GR-384

Benchmarking Network Services Using the POWDER Wireless Testbed

Abstract

5G radio access network (RAN) slicing provides a way to split network infrastructure into self-contained slices which consist of various virtual network functions (VNFs) mapped onto physical nodes. Much work has gone into creating robust mapping and resource allocation algorithms in order to efficiently embed VNFs in the available nodes of a network[1, 2, 3]. However, in order to most efficiently embed these VNFs we need to understand the resource and bandwidth needs of the services we are trying to embed. This project seeks to provide an accurate assessment of the needs of three commonly used network services by testing each network service using real world physical machines on the POWDER network testbed.

Network Slicing

Network slicing is a 5G technology which allows physical infrastructure to be logically split into multiple network slices using virtualization. Each slice consists of a set of VNFs which together provide a service or set of services. Each set of VNFs are embedded into the physical infrastructure based on their resource and bandwidth requirements and the available connections and resources of the physical nodes.

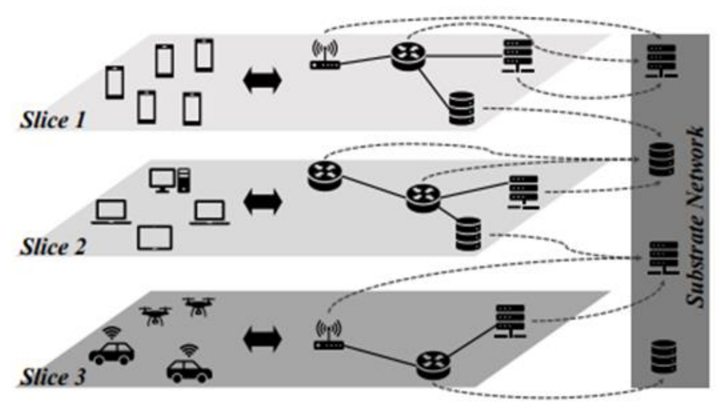

Figure 1: Example of slices being mapped onto physical infrastructure[1]

Objective

In order to efficiently map the VNFs to physical nodes we need to know it's resource and bandwidth requirements. This project designs and implements three testing scenarios for commonly used network services in a real-world environment. We collect resource and bandwidth data from the test runs and use it to analyze the needs of the network services. The project also demonstrates the usefulness of POWDER as a tool for collecting accurate data on network services in a physical testing environment.

Testing Environment

Our project uses the POWDER network testbed[4] to compare the performance of the network services using a real-world LAN environment. We tested three different commonly used network services: E-mail, network file sharing (NFS), and a domain name system (DNS) server. Each network service is put through a testing scenario where we gather data such as bandwidth usage and CPU load on the server nodes. The testing scenarios all involve four client nodes interacting with a server node and using its provided network service (Figure 3). Each node had two 2.4 GHz, 64-bit, 8-Core, Xeon E5-2630v3 processors and 64GB of RAM. The testing scenarios each lasted roughly 15 minutes and attempted to simulate a high-traffic scenario with each client node continuously using the provided network service over the course of the test. The testing scenarios are run and controlled from the POWDER dashboard (Figure 2).

