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Performance Analysis of Softwarized Local Mobile Networks

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***Abstract*—The ever growing and revolutionizing demands in telecommunication industry to facilitate numerous business verticals are pushing towards more softwarized mobile communication technologies. By using the capabilities of network softwarization, a novel telecommunication concept of local mobile network has been developed. The local mobile networks are getting popular due to their capability of providing efficient and reliable local services to a focused use case with higher flexibility. This paper presents the practical implementation aspects of a softwarized local mobile network and compare its performance with a conventional mobile network operator and a hybrid architecture.**

***Index Terms*—Local Mobile Networks, Network Architecture, Network Softwarization, Software-Defined Networking, Network Function Virtualization**

I. INTRODUCTION

Network Softwarization revolutionize the way network and computing infrastructures are designed and operated to deliver the services. The need for flexibility, adaptability, cost efficiency, reduced time to market of future networked services drive the design of programmable networks for the service delivery. Software-Defined Networking (SDN) and Network Function Virtualization (NFV) act as the two pillars of network softwarization where SDN decouples the user and control planes enabling the programmability of the networks and NFV allows network functions to run as virtual instances on commodity hardware[1]. Softwarized networks are easily scalable to meet the increasing network demands, capable of sharing computing and storage resource to increase the efficiency of resource utilization [2]. Moreover, the high expansion/upgrade cost for network service providers due to maintaining multiple heterogeneous networks will be eliminated.

The future wireless communication applications require service providers to put more emphasis on the case specific and location specific service delivery in different vertical sectors such as automotive, health, energy, industry and media. These requirements are expanding beyond the current capabilities of the traditional Mobile Network Operators (MNO) whose services are often designed to serve masses. Hence, the need of locally deployed operators such as micro Operators (uO) [3] to cater for such service requirements is evident. Local operators enable efficient and reliable local service deliveries with shorter deployment timelines due to its specific focus on the use case. Local operator services can coexist with the MNO services in a given location where the local operator focuses on the specific needs and the MNO provides the generic mobile communications services [3]. The term Non-Public Networks (NPN) refers the networks having certain devices which are capable of working on private network as well as public network or roaming between them.

The Software-defined control helps mobile network operators to implement dynamic mobile packet core [4] to address diversified future service demands. Deployment of local operator architectures tailored to serve specific use cases, provides performance benefits compared with the general MNO service provision, as highlighted in [5]. The studies on business models for micro operators, spectrum allocation and sharing for micro operators further justifies the existence of local operators for future service provision. 5G Test Network (5GTN) [6] provides an example for the deployment of such flexible network where core network functionalities are deployed in multiple remote locations to work collaboratively.

Besides the novelty of the local operator concept, the architecture, regulatory and business related aspects for local operators are discussed. However, to the best of our knowledge, a practical implementation of a local operator and a performance comparison with a MNO is not performed. With this regard, we implement a local operator network and analyse its performance compared with the other types of network deployments such as MNO and hybrid.

The remainder of the paper is organized as follows: Section II describes different architectural options for softwarized mobile networks. Section III explains the testbed implementation procedure and discusses the results. Finally, Section IV concludes the paper with the future research directions.

II. DIFFERENT ARCHITECTURAL OPTIONS FOR SOFTWARIZED LOCAL MOBILE NETWORKS

Different architectural options can be derived for softwarized mobile operator networks based on the serving use case, coverage area, the geographic distribution and ownership of the network components.

A. Local Mobile Operator Architecture

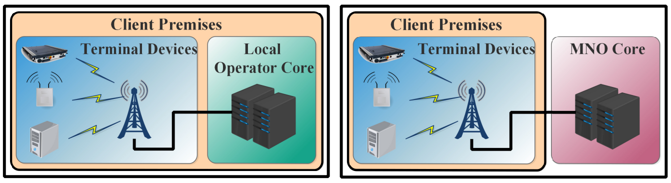
A local mobile operator establishes its network locally to provide services for specific use cases in a specific location such as a factory, hospital, university, shopping mall. The network includes locally deployed access network and the core network components as depicted in Figure 1a. Therefore, most of the communications are confined within the premises. These type of networks are suitable for providing services with strict Quality of Service (QoS) requirements such as ultra-low latency service provision while ensuring better privacy and security. An outside connectivity is desired to perform upgrades, access the internet, upload data to a cloud environment but the critical communications happen locally.

