Floods forecasting and warning operations enhancement by Grid technology adoption in Civil Protection organization

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Abstract

Since few years, Grid computing is a technological revolution in high performance distributed computing allowing large-scale resource sharing, computational power using and supporting collaboration across networks. Presently, the most important effort, in term of Grid technology development, is performed by the EGEE (Enabling Grids for E-science in Europe) project. Moreover, the GMES (Global Monitoring for Environment and Security) initiative is a highly research initiative which must provide a structure framework for data integration and information management. In this context, the European project Cyclops has been introduced in objective of bridging the gap between Grid (EGEE) and Civil Protection (GMES) communities. Presently, it seems difficult to adopt Grid technology in the whole of Civil Protection structures. As realistic simulations, two use-cases have been selected to study the possible reliability of Grid technology in natural disaster warning and forecasting systems field. One of theses two chosen use-cases concerns the floods forecasting service of Gard Region (SPC-GD) which monitors flash floods events to assist Civil Protection emergency operations. Lessons learnt from past extreme events such as during the 8th and 9th September 2002, have emphasized the need of improving the flash-flood monitoring and forecasting operations of this service. Thus, this paper presents a new potential functioning of SPC-GD in crisis management context, taking into account known advantages of Grid technology. Based on a technical descriptive approach (UML), a set of new functionalities and respective technological requirements, from a data-processing point of view, are described and discussed.

Keywords

Civil Protection, grid Technology, crisis management, flash-flood monitoring, rainfall-runoff model, interoperability

Introduction

Flash-flood events have occurred important damages in South-East of France especially during the last decade. A present and active research interests in the enhancement of this specific crisis management. Several research fields are focused on this topic. At the local level, hydrologists performed research for better flood forecasting in evaluating and improving existing models (Ayral, 2005; Ayral *et al.* , 2007; Bouvier *et al.* , 2004) while crisis management specialists analyzed and conceptualized the Civil Protection functioning (Dautun, 2007; Haziza, 2007; Huet *et al.* , 2003; Sauvagnargues-Lesage & Simonet, 2004). At national and international levels, some projects gather Civil Protection end-users and information technology specialists to improve communication and widely interoperability for a better inter-organizational crisis management. In this sense, the Cyclops project is born in 2006. This project aims at bridging the gap between Grid technology, a recent data-processing technology, and Civil Protection communities. Through this project, the presented research focuses on a flash-flood use case. The main objective is to underline the positive aspect of grid adoption for modelling and information system management in flood context. The expected success of this study has to be based on existing researches on geoprocessing grid-enabled (Shi *et al.* , 2002), sensor grids designing (Ghanem *et al.* , 2004), plain flood management on grid architecture (Hluchy *et al.* , 2004, 2006) as well as grid research considering crisis management team as potential grid user (Foster *et al.* , 2001) or implementing large datasets (Chervenak *et al.* , 2000).

1 Research context

1.1 Information technologies and Civil Protection : a present field research

Researches on information technology did not cease to evolve in the last years to design efficient communication systems for many problematics implying technological connections among multi-partners. Web technology advent with important technological improvements of data processing systems open new potentialities in data and information management and exchanges.

From Civil Protection point of view, several researches have been initiated in this sense. If, presently, the use of new technologies are limited in French Civil Protection units, an important need of resources centralization and harmonization has recently emerged from lessons learnt (Huet *et al.* , 2003; Sauvagnargues-Lesage & Simonet, 2004).

The European initiative GMES (Global Monitoring for Environment and Security) launched in 1998 tries to develop "information services on climate change and support in the event of natural disasters" (Achache, 2001; Rohner *et al.* , 2007) in using these services "to enable decision makers to better anticipate or mitigate crisis situations and management issues related to the environment and security" (Mazzetti, 2006).

This research field becomes broader through new European programs such as WIN (Wide Information Network) which establishes an "info-structure" of communication to interconnect different existing European Civil Protection and to enable better systems interoperability and OASIS (Open Advanced System for dISaster and emergency management) which "is intended to facilitate the cooperation between the information systems used by civil protection organizations".

European Civil Protection agencies and their scientific partners increasingly collaborate to manage large-scale crisis implying inter-disciplinary and transnational competencies. In the same way, Cyclops is made up to gather technological and thematic competencies in objective of improving Civil Protection trans-national functioning.

1.2 The Cyclops project : From Civil protection requirements to Grid potentialities

The two-year (2006-2008) European project Cyclops (CYber-Infrastructure for CiviL protection Operative ProcedureS) follows existing researches dealing with the use and the conceptualization of information technology for Civil Protection problematics.

The main objective of this Bottom-Up project is to bring together two research communities, GMES initiative and EGEE (Enabling Grid for E-sciencE) project. The GMES developed services have to be supported by performant technologies to enable efficient and rapid exchanges in crisis management context. Thus, Cyclops project tries to design technological support for GMES services, in bridging the gap between Grid technology, described in next part, and Civil Protection requirements (Sauvagnargues-Lesage & Ayral, 2007). In analyzing and conceptualizing heterogeneous Civil Protection systems and requirements, and "in order to fully exploit the GRID capabilities" (Mazzetti, 2006), project's partners design an innovative architecture (See Fig.1) dedicated to Civil Protection problematics with a user-oriented approach. In April 2004, the EGEE project was born. More than one hundred partners take an active part in the enhancement of grid technology for various topics as High Energy Physics (HEP) Applications, Biomedical Applications, Astrophysics Applications and Earth Science Research. These topics are gathered by virtual organizations (VO) composed of research centres specialized in the grid and concerned end-users. This platform seems well adapted to take in charge Civil Protection applications and services. However some essential enhancings have to be developed to completely integrate them, especially for geospatial resources.

