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!CHAOS: a cloud of controls – MIUR project proposal

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Abstract

This note presents a synthesis of "!CHAOS: a cloud of controls" proposal submitted to MIUR as *Premiale* 2012. The aim of this document is to underline the evolution of the !CHAOS project from a candidate of control systems (CS) for the SuperB accelerator to a prototype of Information Technology (IT) distributed infrastructure, to be dedicated not only to accelerators and large high energy physics (HEP) experiments, but also to the society as a whole and to the industries. In this framework, !CHAOS may potentially become an INFN product, a spinoff, a center of competencies coming from HEP.
Participant laboratories, Institutions and companies have currently undergone several changes with respect to the present document and part of the choices here described have been modified due to the reduction of the budget, the large delay in the delivery of the support and the reduction of personnel since the proposal idea.

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1. Introduction

The !CHAOS (**C**ontrol System based on **H**ighly **A**bstracted **O**perating **S**tructure – but not a mess!) idea has arisen in 2010 as a degree thesis[1] in Computer Science of an INFN colleague – currently the leader of the development framework - with the purpose of introducing novel concepts to accelerators and large experiments control systems coming from the recent evolution in Computer Sciences and technologies.
The high performance web technologies exhibit features deeply integrated with CS' core components that may strongly increase control systems performances and services, preserving scalability, redundancy and stability. The idea was to introduce technologies used for social networks and large web databases, in order to design a system based on a combination of a network distributed cache memory and a non-relational key/value database, high performing storage systems and the complete abstraction of data.
The Tor Vergata control group, who contributed since many years ago to the development of controls for accelerators at LNF, has joined !CHAOS since the beginning of the project. The Frascati and Tor Vergata control groups have a long experience in design, development and implementation of innovative CS. In the '90s, the first PC and LabVIEW®[2] based CS have been successfully developed and operated for the DAΦNE accelerator at LNF, breaking through the common concept of controls [3].
In 2011 the idea has been successfully approved and supported as the control systems for the SuperB accelerator [4,5] and presented in international conferences as a prototype of innovative CS standards [6,7]. In 2012 [8,9,10] and 2013[11] the CSN5 has partly supported the R&D of some issues connected to this innovative platform for storage systems [12]. Finally at the beginning of 2013, we submitted a proposal as *Premiale* 2012. The main objective was to design and implement a prototype for Control as a Services: an infrastructure at national level which may offer a cloud of services and procedures distributed and shared over the LAN/WAN. !CHAOS will monitor and control any hardware device, system or intelligent component and provide resources to processing services, data logging and archiving. This idea was approved and funded by MIUR at the end of 2013 and in July 2014 INFN approved the executive budget to enable the start of the project. In the following paragraphs is presented an extract of the project proposal as presented to MIUR for *Premiale* 2012.

2. Executive Proposal Summary

The !CHAOS project aims at developing a prototype of a ***Control as a Service*** open platform suited for a large number of applications in science, industries and society. The Control Server concept has been introduced to provide emphasis to the innovative !CHAOS architecture that is represented by a scalable and distributed cloud-like infrastructure, providing the services needed for implementing distributed controls and data acquisition systems.
The Italian Institute for Nuclear Physics (INFN), the Italian research agency dedicated to the study of the fundamental constituents of matter has, in virtue of its mission, a solid and recognized experience in the field of sensors, their integration, controls and data acquisition. International access to its research sites and to experimental facilities is provided by means of a large e-infrastructure realized and managed by INFN to serve its wide and distributed community. Modern High Energy Physics experiments and large particle accelerators are nowadays among the most complex examples of System of Systems (SoS) that can be imagined, where requirements in terms of accuracy, stability, scalability, redundancy and reliability are pushed at the highest level.

The project is based on the results of an R&D initiative of INFN-LNF and INFN-Roma "Tor Vergata" aimed to the development of a new architecture for controls of large experimental infrastructures named !CHAOS (Control system based on Highly Abstracted and Open Structure). The analysis of recent developments on high-performance software technologies suggested that the design of a new control system might profit from solutions borrowed from cutting-edge Internet Services, such as Service Oriented Architecture and Cloud Computing. To fully benefitting from these new technologies, the control system model had to be reconsidered, thus leading to the definition of the new "control service" paradigm.
The challenge behind the project is to demonstrate the feasibility of a scalable multi-purpose controls services provider based on the !CHAOS framework and on the INFN e-infrastructure, to improve flexibility of the monitoring, control and data acquisition, storage and analysis of any sensors, devices and SoS.
The participation to the project of national and international scientific partners (University of Tor Vergata Information technology and information engineering, University of Cagliari Information technology, University of Camerino Information technology, CNR IRPI, Stanford Linear Accelerator Center, CalTech) and industrial partners, such as the National Instruments, (a multinational company in the field of controls), and ADF Solaris, (an Italian company, interested in the development of a real use case), guarantees a solid inter-disciplinary and inter-sectorial approach to the project, in order to extend its objectives beyond the mere scientific applications.

