A compact 5G Non-Public Network

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***Abstract*—5G is aimed to play a key role in the digital transformation of the smart manufacturing industry. 3rd Generation Partnership Project (3GPP) has introduced technical features for Non-Public Networks (NPN), allowing highly flexible and dedicated 5G deployments for Industry 4.0 applications. This paper presents insights into the main challenges of 5G NPNs and how we created a portable and compact 5G NPN solution. Our contribution is twofold: (i) we have identified the main concepts for the NPN and designed its architecture; (ii) we have implemented and validated it. This NPN can operate simply with mains electricity input, independently from the public network and public services of the MNO. Such a solution can be an excellent candidate for research purposes due to the very easy deployment, but it is also suitable for commercial, industrial usage.**

***Keywords*—5G, Non-Public Networks, Industry 4.0**

I. Introduction

With the introduction and widespread adoption of 5G, new market and technology opportunities for MNOs, infrastructure providers, and industry players are becoming available that were previously unthinkable [1]. The so-called NPN is perhaps one of the most promising fields of the 5G possibilities [2] within the Business-to-Business (B2B) sector. In other words, 5G-driven Industry 4.0 is coming on strong. The paper summarizes the main challenges of industrial cellular networks' technical and business aspects in Section II. Our NPN solution is introduced in Section III. This section evaluates how we have dealt with some challenges of the market and describes the demo in detail, while Section IV concludes the paper.

II. Related work

With the ongoing digitalization of manufacturing sectors, industrial players, MNOs, vendors, and standardization organizations are paying more attention to the integration of 5G as a communication technology in industrial systems. To become an attractive candidate for industrial use-cases, 5G networks should offer Service Level Agreements (SLAs) in contrast to traditional public mobile services, which primarily operate on a best effort basis. Therefore, dedicated resources are inevitable to serve the needs of Industry 4.0 use cases [3]. NPNs can help to meet the requirements of such applications. 3GPP [4] describes different NPN [5] solutions, offering more choices in terms of the architecture of the industrial network. In general, an NPN is a special service of the MNO, which is implemented based on the agreed SLAs and individual requirements of its business customers. These SLAs are mainly cover capacity, data rate, latency, availability, and coverage area issues. Moreover, NPNs provide a mechanism allowing access only to authorized users.

Even though 5G NPNs are an excellent prospect for industrial applications and industrial systems, several challenges are ahead. First of all, 5G is still in the development phase; even though there are several operating 5G networks all around the globe, these are mostly Non-Standalone (NSA) networks. The rollout and widespread deployment of Standalone (SA) 5G networks has not finished yet. Several issues regarding the architecture, implementation and integration are not unified for different vendors, even for already standardized concepts. Vendors can interpret and implement the same feature differently, leading to compatibility issues both on the operational and on the end-user side. Moreover, there are a very limited number of User Equipment (UE) on the market at this point, especially for industrial purposes. On top of that, the existing ones are not completely reliable and are very expensive compared to 4G UEs or IEEE 802.11 UEs. Another critical challenge of 5G industrial integration is the compatibility with legacy network infrastructures, while 5G networks should meet the requirements of several new use cases.

The challenges presented are mainly technical in nature, but there are several more business-featured difficulties. In the case of an industrial 5G NPN, there will be a significant shift in the market ecosystem as the MNO comes to the industrial ecosystem as a new player. The state or some kind of frequency regulator organization will also play a crucial role in this ecosystem. In several countries – like in Hungary – industrial players cannot buy frequency from the state in contrast to countries such as Germany. [6] discusses this topic in more detail.

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Above all, probably the most critical issue with the 5G in general, not just NPNs is the overall price of such networks. The price of a base station, with pole, optical cabling, hardware cost, Core network, and UEs, is just too much compared to the not so reliable but significantly cheaper IEEE 802.11 solutions or wired network solutions. This can hold back the industry players and also research labs and universities to invest in 5G NPNs. The reduction of the 5G NPNs' overall price has to be one of the flagship goals of the cellular network industry.

