# Techno-economic framework for SDN/NFV based industrial networks: A Wind Park case study

Carmen Mas Machuca*, Petra Vizarreta*, Wolfgang Kellerer*, Vivek Koulkarni§, Hans Einsiedler¶, Massimo Condoluci†, George Petropoulos**, Xavier Vilajosana‡, Ioannis Askoxylakis||, and Khawar Abbasi††
* Technical University of Munich, Germany {cmas, wolfgang.kellerer }@tum.de, petra.vizarreta@lkn.ei.tum.de
§ Siemens AG, Munich, Germany, vivekkulkarni@siemens.com
¶ Deutsche Telekom, Berlin, Germany, Hans.Einsiedler@telekom.de
† Department of Informatics, King's College London, UK, {massimo.condoluci }@kcl.ac.uk
** Intracom Telecom, Peania, Greece, geopet@intracom-telecom.com
‡ Worldsensing, Barcelona, Spain, xvilajosana@worldsensing.com
|| FORTH-ICS, Crete, Greece, asko@ics.forth.gr
†† Intel Research and Development Ireland Limited, Ireland, khawar.abbasi@intel.com

***Abstract*—This paper proposes a framework to perform a techno-economic evaluation of communication networks of industrial networks. Since SDN and NFV promise cost savings, our solution aims at evaluating quantitatively the savings compared with existing solutions. The framework has been applied to the particular case of wind parks.**

## I. Introduction

Industrial networks are becoming more complex, not only due to the increase of task sophistication but also on the significant rise of components that should be configured and monitored. Hence, the communication networks used in industrial environments have to interconnect a larger number of devices with different types of requirements in terms of bandwidth, maximum delay, maximum packet loss, etc. Hence, industrial communication networks have to automatically establish any new required connection, configure any connected device and provide access to certified tenants.

As considered in the EU VirtuWind Project [1], wind parks are considered as a particular case of industrial networks. In this scenario, turbines contain a significant number of sensors and actuators that need to be closely monitored and controlled. The reduction of the Levelized Cost of Electricity (LCOE) is being slightly decrease by a better design of the wind turbines. However, wind park operators aim reducing LCOE more by reducing not only the Capital Expenditures (CAPEX) of the network components, but also the Operational Expenditures (OPEX) over the lifetime of the wind turbines.

Software Defined Networking (SDN) is a communication network paradigm which separates clearly the data plane from the control plane. In this way, basic, lower-cost and standardized hardware can be used in the data plane, leaving the complexity to the network controller(s). Furthermore, Network Function Virtualization (NFV) allows reducing cost and increasing network flexibility by virtualizing network functions (e.g., firewalls, Deep Packet Inspection (DPI)) and deploy them at any commodity hardware.

In this project, we aim at performing a techno-economic assessment of existing and SDN and NFV based communication networks applied to the wind park case study. A wind park , as shown in Fig. 1, consists of several turbines interconnected either in a bus or in a ring topology by switches [2]. Each turbine has different Input/Output (I/O) devices (i.e., sensors, actuators), which receive/send information to a controller. There is one local controller per turbine to perform the most critical actions and few central controllers (offshore and/or onshore depending on the size of the wind park) to perform other functions: e.g., synchronize and coordinate operation of all wind turbines in the park, network management system (NMS) for network configuration, performance and fault monitoring, gateway to the other control centers and Internet. Supervisory Control and Data Acquisition (SCADA) is the system, usually placed a the onshore location, responsible to monitor, supervise and control any industrial device by collecting the data from sensor measurements and configuring the actuators [3].

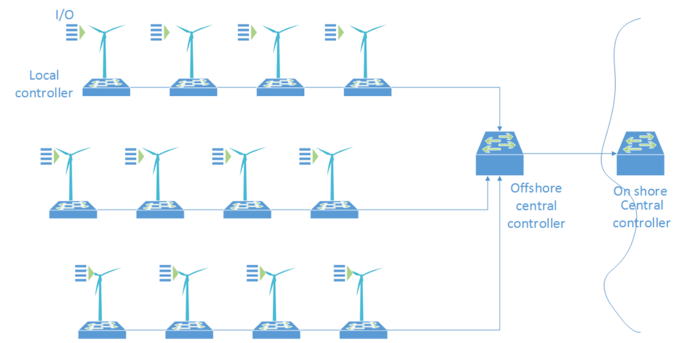


Fig. 1. Example of typical wind park communication network

## II. Techno-Economic Framework

In order to perform a techno-economic evaluation of different communication networks, we propose the scheme depicted in Fig. 2 [4]. The input scenario defines the parameters, aspects and constraints of the network that has to be modelled and analysed. They can be grouped in three different categories, component models, traffic demand and system constraints.

When defining a network, the end nodes and network components have to be defined and modelled. This definition and modelling depend on the level of detail to be considered by the next steps. For example, in the case of the wind park, the whole turbine can be considered as an end node. In case a more detailed analysis of the network is required, by zooming in

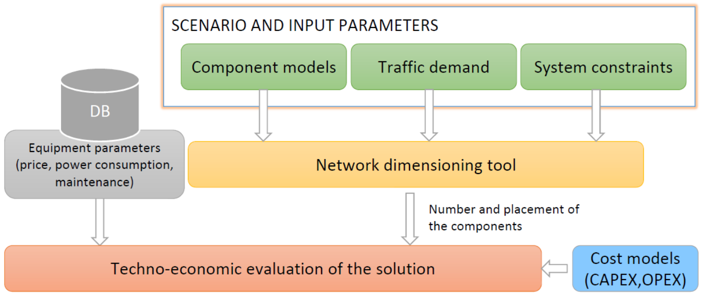


Fig. 2. Proposed Techno-Economic Framework

into the turbine components, each of the sensors and actuators could be considered as end node. When looking at the network switches, they can be modelled based on the number of ports or on their switching capacity. The scenario depends on the number of flows/connections that should be established and their characteristics: source, destination, required capacity, maximum delay, minimum availability, etc. This input includes any constraint that should be considered when dimensioning the network. For example, is there any existing infrastructure that should be considered, are there constraints regarding the location of some components, etc.

