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Demonstration of LAN-type Communication for an Industrial 5G Network

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***Abstract*—To facilitate the adoption of 5G in industrial networks, 3GPP introduced a new 5G feature called 5G LAN-type service in Release 16. The 5G LAN-type service aims to support similar functionalities of Local Area Networks, but on top of the 5G network. As a result, 5G LAN-type service would be expected to offer UE-to-UE communication with ultra-low latency, which is attractive for localised industrial control settings. The requirements of this new service have been specified but its design and implementation are still being studied. In this demo paper, we present a workable design to implement the 5G LAN-type service and demonstrate its benefit in terms of end-to-end (E2E) latency. Our evaluation shows that E2E latency in a 5G LAN-type service is smaller than those in Multi-access Edge Computing scenarios. The testbed provides a platform for exploring challenging aspects of 5G LAN-service design and implementation.**

***Index Terms*—5G, 5GC, industrial network, LAN, low latency**

I. Introduction

5G is a key technology for future industrial networks because of its advantages in providing high density, bandwidth and reliability together with low latency. 3GPP recently introduced a new feature in the 5G standard, namely 5G LAN-type service [2], which aims to support functionalities similar to a LAN together with 5G capabilities, targeting industrial scenarios [1]. LAN is the most common network model in industrial networks since it simplifies direct communication (i.e., D2D). To enable D2D communication in a traditional mobile network, modifications are needed at PHY/MAC layers of user equipment (UE) in previous solutions. Otherwise, the communication between two UEs must go from the source UE to operator infrastructure (i.e., base stations and core network), then to external networks, and finally go back to the destination UE in a reverse path as shown in Fig. 1. As a result, this mechanism causes a high end-to-end (E2E) latency, although the two devices are in the same area.

High latency is one of the barriers to utilizing the mobile network in wireless industrial systems. However, 5G has promised to provide low latency and reliable connectivity, which can satisfy industry requirements. Many studies have been conducted to address the latency drawback of the mobile network in 5G [3]. For example, at the Radio Access Network (RAN), new radio frequencies and scheduling algorithms are utilized to achieve shorter transmission times. In the core network, the Multi-access Edge Computing (MEC) paradigm is proposed to bring computing resources closer to the end user. The 5G LAN-type service is an approach at the core network to deal with latency. Basically, 5G LAN-type service will enable UE-to-UE communication among devices in the same *virtual network* by adding optimized routes in the User Plane Function (UPF) to skip forwarding data to external networks as illustrated in Fig. 1.

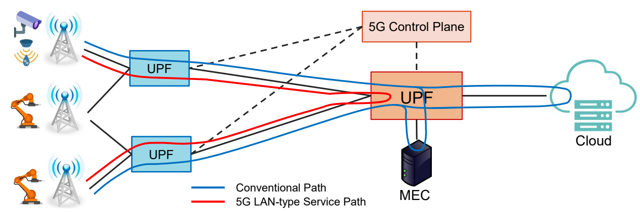

Fig. 1. 5G LAN-type communication path.

5G LAN-type service is expected to facilitate the adoption of 5G in industrial networks and is likely to be widely adopted as it allows legacy industrial LAN networks to transition to 5G without re-designing the network model. Moreover, 5G LAN-type service can also enable the emergence of ultra-low latency applications, e.g., factory automation, health care, and autonomous vehicles. However, 5G LAN-type is still at an early stage, with key details yet to specified. Thus, there is a lack of practical design and implementation studies about this new service. In this demo, we propose an approach to implement LAN-type communication in a 5G network. We then demonstrate the feasibility of our proposed approach and the advantage of 5G LAN-type service in terms of E2E latency.

II. Design of a 5G LAN

Integrating two different technologies is a challenging task, and we aim to minimize changes and ensure compatibility within current 5G systems. Thus, our design does not require any modifications in the UE, RAN, and protocols used in the specifications of 5G but focuses only on the 5G Core Network (5GC). In 5G systems, the 5GC is separated into Control Plane (CP) and UPF. CP is considered the brain of the 5G network, where UE authentication, management, and network control are performed. Meanwhile, the UPF is responsible for conveying data between UEs and external networks. To

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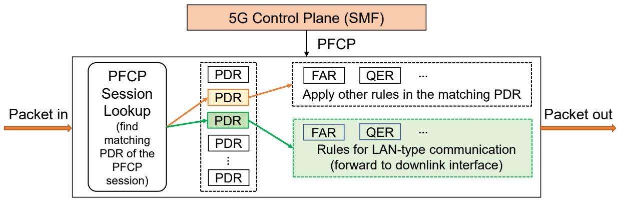

Fig. 2. Packet processing flow in UPF.

