System and Service Integration in Heterogeneous Networks by a Policy Based Network Architecture

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Abstract: **Within this paper, the Academic Network for Wireless Internet Research in Europe (ANWIRE) presents a new policy based architecture for system and service integration in future heterogeneous wireless mobile networks. The proposed generic framework is based on a detailed review and comparative analysis of ongoing research work in the field of system and service integration followed by a respective classification, which is used as a basis to derive requirements of a new integrated architecture. The presented architecture facilitates interworking of heterogeneous systems by considering key enabling technologies like 'Wireless Internet' and 'Reconfigurability' as envisaged by ANWIRE.**

Keywords: System and Service Integration, Heterogeneous Networks, Policy Based Architecture, ANWIRE, Framework Architecture

I. Introduction

System integration is widely considered as an indispensable condition for successful future wireless service provision. Since no individual standard is expected to fulfil all of the (more and more) challenging requirements of modern mobile users, the solution is seen in complementary deployment of several dedicated wireless systems. For this, it is necessary to establish a certain generic architecture, serving as a framework for future system and service integration.

The Academic Network for Wireless Internet Research in Europe, ANWIRE [1], is a thematic network in the context of the 5th European IST Programme that aims at organising and coordinating parallel actions in key research areas of 'Wireless Internet' and 'Reconfigurability', in order to encompass research activities towards the design of a fully integrated system. Promoting and disseminating Wireless Internet and Reconfigurability solutions shall make them available to the research and industrial community. The present paper reflects objectives of work programme for the ANWIRE System Integration Task Force 1.5. The overall aim of this Task Force is to generate proposals for an integrated system and service architecture.

Within the following Section II, a classification and deep analysis of ongoing system integration efforts is provided. Based on these Section III derives requirements for a future integrated architecture. Subsequently Section IV proposes the policy based Generic ANWIRE Integrated system and service Architecture (GAIA)[1]. While this section supplies a generic framework, Section V adopts the presented architecture to a more concrete system installation addressing aspects like Ad hoc networking and End-to-End (E2E) Quality of Service (QoS) provision.

II. Classification of Ongoing System and Service Integration Efforts

A basis starting point for work as conducted in ANWIRE network was to sift current research efforts with respect to system and service integration and to possibly adapt appropriate individual perceptions with respect to ANWIRE aims.

For this, an intensive review of ongoing work was performed and the different approaches were judged based on the achieved system and service integration results. Investigated projects/consortia comprise: ETSI BRAN/3GPP [2], WINE GLASS [3], MOBY DICK [4], SUITED [5], BRAIN/MIND [6], WWRF [7], WSI [8], DRIVE/ OVERDRIVE [9], TRUST/SCOUT [10], MOBIVAS [11], FLOWS [12], and the Chinese 863 Program Project in Wireless Communication (FuTURE) [13]. A detailed overview on each project including key topics, strengths and weaknesses may be found in [14].

The considered projects provided interesting inputs to be considered for an integrated system and service design. Regarding this consideration, we found similarities and divergences in the types of network access technologies to be integrated (Figure 1), the achieved integration level at the management and control planes (Figure 2), the coupling levels of QoS and mobility (Figure 3a), the achieved vertical handover (Figure 3b) and the efforts related to the adaptability and the reconfigurability aspects (Figure 4).

Regarding the types of access networks integrated in the framework of the reviewed projects, despite SUITED that also incorporates satellite-based communications, most of the projects care about the integration of several terrestrial access networks, as shown in Figure 1. Further on, the integration of Ad Hoc networks is an emerging topic of investigation considered only in the projects MIND and FUTURE.

[1]In Greek mythology, GAIA was Mother Earth, who emerged at the creation of the universe.

