Aalto University
School of Electrical
Engineering

Software Defined Grid

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Seppo Borenius, Matti Lehtonen, Jose Costa-Requena
seppo.borenius@aalto.fi

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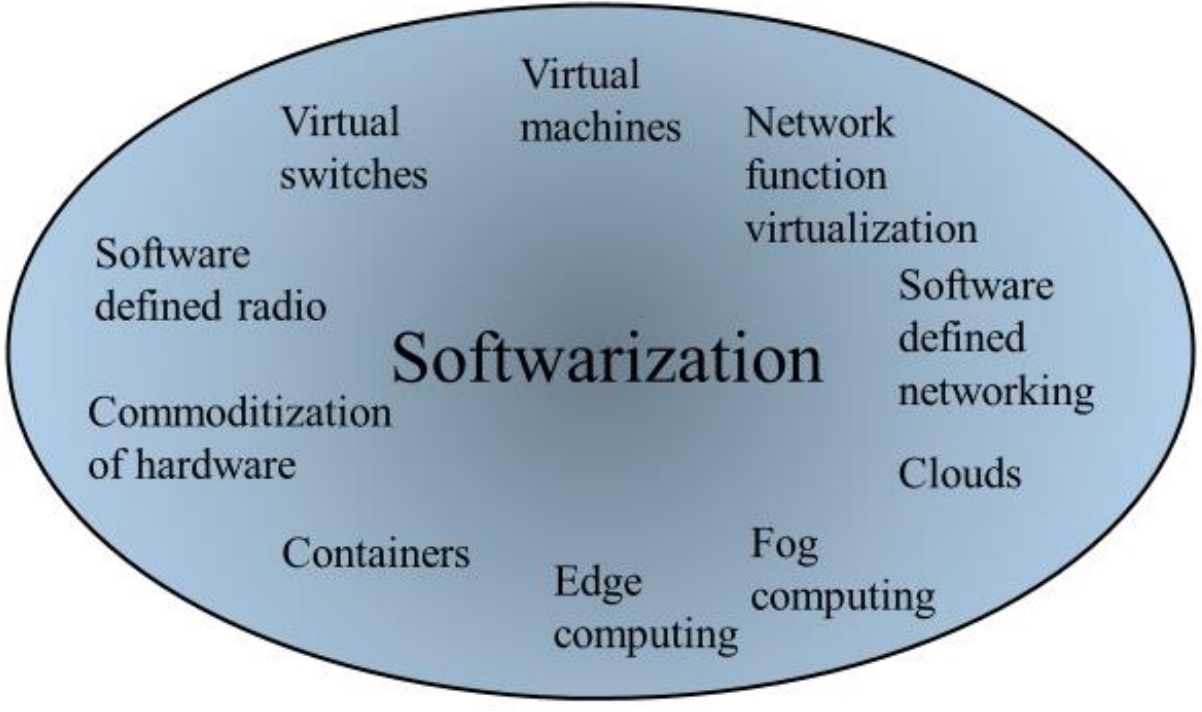
Introduction

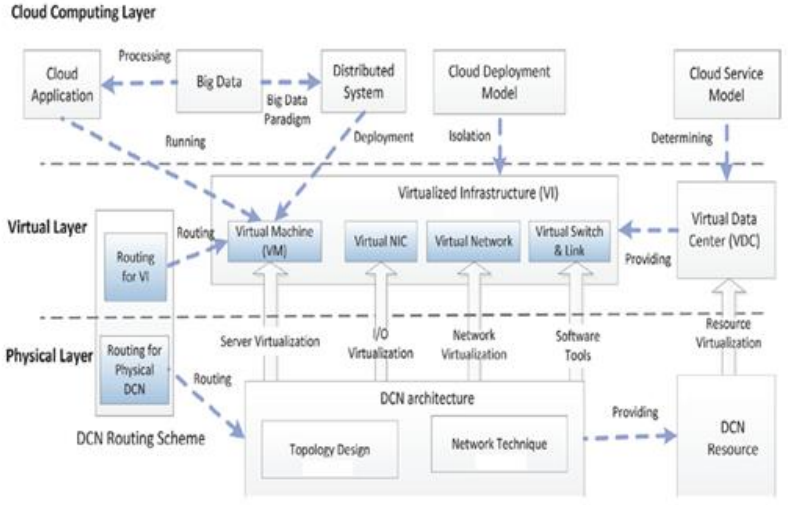
- Softwarization has transformed industries like data center and communications businesses. Key drivers:
  - better adaptability,
  - increased flexibility
  - reduced costs.
- This paper studies the underlying concepts in softwarization and how the evolution in data centers and communications networks has taken place
- The paper further outlines how the similar type of evolution could impact power grids and what kind of benefits it could bring

