A Policy Based Context-aware Service for Next Generation Networks

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Abstract: *The convergence of wired and wireless network services is one of the driving forces behind next generation networks (NGN). These integrated services should be context-aware in order to automatically adapt themselves to the changing environment. Context can be defined as any information, obtained either explicitly or implicitly, that can be used to characterise one certain aspect of an entity involved in a specific application or network service. A context-aware service is one that uses such context for service provision. This paper proposes a policy based context-aware service methodology for next generation networks. A thorough consistency is expected to be achieved by this policy method where policies are well planned to run from context representation through services down to the underlying networks. A context-aware service scenario called the Super-mother is presented to exemplify this methodology based on the policy-based context-aware service system architecture. This paper presents work in an ongoing European Union IST project CONTEXT.*

1. BACKGROUND AND RATIONALE

The convergence of both fixed networks and wireless networks has attracted much research aiming to bring together the high speed of wired networks and the wider coverage of wireless networks (typically represented by GPRS/UMTS). As the hardware and protocols of wireless networks get mature, the demands from higher-level applications and services in integrated networks are rapidly growing, especially when wireless LAN (WLAN) technology becomes increasingly popular for providing IP connectivity and 3G is undergoing deployment stage. This paper tends to contribute to this literature from the services perspective by introducing the idea of context-awareness to the integrated services operating on next generation networks.

Context refers to the physical and social situation in which computational devices are embedded [1]. A c*ontext-aware service* (CAS) can be more flexible and autonomous so as to respond accordingly to the highly changing computational environments. For example, a mobile phone will vibrate rather than ring during a meeting, if the system knows the location of the mobile phone and the meeting schedule. While most of the research on context-aware computing focuses mainly on the human-computer interface (HCI) [1, 2], this paper tends to tackle context awareness from the perspective of networks, i.e., *network-centric* context-aware services. To facilitate the provision of context-aware services, both an appropriate infrastructure to gather, manage, and disseminate contextual information and the design and development of a context model are required. Policies are ideal for context modelling as they easily facilitate the implementation of context-aware services in the underlying networks where policy-based network management (PBNM) is widely regarded as a promising means. PBNM technology can relieve the network administrator of the burden of configuring every single device manually and it is more flexible since network elements can be reconfigured by just producing or changing policies [3, 4]. The policy-based method is well suited as context is usually complex, changing and layered.

This paper is structured as follows. After the scenario description in section 2, section 3 defines and classifies context and describes the policy specification. Then the policy-based context modelling and the context aware service (CAS) system architecture are presented in Section 4 and 5 respectively. Section 6 presents the service implementation with the conclusions and future work in section 7.

2. SCENARIO DESCRIPTION

A typical network-centric context-aware service called *TEANU* (Transparent Enterprise Access for Nomadic User) is described. Consider Katherine, a middle class graphic designer with 3 kids. Katherine works from home a few days a week, using her home network that is connected to her office network. On the due date of the project, Peter, her 9 year old son, fell ill and had to be brought to the hospital. The taxi that is taking them to the hospital is stuck in traffic and upon finishing her project she tries to send her work to the office, using her laptop and a GPRS mobile phone. Unfortunately, the bandwidth of the mobile network is insufficient, and transferring the 5GB file will take about 20 hours, far passing the deadline. However, she had subscribed to this new *TEANU* service that allows transparent roaming between GPRS and WLAN networks. When she arrives at the hospital the *TEANU* service found out that there was an appropriate wireless LAN (WLAN) network in the hospital. It dynamically switched the network connection to this faster wireless network and her work was submitted successfully before the deadline. This scenario is called the S*uper-mother* scenario and will be used throughout the paper for exemplifying this policy based CAS over the NGN.