In concrete terms, the upstream Cyclops research, at the interface of two research fields, disseminates Grid technology researches results to the Civil Protection community and in the other side "provide the EGEE Community with knowledge and requirements that characterize the CP services" (Mazzetti, 2006).

From Civil Protection point of view, scientific contributions are based on natural hazard use cases analysis. Two use cases have been chosen given their double integration, operational and scientific. Winter forest fires problem in Italy and flash-floods in France appear to be representative of main Civil Protection requirements.

The first case study, French one, is related to the flood warning service Grand-Delta (SPC-GD), and the second case concerns the Italian forests fires monitoring system (RISICO) built up by CIMA for the Italian Civil Protection (DPC). In this article, a special focus is made on the flash-flood use case. French use case choice is the result of a long-term integration of SPC-GD in research strategy.

Finally, the Cyclops project aims at implementing already used applications on grid infrastructure as EGEE platform. The Civil Protection applications "porting" (Soberman, 2003) experimentation, to evaluate reliability and effectiveness of grid technology should *a priori* respond to project expectations.

The expected architecture dedicated to serve Civil Protection resources is composed of many layers :

– EGEE hardware infrastructure (processing and networking system)
– remote environmental services provided for example by GMES initiative
– grid services dedicated to Earth sciences services management

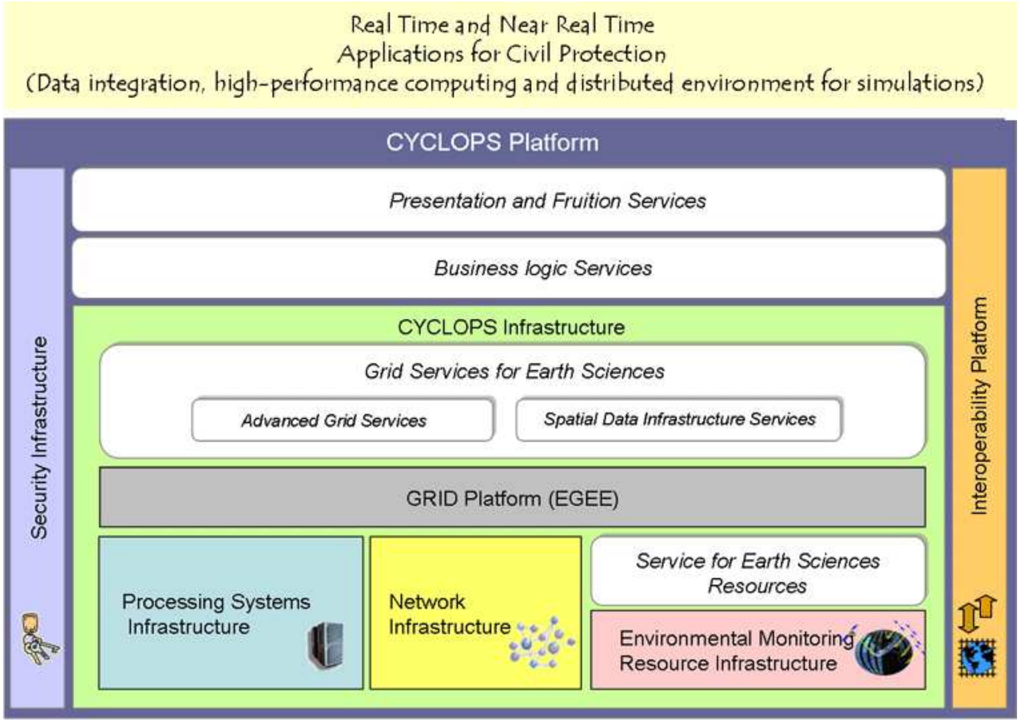

FIG. 1: Expected Cyclops grid-enabled architecture (Cyclops project)

– two layers corresponding to metada and information system management
– last layer to plug existing Civil Protection applications

2 The Grid technology

2.1 Functioning of user-oriented grid technology

Technically, Internet technology and more widely data processing considerably evolved from the hardware and software point of view but also in term of connection speed and bandwidth. New architectures became possible, such as clusters based on a client-server architecture or peer-to-peer architecture where data-processing stations have a double role of client and server. Since the beginning of the Nineties, a new technology being based on the evolution of other technologies was born, it acts of grid technology (De Roure *et al.* , 2003). Initially, regarded as metacomputing, corresponding to remote resources sharing and connection of supercomputers for data-processing research, the developments are directed since 2000 towards the integration of heterogeneous systems for finalities of research but also for production. It can be illustrated by following definitions :

1. In 1998, Kesselman and Foster wrote : "a computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities" (Foster & Kesselman, 2004).

2. In 2001, Foster, Kesselman et Tuecke have described the expected third grid generation characterized by interoperability through virtual organization grouping partners with common objectives. They defined the grid problem as "coordinated resources sharing and problem solving in dynamic, multi-institutional virtual organizations" (Foster *et al.* , 2001).

To summarize, the grid computing is a data-processing architecture allowing sharing and virtualizing geographically distant resources in order to obtain important computation and storage capabilities. Thus, this great availability of resources makes it possible to improve the response times of the data-processing tasks by important computational power and provision to a great quantity of data (TeraBits). Its installation and use have to be preliminary based on the creation of a virtual organization defined by Jägers as "a combination of multiple - geographically dispersed - parties (persons and/or organizations), that by uniting complementary core activities and methods, endeavour to attain a common objective. This virtual organization accords an equal division of power amongst its participants and is dependant on electronic communication (an ICT infrastructure) for the co-ordination of these activities" (Jägers *et al.* , 1998). Foster reused this concept to adapt it to grid technology implementation and use (Foster *et al.* , 2001).

