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TECHNICAL REPORT

**Network Technologies (NTECH);
Automatic network engineering
for the self-managing Future Internet (AFI);
Autonomicity and Self-Management
in Wireless Ad-hoc/Mesh Networks:
Autonomicity-enabled Ad-hoc and
Mesh Network Architectures**

Reference

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Network Technologies (NTECH).

Modal verbs terminology

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Introduction

The distributed nature of Wireless Mesh Networks (WMNs) allows them to benefit from multiple autonomic functionalities. However, the existing landscape of self-x solutions (e.g. self-configuration) is fragmented and the lack of a standardized framework through which interoperable autonomics can be developed has been hampering adoption and deployment of autonomics in real world service networks. There is a need for a standardized architectural framework that enables to comprehensively support and integrate interoperable components for autonomicity in WMNs. Such an architecture (autonomicity-enabled wireless mesh architecture) is the subject of the present document.

The proposed autonomic wireless mesh architecture is an instantiation of the GANA (Generic Autonomic Network Architecture) Reference Model - a standards based approach to autonomics, onto the wireless mesh network architecture. The provided guidelines can now help researchers and engineers build autonomicity-enabled WMNs using a standardized framework that enables adoption and deployment of autonomics by industry, thereby enabling researchers and engineers to contribute to further evolution of the framework described in the present document in ETSI. It has to be noted that the same approach being applied to introducing autonomics in mesh networks in the present document also applies to Ad-hoc wireless networks, and so the present document covers both aspects - hence the document title "Autonomicity and Self-Management in Wireless Ad-hoc/Mesh Networks: Autonomicity-enabled Ad-hoc and Mesh Network Architecture".

The GANA model is being instantiated onto various reference network architectures to create autonomics-enabled reference network architectures. For example, ETSI recently published ETSI TR 103 404 [i.17], which addresses Autonomicity and Self-Management in the Backhaul and Core network parts of the 3GPP Architecture through GANA instantiation onto the Backhaul and Core (EPC) network parts of the 3GPP architecture. Readers may also find ETSI TR 103 404 [i.17] helpful in further understanding how GANA is being applied in various networks. Readers may also follow up on ongoing work in ETSI on instantiation of the GANA onto the Broadband Forum (BBF) architectures that incorporate SDN (Software-Defined Networking) and NFV (Network Functions Virtualization). To obtain some guidance and information on the various types of stakeholders who should get involved and contribute to standards on self-managing future networks, readers may refer to [i.6] and [i.15].

1 Scope

The present document aims to provide recommendations for the introduction of autonomics (management and control intelligence) into Ad-hoc and Mesh Network architectures and their associated management and control architectures.

The present document describes:

- Autonomicity-enabled Ad-hoc and Mesh Network Architecture that is a result of the instantiation of the GANA (Generic Autonomic Networking Architecture) Reference Model on the Ad-hoc and Mesh Network architecture to enable developers of autonomics to introduce autonomics in the architecture
- Relevant autonomicity-enabled functions and operations
- Relevant GANA Decision Elements (DEs) and Reference Points between those DEs

The present document describes the specific desirable features for autonomic management and control of Ad-hoc and mesh network functions through the introduction of Decision Elements (DEs) and their associated control loops at the Network, Node and Function level of the GANA reference model. The Protocol level needed to be additionally addressed due to the need for accommodating the specifics of Ad-hoc and mesh set-ups.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

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[i.5] Ranganai Chaparadza et al. "ETSI Industry Specification Group on Autonomic network engineering for self-managing Future Internet (ETSI ISG AFI)" Abstract Web Information Systems Engineering Volume Editor 2009 WISE 2009.

[i.6] Ranganai Chaparadza, Tony Jokikyyny, Latif Ladid, Jianguo Ding, Arun Prakash, Said Soulhi: The diverse stakeholder roles to involve in Standardization of Emerging and Future Self-Managing Networks: In proceedings of the 3rd IEEE MENS Workshop at IEEE Globecom 2011: 6-10 December 2011, Houston, Texas, USA.

[i.7] ETSI GS AFI 001 (2011-06): "Autonomic network engineering for the self-managing Future Internet (AFI); Scenarios, Use Cases and Requirements for Autonomic/Self-Managing Future Internet".

[i.8] IEEE 802.11™: "IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

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[i.12] M. Wódczak, "Autonomic Cooperation in Ad-Hoc Environments", 5th International Workshop on Localised Algorithms and Protocols for Wireless Sensor Networks (LOCALGOS) in conjunction with IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), Barcelona, Spain, 27-29 June 2011.

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[i.14] M. Wódczak, "Autonomic Cooperative Networking," Springer-Verlag New York, 2012.

[i.15] Ranganai Chaparadza, Tony Jokikyyny, Latif Ladid, Jianguo Ding, Arun Prakash, Said Soulhi: The diverse stakeholder roles to involve in Standardization of Emerging and Future Self-Managing Networks: In proceedings of the 3rd IEEE MENS Workshop at IEEE Globecom 2011: 6-10 December 2011, Houston, Texas, USA.

