ACT5G Report Summary

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Periodic Reporting for period 1 - ACT5G (Anticipatory Networking Techniques in 5G and Beyond)

Reporting period: 2015-05-01 to 2017-04-30

Summary of the context and overall objectives of the project

The ever-growing demand on broadband mobile data calls for substantial capacity and performance improvement in the fifth generation (5G) networks. This evolution has huge impact on society, as virtually all of us are witnessing the importance of the availability of mobile high-speed Internet. Technological advancement in wireless communication systems and networks is also the enabler of the recent development of device-to-device and machine-to-machine communications for smart cities and smart environments (offices and homes).

The research and development for 5G have to address a number of challenges at various layers of the system, such as new transmission technologies, new devices, as well as novel network architecture and management approaches, in order to meet the expectation on performance. To this end, anticipation is a promising approach that equips the network with intelligence to be able to predict events and performance, and thereby enable the optimization of resource usage and sharing of infrastructure that dynamically responds to the changes in the data demand, service requirements, and channel conditions.

The Horizon 2020 MSCA EID project ACT5G has the overall objective of developing models, methods, concepts, and algorithms for network anticipation and network reaction for 5G systems, to significantly improve the service quality as well as deployment cost in comparison to current networks. More specifically, the project aims to

- investigate analytic methods to effectively and efficiently leverage the network data for performance evaluation, addressing the trade-off of accuracy versus complexity;
- develop prediction methods to assess network performance for a range of indicators, such as coverage, link status, interference, load, and user rate at various timescales;
- optimize resource management focusing on heterogeneity in access technology, cell size, and system level specifications, interference management;
- introduce comprehensive business and infrastructure/resource sharing models across operators, with guarantees for security and transparency to the end users.

The ACT5G project also aims at training of early-stage researchers and promoting their career development in Information and Communication technologies (ICT), and hereby to foster human capital for the European Research Area.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far
The project has two technical work packages (WPs).

- WP 1: Network anticipation
- WP 2: Reaction techniques

The following progress has been made for WP 1:

- A literature survey of network data analysis, and network anticipation applied to millimeter wave (mmWave) systems, in order to set the research work in relation to the state-of-the-art and to identify specific research topics for the two early-stage researchers (ESRs) of the WP.
- Study and analysis of the access and usage of WiFi networks using real data traces originating from the Campus environment, using the method of quadratic discriminant supervised learning to characterize the spatio-temporal. The study is within the context of managing networks for smart environments.
- A stochastic model for predicting the probability of service coverage for mmWave systems. The model accounts for coverage by the line-of-sight mmWave beam and non-line-of-sight coverage by reflections. The model is suitable to use for understanding the impact of parameters, such as beam width and density of the obstacles, on the coverage probability.

The following progress has been made for WP 2:

- A literature survey of resource allocation aspects for a number of 5G-oriented transmission techniques (such as MIMO, mmWave, and flexible frame structure) and schemes for sharing of resource and infrastructure among network operators.
- Mathematical modeling, analysis, and solution approaches for scheduling with scalable transmission time interval (TTI), addressing scenarios with mixed types of service requirements (including deadlines), and a comparative study of the performance of scalable TTI.
- Proposal of a techno-economic model that enables dynamic short-term resource sharing as well as resource pricing, while simultaneously collecting revenue for network expansion; the proposed framework allows operators to meet their individual utility targets while optimizing their expenditures based on their respective budgets.

Via the study of data analysis for WiFi networks and prediction modeling for mmWave systems, the main results achieved by WP1 consist in showing that the concept of anticipation and prediction, via learning and analytical modeling, are of clear importance in the evolution of wireless networks. The key results achieved by WP2 include novel models and methods for resource allocation and sharing that are potentially to be used for 5G systems. The scientific contributions related to these results are demonstrated by the research publications. Also, the ESRs have developed their knowledge and research capabilities, as evidenced by the scientific output.

**Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)**

Wireless/mobile broadband communication is a driver for economic growth, social cohesion/inclusion, and for the improvement of welfare and well-being. Disruptive solutions are however required to sustain this evolution. The ACT5G project advocates the introduction of anticipation techniques in future mobile radio networks to boost their performance and reachability. The core concept of anticipatory networking is that, nowadays, tools exist to make reliable prediction about network status and performance. Moreover, information availability is increasing as human behavior is becoming more socially and digitally interconnected. In addition, data centers are available to provide services and tools to analyze huge amounts of data.

As a consequence, not only can researchers tailor their solutions to specific places and users, but also they can anticipate the sequence of locations a user is going to visit or to forecast whether connectivity might be worsening, and to exploit the
forecast information to take action before the event happens. This enables the possibility to take full advantage of prediction techniques. The ACT5G Early Stage Researchers are all targeting specific cutting-edge research challenges to make network anticipation effective and concretely applicable to future generation networks, with potential impact in several dimensions:

-Advanced Doctoral/Research Training approaches: The ACT5G training pattern tightly couples academic and industrial approaches to knowledge acquisition. We posit that the training approach used in ACT5G can constitute a good practice which can be exported to other research fields and educational institutions. Impacted entities: early stage researchers, educational institutions.

-Advancing the state of the art with tangible and concrete proposals: The ACT5G ESRs are highly committed to top-level research on 5G networks with a medium-short time to market, enabled and guaranteed by the presence in the consortium by one of the big players in the 5G arena.

-Creation of novel market opportunities: One of the ACT5G ESRs, namely ESR 4, is working on infrastructure sharing for future generation networks, to assess a brand new business approach to the ownership and management of 5G; the advocated approach decouples the ownership and the use of the network infrastructure, thus opening up to a new era of more flexible and agile mobile network operators.

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