ICT-SHOK Project Proposal: PROFI

**Full Title:** Proactive Future Internet: Smart Semantic Middleware Overlay Architecture for Declarative Networking

ICT-SHOK Programme: Future Internet

**Project duration:** 2+2 years.

**Estimated Resources:** 24 person/years (6 per year)

**Project Responsible Scientist:** Prof. Vagan Terziyan (e-mail: vagan@cc.jyu.fi)

**Project Team:** Industrial Ontologies Group, MIT Department, Agora Center, University of Jyväskylä, and cooperating partners: P2P research group and international collaborators.


**Executive Summary**

Existing initiatives towards Future Internet, e.g. GENI, DARPA’s Active Networks, argue the need for **programmability** of the network components. Some other initiatives extend this with argumentation for **declarative networking**, where the behavior of a network component is specified using some high-level declarative language, with a software-based engine implementing the behavior based on that specification. PROFI subscribes to these visions. Further on, we see at least the following two problems: interoperability of the network elements programmed by different organizations, and the need for flexible cooperation (including coordination, conflict resolution and even negotiation) among network elements. To tackle these problems, PROFI intends utilization of **semantic** languages (based on semantic technologies such as RDF) for declarative specification of network elements’ behaviour, and application of **software agents** as engines executing those specifications.

The major project objective is to provide the basis for such future Internet overlay architecture that will integrate autonomous (self-managed) proactive programmable Internet components. To achieve that, a specialized agent-driven middleware platform PROFI will be designed. It is envisioned that each future Internet programmable component (e.g., host, router, *edge cluster*, *edge node*¹, etc.) will be assigned a representative agent within PROFI. The resulting multi-agent system will be the core of the targeted future Internet overlay architecture for enabling flexibility, adaptability, self-configurability and self-management of the future Internet infrastructure. Utilization of semantic technologies in PROFI will ensure efficient and autonomous coordination among PROFI agents and will thus bring another dimension to interoperability of future Internet components and entities.

¹ Terms taken from GENI vision
Also, Future Internet Upper Ontology will be designed as an important asset contributing to interoperability realization within future Internet platform and in stringent conformance with the major principles laid out in ICT-SHOK Future Internet Strategic Research Agenda (FI-SRA). FI Upper Ontology will be used not only for the benefit of PROFI middleware architecture, but also and most importantly for facilitation of interoperability and integration of existing and brand-new future components, solutions and methodologies which will be developed by various research groups working within FI-SRA. This implies that FI-SRA Ontology will be also used to cope with problems other than specific PROFI issues, such as naming and addressing, interoperability and integration, security, privacy and trust on the scale of the entire future Internet architecture. The core ontology-driven PROFI platform as well as a few demonstration cases of its utilization in various application scenarios will be developed during the project period. The PROFI will enable various information and networking components to automatically discover each other and to configure a complex system functionally composed of the individual components’ functionalities.

**Major Goals**

1. Design of the core agent-driven PROFI platform (as an extension of UBIWARE platform) that will combine semantic description with the agent-driven self-management of Future Internet programmable substrate resources.

2. Design of the Upper Ontology for the domain of Future Internet in compliance with FI-SRA (and as and extension of the UbiVERSE ontology).

3. Design of tools (adapters) for linking Future Internet programmable resources to associated agents within the PROFI platform.

4. Design of basic tools for automatic collection, semantic annotation, management, intelligent processing, integration and visualization of distributed data and behavioral histories of the programmable resources.

5. Design of methods and scenarios for self-management, self-configuration and integration of the Future Internet resources, including cross-layer scenarios (where resources, applications and systems also from various FI layers and beyond those are involved) and their implementation within the PROFI platform.

6. Design of AI support tools for PROFI platform allowing agents to automatically create and utilize configuration plans (in addition to manually predefined), to learn (data mining, knowledge discovery and utilization for management of the underlying networking architecture) and improve individual and collective performance accordingly based on observed histories of the managed resources.

7. Implementation of PROFI platform prototype including pilot ontology, tools and scenarios and representing on top of it a few concrete business cases based on industrial partners needs and covering the scale of Future Internet and beyond in challenging, sophisticated and highly illustrative fashion.
Relevance to FI-SRA

The PROFI concept apparently entails a vision of a multifaceted, multi-purpose and multipronged middleware platform applying multidisciplinary approach to extension and enhancement of the Future Internet vision stipulated within ICT-SHOCK SRA “Future Internet”. Although FI-SRA should be considered the main focus of the PROFI proposal as it approaches many future Internet challenges described in the agenda, the PROFI platform should be rather seen as intelligent stratum between the FI (networking) architecture and the future Web and/or other service oriented environments. Thus, PROFI resides at the intersection of the ICT-SHOCK SRAs “Future Internet” and “Flexible Services” (and in some aspects also “Devices and Interoperability Ecosystems” SRA), and can be implemented as a corresponding cross-program horizontal action research and development project. Below we provide explicit linkage of the PROFI proposal to specific problems and challenges outlined in the mentioned SRAs.

