Resource-Aware Network of Networks
Corrado Moiso, Antonio Manzalini, Roberto Minerva
Agenda

► Scenarios towards Resource-Aware Network of Networks
► Limitations of current Internet
► Architectural vision & enabling technologies
► Some initial results
► Open Issues
Scenarios towards Resource-Aware NoNs

- Future computing, storage and communications resources will be commodities:
  - embedded in all sort of devices and smart things available as part of the landscape;
  - seamless interconnected through a variety of network technologies;
- Users’ devices, network nodes, smart objects and surrounding space (with sensors, actuators, RFID tags, etc.) will create highly decentralized pools of resources, interconnected by a Network of Networks (NoNs):
  - working together for a limited period of time and a limited region of space to support users’ devices in highly personalized and situation-aware services;
- Users will constantly be peers in many networks:
  - personal network, local network, global network, social network, etc.
- Pervasively distributed resources will enable users to have a more active role in the provision of contents and services:
  - service ecosystems will emerge, where several Players (SMEs, LEs, Network/Service Providers, Individuals, etc.) interact to produce, combine, and consume services with direct involvement of their devices, and the surrounding resources;
Are the current Internet and its evolution trends in line?

► One of the pillars of original Internet is the “end to end argument”, but Internet is not “symmetric” any more because, in the prevalent client-server paradigm, servers are more capable and “important” than clients;

► Internet evolution is determined not only by technological progress but mainly from business contrapositions (tussles) that impede a smooth technical evolution and the realization of new business models;

► TelCos tend to bring intelligence in network centralizing functions and creating complex platforms (e.g., IMS, SDP) and contradicting the Internet principles;

► Current IT distributed architectures (e.g., SOA, Cloud Computing) are not able to scale to pervasive environments characterized by high distribution of resources;
Evolution towards Resource-Aware NoNs

Future networks should evolve
from
(almost) static infrastructure focused on communication and networking
to
dynamic clouds of highly distributed resources interconnected as NoNs

► Future network should:
  ► have **borders blurred** and its governing rules and mechanisms will exceed and override the
    controlling mechanisms of single networks;
  ► have to be seen as a “**complex system**” made out of different cooperating entities able to
    self-manage, self-organize and self-optimize;
  ► **interconnect pervasive resources**, offering capabilities, such as computing, storage, routing,
    bandwidth, sensoring, data sourcing and actuating;
  ► be a **decentralized and fragmented infrastructure**, where the global “intelligence” will be
    scattered all over with prevalence at the edges and in users’ devices;
Architectural vision for Resource-Aware NoNs

- **ecosystems of applications**, provided and used by several actors, deployed and executed by composing the features provided by the underlying level;

- **clouds of autonomic components**, virtualizing basic services/resources of the underneath networks; components cooperate, by providing and using resource features in a peer-to-peer way, through self-organized overlay networks;

- **pervasive heterogeneous resources** provided by networks, devices at the edge, “things” interconnected through several types of networks;
Resource-Awareness

► Applications must be fed through dynamically allocating resources made available by multiple networks;

► Resources should be allocated to applications to:
  ► fulfill application needs;
  ► optimize their usage;

► Allocation of shared resources must avoid “Tragedy of Commons”;

► Resources are structured in (self-organized) overlays:
  ► overlays of resources of the same type for distributed allocation policies;
  ► overlays of resources allocated to the same application for creating and self-managing a computing and networking environment;
Enabling technologies for Resource-Aware NoNs

- autonomic capabilities and bio-inspired algorithms (e.g., gossiping protocols, self-organization algorithms), to deal with complexity;

- (self-organized) P2P overlays for clustering components, to guarantee scalability, reliability, and abstraction from underlying network;

- resources virtualization, based on abstraction for coping with heterogeneity and on the definition of dynamic slices for multiple allocations;

- programmable “intelligent” mechanisms, e.g., based on auctions, game theory, etc., for optimized resource allocation and use;

