SmartA: Developing an Architecture for Cognitive Wireless Networks

Carolina Fortuna, Mihael Mohorčič, Gorazd Kandus
Department of Communication Systems
Jožef Stefan Institute
Ljubljana, Slovenia
{carolina.fortuna, miha.mohorcic, gorazd.kandus}@ijs.si

Bogdan Filipič
Department of Intelligent Systems
Jožef Stefan Institute
Ljubljana, Slovenia
bogdan.filipic@ijs.si

***Abstract*—Achieving seamless wireless access in a heterogeneous radio environment is the next milestone in wireless network engineering. In this poster we present the initial steps in developing SmartA, an advanced wireless access segment architecture for efficient service delivery in heterogeneous wireless networks. This architecture makes use of "cognitive" methods to achieve its function. First, we address the problem and identify a suitable technology for representing QoS knowledge for translation of application requirements to network requirements. Then, we present an initial evaluation of the Assignment Engine, a component of SmartA which is responsible for optimally assigning services to be delivered by radio access interfaces. The engine uses multiobjective optimization techniques for minimizing the monetary cost and maximizing the user satisfaction.**

Keywords- cognitive wireless network, SmartA architecture, multiobjective optimization

I. Introduction

From the conceptual point of view, the Cognitive Network can be seen as generalization of the Cognitive Radio concept, which evolved from the Software Defined Radio (SDR), by including the aspects of networking, interaction with user, as well as device and network management [1][2][3]. In [1], a cognitive network is seen as a "fundamentally different sort of network that can assemble itself given high level instructions, reassemble itself as requirements change, automatically discover when something goes wrong, and automatically fix a detected problem or explain why it cannot do so". In [2], the authors go a bit deeper and define how to implement a cognitive network, defining it as "a network with a cognitive process that can perceive current network conditions, then plan, decide and act on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end goals". Finally, according to [3], objects composing a cognitive network should contain "a representation of the Ontology of both internals of the object and the environment the object «lives in» and mechanisms to maintain the global faithfulness and global consistency of these representations". In other words, cognitive networks are seen as being able to think, reason, remember and decide for actions which would lead to fulfilling high level end-to-end goals.

Due to the complexity of communication networks, the introduction of the cognitive network concept is expected to be gradual starting from the edges of the network. Thus, the wireless access segment is expected to be the first to benefit from the implementation of cognitive processes, most notably for the provision of seamless vertical handover between different wireless technologies. Users will be able to benefit from a wide range of services, over different mobile operators using a wireless mobile terminal equipped with several radio access interfaces. The system's technological complexity inherent to such a scenario will be hidden from the user, who will interact with a friendly interface where he or she will be able to specify his/her needs using natural language.

The user requirements will be translated by the applications to platform independent requirements. These application requirements will differ from one application to another (e.g. a streaming application compared to a browsing application) and will need to be properly recognized and translated to network requirements, which are platform and technology dependent. A modular cognitive engine will then care to properly deliver the services required by the user using the "most suitable" pair <network operator, wireless access technology>. The engine will determine this pair for each application according to a set of requirements (e.g. QoS requirements, price requirements, etc.) and given a set of constraints (e.g. power constraints).

II. SmartA

The SmartA architecture introduced in [4] is a representative of a wireless access segment as described in the scenario above. Figure 1 presents the architecture of a mobile terminal able to function in such a scenario. The architecture conforms to the cognitive framework described in [2], it integrates the Context Manager [5], the Resource Manager [6] and the Stack Manager [7] and it introduces the Service Manager in the context of heterogeneous wireless networks.

The components of the Service Manager and their roles are described in [4], whereas this poster focuses on the representation of the knowledge a mobile terminal needs to possess in order to be able to translate application requirements into network requirements, and on an initial evaluation of the Assignment Engine, an entity of the Service Manager taking care of the assignment of services to radio interfaces.

III. QoS Knowledge Representation

The Reasoning Engine uses a set of Rules for reasoning but it also needs knowledge regarding the facts it reasons about. For instance, it must be able to infer that if an application

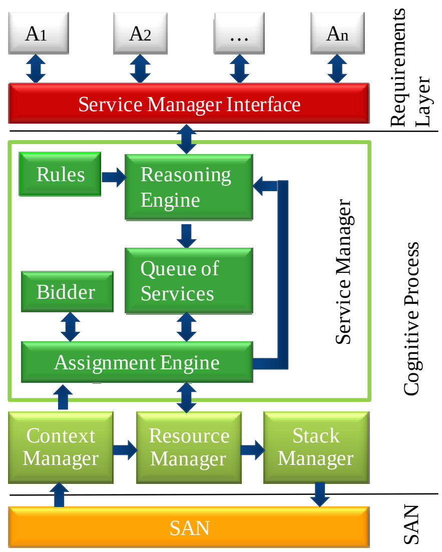

Figure 1. The cognitive mobile terminal.

requires streaming service for a QCIF picture size with frame rate of 15 pictures per second, the network must meet the following requirements: 64 kbps bit rate, 300 ms latency, 20 ms jitter and 10^{-4} packet error rate. This knowledge can be represented by an ontology described using an expressive language that allows encoding rich semantics. Several attempts in specifying QoS have been made over time [8], but QoSOnt [9] appears to be best suited for SmartA. QoSOnt aims at unifying QoS and SLA ontologies and submitting the resulting ontology for standardization [10].