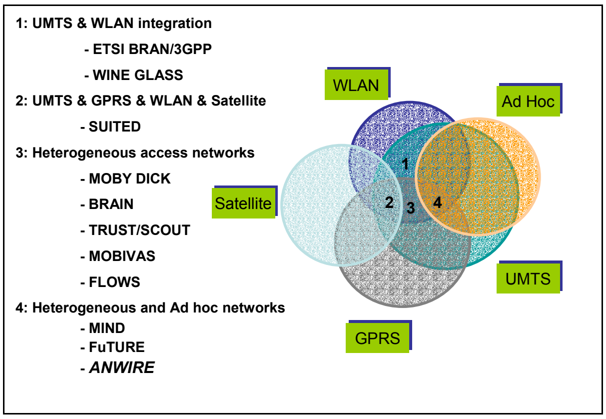

Figure 1: Integration focus of research projects/consortia

Other differences and commonalities were found for the integration efforts in the control and management planes of each project (Figure 2). For instance, in ETSI BRAN, BRAIN/MIND and WINE GLASS, the handover (HO) process was achieved at a higher layer, i.e. session or network based, which could be considered as a low integration method for HO, in contrast with the HO managed at link or physical layer to be considered as a highly integrated mechanism. Some approaches such as FuTURE, ETSI BRAN, SUITED, BRAIN/MIND, WINE GLASS and MOBIVAS, use a low integration strategy for QoS support over heterogeneous networks through *QoS mapping*; others use a higher integration approach with a common set of QoS classes.

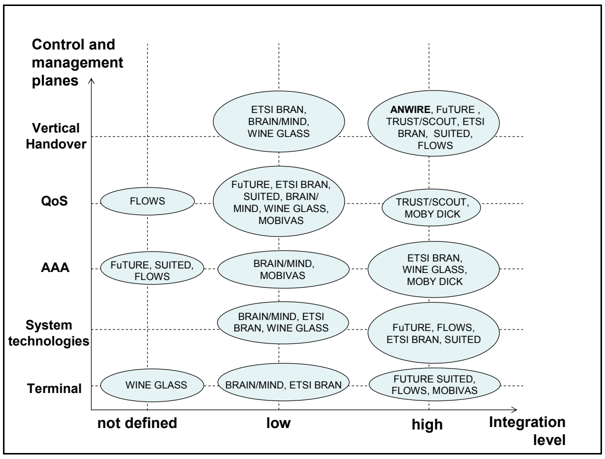

Figure 2: **Control and management integration levels achieved in research projects/consortia**

Concerning Authentication, Authorization and Accounting (AAA), certain initiatives like BRAIN/MIND and MOBIVAS apply different AAA systems in each access network, that exchange database information (low AAA integration), whereas a higher integration was achieved by ETSI BRAN, WINE GLASS and Moby Dick establishing common AAA databases and protocols over their frameworks. Also, the high integration of radio access technologies at link or physical layer marks the differences with respect to the achieved level of system/technology integration among the projects; other alternatives such as FuTURE, FLOWS, ETSI BRAN and SUITED use the required signalling between different radio access technologies for the exchange of information. Finally, the terminal architecture at lower layers differentiated the initiatives in two groups, those that include multimode terminals using different interfaces for each radio access technology (low integration), and other that define multimode terminals using the same interface for different radio access technologies (high integration).

The *seamless horizontal handover* was an important aspect of mobility management considered in most of the projects. The seamless HO provides both, fast and smooth handovers, which offers the minimum handover delay. Only, the FuTURE project introduces a mechanism for *smooth handover* in its framework, which mainly reduces the packet loss. Significant importance in this area is the achieved level of coupling of QoS- and Mobility Managements leading to different ways of reducing the delay in the reestablishment of QoS support after a HO event. Tighter coupling, leading to more seamless HO and faster QoS reestablishment, is achieved using mobility management signals to trigger QoS mechanisms. Figure 3a illustrates the horizontal HO approaches used in different projects.