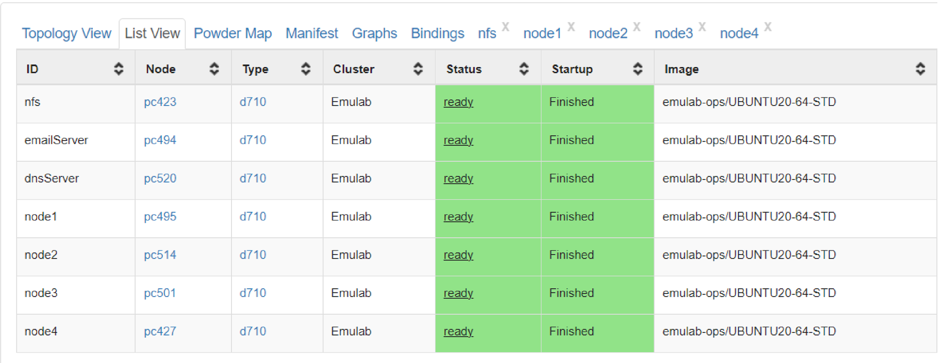

Figure 2: POWDER dashboard for interacting with testing environment

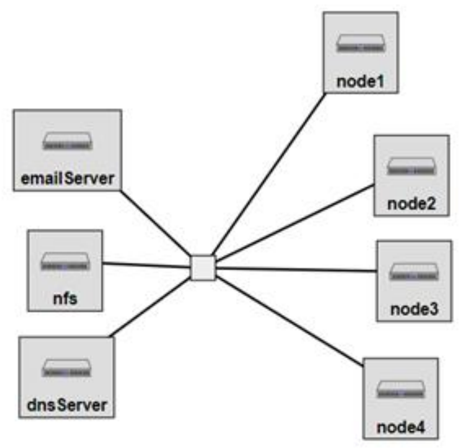

Figure 3: Topology of testing environment

Data Collection

Data was collected through two primary tools, vnstat and the POWDER testbed's built in tools for monitoring CPU load. Vnstat allowed us to see the bandwidth usage data of the server nodes during the testing scenario. The network the nodes were connected over has some background traffic due to POWDER's administrative overhead. To account for this, we also ran a control test and removed its effects from the email and DNS test results. The NFS test was an exception and was unaffected as it was conducted over an isolated VLAN since it did not need to communicate with nodes outside the testing environment to provide its service.

Computing resources were measured through POWDER's provided tools which collected CPU load data from the nodes every 5 minutes. The data is measured as CPU load average which is the average number of processes being executed or waiting to execute over a set time interval. Each testing scenario required some setup up which would have a small impact of the CPU load average. In order to remove this, we waited 15 minutes between setting up and running the tests as well as 15 minutes between tests. This makes sure any CPU load average data is only representative of the network service impact.

