Internet of the Future

BIONETS: From Pervasive Computing Environments to the Internet of the Future

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THE BIONETS PROJECT: FACT SHEET

- Integrated Project funded by EC under the FET proactive initiative on Situated and Autonomic Communications
- Project reference: FP6-027748
- 48 months, project budget $\sim$ 6.95 ME
- Project Coordinator: CREATE-NET
- Consortium comprising academic partners (Univ. of Basel, TU Berlin, Hamburger Technologie-Center, RWTH Aachen, BUTE, London School of Economics, Univ. of Trento, NKUA, Technion), research centers (INRIA, VTT, CREATE-NET, CNR Pisa), industries (Nokia, Sun Microsystems) and operators (Telecom Italia)

BIONETS: 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 More 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

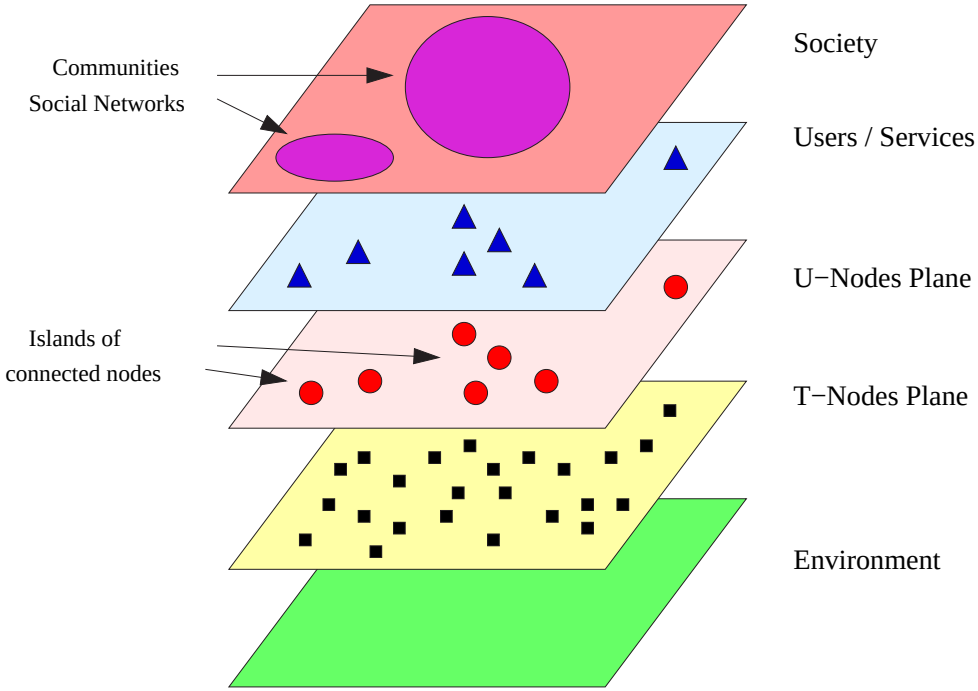
- Pervasive environments will present scale and complexity figures not far from those typical of biological/socio-economical systems
- These 3 issues (heterogeneity, scalability, complexity) already succesfully tackled by *Nature & Society*
- Plenty of examples of biological/socio-economical systems 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

BIONETS at a Glance



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 life-cycle

Evolution in BIONETS

THE SERVICE SIDE

- 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 (micro) and global ecosystem (macro)
- 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)

Evolution and Autonomicity

- Autonomicity usually understood in terms of self-* properties
- Generalization of the 4 self- properties of IBM's Autonomic Computing manifesto: self-configuring, self-optimizing, self-healing, self-protecting
- Autonomic systems need not to require manual intervention for (i) coping with new, unexpected situations (ii) developing new functionalities
- Evolutionary capabilities as a necessary (and sufficient?) condition for obtaining an autonomic system
- Evolution as a specific declination of *self-organization*
- Focus on autonomic *communication* systems

Looking Ahead

FROM BIONETS TO THE INTERNET OF THE FUTURE

- BIONETS solutions cannot be seamlessly applied to Internet environments
- Due to the tight coupling between networks and services
- However, scalability, heterogeneity and complexity issues are present in the Internet world as well
- So can we draw inspiration from BIONETS to design solutions for the Internet of the Future?

A First Proposal

Self-Management of Wireless Mesh Networks

- Self-management as a peculiar property of autonomic communication systems
- Need to design networks that work out of the box
- Some ingredients are known (distributed monitoring, distributed automated traffic engineering, autoconfiguration capabilities) but the full recipe is not
- Application to one of the most promising architecture for access networks: Wireless Mesh Networks
- Possibility of testing (bio-inspired, but not only) solutions in a real-world testbed environment

A Second Proposal

SELF-COMPOSING TCP

- Congestion control as a fundamental problem in (inter)networking
- Starting point: keep the end-to-end nature of current TCP
- TCP behaves poorly in (i) high BDP scenarios (ii) lossy environments
- Coupling error recovery with congestion control harmful for some (multi-media) applications (see DCCP)
- Many modifications proposed (e.g., FAST, BIC, Westwood+, Scalable etc.)
- Our claim: no one-size-fits-all solution
- Let each application *create* its own protocol according to the environment (network status, application needs), by composing some Lego-like blocks
- Main problem: ensure network stability

Conclusions

SUMMARIZING . . .

- BIONETS looks at nature and society for introducing novel networking/service provisioning paradigms suited to pervasive computing environments
- We believe that such approach may lead to interesting results also in an Internet-like scenario
- Two possible research directions for collaborations proposed: self-management of a wireless mesh network and self-composing TCP