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Creating a viable Evolution Path towards Self-Managing Future Internet via a Standardizable Reference Model for Autonomic Network Engineering

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Abstract. Clearly, whether revolutionary/clean-slate approaches or evolutionary approaches should be followed when designing Future Multi-Service Self-Managing Networks, some holistic Reference Models on how to design autonomic/self-managing features within node and network architectures are required. Why Reference models?: (1) to guide both approaches towards further architectural refinements and implementations, and (2) to establish common understanding and allow for standardizable specifications of architectural functional entities and interfaces. Now is the time for *harmonization* and *consolidation* of some ideas emerging (or achieved so far) from both approaches to Future Internet design, through the development of a common, unified and "standardizable" Reference Model for autonomic networking. This paper presents this vision. We also present the design principles of an emerging Generic Autonomic Network Architecture (GANA)—a holistic Reference Model for autonomic networking calling for contributions. We describe different "instantiations" of GANA that demonstrate its use for the management of a wide range of both basic and advanced functions and services, in various networking environments.

Keywords: *pre-Standardization through an Industry Specification Group (ISG), a call for Specifications, Self-managing Networks, Future Internet, Autonomic Network Architectures.*

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1 Introduction

The two basic ways to address the management challenges of the Future Internet could be either evolutionary (incremental) or revolutionary (clean slate). It is a requirement rather than a desire, to develop and test in large-scale environments, an enhanced, flexible and robust intrinsic management approach. The vision presented here is motivated by the EC-funded EFIPSANS-FP7 project [1] which is one of large-scale research projects that is seeking to create a viable roadmap for the evolution of today's networking models, paradigms and protocols (in particular IPv6 protocols) towards the self-managing Future Internet. The rest of this article is organized as follows. We briefly present the rationale behind the call for contributions to the development of a **Standardizable Reference Model** for autonomic network engineering that should be used as a guide for creating an **Evolution Path** towards the Self-Managing Future Internet. We then present a holistic evolvable Reference Model for Autonomic Network Engineering emerging from the EC-funded EFIPSANS-FP7 project [1] called the Generic Autonomic Network Architecture (GANA), emphasizing on the self-management aspects within node/device and network architectures in Future Internet and calling for further developments and contributions from diverse ideas from both revolutionary/clean-slate and evolutionary approaches to Future Internet design. Then, different instantiations of the GANA approach are presented, which demonstrate its use for the management of a wide range of functions and services, including both basic network services such as routing and monitoring, as well as enhanced ones such as mobility and Quality of Service (QoS) management. Finally, we give conclusions and an insight into further work in Section 9.

2 The Vision of a Self-Managing Future Internet

The vision of the Future Internet, is of a self-managing network whose nodes/devices are designed/engineered in such a way that all the so-called traditional network management functions, defined by the FCAPS management framework (Fault, Configuration, Accounting, Performance and Security) [2], as well as the fundamental network functions such as routing, forwarding, monitoring, discovery, fault-detection and fault-removal, are made to automatically feed each other with information (knowledge) such as goals and events, in order to effect feedback processes among the diverse functions. These feedback processes enable reactions of various functions in the network and/or individual nodes/devices, in order to achieve and maintain well defined network goals. In such an evolving environment, it is required the network itself to help detect, diagnose and repair failures, as well as to constantly adapt its configuration and optimize its performance. Looking at **Autonomicity and Self-Manageability,** we see that autonomicity (i.e. control-loops and feed-back mechanisms and processes, as well as the information/knowledge flow used to drive control-loops) [3], becomes an enabler for self-manageability of networks. As such, even the FCAPS functions become diffused within node/device architectures, apart from being part of an overall network architecture—whereby traditionally, a distinct management plane is engineered separately from the other functional planes of the network. Since even the management functions become inherent functions of the fundamental node/device architectures, it means that the functional planes of a self-managing network, would need to be (re)-defined and re-factored (refer to [4]). New concepts, functional entities and their associated architectural design principles that facilitate Self-Management at different levels of node/device and network functionality and abstractions, are required.