3. REQUIREMENTS ANALYSIS

3.1. Context Definition

Schilit *et al*, [1] refer to context as location, identities of nearby people and objects, and changes to those objects. They claim that the important aspects of context are: *where you are, who you are with, and what resources are nearby*. The following definition for context will be used:

Context is any information, obtained either explicitly or implicitly, that can be used to characterise a certain aspect of an entity involved in a ***specific*** *application or* ***network service****. An entity can be a physical object such as a person, a place, a router, a 3G network gateway, a physical link, or a virtual object such as IPsec tunnel, SNMP agent.*

3.2. Classification of Context

Previous definitions of context seed our development of context types. Dey [2, 6] proposed, *location*, *identity*, *environment time*, and *activity* as basic context types for characterising the situation of a particular context entity, as depicted in **Figure 1**. This context classification clearly answers the questions of who (*Identity*), where (*Location*), when (*Time*), and what (*Activity*) for a specific context entity (*ContextEntity*). Furthermore, an object-oriented design of these context types can also be considered. As far as network-related context information is concerned, its categories follow the logically hierarchical structure of network as depicted in **Figure 2**.

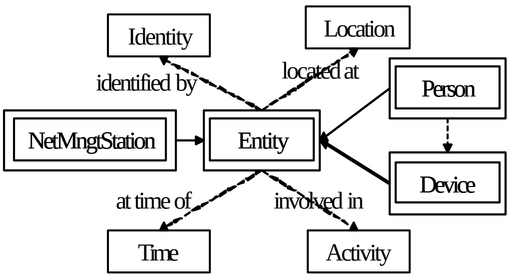

Figure 1: Classification of Context in term of Entity

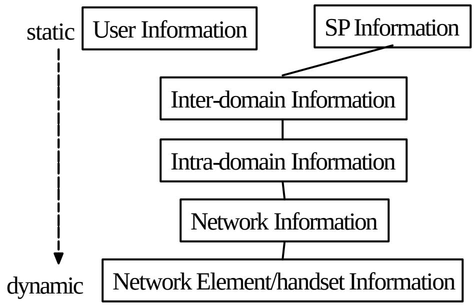

Figure 2: Network-centric Context Information Hierarchy

3.3. Policy Specification

Here policy specification language is a kind of high-level English-like declarative language used by an administrator to add and update management policies. As suggested by the Internet Engineering Task Force (IETF) Policy Framework Working Group [4], policies take the following rule-based format:

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IF {condition(s)} THEN {action(s)}
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It means *action(s)* is/are taken if the corresponding *condition(s)* is/are true. A typical context-aware service scenario can be represented by the following policy, which forces a mobile handset to vibrate rather than ring during meeting time.

IF (location == meetingRoom) and (time within meetingSchedule) THEN MobileVibrateOnly

By this means, any policies related to the context-aware services can be defined.

4. POLICY-BASED CONTEXT MODELLING

4.1. Context Modelling and its Related Work

Context modelling addresses the issue of how to represent the contextual information in a way that can help bridge the gap between the application that uses context information and the deployment of the context-aware service. Schilit in his PhD thesis [8] used a simple model with context being maintained by a set of environment variables. The context model proposed is a network-centric one and thus has the ability to take into account the main underlying network implementation technology, i.e., policy-based network management. Therefore a concrete object oriented context modelling is presented.

4.2. Policy-based Context Information Model

The policy-based context information model is designed based on the IETF PCIM (Policy Core Information Model) and its extensions [9]. **Figure 3** depicts part of the inheritance hierarchy of our information model representing context in a network-centric CAS. It also indicates its relationships to IETF PCIM and PCIM extensions (PCIMe). Context rooting from *ContextVariable* is mainly reflected in this figure as some elements are not shown due to space limitation.

