Standardization of an Autonomicity-Enabled Mesh Architecture Framework, from ETSI-AFI Group perspective: Work in Progress (Part 1 of 2)

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***Abstract*— In this two-part paper we describe the ongoing standardization work on designing an autonomicity-enabled mesh architecture framework. This is work in progress being carried out by the AFI (Autonomic network engineering for the self-managing Future Internet) working group of the European Telecommunications Standards Institute (ETSI). In this first part, we briefly describe the AFI GANA (Generic Autonomic Network Architecture) Reference Model for autonomic network engineering, cognition and self-management, and then discuss instantiation issues: the stability and coordination of autonomic functions as well as governance profiles and policies. The topics covered in this part serve as an introduction to the second part (a separate paper) where we describe the steps needed to accomplish an instantiation of GANA onto wireless mesh networks—thereby creating an autonomicity-enabled mesh architecture.**

***Index Terms*— autonomic network architecture, European Telecommunications Standards Institute (ETSI), self-management, wireless mesh networks.**

I. Introduction

IT is commonly agreed today that, although research on self-*, autonomic management and networking has been ongoing for many years, this has not actually happened in a harmonized manner, thus rendering the standardization of the elaborated concepts a task rather difficult to accomplish. To this effect, the Autonomic network engineering for the self-managing Future Internet (AFI) is a well-focused, dedicated working group that was created under the auspices of ETSI to fill this gap. In particular, AFI's twofold objective is first to establish a common vision of what is meant by an autonomic behavior and, at the same time, to establish a unified approach to autonomic network engineering. By doing so, AFI is expected to provide the various stakeholders in the communications environment (telecommunication, service and others providers, OSS vendors, manufacturers, etc.) with the chance of understanding the advantages and eventually adopt autonomic and self-management solutions.

To accomplish its goal, AFI spans across three main Work Items (WIs). WI#1 [1] is responsible for presenting the scenarios, use cases, and key operator requirements that reflect real-world problems and can benefit from the application of autonomic principles. Based on WI#1 analysis, WI#2 has produced a Generic Autonomic Network Architecture (GANA) Reference Model [2]. This reference model can be seen as a framework within which to specify and design functional blocks, and the characteristic information being conveyed in the reference points among them. The reference model is responsible for autonomic and cognitive management, as well as for the control of network resources such as protocol stacks and mechanisms. Finally, the role of WI#3 is to instantiate the AFI GANA Reference Model onto existing standardized reference architectures for both fixed and wireless network environments including wireless ad-hoc/mesh/sensor networks, ITU-T/TISPAN NGN, 3GPP LTE/EPC, BBF/ADSL FTTH, etc. [3]. This paper focuses on the generic instantiation issues studied within the scope of WI#3 and it comprises the introductory part of the work that is completed in a second part [4], which provides details of instantiating the reference model onto a specific network architecture–an IEEE 802.11 compliant wireless mesh network architecture.

The rest of this paper is structured as follows. Section II revisits the AFI GANA Reference Model and the concepts specified therein. Instantiation issues are discussed in the subsequent sections: the stability and coordination of

