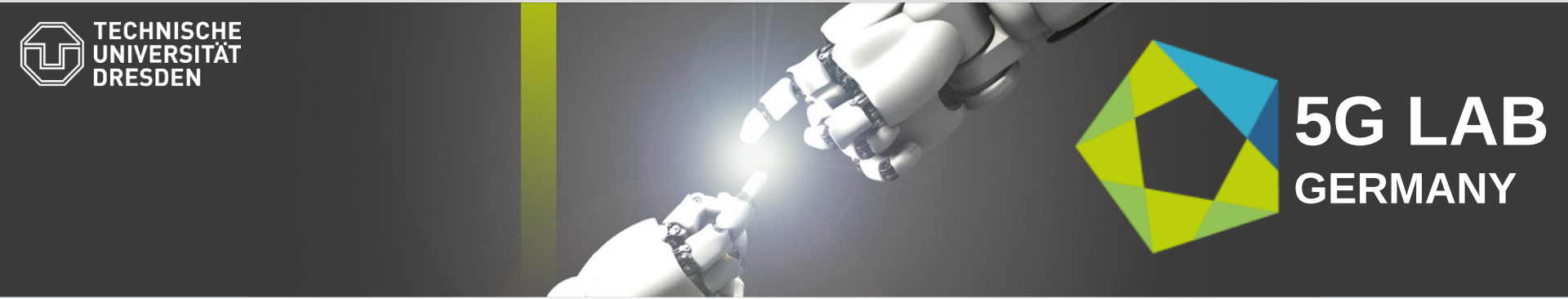

Theory that Matters! Problem-based Learning Towards 5G Communication System and Standards

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Motivation

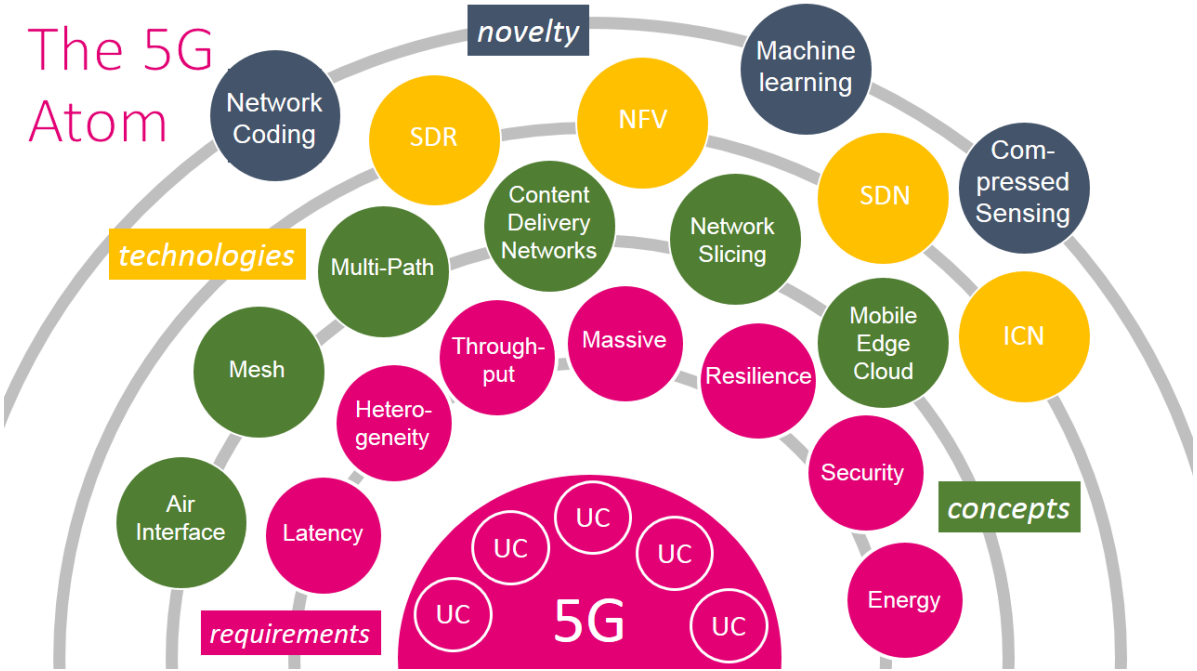
- Teaching current & future technologies: prone to dramatic & fast changes
- We are facing such a situation currently with 5G communication system
- Traditional approach: teaching only matured standards
  - The lag between waiting for the standardized technologies and transferring the knowledge to students