Figure 3b gathers the projects in terms of their efforts in the achieved vertical HO. (Other kinds of mobility between different technologies such as session-based mobility (SIP-Proxy) are not represented in the figure). Another attractive handover technological concept arising in recent projects is *Policy Based Handover* In this the mobile nodes can handoff from one technology to another based on constraints (e.g. user-related such as service costs and performance, or network-related such as load balancing or QoS requirements) other than radio conditions as in 'classical' HO execution. It is considered in greater detail in section IV later on.

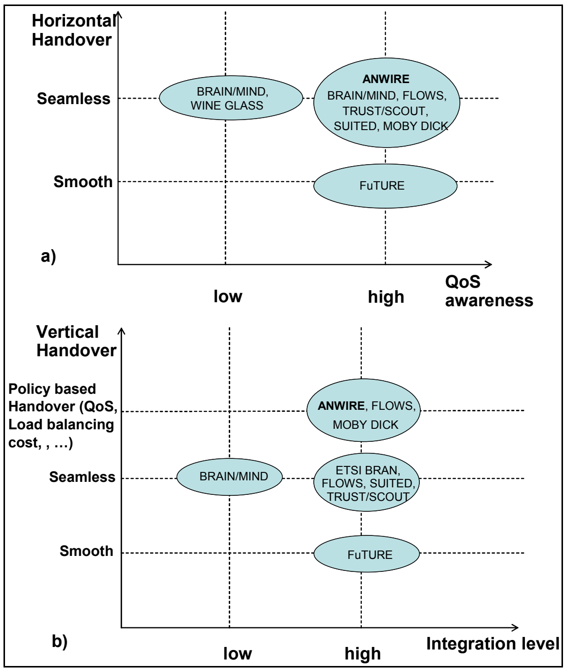

Figure 3: Research projects' technology integration level and handover classifications

Figure 4 finally groups the projects with respect to their efforts in adaptability and reconfigurability. Some projects like BRAN, BRAIN/MIND, MOBIVAS and FLOWS introduce *Adaptability*, as a method to overcome changes experienced by the services during the terminal/user mobility*,* providing the ability of the communication nodes to dynamically change between predefined states. On the other hand, *Reconfigurability* is the capability of the communication nodes to dynamically change from one state to a new one, which was not reachable or existing before. The transition relies on prior external interactions.

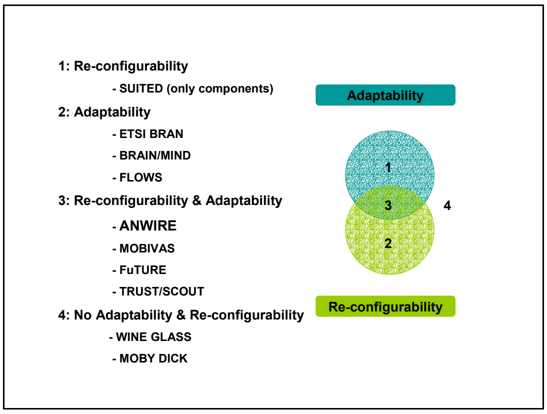

Figure 4: Research projects' adaptability and reconfigurability efforts

III. Requirements for a System and Service Integration Architecture

Through a deeper analysis of system integration approaches, and consideration of commonalities and differences (as discussed above) some requirements, to be taken into account for the design of an integrated system and service architecture, may be deduced. To attain an integrated system issues need to be considered from the viewpoint of various 'parties' – the *network*, the *terminal*, the *services* and the *user*.

From the *network point of view*, the integration system level depends on the communication layers' integration, i.e. *loose integration* is achieved with the integration at the higher layers, whereas *tight integration* is achieved at the link and the physical layers.

The loose integration may be achieved by the integration of the management system of the different networks, and the AAA system. In this integration we need to consider these requirements:

- *System management integration requirements*: The management system of each network can exchange management information with each other. The information can be related to QoS, mobility and security (including AAA). The system management has to consider the personal and service mobility management. Here, session continuation issues, service portability issues, roaming users' issues, and security issues need to be considered.
- *AAA integration requirements*: Depending on the level of integration, the system integration can have a unique AAA system (tight integration) or just exchange information between the AAA systems of the integrated networks.

