Private 5G Networks for Connected Industries

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Executive Summary

This deliverable has been written as part of the work in the project Work Package (WP) 6 “Dissemination”, and reports on the 5G CONNI project dissemination and standardization activities achieved during the first period as well as the activities planned for the second half of the project. The deliverable also gives an updated exploitation plan for each project member.

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List of Acronyms

3GPP	3rd Generation Partnership Project
5G CONNI	5G for Connected Industries
AF	Application Function
ANI	Alpha Networks
API	Application Programming Interface
ATH	Athonet
AWS	Amazon Web Services
CEA	Commissariat à l'énergie atomique et aux énergies alternatives
COVID-19	Corona Virus Disease 2019
CPU	Central Processing Unit
E2E	End-to-End
EML	Edge Machine Learning
EU	European Union
GSP	Graph Signal Processing
HHI	Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute
IEEE	Institute of Electrical and Electronics Engineers
III	Institute for Information Industry
IoT	Internet of Things
IIoT	Industrial Internet of Things
KPI	Key Performance Indicator
LMS	Least Mean Squares
MEC	Multi-Access Edge Computing
NPN	Non-Private Networks
PDU	Packet Data Unit
QoS	Quality of Service
RAN	Radio Access Network (in 3GPP)
SA	Services and System Aspects (in 3GPP)
SGD	Stochastic Gradient Descent
SaaS	Software as a Service
TSC	Time Sensitive Communication
TSN	Time Sensitive Networking
TSP	Traffic Steering Policy
UAV	Unmanned Aerial Vehicle
UE	User Equipment
URLLC	Ultra-Reliable and Low Latency Communication
WP	Work Package

1 Introduction

The main objective of this deliverable is to report on the achieved dissemination, standardization, and exploitation activities during the first period of the project after a plan was presented in Deliverable D6.1, “Dissemination Plan & Project Website”. Furthermore, an updated exploitation plan for the second period of the project will be presented.

As the *status quo* for external dissemination and standardization was heavily impacted by the outbreak of the global COVID-19 pandemic, the dissemination plan presented in D6.1 could not be followed in every aspect. Nevertheless, the 5G CONNI consortium has adapted to the situation and leveraged alternative means like online conferences and special sessions. In the second period, the consortium will continue to disseminate in any way possible under the circumstances and is especially targeting open access journals and online special sessions.

2 Report on dissemination activities

The information about the 5G CONNI project is shared in two ways: through internal and external dissemination:

- *Internal dissemination*: In order to be able to share the main *intra*-project results with all involved partners, email distribution lists and a file sharing repository server were established. This enables active discussion between the project partners. Additionally, key project results were shared at partner-internal workshops.
- *External dissemination*: The consortium has actively participated in international private and public events, conferences and workshops, wherever the COVID-19 situation allowed it. In addition to traditional in-person events, several alternative dissemination means like online conferences or special sessions were leveraged. Relevant project news were shared through press releases and on the project web site, https://5g-conni.eu.

In the following sections, the specific dissemination activities during the first period of the project are described.

2.1 Internal dissemination

For internal dissemination, several resources are provided Fraunhofer HHI as project coordinator. A set of mailing lists has been created with a dedicated list for each WP and a general project-wide list for the whole consortium. These lists are used by the partners for reporting the status of the WP, arranging conference calls and for discussions on important issues.

All information, such as documents, deliverables, software, publications, research activity, obtained results and meeting minutes are stored on an internal and members-only access repository created for the project and hosted at Fraunhofer (https://owncloud.fraunhofer.de). Each member of the project was provided with an individual account and all the published content authored by the project members is stored to take trace of the activities. The repository is organized in folders dedicated to each WP and to managerial aspects.

Each WP leader organizes either bi-weekly or monthly (depending on the WP status) calls among the WP participants to organize the work and to monitor the status of both technical and non-technical aspects. The activities and main information relevant to all project participants are made available on the mailing lists and the call minutes are stored in the repository. In addition to the WP calls, monthly calls including all project partners are organized for exchanging the most important information. Finally, a monthly management call between the Taiwanese and European coordinators ITRI and Fraunhofer HHI was also set up.

Because of the COVID-19 pandemic, in-person meetings were not possible in 2020 and it is still not foreseeable when the consortium can get together to a general assembly in person again. For this reason, the general assemblies in August and December of 2020 were held as online events. Due to the time difference between Taiwan and Europe, the meetings were limited to half-day events, but with stringent scheduling and good cooperation between all partners, both meetings were successful, and all aspects could be discussed. A screenshot of the 2nd Virtual General Assembly in December 2020 can be seen in Figure 1.

