Bibliography

[1] P. Cipresso, I. A. C. Giglioli, M. A. Raya, and G. Riva. The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Front Psychol.*, 9:2086, 2018. DOI: 10.3389/fpsyg.2018.02086. 1

[2] L. Da Xu, W. He, and S. Li. Internet of Things in industries: A survey. *IEEE Trans. Ind. Informat.*, 10(4):2233–2243, November 2014. DOI: 10.1109/tii.2014.2300753. 1

[3] A. Abhashkumar, J.-M. Kang, S. Banerjee, A. Akella, Y. Zhang, and W. Wu. Supporting diverse dynamic intent-based policies using Janus. *Proc. of the 13th International Conference on Emerging Networking Experiments and Technologies (CoNEXT'17). Association for Computing Machinery*, pages 296–309, New York, 2017. DOI: 10.1145/3143361.3143380. 1

[4] N. McKeown, T. Anderson, H. Balakrishnan, G. Parulkar, L. Peterson, J. Rexford, S. Shenker, and J. Turner. OpenFlow: Enabling innovation in campus networks. *SIGCOMM Comput. Commun. Rev.*, 38(2):69–74, 2008. DOI: 10.1145/1355734.1355746. 1, 3

[5] S. Jain, A. Kumar, S. Mandal, J. Ong, L. Poutievski, A. Singh, S. Venkata, J. Wanderer, J. Zhou, M. Zhu, J. Zolla, U. Hölzle, S. Stuart, and A. Vahdat. B4: Experience with a globally-deployed software defined wan. *Proc. of the ACM SIGCOMM Conference on SIGCOMM. Association for Computing Machinery*, pages 3–14, New York, 2013. DOI: 10.1145/2486001.2486019. 1

[6] Z. Zaidi, V. Friderikos, Z. Yousaf, S. Fletcher, M. Dohler, and H. Aghvami. Will SDN be part of 5G?. *IEEE Commun. Surv. Tutor.*, 52(4):3220–3258, 2018. DOI: 10.1109/comst.2018.2836315. 1

[7] B. A. A. Nunes, M. Mendonca, X. Nguyen, K. Obraczka, and T. Turletti. A survey of software-defined networking: Past, present, and future of programmable networks. *IEEE Commun. Surv. Tutor.*, 16(3):1617–1634, 2014. DOI: 10.1109/surv.2014.012214.00180. 2

[8] F. A. Lopes, M. Santos, R. Fidalgo, and S. Fernandes. A software engineering perspective on SDN programmability. *IEEE Commun. Surv. Tutor.*, 18(2):1255–1272, 2016. DOI: 10.1109/comst.2015.2501026. 2

[9] J. C. C. Chica, J. C. Imbachi, and J. F. B. Vega. Security in SDN: A comprehensive survey. *J. Netw. Comput. Appl.*, 159(102595), June 2020. DOI: 10.1016/j.jnca.2020.102595. 2

[10] N. Feamster, J. Rexford, and E. Zegura. The road to SDN: An intellectual history of programmable networks. *SIGCOMM Comput. Commun. Rev.*, 44(2):87–98, 2014. DOI: 10.1145/2602204.2602219. 2

[11] N. Anerousis, P. Chemouil, A. A. Lazar, N. Mihai, and S. B. Weinstein. The origin and evolution of open programmable networks and SDN. *IEEE Commun. Surv. Tutor.*. DOI: 10.1109/comst.2021.3060582. 2

[12] K. Psounis. Active networks: Applications, security, safety, and architectures. *IEEE Commun. Surv.,* 2(1):2–15, 1999. DOI: 10.1109/comst.1999.5340509. 3

[13] M. Caesar, N. Feamster, J. Rexford, A. Shaikh, and J. van der Merwe. Design and implementation of a routing control platform. *2nd USENIX NSDI,* 2005. 3

[14] T. Lakshman, T. Nandagopal, R. Ramjee, K. Sabnani, and T. Woo. The SoftRouter architecture. *3rd ACM Workshop Hot Topics Netw.,* 2004. 3

[15] M. Casado, M. J. Freedman, J. Pettit, J. Luo, N. McKeown, and S. Shenker. Ethane: Taking control of the enterprise. *Proc. of the Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications (SIGCOMM'07). Association for Computing Machinery*, pages 1–12, New York, 2007. DOI: 10.1145/1282380.1282382. 3

[16] www.opennetworking.org 4

[17] www.ietf.org 4

[18] N. Gude, T. Koponen, J. Pettit, B. Pfaff, M. Casado, N. McKeown, and S. Shenker. NOX: Towards an operating system for networks. *SIGCOMM Comput. Commun. Rev.,* 38(3):105–110, 2008. DOI: 10.1145/1384609.1384625. 3

[19] P. Bosshart, D. Daly, G. Gibb, M. Izzard, N. McKeown, J. Rexford, C. Schlesinger, D. Talayco, A. Vahdat, G. Varghese, and D. Walker. P4: Programming protocol-independent packet processors. *SIGCOMM Comput. Commun. Rev.*, 44(3):87–95, July 2014. DOI: 10.1145/2656877.2656890. 4, 123

[20] H. Song. Protocol-oblivious forwarding: Unleash the power of SDN through a future-proof forwarding plane. *Proc. of the 2nd ACM SIGCOMM Workshop on Hot Topics in Software Defined Networking (HotSDN'13). Association for Computing Machinery*, pages 127–132, New York, 2013. DOI: 10.1145/2491185.2491190. 4, 123

[21] C. G. Miller. Telephone Switching System, U.S. Patent 3,189,687A, June 15, 1965. 4

[22] A. G. Fraser. Spider—an experimental data communications system. *Proc. IEEE Conference on Communications*, page 21F, June 1974. 4

[23] F. Bannour, S. Souihi, and A. Mellouk. Distributed SDN control: Survey, taxonomy, and challenges. *IEEE Commun. Surv. Tutor.*, 20(1):333–354, 2018. DOI: 10.1109/comst.2017.2782482. 7, 9

[24] B. Heller, R. Sherwood, and N. McKeown. The controller placement problem. *SIGCOMM Comput. Commun. Rev.*, 42(4):473–478, 2012. DOI: 10.1145/2377677.2377767. 10, 13, 14, 17, 18, 30, 33, 137

[25] T. Das, V. Sridharan, and M. Gurusamy. A survey on controller placement in SDN. *IEEE Commun. Surv. Tutor.*, 22(1):472–503, 2020. DOI: 10.1109/COMST.2019.2935453.

[26] R. Muñoz et al. Integrated SDN/NFV management and orchestration architecture for dynamic deployment of virtual SDN control instances for virtual tenant networks. *J. Opt. Commun. Netw.*, 7(11):62–70, 2015. DOI: 10.1364/JOCN.7.000B62.

