Policy-Based Context Integration & Ontologies in Autonomic Applications to Facilitate the Information Interoperability in NGN

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Abstract

Next generation networks promise new user-centric applications and services. This requires more than a combination of diverse technologies – it requires new functionality. Context-awareness is one example of new functionality, and refers to the set of characteristics and behaviour that make a system aware of its user’s state and the state of the network environment. This paper first surveys several research challenges from the next generation networks supporting services, and then introduces the policy-based paradigm for cross-layered service management interoperability in autonomic computing environments integrating context information in the management operations of pervasive services. A novel policy-based context model is then defined that is suitable for managing services in cross-layered environments using the DEN-ng information model and ontologies. This model extends the functionality of previous solutions for managing context-aware services. Finally a representative Internet and Broadcasting Systems Convergence application scenario inspired by seamless mobility is presented for providing insight on future directions and applications in both the cross-layer interoperability of the systems and NGN area.

1. Introduction

Cross-layer interaction involves both the transmission capabilities of the devices and the elementary services of the middleware environment. Transmission capabilities influence the performance of the network, their impact on the design of new protocols, and the adaptation of existing protocols needs to be studied by modelling and/or simulation of systems. Middleware development impacts the design of interfaces for achieving the interoperability necessary in services over next generation networks (NGN). Cross-layer refers to the joint operation of the physical, link, management and service layers, while context-awareness in NGN refers to the properties that make a system aware of its user’s state and the state of the network environment. This awareness helps the system to adapt its behaviour (e.g., the services and resources that it offers at any one particular time) according to desired business rules, all the while offering interoperable and scalable personalised services. This is also known as context-aware services (CAS) or context-aware applications.

Currently, there are many initiatives that are breaking the current models of how fixed and mobile networks operate and provide services for consumers. Examples exist in standards regarding next generation networks, the public documents to argue research activity are available in [1]-[4] as well as in the industry [5]-[9]. These efforts try to move from a world where the networks are designed and optimised around a specific technology, service, and/or device towards a world in which the user is at the centre of his/her communications universe. In this new world, resources and services become network and device agnostic. In other words, NGN services are no longer device-, network-, and/or vendor-centric as current services are – they now become user-centric.

NGN services require formal, extensible, information model(s) that meet the service management requirements identified in [1]-[9]. This is because a “network Esperanto” does not exist. Rather, different network devices have different programming languages and largely incompatible languages used to express commands and data. Even standards, such as the Simple Network Management Protocol (SNMP) [10], have failed in standardising most of the key information required for management interoperability. This is because there is no fundamental business incentive for device vendors to rebuild how their devices work. Hence, NGN and services will be harder to manage than current applications and services, since NGN applications and services are built from and supported by diverse networks and technologies. As shown in Figure 1, this causes the control plane to be made up of different types of dissimilar control functions. Therefore, a management plane is needed that will coordinate the different types of control planes, ensuring that each network and device plays its part in delivering an end-to-end service.

In NGN services, context-awareness – changes in the business goals (service’s context) and changes in the resource environment (resource’s context) – plays the important role of enabling the management plane to adapt the services and resources that it is offering to the changing demands of the user, as well as adapt to changing environmental conditions, thus helping to manage business, system, and behavioural complexity [11]. Context information is complex, dynamic and heterogeneous. In fact, users as well as devices can have different forms of context, and support multiple “profiles” that express their needs, presence, and other contextual information. Therefore, the efficient handling and distributing of context data and knowledge to support context-awareness
is an important problem. The multiple advantages derived from modelling context [12] have attracted much attention for developing context-aware systems, generating diverse approaches. Nevertheless, most research has focused on realising application-specific context-aware services. Such application-specific uses of context are rarely portable and usable by other applications or services. This adversely impacts the management of NGN services, and makes cross layer interoperability harder to achieve.

