Situated and Autonomic Communication an EC FET European initiative

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with contributions from SAC project coordinators

Categories and Subject Descriptors

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1. A EUROPEAN INITIATIVE

The recent advances in communication and networking technologies and the way in which these are being integrated in the human, working and social framework have made it increasingly evident that there are a number of technical and socio-economic areas whose understanding is still less than satisfactory, and in which long-term research is needed. Current communication/networking solutions appear neither task- nor knowledge-driven, and they are not fully scalable in relation to the ongoing explosion of communication needs, at macro and micro levels.

In general, we can observe that the increasingly higher density mesh of components of communications systems and the resulting growing complexity of control requires more and more distributed and self-organizing structures, relying on simple and dependable elements able to collaborate to produce sophisticated behaviors. The main feature of future communication paradigms will be the ability to adapt to an evolving situation, where new resources can become available, administrative domains can change and economic models can vary accordingly.

To promote and structure the European research efforts in this long-term research area, a proactive initiative titled "Situated and Autonomic Communications" was defined in the Future and Emerging Technologies (FET) part of the IST research program funded by the European Commission. Its definition took place in several open workshops organized by FET under the theme "Communication Paradigms for 2020" (see `http://www.cordis.lu/ist/fet/comms.htm`).

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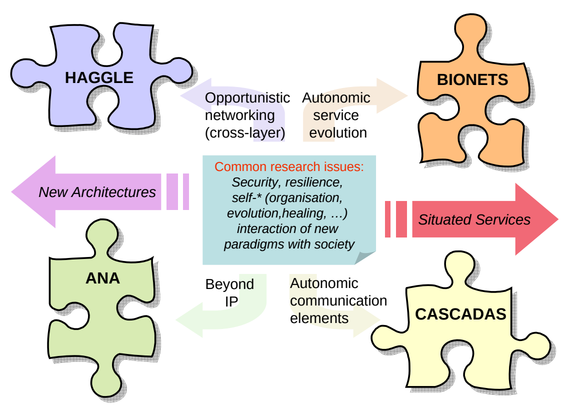
The vision behind this initiative is that of a world pervaded by ubiquitous communication facilities, offering their services to the users and capable of self-organizing and self-preserving their functionalities without any direct human intervention. These new communication/networking paradigms can be situated in multiple and dynamic contexts (ranging from sensor networks to virtual networks of humans), and are expected to be autonomously controlled, self-organizing, radically distributed, technology independent and scale-free, which entails fundamental advances both in the architecture and functionality of the network. Key concerns to ensure are: a) security and trustworthiness; b) overall stability and resilience of the network as it evolves, and c) positive interactions of new communication paradigms with human, social or commercial aspects, in relation to ambient intelligence and future sensorized societies.

The remaining of this paper describes more in detail the 4 Integrated Projects which have been selected in this initiative, following an open call for proposals published in December 2004, for a total funding of 20 M. They all have been launched on 1/1/ 2006.

As depicted in the figure, they cover a wide range of relevant areas for Situated and Autonomic Communications, from an abstract level (trust modeling, game theory, and bio-inspired algorithms) to actual test-beds and experimentations of the proposed concepts and services, aiming at radical changes of the current networking paradigms.



Another project, titled ASTRA (Awareness Services and Systems - Towards theory and Realization) has been recently selected under the FET OPEN scheme (see `http://www.cordis.lu/ist/fet/int-o.htm`) and can be considered as fully relevant to this initiative -several other relevant projects have been recently submitted to FET OPEN and could be launched in the next future.

Further innovative exploratory approaches are sought in future calls to be launched under the 7th Framework research program of the European Commission, whose detailed content will be defined in the course of year 2006.

2. AUTONOMIC NETWORK ARCHITECTURE (ANA)

2.1 Introduction

In the 1970ies and 80ies, the Internet protocol suite was one contender among many others. It prevailed because first, it was open and non-proprietary technology; and second, it pinned down the "waist of the protocol hourglass". This solved the problem of interconnecting N proprietary network standards through N^2 gatewaying services and permitted to bring together uncounted transmission technologies with a potentially unlimited number of network applications. Recent advances in technology (optical transmission, sensor networks) as well as economic tussles, new usage scenarios (intermittently connected devices) and security issues overstrain the current Internet architecture with its end-to-end principle, its single overlay organization, and its address and name space management.

With the research in the ANA project, we want to extend the passive neutrality of the Internet with a dynamic one that permits for an evolution even of the network's core elements and standards. Architecture-determining elements like address handling and network forming that were static beforehand shall be replaced by an autonomic management system that implements the neutrality principles in an active way. New requirements like support for data flow management (e.g., monitoring), security (in a broad sense), and network virtualization mechanisms (e.g., p2p, indirection) shall be integrated. The ultimate goal of the project is to come up with a dynamic and integrated network architecture, where the new neutrality-imposing fixpoint is not the protocol standards, but the way they are handled by the network system itself.