At the network layer integration requirements and issues would include:

- *Seamless Mobility management issues*: Mobility management expectation in homogenous networks tends to be seamless mobility. This is in fact quite a challenging issue, and is still more so for mobility and vertical handover among heterogeneous networks.
- *Routing issues*: These depend on the network type, be it wired, mobile, wireless multihop, Ad Hoc networks, etc...

As mentioned, the integration process at the link and physical layer is here classified as tight integration. The issues, from technological ones to business models, are complex and difficult, even in homogenous networks. At the outset it seems that such tight integration is unattractive and unlikely to happen because of the significant constraints, requirements, compromises etc it will pose in network design and adaptation.

From the *terminal point of view*, the integration system process needs to consider requirements such as:

- *Multimode terminal* supporting different interfaces, one for each network technology.
- *Adaptive and reconfigurable terminal* implementing software defined radio (SDR) and supporting adaptive transmission mechanisms (i.e. adaptability).

From the *user*- and *service point of view*, requirements and issues to be considered by the integration system process include:

- *User identification issues*: Should the user have a unique identifier in the network? If yes, where to store this identifier (may be a smart card)?
- *User contract issues*: Should the user negotiate a service contract with one administrative operator or several operators, or a third party offering this service. The latter would be a new paradigm.
- *User services, adaptive services, always best connected (ABC) user*: A goal in the integrated system is to have the user always best connected, and at least always connected, i.e. having uninterrupted continuous service when changing network technology or changing terminal (through handover of any type or through adaptive and reconfigurable activities) [10], [22].

Finally, security issues need to be considered in each integration system level.

IV. ANWIRE Proposal for an Integrated System and Service Architecture

Policy based management is a new paradigm introduced by the IETF to provide dynamicity and automation in the network management [15]. In the ABC context, this automation and dynamicity will be of a great help. In fact, when a mobile user moves from one network to another, the available resources and the corresponding prices will depend on the available access networks. Dynamicity and automation are two important features of the ABC decision-making process.