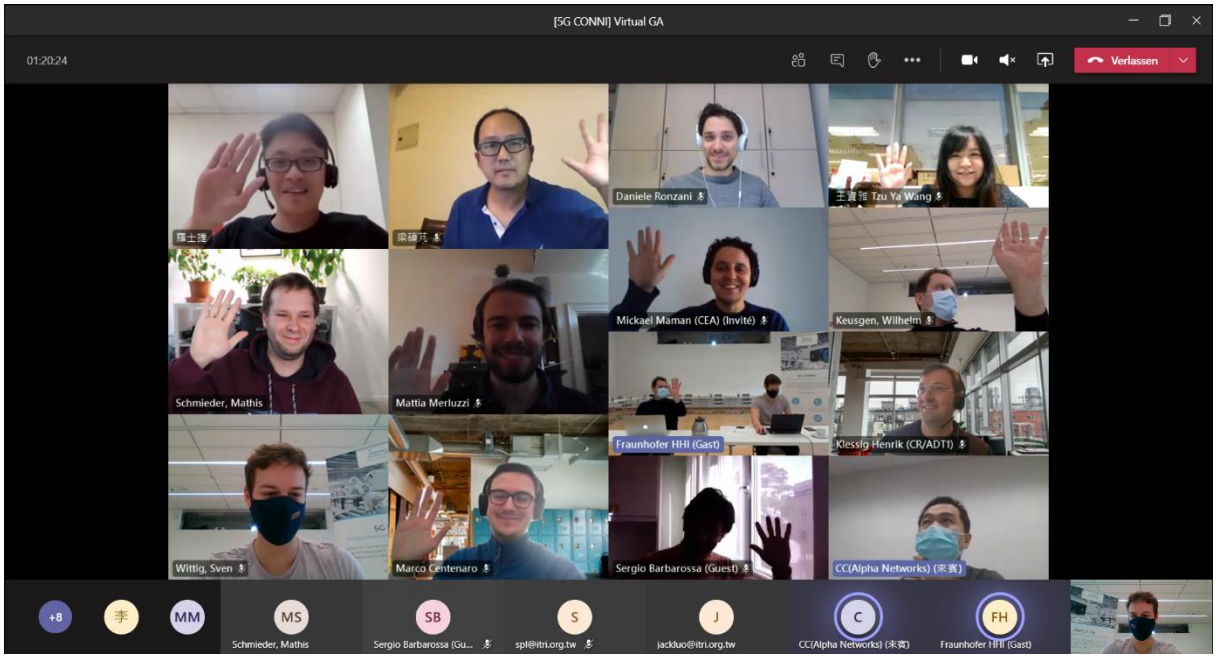

Figure 1: Screenshot of the 2nd Virtual General Assembly

2.1.1 Internal workshop at BOSCH

In addition to pro-actively initiated discussions, meetings and workshops between several stakeholders inside BOSCH, a major 2-day Industrial 5G training has been prepared for the entire BOSCH group. The training has been conducted in October 2020. More than 500 BOSCH associates and managers joined the training, which covered multiple topics including 5G fundamentals, use cases and their challenges and opportunities, industrial 5G details such as secure integration, as well as theoretical and practical insights about ongoing activities. 5G CONNI insights and results have been integrated in most of the topics and with this pro-actively disseminated into the entire BOSCH group. The training has been recorded and made available permanently through BOSCH's internal video platform.

2.2 External dissemination

External dissemination of the main project results was planned, besides through academic publication, via the project website, press releases, posters/leaflets, societies, exhibitions and industry events. Due to the outbreak of the COVID-19 pandemic, most of the planned exhibitions and Industry events, like the Mobile World Congress or 5G Global event, were cancelled in 2020 and 2021. Nevertheless, leaflets and roll-up posters to promote the 5G CONNI project were developed in the first months of the project and are displayed in Figures Figure 2 Figure 3. These press materials will be kept up-to-date with new project results in order to be used when face-to-face events will be possible again.

Despite the unusual circumstances for external dissemination, the 5G CONNI consortium shared project ideas and first results with both scientific and non-scientific audiences through press releases, conference and journal papers and by (co-)organizing several workshops and special sessions. The dissemination activities during the first project period will be described in the following sub-sections.

Figure 2: Roll-up poster prepared for exhibitions

Figure 3: Leaflet promoting 5G CONNI project

2.2.1 5G CONNI web site

A public web site was set up at the beginning of the project under the domain https://5g-conni.eu in order to obtain the broadest possible impact of the project results. Besides providing an overview of the key project ideas and goals, latest news, dissemination activities and deliverables are made available to the general public. During the first period of the project, five news entries about the project, organized workshops and the Free-to-access Open 5G Core were published. Fraunhofer HHI is hosting the web site and is planning on keeping it open at least three years after the project end. A screenshot of the project web site can be seen in Figure 4.

2.2.2 Articles and Press Releases

After the official project announcement at the EU-Taiwan 5G / Beyond 5G Workshop in Taipei, the launch of the project was announced via a press release by the coordinator HHI. Furthermore, Athonet announced a turning point for the 5G cellular industry, that is, an open 5G core network platform which allows anybody, anywhere in the world, to bring up a 5G network for free by simply connecting a radio access network to Amazon Web Services (AWS) over an Internet connection. Mobile operators, radio vendors, device manufacturers, applications developers and enterprises can accelerate their 5G deployments on a free-to-use SaaS environment on AWS. More information can be found here: https://www.linkedin.com/posts/athonet_5g-private5g-bubblecloudrevolution-activity-6709005862251335680-O_Ap

The consortium plans to disseminate further updates on the concepts, objectives and achievements of the project as press releases.

