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BIONETS
Running Services in a Disappearing Network: Anything to Learn from Nature?

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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 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 data-centric architectures*

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

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

- 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

- 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 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.
Supporting BIONETS Services

Devices classified in two categories. T-Nodes, simple and cheap, acting as a distributed interface to the physical environment. U-Nodes, complex portable devices, carried around by users in their daily life.

A two-tier architecture. T-Nodes “read” by U-Nodes in proximity. U-Nodes run services in a cooperative distributed fashion.

BIONETS services build on the limited connectivity offered by U-Nodes.

Interactions among devices driven by the services, which can build on-the-fly the networking support (e.g., protocol stack) they need.
Evolution in BIONETS

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).
Conclusions

SUMMARIZING . . .

- BIONETS looks at nature and society for introducing novel networking/service provisioning paradigms tailored to pervasive computing environments
- Introduces a design shift: from performance-oriented systems to design for robustness and resilience
- Exploits opportunistic communications as a mean to provide a localized support to self-evolving services

POSSIBLE SPIN-OFFS OF BIONETS PATHFINDER

- Self-assembled protocol stacks (in particular: transport protocols)
- Bio-inspired mechanisms for service-driven network self-management
- Biology as a “safe basis” for constructing evolve-able and future-proof pervasive ICT systems