The objective of this article is to underline the use of the middleware G-Lite (Burke *et al.* , 2006) and to emphasize the favourable factors of its use in services dedicated to Civil Protection.

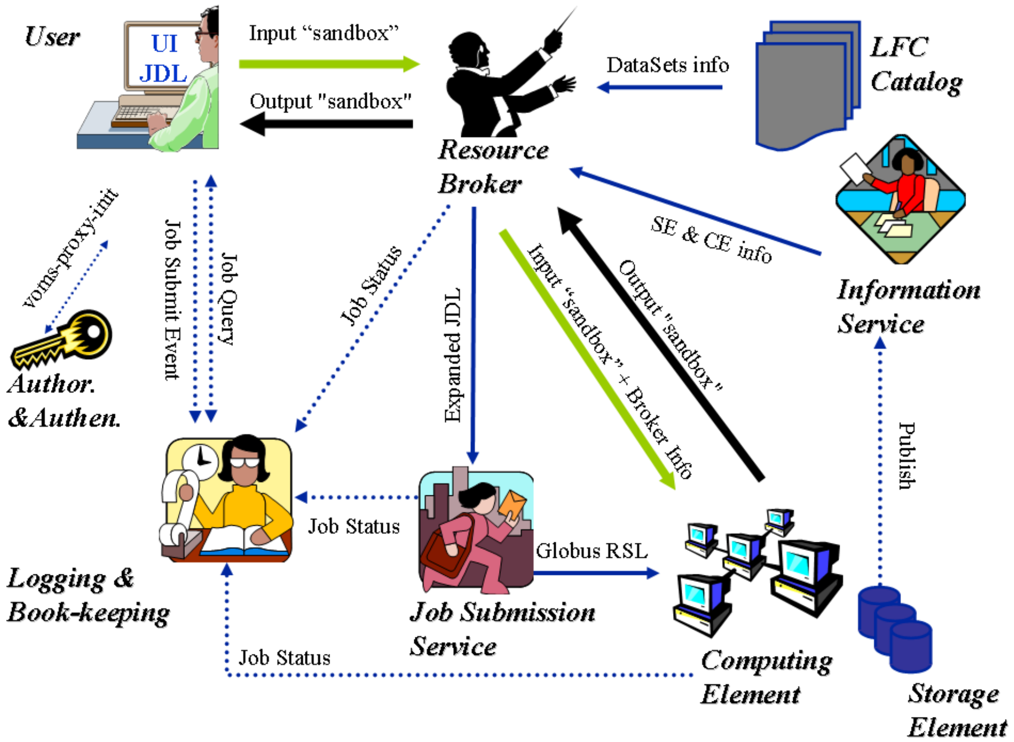

FIG. 2: G-Lite job submission global functioning (EGEE)

The objective of the user is thus to provide algorithms mainly running on Linux operating systems to execute them :
– simultaneously on several computing elements (CE) with different input data stored in storage elements (SE)
– through parallel tasks managed by different CE
From a practical point of view, the use of Grid can break up into 6 stages (Burke *et al.* , 2006)(See Fig.2) :

1. creation of a job
2. secure access to Grid by a *user interface*
3. sending of job and implicit communication with the *resource broker*, functional centre of the grid
4. *resource broker* seeks the best adapted resources to the job execution in collaborating with the *information service* and *replica catalog* to know data location
5. job is running on the selected *CE* thanks to the data provided with the job or retrieved from *SE*. If a problem occurs during the job execution, it is dynamically reallocated to another *CE*. Constantly the user can know the status of his job thanks to the *job submission* and *logging and book-keeping* services.
6. *resource broker* sends the job results to the *user interface*.

Thus, grid functioning offers flexibility in term of use of the available resources, illustrated by an errors management and a dynamic tasks allocation. In addition, the resources virtualization of hardware and software by means of a middleware largely facilitates its use by end-users.

2.2 Earth sciences and Grid technology

Within the framework of the EGEE program, Grid technology is support and subject of research for different virtual organizations. The presented project in this article is included in this program and more particularly in the virtual organization Earth Science Research (ESR) which gathers forty academic partners. The main objective of this VO is to manage, in a collaborative way, various topics such as the Earth observation, hydrology, climate, pollution, meteorology and seismology through common tools, softwares, data set up and functional on the grid.

Studies of natural phenomena require scientific knowledge integration among numerous research fields held by several actors. In addition, georeferenced image and its processing, major element of these research fields, developments of Earth observation technologies as well as the multiplication of the measuring networks require heavy treatments. Thus, Earth sciences are confronted with increasing technological requirements. The geoprocessing integration and the particular management of the georeferenced data (multi-dimensional) within a shared architecture on a large scale, represent a crucial technological challenge (Shi *et al.* , 2002). The use of grid for Earth sciences seems to open new potentialities.

Statistical works, geoprocessing as well as multiple tasks simultaneous execution on large-scale georeferenced databases are now possible (Petitdidier *et al.* , 2007).

Slovak laboratory II-SAS, VO ESR partner, specialized in data processing, worked on plains floods management based on grid technology. This research presently represents the single initiative in Europe. Gradually, various hydrological models and hydraulics were implemented on the grid to finally have an automated workflow where the end-user can interact without grid architecture monitoring. The success of this grid project required collaboration between the various partners of the flood crisis management, usually implying virtual organization creation (Hluchy *et al.* , 2004, 2006). Slovak research represents a solid base in term of data and information management for the follow-up of a hydrological event. The gained experience made it possible to better direct the technological and methodological choices problems of this study. Technological contribution of distributed computing makes it possible to comprehend new potentialities in term of performances analysis, calibration and more widely hydrological rainfall-runoff models improvement.