[27] J. Zhao, H. Qu, J. Zhao, Z. Luan, and Y. Guo. Towards controller placement problem for software-defined network using affinity propagation. *Electron. Lett.*, 2017. DOI: 10.1049/el.2017.0093. 14, 15

[28] G. Wang, Y. Zhao, J. Huang, Q. Duan, and J. Li. A k-means based network partition algorithm for controller placement in software defined network. *Communications (ICC), IEEE International Conference on*, pages 1–6, 2016. DOI: 10.1109/icc.2016.7511441. 14, 15

[29] G. Wang, Y. Zhao, J. Huang, and Y. Wu. An effective approach to controller placement in software defined wide area networks. *IEEE Trans. Netw. Serv. Manage.*, 15(1):344–355, 2018. DOI: 10.1109/tnsm.2017.2785660. 14, 15

[30] M. Jarschel et al. Modeling and performance evaluation of an OpenFlow architecture. *Proc. 23rd Int. Teletraffic Congr.*, pages 1–7, 2011.

[31] B. P. R. Killi, E. A. Reddy, and S. V. Rao. Cooperative game theory based network partitioning for controller placement in SDN. *10th International Conference on Communication Systems and Networks (COMSNETS)*, pages 105–112, Bengaluru, 2018. DOI: 10.1109/comsnets.2018.8328186. 14, 16

[32] G. Yao, J. Bi, Y. Li, and L. Guo. On the capacitated controller placement problem in software defined networks. *IEEE Commun. Lett.*, 18(8):1339–1342, 2014. DOI: 10.1109/lcomm.2014.2332341. 14, 17

[33] C. Gao, H. Wang, F. Zhu, L. Zhai, and S. Yi. A particle swarm optimization algorithm for controller placement problem in software defined network. *International Conference on Algorithms and Architectures for Parallel Processing*, pages 44–54, Springer, 2015. DOI: 10.1007/978-3-319-27137-8_4. 14, 17

[34] S. Liu, H. Wang, S. Yi, and F. Zhu. NCPSO: A solution of the controller placement problem in software defined networks. *International Conference on Algorithms and Architectures for Parallel Processing*, pages 213–225, Springer, 2015. DOI: 10.1007/978-3-319-27137-8_17. 14, 17

[35] T. Zhang, P. Giaccone, A. Bianco, and S. D. Domenico. The role of the inter-controller consensus in the placement of distributed SDN controllers. *Comput. Commun.*, 113(15):1–3, 2017. DOI: 10.1016/j.comcom.2017.09.007. 14, 17

[36] A. Ksentini, M. Bagaa, T. Taleb, and I. Balasingham. On using bargaining game for optimal placement of SDN controllers. *Communications (ICC), IEEE International Conference on*, pages 1–6, 2016. DOI: 10.1109/icc.2016.7511136. 14, 17

[37] Y. Hu, W. Wendong, X. Gong, X. Que, and C. Shiduan. Reliability-aware controller placement for software-defined networks. *IFIP/IEEE International Symposium on Integrated Network Management (IM)*, 2013. 19, 20, 24, 29

[38] Y. Hu, W. Wang, X. Gong, X. Que, and S. Cheng. On reliability-optimized controller placement for software-defined networks. *China Commun.*, 11(2):38–54, February 2014. DOI: 10.1109/cc.2014.6821736. 19, 20, 24, 29

[39] M. Guo and P. Bhattacharya. Controller placement for improving resilience of software-defined networks. *4th International Conference on Networking and Distributed Computing*, 2013. DOI: 10.1109/icndc.2013.15. 20, 21, 30

[40] J. Liug, J. Liu, and R. Xie. Reliability-based controller placement algorithm in software defined networking. *Comput. Sci. Inf. Syst.*, 13(2):547–560, 2016. DOI: 10.2298/csis160225014l. 20, 22, 25

[41] F. Ros and P. Ruiz. Five nines of southbound reliability in software-defined networks. *HotSDN*, 2014. DOI: 10.1145/2620728.2620752. 20, 22, 23, 28, 29

[42] F. J. Ros and P. M. Ruiz. On reliable controller placements in software-defined networks. *Comput. Commun.*, 77:41–51, 2016. DOI: 10.1016/j.comcom.2015.09.008. 20, 22, 23, 28, 29

[43] L. Li, N. Du, H. Liu, R. Zhang, and C. Yan. Towards robust controller placement in software-defined networks against links failure. *IFIP/IEEE Symposium on Integrated Network and Service Management (IM)*. pages 216–223, Arlington, VA, 2019. 20, 23, 24

[44] Q. Zhong, Y. Wang, W. Li, and X. Qiu. A min-cover based controller placement approach to build reliable control network in SDN. *NOMS IEEE/IFIP Network Operations and Management Symposium*, pages 481–487, Istanbul, 2016. DOI: 10.1109/noms.2016.7502847. 20, 24

[45] L. F. Müller, R. R. Oliveira, M. C. Luizelli, L. P. Gaspary, and M. P. Barcellos. Survivor: An enhanced controller placement strategy for improving SDN survivability. *IEEE Global Communications Conference*, 2014. DOI: 10.1109/glocom.2014.7037087. 20, 25

[46] D. Hock et al. Pareto-optimal resilient controller placement in SDN-based core networks. *Teletraffic Congress (ITC), 25th International IEEE*, 2013. DOI: 10.1109/itc.2013.6662939. 20, 25, 26, 27, 29

[47] S. Lange, S. Gebert, T. Zinner, P. Tran-Gia, D. Hock, M. Jarschel, and M. Hoffmann. Heuristic approaches to the controller placement problem in large scale SDN networks. *IEEE Trans. Netw. Serv. Manage.*, 12(1):4–17, 2015. DOI: 10.1109/tnsm.2015.2402432. 20, 25, 26, 29

[48] B. P. R. Killi and S. V. Rao. Optimal model for failure foresight capacitated controller placement in software-defined networks. *IEEE Commun. Lett.*, 20(6):1108–1111, 2016. DOI: 10.1109/lcomm.2016.2550026. 20, 27, 28

[49] B. P. R. Killi and S. V. Rao. Capacitated next controller placement in software defined networks. *IEEE Trans. Netw. Serv. Manage.*, 14(3):514–527, 2017. DOI: 10.1109/tnsm.2017.2720699. 20, 28

[50] M. Tanha, D. Sajjadi, R. Ruby, and J. Pan. Capacity-aware and delay-guaranteed resilient controller placement for software-defined WANs. *IEEE Trans. Netw. Serv. Manage.*, 15(3):991–1005, September 2018. DOI: 10.1109/tnsm.2018.2829661. 20, 28

[51] P. Vizarreta, C. M. Machuca, and W. Kellerer. Controller placement strategies for a resilient SDN control plane. *8th International Workshop on Resilient Networks Design and Modeling (RNDM)*, pages 253–259, Halmstad, 2016. DOI: 10.1109/rndm.2016.7608295. 20, 29, 31

[52] Y. Jiménez, C. Cervelló-Pastor, and A. J. García. On the controller placement for designing a distributed SDN control layer. *IFIP Networking Conference*, 2014. DOI: 10.1109/ifipnetworking.2014.6857117. 20, 30

[53] T. Das and M. Gurusamy. Controller placement for resilient network state synchronization in multi-controller SDN. *IEEE Commun. Lett.*, 24(6), 2020. DOI: 10.1109/lcomm.2020.2979072. 20, 30

[54] A. Sallahi and M. St-Hilaire. Optimal model for the controller placement problem in software defined networks. *IEEE Commun. Lett.*, 19(1):30–33, 2015. DOI: 10.1109/lcomm.2014.2371014. 31, 32

