VIGNESH SIVARAMAN

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EDUCATION

PhD. in Electrical and Computer Engineering — August 2016 to August 2020
National University of Singapore — GPA: 4.93/5
Supervisor: A/Prof. Biplab Sikdar

Graduate Exchange Student — September 2019 to December 2019
University of Toronto
Supervisor: Prof. Ben Liang

M.Tech. in Computer Science & Engineering — July 2014 to June 2016
Indian Institute of Technology, Guwahati — GPA: 9.34/10
Supervisor: A/Prof. T Venkatesh

B.Tech. in Computer Science & Engineering — July 2010 to May 2014
National Institute of Technology, Tiruchirappalli — GPA: 8.25/10
Final Year Project Supervisor: Dr. Shivashankar

RESEARCH SUMMARY

PhD.

Many next generation Internet architectures exist in the literature for addressing various issues like increasing traffic, mobility and efficient content dissemination. It is predicted that the global multimedia traffic would account for 82% of the total Internet traffic by 2022 rendering the content distribution as an important challenge to be addressed. An emerging fundamental architecture for addressing this challenge is Information Centric Networking (ICN). ICN aims to decouple content and from its host and to replace *where* with *what* as the primary entity of the network. ICN is a communication network built with content as the primary entity of the network where the content names are used as identifiers (or addresses) and not the content locations. Along with making this fundamental change, ICN is designed to preserve and leverage the well engineered design principles of TCP/IP that make it simple, reliable, robust, and scalable. The following are the contributions of my doctoral research.

- With the ever-growing mobile data traffic, providing user-mobility has become a necessity. While consumer mobility is implicitly handled in ICN (by interest retransmission), producer mobility is still of one the main challenges as it involves re-routing of interests. After a producer handoff occurs, the producer is unavailable until the corresponding routing entries are updated. Unavialability of producer is a critical issue to addressed as it can seriously affect the quality of experience of the consumers. Moreover, it can lead to multiple retransmission of the requests thereby congesting the network. To this end, we designed a proactive producer mobility management scheme in ICN. The router in the proposed mechanism makes a decision on whether to forward the requests using routing table entries or to multicast to the neighbors based on the number of hops traveled by the request. The intuition behind this mechanism is two-fold: (i) spatial locality of producer and (ii) data packets follow the reverse path of requests in ICN. Moreover, the routing updates are carried out when the data corresponding to the interest is forwarded. Simulation results show that our approach improves the network throughput by 30% and reduces the average delay by 45% when compared to the existing approaches.

- The Pending Interest Table (PIT) is one of the essential components of the ICN forwarding plane responsible for the stateful routing in ICN. The PIT carries out the following functions: (i) routing the content back to the consumer, (ii) aggregation of interests, (iii) other forwarding tasks like loop detection etc. As in any buffer, when the interest arrival rate is greater than the content retrieval rate, PIT becomes full and interests are dropped which affects the quality of experience of consumers. As PIT is a component of the forwarding plane and is required to function at wire speed, thereby making the PIT an expensive resource. Therefore, optimal size of the PIT is essential for the efficient performance of the network and the enhanced consumer experience. To this end, we developed an analytical model for the PIT of a router. The model has (i) a general arrival process to accommodate the diverse nature of traffic, (ii) a service time model which takes into account the caching at the content stores and the mobility of producers, and (iii) a sojourn time distribution which is used to characterize the content delivery time at the consumers. Using this queueing model we formulated an optimization problem to minimize the PIT size at the router while subjecting the interest drop probability to an upper bound. Simulation resutls show that our proposed approach reduces the PIT cost by 38% compared to the existing approaches and our analytical approach deviates from simulations by 8%.
- The in-network caches at the routers are an another important component of ICN. The forwarded content is cached at these caches, thereby enabling faster content retrieval and improving the bandwidth efficiency of the network. On the one hand this approach improves the network performance, but on the other hand it makes the network vulnerable to privacy attacks. As the interest and the content traverse the same path in ICN, the privacy of a user can be breached by inspecting the caches of different routers. Hence, there is a need to design privacy enhancing caching mechanisms. To this end, we proposed a off-path caching strategy which aims to improve the privacy of users. We quantify the user privacy using the mutual information of the system and differential privacy. Using these privacy metrics, we formulated a non-cooperative game among the users which aims to minimize the cost of caching while meeting the different privacy requirements of the users. Along with enhancing the privacy of the users, our mechanism also improves the efficiency of the network by achieving a better caching balance among different routers and by reducing the number of redundant copies of the content. Performance study shows that our proposed caching strategies incur 55% less cost compared to the existing caching strategies.

M.Tech.