3 French flood forecasting system

3.1 Gard region : SPC-GD system

In this section, French global flood forecasting system is briefly described and a more accurate presentation is done for SPC-Grand Delta which is the central interest of this research.

Usually, flood monitoring can be subdivided in two large parts : the forecasting part which includes elements relating to the phenomena observation, the forecast of their consequences and the devices of vigilance and alarm, and the operational part which includes the existing organizations to face up the crisis management.

The former one includes Civil Protection units and administrative stakeholders which collaborate on several levels, from local emergency units to zonal operational centres (COZ) and to national operational service : the COGIC (crisis inter-ministerial management operational centre), depending on flood intensity. For a large scale flood disaster, COGIC has a central role in alert broadcasting and information exchanges among Civil Protection actors, while local and zonal actors have to mainly manage relief operations (Sauvagnargues-Lesage *et al.* , 2007c; Dautun, 2007). Main role of rescues teams concerns population evacuation and post-crisis infrastructure repairs. For this reason, the optimal way to limit population damages for Civil Protection is to rely on meteorological and hydrological hazards warning and forecasting services (Sauvagnargues-Lesage *et al.* , 2007d).

In France, the meteorological aspect is managed by Météo-France and the hydrological case by SPC (flood warning services) and the SCHAPI (floods warning and monitoring hydro-meteorological national service) precisely described in next section. Weather forecasting, implemented by Météo-France, is carried out through three organizations on the na-

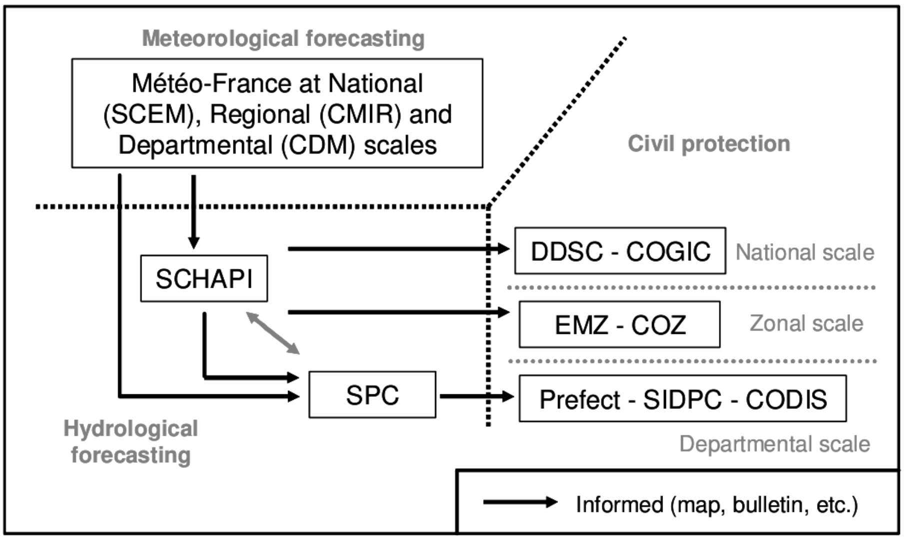

FIG. 3: Flash-flood crisis management actors

tional scale, the central service of meteorology exploitation (SCEM), at Regional level, the interregional weather centres (CMIR) and at the departmental scale, the meteorological departmental centre (CDM). These various services propose weather forecasting on various competence scales, the departmental service thus proposing the more accurate departmental forecasts for crisis management actors (Sauvagnargues-Lesage *et al.* , 2007b) (See Fig.3).

For a potential threatening event, Météo-France carries out a public vigilance map. Depending on hazard intensity special information report is set up and transmitted to the Civil Protection crisis managers and SPC-GD.

If main data and information are provided by meteorological units, the hydrological monitoring represents an important part of the flash flood crisis management. SPC supported by SCHAPI delivers a regular hydrological report. The objective of these teams is to broadcast precise and updated informations on rivers state ain order to complete and improve Civil Protection decision making process. This one is managed at local scale by the authorities of police force (Prefect) and CODIS (departmental operational of fire and rescues centre) (Sauvagnargues-Lesage *et al.* , 2007d). Moreover, flood hazard experts objective is to transmitting alert to mayors and population through Internet.

After this simple presentation which try to underline main partners and kind of information exchanged among them, the description focuses on flood forecasting service of Grand Delta region (See Fig.4).

SPC-GD global organization is based on 170 raingauges and water level stations collected in a central server SIGMA2000 every 5 minutes thanks to 3 concentrators laid on the competency territory(See Fig.5). To complete these measuring stations, rainfall radar system provided by Meteo-France (Rhea) supports forecasters through CALAMAR software (Haziza, 2007). Every 5 minutes, CALAMAR receipts radar images on 10 zones calibrated with measuring stations data. To complete, this data processing chain, a Rainfall-Runoff model called ALHTAÏR (Alarme Hydrologique Territoriale Automatisée par Indicateur de Risque) use output radar images and watersheds characteristics to provide run-off modellings on chosen catchments (Ayral, 2005; Ayral *et al.* , 2007; Sauvagnargues-Lesage *et al.* , 2007d). This model potentially permits a refining of hydrological experts decisions and *a priori* provide a near-real-time hydrological situation to decision-makers such as departmental service of fire and rescues (SDIS) and inter-ministerial service for defence and civil defence (SIDPC) (See Fig.3). This brief description of flash-flood management in Gard and peripheral regions is completed in the next section through presentation of potential improvements.

