Policy Based Networking in the Integration Effort of 4G Networks and Services[1]

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***Abstract*—4G wireless and mobile communication networks have the ambition to integrate heterogeneous wireless access network technologies combining mutual advantages and thus offering a variety of services to the users, maximizing their satisfaction on the one hand and maximizing the network and service providers' profits on the other hand. However, this integration is not achievable without challenges. In this paper, we present related system integration requirements and provide a new framework to support the integration of 4G networks and services. This framework uses a policy based networking concept in order to provide the unified control in the oncoming 4G networks and services. We also provide an analysis of the candidate signaling protocols in this framework. Two approaches are described: i) The unified QoS, mobility, and security signaling and ii) the heterogeneous QoS, mobility, and security signaling. In addition, we introduce user, terminal, network and service profiles and management in order to provide a user centric approach and consider different user, terminal, network, and service constraints in order to better adapt the user service as well as the network configuration to these constraints. Finally, we give a short estimation on the composition of exchanged signaling data with respect to the aspired level of integration.**

Keywords--Policy-based Management, 4G Networks and Services, Always Best Connected, Network Management and Control, Network Signaling.

I. Introduction

Nomadic computing, ubiquitous computing and now ambient computing are the vision of several Internet network experts [1] and are the ultimate objectives of the research network community. Equal goals are followed by the European IST Project ANWIRE (Academic Network for Wireless Internet Research in Europe). ANWIRE is a thematic network established by academic and industrial partners from various EU countries acting in two main overlapping research tracks: i) Wireless Internet and ii) Reconfigurability. ANWIRE aims at organizing 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. Further goals are the promotion and dissemination of concepts with respect to the aforementioned goals to make new ideas available to the research and industrial community.

Basically, all research is about providing transparency to the mobile user anywhere, anytime, from any network and using any terminal. Currently discussions are more focused on Always Best Connected (ABC) concept, e.g. [13], which in our view is a starting point of all these objectives. In fact, in order to provide transparency to the user when using his services anywhere at anytime with any terminal, we need to provide a mechanism to make right decisions depending on the constraints of the mobile user environment. ABC mechanism will consider the price of the available network resources, the QoS requirements of the mobile user services, the terminal characteristics, the network characteristics and the user preferences. A set of rules or policies can be specified and stored in the network that will be triggered and enforced according to the mobile user context and preferences. In this paper we propose to use the (Internet Engineering Task Force) IETF policy-based management architecture to support the ABC mechanism, and we introduce the network and the ABC terminal architectures. We also present a starting point of the ABC protocol needed in that architecture.

In the following paragraphs we provide an analysis of the 4G system integration requirements, and we propose the ABC network and terminal architecture using policy based management model. We also present a brief analysis of the candidate signaling protocols in this architecture and highlight possible approaches.

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II. POLICY BASED NETWORKING OVERVIEW

Policy based management is new paradigm introduced by the IETF to provide simplification and automation in the network management [2]. In the ABC context, this automation and dynamicity will be of great help. In fact, when a mobile user moves from one network to another, the available resources and the corresponding fees depend on the available access networks. Dynamicity and automation are two important features of the ABC decision process.

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 process, the *policy client* called Policy Enforcement Point (PEP) interacts with the policy clients for a given decision, and the *policy repository* which stores the policies introduced by the network administrator based on the business objectives of the network provider. A Local PDP (LPDP) can be deployed in the network nodes with the PEP. This LPDP will replace the PDP when this one is unreachable for some reason like disconnection. A policy management tool is often used to ensure the automatic translation of the policies from the high or business level to the low or network level policies. The interaction between the policy server and the policy clients is achieved by a policy transport protocol. COPS (Common Open Policy Service) is the protocol introduced by the IETF RAP WG (Resource Allocation Protocol) to achieve the network configuration by distributing network policies to the network nodes [3]. Several COPS client types have been specified mainly for QoS network configuration. The framework of policy based management architecture is depicted in Figure 1.

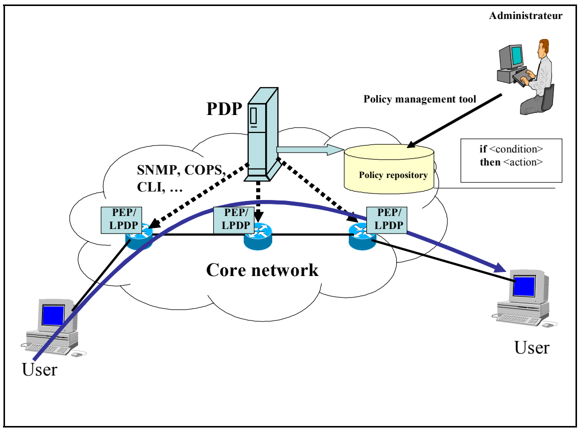

Figure 1. Policy based management framework.