[55] A. Sallahi and M. St-Hilaire. Expansion model for the controller placement problem in software defined networks. *IEEE Commun. Lett.*, 21(2):274–277, 2017. DOI: 10.1109/lcomm.2016.2621746. 31, 32

[56] Z. Zhao and B. Wu. Scalable SDN architecture with distributed placement of controllers for wan. *Concurre. Computat. Pract. Exper.*, 29(16), 2017. DOI: 10.1002/cpe.4030. 31, 32

[57] Y. Hu, T. Luo, N. C. Beaulieu, and C. Deng. The energy-aware controller placement problem in software defined networks. *IEEE Commun. Lett.*, 21(4):741–744, 2017. DOI: 10.1109/lcomm.2016.2645558. 31, 32

[58] Z. Su and M. Hamdi. MDCP: Measurement-aware distributed controller placement for software defined networks. *IEEE 21st International Conference on Parallel and Distributed Systems (ICPADS)*, 2015. DOI: 10.1109/icpads.2015.55. 31, 32

[59] Q. Qin, K. Poularakis, G. Iosifidis, and L. Tassiulas. SDN controller placement at the edge: Optimizing delay and overheads. *IEEE International Conference on Computer Communications (Infocom)*, 2018. DOI: 10.1109/infocom.2018.8485963. 31, 33, 58, 135

[60] Q. Qin, K. Poularakis, G. Iosifidis, S. Kompella, and L. Tassiulas. SDN controller placement with delay-overhead balancing in wireless edge networks. *IEEE Trans. Netw. Serv. Manage.*, 15(4):1446–1459, December 2018. DOI: 10.1109/tnsm.2018.2876064. 31, 33, 58

[61] M. F. Bari, A. R. Roy, S. R. Chowdhury, Q. Zhang, M. F. Zhani, R. Ahmed, and R. Boutaba. Dynamic controller provisioning in software defined networks. *Proc. of the 9th International Conference on Network Service Management (CNSM)*, 2013. DOI: 10.1109/cnsm.2013.6727805.

[62] M. T. I. ul Huque, W. Si, G. Jourjon, and V. Gramoli. Large-scale dynamic controller placement. *IEEE Trans. Netw. Serv. Manage.*, 14(1):63–76, 2017. DOI: 10.1109/tnsm.2017.2651107.

[63] H. K. Rath, V. Revoori, S. M. Nadaf, and A. Simha. Optimal controller placement in software defined networks (SDN) using a non-zero-sum game. *Proc. of IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks*, 2014. DOI: 10.1109/wowmom.2014.6918987.

[64] M. J. Abdel-Rahman, E. A. Mazied, A. MacKenzie, S. Midkiff, M. R. Rizk, and M. El-Nainay. On stochastic controller placement in software-defined wireless networks. *IEEE Wireless Communications and Networking Conference (WCNC)*, 2017. DOI: 10.1109/wcnc.2017.7925942.

[65] K. Sudheera, K. Liyanagea, M. Maa, and P. H. J. Chong. Controller placement optimization in hierarchical distributed software defined vehicular networks. *Comput. Netw.*, 135:226–239, 2018. DOI: 10.1016/j.comnet.2018.02.022.

[66] T. Benson, A. Akella, and D. Maltz. Network traffic characteristics of data centers in the wild. *IMC*, 2010. DOI: 10.1145/1879141.1879175. 33

[67] A. Dixit, F. Hao, S. Mukherjee, T. V. Lakshman, and R. R. Kompella. ElastiCon: An elastic distributed SDN controller. *Proc. ACM/IEEE Symp. Archit. Netw. Commun. Syst. (ANCS)*, pages 17–27, October 2014. DOI: 10.1145/2658260.2658261. 34, 42

[68] H. C. Cheng, Z. Wang and S. Chen. DHA: Distributed decisions on the switch migration toward a scalable SDN control plane. *IFIP Networking Conference (IFIP Networking)*, pages 1–9, IEEE, 2015. DOI: 10.1109/ifipnetworking.2015.7145319. 34, 35, 36, 40

[69] G. Cheng, H. Chen, H. Hu, and J. Lan. Dynamic switch migration towards a scalable SDN control plane. *Int. J. Commun. Syst.*, 29(9):1482–1499, 2016. DOI: 10.1002/dac.3101. 35, 36

[70] T. Wang, F. Liu, J. Guo, and H. Xu. Dynamic SDN controller assignment in data center networks: Stable matching with transfers. *IEEE INFOCOM—The 35th Annual IEEE International Conference on Computer Communications*, pages 1–9, San Francisco, CA, 2016. DOI: 10.1109/infocom.2016.7524357. 35, 37

[71] Y. Kyung, K. Hong, T. M. Nguyen, S. Park, and J. Park. A load distribution scheme over multiple controllers for scalable SDN. *7th International Conference on Ubiquitous and Future Networks*, pages 808–810, Sapporo, 2015. DOI: 10.1109/icufn.2015.7182654. 35, 37

[72] Y. Hu, W. Wang, X. Gong, X. Que, and S. Cheng. Balanceflow: Controller load balancing for openflow networks. *Proc. IEEE CCIS*, pages 780–785, Hangzhou, China, October 2012. DOI: 10.1109/ccis.2012.6664282. 35, 38

[73] H. Selvi, G. Gür, and F. Alagöz. Cooperative load balancing for hierarchical SDN controllers. *Proc. IEEE HPSR*, pages 100–105, Yokohama, Japan, June 2016. DOI: 10.1109/hpsr.2016.7525646. 35, 38

[74] V. Sridharan, M. Gurusamy, and T. Truong-Huu. On multiple controller mapping in software defined networks with resilience constraints. *IEEE Commun. Lett.*, 21(8):1763–1766, August 2017. DOI: 10.1109/lcomm.2017.2696006. 35, 38

[75] Y. Zhou, Y. Wang, J. Yu, J. Ba, and S. Zhang. Load balancing for multiple controllers in SDN based on switches group. *19th Asia-Pacific Network Operations and Management Symposium (APNOMS)*, pages 227–230, Seoul, 2017. DOI: 10.1109/apnoms.2017.8094139. 35, 38, 39

[76] C. Wang, B. Hu, S. Chen, D. Li, and B. Liu. A switch migration-based decision-making scheme for balancing load in SDN. *IEEE Access*, 5:4537–4544, 2017. DOI: 10.1109/access.2017.2684188. 35, 39

[77] T. Hu, J. Lan, J. Zhang et al. EASM: Efficiency-aware switch migration for balancing controller loads in software-defined networking. *Peer-to-Peer Netw. Appl.*, 12:452–464, 2019. DOI: 10.1007/s12083-018-0632-6. 35, 39

[78] Y. Xu, M. Cello, I.-C. Wang, A. Walid, G. Wilfong, C. H.-P. Wen, M. Marchese, and H. J. Chao. Dynamic switch migration in distributed software-defined networks to achieve controller load balance. *IEEE J. Sel. Areas Commun.*, 37(3):515–529, February 2019. DOI: 10.1109/jsac.2019.2894237. 35, 39, 40, 41