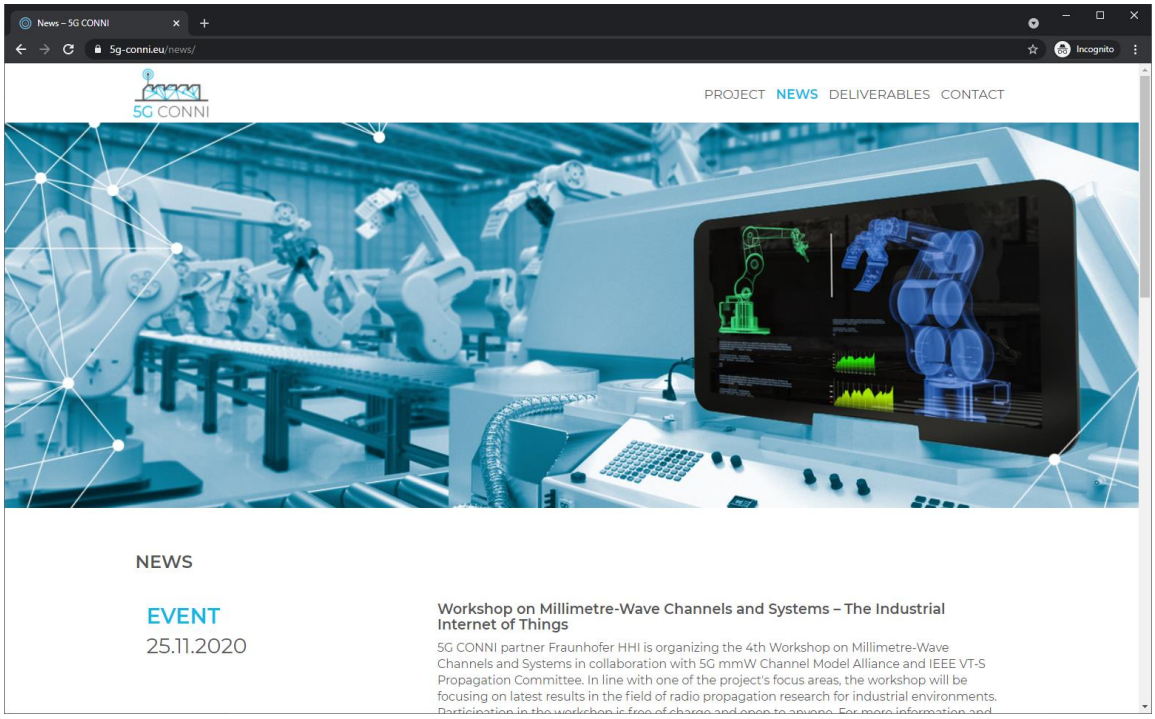

Figure 4: Screenshot of the project web site

2.2.3 Other external dissemination

Athonet hosted the UPTIME conference, held on January 27, 2021 at Villa Marconi, Bologna, Italy, where Tier-1 operators, vendors, end users, and academics met online for discussing the evolution of private mobile networks. A dedicated session was hosted for EU funded projects where 5G-CONNI was presented and discussed.

As most exhibitions are still cancelled, the project partners started to identify alternative means of dissemination to the general non-scientific public. For example, the consortium plans to showcase a virtual booth at the Small Cells World Summit 2021 (https://www.small-cells.world/), which will be held as a virtual online exhibition.

2.3 Scientific publications

The 5G CONNI partners have the ambition to generate a highly visible and impacting footprint of their research outcomes in the scientific community. The main KPI that the project is using to measure this impact is in the form of publications in journals and at best-in-class conferences, as well as through speeches, tutorials, etc.

Task 6.1 covers theses dissemination activities. So far, the 5G CONNI partners have published six scientific international conferences papers and six scientific journal paper. The consortium also participated in one keynote, two invited talks, four tutorials and a summer school and organized five workshops.

The details are provided in the following subsections.

2.3.1 Scientific conferences

The 5G CONNI consortium has actively disseminated project results at international conferences, workshops, and EU commission-specific events. The six scientific international conferences papers are:

1. **"Beyond 5G Private Networks: the 5G CONNI Perspective"** by E. Calvanese Strinati, T. Haustein, M. Maman, W. Keusgen, S. Wittig, M. Schmieder, S. Barbarossa, M. Merluzzi, H. Klessig, F. Giust, D. Ronzani, S.-P. Liang, J. S.-J. Luo, C.-Y. Chien, J.-C. Huang, J.-S. Huang, T.-Y. Wang, published at 2020 IEEE Globecom Workshops, Taipei, Taiwan, 2020, DOI: 10.1109/GCWkshps50303.2020.9367460

   Abstract

   Future Smart Factories will leverage Industry 4.0 and 5G technology to increase both flexibility and efficiency of manufacturing processes, thus ensuring global competitiveness of industrial manufacturing. 5G technologies such as network slicing may accommodate industrial applications in public networks, while Private 5G Networks, operating locally and being highly optimized towards specific applications, may require disruptive technologies to meet the specific and challenging industrial use cases requirements. The 5G CONNI Europe-Taiwan project investigates innovative solutions for Private 5G and beyond Network. This includes the definition of new architectures and measurements tools as well as, the development of innovative technologies and their enabling components in the context of mobile edge assisted URLLC. Building on the premise of Private 5G Networks, the 5G CONNI project will offer an unprecedented integrated end-to-end 5G testing network for testing specifically industrial applications in accordance with updated 5G standardization specifications. The 5G CONNI project will validate its innovative and technologically advanced solutions and components with a real-field cross-continental end-to-end industrial Private 5G Network demonstration between two interconnected industrial manufacturing sites in Taiwan and in Europe.

2. **"Dynamic Resource Allocation for Wireless Edge Machine Learning with Latency And Accuracy Guarantees"** by M. Merluzzi, P. D. Lorenzo and S. Barbarossa (SAP), published at ICASSP 2020 - 2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Barcelona, Spain, 2020, DOI: 10.1109/ICASSP40776.2020.9052927.

   Abstract

   In this paper, we address the problem of dynamic allocation of communication and computation resources for Edge Machine Learning (EML) exploiting Multi-Access Edge Computing (MEC). In particular, we consider an IoT scenario, where sensor devices collect data from the environment and upload them to an edge server that runs a learning algorithm based on Stochastic Gradient Descent (SGD). The aim is to explore the optimal tradeoff between the overall system energy consumption, including IoT devices and edge server, the overall service latency, and the learning accuracy. Building on stochastic optimization tools, we devise an algorithm that jointly allocates radio and computation resources in a dynamic fashion, without requiring prior knowledge of the statistics of the channels, task arrivals, and input data. Finally, we test our algorithm in the specific case the edge server runs a Least Mean Squares (LMS) algorithm on the data acquired by each sensor device.

