DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 36TH CYCLE

Title of the research activity:	**Network Design and Operation Through Artificial Intelligence in 6G**
State of the Art:	The ongoing refactoring of traditional network function in their virtualized software-based counterparts holds the promise to dramatically enhance service delivery and deployment agility. Indeed, business cycles shrink and network function virtualization (NFV) technologies will allow network stakeholders will be able to move quicker than ever, change offerings, promptly add new services, and get better insight, consistency, troubleshooting and visibility into the network status. Still, NFV's flexibility comes along with an obvious toll: the gap between the speed attainable in software opposed to dedicated HW devices is still very significant, and is not going to decrease in the future. Thus, forthcoming approaches will foster the migration from traditional virtual machine (VM)-based solution to more efficient and scalable virtualization technologies. VM-based virtual network function (VNF) solutions are traditionally viewed as heavy in terms of provisioning time and runtime overhead. Instead, container-based VNF can be implemented through higher levels of abstractions by leveraging the better VNF agility, especially for on-demand services running directly in the host environment. In addition to the above, software-based research advances will allow to address main shortcomings of software defined networking (SDN), by supporting data plane programmability, which are now sufficiently mature for being tested in the field. Indeed, a disruptive innovation is being currently happening in terms of models, platforms and systems for supporting programmable data planes and even programmable radio interfaces, with the advent of metamaterials to be software controlled. This will bring programmability down to the data plane by extending the elementary "match/action" abstraction provided by OpenFlow. In addition, this will allow overcome the above performance limitations of NFV by including hardware acceleration devices tailored to the specific needs of network processing and computing. Finally, all these innovations will be framed into the new scenario put forward by the sixth generation of mobile networks (6G). 6G will undergo an unprecedented transformation that will make it substantially different from the previous generations of wireless cellular systems, going beyond mobile Internet. It will be required to support ubiquitous artificial intelligence (AI) services from the core to the end devices of the network. Meanwhile, AI will play a critical role in designing and optimizing 6G architectures, protocols, and operations.
Short description and objectives of the research activity:	The research topics are expected in the following directions: 1. Knowledge centric information and AI for networking. In fact, as the network is becoming more complex and more heterogeneous, softwarization is not going to be sufficient for 6G, especially to support AI-based applications. This include the adoption of knowledge centric information and network inference through machine learning for networking. One of the main application of AI in 6G is automated and closed-loop optimization. In 6G, the mapping between a decision and its effect on the physical system is cost-prohibitive to define and may not be analytically available. Recent advances in AI technologies, such as deep reinforcement learning (DRL), can establish a feedback loop between the decision maker and the physical system, so that the

	decision maker can iteratively refine its action based on the system's feedback to reach optimality eventually. The proposed research activity in this field will focus on intent-based networking. The main novelty of this paradigm is the idea of a network administrator defining a desired state of the network and having automated network orchestration software implement those policies. This concept can be pushed towards customers, allowing them to express in a simple way "what" their virtualized service slice should provide, leaving to the orchestration engine the task to decide "how". Thus, the stakeholders using 6G will simply define their intents, and it will be an AI-empowered decision and orchestration engine to translate these intents into detailed and operative network configurations. With respect to traditional approaches, intent-based networking guarantees a higher degree of automation and abstraction, while it simplifies the management of heterogeneous resources (i.e. NFV implementation options) when dealing with end-to-end slices. This also guarantees a simpler interface towards vertical industries, which is a basic requirement to attract them towards virtualized services, such as those offered by forthcoming 6G networks. 2. Technologies for acceleration and offloading of (performance critical) virtualized components into dedicated network processing devices, specifically smart NICs and programmable switches. The idea is of this research activity is to go beyond the VNFs implementation with state of the art acceleration techniques like DPDK or SR-IOV. The aim is designing packet manipulation processors that are not only able to provide complex packet modifications at line rate, but also programmable by means of high-level Domain Specific Languages, like P4, hence dramatically improving VNFs deployment time and agility. More specifically, the activity will focus on leveraging programmable smart NICs to offload the performance-critical parts of VNFs, i.e. those (such as traffic control algorithms or packet-level manipulation) that are expected to run at multi-gigabit line rates and which can hardly run on commodity ARM/x86 CPUs, since they require the development of highly specialized processing architectures. It is also requested an effort to identify technologies and techniques which permit to exploit HW-based performance acceleration of VNF without the need to directly implement them in hardware, hence improving deployment time and agility. In order to simplify the access to this high performance networking framework, it is fundamental the use of abstraction layers, which can be done in an innovative way by leveraging the novel concept of intent-based networking to manage virtualized network slices, seen in the first proposed research topic.
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