In general there are several different type of NPNs described in 3GPP [4], [5]. Such solutions differ in network capabilities, performance and architecture. Some solutions only add extra radio resources with a shared central core. There are solutions with dedicated core and shared Radio Access Network (RAN), and also, there are completely dedicated solutions operating independently from the MNO public network infrastructure. With our 5G NPN implementation, we have designed and implemented a compact NPN solution that can meet the requirements of the industrial use cases and is very easy to deploy.

III. The NPN and the Demo

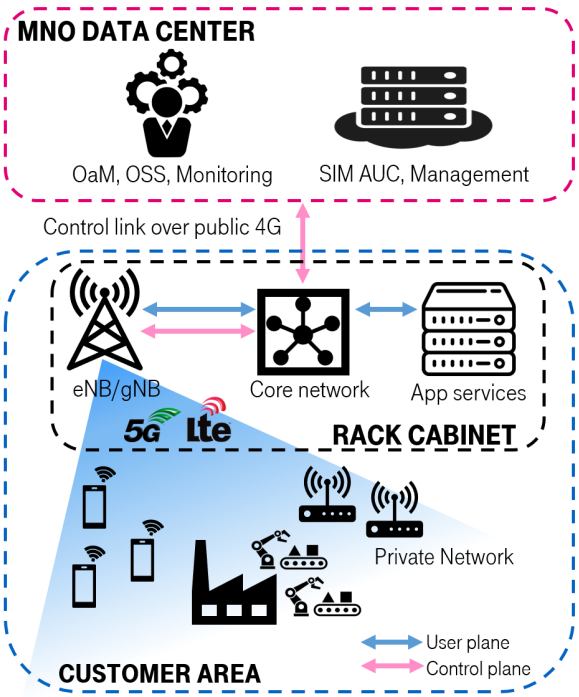

Fig. 1: High-Level design of the implemented NPN

Figure 1 presents the main concepts and high-level architecture of our 5G NSA NPN. It operates as independently as possible from MNOs public network with a dedicated Core network, RAN resources and SIM cards. It contains every network function which is inevitable for a cellular network except the SIM authentication, Operations Support System (OSS) and monitoring, which are still at the MNO Data Center due to state regulations. Our NPN implementation covers the functions highlighted in Figure 1 in the rack cabinet, so the RAN, the Core network, and some simple applications. The hardware elements are installed in a rack cabinet with wheels; its detailed description is presented in Figure 2. The rack contains in less than 10 units the whole Core network, RAN including 5G and 4G Indoor Radio Unit (IRU) and Baseband Unit (BBU), IP routing, Uninterruptible Power Supply (UPS), and Application server. Besides that, one 4G and one 5G indoor antenna were installed on the top of the rack, but it can be scaled up almost arbitrarily. On top of that very compact solution, we integrated a 4G management router responsible for the SIM authentication – providing the s6a interface – towards the MNO data center and provides remote management and monitoring. This 4G router connects to the MNO's public network via a Virtual Private Network (VPN) tunnel with an ordinary SIM card. There is no need for any cabling or hardware integration during the NPN deployment. It can operate with only mains electricity (230 Volts) input and nothing else.

Section I mentioned that the independence and dedicated network resources are fundamental attributes of NPNs. In our solution, public users cannot connect to this NPN as we separated this network on the PLMNID basis from the public network, and users can connect to it only with dedicated SIM cards provisioned by the MNO.

