Theory that Matters! Problem-based learning towards 5G Communication System and Standards

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***Abstract*—In this manuscript, we advocate for our "Theory that Matters!" approach for teaching the next generation of researchers and engineers. By the example of one teaching activity at TU Dresden for graduate students, we present how the new communication standards in the 5G context are integrated in our curriculum. The core of the approach is the combination of lectures, hands-on group sessions, and individual projects holistically covering the 5G communication standardization landscape including softwarization concepts such as software defined networking and network function virtualization. After being trained on the appropriate standards, technologies and tools such as OpenFlow, Docker and OpenStack, students apply the lessons learned to one group project and several individual ones.**

***Index Terms*—5G, NFV, SDN, problem-based learning**

I. Introduction

Teaching the next generation of young researchers and engineers is highly important for industry as well as research institutions. While basic teaching courses did not change their curriculum dramatically over the years, the teaching on current and future technologies is prone to dramatic and fast changes, making it hard to keep the curriculum up to date. We are facing such a situation currently with the 5^{th} generation (5G) of communication technology. Enabling technologies for 5G such as software defined networking (SDN) and network function virtualization (NFV) are discussed at various venues, such as ITU-T, ETSI, 3GPP, and especially IETF. To the best of our knowledge, the traditional approach of teaching matured standards only is insufficiently active to keep up the pace. The lag between understanding the standardized technologies and transferring the knowledge to students limits their competence to stay at the edge of technology advancements. We believe that higher education institutions can proactively engage graduate students and junior researchers alike earlier and to a greater extent in the standardization process. To minimize the risk of wasting efforts on technologies which fail to be adopted, we need to design the curricula in a flexible manner, allowing for shifting technology focus without changing the curriculum's structure.

In this article, we introduce our *"Theory that Matters!"* approach with regard to teaching, consisting of continuous refinement of our curricula. Subsequently, we share our idea of adopting problem-based learning in our *Future Communication Networks* module. We build the content of the module in accordance with IETF's topics which are actively discussed towards standardization. The module consists of not only a series of traditional lectures, but also tutorials, hands-on group sessions, and individual short projects. The advantages of that module design are three-fold. First, it provides students knowledge about state-of-the-art technology, multi-disciplinary skills, a problem-solving mindset and subsequently makes them capable of solving practical technological problems that they might face in their future career. Second, PhD students (or junior researchers) can quickly transfer their knowledge to students and renew their competencies via guiding master students. Last, the module adapts quickly to new knowledge from state-of-the-art technologies while inheriting the stability from current overall curricula of the faculty at the same time.

II. Future Communication Networks module

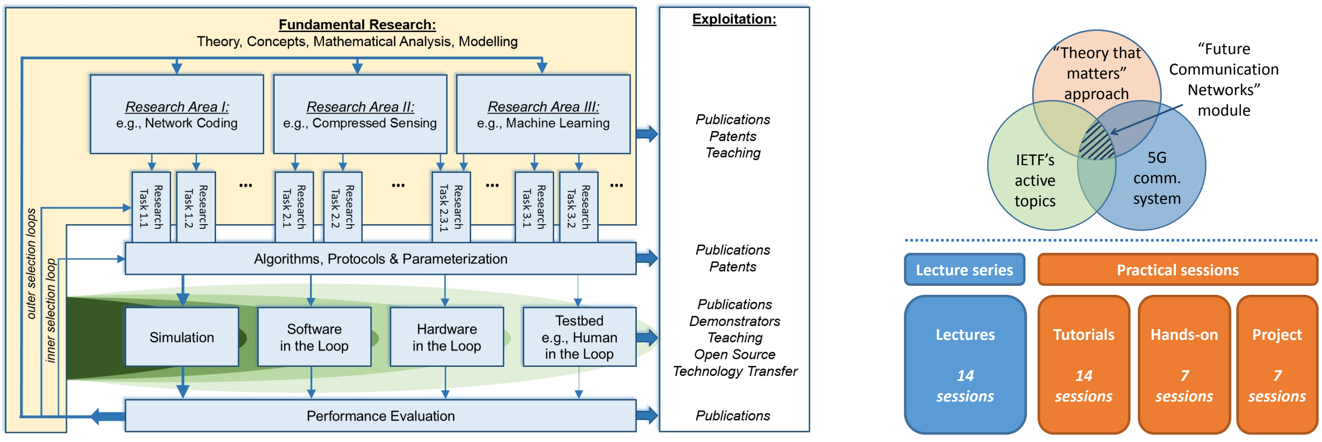
We first describe in this section the "Theory that matters!" approach which allows for a continuous refinement of our curriculum, followed by the idea and the module design.

