PROTON: A Policy-based Solution for Future 4G devices

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Abstract

We present PROTON, *a policy-based solution for 4G mobile devices – it allows users to seamlessly connect to highly integrated heterogeneous wireless networks. The key motivation behind PROTON stems from the statement that handover process complexity will increase in 4G systems, creating the need for augmented knowledge about context, as well as more flexibility. This paper demonstrates (1) how a flexible policy-based approach is suitable for 4G scenarios, and (2) how to incorporate richer context into policies and still maintain a light weight solution appropriate for mobile devices.*

1 Introduction

An integrated network-of-networks (*i.e All-IP network*) is the vision for 4G mobile wireless systems architecture. This envisages that users can benefit in several ways from this unified access platform. The advantages, however, cannot be seized if we do not consider the dynamics and complexity in future environments. For instance, we believe that a model based on mobility hints, cross-layer activity information, and application-specific data can contribute to an effective network usage; what we need is a policy-based solution that can effectively expose context knowledge without a huge overhead.

The 4G architecture demands highly flexible and adaptive mobile clients that can cope with diverse, heterogeneous, and dynamic environments. More technologies, services, and devices join the fray every day, we can be sure that as the QoS gap offered by new access networks closes (see table 1), hard-coded handover algorithms will become obsolete and more flexible solutions will gain importance.

Diversity and heterogeneity in wireless systems' evolution have placed the integration of hybrid mobile data networks as an enormous barrier towards the success of seamless networking. This challenge outstrips embedded-system hard-coded policies (e.g. *handover to the strongest signal* or *always handover to the lowest available overlay*). We see in policy-based solutions the capacity to arise as a promising option for mobility management in future 4G systems.

Table 1. Current and emerging radio access technologies will converge in a highly integrated and heterogeneous *ubiquitous* **network (i.e. 4G system), in which handover process complexity will dramatically increase.**

Network	Coverage	Data Rates	Mobility	Cost
Satellite (B-GAN)	World	Max. 144 kb/s	High	High
GSM/GPRS	Aprox. 35 Km	9.6 kb/s up to 144 kb/s	High	High
IEEE 802.16a	Aprox. 30 Km	Max. 70 Mb/s	Low/Medium	Medium
IEEE 802.20	Aprox. 20 Km	1-9 Mb/s	Very high	High
UMTS	20 Km	up to 2 Mb/s	High	High
HIPERLAN 2	70 up to 300 m	25 Mb/s	Medium/high	Low
IEEE 802.11a	50 up to 300 m	54 Mb/s	Medium/high	Low
IEEE 802.11b	50 up to 300 m	11 Mb/s	Medium/high	Low
Bluetooth	10 m	Max. 700 kb/s	Very low	Low

Motivation – *Seamless roaming and connectivity to highly integrated and heterogeneous networks is the key idea that springs from the 4G vision. Dynamics, flexibility, and reactiveness to context, the main challenges that can be subdued by the deployment of policy-based solutions.*

Overview – The 4G vision poses the challenge of *seamless networking,* which involves (1) connection to many radio access networks (RANs) using a multimode device, (2) assistance for decision, execution, and adaption processes during vertical handovers, (3) minimisation of latency effects to support real-time services, and (4) related management issues such as access control, accounting, and security in the new consolidated platform [4].

Previous solutions [2, 5, 6, 9] have tackled particular aspects of seamless networking. In this paper, we present a policy-based solution, called PROTON, to support devices/users during vertical handovers in next generation mobile systems. This attempt differs from previous approaches in the following key aspects:

a) Application-specific policies: the policy model facilitates the cooperation between application and network layers in order to improve user experience.

b) Context-aware policy model: an important difference with all other previously proposed handover models is that policies here also imply *context* and reflect the relation between user/device and the mobility context.

c) Assistance during the entire handover process: cross-layer and context knowledge are used to support users in decision, execution, and adaptation processes triggered by vertical handovers.

d) Support for new services: 4G communication systems open new opportunities to mobile users. For example, access to multiple RANs poses the possibility for *integrated networks services*, not only high-speed connection with high usability, but users can use multiple services from different providers at the same time, and this results in novel services [4].

The rest of the paper is organised as follows: Section 2 describes the architecture of the Mobile IPv6 testbed used during experimental analysis. Section 3 explores in more detail the design rationale to build this solution and briefly describes PROTON components. In Section 4 we expose the core of the solution, the policy model. Finally, we contrast our work with previous approaches in Section 5, and conclude in Section 6.

2 PROTON MIPv6-based Testbed

To closely emulate the next generation (4G) integrated networking environment, our experimental testbed setup consists of a tightly-coupled, Mobile IPv6-based GPRS-WLAN-LAN testbed as shown in figure 1. The cellular GPRS network infrastructure currently in use is Vodafone UK's production GPRS network. The WLAN access points (APs) are IEEE 802.11b ones. Our testbed has been operational since March 2003, and results showing how we optimise vertical handovers are available [3].