We cannot bring the NPN solution to the conference due to logistics challenges and frequency usage regulations, but the demonstration will include several video presentations. We will show how the actual NPN implementation looks, including the architectural design, hardware elements, and rack cabinet. We are going to present how an ordinary 5G capable UE can connect to this network with the dedicated SIM cards and the differences in network signaling compared to a regular public network connection in terms of network IDs and parameters on video. During the demo, real-time performance results will be presented, including latency, throughput, jitter and packet loss measurements. Currently, we are working on validating the capabilities of the NPN, but the initial results are very promising. We could achieve around 950 Mbps DL and 135 Mbps UL throughput with one UE, but with multiple devices, over 1 Gbps DL and over 200 Mbps UL traffic are easily possible. Figure 3 provides a brief introduction regarding the latency

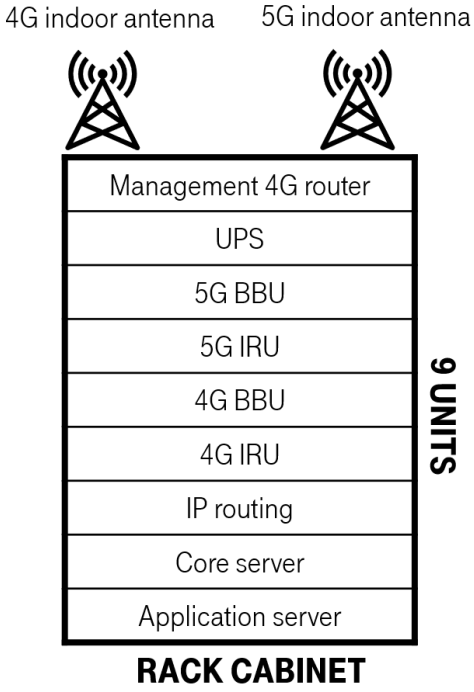

Fig. 2: Hardware elements of the implemented NPN

attributes of the 5G NPN. It provides Round-Trip-Time results between a UE and the Application Server presented on a Complementary Cumulative Distribution Function (CCDF) plot. 10000 UDP packets were generated with fixed packet size (40, 100, 200, 500, 1000 bytes) and fixed Inter-Packet-Gap. The results show that 90% (10^{-1}) of the packets arrived below 10 ms, and 99% (10^{-2}) of the packets arrived below 14 ms, respectively. These results look very promising for a 5G NSA network and open possibilities towards the adoption of latency-critical use-cases. However, further measurements are needed to provide a comprehensive report about the performance boundaries of the system with different UEs and traffic scenarios [7]. These extended measurement results will be introduced at the conference. We will demonstrate some fundamental use cases, such as the IP call between two 5G UEs via a virtual Private Branch eXchange (PBX) application installed on the application server and a media cloud application.

IV. Conclusion

The presented 5G NPN solution supported by a Hungarian MNO is perfectly suitable to demonstrate the final solution at a service level on-demand at the customer's site. This will give a demonstration opportunity and a competitive advantage, as you will be able to demonstrate the service on-site and eliminate deficiencies related to the use case

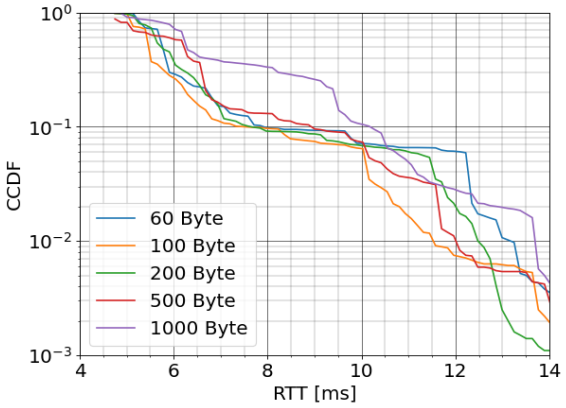

Fig. 3: First glance Round-Trip-Time results of the NPN between a UE and the Application Server

requirements very early. To summarize the advantages and novelty of our NPN solution, it is a very compact and portable 5G NPN and very easy to install. Moreover, as the NPN's building blocks and hardware elements are identical to the macro network's, there is no performance degradation. These attributes make our NPN an excellent candidate for research purposes and industrial usage also.

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