Self adaptive and cognitive network elements

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“People and autonomic systems will work together *iteratively, **in partnership***”
[John Strassner]

INTRODUCTION

The vision of self-adaptive and cognitive network elements that promise to radically change our networking experience must be grounded in the reality and must take the path of a guided evolution; where the guidance is provided by thoughtful engineering having its roots in fundamental research.

The need for cognition in network elements for wireless systems was realised a decade ago [1], however with the *advent* of autonomic computing and communications and with the ongoing convergence of wired and wireless communications the cognitive networking is on the agenda of much broader community of designers. Do we have sufficient guidance from theory, and from which one?

The key difference between wired and wireless packet switching is in the nature of multiplexing. Wireless communications happen in essentially broadcast environment, which is largely being shaped by the communication itself; the multiplexing in wireless takes the form of positive and negative interference, and at certain level of communication *intensity* the cognition becomes a must due to the impossibility of even enumeration of all possible combinations [2] that require analysis for the decision making.

Multiplexing in wired systems, even with multiple access (since it is a non-broadcast one) takes a form of a serialisation of service requests, which makes multiplexing controllable by means of e.g. capacity admission control, and even autonomically controllable by means of monitoring methods based on e.g. large deviation theory. However dynamic in-network service differentiation still remains a dream that can be achieved by means of self-adaptation and cognition. Cognition will enable autonomic multiplexing including much awaited service differentiation, or using the wording of Graca Cravalho [3] will enable “service creation per service element”.

We use the term ‘advent’ above in the non-theological meaning of ‘second coming’ and demonstrate below that indeed self-adaptive and cognitive were in the minds of early Internet designers.

SELF-ORGANISING POLICY

Paul Baran is famous for his work on distributed systems; he was studying how the level of connectivity between autonomous network nodes helps to increase the entire survivability of packet switching network, i.e. to verify that such networks can be operational even after significant topological changes. For this, he was in need of certain routing – fast and easy, which is since then known as “hot potato” routing. Interestingly, in this early design he did not separate routing from the rest of what we would now term networking middleware, and he termed ‘housekeeping”; he described a then unknown IP datagram like this - “Most of the message block would be reserved for whatever type data is to be transmitted, while the remainder would contain housekeeping information such as error detection and routing data" [4].

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Though the centre of mass of his work was on network structural properties he did find a very elegant *co-optimisation* of routing and housekeeping, and it appears that he was the first to introduce in these settings not only policy but the cognition as well: "What is envisioned is a network of unmanned digital switches implementing a ***self-learning policy*** at each node so that overall traffic is effectively routed in a changing environment--without need for a central and possibly vulnerable control point ... The network can be made rapidly responsive to the effects of destruction, repair, and transmission fades by a slight modification of the rules for computing the values on the handover number table" [5].

Today, 45 years after that work we observe that policy is still in the focal point of our attention. Yet we are only demanding that "This evolution of policy, from 'just' a tool to tell if an action should be executed, to being intimately involved in how, where, when, and why configurations are changed and managed, is the next era of policy-based management. [6]". Obviously something went wrong with the Internet engineering; the process of organic growth made the Internet to become a patchwork of kingdoms [7] - policy interoperability and policy multiplexing are largely unsolved problems at the wholesale interface i.e. between Autonomous Systems. As one of the pressing policy challenges of today in wireless the following did emerge (mainly within the cognitive networking domain, for example addressed in the E3 project[1]) - How to balance between autonomic decisions and centralised control by policies?
Can we return to fundamentals and make networking right for a long-term evolution?

BEYOND IP? YES!

First, let us explain what exactly we mean by the "beyond IP" networking. This is fairly easy to describe since we do not need to involve anything else but the text of the Internet Protocol specification; we shall use just two quotes from the RFC791 [8] to make our position clear by subsequent interpretations (as they appear relevant today) of the quoted features.

> Quote 1: [8, page iii, section 1.2] *"The internet protocol can capitalize on the services of its supporting networks to provide various types and qualities of service.*"

The interpretation of today calls for a novel networking design, in which in-network functionality (including in-network decision processes and cognition for self-adaptation) is being orchestrated per service in the way that is either cross-layered (the case of incremental deployment) or layerless (the radical case). It appears to us that the above orchestration is happening nowadays mainly at the boundary of wireless and wired networks, however, we believe that the findings will soon find their way in the core (backbone) Internet.

> Quote 2: [8. page 1, section 1.4] *"The type of service is an abstract or generalized set of parameters which characterize the service choices provided in the networks that make up the internet.*"

In other words the above can be stated as "IP is not a service but a service building block". Who then makes services? IETF (even in IntServ and DiffServ) is explicitly service-neutral, while network operators are usually unable to invest in a proprietary long-term service engineering, thus leaving it to standardisation bodies only, which in turn are not able to support long-term novel research. The way out of this deadlock is in the novel standardisation

[1] ict-e3.eu

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initiative, which can be the ACF[2]. The interpretation of today as well as IntServ and DiffServ experiences point clearly at policy mechanisms as the major communicator between generalised parameters and domain-specific service choices. This [essentially cross-layer] communication must be truly autonomic one in that it must require zero management, or, when available the self-management of networking technologies enabled by cognition. The major challenge here is to assess such systems.

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[2] www.autonomic-communications-forum.org

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