3. **"Dynamic Resource Optimization and Altitude Selection in Uav-Based Multi-Access Edge Computing"** by F. Costanzo, P. D. Lorenzo and S. Barbarossa (SAP), published at ICASSP 2020 - 2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Barcelona, Spain, 2020, DOI: 10.1109/ICASSP40776.2020.9053594.

Abstract

The aim of this work is to develop a dynamic optimization strategy to allocate communication and computation resources in a Multi-access Edge Computing (MEC) scenario, where Unmanned Aerial Vehicles (UAVs) act as flying base station platforms endowed with computation capabilities to provide edge cloud services on demand. Hinging on stochastic optimization tools, we propose a dynamic algorithmic framework that minimizes the overall energy spent by the system, while imposing latency constraints, and optimizing the altitude of the UAV in an online fashion. The method does not require a priori knowledge of channels and/or task arrival statistics. Numerical results illustrate the advantages of the proposed approach.

4. **"Energy Efficient Edge Computing: When Lyapunov Meets Distributed Reinforcement Learning"** by M. Sana, M. Merluzzi, N. di Pietro, E. Calvanese Strinati (SAP and CEA), accepted for publication at IEEE International Conference on Communications (ICC) Workshops 2021

Abstract

In this work, we study the problem of energy-efficient computation offloading enabled by edge computing. In the considered scenario, multiple users simultaneously compete for limited radio and edge computing resources to get offloaded tasks processed under a delay constraint, with the possibility of exploiting low power sleep modes at all network nodes. The radio resource allocation takes into account inter- and intra-cell interference, and the duty cycles of the radio and computing equipment have to be jointly optimized to minimize the overall energy consumption. To address this issue, we formulate the underlying problem as a dynamic long-term optimization. Then, based on Lyapunov stochastic optimization tools, we decouple the formulated problem into a CPU scheduling problem and a radio resource allocation problem to be solved in a per-slot basis. Whereas the first one can be optimally and efficiently solved using a fast iterative algorithm, the second one is solved using distributed multi-agent reinforcement learning due to its non-convexity and NP-hardness. The resulting framework achieves up to 96.5 % performance of the optimal strategy based on exhaustive search, while drastically reducing complexity. The proposed solution also allows to increase the network's energy efficiency compared to a benchmark heuristic approach.

5. **"Dynamic Resource Optimization for Adaptive Federated Learning at the Wireless Network Edge"** by P. Di Lorenzo, C. Battiloro, M. Merluzzi, S. Barbarossa (SAP), accepted for publication at IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) 2021

Abstract

The aim of this paper is to propose a novel dynamic resource allocation strategy for energy-efficient federated learning at the wireless network edge, with latency and learning performance guarantees. We consider a set of devices collecting local data and uploading processed information to an edge server, which runs stochastic gradient descent (SGD) to perform distributed learning and adaptation. Hinging on Lyapunov stochastic optimization tools, we dynamically optimize radio parameters (i.e., set of transmitting devices, transmit powers) and computation resources (i.e., CPU cycles at devices and at server) in order to strike the best trade-off between energy, latency, and performance of the federated learning task. The general framework is then customized

to the case of federated least mean squares (LMS) estimation. Numerical results illustrate the effectiveness of our strategy to perform energy-efficient, low-latency, federated machine learning at the wireless network edge.

6. **"Online Learning of Time-Varying Signals and Graphs"** by S. Sardellitti, S. Barbarossa, P. Di Lorenzo (SAP), accepted for publication at IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) 2021

   Abstract

   The aim of this paper is to propose a method for online learning of time-varying graphs from noisy observations of smooth graph signals collected over the vertices. Starting from an initial graph, and assuming that the topology can undergo the perturbation of a small percentage of edges over time, the method is able to track the graph evolution by exploiting a small perturbation analysis of the Laplacian matrix eigendecomposition, while assuming that the graph signal is bandlimited. The proposed method alternates between estimating the time-varying graph signal and recovering the dynamic graph topology. Numerical results corroborate the effectiveness of the proposed learning strategy in the joint online recovery of graph signal and topology.

2.3.2 Scientific Journals

In addition, contributions to scientific journals are a suitable means to disseminate mature and substantial results of the 5G CONNI consortium with great visibility in the scientific community. A list of the six published targeted journal papers is given in the following:

1. **"Dynamic Computation Offloading in Multi-Access Edge Computing via Ultra-Reliable and Low-Latency Communications"** by M. Merluzzi, P. D. Lorenzo, S. Barbarossa and V. Frascolla (SAP), published in IEEE Transactions on Signal and Information Processing over Networks, vol. 6, pp. 342-356, 2020, DOI: 10.1109/TSIPN.2020.2981266.

   Abstract

   The goal of this work is to propose an energy-efficient algorithm for dynamic computation offloading, in a multi-access edge computing scenario, where multiple mobile users compete for a common pool of radio and computational resources. We focus on delay-critical applications, incorporating an upper bound on the probability that the overall time required to send the data and process them exceeds a prescribed value. In a dynamic setting, the above constraint translates into preventing the sum of the communication and computation queues' lengths from exceeding a given value. Ultra-reliable low latency communications (URLLC) are also taken into account using finite block-lengths and reliability constraints. The proposed algorithm, based on stochastic optimization, strikes an optimal balance between the service delay and the energy spent at the mobile device, while guaranteeing a target out-of-service probability. Starting from a long-term average optimization problem, our algorithm is based on the solution of a convex problem in each time slot, which is provided with a very fast iterative strategy. Finally, we extend the approach to mobile devices having energy harvesting capabilities, typical of Internet of Things scenarios, thus devising an energy efficient dynamic offloading strategy that stabilizes the battery level of each device around a prescribed operating level.

