailed below.

Concerning ICT, with reference to the Horizon 2020 document the contribution of CINA fits naturally into the following points of [A] (part II):
* "1.1.1. A new generation of components and systems: engineering of advanced and smart embedded components and systems" ("large area integration, underlying technologies for the Internet of Things (IoT) including platforms to support the delivery of advanced services, smart integrated systems, systems of systems and complex systems engineering").
* "1.1.3 "Future Internet" ("enable the interconnection of trillions of devices ... that will change the way we communicate, ... This includes R and I on networks, software and services, ...").

These scenarios are typically open-ended IT systems, characterised by a large and/or variable number of interacting parties, each with their own individual properties, goals and behaviours for making decisions. Dynamic choreographies, self-adaptive components, goal-oriented long-running transactions, dynamic evaluations for deciding the correct (global and local) system behaviour, will be investigated by CINA in this perspective, in order to serve as a basis for the deployment of flexible, resilient and reliable services providing strong guarantees on the quality of their behaviour. Adaptation, reversibility, compensation and trustworthy techniques will provide guarantees on behaviour of the developed components even in presence of modifications of the system requirements or in the presence of unexpected events or faults.

CINA will also contribute to the investigation of next-generation programming paradigms, languages, methods and tools that allow for improving the way in which the above systems are developed - considering all the stages of software development, from design to programming, debugging and testing. CINA will pave the way for the next generation theories as required in some of Horizon 2020 Flagships that are in competition (such as FuturICT and Brain just to mention a couple of them).

In particular, the CINA research will make it possible through the combination of several theories such as process calculi, type systems, automata and constraints to explore a new agent-orientation as a paradigm to design and develop advanced computing systems featuring the properties that are keywords of the project, such as autonomicity and adaptation, decentralisation and distribution of control, emerging behaviour and multi-level modelling, correctness and security, and where uncoupled interaction and coordination are key aspects.

The CINA project also contributes to addressing the priority Societal Challenges identified in part III of [A], "Inclusive, Innovative and Secure Societies" (section 6 of [A]) and "Smart green and integrated transport" (section of 4 [A]),
by delivering foundational theories and enabling technologies, and by applying them in three different scenarios, one for building a citizen-centric platform (section 6.2.2), one for emergency management (section 6.3.4) and one for traffic monitoring for low environmental impact (section 4.1.3 and section 4.2.1).

In particular, the territorial citizen-centric service platform will contribute to the "Inclusive, Innovative and Secure Societies" challenge, by promoting "innovation in order to foster efficient, open, and citizen-centric public service (eGovernment)" [B].
This platform also foresees a new, more central role for citizens, who will become more aware of their individual and collective capabilities as "spectauthors", i.e., key actors who are at the same time consumers, inventors and providers of the services in the territory. This scenario will hence cover "social-network dynamics and crowd-sourcing and smart-sourcing for co-production of solutions addressing social problems" [B].

The emergency management as a service is certainly one of the most complex tasks for the Public Administration. Typically it asks for the activation of a set of inter-organisational business processes which are composed by sets of interrelated and sequential activities that are shared and executed by two or more Public Administrations to achieve a common business objective, such as an ICT system able to support crisis response operations by facing issues related to an environment with highly uncertain, highly heterogeneous, fast changing context conditions. CINA contributors, in collaboration with the civil protection, will contribute in building a "secure society"
[B] by proposing ICT solutions characterised by a distributed and decentralised decision logic, high dynamicity and capabilities to consider and handle run-time emerging behaviours, resilience to faults, availability of automated negotiation mechanisms, and by accompanying dynamic integration/adaptation/reconfiguration of the possibly many software agents deployed with a goal in the emergency domain for "strengthening security through border management" [B].