3. Project contents and objectives

The realization of regional and/or national networks able to acquire and check parameters of different kind has become a primary need for different fields of study, such as prognostics, monitoring, statistics, classification and even for applications in the health sector, cultural heritage, environmental monitoring, information for the public, etc. Moreover, the implementation of distributed control systems for devices throughout the territory - *traffic control*, *public transport*, *navigation*, *smart energy grid*, *domotics*, etc. - has become strategically relevant for several applications, such as disaster management.
This type of application requires enough **flexibility and reliability** to easily integrate different types of sensors/devices and large amount of information diversified in terms of data structure, size and rate of variation.
The innovative idea of the proposed project consists of a **new approach to the control** of distributed systems, based on the latest software paradigms, aimed to abstract the components, the produced information and its management methods. This approach is based on the INFN R&D project !CHAOS (*Control System based on Highly Abstracted and Open Structure*) originally developed to manage complex distributed systems, such as particle accelerators and large experimental infrastructures. Due to its inherent scalability, the !CHAOS architecture is also suitable for applications in different fields, such as assembly lines, domotic systems, smart cities, etc.
The controls of sensors, devices and *System of Systems* (SoS), as well as data acquisition and processing, presentation, logging and storage, must rely on solutions inherently **uniform**, **versatile**, **scalable**, **reliable** and therefore adaptable in multiple ways to meet different analysis requirements. This approach involves the development of a set of *open* procedures, allowing to connect over a LAN/WAN (also pre-existing), sensors and generic devices, with no need of knowing - how and where - the devices are located, which is their configuration and data structure.
The project envisages the creation of **a prototype of** a ***Control as a Service*** **infrastructure at national level,** which realizes a ***cloud*** of services and procedures distributed and shared

over the LAN/WAN. The !CHAOS infrastructure allows to monitor and control any hardware device, system, or intelligent component and carries a network of resources to provide processing services, data logging and archiving.
These services will provide to the users procedures to access data and tools for their processing, in a completely transparent way, by respecting the format and the complexity of the system.
The !CHAOS infrastructure enables the creation of homogeneous, scalable and fast databases for the storage of live data and diagnostic information of the devices connected to the cloud.
The ***cloud*** of devices and procedures forming this new infrastructure is based on a mixed cloud and Grid design, in order to provide the following services: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Grid for High Throughput Computing (HTC).

The project foresees the realization of a prototype of Control as a Service to be actualized through specific use cases:
- One of the main tasks of the **INFN** is the design, installation and maintenance of large research infrastructures devoted to nuclear and subnuclear physics. Among these, particles accelerators and large detectors are unique for the development of innovative IT platforms. INFN intends to use the !CHAOS architecture for the INFN flagship project (FP), which involves the construction of a new particle accelerator. Meanwhile the !CHAOS system components — already at an advanced stage of development — are being tested by the particle accelerators operating at the Frascati National Laboratories (DAFNE and SPARC), the excellence of Italian research. Moreover, the INFN proposed !CHAOS as a control architecture for Extreme Light Infrastructure (ELI), one of the European strategic facility.
The FP project aims to study control's performance, time critical and high throughput applications, needed for a complex system with thousand of sensors and devices integrated in a very large SoS.
It is currently under discussion and design a set of use cases in partnership with international research institutions and industrial companies for the development of an open and innovative platform for the management of distributed sensors. For instance, the Stanford Linear Accelerator Center, is collaborating with the !CHAOS project for its application to the control of large detectors for high energy physics. The CalTech University is interested in the development of an architecture able to collect, compare and analyze data coming from a multitude of seismic detectors. National Instruments is interested in exploiting !CHAOS as a component inside its huge software library, in order to enrich the offer in the high energy physics field.

- **National Instruments** (NI) is a world leader in the production of hardware and software for data acquisition, analysis and automation. NI is particularly interested in the field of Big-Physics (LHC, ITER, ESS, etc.), which is the natural environment for INFN projects. NI assists the development of the !CHAOS project with the purpose of integrating the innovative architecture within its software environment LabVIEW®, coming to deliver a breakthrough product, unique and relevant..

- **ADF Solaris**, UNI CEI 11352:2010 certified company, wants to create an opportunity for its technical and commercial development, by delivering a new product for supervision and management of Energy Systems for Energy Service COmpanies (ESCO). Therefore, the ESCO is developing — in collaboration with INFN — a “Sistema di Supervisione e Gestione di Sistemi Energetici per Esco (SSGSEE)” to monitor in real-time an "energy system", understood as a building-systems-users ensemble, according to the UNI CEI standard 11352, as required by the “energy efficiency” project developed by the ESCO companies. This slow

control application may demonstrate the feasibility of a wide area platform, open, accessible, scalable and reliable to control polymorphic sensors/devices/SoS.

