Analysis on Autonomic Characteristics of Quality of Service Management in EPS

Ivaylo Atanasov[1]

Abstract – **Network evolution is driven by deregulated markets, converged services, open competition, virtualisation and new business models. Efficient operation of such networks calls for "autonomic" or self-management functionality embedded into the network in order to maintain operational costs under control. The paper presents analysis on the autonomic characteristics of Quality of Service management functionality in the Evolved Packet System (EPS). Four basic levels of abstraction are considered in the context of standardized functions and future extensions.**

Keywords – **Evolved Packet Core, Policy and Charging Control, Self-management, Autonomic behaviour.**

I. INTRODUCTION

Network evolution features convergence between information technologies and communications, new business models for service provisioning, explosion of multimedia services, and it is driven by new IP based broadband technologies. Such networks require efficient operations and business support. Due to diversity of technologies and business models, and the operators' requirement for lower operating costs, some level of "autonomics" should be embedded into network equipment and operations support systems. This requires embedding self-optimization, self-healing, and self configuration features [1], [2]. Autonomics and self-management technologies are considered as an intelligent solution for network operators to control their own environment in an efficient and effective way [3], [4].

Evolved Packet System (EPS) covers the radio access, the core network and the terminals that comprise the overall mobile system. In EPS, simple and effective Quality of Service (QoS) mechanisms for multi-vendor mobile broadband deployments are defined. Such QoS mechanisms allow service and subscriber differentiation and dynamic, policy-based control on authorization and usage of bearer resources intended for IP-based multimedia traffic [5], [6].

The paper presents an analysis on standardized QoS management mechanisms in EPS and using different levels of abstraction identifies the autonomic characteristics of policy-based QoS and charging control.

The paper is organized as follows. Next section presents in brief the Generic Architecture of Autonomic Networks (GANA) as defined by ETSI in (ETSI GS AFI 002). The third section presents different levels of autonomic behavior of QoS management mechanisms in EPS. The fourth section considers self management characteristics of future optimizations of QoS control in EPS. The conclusion summarizes the contributions.

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II. THE GENERIC AUTONOMIC NETWORK ARCHITECTURE REFERENCE MODEL

Autonomic behavior is characterized by self management capabilities such as self-configuration, self-healing, self optimization, self-organization and self-protecting. It consists of a set of actions triggered by a decision making element (DE) on a Managed Entity (ME) following policies to achieve a goal. The DE drives a control loop to regulate the behavior of the ME exposing features like learning, reasoning, planning and cognition.

In GANA, DE, ME and control loops are designed in four level of abstraction: protocol level, function level, node level and network level (ETSI GS AFI 002). The lowest protocol level is associated with the self management functionality implemented intrinsically within a single network protocol such as TCP or OSPF. The function level abstracts autonomic mechanisms and protocols associated with a particular network function, such as autonomic routing and autonomic fault management. In the node level, the autonomic properties are exposed by a node or system, which means that the main node's DE has access to the views exposed by the lower level DEs operating on abstracted networking functions. The highest level of self-management functionality is the level of the network's overall functionality and behavior. Fig. 1 shows the generic model of an abstract autonomic networked system.

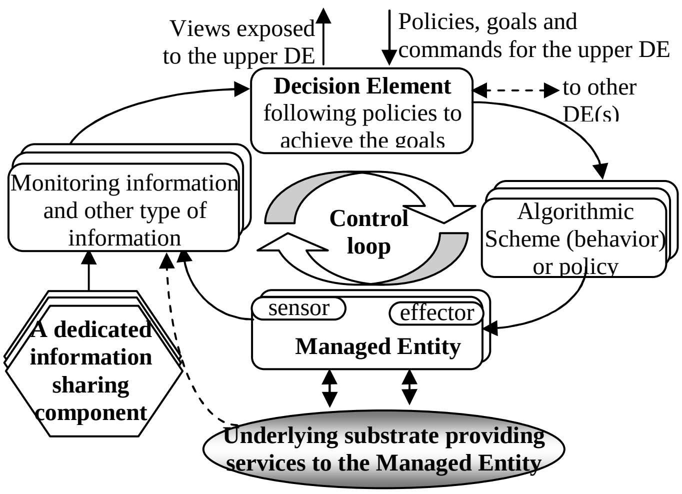

Fig.1 Generic Model of Abstract Autonomic Networked System (ETSI GS AFI 002)

The adopted hierarchy allows some decisions to be taken autonomously at different levels of control and complexity and offers flexibility towards controlling/resolving decision conflicts and priorities.