B. *Hybrid Architecture*

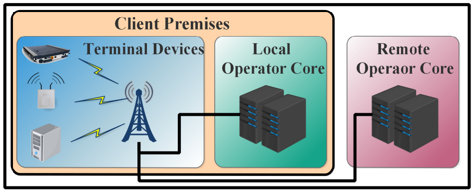
In a hybrid architecture, the network entities are not necessarily confined to one physical location, especially the core network. The distributed nature of the network components and the fact that they are is softwarized, make the network easily adaptable. The network can be a collaboration of multiple operators providing different entities, functioning together to provide the service(s) required as depicted in Figure 1c. A softwarized hybrid operator is capable of deploying the network entities/functions based on the application demands. The cloud based deployments serve generic services and the edge based deployments are suitable for services requiring ultra-low latency. A comparison of properties of local operator architecture and the hybrid architecture is given in Table I and in Figure 1.

TABLE I: Comparison [3], [6], [7]

Local	**Hybrid**
Provides case specific, location specific services for a limited number of users	Possible to provide specific services as well as general services
Network is confined to a specific location. External connectivity is optional for remote access	The network is distributed and may be built by multiple parties
Core Network is located on premises	Different parts of the core network can be in different locations. There can be multiple instances of the same core network entity based on the communication requirements
Expansion and upgrades are easy	Expansion and upgrades are complex than Local mobile networks



(a) Local Operator (b) MNO



(c) Hybrid

Fig. 1: Architectural Options

III. TESTBED IMPLEMENTATION AND RESULTS

The paper compares performance of three deployment options for mobile operator networks, i.e. pure local operator, hybrid model and the MNO. This section comprehensively explains the testbed implementation, experiments conducted and finally analyses the results.

A. *Testbed Environment*

1) Pure local operator: Testbed implementation of the pure local operator has been carried out by integrating a 4G base station provided by Nokia, the EPC from Cumucore [8] and generic mobile devices. This setup was used as a local operator which has its own core network, access network and subscribers. Additionally, the local operator network was provided with an Internet connection using Cumucore EPC. Internet connection is not mandatory for the local operation but it can be used to establish the connection with the outside world.

The base station allows 4G devices to connect and get the services and it supports multiple frequency bands. It supports both indoor and outdoor deployments and can easily be integrated with an external core network with security gateway. Figure 2 depicts the 4G base station we used in our experiments. Cumucore EPC depicted in Figure 3, is a new 4G Evolved Packet Core solution which offers a flexible and scalable 4G core. This can be deployed fast and easily integrated with the 4G base station used for the experiments. The core has been integrated with NFV and SDN technologies which makes it a 5G ready core. We used Nokia 6.1 Android mobile phones capable of working with 4G internet connectivity as the terminal devices. These devices used mobile applications to measure latency and throughput parameters of a given communication using Subscriber Identity Module (SIM) cards belong to the local operator network.

Fig. 2: 4G Base Station

Fig. 3: Cumucore EPC

The following procedure is carried out for setting up the local operator network. First, the 4G base station was assembled according to the guidelines provided. It supports maximum of ten subscribers due to the limited availability of SIM cards. Then the connectivity between the base station and the subscribers was made by inserting its own SIM cards into the terminal devices. The terminal devices were already equipped with the applications to measure latency and throughput. The base station is connected to Cumucore EPC and then the base station is configured with the required parameters such as signal power. Once all devices are powered up, the terminal devices attach to the base station, which completes the local operator network setup. Cumucore EPC provides dynamic IPV4 addresses to the terminal devices. Using those IPV4 addresses we established direct communications between the devices attached to the local operator network. To enable the Internet connectivity to the devices, the EPC was connected to an Internet service provider through a 4G LTE router. The network diagram for the setup is illustrated in Figure 4 and Figure 5 depicts the actual setup of the local operator network.