2.2 Scientific Objective

The scientific objective of this project is to explore and demonstrate fundamental autonomic network principles. We aim at a network model that scales in time and in a functional way; that is, the network can extend both horizontally (more functionality) as well as vertically (different ways of integrating abundant functionality) and change over time. The main premise of our work is that a functionally scaling network is the basis for an evolving network which includes the various self-* attributes such as self-management, self-optimization, self-monitoring, self-repair, and self-protection.

In an Internet de-construction approach we will explore the trends of functional atomization, diffusion and sedimentation that will lead to a replacement of the currently static layering of network functionality. Atomization refers to the decomposition of current layered networking software in smaller units that can be recombined. Functionality that belonged to one layer beforehand will be used in the future at arbitrary places (i.e. diffusion) inside a protocol stack or heap, requiring the introduction of autonomic organisation principles. Finally, sedimentation denotes the tendency of services to form compounds either with other required services or with the service clients.

2.3 Technological objective

In ANA, testbeds and prototypes will be implemented at an early stage, following the Internet tradition that networking software matures through implementation. The feedback obtained from preliminary experimental results will be used to steer and refine the architectural design. Inside the four year program we plan for two such prototyping cycles.

The prototypes will concentrate on the autonomic forming and federation of networks and will take mobility into account. They will be based on the predominant infrastructure of Ethernet switches and wireless access points. A first goal is to demonstrate complete self-organization of individual nodes into a network. We target large network meshes in the range of 10^5 active (routing) elements. In order to show scalability, three approaches are envisaged: a) overlay for interconnecting the participating sites; b) simulations; and c) a distributed open collaborative approach similar to successful initiatives such as "SETI@Home" and "PlanetLab", to include external experimentators and to disseminate ANA results. The second goal is the self-organization of networks into a global network, taking into account multiple administrative domains and the cross-domain support for mobile and intermittently connected nodes.

For more information on the project, see `http://www.csg.ethz.ch/research/projects/ANA`

3. BIOLOGICALLY-INSPIRED AUTONOMIC NETWORKS AND SERVICES (BIONETS)

The motivation for the BIONETS project [1] comes from emerging trends toward pervasive computing and communication environments, characterized by an extremely large number of networked embedded devices [2]. Such devices will possess sensing/identifying capabilities, making it possible for user-situated services to interface directly with the surrounding environment, entailing the possibility of introducing radically novel services, able to enhance our five sense, our communication and tool manipulation capabilities.

These embedded devices will possess computing and (basic) communication capabilities, having the potential to form a massively large networked system, orders of magnitude larger than the current Internet. Overall, the complexity of such environments will not be far from that of biological organisms, ecosystems, and socio-economic communities.

Traditional communication approaches are ineffective in this context, since they fail to address several new features: a wide *heterogeneity* in node capabilities and service requirements, a huge number of nodes with consequent *scalability* issues, the possibly high node mobility and the management *complexity*.

BIONETS aims at a novel approach able to address these challenges. Nature and society exhibit many instances of systems in which large populations are able to reach efficient equilibria and to develop effective collaboration and survival strategies, able to work in the absence of central control and to exploit local interactions. We seek inspiration from these systems to provide a fully integrated network and service environment that scales to large amounts of heterogeneous devices, and that is able to adapt and evolve in an autonomic way.

The BIONETS project builds on two pillars, dealing with networks and services, respectively. Both are permeated by biologically-inspired concepts, and will, in the end, converge to provide a fully autonomic environment for networked services. The first one overcomes device heterogeneity and achieves scalability via an autonomic and localized peer-to-peer service-driven communication paradigm, built around a novel approach to information diffusion, communication and filtering. The second one is a bio-inspired platform, centered around the concept of *evolution*, for the support of autonomic services, that evolve to adapt to the surrounding environment, like living organisms evolve by natural selection. Network operations will be driven by the services, providing an "ad hoc" support when and where needed to fulfill users requests. Security issues will be considered as a fundamental part of the services themselves, representing a key ingredient for achieving a purposeful autonomic system. The network will become just an appendix of the services, which, in turn, become a mirror image of the social networks of users they serve. This new people-centric paradigm breaks the barrier between service providers and users, and sets up the opportunity for "mushrooming" of spontaneous services, therefore paving the way to a service- and user-centric ICT revolution.

The net result of BIONETS will be the provisioning of a digital ecosystem for autonomic services, able to fulfill users demands and needs in a transparent and efficient way by exploiting the unique features of pervasive communication/computing environments.

