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Online Simulation System for Cellular Core Network Performance Measurement

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ABSTRACT

This paper presents an online simulation system capable of acquiring and processing network metrics from a measurement server to output the throughput of cellular core networks. A real-world testbed is set up for simulation result evaluation. Comparison shows that the system can obtain user-level performance closely similar to the result obtained in the real-world test using the same network metrics.

Key Words : network measurement, network simulations

Ⅰ. Introduction

Network operators are facing the challenges to keep up with the increasing demand in their core networks. The LTE-A and wideband LTE-A services offer up to 150 Mbps and 225 Mbps of speed, respectively[1]. Core networks are an important part of the LTE network architecture. Due to the increasing speed on radio access networks, it is also required to increase the capacity of the cellular core network.

Unlike 3G networks, LTE has a simpler and flatter architecture with no radio controller element. In 3G networks, a base station (Node-B) is connected to a Radio Network Controller (RNC). In LTE, as shown in Fig. 1, base stations (eNB) are directly connected to the LTE core networks. It allows the operators to measure

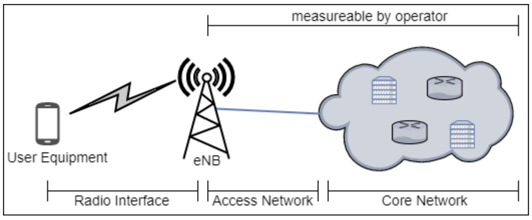

Fig. 1. LTE network architecture

network-level performance from eNB towards core networks.

Network operators can measure network metrics on core networks by utilizing the two-way active monitoring protocol (TWAMP) described in RFC 5357[2]. To perform TWAMP measurement, at least two nodes with a TWAMP capability are needed. One node acts as a TWAMP sender and the other as a TWAMP reflector. The measurement is done by sending time-stamped packets from TWAMP sender to TWAMP reflector. Then, the received packet is sent back by TWAMP reflector with its time-stamp. In this way, the TWAMP sender can calculate desired network metrics.

Some network operators have deployed TWAMP-based measurement servers in their core networks[3]. The measurement servers collect network metrics of core networks such as delay, jitter, and packet loss. Network operators need to know how those network metrics affect the user-level performance. TCP user throughput is affected heavily by the network-level metrics such as delay and packet loss. For example, a congestion window size is halved when a packet loss is detected. The high end-to-end delay leads to low overall TCP throughput. Under the assumption that the radio interface between user equipments (UE) and eNB performs its best, we aim to quantify the user-level performance based

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on the network-level performance metrics, which is acquired by the operator's measurement server.

There have been several studies that are relevant to this paper. Gerber et al. have analyzed throughput perceived by users based on data collected from network operators[4]. Gember et al. have measured TCP downlink throughput directly from participating mobile devices[5]. Although these approaches help users to obtain the knowledge of network performance, they do not satisfy the need of operators for user-level performance monitoring tool. Xu et al. have developed a method for network operators to determine location-based end-to-end performance for 3G networks[6]. However, authors have not provided user-level performance metrics in their proposed solution.

Measurements can be done directly in actual core networks by using network testing tool, such as iPerf[7]. However, it creates an additional load on the core networks, which leads to the performance degradation. Instead of using intrusive active measurements, network operators can use TWAMP that provides network-level performance metrics without burdening the core network[8].

In this paper, we propose a user-level performance measurement system for core network which can obtain TCP user throughput by using only network-level performance metrics, such as delay, jitter, and packet loss. Nevertheless, correctness of simulation results should be assured so that it produces realistic result as if the test is done in a real world. Both the measurement system and its evaluation will be presented in the two following sections.

Ⅱ. Measurement System Overview

The basic purpose of the measurement system is to map from network metrics (i.e., delay, jitter, and packet loss) to user-level performance (i.e., TCP user throughput).

2.1 System Operation

Inside the real core networks, the measurement server collects network metrics (delay, jitter, and packet loss) and reports those to the simulation server. The simulation server maps the network metrics to user-level performance metric. In the simulation, the network metrics acquired from measurement server are set as simulation parameters.

Simulation is done by an open source network simulator (i.e., ns-3), with a simulation model code and network metrics (e.g., delay and loss) as parameter. The simulation results stored in a simulation output file is then inserted into a database as shown in Fig. 2.

By default, the simulation server runs simulation within a real core network to obtain throughput. The simulation server runs multiple simulation instances by using Linux container (Docker)[9].

To reduce the simulation burden, the simulation server maintains a cache that contains a table mapping the network-level performance to the user-level throughput obtained from previous simulations. If the scheduler cannot find nearby results on the cache, it forwards the network metrics to the simulator. Otherwise, the scheduler forwards the network metrics to the Kriging mechanism where the user-level throughput is calculated by interpolation based on the previous results stored in the cache[10].

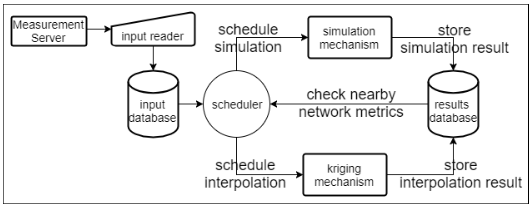

Fig. 2. Measurement system overview

2.2 Simulation Model

Network simulator 3 (ns-3) is widely used by researchers for network simulation[11]. In ns-3, we

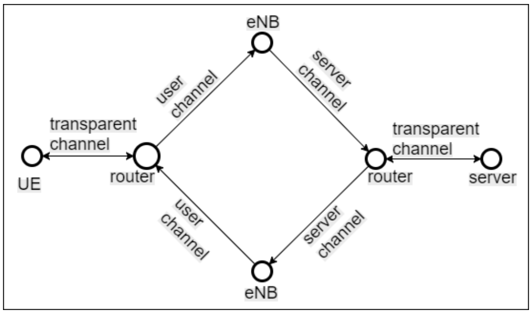

Fig. 3. Core network topology in ns-3 simulator

model a simplified core network topology, as shown in Fig. 3, where there are two nodes which are connected through routers and act as a mobile device (i.e., UE) and a server.