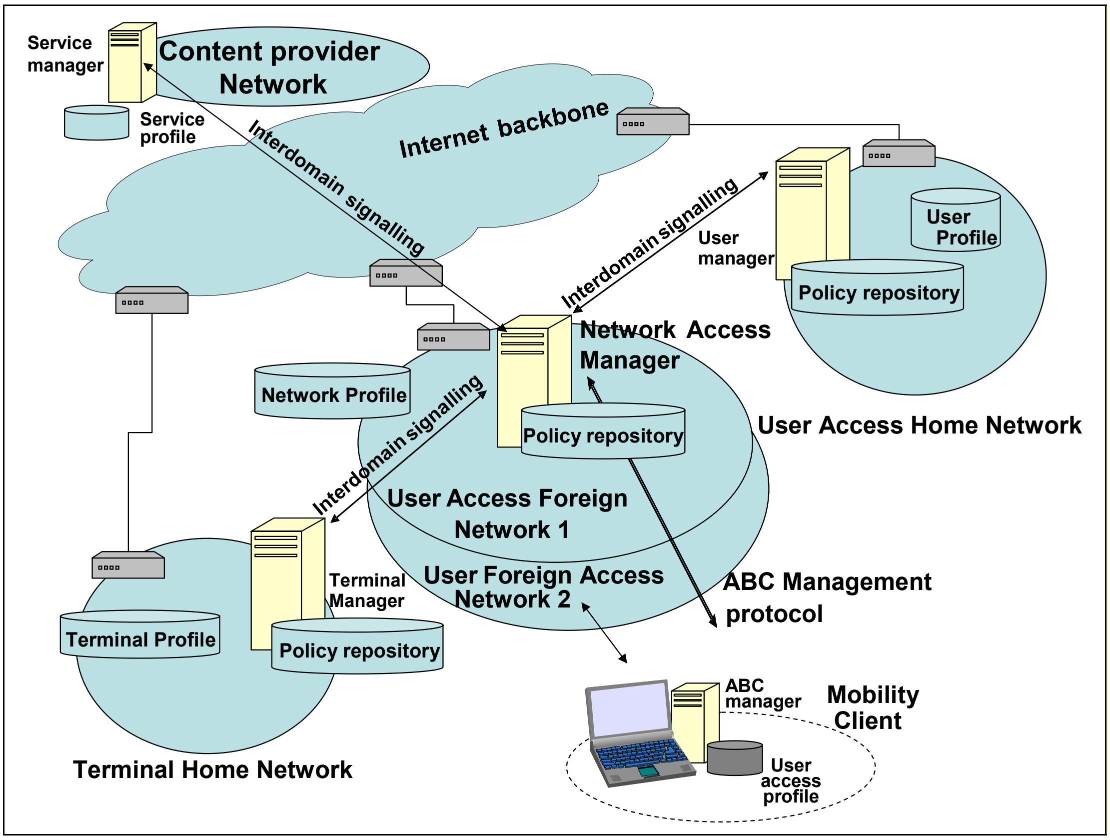

Figure 5: Generic ANWIRE Integrated system and service Architecture (GAIA)

As illustrated on Figure 6, policy based management introduces mainly three components. The policy server in the network part (called also Policy Decision Point, PDP) is responsible for the decision-making process. The policy client (called Policy Enforcement Point, PEP) interacts with the policy servers for a given ABC decision. The Policy Repository is the third component, which stores a set of policies introduced by the network administrator based on the business objectives of the network provider. A *policy* is one or a group of rules, with the form: if <condition> then <action> [17]. A policy management tool is often used to ensure the automatic translation of the policies from the high/business level to the low/network level policies.

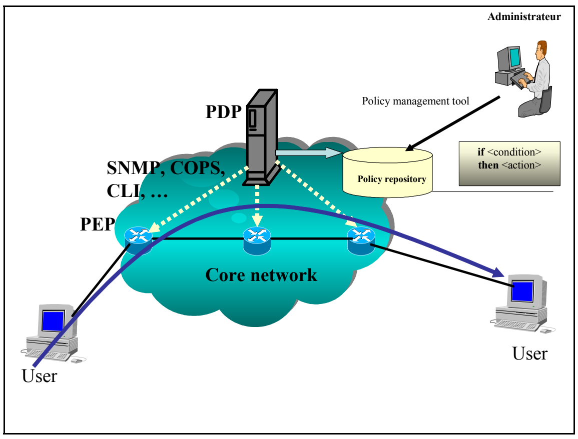

Figure 6: Policy based management framework

The interaction between the policy server and the policy clients is achieved by a policy transport protocol COPS (Common Open Policy Service) [16] introduced by the IETF RAP (Resource Allocation Protocol) WG. Several COPS client types have been specified mainly for QoS network configuration.

Based on the integration system and service requirements, and on the integration research efforts, we propose the Generic ANWIRE Integrated system and service Architecture (GAIA) as illustrated on Figure 5. Policy based management is used to support this system and service integration approach. We assume that the mobile user has a *User home network* maintaining a *user profile,* where all her/his preferences are administered. The terminals are subscribed to the *terminal home networks* where a *terminal profile* is maintained in order to propose for instance a terminal configuration for a given user service. The mobile user (while on the move) will have access to several *user foreign networks* (comprising any wired or wireless network access technology), which also maintain their *network profile*.