In the testbed, the GPRS infrastructure comprises base stations (BSs) that are linked to the SGSN (Serving GPRS Support Node) which is then connected to a GGSN (Gateway GPRS Support node). In the current Vodafone configuration, both SGSN and GGSN node are co-located in a single CGSN (Combined GPRS Support Node). A well provisioned virtual private network (VPN) connects the Lab network to that of the Vodafone's backbone via an IPSec tunnel over the public Internet. A separate "operator-type" RADIUS server is provisioned to authenticate GPRS mobile users/terminals and also assign IP addresses.

For access to the wireless testbed, mobile nodes (e.g., laptops) connect to the local WLAN network and also simultaneously to GPRS via a Phone/PCCard modem. The

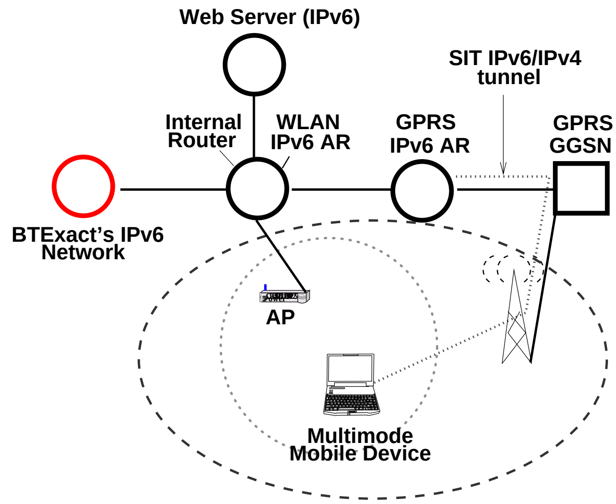

Figure 1. Experimental Testbed for PROTON.

mobile node's MIPv6 implementation is based on that developed by the MediaPoli project [1], chosen for its completeness and open source nature.

3 PROTON Solution

3.1 Design Rationale

PROTON's main objective is to tackle two obstacles in 4G systems: *heterogeneity* and *high dynamics*. To strike the first one, we propose to sense context and design the corresponding policy model to facilitate devices with the required flexibility and adaptiveness [8]. Moreover, to cope with dynamics, we propose a three-level context hierarchy according to sensed data and complexity in the rules applied.

3.2 Networking Context

Context is defined as any information sensed from the environment which may be used to define the behaviour of a system. This section outlines the concept of *Networking Context*, based on the introduction of the fragments in tables 2 and 3.

Networking context fragments are grouped into dynamic and static components. Moreover, these components are organised into a three-level hierarchy according to dynamics and complexity in the applied rules.

Upper level organises highly dynamic components on which simple local rules are applied.

Intermediate level arranges moderate fluctuation fragments that, together with data from the upper level, are used

Table 2. These components show the dynamics of heterogeneous 4G systems; a huge constraint in future policy-based solutions.

Sensed element	Context fragment	e.g. generated event
Presence	Device is attached to host	Interface [INSERT]
Status	Link-layer connectivity	Interface [UP/DOWN]
Connection	Network-layer connectivity	Incoming RAs at [eth0]
Signal Strength	SS received at the interface	[SS] below/above trigger
Handover Latency	Latency of vertical handover	[HL] from X to Y
Network	Profile of a specific network	Mobile host at home network
Congestion	Congestion in the network	Approximated [congestion]
Flows	Traffic classification	Traffic flow of [type] started
Velocity	Current speed of mobile host	Velocity [km/hr] above trigger
Position	Mobile host's position	Current [LAT,LON]
Direction	Moving direction of the MH	MH moving [NORTH]

to obtain aggregated contexts (host connectivity, activity, and location).

Lower level groups static components. We exploit collected data from all three levels to specify and evaluate the policy model.

Table 3. Dynamics in 4G systems demand intense context knowledge –expressed in a policy model– to cope with complexity. Static context components provide steady data which is essential to define and evaluate richer policies.

Component	Data elements	Capability
Network Profile	e.g., cost, bandwidth, RTT, packet loss, jitter, power consumption, and coverage	Information to exploit overlay model's diversity
Application Profile	QoS requirements such as packet loss, error rate, jitter, and latency.	Network aware applications that proactively adapt in 4G environments
User Profile	e.g., budget, security level, available power, priorities, and performance.	Consider user preferences as an input to the policy model
Infrastructure Profile	e.g., base stations and hotspots positions.	Increase proactiveness using network-provided static data

3.3 PROTON components

PROTON main components can be divided into three groups: *Context Management*, *Policy Management*, and *Enforcement groups* (see Figure 2).

Context Management group: *Sentinels* and *Retrievers* are the main components. These are responsible for gathering the Networking Context, applying local rules, and forming aggregated data.

Policy Management group: the *Policy Master* functions as the Policy Decision Point (PDP). Also, in this group we have the policy database, and two extra components: *Conflict Resolution module* and *Context-based profile selector* dedicated to solve potential conflicts in the application of policies.