3. An initiative of an Industry Specification Group (ISG):"Autonomic Network Engineering for the Self-Managing Future Internet" (AFI) has been established in ETSI

ETSI has recently launched the initiatives of Industry Specification Groups (ISGs). An Industry Specification Group (ISG): **Autonomic Network Engineering for the Self-Managing Future Internet (AFI)** has just been established in ETSI by the EU-funded FP7-EFIPSANS project [1]. For more information on the AFI_ISG including the "Rationale" and "***Terms of Reference***" of the AFI_ISG, envisaged liaisons with the likes of IETF, 3GPP, NGMN, TMF, Autonomic Communication Forum (ACF)[12], etc, we refer to http://portal.etsi.org/afi [14]. Through the AFI, we are calling for *Contributions to the Definition and Specifications of a Unified Common Reference Model for Autonomic Network Engineering for the Self-Managing Future Internet* i.e. the further development of *detailed Specifications* of all the issues we have identified as requiring *detailed specifications in the GANA Reference Model*. An **`Evolution Path`** can be created that starts with the current IPv6 and produces Extensions to IPv6 towards IPv6++(refer to [13]) and other types of network architectural extensions such as cross-layering as necessitated by the GANA Reference Model for engineering Autonomic/Self-Managing Networks. In EFIPSANS, some ideas on Extensions to IPv6 are now emerging as early draft IPv6 Extension Headers (new IPv6 protocols that complement existing IPv6 protocols), protocol Options in the Extension Headers that support the notion of Options, extensions to the "*management interfaces*" of some protocols that ensure enriched autonomic control of the protocols by associated autonomic Decision-Making-Elements (DMEs), and network architectural extensions such as cross-layering, etc. Examples of IPv6 protocol extensions being proposed by EFIPSANS include ICMPv6++ for advanced control information exchange, ND++ for advanced Auto-Discovery, DHCPv6++ for advanced Auto-Discovery, some recommendations for Extensions to protocols like OSPFv3, and some newly proposed Extension Headers, etc.

4. The Emerging GANA, as an Evolvable holistic architectural Reference Model for Self-Management within node/device and network architectures

The adopted Generic Autonomic Network Architecture (GANA) [4], sets the fundamental principles and guidelines that need to be followed towards realizing our vision of the Self-Managing Future Internet, and does not intend to provide any specific solution or implementation. In contrast to any other of today's best known approaches, including clean-slate approaches (both pure and non-pure) such as 4D [5], ANA [6], CONMan [7], a Knowledge Plane for the Internet [8], FOCALE [9,3], a Situatedness-based Knowledge Plane for autonomic networking [10], the approach adopted here introduces Autonomic Manager Components for different abstraction levels of functionality, which are designed following the principles of *Hierarchical*, *Peering*, and *Sibling* relationships among each other within a node/device or network. Moreover, these components are capable of performing autonomic control of their associated Managed-Entities, as well as co-operating with each other in driving the self-managing features of the Network(s). Among GANA objectives is to address the following problems and issues: **(1)** Complexity—by defining some abstractions for autonomic/self-management functionality at *four hierarchical levels* as described later; **(2)** How to ensure that the decision-making-processes for autonomicity (self-management behaviours) within a node/device and the network as a whole, are conflict-free; **(3)** Capturing the kind of perspectives offered to end-users or operators of autonomic/self-managing networks, such as the interfaces that are meant to allow humans to define network-level objectives that govern the operation of an autonomic (self-managing) network under the control of an administrative domain.

In GANA, *four levels of abstractions* for which DMEs, MEs and Control-Loops can be designed, are described below (following a bottom up approach).

Level-1: Self-manageability issues may be associated with some implementation of a single network protocol (whether monolithic or modular). This level is the lowest level of abstraction of functionality in GANA and is associated with the manifestation of control-loops, as depicted in Fig. 1.