Key Concepts in Softwarization



Evolution in Data Centers

- Networkworld: “The data center is being repurposed. Some workloads are going to public cloud providers, while others are being assigned to the data center.” [1]
- Gartner: “Organizations need to create an environment that houses more agile infrastructure both on-premises and in the cloud.” [2]
- Gartner: “Leaders must identify whether there are truly strategic reasons to persist with on-premises needs, especially when they consider the significant amount of investment involved.” [3]

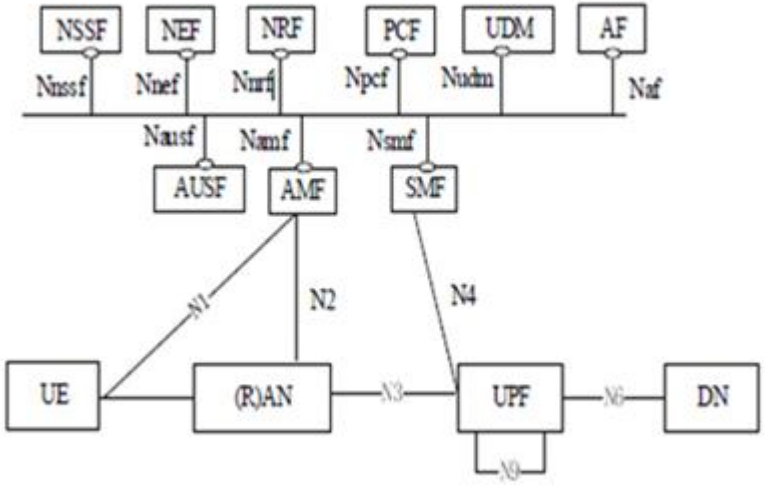


Cloud computing network architecture for virtual data centers, Wang et al [4]

[1] NetworkWorld: ”10 predictions for the data center and the cloud in 2019”, Dec 4, 2018
[2] Gartner: “The Top 10 Trends Impacting Infrastructure and Operations for 2019”, Dec 4, 2018.
[3] Jo Jaspers: “Top 10 Data Center Industry Trends for 2019 According to Gartner”, 2018.
[4] Bin Wang, Zhengwei Qi, Ruhui Maa, Haibing Guana, Athanasios V.Vasilakos: “A survey on data center networking for cloud computing”, ComputerNetworks91(2015)528–547, Elsevier.

Evolution in Cellular Networks

- Earlier cellular network architectures basically defined dedicated hardware entities and interfaces among these entities
- Now the emerging 5G is inherently based of softwarization:“The notion of network virtualization concentrates on the concept of a software-based representation of both the hardware and software resources considering both data and/or control-plane functions”, Afolabi et al [1]



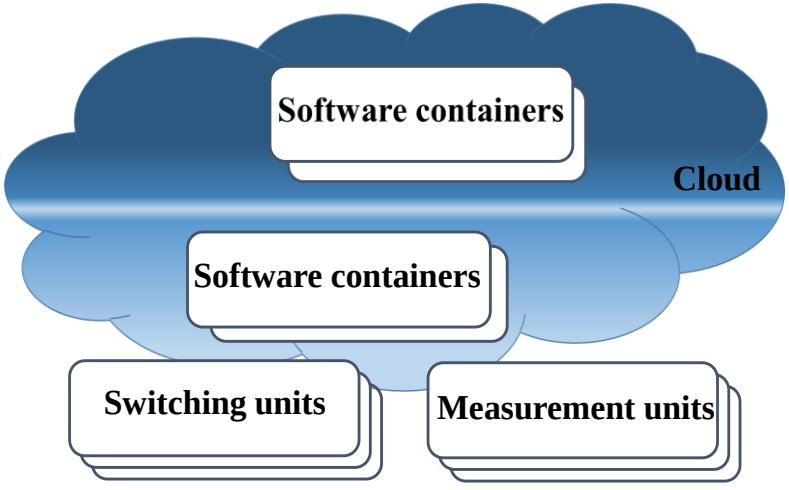
5G System Architecture, ETSI [2]

AMF = Access and Mobility Management Function
SMF = Session Management Function
NSSF = Network Slices Selection Function
UP = User Plane Function
R(AN) = Radio Access Network
DN = Data Network

[1] Ibrahim Afolabi, Tarik Taleb , Konstantinos Samdanis, Adlen Ksentini, and Hannu Flinck: “Network Slicing and Softwarization: A Survey on Principles, Enabling Technologies, and Solutions”, IEEE Communications Surveys & Tutorials, Vol. 20, NO. 3, Third Quarter 2018.
[2] ETSI: “5G; System Architecture for the 5G System (3GPP TS 23.501 version 15.2.0 Release 15)”, 2018.