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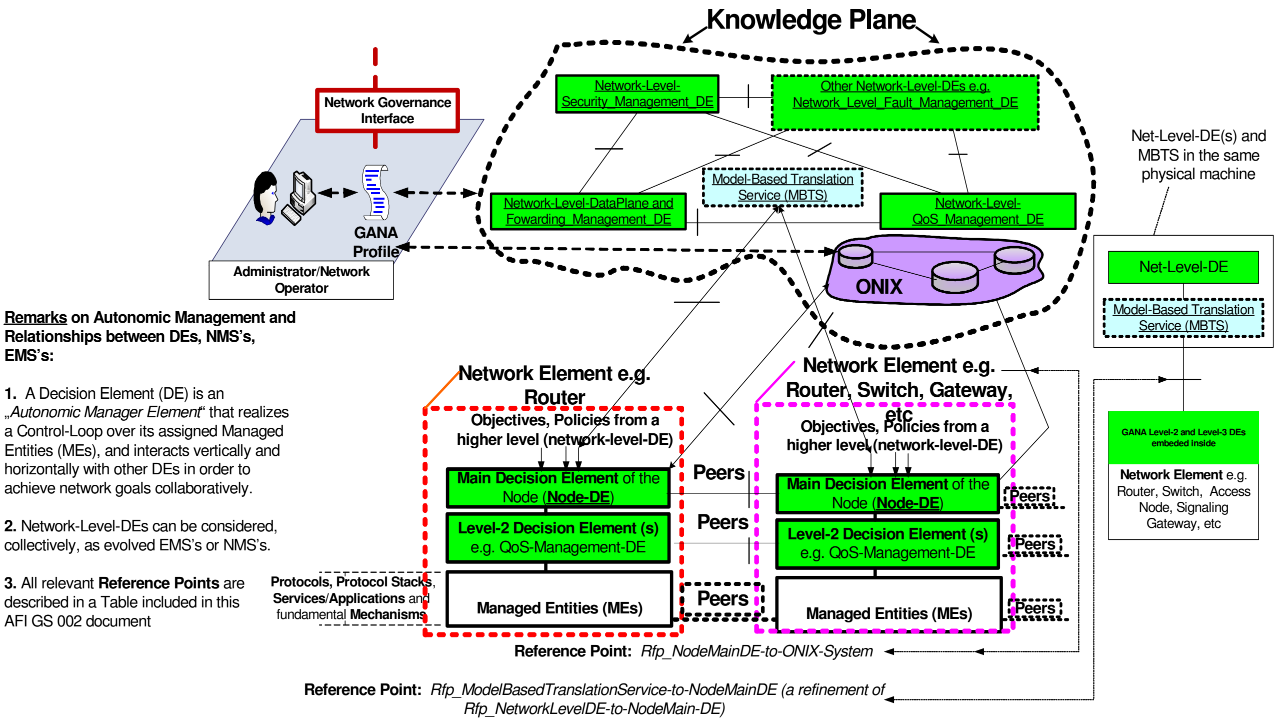

Fig. 1 GANA reference model

autonomic functions (Section III) and governance profiles and policies (Section IV). Finally, Section V concludes the paper.

II. Background on GANA Reference Model

The AFI GANA Reference Model defines Functional Blocks (FBs) and the associated Reference Points (Rfps). These elements are specific to enabling autonomics, cognition, and self-management in a target architecture, when instantiated onto an implementation-oriented reference architecture such as these defined by standardization organizations (e.g., 3GPP, BBF, TISPAN). Fig. 1 presents a general overview of the GANA reference model while its details, related concepts and its evolution, can be found in [2][3][5][4].

Self-manageability in GANA is achieved through instrumenting the devices with autonomic Decision-making-Elements (DEs), which automate network operations by implementing control loops. Such control loops operate using the knowledge regarding events and the state of network resources. They regulate the resources or functions of the network according to its goals. GANA defines the DE as a concept that is associated with (one or more) concrete resources managed by the DE, and implements and drives its control loop based on a continuous learning cycle. At the same time, the DEs are continuously exposed with a local view of their managed resources, together with other cognition functions which retrieve knowledge from other required or potential information suppliers of DEs, such as the environment in which the device hosting the DE is operating. These functions are used by the autonomic element to change the behavior of the managed resources in order to achieve and maintain the goals known by the autonomic element. GANA also adopts the concept of a Managed Entity (ME) to denote a managed resource or an automated task in general, instead of a Managed Element, in order to be more generic and to avoid the confusion arising when one begins to think of an element as only meaning a physical network element.

GANA defines four basic levels of abstractions at which autonomicity can be introduced, namely: Protocol-Level (GANA Level-1); Function-Level (GANA Level-2); Node-Level (GANA Level-3) and Network-Level (GANA Level-4). Since the Protocol-Level involves embedding an intrinsic control loop within an individual protocol, it may not be necessary to introduce such "intelligence" into individual protocols, but rather to focus on introducing autonomicity (control loops) at higher levels of abstraction, starting from the level directly above (i.e., the Function-Level that defines "functions" which abstract individual protocols and mechanisms), up to the Network-Level. This makes the three levels (Level-2 to 4) the most important ones. Therefore, according to the Reference Model (Fig. 1), the three levels of hierarchical control loops that are realized by corresponding Decision-making-Elements (DEs) work collaboratively, from within a Network-Element up to the Network-Level (Knowledge Plane), and demonstrate how autonomics, cognition, and self-management can be gracefully (i.e., non-disruptively) introduced in today's existing architectures.