2. **"Topological Signal Processing Over Simplicial Complexes**" by S. Barbarossa and S. Sardellitti, published in IEEE Transactions on Signal Processing, vol. 68, pp. 2992-3007, 2020, DOI: 10.1109/TSP.2020.2981920

   Abstract

   The goal of this paper is to establish the fundamental tools to analyze signals defined over a topological space, i.e. a set of points along with a set of neighborhood relations. This setup does not require the definition of a metric and then it is especially useful to deal with signals defined over non-metric spaces. We focus on signals defined over simplicial complexes. Graph Signal Processing (GSP) represents a special case of Topological Signal Processing (TSP), referring to the situation where the signals are associated only with the vertices of a graph. Even though the theory can be applied to signals of any order, we focus on signals defined over the edges of a graph and show how building a simplicial complex of order two, i.e. including triangles, yields benefits in the analysis of edge signals. After reviewing the basic principles of algebraic topology, we derive a sampling theory for signals of any order and emphasize the interplay between signals of different order. Then we propose a method to infer the topology of a simplicial complex from data. We conclude with applications to traffic analysis over wireless networks and to the processing of discrete vector fields to illustrate the benefits of the proposed methodologies.

3. **"Topological Signal Processing: Making Sense of Data Building on Multiway Relations**" by S. Barbarossa and S. Sardellitti (SAP), published in IEEE Signal Processing Magazine, vol. 37, no. 6, pp. 174-183, Nov. 2020, DOI: 10.1109/MSP.2020.3014067.

   Abstract

   Uncovering hidden relations in complex data sets is a key step to making sense of the data, which is a hot topic in our era of data deluge. Graph-based representations are examples of tools able to encode relations in a mathematical structure enabling the uncovering of patterns like clusters and paths. However, graphs only capture pairwise relations encoded in the presence of edges, but there are many forms of interaction that cannot be reduced to pairwise relations. To overcome the limitations of graph-based representations, it is necessary to incorporate multiway relations. In this article, we exploit tools from algebraic topology to handle multiway relations. Algebraic topology is a branch of mathematics that uses tools from abstract algebra to study a topological space, that is, a set of points, along with a set of neighborhoods. More specifically, we illustrate topological signal processing (TSP), a framework encompassing a class of methods for analyzing signals defined over a topological space. Given its generality, TSP incorporates graph signal processing (GSP) as a particular case. After motivating the use of topological and geometrical methods for detecting patterns in the data, we present the signal processing tools based on algebraic topology and then illustrate their advantages with respect to graph-based methodology.

4. **"Dynamic Resource Optimization for Decentralized Estimation in Energy Harvesting IoT Networks"** by C. Battiloro, P. Di Lorenzo, P. Banelli and S. Barbarossa (SAP), published in IEEE Internet of Things Journal, DOI: 10.1109/JIOT.2020.3046383.

Abstract

We study decentralized estimation of time-varying signals at a fusion center, when energy harvesting sensors transmit sampled data over rate-constrained links. We propose dynamic strategies to select radio parameters, sampling set, and harvested energy at each node, with the aim of estimating a time-varying signal while ensuring: i) accuracy of the recovery procedure, and ii) stability of the batteries around a prescribed operating level. The approach is based on stochastic optimization tools, which enable adaptive optimization without the need of apriori knowledge of the statistics of radio channels and energy arrivals processes. Numerical results validate the proposed approach for decentralized signal estimation under communication and energy constraints typical of Internet of Things (IoT) scenarios.

5. **"6G networks: Beyond Shannon towards semantic and goal oriented-communications"** by E. Calvanese Strinati and Sergio Barbarossa (CEA and SAP), accepted for publication in Computer Networks (Elsevier), vol. 190, May 2021

Abstract

The goal of this paper is to promote the idea that including semantic and goal-oriented aspects in future 6G networks can produce a significant leap forward in terms of system effectiveness and sustainability. Semantic communication goes beyond the common Shannon paradigm of guaranteeing the correct reception of each single transmitted bit, irrespective of the meaning conveyed by the transmitted bits. The idea is that, whenever communication occurs to convey meaning or to accomplish a goal, what really matters is the impact that the received bits have on the interpretation of the meaning intended by the transmitter or on the accomplishment of a common goal. Focusing on semantic and goal-oriented aspects, and possibly combining them, helps to identify the relevant information, i.e. the information strictly necessary to recover the meaning intended by the transmitter or to accomplish a goal. Combining knowledge representation and reasoning tools with machine learning algorithms paves the way to build semantic learning strategies enabling current machine learning algorithms to achieve better interpretation capabilities and contrast adversarial attacks. 6G semantic networks can bring semantic learning mechanisms at the edge of the network and, at the same time, semantic learning can help 6G networks to improve their efficiency and sustainability.

6. **"Wireless Edge Machine Learning: Resource Allocation and Trade-offs"** by M. Merluzzi, P. Di Lorenzo and S. Barbarossa (SAP), published in IEEE Access, DOI: 10.1109/ACCESS.2021.3066559.