Given the requirements and constraints of the input scenario, an optimal network dimensioning is required. The network should be able to cope with all the expected connections, guaranteeing all their requirements and coping with all the system constraints. The result is the number of network components and their locations, known as Bill of Material (BoM). Special attention has to be paid on the number and placement of controllers and virtual network functions to guarantee all the requirements in terms of delay, availability, etc. Some proposed solutions have been recently published [5], [6].

The costs that should be considered in the assessment have to be modelled. In general, network costs can be categorized as CAPEX or OPEX. Both top-down and bottom-up approaches can be considered. Since the available data from top-down approaches as [7], [8] conceals the contribution of the communication network, we propose using a bottom-up approach by implementing driver-based cost models for CAPEX and OPEX. CAPEX includes cost associated to switches (at the top and/or bottom of the turbine as well as the aggregation switches), gateways, routers, servers, firewalls, etc. OPEX includes network configuration, power consumption, failure reparation, maintenance, Cost of Energy Not Supplied (CENS) and other costs such as service configuration and upgrades.

Based on this model and a complete database containing all the parameters of the network components (e.g., power consumption, component cost based on the purchased volume and year, required maintenance), the techno-economic evaluation is performed. Special attention is paid to the LCOE, which depends on the Annual Energy Production (AEP) which is amount of energy (MWh) that is produced per unit of installed capacity (MW) and on the Fixed Charge Rate (FCR), which counts the financial aspect (discount rate, taxation and depreciation) and operational life of power plant. Hence, the LCOE can be derived according to the following expression [7]:

$$LCOE = \frac{CAPEX * FCR + OPEX}{AEP}$$

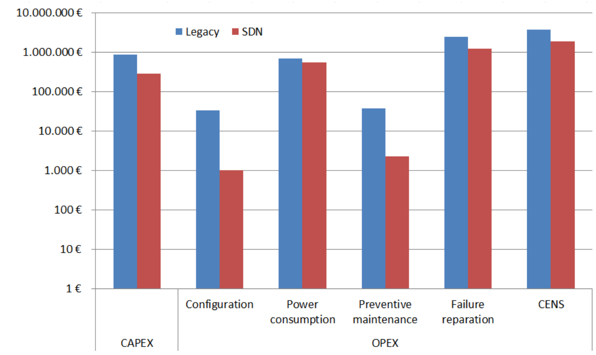


Fig. 3. CAPEX and OPEX comparison of legacy vs SDN/NFV network.

Historical data shows that LCOE is slightly reducing since 2010 and there is pressure to further reduce it by introducing new technologies. Since innovations in communication technologies are not expected to impact directly FCR or AEP, the focus in this study is on CAPEX and OPEX [7], [9].

## III. Results

This study aims at comparing the CAPEX and OPEX costs of legacy vs. SDN/NFV communication networks for the wind park case study. A first wind park scenario has been considered: 20 turbines, 20 years operational time, 50 €/MWh cost energy, 40 MW park power capacity and 3 aggregation nodes [4]. Considering 2 controllers for resiliency purposes, the cost comparison of both solutions is depicted in Fig. 3. It can be observed that for this particular scenario, CENS is the most important cost contributor followed by fault reparation. These are also the factors where SDN/NFV offer most of the savings, followed by CAPEX and power consumption. Other scenarios and different SDN/NFV alternatives are currently being compared to get a more applicable conclusions. Furthermore, real values in terms of e.g., configuration times, are expected to be obtained from the real test-bed at the end of the VirtuWind project.

## Acknowledgment

This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 671648 (VirtuWind).

## References

[1] T. Mahmoodi *et al.*, "Virtuwind: virtual and programmable industrial network prototype deployed in operational wind park," in *Trans. on Emerging Telecom. Tech.*, May 2016.

[2] I. Electrotechnical Commission, "Communications for monitoring and control of wind power plants," in *International standard IEC 61400-25*, December 2006.

[3] A. L. Pettener, "SCADA and communication networks for large scale offshore wind power systems," in *IET RPG 2011*, Sept 2011, pp. 1–6.

[4] C. Mas Machuca, P. Vizarreta *et al.*, "Techno-economic framework and cost models," in *VirtuWind D24 H2020-ICT-2014*, August 2016.

[5] P. Vizarreta *et al.*, "QoS-driven Function Placement reducing Expenditures in NFV deployments," in *IEEE ICC*, May 2017.

[6] P. Vizarreta, C. Mas Machuca, and W. Kellerer, "Controller placement strategies for a resilient SDN control plane," in *RNDM*, Sept 2016.

[7] C. Moné, A. Smith, B. Maples, and M. Hand, "2013 Cost of wind energy review," in *National Renewable Energy Laboratory (NREL)*, 2013.

[8] M. Taylor, "Wind power," in *Renewable Energy Technologies: Cost Analysis series*. International Renewable Energy Agency, June 2012.

[9] T. B. Christensen *et al.*, "Establishing the investment case wind power." Deloitte, April 2014.