IST Mobile Summit

BIONETS: Don’t Reinvent Nature, Just Go For It

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Motivation & Constraints

THE SCENARIO

- Pervasive computing environments: an ubiquitous halo of devices with sensing/identifying capabilities for personalized context-aware services

A TRILOGY OF CHALLENGES

- **scalability**: billions of nodes, a multitude of users and services
- **heterogeneity**: at the device and service level
- **complexity**: management of a large-scale heterogeneous mobile network, provisioning of consistent and secure service operations
The Failure of Conventional Approaches: Some Details

**ISSUES CALLING FOR NOVEL SOLUTIONS**

- Connected networks do not scale (Gupta & Kumar, TIT00). Need to support disconnected operations. *From always-on networks to à la carte ad hoc network support to services*

- Impossible to use a unique global address space. Need to look for novel solutions (attribute-based naming?): *from address-based architectures to context-based architectures*

- Need for extremely cheap long-lasting sensor nodes. Clashes with the hourglass “one-size-fits-all” model. Need to *exploit heterogeneity in multi-tier architectures*

- How to manage my network (large-scale, disconnected, mobile)? *From central control to distributed autonomic operations*
The Very Basic BIONETS Ideas

LEARNING FROM EXAMPLES

- Pervasive environments will present scale and complexity figures not far from those typical of biological/socio-economical systems.

- These 3 issues (heterogeneity, scalability, complexity) already successfully tackled by *Nature & Society*.

- Plenty of examples of biological/socio-economical systems able to reach efficient equilibria in a simple, *autonomic* fashion, without any external control.

- The bottom line: draw inspiration from nature to build a distributed autonomic system based on local interactions.
BIONETS Foundations

THE BIONETS VISION

- Overcome device heterogeneity and achieve scalability via an autonomic and localized peer-to-peer communication paradigm
- Services are autonomic, and 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
- 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
The large-scale BIONETS project picture. Tiny nodes (T-Nodes) gather data from the environment and are read by user nodes (U-Nodes) in proximity. U-Nodes form islands of connected devices and may exchange information when getting into mutual communication range; decisions are taken by the service itself. Services are user-situated, and their interactions reflect the social networks/communities users belong to.
The BIONETS Pillars

The BIONETS project builds on two pillars, dealing with networks and services. They will converge to provide a fully autonomic environment for networked services.

(i) Disappearing network: a novel approach to information diffusion, communication and filtering, replacing E2E Internet approaches with localized service-driven communications.

(ii) Self-evolving services: a bio-inspired platform, centered around the concept of evolution, for the support of autonomic services lifecycle.
The concept of “evolution” in BIONETS builds on the notion of self-organization. Socio-economical processes are envisioned as the factors able to provide the “free energy” necessary to “decrease” the entropy of the system and build order.

Evolution in BIONETS is considered at two levels: single components and global ecosystem.

At the component level, each service will be able to design and build its own protocol stack (and, in some sense, its own network): from self-assembling Lego-like protocol components up to gene expression models for self-generation of code.

At the system level, interactions among service entities will provide the means for services to evolve rapidly (“service mating”) while maintaining global stability properties (Evolutionary Stable Strategies).
Any Example?

A GPS-BASED CAR NAVIGATION SYSTEM

- Metropolitan scenario
- Sensors used to control the state of parking lots, monitor traffic etc.
- Cars movement use to spread information on the actual state of the system
- User interested in finding a free parking close to her/his destination
- Currently, use of traffic message channel + shortest path on a weighted graph (but no parking support)
- Evolution of the path computation algorithm to account for user preferences/feedback and state of parking lots
Wrapping up …

**THE BOTTOM-LINE**

- No need to reinvent the wheel: possible approaches to tackle S&AC are already out there on the ground (literally)
- Every kind of inspiration is allowed in science: building working solutions is the real issue
- When looking for *design rules* for large-scale complex systems, go for biology as the best area to draw inspiration from
- Looking at the future: need to form a new class of young researchers with cross-disciplinary competences, able to keep EU at the cutting edge of research in S&AC field