In particular, as mentioned above, in order to introduce or advance autonomicity in any network architecture, an instantiation needs to be carried out of the FBs and Rfps from the GANA Reference Model onto a target architecture, e.g., the wireless mesh network architecture, the 3GPP network architecture, or the NGN architecture. This instantiation implies the following tasks.

First, it is necessary to instantiate the FBs of the Knowledge Plane, which consist of the Network-Level DEs (as described above) with cognition functions able to expose the local view and able to aggregate different views to retrieve a global view of the behavior of the network, the Model-Based-Translation Service (MBTS), and the Overlay Network for Information eXchange (ONIX). MBTS forms an intermediation layer between the Knowledge Plane and the network elements. ONIX is a distributed scalable system of information servers that supports the publish/subscribe paradigm for information exchange and discovery.

Second, regarding Network-Level DEs: they can perform the role of Policy-Decision Points (PDPs) and such PDPs can be evolved by the Decision Elements. Additionally, Network-Level DEs (in the Knowledge Plane) either evolve EMSs/NMSs or may be implemented as separate run-time entities that then interwork with these EMSs or NMSs.

Third, GANA's Knowledge Plane may complement the existing OAM/OSS Plane by (a) the ONIX information exchange servers which facilitate, through publish/subscribe services, an advanced self-awareness of the elements plugged into the network, their capabilities, network resources, configuration-data/profiles/policies, pointers to information and resources, etc. and (b) establishing the type of autonomic functions (i.e., DEs, their associated control loops and their assignment to specific MEs, as well as parameters they manage and adaptively control) that should be instantiated onto which Network Elements.

Fourth, regarding the end-to-end transport architecture it is necessary to establish the required kinds of distributed control loop coordination and use the instantiated FBs and Rfps for autonomicity/self-management from the reference model, to specify autonomic behaviors (i.e., behaviors of instantiated DEs) within the management and the E2E transport architecture.

III. Stability and Coordination of Autonomic Functions

For addressing stability and coordination of autonomic functions, the WI#2 specification [2] includes techniques and architectural principles that ensure that control loops can be designed in a way that guarantees non-coupling and/or non-conflicting behaviors of autonomic functions (e.g., by time-scaling, ordered decisions), so as to ensure stability.

Following the principles defined by AFI in [2], and in particular, the concept of DE ownership of an ME or ME Parameters, a DE-to-ME Parameters Mapping Table is required for each instantiation of the reference model onto the target node/device architecture. A table per node type or device type must be provided. For all the MEs and parameters

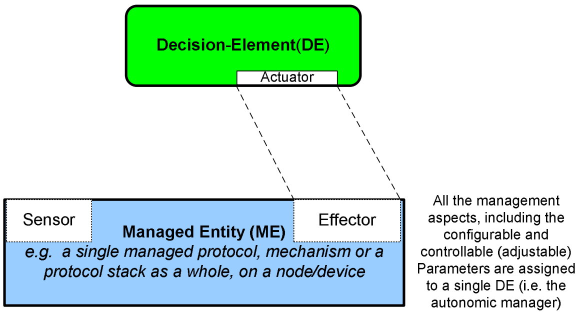

Fig. 2 Parameter mapping Case 1 (preferred mapping): an ME is fully assigned to a single DE, i.e., the ME effector assigned to a single DE.

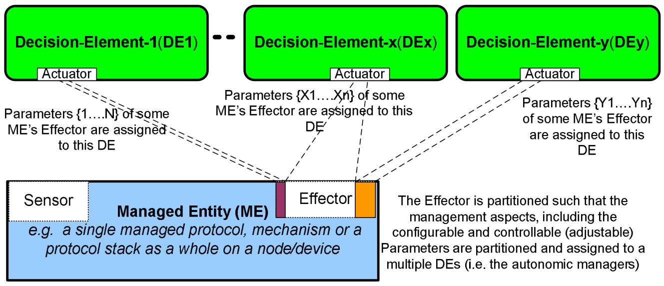

Fig. 3 Parameter mapping Case 2: an ME with an effector partitioned such that varying parameter sets are assigned to different DEs.

at the resources layer of a node/device, this table must provide a one-to-one mapping of a particular configurable and controllable parameter of an ME to a single DE. This mapping is important for the reasons described below, and should be included in the associated standard emerging from the instantiations of the reference model onto a particular reference architecture. This mapping plays an important role at the design time for DE behaviors, as well as in realizing the coordination and collaboration of autonomic functions.

