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Topics:

1. Cloud Architectures and Systems
4. Programming Models for the Cloud

Current Research Activities:

My research activities focus on the fundamentals of cloud application architectures. Unlike traditional computer architecture, network architecture and application architecture research; we focus on the dynamic application-level communication architecture formed at runtime.

We believe that these dynamic runtime networks are ultimately responsible for their behaviors to human interactions. Therefore, the application programming interface (API) (or programming model) is a critically important factor in addition to the networking and computing architecture supports.

Currently, it is commonly accepted that if an application needs performance, reliability must be sacrificed. To achieve reliability, performance must be sacrificed. Large applications must endure higher probability of information losses.

These perceptions were created by the current designs of distributed application APIs and architectures. Looking carefully, one finds flaws in API and architecture design assumptions.

The most notable one is the common practice of two-state API design. All current distributed (and parallel) APIs assume only two states for each operation: success or failure. Non-deterministic behavior is introduced by the third state: "unknown". The "unknown" states are introduced by the timeout events. It happens more often than we would desire. Currently, most programmers would issue a misleading "operation failure" error message. In fact, a "state unknown" message would be more honest.

Our research focuses on the necessary and sufficient conditions for four high level cloud computing services: enterprise messaging, online transaction (and analytics) processing, online parallel processing and online storage systems. These require a holistic methodology that integrates API designs with computing and networking support.

Recent effort expands our research into wireless, sensor network and smart grid applications for future cyber physical systems.

Future Research Problems: Sustainable Cloud Computing Architectures

- a) Cloud application architectures that deliver all-around information assurance. Here we define information assurance as follows:
- More computing and communication (and sensor) components should deliver higher performance.
 - More computing and communication (and sensor) components should deliver higher data and service availability.
 - More computing and communication (and sensor) components should deliver less permanent failures.

Most current applications and systems architectures only aim to address a single goal. Future cloud-ready applications should satisfy all goals simultaneously. These should apply to all cloud computing applications including message, online storage, online transaction processing and online parallel processing. Sensor networks and smart grids can also potentially benefit from these disciplines.

- b) Application architectures that deliver high information security. Here we define information security as controls over the accesses to data and service. Currently, our best effort systems can only control access of data, but not service, since we cannot prevent DOS attacks.
- c) Application architectures that deliver optimal energy efficiency. This problem is related to information assurance since higher energy efficiency is enabled by applications with high information assurance architectures. To achieve optimal energy efficiency requires achieving optimal performances all around.
- d) Application architectures that enable the best possible human efficiency. This problem is particularly concerned with HPC (High Performance Computing) applications where many years of training is required for a HPC programmer to be fluent in domain knowledge and parallel coding methods. Performance optimizations should not require re-writing of parallel codes. HPC task scheduling should not require more than linear complexity. Debugging a cloud application should not require the invention of a “cloud-debugger”.

In summary, we proposed rigorous information assurance and security measures for future cloud application architectures. The proposed topics push forward the existing computer architecture, network architecture and application architecture studies toward an integrated methodology with higher goals. Although seems ambitious, the proposed topics are inspired by the “network dichotomy” where the low level data networks have delivered high information assurance for many decades. The current Internet body contains many lessons that we can learn for building future extreme scale cloud applications.