Through a deeper analysis of the system and services integration approaches used in the well-known international research projects as regards their commonalities and differences, [12], one can deduce the requirements for the design of an integrated system and service 4G architecture. In particular various issues related to the *network*, the *terminal*, the *user,* the *service,* and *security and privacy* need to be studied and resolved. Details on key requirements and issues may be found [11].

III. POLICY BASED NETWORKING IN THE INTEGRATED 4G SYSTEMS

A. *Architecture*

The general architecture, referred to as GAIA (General ANWIRE system and service Integration Architecture) is illustrated on Figure 2. We assume that the mobile user has a home network*,* where all his services are subscribed, i.e., the *User home network* maintains a *user profile*. The terminals hold a second subscription in the *terminal Reconfiguration network* where a *terminal profile* is maintained in order to propose for instance a terminal configuration to a given user service. The mobile user will have access to several *network access providers* which also maintain their *network profile*. These visited networks are named *user foreign networks* and they can comprise any wired or wireless network access technology.

The strengths of the proposed architecture are mainly:

- First, its generic aspect. It provides the control needed in the integration issue of system and services in 4G networks but it is also still open to integrate new features by adding new functional entities corresponding to this issue.
- Second, the policy concept deployment will provide flexibility to change the configuration of the low level view architecture by dynamically deploying the corresponding configuration (policies) stored in the policy repositories and triggered by the 4G constraints such as QoS requirement, wireless access technology cost and resource availability, user preferences, etc.
- Simplification and automation in the configuration, which are very important in the ABC process.

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, a policy repository and a profile. The *Policy Repository* is a set of policies. A *policy* is one or a group of rules, with the form: If <condition> then <action>. We use five profiles with their respective managers, and each profile can 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 re-configuration control of the user terminal (mobility client).

User profile and manager: This profile includes the user preferences and his personal services description, e.g., QoS and tariff preferences, service personalization, subscription requirements, etc. The user manager will perform basically the user authentication (AAA), service subscription and billing. In this integrated environment, there is a need for a complex AAA and billing system. In addition, users will subscribe to a set of personal services that will be stored in his user profile in the home network. The user home network will maintain the user service profile and preferences in order to provide the information necessary to authorize the user to use the home or current network resources, and also support the accounting and billing system. The user manager will be then involved in the authentication procedure of the user during the session establishment in the home or the foreign network. It will also be involved in the *user identification* and *registration* in service portability or personal mobility.

User access Profile and ABC Manager: This manager is involved during the first connection of the mobile node to the network. In fact, intelligence related to the decision mechanism to select an access technology for the mobile terminal is specified in the network, but this intelligence cannot be used during the first connection of the mobile terminal. For this purpose, part of this intelligence will be in the mobile terminal in order to provide the Always Best Connection at the first connection of the mobile node by considering the initial network preferences of the user and applying them with respect to the requested service. The preferences of the user for the technology to be used at the very first connection will be specified in the *user access profile*, which might be stored in the user's terminal or for better flexibility in a user smart card [4]. The Always Best Connected (ABC) manager provides the physical layer intelligence, decision module, reconfiguration module, mobile initiated handover control and service discovery.

Network profile and access manager: 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.

Service profile and manager: This 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. In future 4G networks, service providers need to adapt their service to the access technology used by the mobile nodes. For this purpose, there might be an interaction between the mobile node and the service manager or between the network access manager and the service manager in order to adapt the service to the user terminal characteristics, the network access technology, the user preferences or the current link conditions. A negotiation process will take place before the starting of the service considering all these parameters. The service manager will then decide to provide the service at the service provider site, the user home network site, or the current user access network. It will also decide how the service will be provided to the user, for instance provision of a full version of the service or an adapted version of the service. Note that these negotiation and decision processes are taking place by using a set of policies already stored in the service policy repository service. Note that these negotiation and decision processes are taking place by using a set of policies already stored in the service policy repository

