Harnessing Spatial Analysis for Next-Gen Industry 4.0 Connectivity Beyond 5G

R. Ušaj, L. Koršič, J. Sterle, R.Sušnik
INTERNET INSTITUTE Ltd
Ljubljana, Slovenia
rok.usaj@iinstitute.eu

***Abstract*—In data driven Industry 4.0 environments, efficient communication infrastructure is a prerequisite for achieving expected business defined goals. To ensure the communication infrastructure operates optimally at any time, constant performance monitoring is required, followed by the evaluation of the monitoring results and necessary measures taken. To achieve this goal, we propose a specific combination of continuous and on-demand monitoring processes, monitoring tool and a tool for spatial analysis. The solution comes as a Network Application, thus enabling further possibilities and improvements in relation to the company's IT system.**

Keywords—5G, Beyond 5G, Industry 4.0, spatial analysis, network monitoring, qMON

I. Introduction

The term Industry 4.0 is, according to the McKinsey & Company's definition, the next phase in the digitization of the manufacturing sector, driven by disruptive trends including the rise of data and connectivity, analytics, human-machine interaction, and improvements in robotics [1]. The final goal of Industry 4.0 are improved manufacturing environments, which do not refer only to improved productivity and better quality of the manufacturing process, but also to improved safety, security and satisfaction of the employees.

As Industry 4.0 processes are data driven, they inevitably rely on the network connectivity. Although various wired and wireless connectivity technologies can be employed, the Industry 4.0 is strongly associated with mobile networks, i.e., with 5G in particular [2, 3] since the Industry 4.0 concept matches perfectly with the advances introduced in 5G [4].

Industry 4.0 environments impose significant challenges in terms of 5G network operational performance and technological specifics. This can be clearly observed in specific indoor and outdoor facilities where certain radio propagation obstacles and the dynamics of the manufacturing process cause radio signal interference, interruptions, etc. Therefore, smart monitoring of radio conditions is of paramount importance in order to provide highly available and reliable communications required. The quality assurance Network Monitoring system (qMON), presented in the next section, can be of great help when addressing such challenges.

II. Monitoring 5G/B5G Networks

A. qMON overview

The quality assurance Network Monitoring System (qMON [5]) provides continuous and on-demand monitoring of multiple 5G and Beyond 5G (B5G) network Key Performance Indicators (KPI), radio coverage KPIs and service performance KPIs. Data collected and coupled with comprehensive data analytics and reporting tools enable real-time insight into the conditions/QoS (Quality of Service) available to UEs connected to the network. qMON capabilities are not limited to the mobile environments only, they can be also exercised in fixed networks, wireless networks, cloud environments, etc. The qMON monitoring equipment may be also mounted on a drone to provide vertical dimension of monitored parameters. As well, a video stream originating form the video-camera mounted on the drone may allow for additional post-analytics and root-cause analysis, e.g., identifying potential sources of interferences such as metal obstacles causing signal scattering, etc.

B. qMON arhitecture and its capabilities in scope of orchestration platforms

The qMON is designed and built as a Network Application, thus potentially able to be actively involved with 5G network operations. In turn, as the Network Application, it would be possible for it to automatically steer optimization of 5G network parameters in order to maintain required QoS. Otherwise, the application can still be used as a source of data for controlling Service Level Agreement commitments (24/7) providing various data analyses, reports and triggering alarms set by the customer (e.g., for critical parameters). To achieve this, the qMON Network Application is composed of multiple components: Agent probe (usually called qMON Agent), Network Monitoring component, Measurement Reference component, Agent-probes Management component, Analytics component and Video-Monitoring component.

Each of the qMON Network Application components run in its own container. The Network Application as a whole benefits from features provided by the deployment platform (or orchestrator, e.g., 5G-INDUCE platform [6]), and underlying Kubernetes-based infrastructure, i.e., simplified deployment, scalability, restoration mechanisms, etc.