In this architecture, we propose to define five domains (by *domain*, we refer to a set of network elements administrated by the same *Policy Manager*). In each domain we define a manager entity (i.e. policy server), a policy repository and a profile. We use five profiles with their respective managers, and each profile may have public and private information:

- *Terminal profile and manager:* The terminal profile contains the terminal capabilities (radio access options, reconfiguration option, terminal resources, protocol environment, etc). The terminal manager is in charge of reconfigurability control of the user terminal (mobility client in Figure 6).
- *User profile and manager:* The user profile includes the user preferences and her/his personal services description, e.g., QoS and tariff preferences, service personalization and subscription requirement, service, etc. The manager performs the user authentication, service subscription and billing.
- *Network profile and network access manager*: The network profile contains the network capabilities description (access technology, QoS framework, handover support, coverage...). The network access manager is in charge of the administration and supervision of multiple activities, such as AAA functionalities and connection admission control, handover control, radio resource management, load balancing, location awareness, multi-technology communication, service advertisement, etc.
- *User access profile and ABC manager:* the user access profile contains the initial network preferences of the user and applies them with respect to the requested service. The ABC manager provides the physical layer intelligence, an ABC decision-making module, a reconfiguration module, mobile initiated handover control and service discovery functionality.
- *Service profile and manager:* The service profile includes the description of available services of the respective provider. Among others, the manager is involved in negotiation of service characteristics (service profile, terminal profile, and network profile), service adaptability and service billing.

Depending on the level of integration, the system may have one network access manager for all the access network technologies (a high level of integration) or one for each of them (a low level of integration). An *Interdomain Signalling Protocol* is required in order to ensure the interaction between these managers. The interdomain signalling facilitates the negotiation and information exchange. Another specific interdomain protocol, an *ABC protocol*, between the ABC manager deployed in the user device and the network access manager in the user foreign network is also required for the management of network access choice. The interaction between network elements is shown in Figure 7.

V. Adoptation of the ANWIRE Framework Architecture

A possible concrete realization of the proposed framework architecture is shown in Figure 8.
Here, the respective 'Access Networks' correspond to 'User Foreign Networks' and the 'Access Server' represents a distributed realization of the 'Network

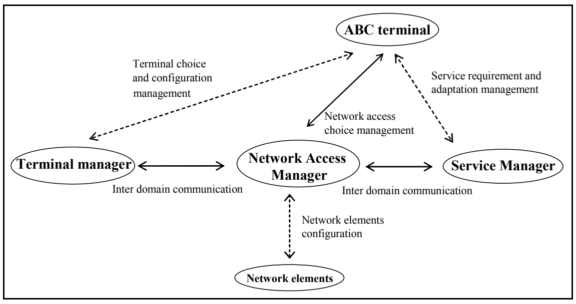

Figure 7: The network elements interactions in the Generic ANWIRE Integrated system and service Architecture (GAIA)

Access Manager' in Figure 5. The 'Interdomain signalling' is indicated by bidirectional (green) arrows.
The proposal also integrates Ad Hoc multi-hop wireless networks. They are represented by bubbles drawn with dashed lines because the boundaries of the Ad Hoc networks are diffused (usually the number of nodes and the physical topology change quite frequently). Here, the mobile terminal acts as a "gateway" or "proxy" for the Ad Hoc networks (presuming that it has a relationship with the operator of a fixed wireless access network –one possible implementation of multi-hop wireless networks, i.e. the spontaneous extension of the fixed access network).

Depending of the scenario and the objectives, the Ad Hoc network could of course have more than one gateway. Vertical handovers from other wireless networks could also be supported.

The mobile terminals serving as a gateway to the Ad Hoc network must provide more functionalities similar to those of the border routers in fixed access network, e.g. understanding Ad Hoc routing protocols on one side and mobility management protocols on the other side. Integration solutions for AAA functionalities and other such issues inside the Ad Hoc network will be required, too. Such solutions will need to respect the different scalable solutions to be used for the different activities: networking, QoS support, mobility management, etc. throughout the integrated 4G network.

A. E2E QoS Realization in GAIA

The Internet Protocol (IP) realizes two main frameworks for QoS provision, namely the Differentiated Services (DiffServ) [18] and the Integrated Services (IntServ) [19]. IntServ performs better in the access systems, due to its ability to provide more accurate QoS, while DiffServ is more scalable in handling large number of flows, and for this reason it is intended for the backbone. Proper IntServ flows aggregation into DiffServ service classes before entering the backbone network completes the picture at the IP layer.