Abstract

The aim of this paper is to propose a resource allocation strategy for dynamic training and inference of machine learning tasks at the edge of the wireless network, with the goal of exploring the trade-off between energy, delay and learning accuracy. The scenario of interest is composed of a set of devices sending a continuous flow of data to an edge server that extracts relevant information running online learning algorithms, within the emerging framework known as Edge Machine Learning (EML). Taking into account the limitations of the edge servers, with respect to a cloud, and the scarcity of resources of mobile devices, we focus on the efficient allocation of radio (e.g., data rate, quantization) and computation (e.g., CPU scheduling) resources, to strike the best trade-off between energy consumption and quality of the EML service, including service end-to-end (E2E) delay and accuracy of the learning task. To this aim, we propose two different dynamic strategies: (i) The first method aims to minimize the system energy

consumption, under constraints on E2E service delay and accuracy; (ii) the second method aims to optimize the learning accuracy, while guaranteeing an E2E delay and a bounded average energy consumption. Then, we present a dynamic resource allocation framework for EML based on stochastic Lyapunov optimization. Our low-complexity algorithms do not require any prior knowledge on the statistics of wireless channels, data arrivals, and data probability distributions. Furthermore, our strategies can incorporate prior knowledge regarding the model underlying the observed data, or can work in a totally data-driven fashion. Several numerical results on synthetic and real data assess the performance of the proposed approach

2.3.3 Workshops and special session organization

The 5G CONNI consortium achieved publicity not only through dissemination of scientific publications, but also through the organization (where possible jointly with other H2020 and Taiwan projects) of workshops, special sessions, industrial seminars and panels at international top ranked conferences and events. The main intention was to disseminate the project vision and results at large, targeting different audiences from academia and research, to industry and vertical markets operators, to institutional policy makers and standardization bodies. The main goal of such events is twofold. First, the goal is to exchange with targeted audiences on 5G CONNI vision, results and achievements by presenting and showing project results also (when possible) with the support of demos, and exchange ideas not only with other projects but also with the relevant industrial stakeholders. The second goal is to establish an ecosystem of potential audiences for future exploitations of the project results.

The consortium has organized the 2nd IEEE Globecom workshop on Future wireless access for Industrial IoT (FutureIIoT) in Taipei, Taiwan, on December 7, 2020. (https://globecom2020.ieee-globecom.org/workshop/ws-02-future-wireless-access-industrial-iot-futureiiot-enabling-industry-40-revolution). During this workshop, three keynotes and 12 paper contributions were presented.

HHI organized a workshop on Radio Channel Measurement and Modelling for the Industrial Internet of Things, in collaboration with the 5G mmWave Channel Model Alliance and IEEE VT-S Propagation Committee in conjunction with the IEEE VTC 2020-Fall conference. During this session, four speakers from Rohde & Schwarz, Ericsson, NIST and TU Braunschweig presented their views on industrial channel measurements and modelling from different points of view, followed by a lively discussion with the audience. More than 30 people attended this online session.

CEA participated in several keynotes, talks or tutorials:

- One keynote in IEEE CAMAD 2020 on 6G and industry 4.0 (https://camad2020.ieee-camad.org/2020/09/10/announcing-speakers/)
- Two invited talks on “6G: the next frontier of research” in 2nd 6G Wireless Summit 2020, and “When cloud meets 6G”, 5G Italy
- Two tutorials on “ When Clouds meet 6G: the academic, industrial and standard perspective” in EUCNC 2020 conference (https://www.eucnc.eu/2019/www.eucnc.eu/tutorials/tutorial-2/index.html) and on “6G: the next frontier, Academic, Industrial and Standard Perspective” in IEEE CCNC (https://ccnc2020.ieee-ccnc.org/program/tutorials#tut-01)
- One industrial seminar on “When clouds meet 6G: the academic, industrial and standard perspectives” in IEEE GLOBECOM 2019 (https://globecom2019.ieee-globecom.org/program/industry-program/industry-tutorialsseminars#its-08)
- Organization of 13th International Workshop on Evolutional Technologies & ecosystems for Beyond 5G and 6G (WDN-5G&6G) in conjunction to the IEEE WCNC 2020

conference (https://wcnc2020.ieee-wcnc.org/workshop/13th-international-workshopevolutional-technologies-ecosystems-beyond-5g-and-6g-wdn-5g6g)

- IEEE ICC Cloud and energy efficiency workshop (https://icc2020.ieee-icc.org/workshop/ws-18-workshop-cloud-technologies-andenergy-efficiency-mobile-communication-networks-cleen)
- First 6G summer school in como Lake on the 20th to 24th of July 2020 (https://lakecomoschool.org/)
- One tutorial on "6G: The next Frontier : The goal oriented wireless semantic communications revolution" in IEEE Consumer Communications & Networking Conference 2021 (https://ccnc2021.ieee-ccnc.org/program/tutorials#6g)

Athonet hosted UPTIME event to The Private 5G & LTE World Community Conference the 27th/28th January 2021 at Villa Griffone, Italy. The aim of the event was to look forward to the next decade of Private 5G with abundant shared and unlicensed spectrum for deployment for end-user Industries, mobile network operators, specialist operators, cloud hyperscalers, and device manufacturers.

The project has submitted a workshop proposal at EUCNC 2021 on 5G and Beyond Mobile Communication Networks for the Industrial Internet of Things (IIoT).

The project is planning to participate in the Small Cells World Summit 2021 (virtual event). (https://www.smallcells.world/) where a speech in the Industry 4.0 session will be given and a virtual booth to display our project achievements will be set up.

2.4 Standardization activities

Besides sharing project results with the academic community, the 5G CONNI consortium is actively monitoring the progress and outcome of standardization bodies working on topics relevant to the project. The focus lies on activities within 3GPP, ETSI MEC and PLUGTESTS. Several active work and study items with relevance to the topics in 5G CONNI were identified and are monitored. Where possible, the consortium tries to push the main results coming out of the project into standards. In the following sub-sections, the specific activities in each forum will be described.

2.4.1 ETSI MEC

The ETSI multi-access edge computing (MEC) industry specification group (ISG) aims at creating a standardized, open IT service environment which allows the efficient and seamless integration of applications from vendors, service providers, and third-parties at the edge of the radio access network. The potential of MEC platforms for an Industry 4.0 scenario entailing Internet of Things (IoT) traffic exchange, which is the core of the 5G CONNI project, is tremendous, as these edge servers and their capabilities are crucial enablers of low-latency applications and a guarantee of user-plane traffic confidentiality.