[79] M. F. Bari, A. R. Roy, S. R. Chowdhury, Q. Zhang, M. F. Zhani, R. Ahmed, and R. Boutaba. Dynamic controller provisioning in software defined networks. *Netw. Serv. Manage. (CNSM), 9th International Conference on IEEE*, pages 18–25, 2013. DOI: 10.1109/cnsm.2013.6727805. 43, 44

[80] M. He, A. Basta, A. Blenk, and W. Kellerer. Modeling flow setup time for controller placement in SDN: Evaluation for dynamic flows, 2017. DOI: 10.1109/icc.2017.7996654. 43, 44

[81] M. T. I. Ul Huque, G. Jourjon, and V. Gramoli. Revisiting the controller placement problem. *Local Computer Networks (LCN), IEEE 40th Conference on*, pages 450–453, 2015. DOI: 10.1109/LCN.2015.7366350. 43, 44

[82] H. K. Rath, V. Revoori, S. Nadaf, and A. Simha. Optimal controller placement in software defined networks (SDN) using a non-zero-sum game. *World of Wireless, Mobile and Multimedia Networks (WoWMoM), IEEE 15th International Symposium on*, pages 1–6, 2014. DOI: 10.1109/wowmom.2014.6918987. 43, 45

[83] X. Lyu, C. Ren, W. Ni, H. Tian, R. P. Liu, and Y. J. Guo. Multi-timescale decentralized online orchestration of software-defined networks. *IEEE J. Sel. Areas Commun.*, 36(12):2716–2730, December 2018. DOI: 10.1109/jsac.2018.2871310. 43, 45, 46, 48

[84] J. Yang, X. Yang, Z. Zhou, X. Wu, T. Benson, and C. Hu. FOCUS: Function offloading from a controller to utilize switch power. *Proc. of IEEE NFV-SDN'16*, 2016. DOI: 10.1109/nfv-sdn.2016.7919498. 48

[85] X. Huang, S. Bian, Z. Shao, and Y. Yang. Predictive switch-controller association and control devolution for SDN systems. *Proc. of IEEE/ACM IWQoS*, 2019. DOI: 10.1145/3326285.3329070. 48

[86] F. Akyildiz, S.-C. Lin, and P. Wang. Wireless software-defined networks (W-SDNs) and network function virtualization (NFV) for 5G cellular systems: An overview and qualitative evaluation. *Comput. Netw.*, 93(12):66–79, 2015. DOI: 10.1016/j.comnet.2015.10.013. 49

[87] M. J. Abdel-Rahman, E. A. Mazied, A. MacKenzie, S. Midkiff, M. R. Rizk, and M. El-Nainay. On stochastic controller placement in software-defined wireless networks. *IEEE Wireless Communications and Networking Conference (WCNC)*, pages 1–6, San Francisco, CA, 2017. DOI: 10.1109/wcnc.2017.7925942. 49, 50

[88] A. Dvir, Y. Haddad, and A. Zilberman. Wireless controller placement problem. *15th IEEE Annual Consumer Communications and Networking Conference (CCNC)*, pages 1–4, Las Vegas, NV, 2018. DOI: 10.1109/ccnc.2018.8319228. 49, 51

[89] M. Johnston and E. Modiano. Controller placement for maximum throughput under delayed CSI. *Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), 13th International Symposium on IEEE*, pages 521–528, 2015. DOI: 10.1109/wiopt.2015.7151114. 49, 52, 53, 103

[90] M. Polese, R. Jana, V. Kounev, K. Zhang, S. Deb, and M. Zorzi. Machine learning at the edge: A data-driven architecture with applications to 5G cellular networks. *IEEE Trans. Mobile Comput.*. DOI: 10.1109/tmc.2020.2999852. 49, 53, 54

[91] M. Alharthi, A. M. Taha, and H. S. Hassanein. Dynamic controller placement in software defined drone networks. *IEEE Global Communications Conference (GLOBECOM)*, pages 1–6, Waikoloa, HI, 2019. DOI: 10.1109/GLOBECOM38437.2019.9013799. 49, 55, 56

[92] B. Lantz, B. Heller, and N. McKeown. A network in a laptop: Rapid prototyping for software-defined networks. *Proc. of the 9th ACM SIGCOMM Workshop on Hot Topics in Networks, ACM*, page 19, 2010. DOI: 10.1145/1868447.1868466. 58

[93] Y. E. Oktian, S. Lee, H. Lee, and J. Lam. Distributed SDN controller system: A survey on design choice. *Computer Networks*, 121(5):100–111, 2017. DOI: 10.1016/j.comnet.2017.04.038. 65

[94] A. S. Muqaddas, P. Giaccone, A. Bianco, and G. Maier. Inter-controller traffic to support consistency in ONOS clusters. *IEEE Trans. Netw. Serv. Manage.*, 14(4):1018–1031, 2017. DOI: 10.1109/tnsm.2017.2723477.

[95] S.-C.-C. P. Wang, I. F. Akyildiz, and M. Luo. Towards optimal network planning for software-defined networks. *IEEE Trans. Mobile Comput.*, 2018. DOI: 10.1109/tmc.2018.2815691.

[96] B. Pfaff et al. OpenFlow switch specification v1.3.0. *Tech. Rep.*, 2012. 61

[97] M. Aslan and A. Matrawy. On the impact of network state collection on the performance of SDN applications. *IEEE Commun. Lett.*, 20(1):5–8, January 2016. DOI: 10.1109/lcomm.2015.2496955. 61

[98] A. Yassine, H. Rahimi, and S. Shirmohammadi. Software defined network traffic measurement: Current trends and challenges. *IEEE Instrument. Measure. Mag.*, 18(2):42–50, April 2015. DOI: 10.1109/mim.2015.7066685. 62

[99] P. Tsai, C. Tsai, C. Hsu, and C. Yang. Network monitoring in software-defined networking: A review. *IEEE Syst. J.*, 12(4):3958–3969, December 2018. DOI: 10.1109/JSYST.2018.2798060. 62

[100] N. L. M. van Adrichem, C. Doerr, and F. A. Kuipers. OpenNetMon: Network monitoring in OpenFlow software-defined networks. *IEEE Network Operations and Management Symposium (NOMS)*, pages 1–8, 2014. DOI: 10.1109/noms.2014.6838228. 62

[101] H. Xu, Z. Yu, C. Qian, X. Li, Z. Liu, and L. Huang. Minimizing flow statistics collection cost using wildcard-based requests in SDNs. *IEEE/ACM Trans. Network.*, 25(6):3587–3601, December 2017. DOI: 10.1109/tnet.2017.2748588. 62, 63

[102] A. Tootoonchian, M. Ghobadi, and Y. Ganjali. OpenTM: Traffic matrix estimator for OpenFlow networks. *Proc. 11th Int. Conf. Passive Active Meas.*, pages 201–210, 2010. DOI: 10.1007/978-3-642-12334-4_21. 63

[103] T. Y. Cheng and X. Jia. Compressive traffic monitoring in hybrid SDN. *IEEE Journal on Selected Areas in Communications*, 36(12):2731–2743, December 2018. DOI: 10.1109/jsac.2018.2871311. 62, 64

[104] D. Levin, A. Wundsam, B. Heller, N. Handigol, and A. Feldmann. Logically centralized? State distribution trade-offs in software defined networks. *ACM HotSDN*, 2012. DOI: 10.1145/2342441.2342443. 65, 66