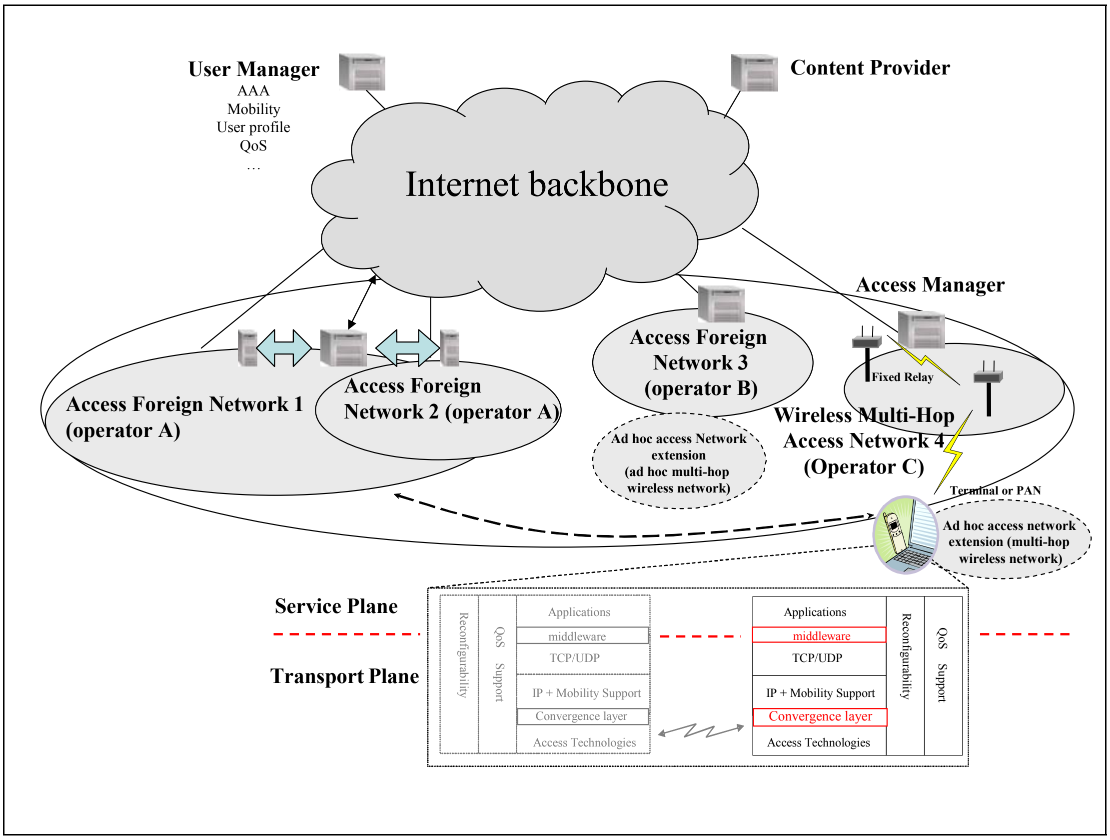

Figure 8: Adaptation of GAIA to concrete system installations

In the backbone network, acceptable QoS can be attained by bandwidth overprovision, while the limited bandwidth of wireless links, does not allow the same in the access networks. For this reason, supporting mechanisms are required in the lower layers to guarantee the QoS agreed by IntServ. In GAIA, we consider Resource ReserVation Protocol (RSVP) as the common signalling protocol at the IP layer of the access networks. The main question to be answered is how to map the procedures and parameters of RSVP, to QoS mechanisms of the access networks. Two of the dominant access networks in GAIA are the UMTS and the WLANs. UMTS is expected to efficiently cover wide areas, while WLANs provide more bandwidth and are intended mainly for hot spots and in-door applications.

