Demonstration of Digital Twins for 5G Connectivity in Industry 4.0

Published Version:
Contoli, C., Rossi, D., Tontini, G., Borsatti, D., Callegati, F. (2021). Demonstration of Digital Twins for 5G Connectivity in Industry 4.0. New York : IEEE [10.1109/NFV-SDN53031.2021.9665099].

Availability:
This version is available at: https://hdl.handle.net/11585/862054 since: 2022-02-21

Published:
DOI: http://doi.org/10.1109/NFV-SDN53031.2021.9665099

Demonstration of Digital Twins for 5G Connectivity in Industry 4.0

Chiara Contoli*, Daniele Rossi* Giacomo Tontini* Davide Borsatti†, Franco Callegati‡
*Centre for Industrial ICT Research - CIRI ICT - University of Bologna
†Department of Electrical, Electronic and Information Engineering - DEI - University of Bologna
‡Department of Computer Science and Engineering - DISI - University of Bologna

***Abstract*—In this demo we address the issue of the integration between 5G and industrial OT environments. We provide a concrete implementation of the 5G Asset Administrative Shell, a key concept proposed by the 5G Alliance for Connected Industries and Automation to promote fully integration between 5G and industrial domain. The proof of concept considers a NFV scenario where the virtual Network Function are orchestrated using Open Source Mano and the network characteristics adapt dynamically to the needs of data flows.**

***Index Terms*—Networks, Digital twin, 5G, Industry 4.0, Quality of Service.**

I. Introduction

The Industry 4.0 (I4.0) is bringing a significant innovations in the manufacturing industry and a major effect is the convergence of the Operation Technology (OT) and Information Technology (IT) ecosystems. On one side this innovation opens up novel scenarios such as the application of digital twins [1] but also poses new problems, such as cyber security threats and dependence on the quality of the communications.

5G promises faster and ubiquitous wireless communications, enhanced flexibility and efficiency, as well as new features such as the support of low latency, to the benefit of time-sensitive applications. For this reason the I4.0 is one of the vertical applications that should benefit from the advent of the 5G. In this scenario the 5G Alliance for Connected Industries and Automation (5G-ACIA) [2] is working to promote the application of the 5G technology to the industrial domain.

One of the issues that are considered by this consortium is the integration of 5G in the factory environment in particular with the OT. The *Asset Administration Shell* (AAS) paradigm, as proposed in [4] is the key concept to allow interoperability of building blocks of different nature or produced by different manufacturer into an Industry 4.0 environment. In [3] is discussed that also 5G components should be equipped with an AAS that allows their full integration in the factory environment.

The goal of this demo is to show a concrete implementation of this concept. It was developed in the framework of the *5GConnect* project, funded by Bi-Rex [5], one of the I4.0 competence centers created by the Italian government. *5GConnect* aims at showing real life application use cases of 5G in manufacturing and providing an effective AAS is key to achieve this goal.

This work was partially funded by the BI-REX Competence Center, under project 5GConnect.

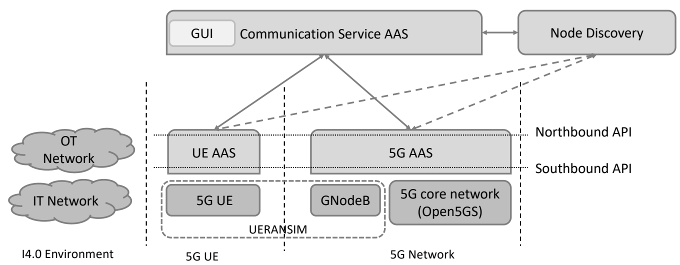

Fig. 1. 5G Service-based architecture comprising 5G User Equipment and 5G System AASs inspired by 5G-ACIA proposal.

II. System Architecture

The system architecture is depicted in Figure 1. There are three high level sub-systems: **IT and OT industrial network elements** that may be source and destination of the information flows, **5G User equipment (UE)** that is used as interface to send/receive the traffic flow over the mobile network, **5G Network** including access and core network for either control and data plane.

The OT and IT network are the networks existing in the factory and therefore depend on the specific location. In this case, for the sake of an effective demonstration, the OT network will be source of video streams, that must be sent with changing quality of service requirements.

UERANSIM [7] is an open source software bundle which includes either the UE (the 5G mobile phone or router) and the 5GnodeB, the base station that connects to the UEs on the radio channel (which is emulated via software in UERANSIM). It is a very flexible and easy to use component.

Finally the 5G core network is implemented exploiting the Open5GS [6], an open source full functional 5G implementation, including all the various services and supporting the full separation between control plane and data plane.

The whole deployment for the demo is in a cloud infrastructure managed by OpenStack. All the network components are implemented as Virtual Network Functions (VNFs) and are instantiated in a fully automated way with Open Source Mano (OSM) [8] which is the platform developed by ETSI to support its standardization activity related to Management and Orchestration of virtualized telecom infrastructures (the NFV-MANO standard).