[105] A. Panda, W. Zheng, X. Hu, A. Krishnamurthy, and S. Shenker. SCL: Simplifying distributed SDN control planes. *USENIX NSDI*, 2017. 65

[106] Z. Guo, M. Su, Y. Xu, Z. Duan, L. Wang, S. Hui, and H. J. Chao. Improving the performance of load balancing in software-defined networks through load variance-based synchronization. *Comput. Netw.*, 68:95–109, 2014. DOI: 10.1016/j.comnet.2013.12.004. 66

[107] A. Singla, S. Tschiatschek, and A. Krause. Noisy submodular maximization via adaptive sampling with applications to crowdsourced image collection summarization. *AAAI*, 2016. 69

[108] K. Poularakis, Q. Qin, L. Ma, S. Kompella, K. K. Leung, and L. Tassiulas. Learning the optimal synchronization rates in distributed SDN control architectures. *IEEE International Conference on Computer Communications (Infocom)*, 2019. DOI: 10.1109/infocom.2019.8737388. 65, 66, 68, 69, 70

[109] Z. Zhang, L. Ma, K. Poularakis, K. K. Leung, and L. Wu. DQ scheduler: Deep reinforcement learning based controller synchronization in distributed SDN. *IEEE International Conference on Communications (ICC)*, 2019. DOI: 10.1109/icc.2019.8761183. 65

[110] Z. Zhang, L. Ma, K. Poularakis, K. Leung, J. Tucker, and A. Swami. MACS: Deep reinforcement learning based SDN controller synchronization policy design. *IEEE International Conference on Network Protocols (ICNP)*, 2019. DOI: 10.1109/icnp.2019.8888034. 65

[111] L. Zhao, J. Hua, Y. Liu, W. Qu, S. Zhang, and S. Zhong. Distributed traffic engineering for multi-domain software defined networks. *ICDCS*, 2019. DOI: 10.1109/icdcs.2019.00056. 71, 72

[112] A. Martey. *IS-IS Network Design Solutions*. Cisco Press, Indianapolis, IN, 2002.

[113] M. K. Mukerjee, D. Han, S. Seshan, and P. Steenkiste. Understanding tradeoffs in incremental deployment of new network architectures. *Proc. of ACM CoNEXT*, 2013. DOI: 10.1145/2535372.2535396. 73

[114] S. Vissicchio, L. Vanberer, and O. Bonaventure. Opportunities and research challenges of hybrid software defined networks. *ACM CCR*, 44(2), 2014. DOI: 10.1145/2602204.2602216. 73

[115] Reuters Technology News, AT&T to buy Cisco Core Routers for Network Upgrade. http://www.reuters.com/article/us-cisco-att-idUSN1039414520071210, July 2016.

[116] Z. Cao, M. Kodialam, and T. V. Lakshman. Traffic steering in software defined networks: Planning and online routing. *ACM DCC*, 2014. DOI: 10.1145/2740070.2627574. 74

[117] S. Agarwal, M. Kodialam, and T. V. Lakshman. Traffic engineering in software defined networks. *IEEE Infocom*, 2013. DOI: 10.1109/infcom.2013.6567024. 74

[118] Light Reading Portal, NEC Slashes OpenFlow SDN Controller Pricing. http://www.lightreading.com/carrier-sdn/sdn-technology/nec-slashes-openflow-sdn-controller-pricing/d/d-id/711391, 2014.

[119] K. Poularakis, G. Iosifidis, G. Smaragdakis, and L. Tassiulas. One step at a time: Optimizing SDN upgrades in ISP networks. *IEEE Infocom*, 2017. DOI: 10.1109/infocom.2017.8057136. 76, 78, 79, 82, 83

[120] K. Poularakis, G. Iosifidis, G. Smaragdakis, and L. Tassiulas. Optimizing gradual SDN upgrades in ISP networks. *IEEE/ACM Trans. Network.*, 27(1):288–301, February 2019. DOI: 10.1109/tnet.2018.2890248. 82, 83

[121] E. H.-K. Wu, B. Kar, and Y.-D. Lin. The budgeted maximum coverage problem in partially deployed software defined networks. *IEEE Trans. Netw. Serv. Manage.*, 13(3):394–406, 2016. DOI: 10.1109/tnsm.2016.2598549. 82, 83

[122] X. Jia, Y. Jiang, and Z. Guo. Incremental switch deployment for hybrid software-defined networks. *IEEE LCN*, 2016. DOI: 10.1109/lcn.2016.95. 82, 83

[123] H. Xu, X.-Y. Li, L. Huang, H. Deng, H. Huang, and H. Wang. Incremental deployment and throughput maximization routing for a hybrid SDN. *IEEE/ACM Trans. Networking*, 2017. DOI: 10.1109/tnet.2017.2657643. 82, 83

[124] L. Wang, Q. Li, Y. Jiang, and J. Wu. Towards mitigating link flooding attack via incremental SDN deployment. *IEEE ISCC*, 2016. DOI: 10.1109/ISCC.2016.7543772. 82, 83

[125] M. Caria, A. Jukan, and M. Hoffmann. Divide and conquer: Partitioning OSPF networks with SDN. *IEEE IM*, 2015. DOI: 10.1109/inm.2015.7140324. 82, 83

[126] M. Caria, A. Jukan, and M. Hoffmann. A performance study of network migration to SDN-enabled traffic engineering. *IEEE Globecom*, 2013. DOI: 10.1109/glocom.2013.6831268. 82, 83

[127] T. Das, M. Caria, A. Jukan, and M. Hoffmann. A techno-economic analysis of network migration to software-defined networking. *ArXiv. 1310.0216v1*, 2013. 82, 83

[128] D. Levin, M. Canini, S. Schmid, F. Schaffert, and A. Feldmann. Panopticon: Reaping the benefits of incremental SDN deployment in enterprise networks. *Proc. of USENIX ATC*, 2014. 82, 83

[129] D. K. Hong, Y. Ma, S. Banerjee, and Z. M. Mao. Incremental deployment of SDN in hybrid enterprise and ISP networks. *ACM SOSR*, 2016. DOI: 10.1145/2890955.2890959. 82, 83

[130] H. Xu, J. Fan, J. Wu, C. Qiao, and L. Huang. Joint deployment and routing in hybrid SDNs. *IEEE/ACM IWQoS*, 2017. DOI: 10.1109/IWQoS.2017.7969133. 82, 83

[131] S. Vissicchio, O. Tilmans, L. Vanbever, and J. Rexford. Central control over distributed routing. *Prof. of ACM SIGCOMM*, 2015. DOI: 10.1145/2785956.2787497. 85

[132] A. Cianfrani, M. Listanti, and M. Polverini. Incremental deployment of segment routing into an ISP network: A traffic engineering perspective. *IEEE/ACM Trans. Networking*, 2017. DOI: 10.1109/tnet.2017.2731419. 86

[133] M. Pioro and D. Mehdi. *Routing, Flow, and Capacity Design in Communication and Computer Networks*. Morgan Kaufmann Publishers, 2004. DOI: 10.1016/B978-0-12-557189-0.X5000-8. 87

