A Policy Management System for Ambient Networks

K. Jean and A. Galis, {kjean, agalis}@ee.ucl.ac.uk,

Department of Electronic Engineering, University College London

Abstract: The dynamicity and heterogeneity of Ambient Networks necessitate a new dynamic, distributed policy management system. Existing policy management systems do not provide the required support for mobility, dynamicity and heterogeneity and are thus inadequate. This paper outlines the requirements, architecture and components for a new distributed policy management system for Ambient Networks. It is a multi-level management system that adapts dynamically to changes in network conditions. The use of distributed hash tables for system wide policy storage further enhances its flexibility and ability to cope with constantly changing network conditions.

1 Introduction

The efficient management of any network is a challenging and daunting affair. This is exacerbated by networks, which are dynamic, heterogeneous and mobile. Networks beyond 3G will be characterised by many of these attributes while providing a plethora of service offerings. They will support a much wider range of communication scenarios beyond existing fixed, mobile and WiFi offerings. The EU-IST Ambient Networks (AN) project [5] focuses on the development of novel networking concepts and systems to support such networks. Given the dynamic and heterogeneous nature of ANs, one of the major challenges is to develop a flexible management system – one that is capable of setting network rules for network, service, context, security, QoS, configuration and mobility management. Policy-based network management provides a means by which network management can be simplified and largely automated. Policies have the ability to dynamically change a system's goals and configuration rules without software recompilation to respond to rapidly changing network conditions. Hence, it can provide a flexible and dynamic network management system for ANs. This paper presents such a system. It explores how a dynamic multi-layer policy management system can meet the policy management needs of Ambient Networks (AN) – needs not satisfied by existing policy management frameworks. This paper begins with an introduction to Ambient Networks and policy-based management. The policy-based management requirements for AN are then detailed. The paper continues with the presentation of the policy system and finishes with the conclusions and future work.

2 Ambient Networks and Policy Management

2.1 Ambient Networks

The Ambient Networks project [7] addresses the creation of innovative network solutions for future mobile and wireless systems. To foster the co-operation between heterogeneous networks, it introduced the concept of network composition/decomposition [8]. Network composition entails the merging of networks to share resources and services while the converse is true for network decomposition. The main feature of an Ambient Network (AN) is an Ambient Control Space (ACS). It is a control plane overlay consisting of a number of functional entities (FEs) that cooperate to implement the overall control functionality. The functional entities are management components responsible for different aspects of network management and include those responsible for composition, network, context, policy and mobility management.

For flexible dynamic management, ANs need a policy management system that enable the storage of, as well as the dynamic changing of rules defining the behaviour of an Ambient Network. This policy system must be distributed to efficiently manage Ambient Networks. It must also be able to efficiently deal with network composition and decomposition. Policies must be technology independent describing high-level system goals which can be translated into low-level configuration rules.

2.2 Policy-based Management

Policies can take many forms. Examples include conditional rules (e.g. if conditions then actions), event-condition-action rules or access control policies [1]. Policies can be simply expressed as a sequence of rules. Policy-based networking provides a degree of network management automation, by linking actions in the network to system-events. Policies permit adaptation of network behaviour

without any modification of the software implementation. Policies introduce network management flexibility as they seek to control network behaviour using sets of high level rules.

The IETF [2][3][4] define a policy-based management framework which consists of Policy Decision Points (PDP), Policy Enforcement Points (PEP), a Policy Repository (PR) and a Policy Management Tool (PMT). The PDP is responsible for determining when the conditions stated in the policies have been satisfied. It communicates these decisions to the PEP, which then enforce the actions contained in the policies. The PMT is used to edit and administer the policies which are stored in the PR.

2.3 Need and Requirements for a New Policy System for Ambient Networks

The frameworks defined by the IETF [2][3][4] are focused on solving network management problems typical of fixed and homogeneous networks. They typically translate business rules or agreements into network management rules and apply them in a static environment. These frameworks were not designed for networks like Ambient Networks as they lack support for dynamicity, mobility and heterogeneity. Requirements like programmability, composition, scalability, fault tolerance and load balancing necessitate a new policy management approach: dynamic policies and a dynamic policy management infrastructure. The main requirements are [6]:

- A common policy system which integrates policies from different functional elements for service, network and context management.
- Policy agents including programmable Policy Enforcement Points (PEP), Policy Decision Points (PDP) for evaluation and Policy Negotiation Points (PNP) for negotiation.
- A Policy Repository (PR) enhanced with policy selection mechanisms, a policy storage/retrieval API and a policy editor.
- A Policy Decision Mechanism for consistency checking of policies during composition and for dynamic conflict checking.
- A run-time policy refinement process from high-level (goals) to low-level (configuration rules) including low-level refinement for the sake of consistency and conflict resolution.
- The AN policy system should be easily integrated with peer-to-peer frameworks.

