Improving Usability and Context Awareness over Fifth Generation (5G) Wireless Networks

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***Abstract*—Current fourth generation wireless networks offer many important innovations, but still leave significant room for improvement towards emerging fifth generation technology. Unfortunately, existing deployments do not generally provide technical solutions to benefit from context-related information, which is crucial to dramatically improve the levels of user experience. As context information changes dynamically and remains largely confidential, network operator might be in good position to control the related aspects. This research envisions that new entities need to be added on the network infrastructure side, which would handle context information for the advanced mobile devices like Android and Sailfish platforms. The novelty of the proposed research relies on context-aware services for heterogeneous networks which will be proposed to efficiently utilize dynamic context-related data.**

I. Introduction

The fourth generation technologies offer aggressive improvements in many important aspects of wireless communication including system design, capacity, energy efficiency, and user quality of service. Despite these innovations, new expectations for (i) network capacity, (ii) uniform connectivity experience across the network, and (iii) high level of quality and user experience have already been widely identified for future fifth generation (5G) technology [1]. It is also expected that various types of wireless devices will cause major influx of traffic on the network in the coming years [2]. Unfortunately, the above factors affect considerably the end user experience. As a conclusion, all the above leads to a need of improving wireless connectivity in many ways [3].

Not only the network capacity and user connectivity need improvements towards 5G networks, but also new emerging features and architectures shall be taken into account. Internet of Everything (IoE) is a novel paradigm to interconnect all the elements of the future networks. It is expected to enrich existing Internet of Things (IoT) paradigm by automating and integrating diverse connections between people, process, data, devices, and objects in an efficient and secure manner [4]. The IoE paradigm and the opportunities it generates have already been recognized by major corporations, such as Amazon, Cisco, Ericsson, GE, IBM, and Qualcomm. IoE enables the sustainable competitive advantage compared to previous less efficient solutions by linking everything via capable smartphones and wireless networks.

The realization of context awareness for IoE requires intelligent, controlled solutions by the network operator, as users are naturally interested in protecting their privacy and thus only the required information shall be collected for the purposes of context-aware operation. The network operator has natural capabilities to access the relevant data and therefore it may provide centralized and dynamic solution for information management, as well as identify devices and provide context-aware services. In addition to new requirements on the network and communication links between the IoE components, novel types of social context are emerging. More specifically, types of environment, user profile, content data, device capability (e.g. storage battery, CPU, wireless radios), user proximity to other users, and the overall quality of the available communication links to other devices and applications are elements of future context.

More broadly, social environments may be categorized into public, semi-public, and familiar, when the user profiles may be accessible by friends, possible friends, and unknown people [5]. Typical scenarios may be defined to describe communication for characteristic cases of social context. For example, a user arriving at a new cafeteria (public place), where he meets people from all categories is an example scenario. Existing technology only provides manual solutions to utilize context information in current networks. Unfortunately, this does not provide possibility for all network items to adapt intelligently to and benefit automatically from the existing information, so that the best possible connection experience could be reached across different scenarios.

As described above, there are important reasons and high expectations behind centralized solutions for context-aware networking, where Quality of Experience (QoE) [6] aspects are taken into account on each level, including dynamic IoE scenarios. Moreover, the final solution needs to be scalable, such that the network provider could enable a rich set of new services for devices and applications. Hence, a uniform architecture providing secure connectivity, where only a limited volume of context information is shared, is crucial.

II. Research objectives and solution proposal

As described in the previous section, there is a full set of new dynamic requirements for the 5G network. Therefore, as a result of this research, novel solutions for the context-aware networking will be proposed. QoE will be taken explicitly into account at each step to ensure that the proposed solutions will remain attractive from the user perspective.

The envisioned novel context-aware network architecture is shown in Fig. 1, which introduces a Mobile Router as a new element in the context-aware network management. The mobile router may be regarded as an evolved version of a

proximity server, which controls information related to context awareness. The execution of the proposed research is divided into four tracks.