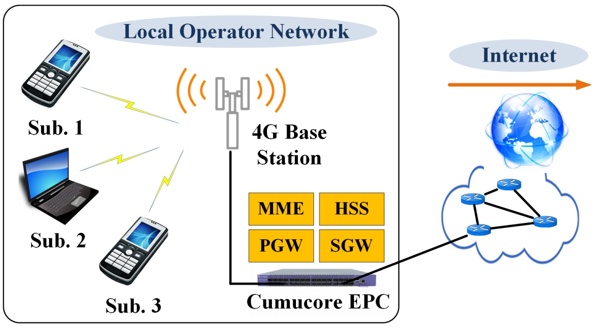


Fig. 4: Network Diagram of Experimental Setup

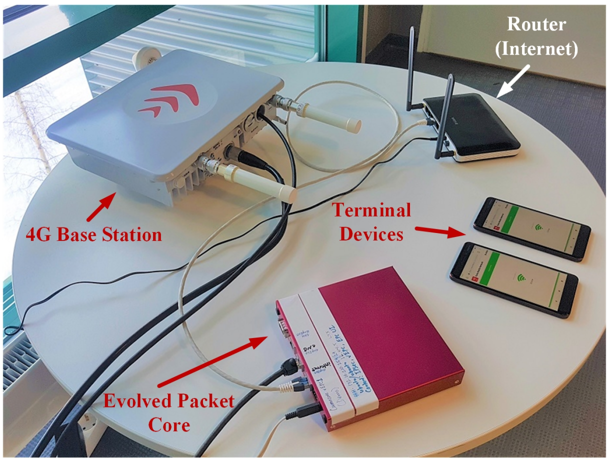


Fig. 5: Experimental Setup of the Devices

2) Hybrid Model: As the hybrid network setup, we used (5GTN) [6] which is available in University of Oulu premises. Figure 6 illustrates the overall architecture of 5GTN [7]. It is comprised of two interconnected environments located at University of Oulu and VTT's 5G laboratory located in Oulu. Each test site contains one macro cell and few small cell eNodeBs (eNB). The core network entities of the test network run on an OpenStack cloud environment. Some of the core network functionalists such as Packet Data Network Gateway (PGW), Serving Gateway (SGW), Mobility Management Entity (MME) are implemented locally at both the test sites. Other core network functionalities run from a remote core network, located at Nokia premises in Tampere, Finland. The remote core network is connected over a Virtual Private Network (VPN). The Mobile Edge Computing (MEC) functionality in the test network is based on Nokia's MEC solution. 5GTN also provides access points for Machine Type Communication (MTC) systems mainly supporting the testings of IoT scenarios and concepts.

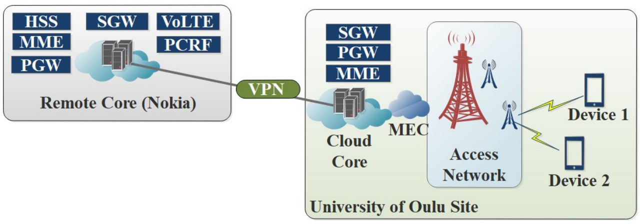


Fig. 6: Network Architecture of 5G Test Network [7]

3) MNO: To implement the MNO network, we used SIM cards from DNA. Based on 2019 financial statements, DNA positions as third service operator in Finland having 29% market share in mobile communications and DNA's 4G network reaches almost 100% of the population in mainland Finland [9]. To enable direct communication between terminal devices, public IPV6 addresses provided by DNA were used. Certain operators block ICMP traffic inside their network, preventing execution of certain commands such as ping command required to take performance measurements. However, with DNA we could overcome these issues and proceed with the setup.

B. Experiments

We conduct two experiments under each network deployment model and obtain performance measurements. The outputs of those experiments are latency and throughput.

1) End-to-End Latency: The objective of this experiment is to measure the E2E latency of the pure local operator based deployment, hybrid architecture deployment and MNO deployment and conduct a performance comparison to identify which has the best performance. Instead of conducting the experiments with the real use cases we discussed, we used ”Network Analyzer” android application and used IPV6 ping command to measure the latency. With two devices, we could easily build a client server setup where the client executes the command and provide us with the latency measurements. Latency measurements for pure local operator and hybrid deployments were taken every two hours per day and an average of ten measurements were taken as the final value. For the MNO, experiment was conducted ten consecutive days and averaged to come up with a more realistic figure.

Figure 7 depicts the latency measurements for the pure local operator, hybrid and MNO deployments with 95% confidence intervals. Observed latency is always lower for local operator network and does not show much variation. This is due to the close proximity of the core network and less external traffic. Conversely, latency of MNO is higher and has significant variations. This is due to the core network distance and the variations in traffic congestion in MNO network at different times. For the hybrid network, latency is in between local operator values and MNO values and shows higher variation compared to the local operator.

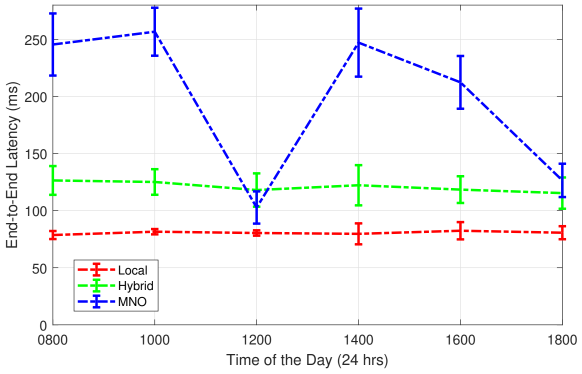


Fig. 7: Comparison of E2E latency

2) Network Throughput: Second experiment measures network throughput of all three architecture deployments and conduct performance comparison. We used ”Magic iPerf” android application and used IPV6 addresses for iperf command to measure the throughput. Similar to the latency experiment, we used the same frequency and the same number of iterations to come up with the final figures.