The DE-to-ME-Parameters Mapping Table is obviously important to DE designers. By referring to this table, a DE designer who designs the behavior of the autonomic manager, can see the parameters that the DE can configure and dynamically control. This dynamic adjustment may require that the DE performs synchronization, collaboration, and coordination with other DEs on the same GANA level or on a higher level.

The mapping table will also be used by an editor, simulator, or validator to enforce constraints on which a given DE is allowed to modify a parameter value of an ME. The table can be imported into a simulation and validation environment, i.e., a development environment in which DEs are designed and their behaviors simulated and validated for autonomic behavior functionality and also validated against potential stability related problems [2]. In the development, simulation and validation environment, the editor, i.e., the Graphical User Interface (GUI) used by DE designers, can be made to import the mapping table in order to enforce constraints on the permissions of the DE designer when setting parameter values for MEs. These constraints can also be enforced within the simulator or validator or a conflicted resolution survey FB in the KP. Alternatively, the constraint checker can relax the constraint by allowing a DE to request parameter value change indirectly via another DE that owns the ME parameter, as described below.

The coordination of autonomic functions (DEs) is done in a twofold manner. First, DEs perform coordination on which parameters (i.e., values) must be changed under given circumstances as guided by a shared optimization and self-adaptation objective commonly understood by the DEs. The coordinating DEs may conclude to change certain parameter values in different time scales or re-order the different hierarchical DEs. The DE that is assigned to manage and control a particular parameter is the one that adjusts the parameter setting after the coordination process of various DEs required to coordinate is completed. Second, indirect parameter adjustments can occur by allowing a designer of a DE logic to indirectly change a parameter value in the logic of the controller by making calls to the DE responsible for managing and controlling the parameter (the owner DE of the parameter). The intercepting DE (the parameter owner) can decide to make the parameter value change, reject it, or postpone the requested change.

Fig. 2 and 3 show how MEs and their parameters can be assigned to particular DEs for autonomic management and control. The figures show how AFI is working on creating the DE-to-ME-Parameters Mapping Tables for the various node types on which a GANA instantiation has been performed.

The partitioning can be driven by the various ME's management aspects and parameters being perceived as "abstracted" by multiple DEs when mapped to the GANA abstractions at Level-2 and Level-3. The ME may exhibit multiple configurable characteristics, e.g., it can be viewed as an "instrument" for enforcing QoS, security, or mobility through a given parameter configuration. Therefore, there is the question of whether to wholly assign the ME to the QoS-Management-DE, Security-Management-DE, Mobility-Management-DE or other relevant DE. But to avoid complexity, the partitioning of the ME effector could be avoided by following the Case 1 option and enforcing any designed DE logics to coordinate through a single DE owner of the whole ME.

In Case 2 (Fig. 3), the DEs need to synchronize their operations and coordinate their parameter value manipulations and, if necessary, also the time scaling for those parameter value modifications, to ensure that the overall behavior of the ME is desirable and fulfils the ME's objectives.

IV. Governance (Profiles and Policies)

The enabling notion of governance is based on the fact that the autonomic network requires as input goals and requirements defined by the human operator. The network must operate with respect to the operator business rules and the operator must trust the autonomic network behavior.

Therefore the AFI governance mechanism (Fig. 4) enables the human operator to define business policies and validate the policies and profiles disseminated by the network governance mechanisms. The business profiles are mapped within a