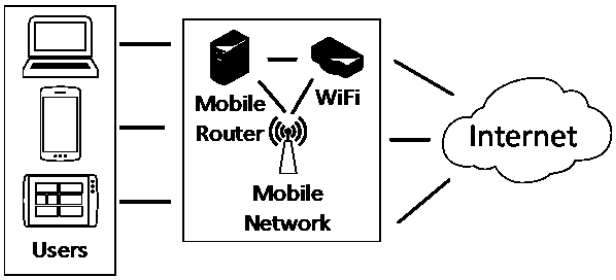

Fig. 1. Architecture of envisioned context-aware system

A. Utilization of context-aware network service

A uniform and coherent solution is needed, which can dynamically utilize and optimize the total capacity of available wireless networks in order to provide congruent user experience about context-aware network. This includes uniform usage of content data, the device capability (e.g., storage battery, CPU, radios), user location proximity to other users, and the overall quality of the available communication links. As the result of this track, a technology demonstrator will be delivered utilizing Mobile Router, where network operator has knowledge on whether a device benefits from WLAN/cellular connection depending on its battery status and various other social variables as described above.

B. Extending context-aware solutions

Whereas the goal of the first track is fairly straightforward, in this track all the system layers of emerging Heterogeneous Networks (HetNets) will be considered for improving context awareness. The three main components to achieve this goal are: (i) the context and group management service enablers, with reasoning and grouping of users based on the context; (ii) content adaptation and delivery based on the context; and (iii) context-related information collection through sensors, context distribution, and context-aware multiparty transport [7]. As a result, network shall be capable to route direct (e.g. D2D) links in case no other options are available. Such an intelligent routing will enable usage of liquid software [8], which may lead to entire infrastructure for dynamically moving functionality and can be used as an example application on this track.

C. Investigate QoE on implemented solutions

The results of the above tracks may be combined with a study of real user behavior. User research is particularly important at this point, since user experience shall be taken into account as early as possible when new technologies are generated (this is also one of the main Intels interests). The user experience study will be conducted in Usability Laboratory of Tampere University of Technology. The study methods will be iterative planning and prototyping. Iterative planning and testing is chosen as it provides regular feedback from users and is thus commonly employed [9]. The prototype test is preferred to ensure that the proposed solution is operating as expected. As a result, we ensure that the considered Mobile Router based solution generates additional effectiveness and attractiveness to the human users in terms of new context-aware network services.

D. Ecosystem and business models of developed services

There is a high demand to link the proposed research to business of existing companies, and even extend collaboration by inviting new partners. The latter is deemed essential since the full power of new technology can only be seen when the promising use cases are utilized by the consortium parties benefiting from them [10]. Our target is to ultimately find a business case to utilize the generated technology.

III. Research infrastructure, environment, and methods

This research relies on the extensive simulation studies to quantify the possibilities for context-aware improvements. In practice, simulation is used to account for numerous factors, such as realistic traffic arrival patterns, user mobility behavior, tight coupling between communicating devices and collocated technologies, application service requirements, wireless channel degradation factors, etc. As there is no off-the-shelf simulation software for 5G networks, the one which is being developed by the W.I.N.T.E.R. group will be used as the starting point for this research. Excellent progress has already made along these lines [11].

The recent research results by the group [12], including the ones completed on top of the Android mobile platform [13], will be used as the base for the proposed research. In addition, Sailfish platform [14] could be integrated into this study to extend the technological perspective. Furthermore, network analyzer (Rohde & Schwarz CW500 [15]) could be employed to improve understanding of HetNets.

Moreover, theoretical knowledge will be applied to support the results of the technical demonstrations. The respective need is rooted in the fact that there are numerous performance parameters and the proposed solutions need to operate with arbitrary number of users, processes, data, devices, and objects. The research is planned to employ: (i) Optimization Theory to identify the best scenario for data delivery, (ii) Theory of Probability and Statistics to estimate unknown parameters, such as user position changes and network load, (iii) Matrix Algebra and System Theory to ensure scalability of the proposed solution. Algorithm Development and Queuing Theory could be further used to avoid resource starvation problems. As described in this section, several technical aspects need to be connected together, as well as with user perspective by this research. In conclusion, the proposed project has excellent support from Intel and University sides, both in technology and theory.

IV. Conclusion

Android and Sailfish platforms offer excellent base to outline use cases for extensive demonstrations of context-aware networking. Moreover, coherent methods for network operators to provide extensive services mindful of the available resources, like WLAN connection quality and context awareness for devices and applications, shall be finalized. Intelligent

algorithms to utilize available information on both application and service provider sides across the HetNet environment are needed to fulfill these targets exploiting QoE research results and wider ecosystem connections.

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