Level-2: The concepts of a Control Loop, Decision-Making Element, Managed-Entity(ies), as well as the related self-manageability issues may be associated with a higher level of abstraction than a single protocol (Fig. 1). This means that the aspects of Autonomicity/Self-management may be addressed at the level of "abstracted networking functions" (or "network functions") such as *routing, forwarding, mobility management, QoS management, etc*. At such a level of abstraction, what is managed by an assigned DME are a group of protocols and mechanisms that are collectively wrapped by what we may call a Function Block or Functional Block, and are considered to belong to the functionality of the abstracted networking functions e.g. all routing protocols and mechanisms of a node become managed by a Decision-Making-Element (Routing_Management_DE) assigned and designed to manage only those protocols and mechanisms. This level of abstraction allows us to talk about autonomicity of self-managing properties at this particular level of abstracted network function e.g. autonomic routing, autonomic forwarding, autonomic QoS management, autonomic mobility management, in the node/network. We call the DEs operating at this level, the "Functions-Level" DEs.

Level-3: On a higher level of autonomic networking functionality than the level of "abstracted networking functions" of a node/network, the concepts of a Control-Loop, Decision-Making Element, Managed-Entity(ies), as well as the related self-manageability issues may be associated with a system (node) as a whole.

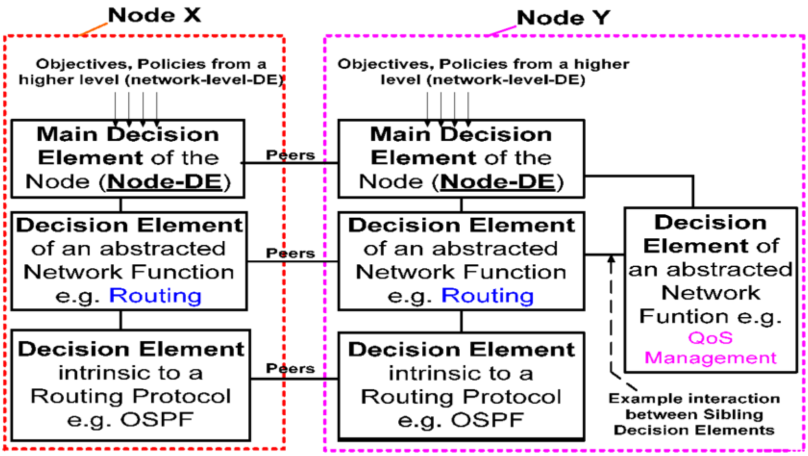


Fig. 1. Examples of Hierarchical, Peering, Sibling Relationships and Interfaces of DEs in GANA, calling for Specifications

Fig. 1 illustrate that at this level of self-management (autonomic) properties, the lower level Decision-Making-Elements operating at the level of abstracted networking functions become the Managed Automated Tasks (Managed-Entities) of the main Decision-Making-Element (DME) of the system (node). This means the node's main DME has access to the "views" exposed by the lower level DMEs and uses its overall knowledge to influence (enforce) the lower level DMEs to take certain desired decisions, which may in turn further influence or enforce desired behaviours on their associated Managed-Entities, down to the lowest level of individual protocol behaviour. A "Sibling" relationship simply means that the entities are created or managed by the same upper level Decision-Making-Element (DME/DE). This means that the entities having a sibling relation can still form other types of peer relationship within the autonomic node or with other entities hosted by other nodes in the network, according to the protocol defined for their needs to communicate with other DEs.

Level-4: The next level of self-manageability (autonomicity) after the "node level" described above, is the "network level". There may exist a logically centralized Decision-Making-Element or isolated decision plane/cloud such as the one proposed in the 4D network architecture [6] that knows (through some means) the objectives, goals or policies to be enforced by the whole network. The objectives, goals or policies may actually require that the main (top-level) DMEs of the nodes of the network covered by the centralized DME or plane export "views" such as events and state information to the centralized DME or plane. This may happen in order for the centralized DME to influence or enforce the DMEs of the nodes to take certain desired decisions following specific network policies that may in turn have an effect of inductive decision changes on the lower level DMEs of individual nodes i.e. down to protocol level decisions. A distributed network–level Control-Loop may be implemented following the above set-up, while another case of implementing a distributed Control-Loop would involve the main Decision-Making Elements of nodes working co-operatively to self-organize and manage the network without the presence of a logically centralized DME or an isolated decision plane that manages the whole network (i.e. the possibility for performing "in-network" management).