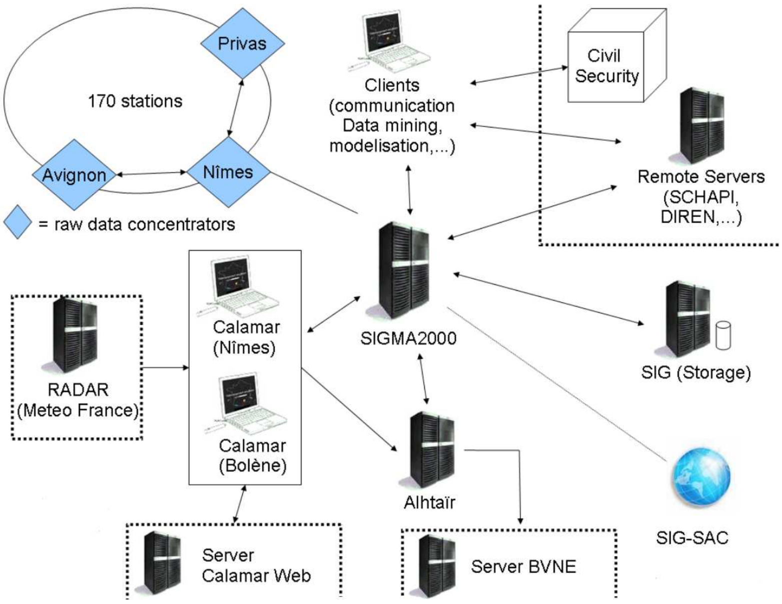

FIG. 4: SPC-GD global data processing system

3.2 Towards Civil Protection requirements

Last years, french policy supported by hydrological researches concentrated their efforts firstly on flash-flood better understanding and secondly on flash-flood events monitoring. Extreme events of last decade (Gard 2002, Gard 2005) and their social, economical and psychological consequences on population and vital infrastructures seemed to justify theses policies evolutions. After these events, different lessons learnt (Huet *et al.* , 2003; Sauvagnargues-Lesage & Simonet, 2004) underline a relative disorganization of Civil Protection services and list weak points of the involved management. Main evolution requirements (Huet *et al.* , 2003; Haziza, 2007) can be summarized by :

- up-to-date information on rainfall and hydrological phenomena,
- an integration and mutualization of all observation networks necessary to flood management and accessible by every crisis management actor,
- a simplification of hydrological report creation and diffusion,
- an optimization of models results to really assist forecasters,
- a better reliability in raw data retrieving and managing to ease models data input,
- the use of geospatial data and geomatic tools to manage crisis and to precisely evaluate damage states in real-time and spatialize hydrological phenomena (Sauvagnargues-Lesage & Simonet, 2004; Sauvagnargues-Lesage & Ayral, 2007).

In this sense, immediately after September 2002 flood, the 1st October 2002 circular relating to flood forecasting services creation has been set up. This prompt political reaction shows the necessity to make evolve the organization of flood monitoring in France. This reform describes a new organization of flood monitoring by :

– the grouping of 52 flood warning services (SAC) in 22 flood forecasting services (SPC) taking in charge consistent units based on a hydrologic approach (kind of flood, specific risks, ...) and enabling workforce strengthening (MEDD, 2002),
– the creation of a central service to support and assist local flood forecasting services : the central service of hydro-meteorology and support to the flood forecasting (SCHAPI). One of important objective of this service is to summarize hydrological situation and broadcast it to decision-makers and especially to population through webmapping interface.

By this evolution, the french government defines new competencies of these services. Indeed, their main objective is not only to monitor the flood to assist Civil Protection decision makers in real-time but also to better anticipate hydrological hazards. This asked evolution implies many innovative researches and reaching this objective represents a long-term approach. From one side, flash-flood models need some important improvements from a hydrological point of view, and on another side information system has to be more reliable and efficient in data exchanging and processing.

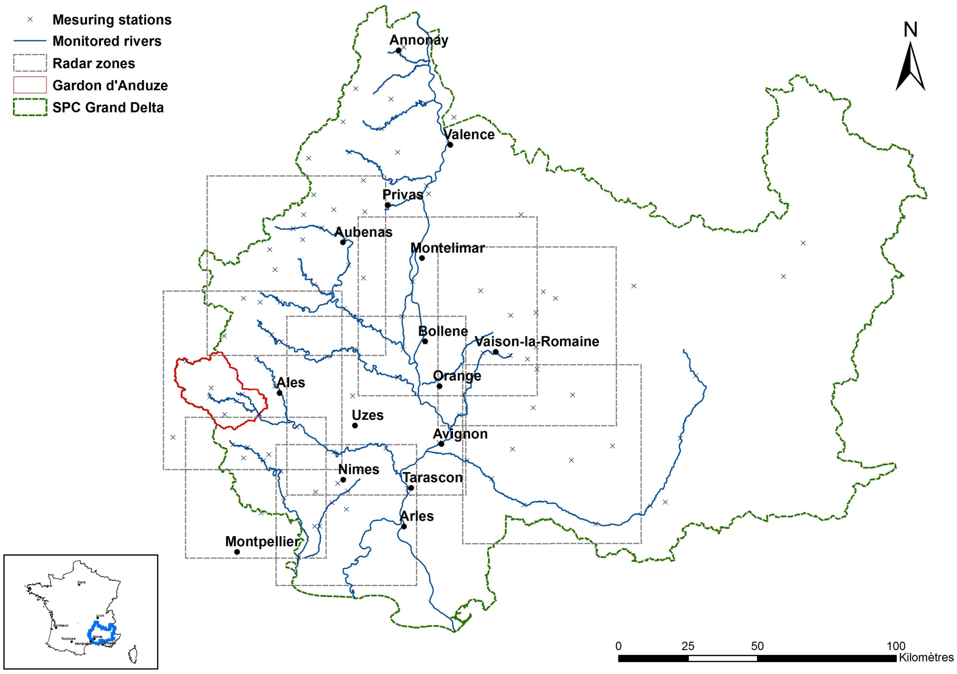

FIG. 5: SPC-Grand Delta competency territory

Cyclops project, through Civil Protection requirements deliverable (Sauvagnargues-Lesage *et al.* , 2007e) summarized these needs in term of functional and non-functional requirements :