3 A Policy Management System for Ambient Network

To deal with the complexity and dynamicity of Ambient Networks and satisfy the requirements for AN policy-based network management (AN PMS), a multi-level distributed policy system is proposed. This policy management system resides on top of a peer-to-peer management framework.

3.1 A Multi-Level Hierarchy

A multi-level hierarchical policy-based management system consists of policies and policy agents at several levels in a hierarchy much like the DNS system. The simplest form is a two-level one, which consists of two levels 0f policies and two levels of policy agents and is presented here. However, it can easily be extended hierarchically to any number of levels. The two types of policies are the peer policies and AN policies. Peer policies are node specific, reside on one peer and only manage this peer. Ambient Network policies manage the entire AN and specific nodes to define AN-wide behaviour. These policies consist of aggregated sets of policy rules of the individual peers that are distributed throughout the AN. The AN policy is used whenever the AN is required to present itself as a single entity from the policy perspective, e.g., during policy negotiation between a peer and an AN to determine whether the peer joins the AN. The AN policy is distributed across the AN using a distributed hash table (DHT). Each peer contains certain AN rules that when combined create the AN policies. During composition these rules are merged to create the AN policies while during decomposition the rules belonging to the peers that are leaving are removed to leave only those from the peers that are currently in the Ambient Network. This allows the dynamic updating of the AN policies to cope with constant churn and dynamic network conditions in Ambient Networks.

A collection of policy agents on two levels manage all the nodes in an Ambient Network. Policy agents consist of policy managers, policy decision points, policy enforcement points, policy repositories and policy negotiation points. On each node there could also be a policy definition tool but that is not necessary. These policy components are responsible for the creation, storage, processing and management of policies. Furthermore, they perform network and node monitoring and evaluation and policy action enforcement. At the higher level, the super peer agents, use the AN policies to manage network-wide aspects of the AN while also using peer policies to manage the node on which they reside. Super peer policy agents react to network status changes on an AN-wide level by automatically reconfiguring the network as needed to deal with fault and performance problems. At the lower level, peer policy agents use the peer policies to manage the node on which they reside by performing local policy controlled configuration, monitoring and reporting. Peer agents become super peer agents when the node on which it resides, becomes a super peer.

3.2 AN Policy Components

Figure 1 details the components of the AN PMS. They are:

- Policy Manager – receive the policies to be loaded into the system from the policy definition tool. It processes the policies and sends the rules to the policy evaluation points for condition evaluation and actions to the policy enforcement points.
- Policy Decision Points (PDPs) – are responsible for the policy evaluation process. It consists of a decision monitoring component (DMC) and a condition evaluator (CE). The CE monitors policy condition variables while the DMC decide when these policy conditions are satisfied.
- Programmable Policy Enforcement Points (PEPs) – enforce the policy actions as specified in the policies. They can be dynamically updated using programmable network techniques.
- Policy Negotiation Points (PNPs) –negotiate which policy rules from peers are included in the AN policy during composition and determines which ones are removed during decomposition.
- Policy Repository (PR) – stores the policies in a node and contains the AN policy DHT nodes. It also contains a policy retrieval API and a policy schema.

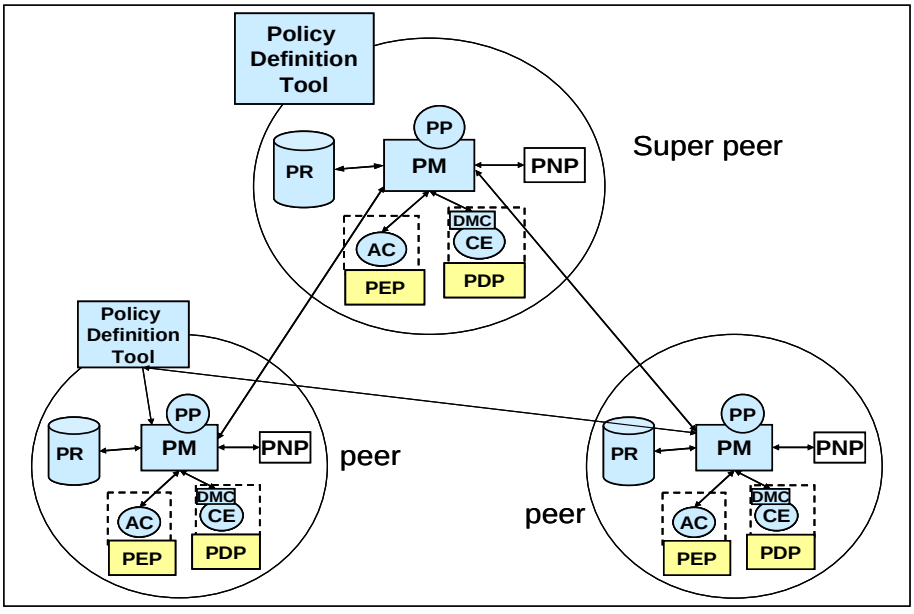

Figure 1: Diagram showing the components of the AN Policy-based Management System