Enforcement group: *Executors* act as the Policy Enforcement Points (PEPs) –according to the IETF Policy Core Information Model (PCIM) [7]– for example, the *Handover Executor*.

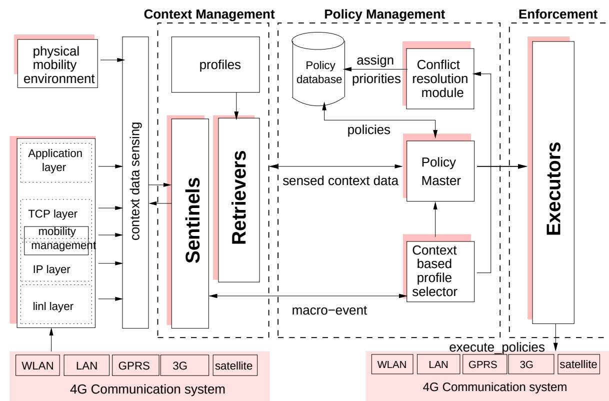

Figure 2. PROTON model stems from the vision of 4G systems.

4 Policy Model

4.1 IETF/PCIM and PROTON

PROTON follows the IETF/PCIM specification to define its policy model [7]. The main reasons for this are: (1) policies can be tagged with different roles, and this is useful to define subsets, (2) policies can be assigned a priority, useful for conflict resolution, and (3) IETF/PCIM can be translated to XML, this is useful for analysis and policy exchange.

4.2 Policy structure and classification

In PROTON's policy model, the condition expression can be simple or compound, and it is related to one or more Networking Context fragments, which belong to one of the following categories: *host connectivity*, *host location*, or *host activity*. Additionally, actions (i.e. operations) target one of the following processes: *handover decision*, *handover execution*, or *handover adaptation*.

4.3 Specification and evaluation

Within each context only a subset of the overall policies of the model needs to be specified, moreover, only a small subset of the specified policies needs to be evaluated under certain circumstances which in turn reduces the complexity dramatically. This argument follows the principle that

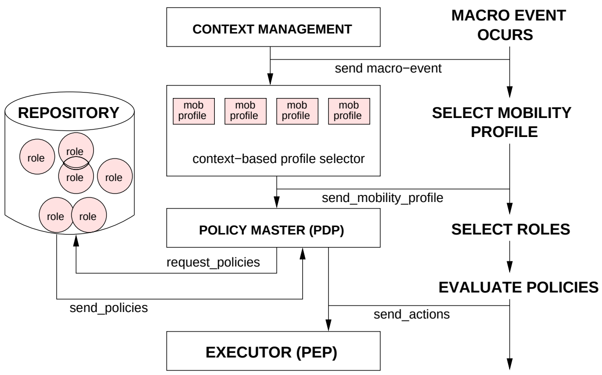

Figure 3. To minimise complexity, PROTON groups policies into roles that are then selected according to mobility profiles.

not all context fragments are important in every scenario. In praxis, policies are grouped in to *roles* such as "upward handover", and then associated to a *mobility-profile*, for example "in-building profile", which is selected due to the occurrence of a *macro-event* (e.g. velocity is 3mph). This process is shown in figure 3.

4.4 Scenario: 4G integrated services

Suppose a 4G system where a 4G mobile user, connects to different RANs. S(he) simultaneously accesses the following networks: *satellite GPS* (to track his location), *WLAN* (to receive video/audio from the closest restaurant), and *GSM* to reserve a table (using SMS) and ring some friends. In this scenario, PROTON-enabled device applies policies, according to current context and mobility profiles, to optimise network usage and maximise user experience.

5 Related Work

Helen J. Wang [9] first showed policy-enabled handovers. However, these policies focus exclusively in the decision making process. She argued that complete mobility assistance would be suboptimal and far too complex considering the environment dynamics. Nevertheless, we sustain that by using the correct data and policy model, we can provide support during the entire vertical handover process and still offer a light weight solution.

MosquitoNet [6] also addresses handover policy issues. This project was focused on choosing the most desirable packet delivery path based on the characteristics of the traffic flow. Instead, PROTON represents a complete support solution for 4G mobility management.

More recent work also considers policy-based handover decisions. POLIMAND [2] shows a policy model for Mobile IP based handovers that uses link layer parameters to assist roaming hosts. However, this policy model is too simple. In contrast, PROTON explores the concept of incorporating Networking Context and building a richer policy model to deal with 4G complexities.

6 Conclusion and Ongoing Work

We presented PROTON, a policy-based solution for 4G mobile devices. This solution tackles three main challenges in future communication systems: decision, execution, and adaptation processes. PROTON stems from the fact that flexibility and adaptiveness will be demanded in future environments, and hard-coded handover algorithms will no longer be enough. Our ongoing work involves a full implementation of PROTON and its evaluation using our testbed.

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