The Science of Cloud Computing

Integrating Cloud Computing with Mobile Platforms, Sensor Networks, and Education

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Research Interests: (4) Programming Models for the Cloud and (6) Cloud Security, Privacy, and Auditing

Instructor, *Mobile and Cloud Computing: Technologies, Opportunities, and Challenges*, December 18-19 (14 Hours), 2010, National Chiao Tung University, Hsinchu, Taiwan.

Publications Related to Cloud Computing:

[1] *Cloud Computing for Mobile Users: Can Offloading Computation Save Energy?, IEEE Computer, April 2010.*
This paper describes the conditions to save energy by sending computation to a cloud server. The conditions include the amount of computation, the size of data exchanged between a mobile system and a cloud server, and the available data rate in a wireless network. The paper was ranked No.1 as "Top Accessed Articles in August 2010" in IEEE Computer.

[2] *Energy Savings in Privacy-Preserving Computation Offloading with Protection by Homomorphic Encryption, HotPower 2010.*
Encrypted images are sent to a server for extracting features in order to find similar images. The images remain encrypted at the server so that privacy is protected.

[3] *Tradeoff between Energy Savings and Privacy Protection in Computation Offloading, International Symposium on Low Power Electronics and Design 2010.*
This paper uses steganography to protect privacy: the original images are embedded inside cover images so that the server cannot easily discover the actual images.

[4] *Real-time Moving Object Recognition and Tracking Using Computation Offloading, IEEE/RSJ International Conference on Intelligent Robots and Systems 2010.*
This paper demonstrates how to use muti-cores on a server to reduce response time for recognizing and tracking a moving object. This is possibly the first paper using computation offloading for executing real-time tasks on a mobile robot.

[5] *Establishing Trust for Computation Offloading, International Conference on Computer Communications and Networks 2009.*
This paper describes a method to detect whether a server has performed the computation as claimed. This method can be used as a foundation to establish a new service (saving energy) in cloud computing for mobile users.

[6] *Ranking Servers based on Energy Savings for Computation Offloading, International Symposium on Low Power Electronics and Design 2009.*
This paper compares how much energy may be saved by different servers; this can be used to determine whether the service is charged fairly.

[7] *Adaptive Computation Offloading for Energy Conservation on Battery-Powered Systems, International Conference on Parallel and Distributed Systems 2007.*
This paper describes a method to determine the condition to send computation to a server. At most twice amount of energy is consumed when compared with a perfect solution.

Research Problems to Investigate:

Three important trends will shape the future of information technology: (i) Cloud computing provides elastic resources, easier task migration, and geographically distributed backups. (ii) Mobile systems have become primary computing platforms for billions of people. These platforms generate large amounts of multimedia data and most of the data are stored on-line. (iii) Sensors are widely deployed for monitoring environment and for security. These sensors have limited computing capabilities; cloud servers can be used to process the data for analysis and decision making. Inspired by these trends, my research interests include

(1) developing programming models and tools to integrate these three types of systems.

(2) designing and implementing a prototype for executing real-time tasks using cloud computing.

(3) investigating efficient methods to protect privacy.

(4) broadening the access of cloud computing to diversified groups of students.

(1) The three types of systems represent significantly different programming environments: They acquire and process different types of data, have different resources, and need to meet different constraints. Cloud servers have rich resources, are massively parallel, and can be reallocated to run different tasks. Mobile platforms have a wide range of input devices collecting data from users. In contrast, each sensor obtains only one type of data and these samples are typically obtained periodically or triggered by events. Sensor nodes have stringent resource constraints in power, storage, wireless bandwidths, as well as performance. Integrating these three types of systems presents significant challenges.

(2) Real-time tasks must finish before their deadlines. Many real-time tasks have high degrees of parallelism and can take advantage of cloud servers' elasticity: these tasks can finish earlier if more servers are used. When cloud computing is integrated with sensor networks, unusual events may trigger emergency simulations. For example, if a massive earthquake is detected by seismic sensors, the sensors could launch simulations to predict whether and where a tsunami could occur. The simulations must complete before a tsunami reaches shorelines. Using dedicated computers for this purpose would be inefficient and uneconomical because earthquakes are rare and research computers may not have the performance for meeting the timing constraints. In order to conduct sensor-triggered emergency simulations, new technologies must be developed so that cloud servers can be reallocated quickly.

(3) As mobile systems and sensors collect and send data to cloud servers for analysis and decision making, the collected information may cause great concerns about privacy. Existing solutions for privacy protection require significant computing resources and are inappropriate for mobile platforms and sensor networks. Efficient methods must be developed to protect privacy.

(4) Cloud computing may play significant roles in education and US economy because (i) A study by IBM in October 2010 indicated that cloud computing would generate many employment opportunities. (ii) Cloud computing could allow students from diversified groups to use services that might be unavailable in these students' learning environments due to limited budgets for purchasing, upgrading, and managing computing facilities. Cloud computing could reduce the barriers for students to pursue careers in computing.