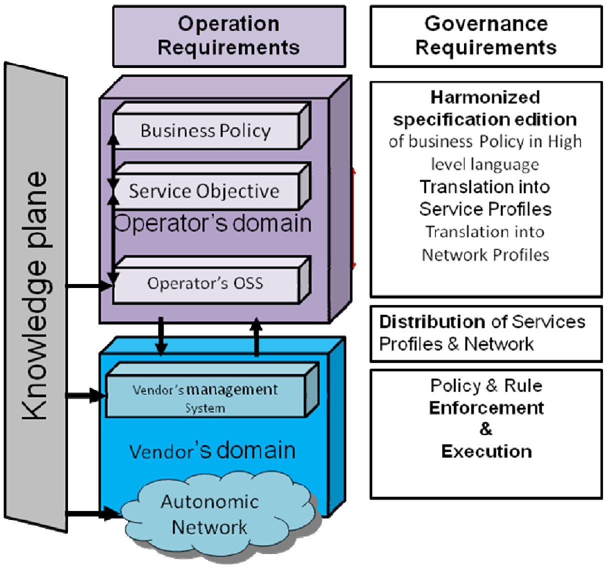

Fig. 4 The GANA governance model

service profile down to technical policies applied in a vendor specific element format for acting as the business provider desires. A common generic model is used to translate the common objectives identified by the business in a specific profile and policy in legacy domain, vendor, and provider solutions. The aim of this mechanism is to guarantee that the AFI reference model is able to achieve manageable autonomicity in order to be able to guide network behavior. Moreover, this procedure can be based on an explicit policy management framework for guiding infrastructure and controlling the network entities. Both policy- or goal-based management approaches may be applied.

The GANA model is also used to self describe the capabilities of any managed element and each Function-Level DE in order to build the knowledge of the capabilities of the network up to the business capabilities of a player [6]. The configuration map is used to translate the vendor specific description into a common GANA description useable in the domain where the network element will be connected to. The Node Main DE is responsible for aggregating the different capabilities and setting the main role of the nodes. The role of the Network-Level DE is to decide which roles a node has to perform in the network according to the policies and goals retrieved by the governance mechanisms.

The GANA governance model supports a policy and profile continuum from the business level down to specific network elements. The GANA governance model can also exchange knowledge using cognitive functions with the different players involved in delivering services to customers. As nowadays services are delivered by a composition of players, the GANA governance model will be facilitated by the integration of services provided by any actors (even customers) in order to deliver a package of services provided by different players but adapted to the user context [7]. However, these cognitive functions exchange only the authorized knowledge in a secure way in order to avoid any disclosure of sensitive knowledge of the different actors [6].

The GANA governance model is finally used so that human operators trust the autonomic network [8]. The Network-Level DE aggregates the different decisions in the network and notifies the human on the current situation of the network. The operator can view the decision of the different DEs in the network but can also interact with these decisions. The operator should validate only Network-Level DEs which perform long term decisions. However, real time decisions or decisions already trusted by providers should not be validated in real time by human providers. In any case the human should be able to modify or disable decisions even those that were not notified to the provider for validations. This mechanism will allow the provider to manage its network by validating any un-trusted DE decision until it trusts those DEs. It allows the provider to learn and know how the network will be self-managed before it will really be self managed without human interactions. This mechanism will also allow the provider to use a legacy management tool if necessary.

V. Conclusion and Further Work

This paper captures a work in progress of the ETSI AFI standardization group that specifies foundations for the deployment of autonomics in modern telecommunications systems. The standardization activity described is called instantiations of the AFI GANA reference model, the model being endorsed by the ETSI AFI group as the tool for deriving specific architectural frameworks in relevant telecommunications systems. The AFI GANA reference model has been developed as the universal and generic understanding and structure for deployment of autonomic functionalities.

Having an autonomic architecture structure derived using the instantiation process, it enables organization of the governance issues for control and monitoring of the network's operations with policies and goals set by a human operator. The autonomics architecture in place is to therefore guide the network behavior with trustworthy mappings of business to service and then technical objectives.

The scope of the group's activities and the applicability of the AFI GANA reference model extend to various types of telecommunications systems. Similar processes of instantiations to other telecommunications systems (e.g., cellular networks, broadband networks, ad-hoc networks) are being conducted by the group. Finally, the autonomics feature being standardized by the group are to foster specific solutions (e.g., information exchange protocols in Reference Points, DE's computer intelligence and algorithms, Knowledge Plane information modeling, control and management plane protocols in the telecommunications systems) as they are intended as enablers of further implementation-specific design and frameworks for the expansion of future networks with embedded autonomic capabilities. As discussed in [9] various stakeholders are required to join the ongoing standardization efforts and contribute to a faster pace of maturity and adoption of standards while contributing to the evolution of these standards.

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