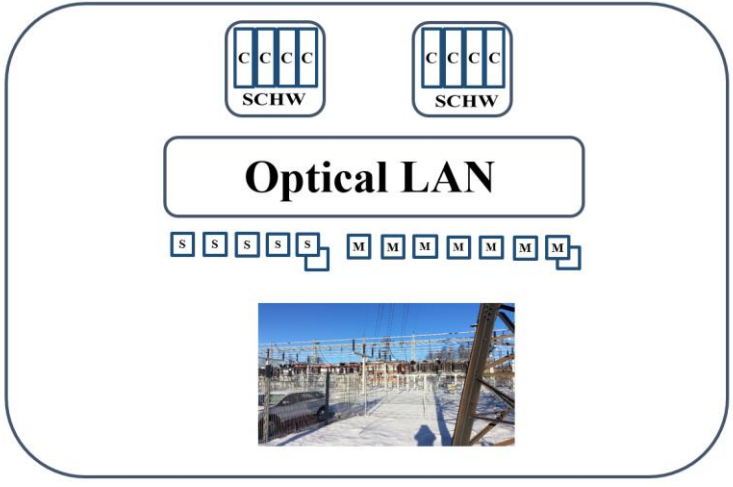
Software Defined Grid Overview

- Power grid switching devices and measuring devices are clearly separated from the software controlling them
- The software runs in the cloud in software containers
- Software containers are placed either in close proximity to the switching and measurement units, or more centralized in the cloud depending on the functionality they provide
- Application functionality, e.g. for the power flow solution for the whole grid, is divided into multiple containers which interact with each other according to the principles of service-oriented architecture (SOA)
- Applications and containers are managed on grid level by a container-orchestration system, e.g. Kubernetes