Policy based management has proven useful for network management. Several initiatives have used policy management approaches to tackle the problem of fast and customisable service delivery, including OPES [13] and E-Services [14]. In this paper, we go one step further and promote the use of the policy-based paradigm for governing the managed environment by taking into account context information. This enables the lifecycle of NGN services and resources to be better and more efficiently managed. For example, by using context changes to alter the current working set of policies, different behaviour is realised. This requires a network management “lingua franca” – a common set of terminology and definitions upon which management decisions can be made. We use the DEN-ng information model [15][16] as this network lingua franca. The DEN-ng model takes into account variation in context information by representing context changes as changes that affect the state of a managed entity, and relates these variations to changes in the management, operation and performance of services and resources.

This approach is also being used for the investigation of autonomic computing [15][17]. The synergy obtained from autonomic computing, which also uses the policy-based paradigm, and the NGN work cited above, requires the definition of a new, extensible, and scalable knowledge platform that can address cross layer interoperability, which is another innovative aspect of our ongoing research work. This paper integrates enhances the existing DEN-ng context-aware policy model by using the following approaches: markup schemas, graphical models, object-oriented models, and ontology models. This enables the management of context-aware services in an extensible, scalable, fashion. A novel model-driven approach is realised: context information is used to determine the set of policies (and hence functionality) provided at any given time.

This paper is structured as follows. In Section 2, we present the user’s requirements as well as NGNs demands on the context information that is used to support pervasive services those requirement will support the research work in next sections. Section 3 presents the DEN-ng policy-based model, followed by a high-level information architecture that describes service management in cross layer environments over next generation networks, and the review of earlier work in representation task. Section 4 presents a scenario intended to depict the information interoperability necessary to support pervasive services and show the business opportunities and advantages in the convergence of Internet and Broadcasting Systems in NGN, highlighting the importance of the research work towards the cross layer interoperability of the systems in autonomic communications. Finally, Section 5 presents conclusions and future research work.

2. Services Requirements & Context Integration

2.1 User’s Requirements for Context-Aware Services

This section describes the envisaged requirements for context-aware services from each of the parties involved in the service value-chain. We survey what benefits can be obtained for each of these operators with the introduction of context information models that represent the effective functionality of context-aware services (CAS) in a vendor- and technology-neutral format. This section refers to work done in the EU-IST Context project and EMANICS Research Network; the public documentation that defines the state of the art of context-aware services in the pervasive computing knowledge area is available in [18] and [19], respectively.

End-User Requirements
- Cheap end-user devices while providing new functionality.
- Device manufacturer independence.
- Selection from an extensive range of new services.
- Personalised/Smarter Services

Service Providers Requirements
- Personalised services allowing customisation of respective service portfolios.
- Significant technological and operational savings as result of standardisation of context information models.
- Significant added revenue from context-aware services.

Content Providers Requirements
- Exploitation of context information resulting from common platforms using standardised context information models.
- Flexible entering of partnerships facilitated through standardised context information models.
- The freedom to use any particular service provider for the advertising and providing of content.

Network Providers Requirements
- Significant technological and operational savings by using standardised context information models.
- Common equipment requirements and support for CAS based on standard context information models.
- New business opportunities that result from context-aware services.
2.2 Challenges to Support Pervasive Services in NGN

Modern IT systems are driven by the context information that they use to adapt, modify and change the services operation and management offered by their organisations. This is called context-awareness, which necessitates the definition of a variety of information required to operate services in next generation networks.

Multiple different NGN scenarios are typified by complex and distributed applications, which in terms of implementation and resources deployment, represent a high management cost. In addition, this creates technology-specific dependencies, which in turn make integration almost impossible.

This section defines the properties of context-aware services that describe how management systems use context information for cross layer environments in next generation networks to facilitate information interoperability.

Figure 2 shows the context-aware requirements for supporting services, their relationships, and the level of influence between the properties that enable the advantages of using context information to be realised by management systems. This figure depicts the level of influence of next generation network requirements supporting context-aware services, and how those are related with the service and network views, respectively.

This section surveys the envisaged requirements for NGNs supporting context-aware services. Those requirements are related to management systems supporting services and using context information. The requirements are related to the scalability and automation of the systems. These properties will produce increased extensibility and flexibility, as well as produce attendant network and service management cost reductions. They also demand implementation advantages for services as follows.