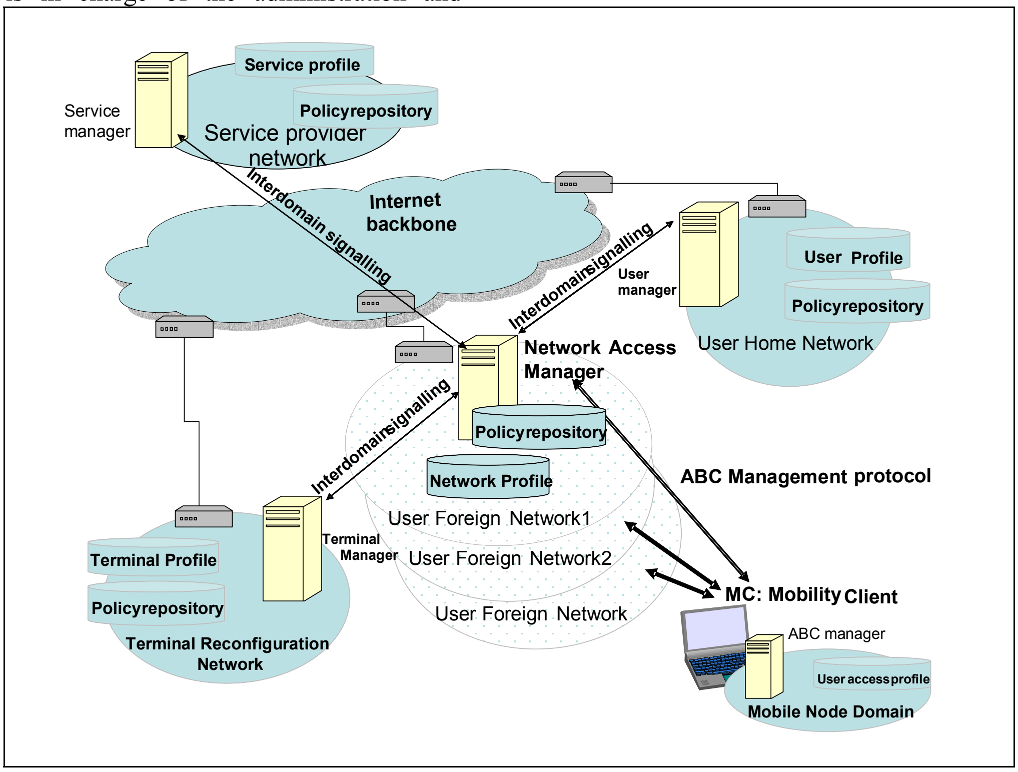

Figure 2. ANWIRE Framework Architecture for system and service integration

B. Mapping of Policy based Networking Entities to GAIA

The mobile node will implement a policy enforcement module in order to interact with the different managers proposed in this architecture. From implementation point of view, this policy enforcement module will be the PEP (Policy Enforcement Point) proposed in the IETF policy based management architecture. Each manager will implement a PDP (Policy Decision Point) that will provide the configuration to the mobile terminal and also to the network nodes in order to run a user service with the required service level and considering all the parameters related to the ABC context. The Policy Enforcement Point in the mobile terminal will interact with the network access manager of each wireless access technology. It will be used to trigger the decisions from the policy server (PDP: Policy Decision Point) and also to enforce the configuration sent by the policy server. This configuration can be sent for instance by the Terminal Manager from the terminal reconfigurability network to adapt the terminal to support the user service or by the network access manager to adapt the user service to the network available resources described by the network profile, or by the user service manager to adapt the service to the user preferences or to ensure the service portability. Finally, the ABC manager in the mobile terminal will be implemented as a LPDP (Local PDP) since this is defined by the IETF as a component behaving as a PDP while the PEP cannot reach the PDP [5]. In our case, the mobile terminal before being connected cannot communicate with the PDP in the network, so the LPDP will make the decision related to the choice of the best connection to the user during the first connection.

The interaction between the policy client and the different managers is illustrated on Figure 3.

