NSF PI meeting on "The Science of Cloud Computing"

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Topics:
1. Green Clouds
2. Cloud Architectures and Systems

Summary of current research on cloud computing:

The goal of the current research is to develop a framework—the Forecast-as- a-service (FaaS) framework —that achieves two purposes. The first purpose is to enable the combined use of different types of data from different sources and enhances the synthesis of more accurate forecasts using prediction results from different models. The second purpose is to support on-demand delivery of forecasts of different types and at different levels of detail for different prices. The FaaS framework is implemented by using the Azure platform to provide on-demand wind and solar power forecasting services at a customer-specified location for different types of customers. The customers include renewable energy users, renewable energy providers, power system operators, and potential users/producers that are at different stages of planning for new facilities.

The FaaS framework involves the orchestration of service activities performed by three SOA-based frameworks. In response to a particular customer forecast request, the FaaS framework, through the Forecast Generator Framework (FGF), determines what level of service is requested and whether internal resources, through the services provided by the Internal Data Retrieval Framework (IDRF), are adequate to meet the request. If external resources are needed, the FaaS controller invokes the External Data Collection Framework (EDCF) and communicates with various sources for weather information, geographic information, measurement data, and other pertinent information that is needed to meet the customer request.

The current research involves cooperation between academia (Virginia Tech), government (National Renewable Energy Laboratory of the U.S. Department of Energy) and industry (Detroit Edison of DTE Energy Company, and Electrical Distribution Design Inc.).

Abstract for future research:

Development of Forecast-Enhanced Power-Aware Computing and Energy Management Framework to Support the Realization of Green Clouds

Cloud-computing data centers are already providing energy savings and environmental benefits due to virtualization. Further improvement in energy efficiency can be obtained by implementing various power-aware computing techniques and energy management schemes. However, no matter how efficient a data center becomes, it must obtain its electric power from somewhere. Ideally, a green cloud can be sustained on renewable energy alone. Due to the intermittent and uncertain nature of wind and solar power, cloud-computing data centers using renewable energy will still rely on expensive energy-storage devices or power sources that emit greenhouse gas either as backup or to maintain high power quality.

Accurate forecast is key to effective utilization of weather-dependent renewable energy sources such as wind and solar. Even though the energy available from these sources is intermittent and uncertain, strategies can be developed to maximize their use if information about them can be known in advance and with some certainty. For example, electric power from solar arrays is highly dependent on the nature and movement of clouds. Using information from the weather forecast and satellite images, the nature of the cloud can be identified and the cloud movement can be predicted for the near future. Consequently, the electric power available from the affected solar arrays can be forecasted with quantified certainty for different time scales (minutes, hours, days) in advance. Using the forecast information, coordinated power-aware computing techniques and energy management schemes can be developed to maximize the utilization of the available renewable energy.

The goal of the proposed research is to develop a Forecast-Enhanced Power-Aware Computing (FEPAC) and energy management framework that adopts a holistic approach taking into account of factors on both the energy supply side and the power demand side. The FEPAC framework will utilize results from the current research on Forecast-as-a-Service (FaaS) to generate on-demand forecasts of wind and solar power at different locations for different time scales into the near future. The FEPAC framework will maximize the use of the forecasted energy to meet the power need of the data center by coordinating the use of various energy management and power-aware computing techniques. Computing tasks are scheduled, right-sized, re-routed, load-balanced, etc. such that the total power consumption does not exceed the total power budget imposed by the renewable energy sources. The effectiveness of the FEPAC framework greatly increases when it is applied to coordinate multiple data centers at diverse locations that have abundant renewable energy. The FEPAC framework has promising potential to make green clouds self-sustainable.

Current research in data-center energy management and power-aware computing is mainly focused on the improvement of energy efficiency and the reduction of power consumption. These efforts may be roughly classified into four broad categories: (1) Low-power hardware; (2) power-aware computer architecture; (3) operating system and system software for energy/thermal management; and (4) energy-aware software/applications. The proposed FEPAC framework adds a new category – energy supply forecast – and expands the goal beyond energy efficiency into effective utilization of available energy supply. The new category can be coordinated with any of the four existing categories individually or in different combinations. The current power-aware computing may be viewed as a special case of the FEPAC framework when the energy supply is forecasted to be continuously available.

Since the FEPAC framework enables maximum utilization of available energy from renewable energy sources, the unit cost of electricity (in dollar/kilowatt-hour) from renewable energy sources could be reduced. The FEPAC framework has the potential to have a profound impact on the economics and performance of data centers and cloud computing, and even the future of the renewable energy industry itself.