**Scalability**
- High levels of scalability due to the inherent necessity to represent diverse types of context information within multiple services.
- The necessity to extend context information to other platforms supporting different services.
- Solutions that scale according number of users and services in acquiring and filtering context information.

**Extensibility**
- The extensibility as a property necessary to support services using different technologies.
- Multiple technologies with different platforms and languages using the context information.

**Automation**
- Mechanisms for automatic service creation, operation and management of the information and services.
- Reduce as much as possible the need of any human intervention to manage services.
- Software solutions for supporting self-* operations in terms of diverse user-centred services.

**Flexibility**
- The capability for adapting the service lifecycle management operations to market and user needs.
- The necessary abstraction mechanisms to represent the underlying network services and networks.
- Middleware solutions that enable business goals to determine context-specific network services and resources.

**Integration**
- Adaptation for new technologies supporting context-aware services from different providers with different implementation mechanisms.
- Low level service interactions to reduce time-slots and guarantee the service integration.
- Full-integration with systems that are not designed under the perspective of reuse and exchange information.

**Independence**
- Service Providers need independence from equipment manufacturers promoting the interoperability of the context information for supporting services.
- Support for multiple management and operations languages.

**Management Cost**
- Reduce the management cost by lowering the number of skilled resources for management.
- Reduction of traffic and data signalling.

2.3 Analysis and Outlook

The inherent necessity to increase the functionality of the networks by supporting context-aware service requirements, such as interoperability of data, voice and multimedia contents using the same network, sets the basis for a new challenge: the necessity to integrate context information in the management operations of these services, as opposed to “just” using context to express the state of users and services.

We aim to use this knowledge to create an extensible information model, based on the approach of DEN-ng. This initiative creates the basis to find the best way to integrate context information into service management operations using formal mechanisms such as ontologies; it also is used to propose extensions for the support of autonomic seamless mobility scenarios.
We studied the main requirements that users and NGNs have as specified by the ITU-T, and derived the need to create an information model that can efficiently manage different types of context information. Specifically, we need to integrate context information into network management operations to better represent business goals. Such management operations are independent from the service itself, meaning that the variation in operation and content of network services are “reflected” in service operations as a result of events that can modify - using policies as the orchestration mechanism - the state of the network. Hence, policy-based management, when merged with context data, can be used to provide self-management of the systems and the services that they support.

The common factor in the service and NGN requirements is the necessity to integrate context information into the management operations, and then endow those services and networks with the information necessary to modify the service lifecycle operations according to business goals and network conditions following autonomic principles. We use formal mechanisms for representing and sharing information, such as ontologies, and as such propose an ontology for the DEN-ng model that we call DENON-ng.

We propose to verify the scope of the model based on the previous description of context-aware services and next generation networks requirements by integrating context information in the management operations using DENON-ng. We then extend this proposal to autonomic seamless applications by using the FOCALE architecture.

3. Policy-Based Model & Services Management

This section presents research activity on the policy-based model and representation of policy-based approaches for context modelling following the requirements presented in the previous section. It also describes an architecture and the formal language that helps to support the functionality of the policy model for managing services over next generation networks (NGNs) for supporting cross layer information interoperability.

3.1 DEN-ng Policy Model

The promises of Policy Based Management (PBM) are varied and today demonstrated as suitable for supporting network operations and services. These promises are often conceptualised as a single, simple means to control the network. In particular, their ability to hide vendor-specific interfaces is very important. Without this ability, a common interface to programming the same function in different network devices cannot be accomplished.

The most of approaches to management and configure networks lack in the capacity for achieving new business goals and technical objectives, as they can not to process network services as a part of the business operations. Furthermore this conditions avoid new business roles can modify the systems in terms to adapting demands of dynamic and changing user needs and environmental conditions. A typical example is understood when traditional management protocols are unable to express business rules, policies and processes in a standard form (we refer to SNMP or CLI). They have no concept of a customer, and hence when they report a fault, it is impossible to determine which if any customers are affected from data retrieved by the protocol or even the commands. This makes it nearly impossible to use traditional management protocols to directly change the configuration of the network in response to new or altered business requirements. Instead, software solutions are when the business requirements must be translated o a form that can then be contained into SNMP or CLI instructions. Additionally, the software solutions must be designed and implemented using wrappers being in accordance to the diversity of fixed and wireless technologies that have countless variations of information, formats and meanings. Our research activity is focussed on acquiring the user’s context and his or her applications, and to use policy management and ontology-based reasoning to support cross layer interoperability in next generation networks (NGNs).

