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Autonomic Networking Definitions Revisited
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Abstract

This document revisits the autonomic networking terminology established in peer-reviewed literature, aiming to contribute to the ongoing discussion in the IRTF NMRG about how to move forward with standardizing various autonomic networking aspects.

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1. Introduction

The IRTF Network Management Research Group (NMRG) has been working on a set of definitions for autonomic networking. Defining and agreeing on autonomic networking terminology is not an easy task as discussed in [TAN]. In general, autonomic operation is associated with a range of properties, such as self-configuration, self-healing, self-optimization, and self-protection [ACDawn]. It is worth pointing out that although there is some implicit consensus within the autonomic computing community on the key properties/attributes, in the autonomic networking community this is not necessarily the case. In the past, the common ground between different projects and different contexts of operation was the presence of self-* properties, without converging to a minimum set or different levels of autonomic behavior or where this behavior needs to be manifested.

Behringer et al. [I-D.irtf-nmrg-autonomic-network-definitions] describe a set of design goals and non-goals for autonomic networking and introduce a model reference architecture in the context of future IETF standardization [I-D.behringer-autonomic-control-plane].

Prior to this recent effort at the NMRG, autonomic networking has been the focus of several research projects over the last decade. For example, Bouabene et al. [ANA] detail an autonomic network architecture (ANA). Nguengang et al. [UMFSpec] propose a unified management framework (UMF) which has autonomic properties and functions at its core. Chaparadza et al. [SelfFI] introduce an elegant and "standardizable" [sic] generic autonomic networking architecture (GANA) which they propose to be adopted as a reference model. GANA was indeed further elaborated under the auspices of ETSI as a group specification [GANA]. This list of earlier work in only indicative to the breadth of research in this area over the last decade. However, standardization remains an open question and

deployment has been limited to specific mechanisms only [I-D.irtf-nmrg-an-gap-analysis].

We concur with Behringer et al. [I-D.irtf-nmrg-autonomic-network-definitions] that for most of the work in IETF it suffices to define autonomic behaviour at the node level. However, recent standardization efforts in the IETF, such as, for example, I2RS [I-D.ietf-i2rs-problem-statement], SFC [I-D.ietf-sfc-problem-statement], ABNO [I-D.farrkingel-pce-abno-architecture], SUPA [I-D.pentikousis-supa-mapping], and LIME to name a few, and new research groups at the IRTF (SDNRG and proposed NFVRG), indicate that one may consider that the NMRG should perhaps dig a bit deeper before finalizing the definitions and goals document. In particular, one could reconsider the aspects of defining node-level autonomicity only.

This document revisits the autonomic networking definitions proposed earlier in the peer-reviewed literature Section 2 ,and relates them with such recent developments aiming to assist in the definition of coherent terminology in this emerging area of standardization at the IETF.

2. Definitions

After some thorough analysis and discussion, Schmid et al. [TAN] put forward the following definition, which captures in a concrete and concise manner the essence of autonomicity:

> An Autonomic System is a system that operates and serves its purpose by managing its own self without external intervention even in case of environmental changes.

Note that the authors explicitly define autonomicity at the system level, not at the node level. They go on to list the minimum set of properties that an autonomic system should possess. Namely, an autonomic system is

- o automatic, i.e. it can "self-control its internal functions and operations"
- o adaptive, i.e. it can change its "configuration, state and functions", and
- o aware, i.e. it can "monitor its operational context".

In principle, an autonomic system could wholly replace a non-autonomic one. In practice, however, real-world deployments will

include legacy network elements and services as well as new autonomic ones.

A salient paper in the autonomic networking area is [FOCALE], in which Strassner et al. lay the foundation for an autonomic network architecture. We will not delve into the details of FOCALE, but we do note that the authors define three types of managed components depending on their autonomic capabilities. In the remainder of this document we consider that FOCALE "components" equate to network resources as defined in [I-D.irtf-sdnrg-layer-terminology], i.e. each network resource is a "physical or virtual component available within a system", and build on the definitions further.

In this sense, legacy equipment can be seen as autonomically unaware resources, and can only be managed using traditional mechanisms. In practice, field equipment could be upgraded to support certain autonomic features, thus becoming autonomically-aware managed network resources. This type of network element would typically require a mediation layer as suggested in [FOCALE] or at the very least certain system software updates. Finally, a deployment could include fully autonomically-enabled network resources. FOCALE explicitly aims to "accommodate legacy components" and foresees the deployment of an autonomic manager "that orchestrates the behaviour of other autonomic components in the system."