- cognitive cross layering, to allow the network to perceive conditions, decide and act autonomically to reach local/global/end-to-end goals in an optimal way, in cooperation with autonomic and self-organizing behaviour of resources;

- viral communication mechanisms to better integrate users devices and exploit their device-to-device communication and networking features (e.g., local communication networks, mesh or opportunistic networking);
Virtualisation of resources and functions

- It enables multiple heterogeneous resources/networks to cohabit on a shared physical substrate of processing, storage and network:
  - flexible abstraction of capabilities, to avoid losing the access to specific features;
  - creation of “isolated” slices of resource features;
  - distributed algorithms for negotiation and dynamic allocation of slices to overlays;

Credit:: M. Chowdhury and R. Boutaba
A Survey of Network Virtualization
(Virtualized) Resource Overlays

- They are used to structure the virtualized resources needed to deliver applications to a specific individual/community/enterprise:
  - create a uniform computational and networking environment to deliver applications in pervasive and multi-domain contexts;
  - provide autonomic self-CHOP features for their management;
  - self-adapt their configuration according to the dynamically evolving conditions on available resources and network parameters (e.g., traffic, QoS), and users’ needs;
  - decouple applications from actual resources and ease migration paths;
Distributed Autonomic Components

- ACs wrap and enhance virtualized resources/service elements, with self-managing, self-adapting and self-organizing features;

- ACs are able to:
  - react to (unplanned) internal or external events, according to execution plans;
  - interact and cooperate with other (near) ACs;
  - modify their behavior through the dynamic application and composition of plans;
Service Eco-systems on Resource-Aware NoNs

Dynamic Negotiation and Allocation

Overlays of Virtualized Resources

Virtualized Resources

Virtualized Resources

Distributed Applications

Service/Application Provider

Users

Telco

Users
Initial results: Autonomic Communication Element and Toolkit

- **ACE** is an autonomic component abstracting functions and/or resources;
- Distributed systems are composed by interacting and self-organizing ACEs;
- **ACE** consists of organs performing autonomic capabilities and assuring self-* behavior in the distributed system;

ACE Toolkit is available in OpenSource at http://sourceforge.net/projects/acetoolkit/

CASCADAS ACE
http://www.cascadas-project.org/

- **ACE toolkit** is running on servers, laptop and mobile devices (e.g. Symbian and Android);
- **ACE toolkit** is highly stable and shows good scalability in terms memory, threads and communication delays;
- **ACE toolkit** is complemented by a set of libraries for: supervision, self-organization, knowledge network management, and security;
Initial results: Self-* distributed supervision algorithms

- Supervision of a distributed cloud of pervasive resources where nodes can dynamically join/leave the cloud;
- The cloud is managed through a set of ACs interworking through an overlay network:
  - Supervision logic is fully distributed:
    - no centralized knowledge of system state;
    - information exchange through gossiping;
    - local decisions performed by ACs based on local state and data exchanged with neighbors;
- Initial applications to fault recovery, load balancing, and power saving;
- Some results:
  1. the system with LB is stable;
  2. the system with LB+PS has a power saving of ~14%;
  3. limited increment of execution time (~5%), in normal load periods;
(Some) open issues

► Network Virtualization, e.g.:
  ► Switch virtualization

► Distributed control of innovative switching paradigms, e.g.:
  ► Access control of users and machine/devices

► Security, e.g.:
  ► Adoption of cross-layer cognitive solutions
  ► Immune systems inspired algorithms

► Identity Management, e.g.:
  ► Identities associated to each framework elements
  ► Strongly related to the social network relationships
  ► Contracts for dynamic access to profile data

► Trustness, e.g.:
  ► Integration of overlays with social networking information
  ► Enforcing cooperative behaviour, by gossiping information on free-riders, and punishing them

► ... and many others ...
Thanks!

- corrado.moiso@telecomitalia.it
- antonio.manzalini@telecomitalia.it
- roberto.minerva@telecomitalia.it