The UMTS framework for integrated IP E2E QoS provision and interworking is described in [20]. The main functional entities are the IP Bearer Service (BS) Manager and the Translation/Mapping function that are present both in GGSN as well as in the User Equipment (UE). The IP BS Manager uses standard IP mechanisms to manage the IP bearer services. Its main function is to interface UMTS with the IP core and the used mechanisms may be different from the internal mechanisms used within the UMTS. The Translation Function interacts with the IP BS Manager and provides the interworking between the mechanisms and service parameters used within UMTS BS and those within the IP Bearer Service. In the GGSN the Translation Function maps the IP QoS parameters (i.e., RSVP parameters) to adequate UMTS QoS Parameters, while in the UE the user/application QoS parameters are mapped to either PDP context parameters or IP layer parameters (e.g., RSVP). It is evident that the translation function is an integral part of the UMTS - IP QoS interworking since, without proper mapping, UMTS will fail to provide a bearer service that will be consistent and aligned with the corresponding IP BS of the IP core. Work in GAIA is focused mainly in this mapping.

On the other hand, QoS provision in WLANs depends on the specific technology used. IEEE 802.11 is considered as the major standard for WLANs. In IEEE 802.11e [21], which forms the QoS extension for legacy IEEE 802.11, the QoS mechanism is applied per Traffic Stream (TS). A TS is a set of MSDUs to be delivered subject to the QoS parameters values provided to the MAC sublayer in a particular traffic specification (TSPEC) element. Adequately, a similar mapping is required between RSVP traffic and QoS parameters and 802.11e TSPEC. Additionally, the signalling exchange for TS setup should be triggered by corresponding RSVP messages, being part of the interdomain signalling in GAIA. But besides that, the unstable wireless links ask for additional mechanisms in WLANs, in order to efficiently support static resource reservation based schemes such as RSVP. These mechanisms include:

- An admission control algorithm realized in GAIA network access manager, see Figure 5, Figure 8, which considers not only the current available bandwidth, but also the expected instabilities of the wireless link. In this way, it might choose not to accept flows, even though there are available resources at the time of the request, if quality degradations are expected.

- o A traffic-scheduling algorithm for the wireless medium, that is capable of arranging transmissions in such a way that the QoS is maintained for all flows. This algorithm should take as input the traffic and QoS parameters provided in the TS by RSVP, and try to maintain the agreed values under all traffic and channel conditions.
- o A flow rejection algorithm that detects conditions of the overall bandwidth below the required limit and rejects a number of flows to allow the rest to operate as required. The critical question for the algorithm is how many flows and which in particular should be rejected to cause as less inconvenience to the users and the network as possible.

From the above discussion, it is clear that, besides the basic framework for E2E QoS provision, a considerable number of adjustments, clarifications and supporting mechanisms are required to provide a complete E2E QoS system.

VI. Summary and Conclusion

The present paper introduces a generic policy based architecture for system and service integration in future heterogeneous wireless mobile networks. Since system integration is seen as a major research challenge for the development of proper upcoming integrated networks beyond 3G, the Academic Network for Wireless Internet Research in Europe, ANWIRE, aims on bringing together key enabling technologies like 'Wireless Internet' and 'Reconfigurability' in order to propose an adequate framework. Research conducted within ANWIRE network thereby comprises a classification and analysis of ongoing system integration efforts judging similarities and divergences of the individual approaches to possibly identify the suitable solutions and to adapt them to ANWIRE aims. Based on subsequently derived requirements on integration a policy based Generic ANWIRE Integrated system and service Architecture (GAIA) was conceived and explained in this paper. While the presented architecture is still quite generic and embryonic, an exemplary and more concrete adaptation is considered, which addresses more detailed aspects like Ad hoc networking and E2E QoS provision.

Future work requires ongoing deeper study of the integration issues and more detailed specification of the interactions within the presented domains, which will lead to many adjustments and refinements to the GAIA outlined here. This is ongoing within ANWIRE.

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