1. Functional requirements
   – Geospatial information access and publishing
   – Authentification and Authorization
   – Files replica
   – Higher resolution processing
2. Non-functional requirements
   – Computational power
   – Time of response / Bandwidth
   – Quality of service negotiation
   – Interoperability
   – Storage capacities

These requirements are linked to Grid technology potentialities. In taking into account Grid characteristics, presented research has focuses to past lessons learnt resulting for extreme events and existing system functioning to perform a whole of requirements. Future researches have to implement some experimental applications on Grid platform in order to underline and specify effective Grid power for these Civil Protection requirements. Strategies of this experimental phase make up the last part of this article.

4 Ongoing developments and researches

4.1 A first confrontation between CP and grid technology

Based on a lessons learnt report (Huet *et al.* , 2003) and specific Civil Protection requirements (Sauvagnargues-Lesage *et al.* , 2007e) and following the previously SPC-GD description, a potential and improved functioning is presented. Presently, few researches used Grid technology to enable hydrological modelling. As specified in previous section, II-SAS laboratory developed a complex workflow to manage Danube flood events (Hluchy *et al.* , 2004, 2006), however this kind of flood differs considerably from flash-flood phenomena. The consideration of the high kinetic of flash-flood (generally few hours) becomes one of the most important parameter of improvements research.

Previous described requirements can not all be reached by this presented research. Grid technology evolution from the technical point of view can probably enable such objectives, Cyclops project may certainly guides them. The user-oriented approach defined in this article is dependant of technological innovations and different to Cyclops objectives. Grid present state and relative low technological level of SPC-GD encourages an integrated and progressive experimentation.

The accurate understanding of SPC-GD ongoing functioning represents the first step to Grid-enabled system. UML (Unified Modelling Language) modelling seems to be well adapted to reach efficiently this goal. It is a standardized visual language to represent real situation and functioning of an existing or designing system (Corp & Partners, 1997). The potential global functioning of SPC-GD can be presented thanks to a use case diagram which "shows the relationship among actors and use cases within a system" (Corp & Partners, 1997). It focuses on decision-making process which underlines data and information exchanges among system's units and actors. This diagram is voluntarily non exhaustive, it's widely centred on real-time hydrological context of the crisis management.

This service is an information-oriented system based on raw and modelized data provided by automatic and independent programs. The forecaster, main actor, uses and monitors system's units to elaborate an updated and more accurate hydrological report. He evaluates the raw input data as water levels and radar responses and follows rainfall cycles thanks to rain gauge stations (Huet *et al.* , 2003). For efficient flash flood forecasting, rainfall-runoff model ALHTAÏR have to provide modelized discharges for ungauged watersheds (Ayral, 2005). Efficient results are necessary to better analyze the water flows dynamic on the entire competence territory and to precisely evaluate their localization. This future system,

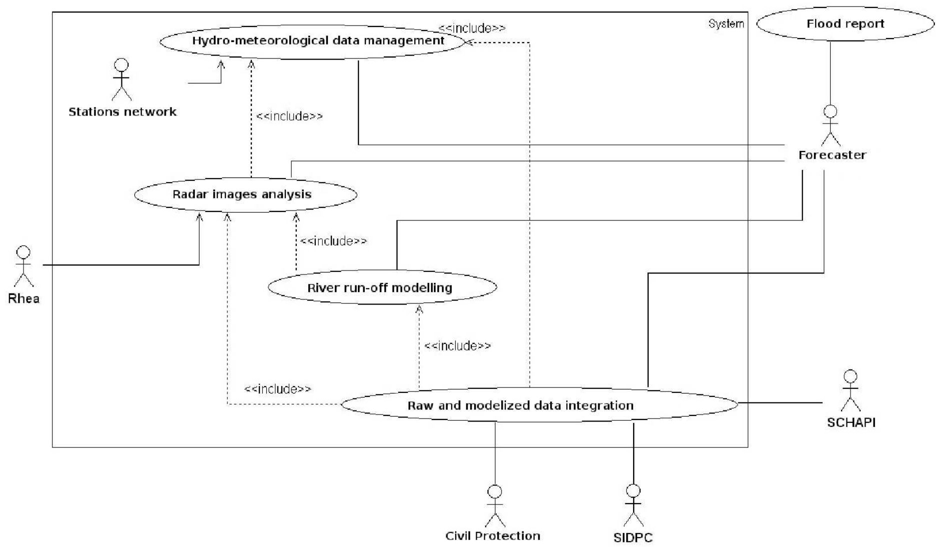

FIG. 6: Flash-flood crisis management UML use cases diagram

widely based on the existing one, has been decomposed in four main UML use cases (See Fig.6) :

- the first use case concerns measuring data retrieving (unstandardized XML) and interpretation from 170 stations. No modifications will be applied on this case, except some standardization operations for data communication.
- the second one focuses on the radar images calibration and rainfall analysis thanks to CALAMAR software. Given the private implementation of this software, presented research directly used as input calibrated radar images,
- the third case which is widely described in the next section, interests on modelling approach. This use case represents the core of future implementation. It initially concerns ALHTAÏR application,
- the later use case describe the integrating and broadcasting of all retrieved and produced data in an unique spatial decision support system. It concerns interoperability Civil Protection requirements.