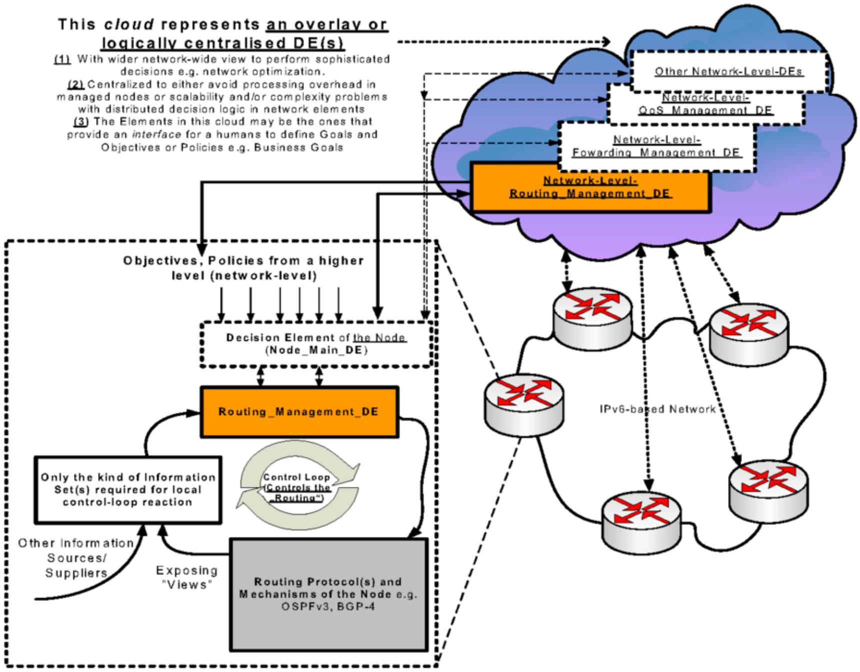


Fig. 2. Autonomicity as a feature in Routing Functionality in a IPv6 based network

5. The Instantiation of GANA for Routing and Autonomicity in Fixed Networks

The Routing Functionality (Function) of nodes in a fixed IPv6 based network and the network as whole can be made autonomic by making diverse Routing Schemes and Routing Protocol Parameters employed and altered based on network-objectives, changing network context and the dynamic network views in terms of events, topology changes, etc. Fig. 2 depicts how the routing behaviour of a device and the network as a whole can be made autonomic. Two types of Control-Loops are required for managing/controlling the routing behaviour. The first type is a node-local control loop that consists of a Routing_Management_DE embedded inside an autonomic node e.g. a router. The local Routing_Management_DE is meant to process only that kind of information that is required to enable the node to react autonomically (according to some goals) by adjusting or changing the behaviour of the individual Routing protocols and mechanisms required to be running on the node. The Routing _Management_DE reacts to "views", such as "events or incidents" exposed by its Managed Entities (MEs)—the Routing protocols or mechanisms. Therefore, the Routing_Management_DE implements the *self-configuration and dynamic reconfiguration* feature specific to the routing functionality of the autonomic node. It is important to note that due to scalability, overhead and complexity problems that arise with attempting to make a Routing_Management_DE of a node process huge information/data for the control loop, a logically centralised Decision Element(s), may be required, in order to relieve the burden. In such a case, a network-wide

Control Loop is required in addition to the node-local control (with both types of loops focussed on controlling/managing the routing behaviour in an autonomic way). Therefore, both types of control loops need to work together in parallel via the interaction of their associated Routing_Management_DEs (one in the node and another in the realm of the logically centralised network overlay decision making elements). The node-scoped (node-local) Routing_Management_DE focuses on addressing those limited routing control/management issues for which the node needs to react fast and autonomously. At the same time however, it listens for control from the network-level Routing_Management_DE that has wider network-views and dedicated computational power, and is able to compute routing specific policies and new parameter values to be used by individual routing protocols of the node, based on the wider network-views it knows, and disseminate the computed values/parameters to multiple node-scoped Routing_Management_DEs of the network-domain. The interaction between the two types of Routing_Management_DEs is achieved through the Node_Main_DE of a node which verifies those interactions against the overall security policies of the node. The node-scoped Routing_Management_DE also relays the "views" such as "events or incidents" to the network-level Routing_Management_DE for further reasoning.

