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Internet of Things and the Economics of 5G-Based Sector Coupling

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Abstract

Sector coupling has traditionally been a rather narrow concept to analyze synergies of urban system integration with particular focus on transport, energy and waste systems. The evolution of the fifth generation (5G) networks with its fixed and mobile convergence fundamentally enlarges the potentials of sector coupling in network industries. 5G has the character of an application-agnostic General-Purpose Technology (GPT) building a critical input for a large and open set of downstream Internet of Things (IoT) applications. Due to this vertical relationship vertical sector coupling gains particular relevance in all network industries and beyond in many areas of the App economy. Moreover, the potentials of 5G based horizontal sector coupling increases.

Keywords

Internet of Things • 5G • Generalized purpose technology • Big data • Edge computing

Introduction

5G: A new GPT

There is a long tradition by economic historians emphasizing the role played by a few key technologies (coined GPT) such as steam engine, electricity, and semiconductors on economic growth. Basic characteristics of a GPT are pervasiveness within the whole economy, improvement over time and innovational complementarities between the upstream GPT and downstream application sectors. A rigorous analysis of the basic characteristics of a GPT has been provided considering the pervasiveness of semiconductors in a stylized model with quality of GPT defined as one-dimensional homogeneous parameter reflecting density of transistors on a chip [1]. During the last decade's Information and Communication Technologies (ICT) are undergoing tremendous innovations from microprocessors and digital computers towards networked computers based on all-IP broadband communication networks. 5G technology can be considered as a next generation disruptive GPT with multidimensional Quality of Service (QoS) bandwidth capacity. 5G is spawning downstream innovations for an increasing open set of IoT applications, thereby becoming an essential driver for future dynamics in smart network industries [2].

In order to support a large variety of usage scenarios and applications 5G entails demanding requirements for throughput capacity (enhanced broadband) and critical communications (low latency, high reliability), as well as the requirements of massive IoT (large number of connections with low power, low cost). Thus, the necessity for complementary combinations of throughput capacity, critical communications and massive IoT arises [3]. This is partly due to the fact that throughput is not a substitute for QoS traffic requirements. In particular, the over-provisioning of network capacities is not only economically inefficient but cannot provide the required QoS guarantees. Depending on the characteristics of heterogeneous application services, the complementary mix of all-IP broadband infrastructure, including the appropriate frequency capacities, and QoS latency guarantees must be chosen. The entrepreneurial task of 5G network providers is to offer network capacities tailored to the requirements of downstream application sectors. All-IP broadband networks with active traffic management require pricing and investment decisions taking into account the multidimensional character of bandwidth capacities with different QoS parameters such as jitter, delay and packet loss. Depending on the requirements of downstream applications for heterogeneous QoS guarantees and throughput capacities the choice of the traffic architecture, the design of hierarchy of traffic classes with stochastic or deterministic QoS guarantees vary. Economically efficient social optimal capacity allocations are based on demand-driven entrepreneurial search for innovative traffic architectures and concomitant pricing and QoS differentiation strategies. The proper economic incentives for a hierarchy of traffic classes can be derived within a multi-channel pricing model and implemented by admission control and restoration priority parameters resulting in a monotone relation of required bandwidth capacities for more strictly defined QoS parameters. Highest traffic classes providing maximum QoS guarantees to meet the most stringent requirements of highly QoS sensitive applications require paid prioritization with the highest charges for the top priority class. Since data packet transmission within 5G general-purpose broadband networks is application-agnostic market driven optimal capacity allocations result into a dynamic and adaptive state of non-discrimination. Thus, market driven network neutrality is a result of optimal QoS differentiation strategies whereas regulatory interventions into active traffic management under the heading of net neutrality regulation would disturb the social optimal entrepreneurial search process [4,5].

