

Alma Mater Studiorum Università di Bologna  
Archivio istituzionale della ricerca

Demonstration of Digital Twins for 5G Connectivity in Industry 4.0

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

*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>

*Terms of use:*

Some rights reserved. The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>).  
When citing, please refer to the published version.

(Article begins on next page)

This is the final peer-reviewed accepted manuscript of:

**C. Contoli, D. Rossi, G. Tontini, D. Borsatti and F. Callegati, "Demonstration of Digital Twins for 5G Connectivity in Industry 4.0," *2021 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN)*, 2021, pp. 102-103.**

The final published version is available online at: <https://dx.doi.org/10.1109/NFV-SDN53031.2021.9665099>

Rights / License:

The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

*This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>)*

***When citing, please refer to the published version.***

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 shows 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](https://en.wikipedia.org/wiki/Adaptive_bitrate_streaming)