- Many critical e-commerce and financial services are deployed on geo-distributed data centers for scalability and availability. Recent market surveys show that failure of a data center is inevitable resulting in a huge financial loss. Fault-tolerance in distributed data centers is typically handled by provisioning spare capacity to mask failure at a site. We argued that the operating cost and data replication cost (for data availability) must be considered in spare capacity provisioning along with minimizing the number of servers. Since the operating cost and client demand vary across space and time, we propose cost-aware capacity provisioning to minimize the total cost of ownership (TCO) for fault-tolerant data centers. We formulated the problem of spare capacity provisioning in fault-tolerant distributed data centers using mixed integer linear programming (MILP), with an objective of minimizing the TCO. The model accounts for heterogeneous client demand, data replication strategies (single and multiple site), variation in electricity price and carbon tax, and delay constraints while computing the spare capacity.
- The operational cost of a data center is influenced by factors such as electricity prices, server/data center failure, green energy availability, and client demand. Therefore, cost aware load balancing in geo-distributed data centers must consider the spatio-temporal variation in these factors to minimize the operating cost. In a distributed data center, the user requests are served by the front-end proxy servers independent of each other. Each proxy server prefers to get its requests served by the data center first to minimize the service delay. In order to model this selfish nature in distributed load balancing, we formulated the load balancing as a non-cooperative game among a finite number of

front-end proxy servers. The objective of the game is to minimize the sum of the energy cost and the revenue loss due to delayed service.

JOURNAL PUBLICATIONS

- **Sivaraman Vignesh** and B. Sikdar, "A defense mechanism against timing attacks on user privacy in ICN," *IEEE/ACM Transactions on Networking*, Under 2nd round of revision
- **Sivaraman Vignesh**and Biplab Sikdar, "Peek: A proactive producer mobility management scheme for information-centric wireless sensor networking," *IEEE Internet of Things Journal*, Under revision
- **Sivaraman Vignesh** and B. Sikdar, "A game theoretic approach for enhancing data privacy in SDN-based smart grids," *IEEE Internet of Things Journal*, 2020, In press
- **Sivaraman Vignesh**, D. Guha, and B. Sikdar, "Optimal pending interest table size for ICN with mobile producers," *IEEE/ACM Transactions on Networking*, vol. 28, no. 4, pp. 1615–1628, 2020
- R. Tripathi, **S. Vignesh**, V. Tamarapalli, A. T. Chronopoulos, and H. Siar, "Non-cooperative power and latency aware load balancing in distributed data centers," *Journal of Parallel and Distributed Computing*, vol. 107, pp. 76–86, 2017
- R. Tripathi, **S. Vignesh**, V. Tamarapalli, and D. Medhi, "Cost efficient design of fault tolerant geo-distributed data centers," *IEEE Transactions on Network and Service Management*, vol. 14, no. 2, pp. 289–301, 2017
- R. Tripathi, **S. Vignesh**, and V. Tamarapalli, "Optimizing green energy, cost, and availability in distributed data centers," *IEEE Communications Letters*, vol. 21, no. 3, pp. 500–503, 2017

CONFERENCE PUBLICATIONS

- **Sivaraman Vignesh** and K. Meel, "A projected model counting approach for estimating reachability in stochastic networks," in *AAAI Conference on Artificial Intelligence*, 2022, In-preparation
- **Sivaraman Vignesh**, D. Guha, and B. Sikdar, "Towards seamless producer mobility in Information Centric Vehicular Networks," in *IEEE Vehicular Technology Conference*, Spring-2020
- **Vignesh Sivaraman** and B. Sikdar, "Hop-count based forwarding for seamless producer mobility in NDN," in *IEEE GLOBECOM*, 2017
- R. Tripathi, **S. Vignesh**, and V. Tamarapalli, "Minimizing cost of provisioning in fault-tolerant distributed data centers with durability constraints," in *IEEE ICC*, 2016
- R. Tripathi, **S. Vignesh**, and V. Tamarapalli, "Cost-aware capacity provisioning for fault-tolerant geo-distributed data centers," in *COMSNETS*, 2016
- **S. Vignesh**, R. Tripathi, and V. Tamarapalli, "Minimizing the cost of designing fault-tolerant CDN data centers," in *IEEE ANTS*, 2016

TECHNICAL STRENGTHS

Programing Languages	C, C++, Python, Java, Matlab
Simulation Tools	NS-3, Mininet

TEACHING ASSISTANTSHIP

National University of Singapore

- Network Protocols and Applications
- Microcontroller Programming and Interfacing

- Programming for Computer Interfaces

Indian Institute of Technology, Guwahati

- Computer Networks
- Computer Systems