  Is it sufficiently active to keep up the pace?
- Proactively engage students and researchers earlier & at greater extent
- !!! The risk: efforts invested in updating the curriculum might be wasted
- Flexible design of the curricula, allowing for shifting technology focus without changing the curriculum's structure

Content

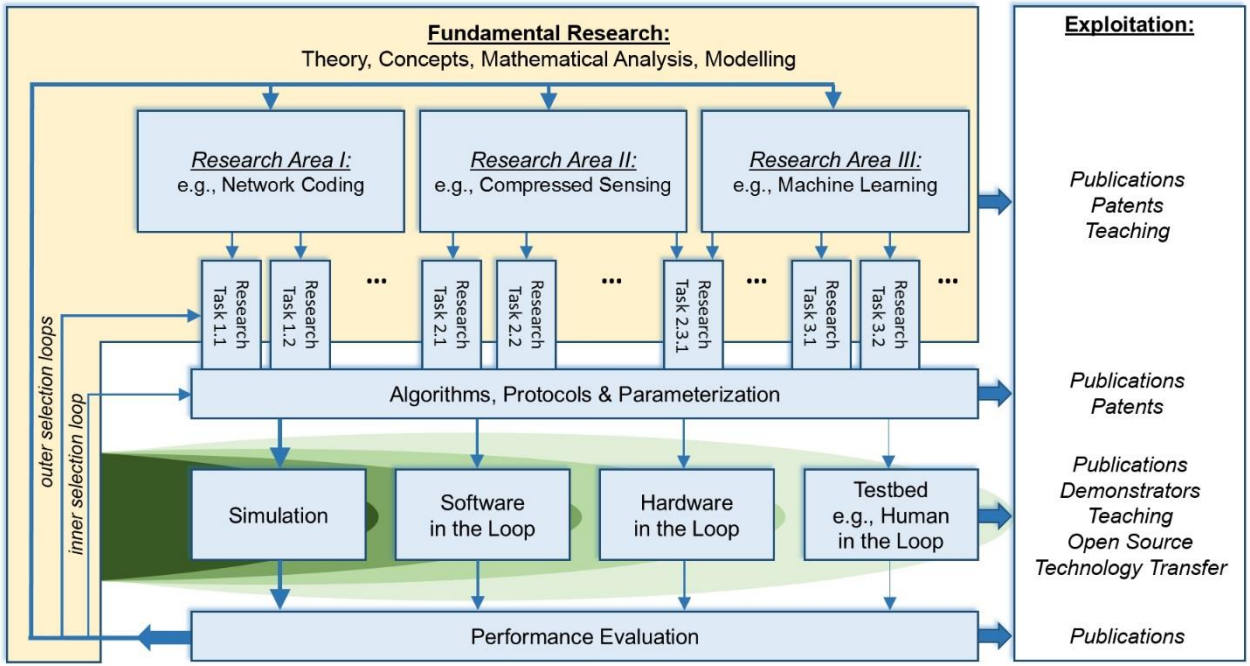
- Towards 5G communication system
- Approach: Theory that matters!
- Idea of “Future Communication Networks”
- Design of the module
- Case study
- Conclusion