For more information on the project, see `http://www.create-net.org/bionets/`

4. COMPONENT-WARE FOR AUTONOMIC, SITUATION-AWARE COMMUNICATIONS, AND DYNAMICALLY ADAPTABLE SERVICES(CASCADAS)

CASCADAS is a three year project. It aims to enable and promote a radical paradigm transition towards a self-* autonomic network of services: from an environment characterized by a disordered set of computing and communication resources towards future self-organizing, self-managing, and context-aware autonomous networks able to provide composite, highly-distributed, pervasive services [3].

Making the above vision become real is very challenging and has the potential to revolutionize communication systems, in that it requires a deep re-thinking of our current way of designing, developing and deploying distributed systems and applications. Currently, this mostly involves off-line optimization and manual configuration activities, and relies on direct user intervention for the personalization and adaptation of the system to the context, rather than being capable of autonomous self-configuration, self-adaption and self-optimization [4].

The general goal is to reduce the costs associated to the development and configuration of complex communication services, to leverage the exploitation of distributed computing and communication resources, and to make services more usable in line with user needs and expectations.

CASCADAS will identify, develop, and build upon a new model of distributed components, called ACEs (Autonomic Communication Elements), which have the ability to self-organize autonomously and cooperatively with each other, and to reason about - and adapt to - the general and specific context in which they operate (physical, technological, social, user-specific and request-specific). Biological systems presenting autonomous and decentralized collective intelligence (e.g. functional self-organization in living societies [5]) will be an important source of adequate models for the research activities of the project.

From a technical viewpoint, the problem will be approached by conceiving a form of application-level overlay network composed of service components, supported at the execution level by mid-level components that can enforce in an autonomic manner important features such as security [6], QoS [7], self-supervision, self-survivability and knowledge-based self-adaptation. CASCADAS considers developing and deploying each of these components, both at the application level and at the mid-level, in terms of self-similar ACE components or ACE aggregates. These components will dynamically self-organize as needed with each other and with entities that are already deployed [8, 9], and will interact so as to provide the desired functionality in a situation-aware manner with minimal configuration effort.

An integrated open source toolkit of abstractions, algorithms, tools, and autonomic communication recipes will be delivered as a main project result. A comprehensive demonstration of an overlay network of autonomic services will be also developed, and training activities will be organized in the form of a summer school and a forum for e-learning. The above scientific and technological objectives will also be complemented by socioeconomic research to study how strategic needs of social or commercial nature impact on future communication paradigms and how autonomic communication technologies can support the Connected Society in 2020.

For more information on the project, see `http://www.cascadas-project.org/`

5. HAGGLE

Haggle is an autonomic architecture for opportunistic communication among mobile users. While current applications are mostly optimized around infrastructure connectivity (e.g. requiring centralized services such as DNS lookups), in reality mobile users have three methods for transporting data: local wireless connectivity with neighbors, various types of infrastructure connectivity when available (e.g. WiFi, SMS), and physical mobility of users moving from place to place [10] (since users can act as "message ferries" [11]). The aim of the Haggle architecture is to provide a seamless, self-configuring framework allowing applications to transparently make use of all three. Haggle must incorporate "delay tolerance" [12], delay disruption, as well as making full use of intermittent infrastructure connectivity [13] when an opportunity for this arises. Haggle will support a new range of communication services, and extend the penetration of legacy applications.

In order to achieve this, we depart from the existing TCP/IP protocol suite, instead completely eliminating layering above the data-link. We exploit user-level information for message forwarding instead of using anonymous network-layer identifiers such as IP addresses. Network-addressable identifiers are only used at the time that data is actually forwarded. To cope with the lack of infrastructure, we empower intermediate nodes in the network to make intelligent forwarding decisions based on local information. This information might include previous observations of the mobility patterns and behaviors of other nodes, and estimates of the relevance and importance of local data objects to other nodes. Furthermore, in the mobile networking scenario we target, intermediate nodes are likely to be valid recipients for data in transit such as cached web pages - thus they may choose to keep the data as well as forward it.

The Haggle project will explore these ideas with real users, real devices, real applications, and real deployments. Over the next four years, we will design and implement the node architecture and communications architecture necessary for these goals. We will release this software for public use as open source, and perform multiple trials scaling up to hundreds of users. We will perform extensive measurement, analysis and modeling of human mobility patterns, and use this in the informed design of forwarding algorithms. Finally, we will explore security issues and human factors concerns such as privacy and usability.

For more information on the project, see `http://www.haggleproject.org/`

6. ACKNOWLEDGMENTS

This article is introduced by Fabrizio Sestini, EC officer in charge of the FET Situated and Autonomic Communication program. However, each project presentation has been provided by projects' parters which can be identified on the projects' web sites.

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