Realization of the PROFI platform (see fig. 1) will make significant contributions to major features of the future Internet and other ICT ecosystems including future networked ICT service architectures and smart ubiquitous environments.

The primary elements of innovation within the PROFI approach are declarative networking overlay architecture comprising programmable network components and associated agent-based semantic management system. This particular middleware solution adds to overall network system flexibility, openness, and manageability.

The principal outcomes the PROFI approach focuses on include:

- **Resource-oriented networking**: PROFI builds upon the information networking paradigm of the Future Internet and extends it via unifying treatment of all types of communication actors (devices, network nodes, information objects, applications and services, etc.). In addition to changing from physical to logical binding of communication actors, this paradigm unifies principles (logical naming and addressing, metadata-based search and discovery) of communication among groups of various resources, should they be hardware components or high-level service artifacts. This type of communication framework will in consequence allow easy establishment of cross-layer communication links (e.g., between a network node and an informational object).

- **Interoperability**: as technical interoperability will be laid as fundamental principle of the Future Internet design, this type of interoperability must be largely provided by the future Internet itself. PROFI’s major concern is semantic interoperability amongst future Internet resources. Semantic interoperability is a prerequisite for seamless information internetworking and integration, and for smooth autonomous communication between various FI resources. What is more, semantic interoperability framework is an absolute must for successful mediation between FI and Web/SOA resources. Semantic interoperability can be achieved by exploitation of rich metadata describing informational objects and semantic resource descriptions written in compliance with well-established semantic standards and on the base of predefined domain ontologies and FI Upper Ontology.
• **Self-manageability**: self-manageability is another important dimension of the future Internet, where the PROFI approach can bring significant values. PROFI brings self-management aboard via presenting totally distributed agent-driven proactive management system. PROFI agents monitor various components, resources and properties within the system architecture and react to changes occurred by reconfiguring the architecture in certain way with respect to the predefined configuration plan. Configuration plans basically represent enhanced business models which are adhered to during accomplished communication procedures between different parties. Due to purely distributed layout of the agent system and outstanding agents’ programmability, merely all existing and new business models can be formalized and enacted by the PROFI management platform. In addition to this, PROFI agents are capable of learning via utilizing available data mining algorithms and further dynamically reconfiguring the
managed architecture on the basis of acquired knowledge. PROFI can be deployed on top of any architectural model due to benefits of agent technologies and open resource interfaces. Also, PROFI platform can make use of contextual information from the managed networking environment.

- **Trust and reputation:** Trust is identified as one of the major and most crucial challenges of the future Internet. We envisage a semantic ontology-based approach to building a universal trust management system. To make trust descriptions interpretable and processable by autonomous trust management procedures and modules, trust data should be given explicit meaning via semantic annotation. Semantic trust concepts and properties will be utilized and interpreted using common trust ontologies. This approach to trust modeling is especially flexible because it allows for various trust models to be utilized throughout the system seamlessly at the same time. Trust information can be incorporated as part of semantic resource descriptions and stored in dedicated places within the PROFI platform. Communication and retrieval of trust information will be accomplished through corresponding agent-to-agent communication. Agents representing communicating resources must be configured appropriately to handle all necessary trust management activities between the corresponding communication parties. Trust management procedures can be realized as a set of specific business scenarios in the form of agent configuration plans.

**PROFI team**

Principal actor will be the University of Jyväskylä. The project team (Industrial Ontologies Group in cooperation with P2P Group) is a well-established research unit with good experience in both research and development. The experience of the research group within the PROFI domain can be proven by the results of the recently finished SmartResource ("Proactive Self-Maintained Resources in Semantic Web") Tekes project and ongoing UBIWARE ("Smart Semantic Middleware for Ubiquitous Computing") Tekes project. These results and developed tools form the basis for PROFI platform research, development and implementation activities. More details are in: [http://www.cs.jyu.fi/ai/OntoGroup/projects.htm](http://www.cs.jyu.fi/ai/OntoGroup/projects.htm). The extended vision of the PROFI concept has been recently submitted as FP7 proposal named PRIME ("Proactive Inter-Middleware for Integrating Embedded and Enterprise Systems"). The group has been also involved to some tasks in Adaptive Services Grid FP6 EU project (both research and software development); to a workpackage in InBCT Tekes Project (resulted in “Semantic Google” research concept and software); to a workpackage in SCOMA Tekes project (Semantic Web Portal development).

**Main international collaborators**

University of California, Berkeley (declarative networking); Massachusetts Institute of Technology, Data Center (semantics in RFID-based systems); University of Southern California (multi-agent systems); Lulea Technical University (telecommunications); VU Amsterdam (agents and Semantic Web); University of Athens (Service-Oriented Architectures), and many others.