Towards 5G communication system



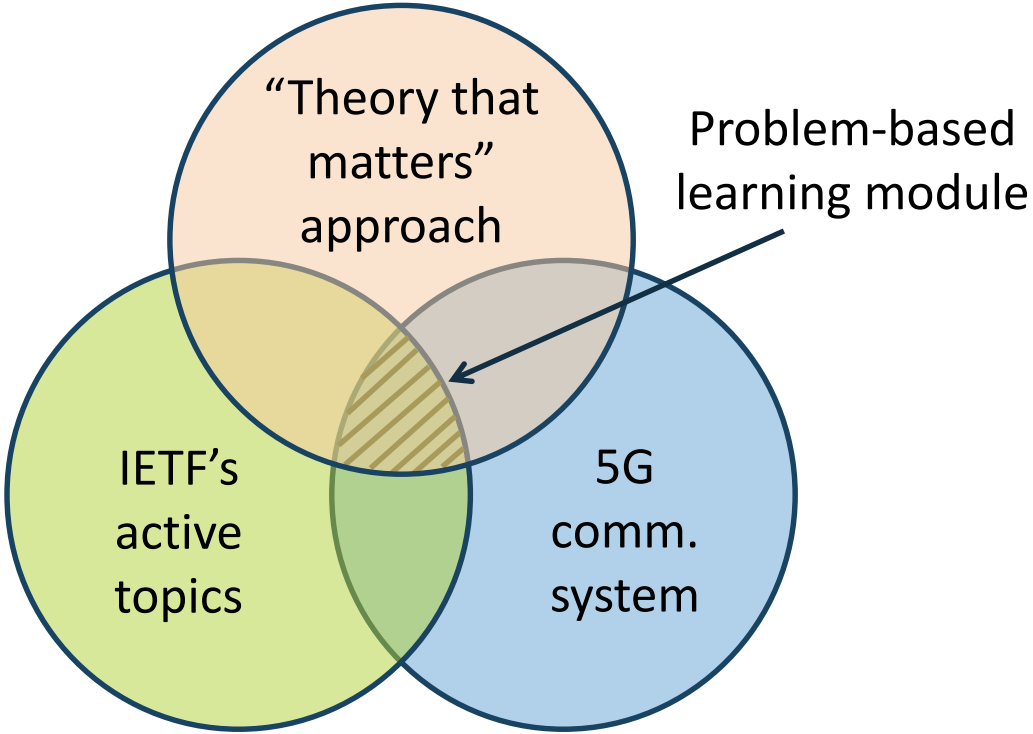
- Standardization has also been taking place very actively
- A substantial number of 5G topics are covered within the umbrella of IETF:
  - Network Coding
  - NFV, SDN
  - ICN, CDN
  - MP-TCP

Approach: Theory that matters!



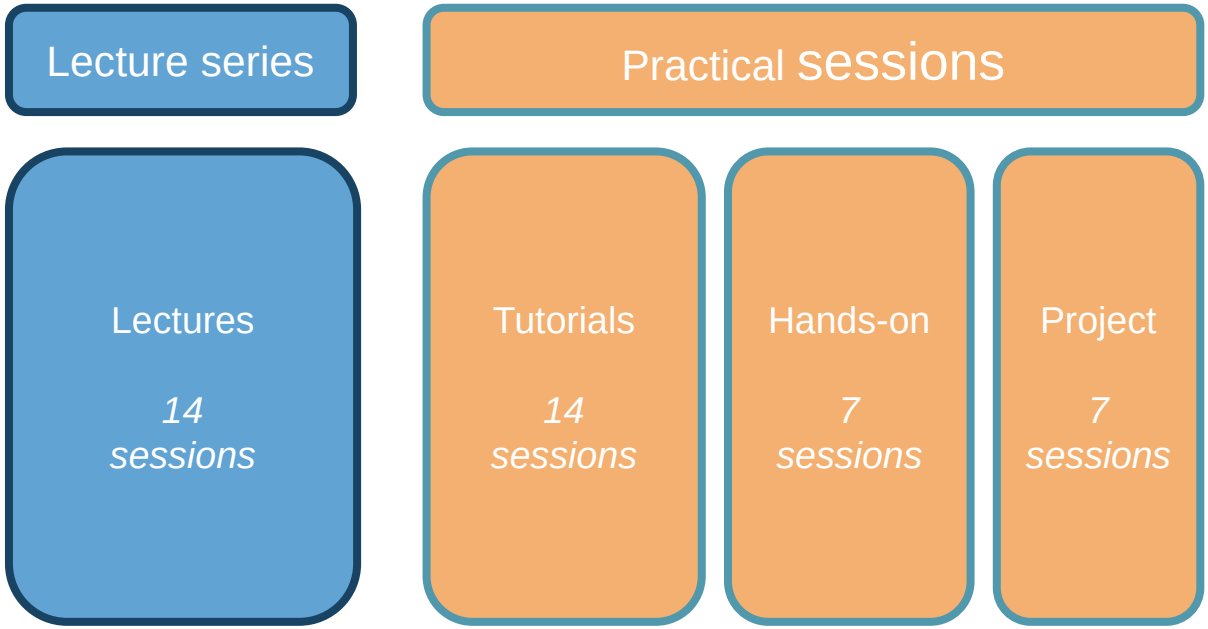
- To explore new knowledge that might be applied in real-life scenarios
- Advocate the applicability of research outcomes that can be applied in real life
- Enables a continuous refinement of both research areas and respective curriculum

Idea of “Future Communication Networks”



- Content of the module stems directly from the 5G concepts and novel technologies
- To deploy our module, we apply ***problem-based learning (PBL)***
- Two factors facilitate this renovation:
  - Students: main characters in the search of knowledge, and the lecturers provide guidance
  - Junior researchers involve in the teaching of topics and tools

