The National Weather Sensor Grid *

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1 Introduction

With the rapid advances in technologies such as MEMS sensors, low-power embedded processing and wireless networking, sensor networks are becoming more powerful in terms of data acquisition and processing capabilities. Sensor networks can now be deployed in the physical world for various important applications such as environmental monitoring, weather monitoring and modeling, military surveillance, healthcare monitoring, tracking of goods and manufacturing processes, smart homes and offices, etc.

The field of sensor networks has grown dramatically in recent years. However, it remains a daunting challenge to deploy large-scale sensor networks. It is also difficult to integrate sensor networks with existing IT infrastructures such as the Internet. Thus, sensor networks often operate as separate information silos, and the sensor resources and data cannot be easily shared. In fact, with a large number of sensor devices potentially deployed over a wide area, sensor networks are important distributed computing resources that can be shared by different users and applications.

Grid computing is an established standards-based approach to solve large-scale problems through coordinated sharing of distributed and heterogeneous resources in dynamic virtual organizations. Most existing developments in grid computing focus on *compute grids*, which provide distributed computational resources for compute-intensive applications, and *data grids*, which provide seamless access to large amounts of distributed data and storage resources.

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Most recently, the concept of *sensor grids* [1] has received increasing attention from the research community. Sensor grids extend the grid computing paradigm to the sharing of sensor resources in sensor networks. A sensor grid integrates sensor networks with the computational and storage resources in the conventional grid fabric. The vast amount of data collected by the sensors can be stored, processed and analyzed by the computational and data storage resources of the grid. Sensor resources can be efficiently shared by different users and applications through the resource sharing and coordination capabilities of the grid.

The National Weather Study Project (NWSP) is a large-scale community-based environmental initiative in Singapore that aims to promote the awareness about weather patterns, climate change, global warming and the environment. In this project, hundreds of mini weather stations are deployed in schools throughout Singapore. Each weather station contains several sensors for measuring weather parameters such as temperature, rainfall, humidity, wind speed and direction, etc. Since the geographical locations of these school weather stations cover most parts of Singapore, the microclimate weather data from these stations provide a good profile of the weather patterns within Singapore.

We are designing and building the *National Weather Sensor Grid (NWSG)* to support and to realize the full potential of the NWSP. The NWSG has several important features. First, it connects the weather stations via the Internet to automatically collect and aggregate weather data in real-time. Second, the weather data are logically stored in a Central Data Depository (CDD) which can be implemented using distributed data storage resources. Third, the NWSG integrates computational resources for the compute-intensive processing of weather data. Fourth, the weather data can be easily accessible and shared via the web through mash-ups, blogs, and other user applications. We are developing techniques and tools to efficiently publish, query, process, visualize, archive and search the vast amount of weather data. Finally, the NWSG should be scalable to handle hundreds of weather stations, and also extensible to handle different types of sensors besides weather stations.

At present, we have developed a prototype of the NWSG with several connected weather stations. This prototype enables us to improve the design of the sensor grid architecture. It also provides several useful services for the users to access and visualize the weather data.

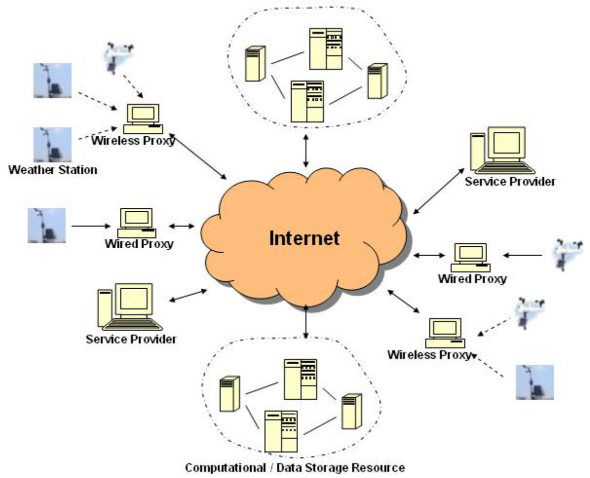

Figure 1. Sensor Grid Architecture

2 System Architecture

Figure 1 shows the system architecture of the National Weather Sensor Grid (NWSG). It consists of several major components.

Sensor Resource. In the NWSG, the sensor resources are different types of weather stations. There are two types of weather stations deployed in this project; namely, the Davis Vantage Pro II and the WeatherHawk. Each weather station integrates several sensors that directly measure weather parameters like temperature, rainfall, humidity, wind speed and direction, solar radiation, barometric pressure, etc. A weather station or a group of weather stations are connected to the sensor grid through a proxy system, which is currently implemented as a desktop or laptop PC running a set of middleware services. The proxy may be wired or wireless.

The proxy will automatically retrieve weather data from the weather stations and send the data to the sensor grid via the Internet. The proxy performs some data processing tasks. For example, it computes several indirect weather parameters such as heat index and dew point using the direct measurable weather parameters. It is also possible for the proxy to control the operation of the weather station.

Computational/Data Storage Resource. A computational/data storage resource refers to any resource that performs computational and/or data management tasks. These resources are capable of efficiently handling large-scale computational or data management jobs. They are managed by middleware services that we are developing based on standard grid protocols such as Globus.

In our current prototype, these resources consist of a single database and several grid resource nodes. Although the single database can handle the weather data for now, we plan to extend it to a distributed database for better scalability as more weather stations are connected to our system. With the microclimate weather data collected throughout Singapore, we can develop weather models and perform sophisticated computations. The computational resources are therefore essential to perform such computational-intensive jobs with relatively low cost.

Service Provider. The term *service* is used in the grid computing context. Apart from conventional computational and data processing jobs, the sensor grid can provide some useful services to the users. The service provider makes use of the weather stations, computational resources, and data storage resources to provide the services. The users can subscribe to these services through standard grid computing mechanisms.

Currently, we provide rain and temperature alert services to users. Once a user has subscribed to these services, the user will be notified if it is raining or if the temperature is too high in certain locations. We also provide a weather display service which displays the weather conditions at user specified locations in a flexible manner on web sites, blogs, or other user applications.

3 Demonstration Highlights

We will demonstrate several features of our National Weather Sensor Grid (NWSG) prototype. First, we will show the distribution of the connected weather stations in Singapore. We currently use two geo-centric web interfaces to display and visualize the weather station information.

The first interface is Microsoft SensorMap [2], which is specially designed for sensor information publishing. We publish the weather station information using SensorMap's supported sensor types, and graphically display the weather data using dynamically generated HTML pages. The second interface is Google Earth. We generate kml script which overlays the weather stations on the satellite map of Singapore, together with dynamically updated snapshots of the weather data last captured from the weather stations.

We will demonstrate how a user submits a request for a particular type of computational or data processing job, and how the sensor grid completes the job and returns the results to the user. Finally, we will show the weather alert services and how users can subscribe to these services on the web.

4 References

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