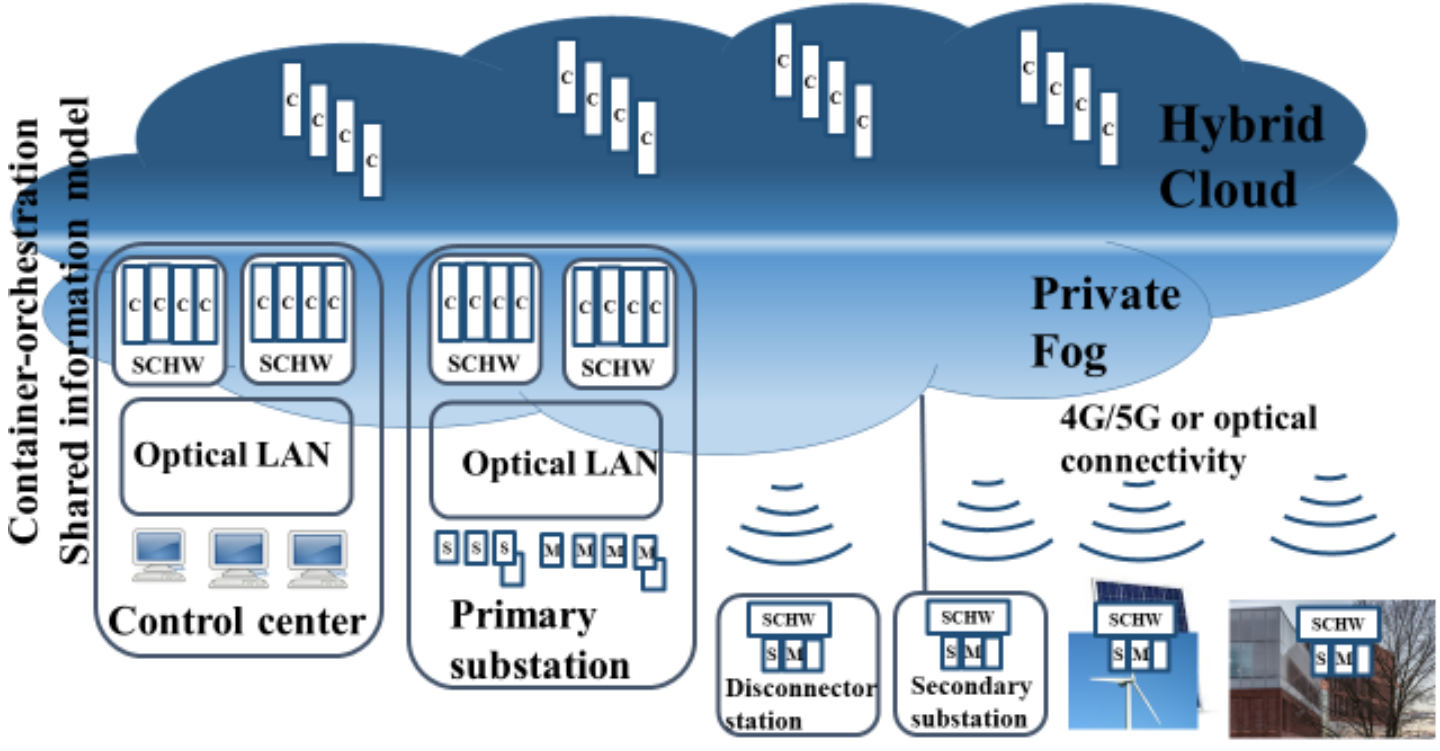
Software Defined Grid Substations

- Primary substation level
  - Switching devices, e,g. circuit breakers, and measurement units like sensors are relatively similar and not providing too much differentiation
  - Control and data processing is moved to separate control entities
  - Control entities run as containers on standard inexpensive blades and motherboards
  - Common software tools would exist to configure and manage (orchestrate) all control entities
- Secondary substation (distribution transformer station)
  - The controlling network virtual functions (NFVs) would be running on standard small-scale computing platforms, e.g. Raspberry Pi
  - Commoditized measurement devices (sensors) and switching devices are directly connected to computing platform



SCWH = Standard Computing Hardware
C = Container
S = Switching
M = Measurement
IED = Intelligent Electric Device

Software Defined Grid Architecture



Comparisons and Limitations (1/3)

	Traditional power grid	Software defined grid
Hardware and software integration	Power grid devices and related software integrated	Power grid devices and related software separated
Computing platforms	Purpose built computing platforms	Standard computing platforms
Allocation on computing resources	Fixed statically allocated computing resources	Cloud based solution: on-demand network access to a pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort
Communication links	Dedicated communication links	Shared communication links
Data storage	Dedicated data storage	Shared data storage

Comparisons and Limitations (2/3)

- Adaptability and flexibility
  - Separating power grid hardware from the related software, by utilizing standard computing platforms and by running the applications as containers in the elastic cloud. This separation enables that modifications can be done by orchestrating a suitable set of software containers according to the changed needs.
- Cost savings
  - Utilizing standard computing platforms and running software containers on them
- Performance
  - Distribution of functionality to containers needs to be carefully considered in order to avoid excessive communications between some containers

Comparisons and Limitations (3/3)

- Security challenges related to communication networks and multitenancy, i.e. ultimately sharing the same computing and communications platform with other users. Means to address the concerns:
  - Tunnelling, public key encryption and network slicing
  - The most critical, e.g. control related applications could be located in the private part of the cloud
- Advantages related to security
  - Cloud environments are run by large enterprises as their primary business, so they are well maintained and operated.
  - Software defined networking (SDN) enables unified security management for switching units and measurement units (sensors)
  - Network Function Virtualization (NFV) and network slicing inherently provide separation of users

New and Changed Business Roles

- Purely software focused companies will emerge or strengthen their position. These will provide container-based functionality. Customers pick best of breed functionality in containers and also change it more frequently based on evolving needs.
- Some of the established power grid technology suppliers transform themselves to software companies integrating offerings of their competitors into their product and service portfolio
- Totally new entrants might rapidly be introduced similarly as e.g. Google, Amazon, Facebook and Tesla have transformed multiple other businesses

Conclusions

- Sofwarization is a strong trend impacting many industries
- It has transformed data centers and cellular networks. Also e.g. manufacturing is undergoing the same type of change. This evolution is known as Industry 4.0.
- Similarly a Software Defined Grid could emerge. It could potentially significantly reshape power grid technology provider business. Resources sharing and shared connectivity imply also challenges related to security, reliability and performance. These must be addressed in order to be able to benefit from adaptability, increased flexibility and reduced costs enabled by softwarization.
- Evolution towards Software Defined Grids is made more likely as smart grids must combine traditional power grid technologies with already softwarized communications and information technologies to create a sustainable electric energy system

Thank You!

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