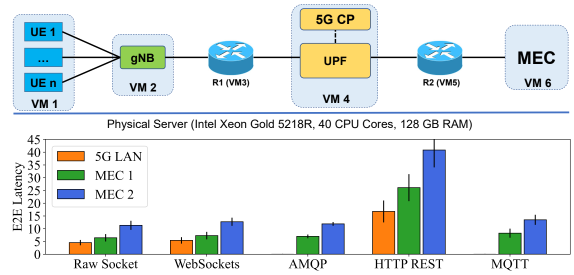

Fig. 3. Setup of 5G testbed and evaluation result.

enable LAN-type communication in 5G, two main tasks are needed: (1) defining *virtual networks*, and (2) setting up new forwarding paths. The first task is implemented in the CP, while the second in both CP and UPF.

As each UE will be allocated a local IP address when it connects to the 5G network, we can designate IP subnets to create virtual networks. In particular, each virtual network that represents a group of devices will be assigned a unique IP pool. The IP pool and group information can be stored together with the information of each device in a database. Whenever a UE connects to a 5G network, it will be allocated an IP address from its pool by the Session Management Function (SMF) in the CP. Since IP address allocation is a fundamental configuration service, it can easily be customized and integrated into the SMF.

SMF is responsible for managing the connectivity between UE and external networks through the UPF. The UPF is a complex packet processing component that can perform packet encapsulation/decapsulation, inspection, routing, and QoS handling. It is important to note that the UPF handles UE traffic based on information received from the SMF via the Packet Forwarding Control Protocol (PFCP) [4]. That information includes Packet Detection Rules (PDR), Forwarding Action Rules (FAR), QoS Enforcement Rules, QoS Enforcement Rules, Buffering Action Rules, and Usage Reporting Rules [4]. Especially, PDR and FAR are necessary to set up a new forwarding path between UEs. A PDR allows the UPF to detect any traffic in the network by leveraging 5-tuple information in IP packets, while a FAR specifies an interface on which to forward traffic. For example, if we define a PDR that identifies traffic from a specific subnet IP address to a particular UE IP address, we can link this PDR to a FAR to forward the traffic back to the RAN (i.e., downlink interface) to enable direct communication between devices in a subnet (virtual network). Similarly, by creating PDRs and FARs for all devices in one virtual network, we can enable LAN-type communication in that virtual network.

III. Demonstration

The demonstration of 5G LAN-type service is implemented using Aether and UERANSIM open-source software. The setup of the testbed is illustrated in Fig. 3. The 5GC (Aether) was deployed on top of the Kubernetes environment, while UE and RAN (UERANSIM) were deployed by Docker Compose. We used two UEs to form a virtual network in our demonstration scenario. We create PFCP messages and inject them into the UPF to set up the LAN-type communication between two UEs. A Python program sends and receives packets that contain system timestamps, allowing us to measure the E2E latency over different communication protocols. The guidelines and codes for the testbed setup and evaluation are available at *https://github.com/linhanphan/5glan*.

We compared the E2E latency of the 5G LAN-type service with two MEC settings. In the first setting (MEC 1), the UPF and MEC server are co-located, and thus there is minimal latency. In the second setting (MEC 2) a 5 ms delay is added between the UPF and MEC server, corresponding to the situation where the MEC server is located in different regions or in the cloud. Fig. 3 shows that the E2E latency in LAN-type communication is always smaller than with the MEC models. Note that we can not evaluate the E2E latency of AMQP and MQTT in the 5G LAN scenario since these protocols do not support D2D communication. As the UPF can be deployed near the RAN in 5G systems, 5G LAN-type service can enable direct UE-to-UE communication with ultra-low E2E latency.

IV. Discussion

5G LAN-type service will be an important feature to bring 5G into the industrial Internet of Things, while posing new research challenges. For example, how to efficiently support a large number of virtual networks and devices, how to ensure QoS and isolation among virtual networks, how to enable multicast and broadcast communication, and how to design new communication protocols for D2D networks. The proposed design requires further study to become a complete solution. However, we believe that our current testbed can facilitate studies of applications that leverage the advantages of 5G LAN-type service, such as time-sensitive networking in 5G, factory automation, and ultra-reliable low-latency communication applications.

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