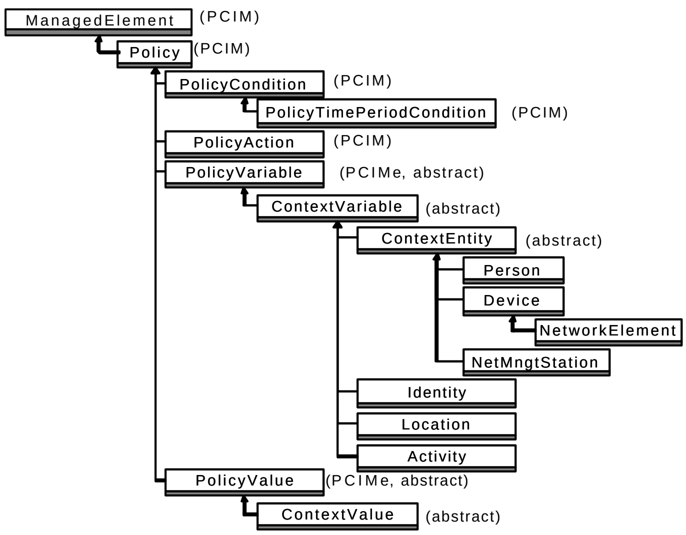

Figure 3: Class Inheritance Hierarchy in the Context Information Model

Context information is expressed in the policy conditions in the form of elementary Boolean expressions of the form: <*Context Variable*> *MATCH* <*Context Value*>. Therefore, the modelling of context information starts from *ContextVariable* and *ContextValue*. As discussed in the classification of context, every context entity should at least be described by four basic features, i.e., identity, location, activity and time. The first three of them are modelled in this class hierarchy as shown in **Figure 3**. The time feature of context can be directly expressed by *PolicyTimePeriodCondition* which is available as a direct child of *PolicyCondition* in the IETF PCIM. Network elements play a vital role in CAS providing and as such, *NetworkElement* class is defined explicitly as a child of *Device* class. Network management station (*NetMngtStation*), which maintains intra/inter-domain information, is defined as a kind of entity that has all the four basic context types. *ContextValue* is used for modelling context values and constants used in context-related policy conditions.

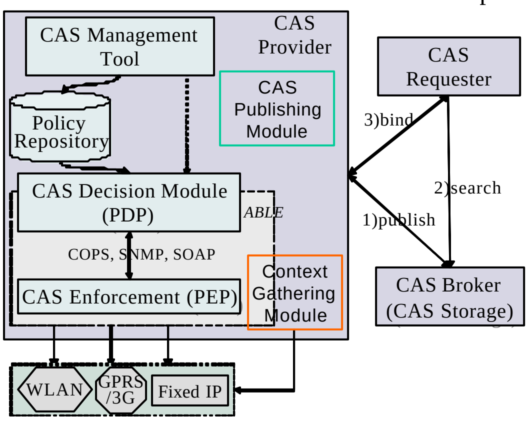

Figure 4: Policy-based Active CAS System Architecture.

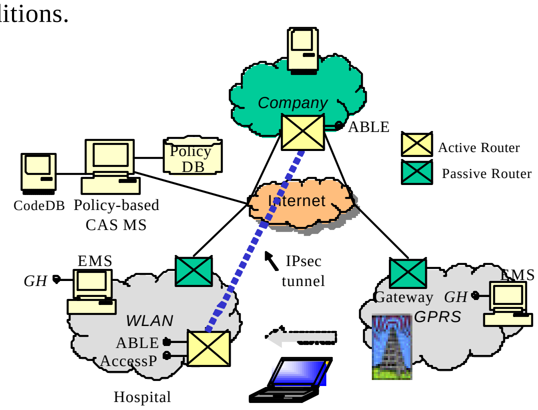

Figure 5: Test-bed for TEANU Super-mother scenario.

5. POLICY-BASED SYSTEM ARCHITECTURE

A policy-based active CAS system architecture, as depicted in **Figure 4**, has been designed. Its components are organized in terms of the PBNM structure as proposed by IETF Policy Framework Group. The PBNM system for the CAS management mainly includes four components: policy management tool, policy repository, Policy Decision Point (PDP) and Policy Enforcement Point (PEP). The policy management tool serves as a policy creation environment for the administrator to define/edit/view policies in a high-level declarative language. After validation, new or updated policies are translated into a kind of object oriented representation and stored in the policy repository. Once the new or updated policy is stored, the corresponding PDP retrieves the policy and enforces it on the PEP.