Results

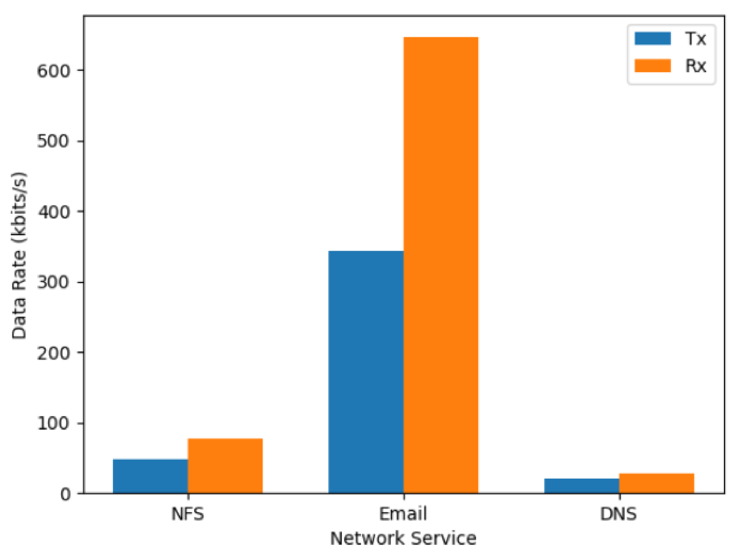

Figure 4: The average data rates for each testing scenario

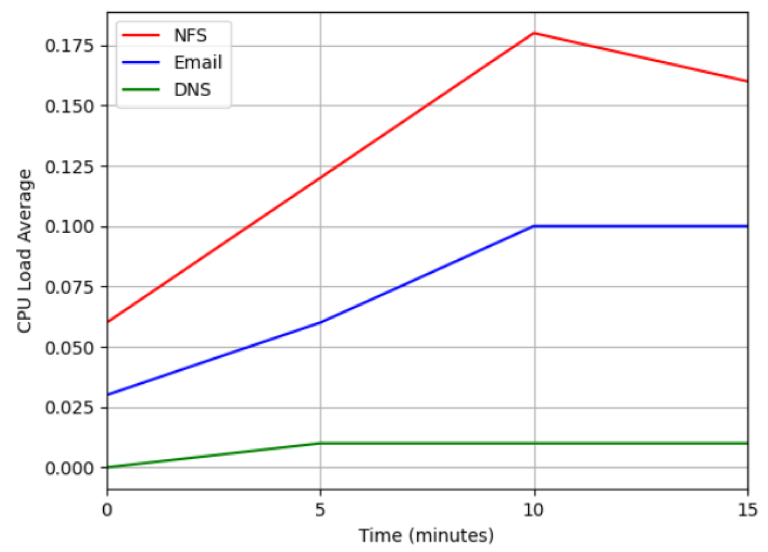

Figure 5: CPU load average of server nodes during network service tests

Analysis

Figure 4 shows the Transmitting (Tx) and receiving (Rx) data rates for each of the server nodes during the testing scenarios. NFS and DNS both had relatively low data rates over the course of the tests. This translates to low bandwidth requirements when embedding for network slicing. On the other hand, the email service had much higher data rates than the other two over the course of the test so an embedding algorithm would have to make sure it's embedded in a physical node with high bandwidth capacity connections.

Figure 5 shows the CPU load average for each of the server nodes over the 15 minute-test period. NFS had the highest CPU load average, so when it is being embedded it would require a physical node with enough available resources to meet its relatively high needs. On the opposite end of the spectrum, DNS had very little impact on the CPU load average and could be embedded fairly easily. During all the testing scenarios, the CPU load average gradually climbed until it reached it's peak 10 minutes into testing. Due to the number of service requests per second staying consistent throughout the testing scenario, this is an unexpected trend in the data. We believe that this trend was caused by the way POWDER collects and displays the data. POWDER updates the CPU load average data for its nodes every 5 minutes, but based on the results it is likely the time period being used to average the data is much longer than that. Future research using POWDER would account for this by increasing the length of the test to have more data points with accurate CPU load data, or by using different monitoring tools to gather the data independently of POWDER.

Conclusions

This project sought to test three network services in order to collect data for use in RAN slicing embedding algorithms. We found that of the three network services, DNS has the smallest requirements in terms of both bandwidth usage and computing resources. As such, DNS could be very easily embedded in network slicing. Email and NFS both have stricter requirements with email requiring more bandwidth and NFS requiring greater computing resources. The data collected on these resource requirements can be used to efficiently embed these services onto physical nodes with network slicing.

Future Work

Further research could involve expanding upon the current dataset and testing more network service in order to provide a broader analysis of resource and bandwidth requirements. The number of tests or length of the tests could also be expanded upon to try and determine possible error or limitation of testing using the POWDER testbed. Another avenue of research could involve using the collected data to develop more efficient embedding or remapping algorithms. These algorithms could also be tested through the POWDER network testbed in order to determine their effectiveness in a real-world environment. Different algorithms could also be compared using POWDER to see if their theoretical efficiency matches actual tested efficiency when used on physical nodes.

See More

Scan this QR code to see the project GitHub. For those interested in using the test code themselves, you will need to create an account on the POWDER testbed website.
www.powderwireless.net

Acknowledgments

This research was supported in part by the US NSF grant CNS-2103405. Thank you to Dr. Tu Nguyen and the faculty at the University of Utah for making this project possible.

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References

[1] NSF CNS-2103405: CRII: CNS: Towards Robust RAN Slicing: Theories, Algorithms, and Applications,, Tu Nguyen (PI).

[2] Linh Le, Tu N. Nguyen, Kun Suo, and Selena J. He, "*5G Network Slicing and Drone-Assisted Applications: A Deep Reinforcement Learning Approach,*" In The 28th Annual International Conference on Mobile Computing and Networking WORKSHOP (ACM MobiCom WORKSHOP 2022), pp. 109-114, 2022.

[3] Kashyab J. Ambarani, Shivansh Sharma, Shravan Komarabattini, My T. Thai, and Tu N. Nguyen, "*Enforcing Resource Allocation and VNF Embedding in RAN Slicing,*" In 2021 IEEE Global Communications Conference (GLOBECOM), pp. 1–6, vol. , 2021.

[4] *Powder (the Platform for Open Wireless Data-Driven Experimental Research)*, University of Utah, https://www.powderwireless.net/.

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