C. Monitoring in Industry 4.0 environments

Continuous and on-demand monitoring of 5G/B5G network in industrial environments help at assuring high availability of (critical) communications which are inevitably required for the industrial processes to run properly (e.g., automated fork-lift operations). The monitoring process should include verifying both network connectivity and service availability for the customer to have complete information in order to maintain high availability of the business processes. Optimal data collection process includes continuous data collection process provided by qMON probes installed at fixed locations, and on-demand data collection process provided by qMON probes installed on drones.

III. Tools for Spatial Analysis

One of the most powerful visual analytical tool accompanied by qMON is a tool for spatial analysis which serves for presenting monitoring data in a 3D space, allowing for specific root cause analysis or just as an enhanced visual representation of KPIs (Fig. 1). Although there is no specific limitation considering which KPIs can be presented by this tool in 3D, it would be, in real world, most common to present parameters such as Reference Signal Received Power (RSRP), Received Signal Strength Indicator (RSSI), Signal to Interference & Noise Ratio (SINR), etc.

Fig. 1. Spatial visualization of a set of monitored values in a 3D map.

A. Architecture of the tool

The tool is part of qMON Analytic component (for the reference, see list of qMON components in section II.B.) and therefore it extends its original functionalities with 3rd spatial dimension, which, however, is only possible to be exploited in case monitoring data, acquired by qMON Monitoring sub-component, have been recorded and are available for all spatial dimensions. Fig. 2 depicts the architecture of the tool.

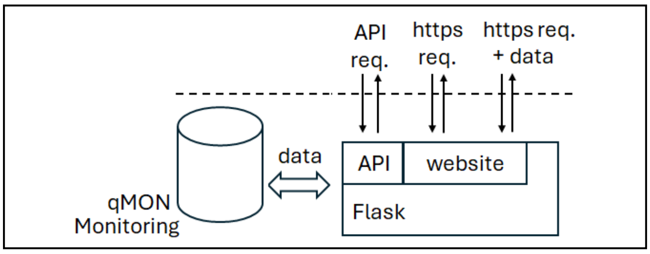

Fig. 2. Architecture of the tool for spatial analysis.

Main input to the tool are monitoring data the customer would like to analyse. Another important input to the tool are 3D maps allowing for spatial presentation of the monitoring data. Being part of the qMON, the tool for spatial analysis already contains interface towards the qMON Monitoring components where monitoring data are usually stored and can be therefore easily shared by the spatial analysis tool. Otherwise, monitoring data can be uploaded to the tool from any file containing data in requested format. Both options are also available for the customer via web portal, while the first option (i.e., acquiring data from qMON Monitoring) is also available via Application Programming Interface (API), thus allowing integration of the tool with 3rd party analytics and reporting software such as Grafana.

The spatial analysis tool run on the Flask server. The application has been developed in Python3, utilizing PYdeck library with the deck.gl for graphical manipulations.

B. Graphical user interface

Since the tool is intended for the visual analysis purposes, its output is a HTML based code ready to be presented in a web browser client. The output HTML file includes the representation of monitoring data within a 3D map. It allows a customer for further applying visual filters also being part of the tool, e.g., selecting specific data/KPI (e.g., RSRP, RSSI, etc.), limiting represented data to specific access technology and/or frequency band, limiting data representation to a single base station, etc. It is worth mentioning the tool allows for the animation of the data presented (based on the monitoring data time sequence, i.e., following absolute time of monitoring data recordings), thus allowing the customer for an analysis of dynamical phenomena.

IV. Conclusion

The proposed approach for network and services monitoring process for Industry 4.0 environments has been so far tested in multiple real environments of various industry verticals (manufacturing, logistics, telco). Considering business owners feedback, the proposed approach is perceived as very promising, which also includes benefits introduced by the virtualization/cloud-native approach, orchestration and Network Application concept. The latter, joined with 5G/B5G networks (i.e., global standard), is a potential cost optimization factor seen as a further opportunity for creating new and/or digitizing old services and thus expanding business. To a certain extent, this is already a trend in the industry/manufacturing vertical, which has the highest number of deployed 4G or 5G non-public networks comparing to other verticals [7].

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