6. The Instantiation of GANA for Mobility and QoS Management and Autonomicity in Heterogeneous Wireless Networks

Based on GANA's design principles, we describe an overall autonomic driven mobility and QoS management architecture, which adopts current mechanisms, methodologies and protocols, enhanced with autonomic behaviours. Figure 3 illustrates the fundamental DEs and their corresponding interactions, that allows us to enable autonomic mobility management and QoS-driven resource allocation functionalities of devices (i.e. mobile node (MN) and base station (BS)) and thus networks, over a heterogeneous wireless environment (e.g. when two networks coexist namely X (CDMA cellular) and Y (WLAN)).

A mobile node's Resource Allocation and QoS provisioning DE regarding network X (i.e. X_MN_R&Q_DE) realises a self-adaptation mechanism – with respect to QoS-aware self-optimization – in terms of a node's local control loop that: a) constantly monitors a user's services performance as well as the corresponding environmental changes, b) analyzes their current status with respect to QoS requirements and, c), reacts to QoS triggering events towards optimizing its services performance. In accordance to the DEs' hierarchy in GANA, on the one hand a node's X_MN_R&Q_DE controls node's resource allocation and QoS provisioning protocol concerning network X, while on the other hand it is controlled (i.e. is a managed entity) by node's QoS_Management_DE.

A mobile node's QoS_Management_DE is responsible for controlling the corresponding protocols' X_MN_R&Q_DEs, which exist for each one of the available networks in the node's locality, when it has multimode capabilities, by enabling advance autonomic functionalities regarding overall node's current services,

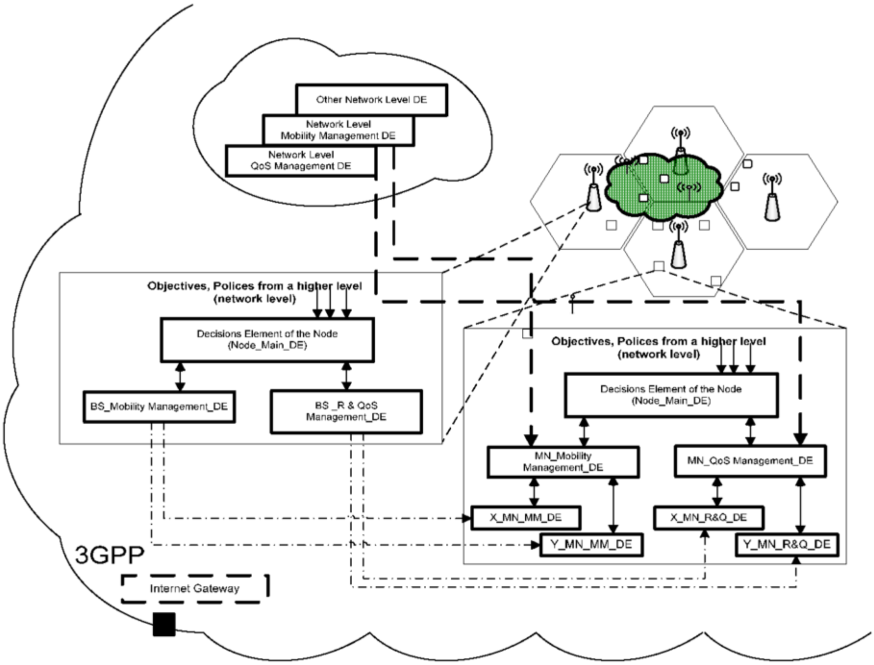


Fig. 3. Autonomicity as a feature in Mobility Management & QoS Management in Heterogeneous Wireless Networks.

such as: a) optimal available networks' – requested services' assignment, b) node's QoS-related available resource allocation prioritization, and finally c) steering overall node's QoS-aware behaviour by complying to overall network policies imposed by Network Level QoS Management DEs. The interaction between the two types of QoS DEs (i.e. node's QoS_Management_DE and Network Level QoS Management DE) is achieved through Node_Main_DE which verifies those interactions against the overall security policies of the node. In an X-type network cell base station (e.g. eNodeB), BS_R&Q_DE enables autonomic call admission control (CAC) and QoS-aware resource allocation mechanism, by realizing optimal self-adapting radio-resources (e.g. power and rate) allocation procedures that simultaneously satisfy various and often diverse users' services QoS prerequisites, residing at X cell's base stations. Towards achieving the above goal, each base station's BS_R&Q_DE interacts with the corresponding currently attached nodes' X_MN_R&Q_DEs (i.e. peering Des). Finally, neighbouring base stations' BS_R&Q_DEs of various co-located wireless networks collaboration allows the realization of proficient joint resource allocation and load balancing mechanisms.