The QoS management mechanism in EPS allows dynamic service-aware control on bearer resources used for multimedia packet traffic which is integrated with charging control (3GPP TS 23.203). The next section studies the standardised QoS management functionality and provides abstraction of autonomic characteristics onto the four levels of GANA referenced model.

III. Autonomous Behaviour of QoS Management Mechanism

The EPS bearer represents the level of granularity for QoS control in EPS and provides a logical transmission path with well-defined QoS properties between the mobile device and the network. The QoS management in EPS allows authorization of and usage monitoring of EPS bearers.

A. QoS management in GANA protocol level

The signaling protocol used for QoS management is Diameter. In EPS, the protocol is used for Authentication Authorization and Accounting functions. It does not provide intrinsic autonomic behavior in the context of QoS management, as no QoS control decision logic is embedded in it. But the protocol itself provides autonomous behavior in the context of Diameter request routing and peer discovery. In EPS, a logical entity called Diameter Routing Agent (DRA) is used during the selection/discovery of the function responsible for policy based QoS control. DRA ensures that all Diameter sessions established over the respective reference points for a certain IP session reach the same function responsible for policy based QoS control when multiple functions have been deployed in a Diameter realm.

The reason for excluding the intrinsic behavior related to QoS management in Diameter protocol is that the protocol has become too hard to manage due to intrinsic decision logic in other contexts that may interact in an undesired way with the decision logic of other protocols. This means that QoS management decision logic is implemented at a level higher, i.e. outside the individual protocol.

B. QoS management in GANA function level

QoS management in EPS is based on policies (3GPP TS 23.203). Policy control refers to gating control, QoS control, application detection control, and usage monitoring control. The gating control refers to blocking or allowing of packets, belonging to a service data flow to pass through between desired endpoints. QoS control is the capability of authorization and enforcement of the maximum QoS that is authorised for an IP flow(s). With application detection control feature, it is possible to request the detection of specified application traffic and receive notifications on the start and stop of application traffic. Usage monitoring control allows the operator to enforce dynamic policy decisions based on the total network usage in real time.

Fig.2 illustrates the mapping of policy control functionality onto GANA functional level.

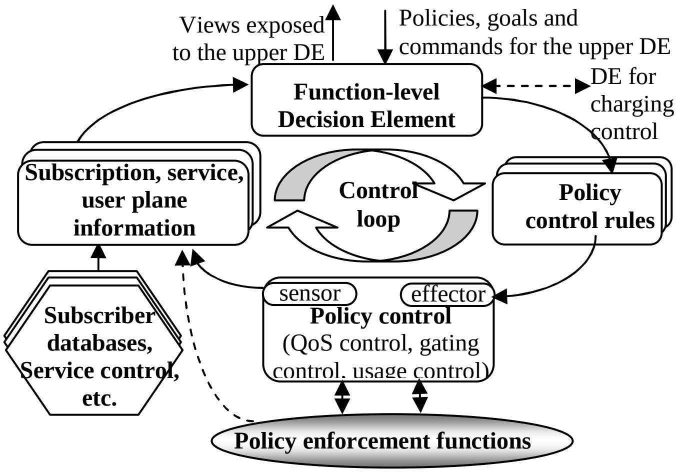

Fig.2 A control loop specific to an abstracted policy control function

The DE implements the decision logic for policy control. The policy control DE uses subscription information from subscriber databases for an IP session at establishment or a gateway control session at establishment. The subscription information may include user profile configuration indicating whether application detection and control should be enabled. The subscription information is retained as it is relevant for policy control decisions until the IP session termination and the gateway control session termination. The policy control DE uses also service information (e.g. acceptable bandwidth, usage threshold). If access network data are used for policy control decisions, congestion level and access technology information may also be included. The policy control DE makes decisions encoded into policy control rules. A dynamic policy control rule may include information related to service data flow detection, information related to policy control (i.e. gating control and QoS control) and usage monitoring control. The policy control rules may be dynamically changed during the session, based on reporting of usage information.

Another function that exposes autonomicity is the charging control function. Charging control includes means for both offline and online charging. The charging information can affect in real time the services being used. The interaction between policy control and charging control ensures coherent charging between IP connectivity access network and service control and is called Policy and Charging Control (PCC). The credit management applies for online charging and it enables policy control based on subscriber spending limits. The information about usage of resources may be used for offline charging. With PCC, the rules generated by the DE include charging information also.

C. QoS management in GANA system level

In the GANA node level of self-managing (autonomic) properties, the lower level DEs operating on the level of abstracted networking functions (such as Policy control DE and Charging control DE) become some of the managed automated tasks of the main DE of the system (node). This means the node's main DE has access to the "views" exposed by the lower level DEs and uses its knowledge of the higher level (system and network level objectives/goals) to influence (enforce) the lower level DEs to take certain desired decisions, which may in turn further influence or enforce desired behaviors on their associated managed resources.