Design of the module



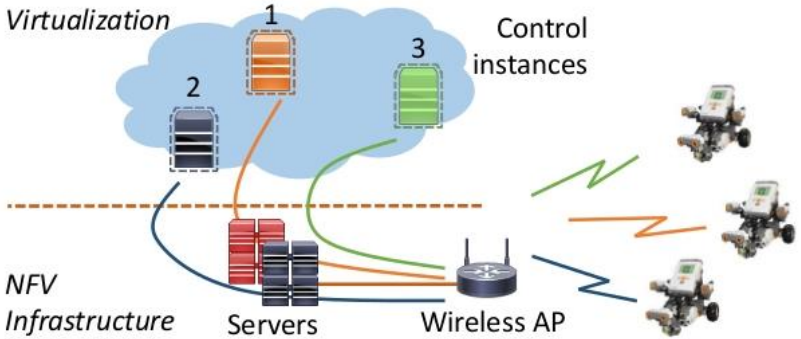
- Lecture series: self-contained presentations
- By the end of the semester, students have to take an examination for this module which consists of two parts:
  - An oral examination
  - A presentation with demonstration of the project work

Case study: Winter semester 2016 (1)

Week	Lectures	**Practical sessions** (including tutorials, hands-on group sessions and project work)
1	Introduction to module's lectures with respect to IETF/IRTF, IEEE, ETSI working groups	Overview practical sessions: The idea and examples of PBL, exam
2	Guided visit to 5G Lab Germany: Research Facilities and 5G testbeds	Python and KODO – the network coding library Tools for managing small testbeds: SCP, Rsync, Python fabric
3	Tactile Internet & Cyber-Physical Systems	Network tools: Wireshark, Tshark, Iperf3, Mausezahn, nmap Enabling and using Multipath TCP in the Linux kernel
4	Software Defined Networks	NS-3 – the network simulator I: Introduction NS-3 – the network simulator II: Network coding in NS-3
5	Network Function Virtualization	Hands-on session 1: First Contact with Lego robot Mininet: A scalable network emulation environment
6	Mobile Edge Computing	Docker container: Introduction Hands-on session 2: Wireless access to Lego robot
7	General topics on multi-path communication	Docker II: Managing docker images Docker III: Managing multi-container dependencies
8	Quic protocol and Multi-Path TCP	Hands-on session 3: Path-detection – Control algorithm OpenStack I: Installation and Dashboard
9	Guest Lecture from Bruno Jacobfeuerborn (CTO of Deutsche Telekom)	OpenStack II: Topology creation and management Hands-on session 4: cloud-based control algorithm
10	Performance evaluation tools	Software Defined Networks I: Ryu and Open vSwitch (Installation) Software Defined Networks II: Ryu and Open vSwitch (North-bound API)
11	Discrete event and random numbers	Machine learning I: Introduction and basic tools Machine learning II: Advanced topics
12	IoT and LoRa	Hands-on session 5: Putting it all together Processing experiment results: Jupyter notebook, Pandas library and Matplotlib
13	WebRTC, ICN, CDN	Project work 1 Project work 2
14	Summary of the module and exam preparation	

Case study: Winter semester 2016 (2)

- Thematic problem for *hands-on*: “Mobile Edge Computing”
- Object under control: Lego robot which has to detect the path on the ground and moves forward
- The challenge is to detach the control software of the robot from the robot’s hardware and then host the software in a cloud environment
- There are totally five hands-on sessions:
  1. First contact with Lego robot
  2. Wireless access to Lego robot
  3. Path-detection – control algorithm
  4. Cloud-based control software
  5. Putting it all together



Case study: Winter semester 2016 (3)

- Researchers of the group propose *individual projects* involving technologies introduced in the lectures and tutorials
- Each student selects one individual project. E.g.: “Performance evaluation of virtualization technologies in live migration”
  1. Deploy a cloud computing testbed using the OpenStack framework to support several virtualization technologies such as KVM, Xen and Docker
  2. Perform live migration of services and collect data such as latency
  3. Analyze results, by data analysis libraries introduced in the module
  4. Present experiments in a short report

Conclusions

- “Theory that matters!”: our teaching approach at TU Dresden
- “Future Communication Networks” module: To convey 5G standardization activities into the teaching curriculum, including
  - Lecture series and tutorials
  - Hands-on group sessions and individual projects
- The 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
- *Future work:* quantitatively assessing the module via survey to internship hosts, companies and students