Towards enabling autonomic nodes seamless mobility capabilities over a heterogeneous wireless environment, the following autonomic functionalities (i.e. DEs) are introduced in each of the networks components. A mobile node's Mobility Management DE for network X (i.e. X_MN_MM_DE) controls and enhances with self-adaptation attributes node's horizontal handoff, vertical handoff, and mobile IPv6 functionalities. Moreover, since when a mobile node is roaming over a heterogeneous wireless environment can be simultaneously attached to more that one access wireless networks at its locality, its corresponding X_MN_MM_DEs for each of the available X networks' are controlled and managed by an upper in the hierarchy of GANA-based DE, namely Mobility Management DE (i.e. MN_ Mobility Management _DE belonging at Functions-Level). A node's MN_Mobility_Management_DE introduces autonomicity in mobile node's or corresponding services' advanced mobility functionalities such as, multihoming (i.e. in terms of assigning different services to different access networks), multi-connection (i.e. in terms of splitting the data of one application across multiple connections) and dynamic alteration of the networks that a node is currently attached to at the event of QoS-triggering affairs. The latter is achieved via interacting with the corresponding node's QoS_Management_DE. Moreover, a node's MN_Mobility Management_DE is steering the overall node's mobility behaviour by complying nodes actions with the overall network policies imposed by the Network Level Mobility Management DEs through its Node_Main_DE.

7. The Instantiation of GANA for Traffic Monitoring and Autonomicity in Fixed Networks

Autonomicity as a feature of Traffic Monitoring, coupled with Quality of Service (QoS) management functions of an ingress edge router are at focus within this instantiation of GANA. The objective of QoS control at the ingress within a DiffServ domain is to ensure traffic admitted to the network is appropriately classified, policed and shaped to ensure QoS targets imposed on traffic will be maintained as traffic passes through the network.

The configuration of network monitoring protocols and mechanisms can be managed through a dedicated Traffic-Monitoring-DE designed to operate inside a node. The monitoring information collected by the monitoring protocols is required for driving the behaviours of diverse DEs and some pure MEs of a node, and should be of the minimum level of accuracy required by the requesting network functions and applications i.e. pure MEs and/or DEs of a node. Therefore, as traffic and network conditions change, monitoring protocols and mechanisms require to be constantly re-configured by the Traffic-Monitoring-DE to ensure certain requirements and goals are satisfied, as necessitated by the requirements from DEs and MEs of the node(s).

This instantiation focuses on developing autonomic features for the QoS_DE and its associated Admission Control AC_ME that is considered to belong to the lowest level of MEs in GANA, and for the Traffic-Monitoring-DE and its associated specialized Traffic Measurement ME (TM_ME) called the Effective Bandwidth measurement entity of the ingress edge router, also considered to belong to the lowest level of MEs in GANA and being autonomically controlled by the Traffic-Monitoring-DE. There is a dependency relationship between the two of the lowest level MEs according to GANA (Fig. 4), and as conditions change within the network, each of the two lowest level MEs can be re-configured by their associated DEs to operate in an optimal manner in the face of these changes. The autonomic behaviour instilled within the ingress edge node is the ability to control the admission of traffic into the network, while maintaining a high degree of confidence in the admission decisions under varying traffic conditions. This is provisioned by an interaction between the Traffic-Monitoring_DE and the QoS_DE where the traffic monitoring requirements of the AC_DE change and the associated TM_ME must be re-configured dynamically by the Traffic-Monitoring_DE to suit.

