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Scheduling strategies for enabling meteorological simulation on hybrid clouds

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ABSTRACT

The flexible and *pay-as-you-go* computing capabilities offered by Cloud infrastructures are very attractive for high-demanding e-Science applications like weather prediction simulators. For their ability to couple the scalability offered by public service provider with the greater control and customization provided by Private Clouds, Hybrid Clouds seem a particularly appealing solution to support meteorological researchers and weather departments in their every-day activity. Cloud Brokers interfacing customers with Cloud providers, may support scientists in the deployment and execution of demanding meteorological simulations, by hiding all the intricacies related to the management of powerful but often complex HPC systems.

The paper presents a set of brokering strategies for Hybrid Clouds aimed at the execution of various instances of the weather prediction WRF model subject to different user requirements and computational conditions. A simulation-based analysis documents the performance of the different scheduling strategies at varying workloads and system configuration.

1. Introduction

Extreme precipitation and flooding events are among the greatest risks to human life and property, and represent one of the main issues of the 21st century with significant societal and economic implications. To cope with these issues a Meteorological research major objective is to enable the acceleration and the integration of advances in the everyday forecasts thus improving the environment protection. Actually, predicting weather and climate and their impacts is a crucial task both for research groups as well for civil protection departments. Moreover preventing hazards such as floods and landslides needs to address manifold issues that involve not only meteorology scientists but also requires a strong connection and collaboration with the ICT community to explore new technological solutions and approaches [1]. In particular, running prediction systems (e.g. WRF, MESO-NH) in a timely and efficient way, both for research and even more for possible operational application, usually requires the use of high performance computing resources that are both costly and not always easily accessible. In particular the Weather Research and Forecasting (WRF) model is a numerical weather prediction and atmospheric simulation system developed to advance the understanding and the prediction of mesoscale weather and

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accelerate the transfer of research advances into operations. This is ''the reference'' model for a large community of users, and reflects flexible, state-of-the-art, portable code that is efficient in computing environments ranging from massively-parallel supercomputers to laptops. The computational capacity of underlying may actually represent a limitation in the every-day-life work of each meteorology scientist [2].

A key factor of Cloud computing is represented by its on-demand, pay-per-use approach towards virtualized and distributed ICT solutions—in contrast to the creation and the maintenance of expensive, tightly pre-configured IT infrastructures, necessary to grant analogous services at the same level of business continuity. Hybrid Clouds (HC) integrating internal (private) and external (public) resources, couple the scalability offered by Public Clouds with the greater control supplied by private ones. A (Hybrid) Cloud Broker (CB) – acting as an intermediary between users and providers of Public Cloud services – may support meteorologists in the selection of the most suitable computational platform depending on their simulation objectives, optionally adding the provisioning of dedicated services with higher levels of quality.

Fostered by the research activities of the FP7 EU Distributed Research Infrastructure for Hydro-Meteorology (DRIHM) project (2012–2015) – aimed to enable Hydro-Meteorology research to make a step beyond the state of the art in the modeling of forecasting chain [3] – the present paper analyzes the performance behavior of a brokering algorithm for Hybrid Clouds in adequately responding to the operational constraints raised by different instances of meteorological models, that, as in the case of WRF, may have various kind of users and computational requirements as revealed, for instance, in [4]. We analyzed the behavior of different scheduling strategies, through simulation, by comparing the results achieved by the brokering algorithm with respect to different system configurations and type of workloads. To this end the study will take into account both the CB and the user (i.e. meteo researcher and professional) perspectives, by considering metrics such as revenue, user satisfaction and system utilization.

Section 2, introduces WRF, its computational issues and their relations with user requirements. Section 3 briefly reports on some related work. Section 4 presents the rationale under the brokering strategies. Section 5 details the simulation setup, while Section 6 presents and discusses the results. In Section 7 some conclusions are drawn.

2. The weather research and forecasting model

The Weather Research and Forecasting (WRF) model is a numerical weather prediction and atmospheric simulation system designed for both research and operational applications [5]. The effort to develop WRF began in the latter part of the 1990s and was a collaborative partnership among the US Institutions, Universities and Laboratories, in particular the National Oceanic and Atmospheric Administration (NOAA), the National Center for Atmospheric Research (NCAR), and more than 150 other organizations and universities in the United States and abroad [6]. Indeed, it represents a multi-agency effort to build a next-generation mesoscale forecast model and data assimilation system to advance the understanding and prediction of mesoscale weather and accelerate the transfer of research advances into operations. Its spectrum of physics and dynamics options reflects the experience and the input of the broad scientific community. In fact, WRF has grown to a large worldwide community of users (over 20,000 in over 130 countries), and it is now considered a community model contributed by the many research community developers.

WRF is a next-generation forecast model and reflects flexible, state-of-the-art, portable code that is efficient in computing environments ranging from massively parallel supercomputers to laptops. The model serves a wide range of meteorological applications across scales ranging from meters to thousands of kilometers. Applications include real-time Numerical Weather Prediction, tropical cyclone and hurricane research and prediction, regional climate, atmospheric chemistry and air quality, and basic atmospheric research. WRF allows researchers to simulations using real data (observations, analyses) or idealized atmospheric conditions [7]. The WRF model is frequently used in operational mode in a very large community, widespread from American continents to Europe, through Asia and Israel.[1] Apart from US, where the model is run for real time forecasts from different departments of the National Oceanic and Atmospheric Administration, such as the Global Systems Division and the National Severe Storm Laboratory, and other Universities, the model is actually used also in Mexico and Uruguay. As for Europe, many national and regional forecasts are obtained exploiting WRF, just to name a few, the LaMMA Consortium in Italy [8], the Earth Sciences Department of the Barcelona Supercomputing Center in Spain [9], the Republic Hydro-meteorological Service of Serbia [10].

2.1. Computational aspects

The WRF model represents the atmosphere as a number of variables of state discretized over regular Cartesian grids. The core is based on an Eulerian solver for the fully compressible nonhydrostatic equations. The model uses terrain-following, hydrostatic-pressure vertical coordinate with the top of the model being a constant pressure surface. The horizontal grid is the Arakawa-C grid. The time integration scheme in the model uses the third-order Runge–Kutta scheme, and the spatial discretization employs 2nd to 6th order schemes [7]. Weather prediction codes are by nature I/O (mostly output) intensive, repeatedly writing out a time series of 3D representations of the atmosphere. The most common standard used for data

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[1] WRF Real-time Forecasting, http://wrf-model.org/plots/wrfrealtime.php.