In this context, Athonet provided two contributions (MEC(20)000308 and MEC(20)000444) for the ETSI MEC033 – IoT API specifications, which were accepted in MEC#23 (Sep. 2020) and MEC#24 (Dec. 2020), respectively. The contributions deal with the IoT service description and the data model that will be manipulated by the RESTful APIs. Furthermore, Athonet has been following the regular meetings of ETSI MEC ISGto track the ongoing standardization activities.

2.4.2 3GPP

Several ongoing Release 17 work and study items in 3GPP RAN are dealing with topics relevant to this project, including unlicensed access, dynamic spectrum sharing, edge networks and flexible local area data networks. Two items were identified to be of special relevance to the 5G CONNI project: *Management of Non-Public-Networks* is a 3GPP Release 17 work item

that defines management requirements for and roles in non-public networks (NPN), and specifies deployment scenarios, including those in factories. Special attention is given to provisioning and exposure of management functions, services and data. These topics are well aligned with the activities in work package 2 of the 5G CONNI project.

Furthermore, the 3GPP Release 17 study item *Study on enhanced support of NPN* focuses on the credential and subscription handling in NPN. Onboarding and provisioning procedures and entities handling the subscription will be defined in this study item. As these topics are very relevant to the 5G CONNI project, the progress is being followed.

Although no specific contributions to 3GPP are planned yet, the consortium is following the progress and keeps discussing where results could be leveraged in standardization.

The consortium is also tracking 3GPP activities in the SA topic group where a contribution for core network enhancements was already submitted. The contribution proposes conclusions and a way forward for Key Issue #2, UE-UE TSC communication, with three main solutions. Take the solution which PCF determines impacts to PDU Sessions based on QoS requirements and traffic description information provided by the AF (or TSN AF) or UEs and/or dynamic policies. Also, the forwarding process for the UE-UE TSC traffic can rely on UPF implementation or be determined by the SMF using the UEs PDU Session attributes, the TSC PDU service type, and traffic filtering information.

2.4.3 IEEE

Starting in 2020, HHI has been actively involved in the setup of a working group developing a standard recommended practice for the validation of radio channel sounders up to millimeter-wave frequencies. The goal of this activity is to establish a standard for the performance assessment of channel sounders, facilitating comparability of research results between different technical realizations, research groups and measurement campaigns. This will help in increasing the validity and impact of results obtained in adherence to the standard, for example by allowing to pool data for statistical evaluation. In February 2021, the working group was officially established as WG P2982 of the IEEE Standards Association. Multiple employees of HHI with 5G CONNI involvement are participating in the group, also filling the position of vice chair. This activity has also enabled a more targeted dissemination of the radio channel measurement activities in 5G CONNI, leading to the organization of multiple topical workshops and special sessions at international conferences.

As part of its ongoing activities in 5G CONNI WP3, HHI is planning to contribute to the newly developed standard in the areas of performance metric definition, conducted verification and OTA verification of angle-of-arrival measurements.

2.4.4 Additional industrial fora

In addition to the standardization bodies, consortium members are also participating at industry alliances. For example, Athonet is following the activities of 5G-ACIA and foresees a more in-depth collaboration with Bosch in such an industry alliance.

Furthermore, the results of the radio channel measurements in work package 3 will be shared with appropriate channel modelling partners like 3GPP or ITU, and with local regulatory bodies, where applicable.

3 Updated Exploitation plans

In the following period of the project, the consortium is planning on continuing and intensifying the dissemination of project results. As the work packages are progressing, more and more results are generated that can be disseminated to both scientific and non-scientific audiences.

Especially the output of work packages 2 and 3 will be highly interesting for the general public and several publications are planned.

As an improvement of the global COVID-19 situation is still not foreseeable, the consortium will continue to focus on online events and open access journals as main means for dissemination. Several workshops and special sessions are already being planned and discussions about participation in online fares are going on.

Several partners are planning to prepare invention disclosures based on the work done in the 5G CONNI project.

3.1 Partner Update

In the following, every partner will give an update on their planned dissemination activities within the next period of the 5G CONNI project.

3.1.1 Alpha Networks

Alpha Networks will continue developing RAN for 5G CONNI project. ANI has developed gNodeB and CPE prototype, and the RAN prototype has been deployed at 5G CONNI Taiwan demo site. In the following period of 5G CONNI project, ANI will optimize RAN to fulfill use case requirement.

3.1.2 Athonet

Athonet will benefit from the results of the 5G CONNI project in several ways. The integration/interoperability with other consortium partners will foster the development of a top-level virtualized solutions for 5G connectivity. Moreover, the project pilots will promote the adoption of private deployments of 5G mobile networks, thus increasing the awareness and business opportunities created by this technology for industrial applications. This trend will eventually accelerate the corporate market growth.

3.1.3 BOSCH

Up until now, BOSCH has been following the initially planned exploitation plan and has already achieved a solid understanding of the operation and maintenance of private 5G networks, their different architectures, the concerns and requirements of operator models and IT security requirements. The results and insights have pro-actively been transferred into various BOSCH divisions for further consideration and innovation.

5G CONNI continues to be one of the major 5G activities at BOSCH with a large anticipated impact in several ways during the second project period. This includes exploiting the deep understanding of operator models in various settings of the more than 200 BOSCH plants in terms of regulations, stakeholder constellations and architectural requirements. This along with secure integration concepts will accelerate the wide-spread roll-out of interconnected private 5G networks across the entire BOSCH group. Also, innovative algorithms for 5G-connected robots are actively patented and implemented during the course of the project, which are expected to lead to advantageous 5G-based automation products, as well as, to facilitate the continued identification and evaluation of new business opportunities in the context of 5G-enabled factories.