IV. The Assignment Engine

Simultaneous delivery of services via several existing radio interfaces is a combinatorial optimization problem, similar to the problem of assigning processes to multiple processors. In the proposed SmartA architecture the assignment of services to interfaces is the responsibility of the Assignment Engine. This assignment could be performed in several ways, depending on the definition of the problem. For instance, the assignment could be performed by optimizing a single objective (i.e. minimize the cost OR maximize the user satisfaction), or by optimizing multiple objectives at the same time (i.e. minimize the cost AND maximize the user satisfaction). The first approach is computationally less expensive than the second one, but it may lead to less satisfactory overall assignment, since it does not take advantage of the variety of features existing on the heterogeneous device.

We performed initial numerical experiments in solving the problem using a scenario with three radio interfaces (UMTS, WLAN and mobile WiMAX) and four distinct services (VoIP, http, mail and ftp). We exhaustively searched for all possible solutions and identified the feasible ones that met the constraints). We considered four hard constraints, the data rate, latency, jitter and packet error rate, although, considering the application domain, some constraints could be considered soft (i.e. allocate a service to an interface that has slightly higher latency). We identified 120 possible solutions out of which 7 proved feasible and are plotted in Figure 2. If the objective of the assignment would be to minimize the cost, solution 1 would be the best, whereas if the objective would be to maximize the user satisfaction, solution 3 would be the best. Given both objectives, there is no single best assignment, so there is a need to solve a multiobjective optimization problem. It involves identifying a set of non-dominated or Pareto optimal solutions (in our case it consists of solutions 1, 2, and 3), and then selecting the most appropriate solution with respect to additional preferences [11].

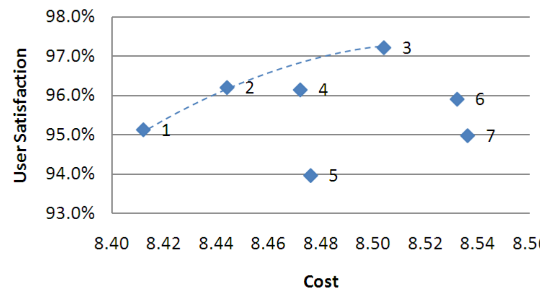

Figure 2. Feasible solutions to the test assignment problem.

V. Conclusions And Future Work

SmartA is a complex modular wireless access segment architecture based on cross domain technologies such as machine learning, stochastic optimizations of systems, knowledge discovery and wireless networks. In this poster we presented the scenario in which such architecture is meant to function. We identified QoSOnt as a potential candidate for representing QoS knowledge that can be used in translations. Finally, we presented an initial numerical evaluation of the Assignment Engine. The next step in developing SmartA is to evaluate QoSOnt and integrate it with the Assignment Engine, in order to support the most appropriate assignment with respect to additional preferences.

References

[1] D.D. Clark, C. Partrige, J.C. Ramming and J.T. Wroclawski, "A knowledge plane for the Internet", SIGCOMM 2003, Karlsruhe, Germany, Aug. 25-29, 2003.

[2] R.W. Thomas, "Cognitive networks", PhD Dissertation, Virginia Polytechnic and State University, Jun. 15, 2007, Blacksburg, Virginia.

[3] P. Balamuralidhar, R. Prasad, "A context driven architecture for cognitive radio nodes", Wireless Personal Communications, Vol. 45, Issue 3, pp. 423 – 434, May 2008.

[4] C. Fortuna, M. Mohorcic, "Advanced access architecture for efficient service delivery in heterogeneous wireless networks", International Workshop on Cognitive Networks and Communications, August 25-27, 2008, Hangzhou, China.

[5] Q. Mahmoud, "Cognitive networks – towards self-aware networks", John Wiley & Sons, 2007, pp. 34. ISBN: 9780470061961.

[6] P. Mahonen, M. Petrova, J. Riihijarvi and M. Wellens, "Cognitive wireless networks: your network just became a teenager", INFOCOM, Barcelona, Spain, Apr. 23-29, 2006.

[7] P. Sutton, L. E. Doyle, K. E. Nolan, "A reconfigurable platform for cognitive networks", CROWNCOM , Mykonos Island, Greece, pp. 1-5, June 8-10, 2006.

[8] J. Jin, K. Nahrstedt, "QoS specification languages for distributed multimedia applications: a survey and taxonomy", IEEE Multimedia, Vol. 11, Issue 3, pp. 74-87, July-Sept, 2004.

[9] G. Dobson, R. Lock, I. Sommerville, "QoSOnt: a QoS ontology for service-centric systems", 31st EUROMICRO, Porto, Portugal, Aug.-Sept. 2005.

[10] G. Dobson, A. Sanchez-Macian, "Towards unified QoS/SLA ontologies", IEEE Service Computing Workshop, Sept. 18-22, 2006.

[11] K. Deb, "Multi-objective optimization using evolutionary algorithms", John Wiley & Sons, Chichester, UK, 2001.