[134] S. Agarwal, M. Kodialam, and T. V. Lakshman. Traffic engineering in software defined networks. *Infocom*, 2013. DOI: 10.1109/infcom.2013.6567024. 88, 90

[135] N. Buchbinder and J. Naor. Improved bounds for online routing and packing via a primal-dual approach. *47th Annual IEEE Symposium on Foundations of Computer Science (FOCS'06)*, pages 293–304, 2006. DOI: 10.1109/focs.2006.39. 91

[136] L. Luo, H. Yu, Z. Ye, and X. Du. Online deadline-aware bulk transfer over inter-datacenter WANs. *INFOCOM—IEEE Conference on Computer Communications*, pages 630–638, 2018. DOI: 10.1109/infocom.2018.8485828. 91

[137] O. Alhussein and W. Zhuang. Robust online composition, routing and NF placement for NFV-enabled services. *IEEE J. Select. Areas Commun.*, 38(6):1089–1101, June 2020. DOI: 10.1109/jsac.2020.2986612. 91

[138] M. Huang, W. Liang, Z. Xu, W. Xu, S. Guo, and Y. Xu. Dynamic routing for network throughput maximization in software-defined networks. *INFOCOM—The 35th Annual IEEE International Conference on Computer Communications*, pages 1–9, 2016. DOI: 10.1109/infocom.2016.7524613. 91

[139] N. Liakopoulos, A. Destounis, G. Paschos, T. Spyropoulos, and P. Mertikopoulos. Cautious regret minimization: Online optimization with long-term budget constraints. *ICML*, 2019. 92

[140] M. Rifai et al. Too many SDN rules? Compress them with MINNIE. *IEEE Global Communications Conference (GLOBECOM)*, pages 1–7, 2015. DOI: 10.1109/GLOCOM.2015.7417661. 94

[141] R. Cohen, L. Lewin-Eytan, J. S. Naor, and D. Raz. On the effect of forwarding table size on SDN network utilization. *INFOCOM—IEEE Conference on Computer Communications*, pages 1734–1742, 2014. DOI: 10.1109/infocom.2014.6848111. 93

[142] X. Nguyen, D. Saucez, C. Barakat, and T. Turletti. OFFICER: A general optimization framework for OpenFlow rule allocation and endpoint policy enforcement. *IEEE Conference on Computer Communications (INFOCOM)*, pages 478–486, 2015. DOI: 10.1109/infocom.2015.7218414. 93

[143] B. Heller, S. Seetharaman, P. Mahadevan, Y. Yiakoumis, P. Sharma, S. Banerjee, and N. McKeown. ElasticTree: Saving energy in data center networks. *NSDI*, 2010. 94

[144] P. T. Congdon, P. Mohapatra, M. Farrens, and V. Akella. Simultaneously reducing latency and power consumption in OpenFlow switches. *IEEE/ACM Trans. Netw.*, 22(3):1007–1020, June 2014. DOI: 10.1109/tnet.2013.2270436. 94

[145] S. Jouet, C. Perkins, and D. Pezaros. OTCP: SDN-managed congestion control for data center networks. *NOMS—IEEE/IFIP Network Operations and Management Symposium*, pages 171–179, Istanbul, 2016. DOI: 10.1109/noms.2016.7502810. 98

[146] J. Perry, A. Ousterhout, H. Balakrishnan, D. Shah, and H. Fugal. Fastpass: A centralized "zero-queue" data center network. *Proc. of the ACM Conference on SIGCOMM (SIGCOMM'14). Association for Computing Machinery*, 307–318, New York, 2014. DOI: 10.1145/2619239.2626309. 99

[147] M. Al-Fares, S. Radhakrishnan, B. Raghavan, N. Huang, and A. Vahdat. Hedera: Dynamic flow scheduling for data center networks. *NSDI*, 2010. 99

[148] B. C. Vattikonda, G. Porter, A. Vahdat, and A. C. Snoeren. Practical TDMA for datacenter ethernet. *EuroSys*, 2012. DOI: 10.1145/2168836.2168859. 99

[149] J. Perry, H. Balakrishnan, and D. Shah. Flowtune: Flowlet control for datacenter networks. *14th USENIX Symposium on Networked Systems Design and Implementation (NSDI'17). USENIX Association*, Boston, MA, 2017. 99

[150] L. Liu, D. Li, and J. Wu. TAPS: Software defined task-level deadline-aware preemptive flow scheduling in data centers. *44th International Conference on Parallel Processing*, pages 659–668, Beijing, 2015. DOI: 10.1109/icpp.2015.75. 99

[151] R. Bhatia, F. Hao, M. Kodialam, and T. V. Lakshman. Optimized network traffic engineering using segment routing. *IEEE Conference on Computer Communications (INFOCOM)*, pages 657–665, Kowloon, 2015. DOI: 10.1109/infocom.2015.7218434. 95, 96, 97

[152] P. L. Ventre, S. Salsano, M. Polverini, A. Cianfrani, A. Abdelsalam, C. Filsfils, P. Camarillo, and F. Clad. Segment routing: A comprehensive survey of research activities, standardization efforts and implementation results. *ArXiv:1904.03471*, 2020. DOI: 10.1109/comst.2020.3036826. 97

[153] L. Tassiulas and A. Ephremides. Stability properties of constrained queueing systems and scheduling policies for maximum throughput in multihop radio networks. *29th IEEE Conference on Decision and Control*, 4:2130–2132, 1990. DOI: 10.1109/CDC.1990.204000. 102, 103

[154] Z. Jiao, B. Zhang, C. Li, and H. T. Mouftah. Backpressure-based routing and scheduling protocols for wireless multihop networks: A survey. *IEEE Wireless Commun.*, 23(1):102–110, February 2016. DOI: 10.1109/mwc.2016.7422412. 103

[155] A. Sinha and E. Modiano. Optimal control for generalized network-flow problems. *IEEE/ACM Trans. Network.*, 26(1):506–519, February 2018. DOI: 10.1109/TNET.2017.2783846. 104

[156] Q. Liang and E. Modiano. Optimal network control in partially-controllable networks. *INFOCOM—IEEE Conference on Computer Communications*, pages 397–405, 2019. DOI: 10.1109/infocom.2019.8737528. 104

[157] N. Alliance. NGMN 5G P1 requirements and architecture work stream end-to-end architecture description of network slicing concept. https://www.ngmn.org/uploads/media/161010 010 NGMN Network Slicing framework v1.0.8.pdf, 2016.

