Internet of Things and the challenges for infrastructure investments in 5G-based smart network industries

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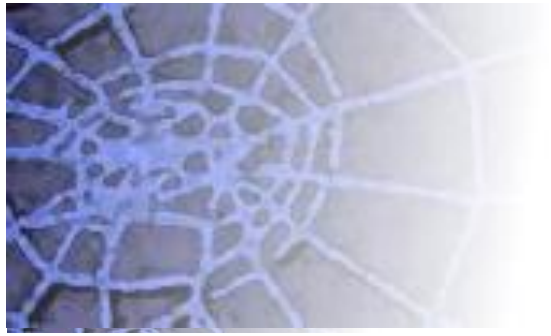
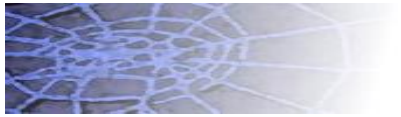


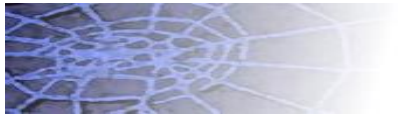
Outline

- The 5G-driven dynamics of future smart network industries is characterized from the perspective of Internet of Things (IoT) and subsequent use cases (verticals).
- The focus is on disruptive changes of the network architecture and value chains of cross-border European smart physical network infrastructures with particular need for interoperability and interconnections on the virtual side.
- Firstly, the important role of quality of service (QoS) differentiation of 5G networks and subsequent network slicing and their relation to 5G-based virtual networks are analyzed.
- Secondly, the evolution of the European Future Railway Mobile Communication System (FRMCS) is investigated. It is shown that digitalization of European railroads is driven by innovational complementarities on the whole value chain of railroad systems and tremendous impact on forward looking economic investment decisions.
- Thirdly, cross-border oriented 5G-based connected and automated mobility (CAM) projects are analyzed with particular focus on the challenges of 5G cross-border corridors and concomitant investment problems involved.



The economics of 5G-based network slicing

- The transition towards 5G broadband networks with its convergence of fixed and mobile networks enables a large variety of QoS differentiation of data packet transmission and thereby becomes an important General Purpose Technology for a large and open set of IoT applications in various network industries. Heterogeneous requirements of different use cases regarding throughput capacity, latency and reliability guarantees and massive machine-to-machine type communications create the necessities for logically separated QoS classes within 5G networks.
- It is necessity to tailor the network slicing from the perspective of the requirements of 5G-based big data virtual networks. Whereas the focus of traffic service providers is to offer QoS differentiated bandwidth capacities for a large variety of possible applications, the entrepreneurial governance problem of big data virtual network providers is to combine a specific QoS bandwidth capacity with other virtual resources (big data processing, sensor networks, geo-location services) to provide the required complementarity to the specific physical applications.
- Network slicing is based on separate independent end-to-end-logical networks on the same 5G network infrastructure applications where each network slice has its own service level agreement and objectives requirements. Some network slices are local, others may have a regional or cross-country footprint with several network operators involved.
- Interoperability and interconnection between different virtual networks are not standardized. In contrast, large standardization efforts of network slicing for purposes of interoperability and interconnection can be observed in particular from the perspective of end-to-end QoS guarantees for a sequence of virtual networks.



Innovational complementarities and disruptive investment challenges in digitalized railway systems

- Network slicing enables the configuration and operation of logically independent end-to-end (E2E) networks which are highly customizable and controllable, as if they were based on physically separated networks. Due to the large variety of rail use cases multiple virtual E2E network slices can be designed with heterogeneous QoS characteristics on a common 5G physical communications infrastructure.
- A network slice can span all domains of the network, from the radio access via the backhaul transport network to the core functionality and encompasses specific control and user plane handling needed for each slice. Dependent on the necessities of the use cases under consideration a bandwidth capacity with a specific spectrum frequency and QoS guarantee can be combined with other ICT components such as cloud computing (central or edge), camera-based sensor networks and geo-positioning services. An important dimension of virtual network for safety critical rail applications is also cyber security as elaborated in FRMCS end-to-end security.
- Train-operator platforms gain the potential to shift network intelligence from the railroad tracks to the trains and 5G-based train traffic control systems and thereby strongly increase the railroad track capacities without the requirement of building new additional railroad tracks. The shift from fixed block system to 5G communication based moving block system with strong impact of increasing track capacities becomes only possible due to QoS guarantees of very low latency and related safety improvements.

Innovational complementarities and disruptive investment challenges on digitalized European highways (1)

- The transition to 5G-based connected and automated vehicles requires the building of 5G networks and network slicing on the virtual side and the path-dependent upgrading of the physical road-side infrastructure. The role of innovational complementarities requires also to upgrade the vehicles. The role of 5G networks along transport corridors points to the particular relevance on cross-border interoperability issues.
- Developing a cross-border oriented 5G-based connected and automated mobility (5G CAM) ecosystem in Europe drives the focus on innovational complementarities between digitalized vehicles, digitalized road traffic control and digitalized road infrastructure to enable vehicle to vehicle communication, vehicle to infrastructure communication and Infrastructure to Infrastructure communication.
- A particular challenge of the future governance of 5G-enabled CAM ecosystem is the interaction of the traditionally separated actors involved which may either come from the physical side such as automobile manufacturers, road operators or from the ICT based virtual side such as cloud providers (central cloud, edge cloud), camera-based sensor and locational geo-positioning service providers and new players providing disruptive innovative services by building new shared mobility driverless operator platforms.
- Innovative application services such as networked driverless vehicles require digitalization investments in upgrading road-side infrastructure with sensors and positioning systems, investments in new upgraded vehicles and investments into operator platforms.

Innovational complementarities and disruptive investment challenges on digitalized European highways (2)

- A first phase of cross-border projects started in November 2018 primarily focusing on highway projects and its cross-border challenges as part of the European Commission`s 5G Public Private Partnership. Within the multi-tenant platforms, 5G-GroCo, 5G-Carmen and 5G-MOBIX, the EU supports these 5G cross border corridor projects for large-scale testing of automated mobility.
- A second phase of cross-border projects started in September 2020 enlarging intermodal perspectives by including road and rail 5G network infrastructures (5G-Med); including ports and maritime routes (5G-Routes), and uninterrupted cross-border teleoperate transport for roads and maritime based on 5G connectivity between the ports of Antwerp (Belgium) and Vlissingen (NL) (5G-Blueprint).
- Particular challenges of future cross-border solutions are the requirements of large standardization efforts of network slices from the perspective of end-to-end QoS guarantees for a sequence of networks for interoperability and interconnection purposes.