3.1.4 CEA

CEA has followed the initial exploitation plans until now. On the one hand, the outcomes of CEA's investigations on how to manage a private 5G network (orchestration and mobile edge computing), having the specific targets of improving QoS (reliability, latency, availability...) in future 5G networks, will be protected through patents whenever applicable, and they will be disseminated through publications in high-rank international conferences, journals, and work-

shops. A patent and a conference paper are in preparation on the topics of network orchestration, all related to 5G CONNI activities. CEA will continue to promote the researches carried in the project in several tutorials and workshops. On the other hand, CEA aims at the integration of some of the most promising concepts of multiple access in future communication devices with the objective to address a wide range of services. The results of 5G CONNI will contribute to enhance the offers of CEA to industrial partners in search of wireless URLLC solutions for future applications.

3.1.5 Chunghwa Telecom

CHT has followed the initial exploitation plans until now. CHT contributes bump-in-the-wire 5G SA MEC for the Taiwanese testbed of the 5G-CONNI project. CHT has developed a 5G SA MEC prototype and the monitoring mechanism of VNF on the ECoreCloud platform and integrated Process Diagnostics using Augmented Reality application. These results are implemented on ITRI's IMTC demo site and exhibited in IEEE Globecom 2020 event. CHT will continue to develop bump-in-the-wire 5G SA MEC to satisfy the requirements of use cases for the 5G-CONNI project. Industrial applications will also be managed by the ECC platform for monitoring. CHT will continue to observe edge computing development and propose suitable 5G solutions for industrial applications.

3.1.6 HHI

HHI will continue to provide the necessary tools for the project-internal dissemination, specifically the mailing lists and repository server, and will also continue hosting the project web site. The measurement results of WP3 will be used in two conference paper that will be submitted to conferences like EuCAP or IEEE VTC, and in at least one IEEE Access journal paper. Furthermore, the channel parameters will be shared with the appropriate standardization subgroups in 3GPP and ITU, and with local regulatory bodies where applicable (especially w.r.t. indoor-to-outdoor measurements).

The technical activities within 5G CONNI towards a 5G end-to-end demonstration system are directly contributing to the constant evolution of HHI's 5G Testbed (https://5g-berlin.de/5g-testbed/) towards an open, multi-site, multi-tenant test infrastructure accessible to a variety of industry and academic partners.

HHI will continue to monitor relevant 3GPP study and work items and contribute where feasible, but no contributions are planned as of yet. Finally, HHI will continue its active contribution to the IEEE P2982 Millimeter-Wave Channel Sounder Verification working group, where results of WP3 will also be leveraged.

3.1.7 III

III is the main maintainer and key contributor of the 5G SA core network for use cases in Taiwan demo site. For the additional exploitation plan from III, include deploying the III Core on kubenetes platform for system integration. Also, support a PoC testbed in both internal and external demo events demonstrated in IEEE Globecom 2020 5G-CONNI project booth. Furthermore, for monitoring the 5G system execution and resource usage status for applications, III also develops and enhances the OAM system to raise the performance and manage the resource.

3.1.8 ITRI

ITRI has been disseminating the project results through speeches and demonstration in public events. More specifically, proof of concept results of the use case "Using Augmented/Virtual Reality for Process Diagnosis" have been showcased in IEEE Globecom 2020. In addition, ITRI has contributed to the joint 5G CONNI paper and presented it at IEEE Globecom 2020 workshop on Future wireless access for Industrial IoT (FutureIIoT). ITRI will continue this effort

for the innovations and developments of the 5G CONNI project to maximize the exploitation for the common good of the mobile wireless industry as a whole.

3.1.9 Sapienza

Sapienza plans to continue exploiting the results obtained within 5G CONNI, to publish conference and journal papers, as well as to give talks in events, workshops, summer/winter schools, etc. More specifically, Sapienza plans to submit papers to next conferences (and workshops) on communications and signal processing (e.g., EuCNC 2021, IEEE ICASSP 2022). Different journals are in preparation on the topics of Federated Learning, Computation offloading and time-varying graphs, all related to 5G CONNI activities, to be submitted to top IEEE transactions. From an education point of view, Sapienza plans to exploit these results in master and PhD courses, as well as to propose master and PhD thesis on the topics related to 5G CONNI.

4 Conclusion

In this deliverable, the dissemination and standardization results of the first period of the 5G CONNI project were summarized. Even though the *status quo* for dissemination to both scientific and non-scientific audiences is heavily impacted by the global COVID-19 situation, the project managed to share its visions and first results with a broad audience during 2020. Besides a paper co-authored by the whole consortium on the 5G CONNI vision that was presented during IEEE Globecom 2020 and which will be extended to a journal paper for Eurasip, five other conference papers and six journal papers were already published. As more project results become available, the consortium is already planning additional publications and it can be expected that the amount of dissemination will intensify in the following months.

A number of project partners held several (invited) keynote talks and (co-)organized workshops and special sessions, where the 5G CONNI vision and perspective was disseminated to a broad audience. In the coming project period, the consortium will continue to focus on online events and workshops.

The goal of work package 6 is not only dissemination, but also pushing the results of the 5G CONNI project into standardization. In the past period, several consortium members have monitored appropriate fora like 3GPP and ETSI MEC. A number of relevant study and work items were identified and are being followed by project members, and three contributions to 3GPP SA and ETSI MEC were already prepared. The consortium is continuing to monitor the work in the standardization bodies and will contribute where feasible.

Finally, an update by each project partner on their specific, updated exploitation plan for the coming project period is provided.