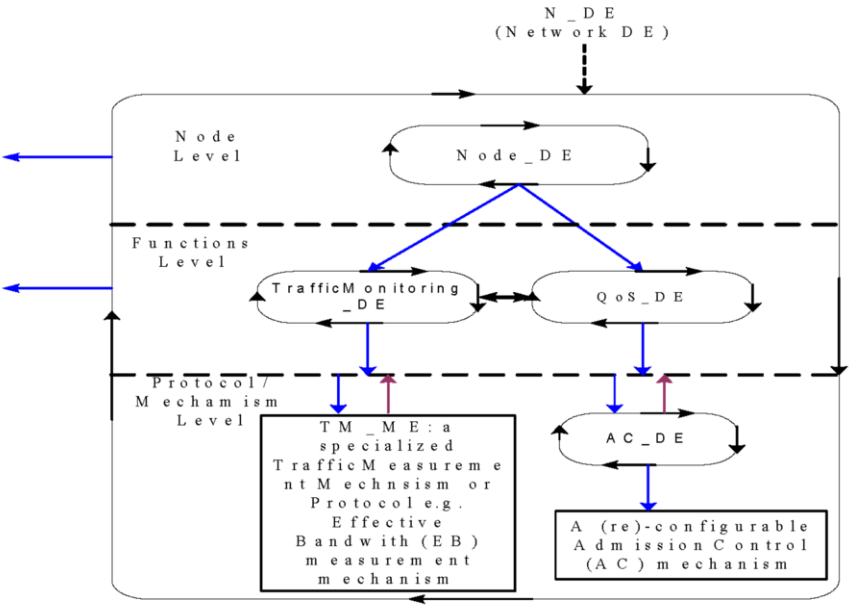
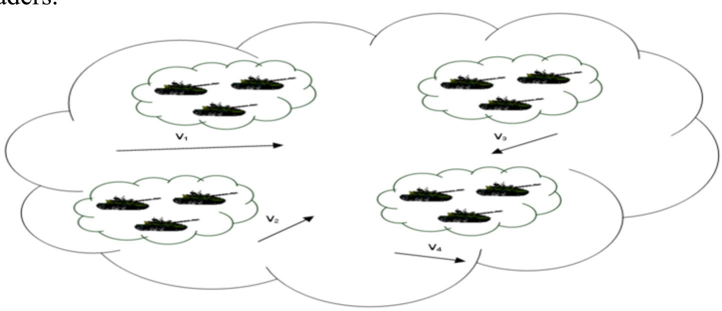


Fig. 4. Autonomicity as a feature of Traffic Monitoring Functionality

8. The Instantiation of GANA for Auto-Configurations in MANETS

Auto-configuration is one of the key aspects of IPv6-based Future Internet. This especially holds true for tactical environments where one can envisage multiple groups of mobile nodes forming MANETs on the move. These groups might merge or further split as well as encounter specific faulty conditions (Figure 5). The role of auto-configuration is then not only to enable an efficient address assignment scheme but also provide certain capabilities making it feasible for the network to survive as a whole. The measure of the level of survivability might be defined e.g. as the ability to offer basic services such as routing. For this purpose the auto-configuration entity must interact with some other entities including the ones responsible for fault-management, resilience and survivability as well as routing. This puts sophisticated requirements on the architecture of such an autonomic network and that is where GANA comes into play. In particular it is envisaged that the aforementioned different entities are instantiated by their corresponding Decision Elements (DEs) that interact among themselves and control specific Managed Entities (MEs). In particular, the Fault-Management-DE (FM_DE) is responsible for fault diagnosis, localization, isolation and removal. This DE analyses information regarding the current situation in the network and not only tries to resolve the existing problems but, what is more, based on different symptoms makes an attempt to infer what other problems might be coming. This information is really crucial because the Resilience and Survivability DE (RS_DE) may exploit it for the purposes of MANET reorganization so it becomes ready to survive both the existing situation and its negative consequences. For this purpose there might arise e.g. the need one of the groups of the nodes to split in two parts so each of them joins another neighboring group. As a consequence the network might become more resilient but on the other hand, one needs to keep in mind that this network should be still in a position to offer other basic functions such as routing. This requirement suggests that autonomic decisions need to be taken by different DEs depending on the current situation in the network. The Auto-configuration DE (AC_DE) is then not only responsible for the optimum deployment but also provides quick and efficient IPv6 address configuration so duplicate addresses are efficiently avoided. It exploits information delivered by RS_DE on the basis on the FM_DE and also interacts with the Routing DE (RT_DE). The purpose of this interaction is that on the one hand the AC_DE, being aware of the requirements pertaining to routing, may try to make decisions that include taking into account these requirements. On the other hand, even if there are no specific requirements but it is possible to offer reliable routing, the interaction between RT_DE and AC_DE might result in a better overall network robustness as regards the network itself (a group of nodes) and the services it offers. All the aforementioned DEs are assumed to operate at the *Functions-Level* of GANA's hierarchy of DEs, but one could still try to define their mutual hierarchical relations when viewed from AC_DE perspective. Information exchange among them is assumed to be performed with the aid of some specially designed new IPv6 Extension Headers.