[i.16] ETSI White Paper no. 16: "The Generic Autonomic Networking Architecture Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services".

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[i.17] ETSI TR 103 404 (V1.1.1): "Network Technologies (NTECH); Autonomic network engineering for the self-managing Future Internet (AFI); Autonomicity and Self-Management in the Backhaul and Core network parts of the 3GPP Architecture".

[i.18] ETSI TS 103 194: "Network Technologies (NTECH); Autonomic network engineering for the self-managing Future Internet (AFI); Scenarios, Use Cases and Requirements for Autonomic/Self-Managing Future Internet".

[i.19] ETSI GS AFI 002 (V1.1.1): "Autonomic network engineering for the self-managing Future Internet (AFI); Generic Autonomic Network Architecture (An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management)".

NOTE An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management.

[i.20] IEEE 802.21™: "IEEE Standard for Local and metroploitan area networks - Media Independent Handover Services".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Autonomic Behaviour (AB): process which understands how desired Managed Entity (ME) behaviours are learned, influenced or changed, and how, in turn, these affect other elements, groups and networks [i.18]

NOTE: In the GANA model, an autonomic behaviour is any behaviour of a DE that is observable on its interfaces. A GANA DE is also called an Autonomic function (AF).

autonomic networking: networking paradigm that enables network devices or elements (physical or virtual) and the overall network architecture and its management and control architecture to exhibit the so-called self-managing properties, namely:

- auto-discovery of information and entities
- Self-configuration (auto-configuration), Self-diagnosing, Self-repair (Self-healing)
- Self-optimization, and other self-* properties

NOTE 1: Autonomic Networking can also be interpreted as a discipline involving the design of systems (e.g. network nodes) that are self-managing at the individual system levels and together as a larger system that forms a communication network of systems.

NOTE 2: The term "autonomic" comes from the autonomic nervous system (a closed control loop structure), which controls many organs and muscles in the human body. Usually, humans are unaware of its workings because it functions in an involuntary, reflexive manner - for example, humans do not notice when their heart beats faster or their blood vessels change size in response to temperature, posture, food intake, stressful experiences and other changes to which human are exposed. And their autonomic nervous system is always working [i.18].

Decision Making Element (DME): functional entity designed and assigned to autonomically manage and control its assigned Managed Entities (MEs) by dynamically (re)-configuring the MEs and their configurable and controllable parameters in a closed-control loop fashion

NOTE 1: Decision Making Elements (DMEs) [i.19] referred in short as Decision Elements (DEs) fulfil the role of Autonomic Manager Elements.

NOTE 2: In GANA a DE is assigned (by design) to very specific MEs that it is designed to autonomically manage and control (ETSI GS AFI 002 [i.19] provides more details on the notion of ownership of MEs by specific DEs required in a network element architecture and the overall network architecture).

Managed Entities (MEs): physical or logical resource that can be managed by an Autonomic Manager Element (i.e. a Decision Element) in terms of its orchestration, configuration and re-configuration through parameter settings [i.18]

NOTE: MEs and their associated configurable parameters are assigned to be managed and controlled by a concrete DE such that an ME parameter is mapped to one DE. MEs can be protocols, whole protocol stacks, and mechanisms, meaning that they can be fundamental functional and manageable entities at the bottom of the management hierarchy (at the fundamental resources layer in a network element or node) such as individual protocols or stacks, OSI layer 7 or TCP/IP application layer applications and other types of resources or managed mechanisms hosted in a network element (NE) or in the network in general, whereby an ME exposes a management interface through which it can be managed. MEs can also be composite MEs such as whole NEs themselves (i.e. MEs that embed sub-MEs).

overlay: logical network that runs on top of another network

EXAMPLE: Peer-to-peer networks are overlay networks on the Internet. They use their own addressing system for determining how files are distributed and accessed, which provides a layer on top of the Internet's IP addressing.

self-advertising: capability of a component or system to advertise its self-model, capability description model, or some information signalling message (such as an IPv6 router advertisement message) to the network in order to enable other entities to discover it and be able to communicate with it, or to enable other entities to know whatever is being advertised

self-awareness: capability of a component or system to "know itself" and be aware of its state and its behaviours

NOTE: Knowledge about "self" is described by a "self-model".

self-configuration: capability of a component or system to configure and reconfigure itself under varying and unpredictable conditions

self-healing: capability of a component or system to detect and recover from problems (manifestations of faults, errors, failures, and other forms of degradation) and continue to function smoothly

self-monitoring: capability of a component or system to observe its internal state, for example by monitoring quality-of-service metrics such as reliability, precision, rapidity, or throughput

self-optimization: capability of a component or system to detect suboptimal behaviours and optimize itself to improve its execution

self-organizing function: function that includes processes which require minimum manual intervention

self-regulation: capability of a component or system to regulate its internal parameters so as to assure a quality-of-service metric such as reliability, precision, rapidity, or throughput