The **objectives of the project** are addressed by the development of an ICT related infrastructure and the creation of new services in many different fields, like networks for society, environmental management, energy problems, agriculture, as well as the integration of sensors, complex devices, SoS, etc., foreseeing its integration through an interface based on "open" protocols.
In particular, the project has the following specific objectives:

- Create an open source and scalable platform for the control of large scale distributed sensors, complex devices and SoS, based on the latest information technologies, ensuring high performance throughput, scalability, reliability, up with the growing demands of technology and market.
- Increase control performance and time critical application
- Ensure, through open source and open hardware, greater availability on the market of devices and drivers.
- Reduce costs and the development time.
- Overcome the problems of standardization and integration, ensuring compatibility with most of the common standards.
- Realize a versatile and homogenous platform, ensuring historicization, storage, analysis, access and presentation of polymorphic data.
- Demonstrate the feasibility of a national platform, open, accessible, scalable and reliable to control polymorphic sensor/devices/SoS.

Potential end users of **the project** are researchers, technologists, technicians of INFN and partners that have the opportunity to *develop skills and grow their competencies* in an emerging field of IT. Future target of the possible evolution of the project is the society as a whole through the infinite applications that could be implemented through this e-infrastructure.
Another project target is constituted by young technologists (software engineering, developer, electronic engineer and technician, etc) that will be trained by the !CHAOS staff. In fact, the project is financing research/technical fellows and PhD positions, in order to emphasize the impact on young students. The close cooperation with many Italian universities, that have already provided support to the project in the R&D phase, ensures that !CHAOS may involve a pool of young students for the platform development and the management of fundamental tasks, generating an exceptional opportunity of training.

5. Work Plan – Description of the action foreseen in the project

The project is divided in 5 work packages, we briefly report them:

Work Package 1 – MANAGEMENT AND DISSEMINATION
This WP is dedicated to the management and dissemination of the project ideas and its results.
Work Package 2 – SOFTWARE DEVELOPMENT
This WP is addressing the development of the remaining part of the !CHOAS architecture. The !CHOAS R&D actually started 3 years ago with the idea of designing a new controls architecture able to overcome some of the issues related to the most common standards. Currently it has been updated and guarantees the technical requirements and performance of a

novel accelerator complex. The scalability and flexibility of the architecture allows to extrapolate the system from a local area application, although very complex, as represented by the SoS accelerator example, to very different applications for the society and in a wide area, such as a city.
In order to permit this further implementation of the !CHOAS architecture, part of the core algorithms still have to be developed:

- Common Framework: development of common code and logic used by any node.
- Metadata Services: distributed information system that manage the topological, syntax and semantic information of all node.
- Live and History Data Services: distributed services dedicated to live and historical data management.
- Control Unit, Execution Unit and User Interface: the software dedicated to the data acquisition, device control, logical algorithms and data access and presentation.

Work Package 3 – FRONT END DRIVERS
This WP is focused on the implementation of !CHAOS for the use cases involved within the project: ESCO and INFN Flagship Project (FP). It includes the development of a library of HW component drivers (Control Unit classes and low level drivers), Execution and User Interface Units that respectively implement the control algorithm and the data presentation and handling in !CHAOS.
In synergy with the front-end drivers development, this work package focuses also on the creation of an adaptation layer to facilitate the reuse of third part drivers and interfaces developed in LabVIEW® and Tango.
In summary, the main objectives of this Work Package are:

- Define, in collaboration with WP4, requirements and specification of the use case application - ESCO and INFN FP - in terms of software and hardware needed.
- !CHAOS implementation for ESCO, deployment, test and qualification.
- !CHAOS implementation for FP, deployment, test and qualification.
- Development of APIs to allow the integration of LabVIEW® drivers/GUI and Tango drivers, moreover to study and develop the integration of !CHAOS in the LabVIEW® framework.

Work Package 4 – HARDWARE DEVELOPMENT
This WP is dedicated to the implementation of the Hardware Reference Platform (HRP) needed for the !CHAOS use cases. The HRP includes the processor hosting the CU task, device interfaces, I/O integration, signal conditioning, defined by the use cases (the local area control prototype applied to accelerators and the wide area control system for environmental sensors). Moreover the WP includes the development of a multipurpose network connection between the HRP and the !CHOAS infrastructure.
The WP expects to realise the following activities:

- Development of the HRP for the ESCO use case;
- Development of the HRP for testing the critical parts of an accelerator control system prototype;
- Studyof a multipurpose HRP.

Work Package 5 – COMPUTING, STORING AND ACCESS POLICY
The WP is addressing the development and implementation of a homogeneous, complete and integrated private cloud infrastructure solution based on open source software that meets the !CHAOS needs.