Fig, 5. Tactical MANET scenario

9. Conclusions and Future Work

In this paper, we presented the idea of a new initiative concerning the establishment of an Industry Specification Group (ISG): "**Autonomic Network Engineering for the Self-Managing Future Internet (AFI)**" within ETSI. [14] presents the rationale behind this new initiative. Further information regarding the developments related to this initiative including invitations for participation to the activities of the AFI_ISG can be found in [14]. Therefore, this paper also serves to communicate the initiative to the wider community. In this paper, we also presented an emerging holistic reference model for autonomic network engineering (GANA), as a fundamental enabler for self-management within node and network architectures. GANA should be seen as a common reference model that can benefit both the evolutionary and revolutionary approaches towards Future Internet design, with both approaches contributing to its further development. Such *harmonized contributions* of consolidated ideas and concepts from both revolutionary/clean-slate approaches and evolutionary approaches, to the further development of GANA, e.g. from results from multiple research projects (past and future), can be achieved only through the AFI_ISG.

Acknowledgement

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References

1. EC funded- FP7-EFIPSANS Project: http://efipsans.org/
2. The FCAPS management Framework: ITU-T Rec. M. 3400.
3. B. Jennings, S. van der Meer, S. Balasubramaniam, D. Botvich, M.O. Foghlu, W. Donnelly, J.Strassner, "Towards Autonomic Management of Communications Networks," IEEE Communications Magazine, Vol. 45, pp. 112-121, Oct. 2007.
4. R. Chaparadza, "Requirements for a Generic Autonomic Network Architecture (GANA), suitable for Standardizable Autonomic Behaviour Specifications of Decision-Making-Elements (DMEs) for Diverse Networking Environments," to appear in International Engineering Consortium (IEC) in the Annual Review of Com., Volume 61, Dec. 2008.
5. A. Greenberg et al, "A clean slate 4D approach to network control and management," ACM SIGCOMM Computer Comm.Review, vol. 35(5), pp.41-54, 2005.
6. European IST FP6 ANA(Autonomic Network Architecture) Project: http://www.ana-project.org/
7. H. Ballani, and P. Francis, "CONMan: A Step Towards Network Manageability," ACM SIGCOMM Computer Comm.Review, vol. 37(4), pp.205-216, 2007.
8. D. D. Clark, C. Partridge, J. C. Ramming, and J. T. Wroclawski, "A Knowledge Plane for the Internet," in Proc. of ACM SIGCOMM 2003, Karlsruhe, Germany, Aug. 25-29, 2003.
9. J. C. Strassner, N. Agoulmine, and E.Lehtihet, "FOCALE – A Novel Autonomic Networking Architecture," In proc of the Latin American Autonomic Computing Symposium (LAACS), Campo Grande, MS, Brazil 2006.
10. T. Bullot et al, "A situatedness-based knowledge plane for autonomic networking," International Journal of Network Management, John Wiley & Sons, 2008.
11. IBM article: Understand the autonomic manager concept: http://www-128.ibm.com/developerworks/library/ac-amconcept/.
12. Autonomic Communication Forum (ACF): http://www.autonomic-communication-forum.org/
13. Chaparadza R.: Evolution of the current IPv6 towards IPv6++ (IPv6 with Autonomic Flavours). Published by the International Engineering Consortium (IEC) in the Review of Communications, Volume 60, December 2007.
14. AFI_ISG: Autonomic network engineering for the self-managing Future Internet (AFI): http://portal.etsi.org/afi