Fig.3 illustrates the mapping of PCC functionality onto GANA system level. In the context of collaborative autonomic functions performed by each functional entity, the whole PCC functionality may be considered at a system level functionality.

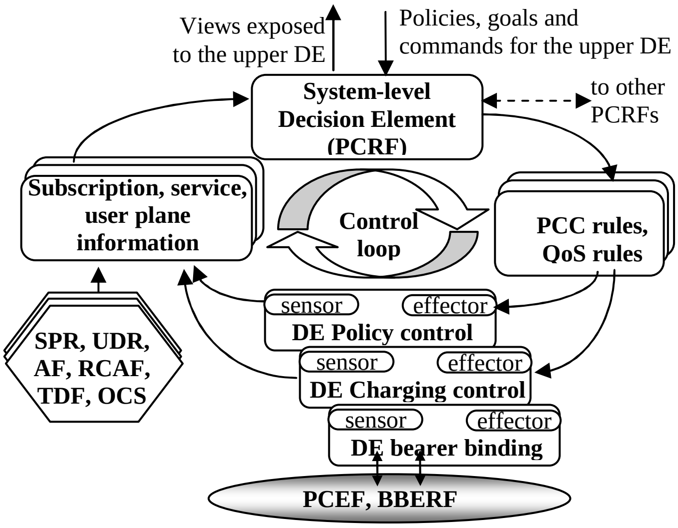

Fig.3 Mapping of PCC functionality onto GANA node-level

The Policy and Charging Control Function (PCRF) appears to the main DE. It receives session information from the access network and subscription information from subscriber databases. The PCRF takes the available information and based on the policies configured by the network operator, creates service-session-level policy decisions. The decisions are provided to the PCEF and the BBERF.

The Policy and Charging Enforcement Function (PCEF) enforces policy decisions (gating, maximum bit rate policing) received form the PCRF and also notifies the PCRF about user- and access network-specific events. The PCEF performs measurements of user plane and reports usage of resources to the PCRF. The Bearer Binding and Event Reporting Function (BBERF) supports a part of the PCEF functions such as bearer binding and event reporting to the PCRF. The Application Function (AF) interacts with applications and services requiring dynamic PCC. Using the application level signaling, the AF extracts session information and provides it to the PCRF. The AF may receive notifications form the PCRF about events occurred in the user plane in case of active subscription. The RAN Congestion Awareness Function (RCAF) reports congestion information in the Radio Access Network (RAN) user plane. This allows the PCRF to take the RAN user plane congestion status into account for policy decisions. The Subscription Profile Repository (SPR) and the User Data Repository (UDR) are databases that store PCC-related subscription data. The Traffic Detection Function (TDF) is a functional entity that provides ADC functionality using packet inspection. It reports detected applications to the PCRF. The OCS is a credit management system for prepaid charging. The PCRF interacts with the OCS to check out credit and report credit status.

In the context of autonomic management, all the SPR, UDR, AF, RCAF, TDF and OCS provide dedicated monitoring and subscription related information to the PCRF required to make PCC decisions. The PCRF provides the PCC rule to the PCEF.

D. QoS management in GANA network level

Fig.4 illustrates the mapping of QoS management functionality onto GANA network level.

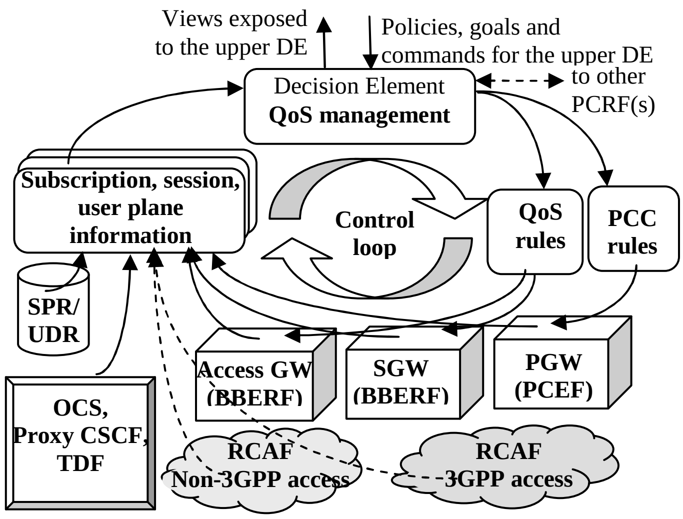

Fig.4 Mapping of QoS management functionality onto GANA network-level

In EPS, the decision logic for QoS management is distributed between different nodes. The Serving gateway (SGW) and Packet Data Network Gateway (PGW) handle the IP packets flowing to and from the mobile devices. The SGW implements the decision logic for mobility between 3GPP access and LTE (Long Term Evolution). The PGW is the point of interconnection to external IP networks and in addition to IP address allocation it implements the decision logic for charging, packet filtering, and policy-based control of user specific IP flows.