Figure 1 illustrates a simple sketch of an autonomic networking control loop, based on Fig. 2 of [FOCALE]. In short, an autonomic manager gathers data from the managed resource(s), evaluates the current state, compares it with the desired one, and configures the managed resource as necessary. As illustrated, this simple system possess the minimum set of properties introduced above.

```
                         +---------------------+
 (Maintenance Loop)      | Actual vs. desired  |  Autonomic manager
         +-------------->| state evaluation    |
         |               | and decision making |
         |               +----------o----------+
         v                          |
 +-----------------+                | New configuration
 | Data gathering |                 | (Adjustment Loop)
 +-----------------+                |
         ^                          v
         |                +------------------+
         +----------------o Managed resource |
                          +------------------+
```

Figure 1: Simple sketch of an autonomic networking control loop

Of course, all three types of network resources (autonomically-unaware, -aware, and -enabled) need to be managed. One viable approach is proposed by Nguengang et al. [UMFSpec] who describe an architecture based on the definition of two types of management systems depending on the capacity of the underlying nodes, namely an Enhanced Legacy Management System (ELMS) or a Future Management System (FMS). In this context, it is worth considering the approaches taken in other disciplines. For example, in aviation, auto-navigation systems solve this challenge by means of distributed consensus among an odd-number of controllers/manager that independently carry out the tasks of data gathering and state evaluation, and then make an election for each decision. On the other hand, bio-inspired systems have emergent coordination (of managers) following principles such as entropy or mass action.

Finally, autonomic properties are highly desirable in the context of new mobile architectures. For example, Barth and Kuehn [SON4G] discuss the need for self-* properties in the context of small cell deployments in 4G/LTE, while Hamalainen et al. [LTESON] and provide a comprehensive guide and handy references to the efforts in 3GPP along these lines.

3. Operational Considerations and Outlook

This section briefly describes emerging operational considerations that in the author's view should be taken into account as we move forward with autonomic networking standardization in the IETF and IRTF context.

3.1. New Deployment Models

Strassner et al. [FOCALE] highlight that an important goal of autonomics is "making the life of the user easier by changing the focus from a computer-centric to a task-centric model". Deployment of new network technologies is typically a time-consuming, labour-intensive and cumbersome task. In the past, we have seen that if the newly designed infrastructure cannot be managed satisfactorily adverse results, such as service launch delays, may be inevitable. As we move forward with new deployment models which are oriented towards softwarized and cloudified network functions, autonomic networking principles may prove invaluable.

As per [TAN], autonomic systems are by design programmable, which bodes well with the emerging deployment models which emphasize agility and shorter technology introduction cycles. We argue that autonomic networking definitions, goals and gap analysis within the context of IETF standardization should take this more into consideration. Further, recent initiatives such as SUPA

[I-D.pentikousis-supa-mapping] point towards infrastructures which are managed through intent (generic policies), for instance, as opposed to network element specific configuration.

3.2. Programmable Network Elements and Functions

Although the development of models such as FoRCES [RFC5812] coincided with the core of the above-mentioned autonomic networking research literature, by and large, the two areas did not cross-pollinate. It appears that as SDN and NFV principles reach a wider audience of researchers and practitioners, fully programmable network elements and functions could be further introduced in autonomic networking architectures. Indeed, moving towards a "task-centric model" relates well with other efforts in IETF such as SFC [I-D.ietf-sfc-problem-statement]

3.3. Autonomic Planes

Recent work at the SDNRG [I-D.irtf-sdnrg-layer-terminology] highlighted the need for the wider SDN community to think in terms of control, management, and operational planes comprehensiveness and complementarity. As we have seen above, earlier work in autonomic networking has been primarily focusing on management aspects (cf. [UMFSpec]), while recent work in NMRG is focusing on standardizing an autonomic networking control plane [I-D.behringer-autonomic-control-plane].

For an autonomic plane, there is the challenge on "which functionality to place where". For example, one could consider an architecture in which all three planes have autonomic features. Alternatively, one could adopt a knowledge plane approach [KP2003] establishing a separate, virtual/logical plane. A way forward could be to consider autonomics in NMRG in the context of programmable networks and through a more comprehensive manner.

3.4. DevOps

John et al. [NSC] elaborate on the concept of continuous network service delivery. In this context, the authors argue for the need of programmable observation points which could be inserted in a dynamic service chain on demand. They expect that future service provider DevOps would require new management technologies "based on the experience from data centers" thus "addressing the challenges of dynamic service chaining". This bodes well with the model illustrated in Figure 1 and we could expect more results in this direction in the future.

4. Acknowledgements

This document would not have been possible without the stimulating discussion during the NMRG meeting at IETF 90 in Toronto. Many thanks to all participants.

5. IANA Considerations

This memo includes no request to IANA.

6. Security Considerations

This document does not propose a new network architecture or protocol and as such does not have any impact on the security of the Internet.

Autonomic networking introduces a range of opportunities for formal verification techniques which could increase trustworthiness, although this is clearly beyond the scope of this first version of this document. Interested readers should consult [ACSec] for an early exploration of the issues at hand in the context of autonomic computing.

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