[158] M. Liu, A. W. Richa, M. Rost, and S. Schmid. A constant approximation for maximum throughput multicommodity routing and its application to delay-tolerant network scheduling. *INFOCOM*, pages 46–54, 2019. DOI: 10.1109/infocom.2019.8737402. 110

[159] R. Cohen, L. Lewin-Eytan, J. S. Naor, and D. Raz. Near optimal placement of virtual network functions. *IEEE Infocom*, 2015. DOI: 10.1109/infocom.2015.7218511. 110

[160] I. Benkacem, T. Taleb, M. Bagaa, and H. Flinck. Optimal VNFs placement in CDN slicing over multi-cloud environment. *IEEE J. Select. Areas Commun.*, 36(3):616–627, 2018. DOI: 10.1109/jsac.2018.2815441. 110

[161] A. Laghrissi, T. Taleb, and M. Bagaa. Conformal mapping for optimal network slice planning based on canonical domains. *IEEE J. Select. Areas Commun.*, 36(3):519–528, 2018. DOI: 10.1109/jsac.2018.2815436. 110

[162] M. Rost and S. Schmid. Virtual network embedding approximations: Leveraging randomized rounding. *IFIP Networking*, 2018. 110, 112

[163] M. A. T. Nejad, S. Parsaeefard, M. A. Maddah-Ali, T. Mahmoodi, and B. H. Khalaj. vSPACE: VNF simultaneous placement, admission control and embedding. *IEEE J. Select. Areas Commun.*, 36(3):542–557, 2018. DOI: 10.1109/jsac.2018.2815318. 110

[164] J. Pei, P. Hong, K. Xue, and D. Li. Efficiently embedding service function chains with dynamic virtual network function placement in geo-distributed cloud system. *IEEE Trans. Parallel Distrib. Syst.*, 2019. DOI: 10.1109/tpds.2018.2880992. 110

[165] B. Addis, D. Belabed, M. Bouet, and S. Secci. Virtual network functions placement and routing optimization. *Cloudnet*, 2015. DOI: 10.1109/cloudnet.2015.7335301. 110

[166] M. Barcelo, A. Correa, J. Llorca, A. M. Tulino, J. L. Vicario, and A. Morell. IoT-cloud service optimization in next generation smart environments. *IEEE J. Select. Areas Commun.*, 2016. DOI: 10.1109/jsac.2016.2621398. 110

[167] J. Liu, W. Lu, F. Zhou, P. Lu, and Z. Zhu. On dynamic service function chain deployment and readjustment. *IEEE Trans. Netw. Serv. Manage.*, 14(3):543–553, 2017. DOI: 10.1109/tnsm.2017.2711610. 110

[168] C. Pham, N. H. Tran, S. Ren, W. Saad, and C. S. Hong. Traffic-aware and energy efficient VNF placement for service chaining: Joint sampling and matching approach. *IEEE Trans. Serv. Comput.*, 2017. DOI: 10.1109/tsc.2017.2671867. 110

[169] S. Agarwal, F. Malandrino, C. F. Chiasserini, and S. De. VNF placement and resource allocation for the support of vertical services in 5G networks. *IEEE/ACM Trans. Network.*, 2019. DOI: 10.1109/tnet.2018.2890631. 110

[170] I. Baev, R. Rajaraman, and C. Swamy. Approximation algorithms for data placement problems. *SIAM J. Comp.*, 38, 2008. DOI: 10.1137/080715421. 110

[171] S. Borst, V. Gupta, and A. Walid. Distributed caching algorithms for content distribution networks. *IEEE Infocom*, 2010. DOI: 10.1109/infcom.2010.5461964. 110

[172] K. Shanmugam, N. Golrezaei, A. Dimakis, A. Molisch, and G. Caire. FemtoCaching: Wireless content delivery through distributed caching helpers. *IEEE Trans. Inform. Theor.*, 59(12), 2013. DOI: 10.1109/tit.2013.2281606. 110

[173] T. He, H. Khamfroush, S. Wang, T. L. Porta, and S. Stein. It's hard to share: Joint service placement and request scheduling in edge clouds with sharable and non-sharable resources. *IEEE ICDCS*, 2018. DOI: 10.1109/icdcs.2018.00044. 110

[174] J. Xu, L. Chen, and P. Zhou. Joint service caching and task offloading for mobile edge computing in dense networks. *IEEE Infocom*, 2018. DOI: 10.1109/INFOCOM.2018.8485977. 110

[175] K. Poularakis, J. Llorca, A. Tulino, I. Taylor, and L. Tassiulas. Joint service placement and request routing in multi-cell mobile edge computing networks. *IEEE Infocom*, 2019. DOI: 10.1109/infocom.2019.8737385. 110

[176] K. Poularakis, J. Llorca, A. Tulino, and L. Tassiulas. Approximation algorithms for data-intensive service chain embedding. *ACM Mobihoc*, 2020. DOI: 10.1145/3397166.3409149. 111, 114

[177] T. Hurley, J. E. Perdomo, and A. Perez-Pons. HMM-based intrusion detection system for software defined networking. *Proc. IEEE ICMLA*, pages 617–621, Anaheim, CA, December 2016. DOI: 10.1109/icmla.2016.0108. 117

[178] T. A. Tang, L. Mhamdi, D. McLernon, S. A. R. Zaidi, and M. Ghogho. Deep learning approach for network intrusion detection in software defined networking. *Proc. IEEE WINCOM*, pages 258–263, Fes, Morocco, October 2016. DOI: 10.1109/wincom.2016.7777224. 117

[179] T. Tang, S. A. R. Zaidi, D. McLernon, L. Mhamdi, and M. Ghogho. Deep recurrent neural network for intrusion detection in SDN-based networks. *Proc. IEEE NetSoft*, pages 1–5, Montreal, QC, Canada, 2018. DOI: 10.1109/netsoft.2018.8460090. 117

[180] N. Napiah, M. Y. I. B. Idris, R. Ramli, and I. Ahmedy. Compression header analyzer intrusion detection system (cha-ids) for 6lowpan communication protocol. *IEEE Access*, 6:16 623–16 638, 2018. DOI: 10.1109/access.2018.2798626. 117

[181] W. Wang, M. Zhu, J. Wang, X. Zeng, and Z. Yang. End-to-end encrypted traffic classification with one-dimensional convolution neural networks. *IEEE International Conference on Intelligence and Security Informatics (ISI)*, pages 43–48, 2017. DOI: 10.1109/isi.2017.8004872. 117

[182] M. Lotfollahi, M. J. Siavoshani, R. S. H. Zade, and M. Saberian. Deeppacket: A novel approach for encrypted traffic classification using deep learning. *Soft Computing*, pages 1–14, 2017. DOI: 10.1007/s00500-019-04030-2. 117

[183] Z. Wang. The applications of deep learning on traffic identification. *BlackHat*, 24, 2015. 117

[184] Q. Qin, K. Poularakis, and L. Tassiulas. A learning approach with programmable data plane towards IoT security. *IEEE International Conference on Distributed Computing Systems (ICDCS)*, 2020. DOI: 10.1109/icdcs47774.2020.00064. 117, 118

[185] A. Capone, C. Cascone, A. Q. T. Nguyen, and B. Sansò. Detour planning for fast and reliable failure recovery in SDN with OpenState. *11th International Conference on the Design of Reliable Communication Networks (DRCN)*, pages 25–32, 2015. DOI: 10.1109/drcn.2015.7148981. 121

[186] X. Zhang, L. Cui, K. Wei, F. P. Tso, Y. Ji, and W. Jia. A survey on stateful data plane in software defined networks. *Comput. Netw.*, page 107597, 2020. DOI: 10.1016/j.comnet.2020.107597. 121

[187] C. Kim, A. Sivaraman, N. Katta, A. Bas, A. Dixit, and L. J. Wobker. In-band network telemetry via programmable data planes. *ACM SIGCOMM Symposium on SDN Research (SOSR)*, 2015. 124