EPS supports different mobility protocols depending on which access technology is used. GPRS Tunneling Protocol (GTP) or Mobile IP-based protocols may be used between SGW and PGW. When GTP is used between SGW and PGW, the bearers are terminated in the PGW, which can use bearer procedures to control EPS bearers. This model is known as "on-path" model because the QoS/bearer signaling using GTP follows the same path as the user plane. In this model, the PCRF controls the QoS by providing the QoS information to PCEF in the PGW. When a Mobile IP-based protocol is used towards PGW, the decision logic for QoS and bearer reservation procedures is implemented closer to the Radio Access Network and PGW is not involved in policy control.

For 3GPP family of accesses, these procedures take place in the SGW. For other types of access, the Access GW in the access network is involved in policy control. This model is known as "off-path" model. In the "off-path" model the PGW is involved in charging control.

For IP Multimedia Subsystem (IMS), the AF corresponds to the Proxy Call Session Control Function (CSCF). For non-IMS service, the AF may be a video streaming server or Open Service Access/ Parlay X gateway.

For roaming scenarios, the Home PCRF located in the subscriber home network is not allowed to directly control a policy enforcement entity in the visited network that serves the roaming subscriber. Control of allowed services and the authorization of EPS bearers are always handled by the Home PCRF. For roaming scenarios, the Visited PCRF may accept or reject, but not change, policy decisions coming from the home network. This allows the visited operator to control the usage of EPS bearers in its access network.

IV. Future Enhancements of QoS Management in EPS

Current research work studies a possible enhanced functionality of PCC related to interworking with the Access Network Discovery and Selection Function (ANDSF) in EPS [7], [8], [9]. The ANDSF contains data management and control functionality and allows the network operator to define policies that prioritize between different access technologies if several non-3GPP access networks are available (3GPP TS 23.402). It can provide the mobile device with three types of information: access network discovery and selection information, intersystem mobility policies, and intersystem routing policies. The ANDSF may interact with policy and charging control to assist the resource reservation in re-selection and handover procedures.

In the GANA network level, the autonomic behavior of QoS management may be extended as shown in Fig.5, where Home Subscriber Server is a subscriber database.

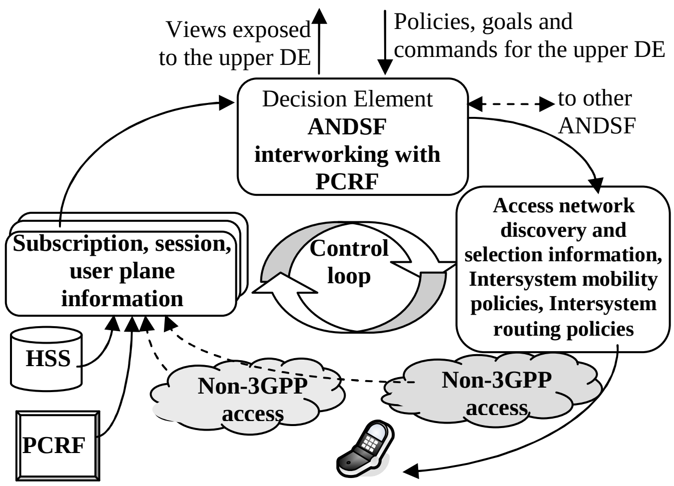

Fig.5 Abstract Autonomic Networked System with interaction between access network discovery and selection function and policy and charging control

V. Conclusion

The paper presents a study on autonomous behaviour of QoS management mechanisms in the Evolved Packet System. The standardized policy and charging control functionality is analysed and autonomic characteristics are abstracted in the four levels of the Generic Autonomic Network Architecture.

In the protocol level, the Diameter protocol used for PCC signalling exposes autonomicity during selection/discovering of the policy and charging control function. In the function level, different QoS management functions like policy control and charging control have autonomic characteristics in making decisions on authorization of EPS bearers. Combining different QoS management functions allows abstraction in a system level. The overall QoS management mechanism which considers the distributed network functionality exposes self-manageability in the network level. Further optimization of autonomic characteristics of QoS management in the network level may be achieved by interworking with access network discovery and detection functions.

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