The modelling of urban traffic and evaluation of its environmental impact are crucial for improving everyday life. The definition of novel exact or approximate

quantitative analysis methods will allow a contribution to smart transport. In this respect the investigated formalisms can support the definition of novel interacting paradigms leading to cooperative applications and planning supporting the local decisions to be taken by the single citizens in order to have a global impact on the whole organisation and to improve organisational and efficiency aspects of transportation. CINA contributes in “improving transport and mobility in urban areas' [B] by gathering information from the urban traffic system through a network of sensors and by offering smart real-time information to the final users. This aims at encouraging citizens' good practices in mobility and hence at reducing the global traffic intensity and the consequent air/noise pollution. Moreover, the traffic model analysis allows for the definition of a control policy of the traffic flows which is implemented by means of the computation of an optimal configuration of the traffic actuators (e.g., traffic lights, dynamic panels of preferred directions, real-time information on mobile phones) with an impact on “a substantial reduction of traffic congestion" [B].

- [A] Establishing the Specific Programme Implementing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020), Proposal for a Council Decision, European Commission, Brussels, 30.11.2011 COM(2011) 811 final 2011/0402 (CNS)
- [B] Site Horizon 2020, http://ec.europa.eu/research/horizon2020/

Formalized Collaborations with letters of intents
The participants to the CINA project have many long-standing collaborations with outstanding researchers of prestigious universities and research centers, which will be very useful for the development of the project. The legal representatives of some of these universities and research centers signed collaboration letters (enclosed in the models B) that we list with the main collaboration topics:
* Charles University Prague (CZ) on languages for autonomic systems with UNIFI;
* CWI (NL) on static analysis of concurrent and object-oriented systems with UNIGE;
* IMDEA (ES) on the verification of concurrent software with UNIGE;
* Imperial College (UK) on modular and hierarchical models of highly dynamic systems with UNIVE;
* MT-LAB (DK) on quantitative analysis with IMT;
* Queen Mary College (UK) on session types with UNITO;
* UBA (ARG) on long-running interactions with IMT;
* Univ. of California at Riverside (USA) on quantitative evaluation with UNITO;
* UCL (UK) on quantitative models of Information Flow with UNIFI;
* Univ. Complutense de Madrid on methods for trustworthy systems with UNIPI;
* Univ. of Leicester (UK) on languages and models for adaptivity with UNIPI;
* Univ. of Reykjavik (Iceland) on self-adaptive systems with UNICAM;
* Univ. of Saarlandes (DE) on security and privacy for distributed authorization systems with UNIVE;
* Univ. of Stony Brook (USA) on modeling of adaptive systems with UNICAM.
* Vienna University of Technology (A) on compositional models of interactive systems with IMT.

Other Formalized Collaborations
The CINA project will aim to maximise the effects of its research on social innovation through establishing a range of partnerships with European, national and regional academic and industrial bodies. A primary source of possible partnerships will be existing and forthcoming research projects. We indicate below the first 4 between the most important CINA collaborations with other research institutes at the national and international level, then some on-going EU and Italian projects and networks of excellence (we cannot list more due to lack of space).

EIT ICT
Both UNIBO and FBK are actively involved in EIT ICT Italy, an EU initiative aiming at innovation in ICT in education, research and business, by establishing new types of partnership between leading companies, research centres, and universities in Europe. The theme of CINA is well in line with those developed within EIT ICT Labs, in particular the action line on digital cities of the future. Sangiorgi is the Head for the Bologna site within EIT.

INRIA Research Team Focus
The Research Team Focus is a joint effort between the INRIA (France) and UNIBO on the theme of models and languages for distributed systems. This is presently the only team that INRIA has established in a foreign university. This team has been placed under the responsibility of Sangiorgi.

Civil Protection of Region Marche
UNICAM and the division of Civil Protection of Region Marche have a recent agreement for modelling and analysing complex and adaptive systems for evaluation of emergencies and taking appropriate decisions, and deriving efficient business processes.

Marine Institute of CNR (ISMAR)
UNICAM is collaborating with ISMAR for the definition of agent-based multiscale spatio-temporal models of populations in marine ecosystems. The main objective is the prediction of the dynamic evolution of such populations by using 3D-simulation methods.