Flash-flood forecasting system represents the hydrological portal for flash-flood crisis management. The use cases diagram underlines this specificity. Also, a second level of external actors is represented at the bottom of the figure, they correspond to operational decision makers (Civil Protection) and SCHAPI which assists SPC-GD in data mining and analysis. As shown in the diagram, the integrated, and potentially automatic, communication processes, originally based on fax and phone, includes all of these partners.

This general presentation of ongoing functioning is based on the Grid technology technical characteristics. The Grid has to be seen as a ready to use system for users (Soberman, 2003, 2005). The grid architecture complexity is hidden and virtualized as if user used a single resource. Thus, a unique computer seems necessary to access grid. The large number of processors and memory provides an important computational power and storage capacities to take in charge SPC-GD information system and more widely Civil Protection ones. Thus, from this theoretical presentation, improvements firstly concerns new modelling potentialities and data sharing facilities. The following section focuses on this topic and introduces future research developments.

4.2 A new technological functioning design

The Grid puts simultaneously many resources at user's disposal. This distributed architecture based on resources parallelization enables simultaneous algorithms execution. This opportunity may open new opportunities in hydrological modelling. Indeed, presently for example ALHTAÏR system is based on client-server architecture to simultaneously modelize several watersheds. In crisis management context, numerous simulation instances are necessary to monitor the whole of watersheds discharges in a near-real-time. The increase of the number of instance has been identified as a limiting factor (Huet *et al.* , 2003). This basis represents one of the most important factors for this Grid technology experimentation. The ongoing research is based on 4 main study scales :

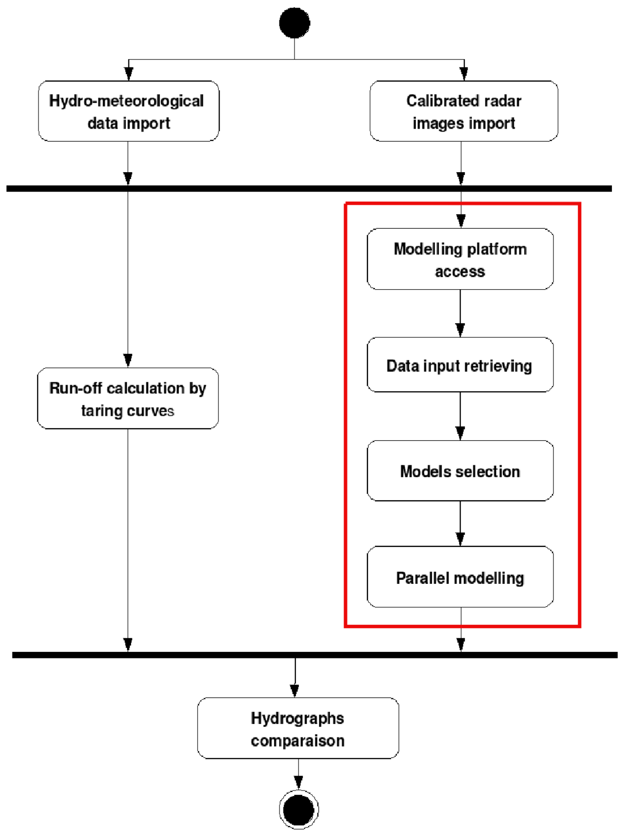

FIG. 7: River run-off modelling UML activity diagram

1. two for hydrological context
   – a single model (ALHTAÏR) improvement
   – a multi-models platform to confront modelling results and precise forecasters' hydrological reports
2. two for interoperability context
   – a hydrological-oriented information system using geospatial web services (OWS) grid implementation (Angelini *et al.* , 2008)
   – an integrated Civil Protection system based on virtual organization concept

The following paragraph details awaited improvements and involved methodologies to reach a critical evaluation of Grid technology adoption for Civil Protection problems.

Based on the organizational view, illustrated by use cases diagram, a UML activity diagram whose purpose "is to focus on flows driven by internal processing" (Corp & Partners, 1997), has been created. By this way, general flow of tasks implied in the hydrological scale is described (See Fig.7).

The objective of this diagram is to underline the place of the grid technology in "river run-off modelling" use case in the new SPC-GD functioning (Red box).

For the first scale, ALHTAÏR is currently porting on G-Lite middleware from sequential to parallel executions.

Concerning the ALHTAÏR functioning, Grid technology adoption has oriented researches towards three strategies :

– The calibration and sensitivity tests during hydrological event or in prevention stage to respectively improve modelling performances and assess models effectiveness in real-time,
– the simultaneous watersheds modellings, in using one grid job submission per watershed-model couple,
– the sub-watershed modelling thanks to parallelization process potentially permitting a better run-off spatialization (See Fig.8).

Concerning the multi-models scale, two assumptions guided this experimental phase. On one hand, catchments responses heterogeneity on SPC-GD competency territory prevents a single-model approach to follow up hydrological situation in real-time. On an other hand, to enhance hydrological forecasting reliability, it seems interesting to use several models for the same watershed in order to modelling results confrontation. In this sense, a program, called BVNE (Bassins Versants Numériques Expérimentaux) and set up by SCHAPI, develops a common methodology for a large-scale models inter-comparison in order to better understand flash flood genesis.

The objective of this study scale is to obtain simultaneous modellings based on the same rainfall and hydrological input data. Forecasters may assess several hydrographs on the same watersheds and precise their expertise for Civil Protection decision-makers.