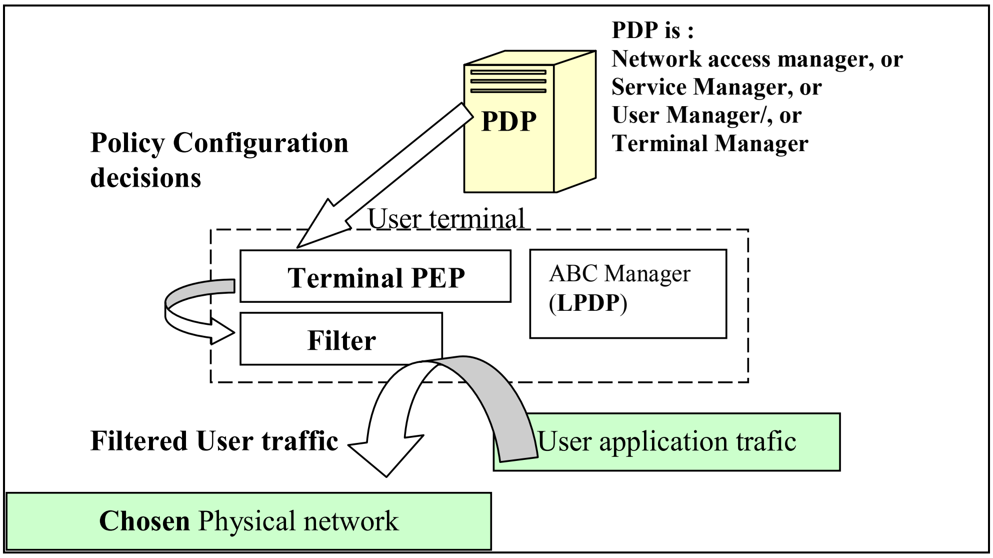

Figure 3. GAIA architecture mapping to Policy Based Networking elements.

C. Signalling Protocol

Depending on the level of integration, the system can 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 Signaling Protocol* is required in order to ensure the interaction between these managers. The Interdomain signaling facilitates the negotiation or information exchange. A specific Interdomain protocol, an *ABC protocol*, between the ABC manager in the user device side and the network access manager in the network side is also required for network access choice management. The Network elements interaction is shown in Figure 4.

Depending on the integration level achieved in the control and management plane, this inter-domain signaling could be comprised by just one unified integrated protocol or by a set of integrated protocol (with different coupling level) in order to manage and coordinate all the relevant functionalities of the architecture, such as mobility, AAA, QoS management and others.

The first approach represents a unified signaling protocol that facilitates management functionalities in a homogeneous way; it is also an example of a tight coupling of management functionalities. There are many examples that provide partial solution of the tight coupling of management activities, for instance, QoS and routing integrated functionalities [6], mobility and AAA [7] or QoS and security [8]. A more complete solution in [10] proposes to extend COPS (Common Open Policy Service) protocol to provide the interaction among the dedicated management protocols (mobility, QoS and security).

The second option is an integrated system of dedicated protocols that interact in a loose coupling approach, i.e. the management protocols coordinates their operation, for instance, the reception of one protocol message activates/triggers the signaling of another protocols. This approach has the advantage that different protocols can evolve in an independent way, but it could increase the network load or could delay the service continuity after a vertical handoff experienced by the mobile terminal. There are examples of partial solution of integrated management functions. One of the most complete frameworks is provided by [9] where an interdomain signaling is proposed by using SIP, QoS and AAA protocols.

The decision regarding the selection of a tight or a loose coupling of signaling protocols in our architecture will consider many factors such as the number of total messages required (scalability), the total system delay for QoS, the tolerance, the flexible deployment and others.

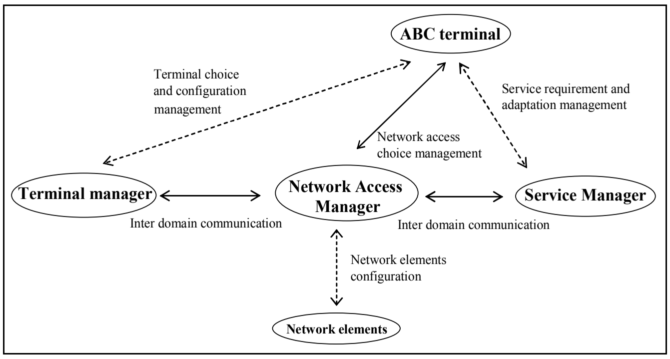

Figure 4. The network elements interactions of ANWIRE high level architecture

D. *Information Model*

While the previous section deals with the question *how* any kind of information could be transferred between participating domains and managers, it is of fundamental interest *what* and *how much* information needs to be provided. Depending on the integration level to be achieved the amount of data to be exchanged varies. While a tight integration may result in a minimum data exchange due to a possible policy maker that makes decisions on behalf of other entities, the loose integration entails the necessity for increased need of advertisement. Obviously the loose integration cannot judge that easily (according to the ABC principle) which connection type is preferable for the user and thus needs to pay for a less complex infrastructure with an increased amount of signaling.

IV. CONCLUSION

In this paper we provide an analysis of system and service requirements and we present our 4G integrated system architecture as proposed in the ANWIRE project. Further on, an analysis of the candidate signaling protocol to be provided in this architecture is given together with some preliminary considerations on the amount and content of signaling data to be exchanged, dependent on the aspired level of integration.

The main interest of using policy based management architecture is the adoption of dynamicity and automation in the configuration of the network nodes and mobile terminals that is very important in the decision process of the ABC concept. For this purpose, we also introduce the usage of the terminal profile, the network profile and the user's service profile and preferences. All these profiles will help to achieve Always Best Connected (ABC) decisions which finally will provide mobile users service support in a transparent way in the new 4G environment.

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