A. *"Theory that matters!" approach*

The underlying idea of the approach is to explore new knowledge that might be applied in real-life scenarios with products and industrial standards. While acknowledging the importance of fundamental research, we advocate the applicability of research outcomes that can be applied in real life. The approach enables a continuous refinement of both research areas and respective curriculum. In this process, the applicability of solutions with tangible outcomes is tested at various phases, from fundamental research to algorithm and protocol design, evaluation methodologies, and finally performance evaluation as illustrated in Fig. 1(a).

B. *Idea of the Future Communication Networks module*

With regard to teaching, we deploy the "Theory that matters!" approach in the *"Future Communication Networks"* module. The module content stems directly from the 5G concepts and novel technologies, which are being standardized. As illustrated in Fig. 1(b), the module is the intersection of the "Theory that matters!" approach, 5G communication systems and IETF active topics. Following the progress at IETF's quarterly meetings, one should be able to spot open problems which are actively and openly discussed towards standardization. Those open problems are of interest for our module. The way we deploy our module is through applying the problem-based learning (PBL) pedagogical technique [1].



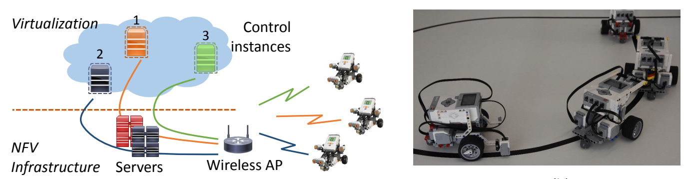
(a) (b)

Fig. 1. (a) "Theory that matters" approach to enforce a continuous refinement of the research area and teaching: selection loops at various stages to filter out research branches which fail to find its way to applicable outcomes. (b) Future Communication Networks module: i) Formation of the module as the intersection of the "Theory that matters!" approach, IETF's active topics and 5G communication system (upper) and ii) Structure of the module (lower).

PBL teaches concepts and skills to students through the process of solving a predefined problem. Students are required to work in small groups and fulfill a project, that is, a time-limited process with a tangible outcome [2]. Consequently, the students not only gain the required knowledge but also develop skills such as project management, bibliography retrieval and team cooperation. With PBL, every year the lectures are renewed towards the problems that students need to solve. Two factors facilitate this renovation: *(i)* the students are the main characters in the search of knowledge, and the lecturers provide guidance; *(ii)* several junior researchers are involved in the teaching of different topics and tools, therefore the renewal process is propagated.

C. Design of the Future Communication Networks module

The module comprises of lecture series and practical sessions. The lecture series consists of self-contained presentations on a variety of 5G topics and with a special focus on NFV and SDN. Additionally, students need to learn suitable tools and problem-solving skills to be able to solve real-world problems. The module, therefore, needs to include a substantial amount of practice, devoting two third of the overall module for practical sessions. The module includes series of *tutorials*, *hands-on group sessions* and *individual short projects*, besides traditional *lectures series*, as illustrated in Fig. 1(b). Tutorials in the module focus on the practical aspects of 5G-enabling technologies, especially tools which are publicly available and widely used in research and industrial environment such as OpenStack for NFV and Kodo [3] for network coding [4]. In addition to that, hands-on group sessions train students about problem solving by working in groups. We give all students one common problem which is also of interest and being actively discussed at IETF. As an example, Figure 2 illustrates the hands-on group session with Lego robots, in which students needs to deploy robot controlling softwares as virtualized network functions running on commodity servers. The goal is to teach students tools and techniques needed in the 5G ecosystem. Finally, topics for individual short projects are proposed by junior or senior researchers of the group. Junior researchers will assist and guide students, but the students should be able to apply the right tool and solve the problem themselves. By the end of the semester, students have to take an examination for this module which consists of two parts: an oral examination to test tests students their ability to comprehend a broader landscape of taucht technologies and a presentation with demonstration of the project work to test their deep knowledge on a specific tool set.



(a) (b)

Fig. 2. Hands-on sessions with Lego robots: a) Overall scenarios applying virtualization, deploying control instances to remotely control Lego robots; b) Practical setup with Lego robots, detecting and following predefined paths.

III. Summaries

In this manuscript we describe our teaching approach at TU Dresden, referred to as "Theory that matters!", that is used to convey 5G standardization activities into the teaching curriculum by the Future Communication Networks module, including lecture series, tutorials, hands-on group sessions, as well as individual projects. The described approach is time consuming as the material needs to be adapted and compiled on a semester basis, but it guarantees a high quality teaching approach for the students.

References

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