After a CAS is mature for deployment, the CASP can publish it to the CAS storage, so that it can be searched for by any CAS requester like Katharine. Active networks technology is explored in this architecture as an enabling tool for fast and flexible service delivery. The active node, the core of the active network, is based on *DINA*. *DINA* [10] is an active network platform that allows the efficient programming of network nodes and function provisioning on the fly.

6. IMPLEMENTATION

The test-bed for implementing the context-aware integrated service *Super-mother* scenario is depicted in

Figure 5. Its function is to simulate the scenario which begins from the point when Katharine enters into the hospital where WLAN is available and ends at the point when the data from the Katharine's laptop begins to transport data through an IPsec tunnel between the hospital WLAN Access Point and ingress router of her office network. A policy-based CAS Management Station (MS), belonging to the Context-Aware Service Provider (CASP), is used by the service administrator to manage context information, services and networks. EMS (Element Management Station) is introduced for the management of the *DINA* execution environment, access point, etc.

The workflow of this *super-mother* scenario is as follow:

1. When the customer subscribes, she provides the CASP with her WLAN card MAC address. The MAC addresses are sent to all access points (AP) that are involved in this CAS.
2. The location sensor (AP in this case) serving as the PEP sends a signal to the CASP if Katharine enters into the scope of AP.
3. Based on the policies in CAS management system and the relevant context information, the CAS Decision Module decides which policies to be sent to the WLAN domain.
4. After policies arrive at the EMS, it begins to configure the access control table of the AP to allow Katharine to get access to the AP. Then Katharine's uploading traffic will be automatically switched from GPRS connection to WLAN connection.
5. The destination address of Katherine's packets is noted. Based on the security policy, an IPsec VPN is set up between the hospital and her office.
6. This is done through active packets sent to the gateway machine in WLAN domain and to the ingress router of the office. Then Katherine's traffic goes through this secure tunnel.

7. CONCLUSIONS AND FUTURE WORK

This paper provides a policy based context-aware service over NGN. This CAS can adapt itself to the complex and changing environment dynamically according to the policies resulting from the Service Level Agreement (SLA) and rules set by the network administrator. This paper also contributes to the current literature of context-aware computing research by extending it from the traditional human computer interface field to the network and service provisioning and management field. Based on the context model and CAS system architecture, a concrete context-aware service scenario *Super-mother* has demonstrated the applicability of the policy methodology for context-aware services over next generation networks. Further refinement of policy-based context model, as well as testing and validation is the main future work.

8. REFERENCES

[1] B. Schilit, M. Theimer. "Disseminating Active Map Information to Mobile Hosts". *IEEE Network*, 8(5): 22-32, 1994.

[2] A. K. Dey and G. D. Abowd. "Towards a better understanding of context and contextawareness". Proceedings of Workshop on the What, Who, Where, When and How of Context-Awareness, April, 2000.

[3] M. Sloman. "Policy Driven Management For Distributed Systems," *Journal of Network and System Management*, vol. 2, no. 4, Dec. 1994, pp. 333–60.

[4] IETF Policy Framework Working Group web page: http://www.ietf.org/html.charters/policy-charter.html

[5] M. Ebling, G.D.H. Hunt and H. Lei. "Issues of Context Services for Pervasive Computing". *Proceedings of Workshop on Middleware for Mobile Computing*, Heidelberg, Germany, 2001.

[6] A. K. Dey. "Providing Architectural Support for Building Context-Aware Applications". PhD thesis, Georgia Institute of Technology, November 2000.

[7] J. Jason. IPsec Configuration Policy Model. IETF draft, Aug., 2002

[8] B.N., Schilit. *A Context-Aware System Architecture for Mobile Distributed Computing*, PhD thesis, 1995.

[9] B. Moore. "Policy Core Information Model Extensions". IETF-RFC 3460, IETF Policy Framework Working Group, Jan. 2003.

[10] D. Raz and Y. Shavitt. “Active Networks for Efficient Distributed Network Management”. *IEEE Communications Magazine*, 38(3):138-143, March 2000.