This infrastructure provides resources and services matching the requirements of !CHAOS services and users. This includes: computing resources of different capabilities, persistent storage resources and configurable networking resources. The services will be dynamically configurable and will include security, management services and a web portal to access and to manage the infrastructure.
Within this infrastructure it will be possible the provisioning of resources based on three different models:

- IaaS (Infrastructure as a Service): the scalability and flexibility via dynamic ("on-demand") provisioning of resources will easily allow the users to obtain, configure and deploy cloud services themselves through a web based portal and using cloud service catalogues, without requiring the assistance of IT.
- PaaS (Platform as a Service): to deliver a computing platform including operating systems, programming language execution environment, database and web server. Developers can develop and run their software solutions on a cloud platform without managing the underlying hardware and software details.
- Grid: Grid core services will be necessary for the execution of HTC (High Throughput Computing) tasks of type as historical analyses, simulations and other applications that typically require non-interactive workloads and involve a large number of files. Within a set of core Grid services, it will be possible to exploit the Grid resources offered by the Italian (IGI) and European infrastructure (EGI) in an opportunistic way.

The work package also aimed to define and implement the authentication and authorization infrastructure (AAI) that should guarantee control of access to !CHAOS resources. The AAI will support federated single sign-on mechanisms that will be agreed upon (IDEM authentication federation, or social networks accounts depending on the desired level of security), and allow for federated distributed authorization policies.

6. Resources to be committed

The following table shows the resources to be committed for the project activities of each WPs, the total costs of the project and the contribution requested to the MIUR.

WP/(k€)	Personnel	Subcont.	Consum.	Equipm.	Infrastr.	Overheads	Other	Total
WP1	172.5	10	4	2	0	0	18	206.5
WP2	262.5	0	2	4	0	0	14	282.5
WP3	262.5	0	1	49	0	0	11	323.5
WP4	272	10	30	172	0	0	14	498
WP5	185.5	5	7	70	120	0	12	399.5
Total Costs	1155	25	44	297	120	0	69	1710
% of Costs	68	1	3	17	7	0	4	100
Incoming	99	0	0	85	0	0	4	188
Contribution FOE (k€)								**1522**

Costs details:
The personnel cost has been evaluated assuming an average standard cost of 55k euro/person/year for permanent staff and 24k euro/person/year for research/technical fellow and PhD positions. Furthermore, 2k euro/person of other costs have been added for trips

(kickoff meeting, participation at conference for dissemination, etc), and 2k euro/person on equipment costs for fellow/PhD as startup equipment (personal computers, etc).

The WP1 costs include the Project Manager and Technical Manager, and the contribution of the administration, secretary training and press office services. It includes also web manager and personnel participating in the management of partners. It includes also the support of 1 FTE under 35 fellow in science communication and project management. (FTE 2.3, FTE under 35: 1)

The costs of WP2 are mainly related to developers and software engineers (among which 4 under 35 and a woman). The WP foreseen the support of 2 fellows under 35. It includes also support of the computing service and IT manager in the participating structure needed to support the development phase. (FTE: 3.9, FTE under 35: 2)

The costs of WP3 are mainly motivated by the personnel costs and foreseen the support of 2 under 35 fellows, while the equipment cost is justified by the acquisition of the pxi crate, controller and boards for the developments o preliminary tests (in particular for the FP) and low cost controllers for tests and standardization, porting, testing of the software release. It includes also the support of the computing service and IT manager in the participating structure needed to support the development phase. (FTE: 3, FTE under 35: 2)

The costs of WP4 rely on the collaboration of the LNF services of electronics and automation, LNS, Perugia and Tor Vergata. It foreseen the support of 4 under 35 fellows and includes the equipment needed for the hardware implementations. (FTE: 2.7, FTE under 35: 4)

The main costs of WP5 are due to personnel (1 FTE under 35) and infrastructure and services mirroring among CNAF, LNF and partially LNS. The WP foresees the support of 2 fellows under 35 years. (FTE: 1.5, FTE under 35: 3).

In conclusion, the main costs of the project are due to personnel (25.4 FTE, 68% of the total costs) composed of 14.4 FTE INFN staff, of which about 1 FTE women and 3 less than 35 years old, and of 8 FTE, under 35 years old, recruited through the support of fellow positions and PhDs.

7. Conclusion

The proposal, here shortly summarized, was successfully approved and funded by MIUR for 600k euro and since July 2014 the INFN provides to the !CHAOS group the permission to hire personnel - only through training contracts - and place orders for the development of the project.

The Kickoff meeting was held on the 9th of April 2014 and the project management board currently holds regular meetings every month. Documentations and improvements are available on the project website http://chaos.infn.it.

8. Acknowledgments

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