ALLOW: Adaptable Pervasive Flows
The objective of the project is to develop a new programming paradigm for human-oriented pervasive applications. This paradigm will enable pervasive technical systems to adapt automatically and seamlessly to humans, explicitly supporting people in achieving well-defined goals in dynamically changing environments and contexts. FBK is one of the 4 partners of this project.

ASCENS: Autonomic Service-Components Ensembles
The goal of the ASCENS project is to build ensembles in a way that combines the maturity and wide applicability of traditional software engineering approaches with the assurance about functional and non-functional properties provided by formal methods and the flexibility, low management overhead, and optimal utilization of resources promised by autonomic, adaptive, self-aware systems. The partners of this project are 15 and include IMT, UNIFI and UNIPI.

CHOReOS: Large Scale Choreographies for the Future Internet
The CHOReOS project positions itself in the context of the Ultra-Large-Scale (ULS) Future Internet of software services. To address the challenges inherent of ULS as well as other key requirements of the Future Internet, CHOReOS revisits the concept of choreography-based service composition in service-oriented systems. UNICAM is one of the 16 partners.

Formal Verification of Object-Oriented Software
The goal of this action is to co-ordinate the development of verification technology, to achieve the reach and power needed to assure reliability of object-oriented programs on an industrial scale. This action concentrates on program verification: the construction of logical proofs that programs are correct. Damiani, Giannini and Zucca are group leaders in this action.

HATS: Highly Adaptable and Trustworthy Software using Formal Models
The main outcome of this project is a methodological and tool framework achieving an unprecedented level of trust and informal processes are replaced with rigorous analyses based on formal semantics. The consortium includes 13 institutions, and one of them is UNIBO. Montanari is one of the 3 members of the Scientific Advisory Board.

ICARMarche
The project ICARMarche intends to contribute to the development of a interoperability infrastructure in Marche Region according to the National Public Internet-working System and the results of the ICAR national project. UNICAM is a partner of this project.

ParaPhrase: Parallel Patterns for Adaptive Heterogeneous Multicore Systems
The ParaPhrase project aims to produce a new structured design and implementation process for heterogeneous parallel architectures, which may be dynamically re-mapped to meet application needs and hardware availability. The consortium includes 6 academic partners (one is UNITO) and 3 industrial partners.

SAPERE: Self-Aware Pervasive Service Ecosystems
The objective of SAPERE is the development of a highly-innovative theoretical and practical framework for the decentralized deployment and execution of self-aware and adaptive services for future and emerging pervasive network scenarios. UNIBO is one of the 4 partners of this project.

S-Cube: European Network of Excellence in Software Services and Systems
The S-Cube consortium consists of 16 partners, and one of them is FBK. The aim is establishing an integrated, multidisciplinary, vibrant research community for

helping shape the software-service based Internet which is the backbone of our future interactive society.

17 - Total Months/man dedicated to this Project

		Mesi/Persona
17.1 Hired personnel of the University/Body of the Associated Investigator	a) professors/researchers/technologysts	0
	b) technicians	0
17.2 Hired personnel of other Universities/Bodies	a) professors/researchers/technologysts	0
	b) technicians	0
17.3 Non hired personnel collaborating on the program	a) research grant holders	0
	b) PhD grant holders	0
	c) contract professor	0
	d) temporary collaboration co.co.co. (solo per EPR)	0
17.4 Personale dipendente o non dipendente da destinare a questo specifico Progetto	a) research grant holders	0
	b) short-term researcher	0
	c) PhD grant holders	0
	d) temporary collaboration (co.co.co.)	0
	TOTAL	**0**

18 - Total cost of the Research Unit Program, per single item

Associated Investigator of the Research Unit Program	MIUR Funding	University/Body Funding	Total cost of the Research Unit Program
TOTALE	**0**	**0**	**0**