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3rd Generation Partnership Project
AF	Autonomic Function
AFI	Autonomic network engineering for the self-managing Future Internet
AMC	Autonomic Management and Control
AN	Access Network
BBF	BroadBand Forum
CA	Collision Avoidance
CM DE	Cooperation Management Decision Element
CM	Cooperation Management
CM-DE	Cooperation Management Decision Element
CO DE	Cooperation Orchestration Decision Element
CO	Cooperation Orchestration
COTS	Commercial-Off-The-Shelf
CR DE	Cooperative Relaying Decision Element
CR	Cooperative Relaying
CR-DE	Cooperative Relaying Management-Decision Element
CSMA	Carrier Sense Multiple Access
DE	Decision-making-Element
DP&F	Data Plane and forwarding
DSTBC	Distributed Spatio-Temporal Block Coding
E2E	end-to-end
EDCA	Enhanced Distributed Channel Access
EMS	Element Management System
EPC	Evolved Packet Core
FB	Functional Block
FM DE	Fault Management DE
FM	Fault Management Decision Element
GANA	Generic Autonomic Network Architecture
GCP	Generic control Plane management
GS	Group Specifications
GUI	Graphical User Interface
GW	GateWay
HRP	Horizontal reference point

HWMP	Hybrid Wireless Mesh Protocol
KP	Knowledge plan
MAN	Mesh Access Node
MANET	Mesh Ad-hoc Network
MBTS	Model Based Translation Service
MCCA	MCF (Mesh Coordination Function) Controlled Channel Access
MCF	Mesh Coordination Function
ME	Managed Entity
MGW	Mesh Gateway
MN	Mesh Node
MPR	Multi-Point Relay
MRN	Mesh Relay Node
NFC	Near Field Communications
NMS	Network Management System
OLSR	Optimised Link State Routing
ONIX	Overlay Network Information Exchange
PDP	Policy Decision Point
PREQ	Path Request
QoS	Quality of Service
RFID	Radio Frequency Identification
Rfps	Reference Points
RM DE	Routing Management DE
RR-DE	Re-Routing Decision Element
RS DE	Resilience and Survivability DE
RS	Resilience and Survivability
RTS/CTS	Request to Send/Clear to Send
SDN	Software Defined Networking
SNMP	Simple Network Management Protocol
SO	Self-Optimization
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
VCS	Virtual Cooperative Sets
VRP	Vertical Reference point
WAN	Wide Area Network
WMN	Wireless Mesh Network

4 GANA Reference Model

4.1 Background

The 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 target architecture, when instantiated onto implementation-orientated reference architecture such as the architectures defined by standardization organizations (3GPP, BBF, ITU-T, and IEEE).

Figure 1 presents a general overview of the GANA reference model while its details, related concepts and its evolution are described in [i.18], [i.1], [i.2]. Note that in reference to Figure 1, HRP means Horizontal Reference Point, while VRP means Vertical Reference Point.

The ETSI White Paper No.16 [i.16] is a good source for a brief description of the GANA, including how it integrates with emerging networking paradigms of SDN (Software Defined Networking), Network Functions Virtualization (NFV), E2E (End-to-End) Service Orchestration and Big-Data analytics for driving management and control of networks and services.

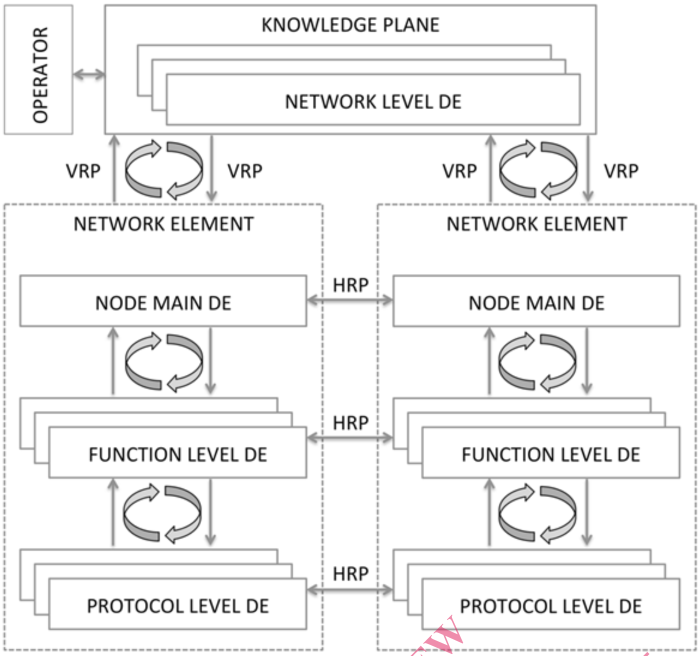

Figure 1: GANA reference model

Self-manageability in GANA is achieved through instrumenting the devices with autonomic Decision-making-Elements (DEs), which automate network operations by implementing control loops (Figure 2). 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 behaviour 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.

As outlined in Figure 1, 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);
- 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 (Figure 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), demonstrate how autonomics, cognition, and self-management can be gracefully (i.e. non-disruptively) introduced in today's existing architectures.