Research Statement

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Background

My research strategy is mainly application-driven, i.e., the focus is on developing novel applications to exploit the full potentials and to expose any limitations of emerging technologies. My background is firmly rooted in cluster and cloud computing, however, I believe that the decentralized computing model, currently made possible and popularized by blockchain technologies, will gradually take over the prevalent cloud-based, centralized model in the near future.

Research Areas

From the cloud based computing model…

I have been spending many years working on a wide range of distributed computing applications. The journey started with online gaming supported by networked clusters; and later by grid computing. Multi-player online gaming is a very demanding application due to its stringent requirements in terms of processing and network latency for supporting a highly interactive experience. As a result, the computing and network resource optimizations have been the central research problems in this area. We first developed effective load balancing techniques for local gaming clusters [1]. However, the issue of network latency mandated a geographically distributed server architecture leading to our adoption of grid computing and our formulation of the novel optimal game server placement problem [2-4].

Grid computing resources tend to be heterogeneous, which have made it not really suitable for time-critical applications like online gaming. Most recently, it is cloud computing that has taken the centre stage in my research agenda. Public cloud services such as AWS EC2 supply well-curated computing resource, but at a significant cost. Therefore, my focus has been on finding a good trade-off between the quality of services of online gaming and simulation applications [5-7], machine learning/big data [8], etc., and their resource provisioning cost. The work has been supported by funding from MOE Tier-1 Academic Fund, IMDA Green Data Centre Programme and Amazon Web Services (as a principal/co-investigator).

The consolidation of data and analytic capabilities into centralized data centers brings to wider attention co-resident security issues, in which side-channel attacks could retrieve confidential data from co-located cloud virtual machines. We framed

this problem as a security-resource trade-off, in which practical VM placement approaches could be implemented into existing cloud providers [9-12].

To the decentralized computing model of the future…

Centralized clouds pose serious problems in terms of energy usage and data privacy. Decentralized computing has been around for a while – but only with blockchain it has started to show great potential. I strongly believe that it is the future of computing; as it enables cooperation and collaborative decision making on a level that we have never seen before:

1) There are inherent security features – no single malicious participant can influence the system in the way he wants without consensus. As a result, there is no explicit trust relationship required between collaborators – this enables very large scale cooperative networks.

2) It is privacy-preserving: you can collaborate without exposing your private data – this is a huge advantage for any organizations or individuals. For instance, people are starting to do blockchain-based AI in which different stakeholders can jointly develop far better joint AI models without the need to share their datasets or their decision making logic/processes. This is also what our team is doing with the blockchain-based reinforcement learning agents [13].

3) The centralized computing model would still be relevant in the meantime – there are just too much high quality data accumulated at big corporations, and it is currently not exactly fast and cheap enough to transport such data around. But network speed and throughput are getting better, at the same time regulations, e.g., the GDPR (EU), on data privacy is catching up with the big guys – they might have to break up into smaller independent but cooperative entities eventually. This will form the basis to push decentralized computing into the mainstream.

4) Big, centralized data centers as they are today are too inefficient in terms of energy consumption. They also represent the bottlenecks of the world's economy – they are obvious targets of cyberwarfare. Micro-data centers securely linked via blockchain could be the future computing platform – they are not owned by any single entity.

Hence the current research plan…

I am moving towards the decentralized computing model using the same research strategy, i.e., by developing new applications leveraging the new technologies. For instance, we have successfully developed an AI-based air traffic flow management (ATFM) application on top of the permissioned blockchain Hyperledger Fabric. The prototype system incorporates simple reinforcement learning techniques to carry out local optimization, and leverages Hyperledger's smart contracts to aggregate local results into global optimization strategies [13].

Our current plan is to further develop blockchain-based distributed optimization techniques and privacy-preserving AI capabilities in several selected domains, namely, microgrid management, teaching and learning, and ATFM. These efforts have been well supported by the latest round of funding from MOE Tier-1 Academic Fund (2018-2020, as PI), Civil Aviation Authority of Singapore (2018-2019, as PI), and EMA Energy Resilience Programme (2018-2021, as co-PI).

Selected Publications and Outputs

[1] Ta Nguyen Binh Duong, Suiping Zhou: A dynamic load sharing algorithm for massively multiplayer online games. ICON 2003: 131-136.
[2] Ta Nguyen Binh Duong, Suiping Zhou: Efficient client-to-server assignments for distributed virtual environments. IPDPS 2006.
[3] Ta Nguyen Binh Duong, Suiping Zhou: A two-phase approach to interactivity enhancement for large-scale distributed virtual environments. Computer Networks 51(14): 4131-4152 (2007).
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Interactivity-Constrained Server Provisioning in Large-Scale Distributed Virtual Environments. IEEE Trans. Parallel Distrib. Syst. 23(2): 304-312 (2012).
[5] Ta Nguyen Binh Duong, Xiaorong Li, Rick Siow Mong Goh, Xueyan Tang, Wentong Cai: QoS-Aware Revenue-Cost Optimization for Latency-Sensitive Services in IaaS Clouds. DS-RT 2012: 11-18.
[6] Ta Nguyen Binh Duong, Xiaorong Li, Rick Siow Mong Goh: A Framework for Dynamic Resource Provisioning and Adaptation in IaaS Clouds. CloudCom 2011: 312-319.
[7] Ta Nguyen Binh Duong, Jinghui Zhong, Wentong Cai, Zengxiang Li, Suiping Zhou: RA2: Predicting Simulation Execution Time for Cloud-Based Design Space Explorations. DS-RT 2016: 120-127
[8] Ta Nguyen Binh Duong: FC2: cloud-based cluster provisioning for distributed machine learning. Cluster Computing Journal (2019), Springer (new).
[9] Varun Natu, Ta Nguyen Binh Duong: Secure Virtual Machine Placement in Infrastructure Cloud Services (nominated for best paper). SOCA 2017: 26-33
[10] Ta Nguyen Binh Duong, Neha Pimpalkar: Handling Co-Resident Attacks: A Case for Cost-Efficient Dedicated Resource Provisioning. IEEE CLOUD 2018: 849-852
[11] Amit Agarwal, Ta Nguyen Binh Duong: Co- Location Resistant Virtual Machine Placement in Cloud Data Centers. ICPADS 2018: 61-68
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[13] Ta Nguyen Binh Duong, K. Todi, U. Chaudhary, Hong-Linh Truong, "Decentralizing Air Traffic Flow Management with Blockchain based Reinforcement Learning", 17th IEEE International Conference on Industrial Informatics, July 2019.

[14] Ta Nguyen Binh Duong, Vu Duc Long, "Group Instance: Flexible Co-Location Resistant Virtual Machine Placement in IaaS Clouds", 29th IEEE International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises, 2020.
[15] Lwin Khin Shar, Ta Nguyen Binh Duong, Lingxiao Jiang, David Lo, Wei Minn, Kiah Yong Yeo Glenn and Eugene Kim, "SmartFuzz: An Automated Smart Fuzzing Approach for Testing SmartThings Apps", 27th Asia-Pacific Software Engineering Conference, 2020.
[16] Huaizheng Zhang; Yuanming Li; Qiming Ai; Yong Luo; Yonggang Wen; Yichao Jin; Ta Nguyen Binh Duong, "Hysia: Serving DNN-Based Video-to-Retail Applications in Cloud", ACM Multimedia, 2020.