Figure 8 depicts the throughput measurements for the pure local operator, hybrid and MNO deployments with 95% confidence intervals. Observed throughput is always higher for local operator and hybrid deployments compared to MNO. This is because the only traffic in local operator and hybrid networks is the test traffic originated by very few devices compared to MNO, leading to less congestion. Conversely, throughput of MNO is lower in all the cases. There could be multiple reasons for this. Traffic congestion at MNO network, operator policies such as QoS limits.

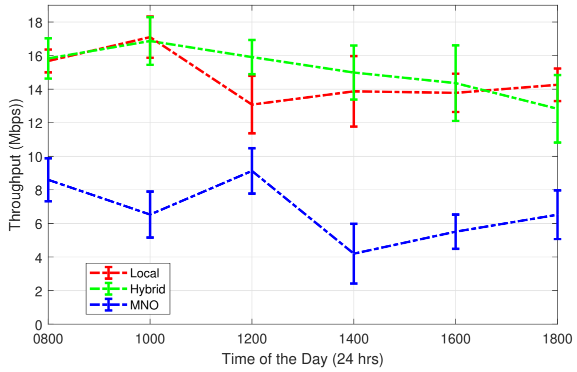


Fig. 8: Comparison of throughput

IV. Conclusions and Future Work

Softwarized networks provide flexible, adaptable, cost efficient way to cater the emerging future communications needs with varying requirements. Future wireless communication applications require service providers to put more emphasis on the case specific services, and the deployment of local mobile networks is proposed as a solution for this. Network softwarization enables the customization of core and access network components of a mobile network operator, benefiting the diversified requirements of each use case. This paper explores the benefits of utilizing local mobile operator networks and easily customize networks to serve specific use cases over the service provision via MNO. The paper presents the latency and throughput measurements for three deployment models called local operator, hybrid operator and MNO and argues that the selection of local and hybrid operators is beneficial in terms of performance measurements.

In future, we extend the experiment into real world use cases such as Augmented Reality (AR) where ultra-low latency requirement is a must. In a HIGHLY localized environment, the local operator is expected to perform better than the hybrid operator. Use cases such as sensor networks where massive connectivity is required, and mobile robots will also be considered. The combination of those use cases will resemble a future factory environment. Analysing the dynamic placement of network functions based on demand will also be considered as a future research direction. This analysis will help to find the optimal strategy for network establishment with distributed use cases, such as geographically separated branches of a factory having similar operation. We also plan to perform the experiments in a standalone 5G environment as soon as they are ready. The local operator setup will be built with 5G base station and 5G core network and the performance comparison against MNO offered 5G services will be carried out. A performance comparison between softwarized 4G network against the 5G network is also considered as a future research direction.

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References

[1] M. Liyanage, A. Gurtov, and M. Ylianttila, *Software Defined Mobile Networks (SDMN): Beyond LTE Network Architecture*. John Wiley & Sons, 2015.

[2] F.-Y. Wang, L. Yang, X. Cheng, S. Han, and J. Yang, “Network Softwarization and Parallel Networks: Beyond Software-Defined Networks,” *IEEE network*, vol. 30, no. 4, pp. 60–65, 2016.

[3] M. Matinmikko, M. Latva-Aho, P. Ahokangas, S. Yrjölä, and T. Koivumäki, “Micro Operators to boost Local Service Delivery in 5G,” *Wireless Personal Communications*, vol. 95, no. 1, pp. 69–82, 2017.

[4] M. R. Sama, L. M. Contreras, J. Kaippallimalil, I. Akiyoshi, H. Qian, and H. Ni, “Software-defined Control of the Virtualized Mobile Packet Core,” *IEEE Communications Magazine*, vol. 53, no. 2, pp. 107–115, 2015.

[5] Y. Siriwardhana, P. Porambage, M. Liyanage, J. S. Walia, M. Matinmikko-Blue, and M. Ylianttila, “Micro-operator driven Local 5G Network Architecture for Industrial Internet,” in *2019 IEEE Wireless Communications and Networking Conference (WCNC)*. IEEE, 2019, pp. 1–8.

[6] “5G Test Network.” [Online]. Available: https://www.5gtn.fi/

[7] E. Piri, P. Ruuska, T. Kanstrén, J. Mäkelä, J. Korva, A. Hekkala, A. Pouttu, O. Liinamaa, M. Latva-Aho, K. Vierimaa *et al.*, “5GTN: A Test Network for 5G Application Development and Testing,” in *2016 European Conference on Networks and Communications (EuCNC)*. IEEE, 2016, pp. 313–318.

[8] “Cumucore EPC.” [Online]. Available: https://www.cumucore.com/

[9] “DNA Annual Report 2018.” [Online]. Available: https://corporate.dna.fi/investors/reports/financial-reports