The Governance of 5G-Based Big Data Virtual Networks

IoT has a physical side of applications and use cases and a complementary virtual side. A division of labour between application-agnostic 5G traffic service provider on one hand and application driven 5G-based big data virtual network provider arises. Whereas QoS differentiated 5G bandwidth capacities constitute an essential input for application driven big data virtual networks, the entrepreneurial task of big data virtual network providers is to combine the required bandwidth capacity with other network resources such as frequencies and big data value chains according to the specific requirements of IoT applications. The required network resources and the requisite geographical dimension (local, regional, country-wide, or cross-country footprints) may vary strongly according to the necessities of the applications under consideration. Data value chains may have different

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faces depending on the underlying requirements of IoT applications. This may entail data collection via (camera-based) sensors, aggregation of data, data processing, data analysis, use and re-use of data, taking into account the potentials of alternative cloud service models and the division of labour between central cloud and edge cloud. The entrepreneurial task in building data value chains consisting of privately held non-personal data gains increasing importance in the IoT and related artificial intelligence-based machine learning [2].

Discussion

Big data driven vertical sector coupling

5G-based vertical sector coupling is driven by the open set of IoT applications and use cases. There is an increasing literature about the growing number and diversity of IoT applications and use cases. The verticals cartography project entails a large data base of ongoing use case trials in different countries and industries [6]. They entail, for example, smart agriculture, smart energy, smart sustainable city applications and e-health. In addition, 5G enables local industrial networks, such as industry 4.0 (smart manufacturing) and smart harbours. Entrepreneurs need to explore and exploit the innovational complementarities between (upstream) 5G networks and downstream applications and use cases. In this context the concept of 5G network slicing of logically separated network capacities gains increasing relevance in order to implement end-to-end QoS guarantees. Interconnection and interoperability between different virtual networks could be facilitated by efforts to standardize network slices. In this perspective, local industrial networks are “natural experiments” of a competitive search process toward innovative vertical sector coupling solutions [7].

Big data-driven horizontal sector coupling

There is an open and ever-expanding set of physical IoT applications requiring operator platforms in their role as coordinators, aggregators, and organizers of smart physical network services. Operator platforms play an active role in the creation of new innovative markets for physical network services and complementary 5G-based virtual networks and thereby increasing the potentials for vertical sector coupling. The focus is on the governance of operator platforms driven by the requirements of IoT applications and the future role of entrepreneurial decision-making within operator platforms. New challenges and requirements for a variety of heterogeneous operator platforms have arisen, combining the requirements of physical IoT applications with complementary 5G-based virtual networks. Platform-based services are also increasing the potentials for 5G-based horizontal sector coupling, as illustrated for the cases of mobility-as-a-service platforms as well as networked driverless vehicle platforms.

The transition from conventional intramodal markets towards intermodal mobility-as-a-service markets is characterized by an evolving multiplicity of combinations of shared mobility services. Blurring market borderlines between public scheduled and on demand services provides offer ample opportunities for horizontal markets sector coupling. Shared mobility services are based on big data virtual networks combining real-time mobile communications, global navigation system services (geo positioning) and sensor-generated data processing. There is a large potential to replace infrastructure-generated data by sensor-generated data by means of mobile phones on-board navigation enabling vehicle-to-vehicle communications. 5G-based big data networks for shared mobility services are able to locate and track people and vehicles, supported by global navigation satellite systems. Use cases of location-based data services include ride hailing apps, multimodal routing services and multi-modal big data process. Due to 5G-based innovations, conventional different markets for transportation services provided by taxis, private hire vehicles as well as ride sourcing services are converging resulting into horizontal sector coupling [2].

Conclusion

Networked driverless vehicle platforms are driven by mobile edge computing requiring the devices to connect to the 5G network, moving across different cells with tactile QoS requirements, coupling the requirements of safety relevant and non-safety relevant applications. The shift from driver responsibility to networked driverless vehicle platforms requires highest performance of all dimensions of the big data virtual networks involved. This includes the interactive sharing of anonymized, camera-based high volume sensor data with ultra-high bandwidth QoS requirements of the tactile Internet such as ultra-high position accuracy, the guarantee of ultra-low latency and an appropriate shift from central cloud toward edge cloud resulting into lower latency and bandwidth consumption. Big data-driven network vehicle requirements become relevant not only for road vehicles, but also for other connected vehicles such as 5G-based future railway mobile communication systems or smart harbour solutions with large potentials of horizontal sector coupling.

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