Figure 1 ahows that the AAS are built hierarchically, with an AAS for the "network service" required by the application which works on top of two AASs, the former for the 5G UE, the latter for the 5G core network. The AAS are also virtualized, implemented as NodeJS microservices. It is worth noting that the implementation of these entities strictly depends on the type of physical or virtual device underneath; however the standardization of the interfaces does not alter the interaction with other entities, nor their behavior.

The interfaces exposed by the AASs enable monitoring and allow to control the state of the system. For instance they are able to: provide a summarized view of how many devices are connected, how many communication sessions have been established and dynamically change network capabilities on a per QoS-flow basics.

Considering that 5G components can be distributed in different nodes of the network, and multiple UEs can connect, a third architectural component has been designed: the ***node discovery***, that acts as a centralized registrar server where all the AAS of the system register and may dynamically discover which entities are currently active.

Last but not least, in order to ease the view and control of the system, a ***web dashboard*** is available, that continuously communicates with the other entities and allows to enable changes based on the needs.

III. Demonstration Walkthrough

The goal of this demo is twofold: demonstrate the fully automated deployment of the whole infrastructure, and then the integration on demand of 5G networking with the normal operations of the manufacturing plant. In practise the AAS will be exploited to adapt the network characteristics to the needs of individual data flow in a dynamic way, fully transparent to the end user. The demo will be shown through the GUI.

A. Demonstration Scenario

The demo considers the following scenario: in a manufacturing environment, a video monitoring system of a machine inside the production plant is connected to a 5G network for remote maintenance purpose. The video stream is encapsulated in a so called *PDU Session*, which is tunnel used by the 5G network to logically identify a data flow. We assume that the content of this video stream is not strictly necessary to provide the continuity of the production process, but may become very important in some specific situations.

Therefore there is no need to provide the maximum network quality to the video stream, which can be acceptable even with a coarse quality in normal operations. Nonetheless when required the video must be granted large bandwidth to achieve high quality and definition.

Our objective is to show that we are able to change the network requirements related to the PDU session which is devoted to transport the video stream. In this way, we are able to dynamically adapt the bandwidth of the PDU session based on application needs, and without affecting other PDU sessions transported in the network.

B. Demonstration Workflow

The demo starts with the demonstration of the automated deployment of the whole infrastructure using OSM. Then an Apache server is set up to play a pre-recorded video which exemplifies the source from the manufacturing environment.

One 5G UE is connected to the 5G antenna and via the GUI its AAS allows the configuration of PDU sessions with specific Quality of Service (QoS) characteristics.

Upon request the PDU session is established, with guaranteed bandwidth and a minimum latency threshold. Since in the proposed scenario the bandwidth used by the video stream must be as low as possible, through the GUI we indicate to the 5G system a limited/moderate bandwidth requirement.

A player with Adaptive Bit-Rate (ABR) [9] support is started, and the process is linked to the previously created communication interface related to the PDU session with the desired requirements. Thanks to the ABR algorithm, the video is immediately visible at a quality subject to the limit imposed by the current available bandwidth.

Through the dashboard in the GUI, it is possible to ask the AAS of the communication service that at some time a larger bandwidth is required for the video. Automatically the previous PDU session is tore down and a new one is created with the new QoS requirement.

The video player, except for a very limited period of time in which no data are received and the buffered ones are used, won't notice any connection failure as the communication interface is the same as before. It will simply start requesting video fragments at a gradually increasing quality, bringing the stream to the maximum possible resolution allowed by the new communication characteristics.

IV. Conclusions

In this demo we present an implementation of the Asset Administrative Shells for a 5G network applied to the industrial environment and demonstrate dynamic adaptation of the network characteristics to the needs of the data flows.

References

[1] Digital Twin and Asset Administration Shell Concepts and Application in the Industrial Internet and Industrie 4.0 - An Industrial Internet Consortium and Plattform Industrie 4.0 Joint Whitepaper - *https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/Digital-Twin-and-Asset-Administration-Shell-Concepts.html*

[2] *https://5g-acia.org*, visited on August 2nd, 2021.

[3] 5G Alliance for Connected Industries and Automation , "Using Digital Twins to Integrate 5G into Production Networks," 5G-ACIA White Paper, *https://5g-acia.org/whitepapers/using-digital-twins-to-integrate-5g-into-production-networks/*, February 2021.

[4] 2030 Vision for Industrie 4.0 *https://industrie40.isometric.site/\#/5d674e14c798d1000ebc57fe*

[5] *https://bi-rex.it/en/* visited on August 2nd, 2021.

[6] Open5GS *https://open5gs.org/*

[7] UERANSIM *https://github.com/aligungr/UERANSIM*

[8] Open Source Mano *https://osm.etsi.org/*

[9] Adaptive Bitrate Streaming *https://en.wikipedia.org/wiki/Adaptive_bitrate_streaming*