Channels in ns-3 have two configurable properties, delay and bandwidth. There are three types of channels in the simulation model. User channels act as links between UE and eNB as shown in Fig. 1. Link bandwidth properties of user channels represent LTE radio access bandwidth[1], which are set to 150 Mbps or 225 Mbps. Network metrics such as delay, packet loss, and jitter are set on server channels. Transparent channels are set with no delay and unlimited bandwidth. The arrows in Fig. 3 show the direction of packet flows.

iPerf is executed on top of one of the end nodes in the simulation. At the end of the test, we can obtain the user-level throughput from iPerf. With network metrics, which is measured in the core network in real time, set on connecting routers in simulation, the user-level throughput from the simulation is able to predict the actual user-level throughput currently perceived by real UEs.

Ⅲ. Evaluation

Making sure the correctness of results from the measurement system is crucial. We set up a testbed as shown in Fig. 4. Four routers and two PCs are used for testing. Routing tables on routers are set to implement the packet flow

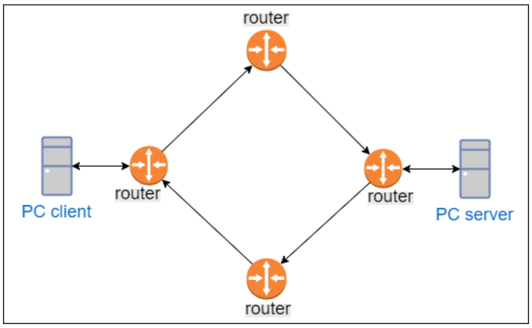

Fig. 4. Testbed topology

shown in Fig. 3.

NetEm is employed on routers for traffic shaping[12]. Bandwidth and network metrics can be defined as NetEm parameters. Hence, either LTE-A or wideband LTE-A can be emulated on testbed along with given network metrics. User-level throughput can be obtained by running iPerf on two PCs.

The comparison between the simulation results and real-world network measuremenst is shown in Fig. 5. Two figures in the left show the throughput according to the delay when the packet loss is zero. Two figures in the right show the throughput as a function of a packet loss when the delay is set to 100 ms. In all figures, the experimental results are very similar to the simulation ones.

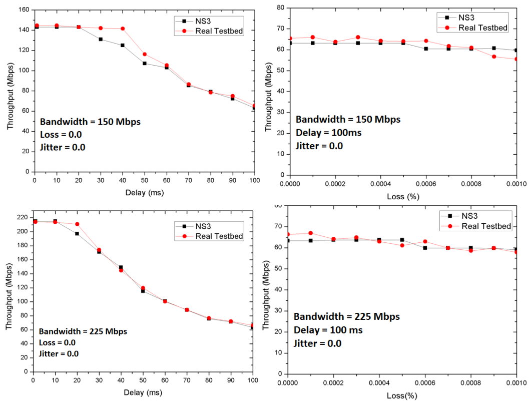

Fig. 5. Comparison between simulation and experimental result

Ⅳ. Conclusion

In the paper, we have built a performance measurement system to provide a means for network operators to measure the user-level performance based on the network metrics. The simulation system well predicts the TCP user throughput measured in the real testbed.

References

[1] J. Gozalvez, "South korea launches LTE-Advanced [Mobile Radio]," *IEEE Veh. Technol. Mag.*, vol. 9, no. 1, pp. 10-27, Mar. 2014.

[2] K. Yum, J. Z. Babiarz, K. Hedayat, R. M. Krzanowski, and A. Morton, *A two-way active measurement protocol* (TWAMP), Retrieved May, 7, 2017, from https://tools.ietf.org/html/rfc5357.

[3] *Accedian Monitoring Solution Applied to SK Telecom's Network to Assure End-to-End Performance*, Retrieved Oct., 24, 2017 from https://accedian.com/blog/2015/07/14/sktelecom/.

[4] A. Gerber, J. Pang, O. Spatscheck, and S. Venkataraman, "Speed testing without speed tests: estimating achievable download speed from passive measurements," in *Proc. IMC 2010*, pp. 424-430, Melbourne, Australia, Nov. 2010.

[5] A. Gember, A. Akella, J. Pang, A. Varshavsky, and R. Caceres, "Obtaining in-context measurements of cellular network performance," in *Proc. IMC 2012*, pp. 287-300, Boston, MA, Nov. 2012.

[6] Q. Xu, A. Gerber, Z. M. Mao, and J. Pang, "AccuLoc: Practical localization of performance measurements in 3G networks," in *Proc. MobiSys 2011*, Washington, DC, Jun. 2011.

[7] iPerf - The TCP, *UDP and SCTP network bandwidth measurement tool*, Retrieved May, 15, 2017, from https://iperf.fr.

[8] V. Mohan, Y. R. J. Reddy, and K. Kalpana, "Active and passive network measurements: a survey," *Int. J. Comput. Sci. Inf. Technol.*, vol. 2, no. 4, pp. 1372-1385, May 2012.

[9] *What is Docker*, Retrieved May, 7, 2017, from https://www.docker.com/what-docker.

[10] W. H. Press, et al., *Numerical Recipes: The Art of Scientific Computing*, 3rd Ed., Cambridge University Press, 2007.

[11] ns-3, Retrieved May 7, 2017, from https://www.nsnam.org.

[12] netem [Linux Foundation Wiki], Retrieved May, 8, 2017, from https://wiki.linuxfoundation.org/networking/netem.