[188] T. Pan et al. INT-path: Towards optimal path planning for in-band network-wide telemetry. *INFOCOM—IEEE Conference on Computer Communications*, pages 487–495, 2019. DOI: 10.1109/infocom.2019.8737529. 124

[189] X. Yu, H. Xu, D. Yao, H. Wang, and L. Huang. CountMax: A lightweight and cooperative sketch measurement for software-defined networks. *IEEE/ACM Trans. Network.*, 26(6):2774–2786, December 2018. DOI: 10.1109/tnet.2018.2877700. 126

[190] Y. Zhai, H. Xu, H. Wang, Z. Meng, and H. Huang. Joint routing and sketch configuration in software-defined networking. *IEEE/ACM Trans. Network.*, 28(5):2092–2105, October 2020. DOI: 10.1109/tnet.2020.3002783. 126, 127

[191] H. Wang and B. Li. Lube: Mitigating bottlenecks in wide area data analytics. *HotCloud*, 2017. 131

[192] A. Valadarsky, M. Schapira, D. Shahaf, and A. Tamar. Learning to route. *Proc. ACM HotNets*, pages 185–191, 2017. DOI: 10.1145/3152434.3152441. 131, 132

[193] H. Mao, M. Alizadeh, I. Menache, and S. Kandula. Resource management with deep reinforcement learning. *HotNets*, 2016. DOI: 10.1145/3005745.3005750. 131

[194] K. Winstein and H. Balakrishnan. TCP ex Machina: Computer-generated congestion control. *SIGCOMM*, 2013. DOI: 10.1145/2534169.2486020. 131

[195] H. Mao, R. Netravali, and M. Alizadeh. Neural adaptive bitrate streaming with pensive. *SIGCOMM*, 2017. DOI: 10.1145/3098822.3098843. 131

[196] J. Xie, F. R. Yu, T. Huang, R. Xie, J. Liu, and Y. Liu. A survey of machine learning techniques applied to software defined networking (SDN): Research issues and challenges. *IEEE Commun. Surv. Tutor.* , 2018. DOI: 10.1109/comst.2018.2866942. 131

[197] R. Muñoz et al. Integrated SDN/NFV management and orchestration architecture for dynamic deployment of virtual SDN control instances for virtual tenant networks. *J. Opt. Commun. Netw.*, 7(11):62–70, 2015. DOI: 10.1364/jocn.7.000b62.

[198] Q. Qin, K. Poularakis, K. K. Leung, and L. Tassiulas. Line-speed and scalable intrusion detection at the network edge via federated learning. *IFIP Networking*, 2020. 133

[199] X. Jin et al. SoftCell: Taking control of cellular core networks. *Proc. ACM CoNEXT*, pages 1–14, 2013. 133

[200] A. Gudipati et al. SoftRAN: Software defined radio access network. *Proc. ACM HotSDN*, pages 25–30, 2013. DOI: 10.1145/2491185.2491207. 133

[201] M. Bansal et al. Openradio: A programmable wireless data plane. *Proc. ACM HotSDN*, pages 109–14, 2012. DOI: 10.1145/2342441.2342464. 133

[202] J. Lee et al. meSDN: Mobile extension of SDN. *Proc. 5th Int. Workshop Mobile Cloud Comput. Services*, pages 7–14, Bretton Woods, NH, 2014. DOI: 10.1145/2609908.2609948. 133

[203] K. Poularakis, Q. Qin, K. M. Marcus, K. S. Chan, K. K. Leung, and L. Tassiulas. Hybrid SDN control in mobile ad hoc networks. *IEEE Workshop on Distributed Analytics Infrastructure and Algorithms for Multi-Organization Federations, in Proc. of IEEE Smart Computing*, 2019. DOI: 10.1109/smartcomp.2019.00038. 133

[204] ARL project. Dais ITA: The distributed analytics and information science international technology alliance, 2016–2021. 65, 133

Authors' Biographies

KONSTANTINOS POULARAKIS

Konstantinos Poularakis is a Research Scientist at Yale University. His research interests lie in the area of network optimization and machine learning with emphasis on emerging architectures such as software-defined networks, mobile edge computing, and caching networks. His research has been recognized by several awards and scholarships from sources including the Greek State Scholarships foundation (2011), the Center for Research and Technology Hellas (2012), the Alexander S. Onassis Public Benefit Foundation (2013), and the Bodossaki Foundation (2016). He also received the Best Paper Award at the IEEE Infocom 2017 and IEEE ICC 2019 conferences. Konstantinos obtained his Diploma, M.S., and Ph.D. degrees in Electrical Engineering from the University of Thessaly, Greece, in 2011, 2013, and 2016 respectively. In 2014, he was a Research Intern with Technicolor Research, Paris.

LEANDROS TASSIULAS

Leandros Tassiulas is the John C. Malone Professor of Electrical Engineering at Yale University. His research interests are in the field of computer and communication networks with emphasis on fundamental mathematical models and algorithms of complex networks, architectures, and protocols of wireless systems, sensor networks, novel internet architectures, and experimental platforms for network research. His most notable contributions include the max-weight scheduling algorithm and the back-pressure network control policy, opportunistic scheduling in wireless, the maximum lifetime approach for wireless network energy management, and the consideration of joint access control and antenna transmission management in multiple antenna wireless systems. Dr. Tassiulas is a Fellow of IEEE (2007) and the ACM (2020). His research has been recognized by several awards including the IEEE Koji

Kobayashi Computer and Communications Award (2016), the ACM SIGMETRICS Achievement Award 2020, the inaugural INFOCOM 2007 Achievement Award "for fundamental contributions to resource allocation in communication networks," several best paper awards including the at INFOCOM 1994, and 2017 and Mobihoc 2016, a National Science Foundation (NSF) Research Initiation Award (1992), an NSF CAREER Award (1995), an Office of Naval Research Young Investigator Award (1997), and a Bodossaki Foundation Award (1999). He holds a Ph.D. in Electrical Engineering from the University of Maryland, College Park (1991) and a Diploma in Electrical Engineering from Aristotle University of Thessaloniki (1987). He has held faculty positions at Polytechnic University, New York, University of Maryland, College Park, and University of Thessaly, and University of Ioannina, Greece.

T.V. LAKSHMAN

T.V. Lakshman is the Head of the Networks Research Group, Nokia Bell Laboratories. His research contributions to networking span a spectrum of topics, including software-defined networking, traffic management, switch architectures, network optimization, TCP performance, and machine-learning applications to networks. He is a recipient of several IEEE and ACM awards, including the IEEE Leonard Abraham Prize, the IEEE Communication Society William R. Bennett Prize, the IEEE INFOCOM Achievement Award, the IEEE Fred W. Ellersick Prize Paper Award, the ACM SIGMETRICS Best Paper Award, and the IEEE Infocom Best Paper Award. He also received the 2010 Thomas Alva Edison Patent Award from the R&D Council of New Jersey. He has been an Editor of the *IEEE/ACM Transactions on Networking* and the *IEEE Transactions on Mobile Computing*. He is a Fellow of IEEE, ACM, and Bell Labs. He received the Master's degree (Physics) from the Indian Institute of Science, Bengaluru, India, and the M.S. and Ph.D. degrees in Computer Science from the University of Maryland, College Park.