4 Role of DHTs

Distributed hash tables (DHTs) are scalable, decentralized storage systems that map a set of keys among participating nodes to certain stored values or data [10]. Due to a DHT's ability to deal with constant churn (the constant joining and leaving of a network by nodes [11]), (de)composition [13]

and its scalability, it is used as the storage medium for AN policies. Each AN contains a AN policy DHT which stores the policy rules that each peer contributes to form the AN policies. In each policy repository of an AN network node, a certain section contains these particular policy rules. It is these components that create the AN policy DHT. The super peer in each AN becomes the gateway in the AN policy DHT. Through this gateway, the network nodes in the AN join the AN policy DHT as they join the AN network and they become DHT nodes. When policy negotiations are complete the AN policy rules in each node become part of the AN policy DHT. When an AN network node drops out of the AN, the policy rules that it contributed are then removed from the AN policy DHT. The use of DHTs for AN policy storage is particularly useful during composition and decomposition. The AN policy DHTs merge and demerge during composition and decomposition respectively. Details of the composition and decomposition of DHTs in Ambient Networks can be found in [13].

5 Conclusions and Future Work

The dynamicity, heterogeneity and composability of Ambient Networks necessitate a new dynamic, distributed policy management system. This AN PMS is a multi-layer system consisting of two tiers of policies and policy agents. This paper has outlined the requirements for such a system as well as the overall system architecture and components. The AN PMS adapts dynamically to changes in network conditions. The use of programmable components and DHTs further enhance its flexibility and ability to cope with dynamic network conditions. Future work entails the implementation of the AN PMS, its testing and evaluation as well as its integration in the overall Ambient Network management architecture. Further refinement of the AN PMS includes the inclusion of stronger policy conflict resolution and the inclusion of a security framework.

References

[1] G. Stone, B. Lundy and G. Xie, “Network Policy Languages: A Survey and a New Approach,” IEEE Network, Jan- Feb 2001.

[2] IETF Policy Framework, www.ietf.org/html.charters/OLD/policy-charter.html

[3] R. Yavatkar, D. Pendarakis and R. Guerin, “A Framework for Policy Based Admission Control,” RFC 2753, IETF, Jan 2000.

[4] B. Moore et al., “Policy Core Information Model”, RFC 3060, IETF, Feb 2001.

[5] N. Niebert et al., “Ambient Networks: An Architecture for Communication Networks Beyond 3G”, IEEE Wireless Communications, April 2004.

[6] K. Jean, B. Ohlman, A. Galis, I. Herwono, J. Nielsen, “Requirements for Policy Framework for Ambient Networks,” Wireless World Research Forum, WWRF16 26-28 April 2006, Shanghai; China.

[7] IST project 507134 Ambient Networks, http://www.ambient-networks.org.

[8] F. Pittmann, et al., “Ambient Networking: Concepts and Architecture”, IST-2002-507134-AN/WP1/D08, Ambient Network Project, 2005.

[9] H. Abramovich et al, “AN Framework Architecture”, IST-2002-507134-AN/WP1-D05, Ambient Network Project, 2005.

[10] DHT Wikipedia definition, http://en.wikipedia.org/wiki/Distributed_hash_table.

[11] A. Rowstron and P. Druschel, “Pastry: Scalable, decentralized object location, and routing for large-scale peer-to-peer systems,” Lecture Notes in Computer Science, vol. 2218, pp. 329–350, Springer 2001.

[12] P. Ganesan and G. S. Manku, “Optimal routing in Chord,” in the Proceedings of the Fifteenth Annual ACM-SIAM Symposium on Discrete Algorithms, (SODA 2004), J. Ian Munro (eds.), New Orleans, Louisiana, USA, Jan, 2004.

[13] L. Cheng et al, “Distributed Hash Tables Composition and Decomposition in Ambient Networks,” submitted to the 17th IFIP/IEEE International Workshop on Distributed Systems, DSOM 2006 Dublin, Ireland, Oct. 2006.