The two last scales concern one of most important Civil Protection requirements, the interoperability. This approach may permit to analyze possibilities of this topic through Grid technology. For hydrological information system (flood hazard experts) and for Civil Protection virtual organization, respectively a experimentation and a more theoretical research have to be set up to precisely analyze :

– data exchanges or integration
– metadata implementation
– security potentialities
– thematic filtering

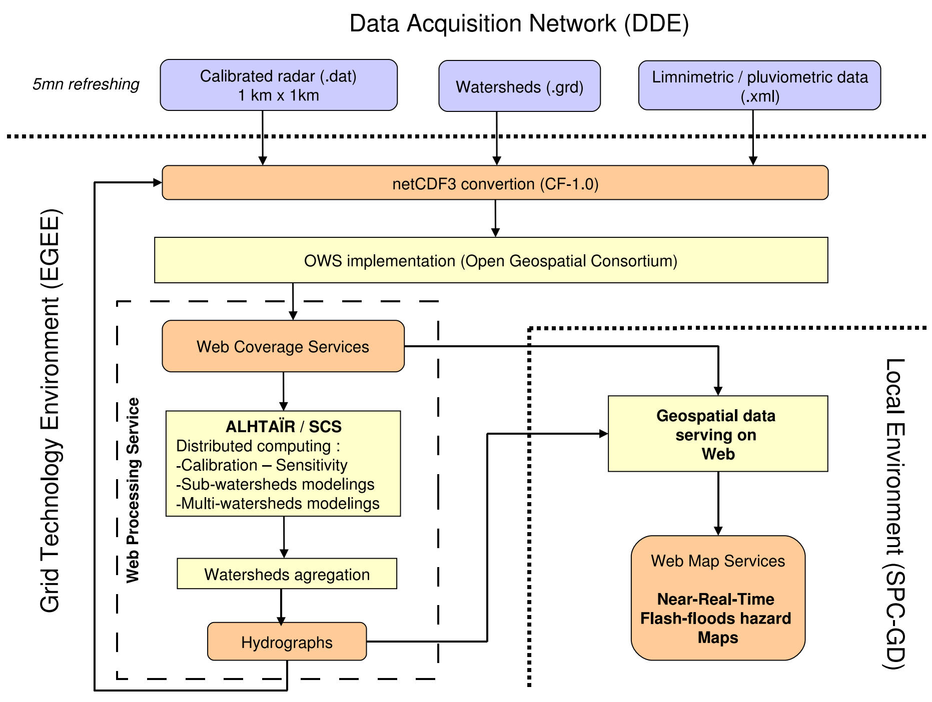

FIG. 8: Flash-flood management ongoing data-processing architecture

The interoperability may permit faster resources exchanges by standardized services implementation. As seen previously in Civil Protection requirements through Cyclops project results, geospatial resources may potentially improve crisis management for a better understanding of hazard and rescue situations. This experimentation may to be based on standardized geospatial interfaces specified by the Open Geospatial Consortium (OGC). These services, initially designed for web technology, have to be adapted for Grid-enabled solution, in following in progress IMAA-CNR and CIMA research on the G.RISICO system (Angelini *et al.* , 2008; D'Andrea *et al.* , 2008).

Among Open geospatial consortium Web Services (OWS), two of them have been selected :

- Web Coverage Service (WCS) to wrap calibrated radar images already stored in standard format (NetCDF)
- Web Processing Service (WPS) to manage Grid processing in "activating various independent data access services ", "distributing an adequate number of jobs on the grid" and "being responsible for the execution of the core algorithm" (ALHTAÏR for this research) (Angelini *et al.* , 2008).

Through these scales, the final objective is the design of flash flood spatial decision support system implemented on Grid platform to ease and integrate hydrological expertise among flood hazard experts and to broadcast it to the overall partners involved in the crisis management, enabling a more integrated communication.

To summarize these two last approaches, in particular the first one, a grid workflow has been produced (See Fig.8). From top to bottom, raw data are retrieving and are sent to Grid platform, a NetCDF file is generated to store rainfall and measured discharges data for each radar zones. This NetCDF are wrapped in web coverage services. Web processing service manages radar images service, hydrological algorithm executions and results retrieving. Raw and resulting data are integrated through geospatial web services in a unique web portal accessible by involved partners.

Finally, the subjacent objective of these two scales is to produce a feasibility study on the use of the grid in underlining network security and interoperability approach potentialities necessary for a real grid adoption in Civil Protection units, as Cyclops expected architecture.

Conclusion

In this paper, a discussion is handled on the potential use of grid technology for Civil Protection problematics. This recent technology offers important capabilities in term of distributed computing and resources sharing. In taking into account this data-processing gain, known technological and organizational weakness of Civil Protection units and in underlining their long-term requirements a set of specific improvements have been designed. Initiated and negotiated by Cyclops project partners, two use cases have been selected to define grid necessary enhancements to manage Civil Protection requirements and to properly evaluate grid potentialities for natural hazards monitoring. In this study, a particular attention on flash-flood hazard has been set up. Through UML analysis SPC-GD functioning improvements based on grid specificities have been designed. Grid technological potentialities has directed improvements towards a more integrated and interoperable system among involved partners and enabling heavy and numerous hydrological modellings in a real time context. One an other hand, dynamic aspect in resources monitoring and geographic distance between hazard location and used resources illustrate some positive aspects in term of resources security for grid adoption in Civil Protection agencies.

Finally, given the research-oriented of this study, grid technology represents a important support to share resources between operational units and involved scientific partners in a integrated way for prevention and post-crisis stages.

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