The DEN-ng object-oriented information model helps solve this problem in terms of integration using semantic tools as formal mechanisms. DEN-ng provides a cohesive, comprehensive and extensible means to represent things of interest in a managed environment. Things of interest include users, policies, processes, routers, services, and even protocol configuration (cross layered interoperability). Extensibility is achieved using a combination of software patterns and abstraction mechanisms, such as roles [16].

Information models are the glue that enables different components, manufactured by different vendors, to interoperate - whether they are network devices, software, or something else. As an abstraction and representation of the entities in a managed environment, DEN-ng defines the attributes, operations and relationships of these managed entities, independent of any specific type of repository, software usage, or access protocol. DEN-ng describes the business, system, implementation and runtime aspects of managed entities and their relationships in a simple but comprehensive form following the OWL language basis.

The DEN-ng policy model is rich and robust. More importantly, it has been built as a fundamental part of the DEN-ng model, meaning that all managed entities can be inherently related to and managed by policy. Hence, by extending the DEN-ng model to represent context, policy and context can also be related to each other. A simplified version of our preliminary context model is shown in Figure 3. This context model is unique, in that it relates Context to Policy to Management Information. Conceptually, this model works as follows: Context determines the working set of Policies that can be invoked; this working set of Policies defines the set of Roles and Profiles that can be assumed by the set of ManagedEntities involved in defining context. The working set of Policies also defines the set of Management Information that is of interest (for that specific Context).
The SelectsPolicies aggregation defines a given set of Policies that must be present to support the behaviour of that particular context. It is an aggregation to show that Context and Policy are strongly related (a whole-part relationship). This enables changes in context to change the set of policies that are used for orchestrating system behaviour. The association PolicyResultAffectsContext enables policy results to influence Context. For example, the success or a failure of the execution of a policy can affect the state of the system.

The selected working set of Policies defines the appropriate roles of the ManagedEntities that form Context; this enables Context to manage system functionality (through roles) at a higher level of abstraction. In particular, this means that policy determines the set of roles that can be assumed for a given Context. This is represented by the GovernsManagedEntityRoles aggregation. When these ManagedEntityRoles are defined, they are then linked to Context using the ContextDependsOnManagedEntityRoles association; the ManagedEntityRoleAltersContext and the ManagedEntityRoleUsesPolicy associations are used to feedback information from ManagedEntityRoles to Context and Policy, respectively.

Context also defines and depends on the management data collected from a ManagedEntity. First, Policy is used to define which management information will be collected and examined (via the GovernsManagementInfo aggregation); this management information affects policy using the ManagementInfoUsesPolicy association. Once the management information is defined, then the two associations ContextDependsOnMgmtInfo and MgmtInfoAltersContext codify these dependencies (e.g., context defines the management info to monitor, and the values of these management data affect context, respectively).

Given the above definitions, the relationship between Policy and Context becomes clearer. When a Context is established, it can select a set of Policies that are used to govern the system. The governance is done by selecting an appropriate set of ManagedEntityRoles that provide access to the functionality of the ManagedEntity. These ManagedEntityRoles provide control points for functionality that needs to be governed. Similarly, the result of executing a Policy may alter Context (e.g., an Action didn’t succeed, and new corrective action must be taken; or, a set of configuration changes did succeed, and the system is back in its desired state) such that a new Context is established, which in turn loads a new set of Policies. Note that loading and unloading ManagedEntityRoles is a relatively lightweight operation – as result that we are simply abstracting the functionality and/or control points of ManagedEntities (e.g., we are not changing the system’s state directly converting on heavyweight work).

3.2 DEN-ng PBSM Architecture

The DEN-ng architecture emerges as an alternative addressing the problems defined in [16] for the classical approach to PBSM architecture shown in the Figure 4.

This paper present research work enhancing the DEN-ng architecture as follows. Figure 5 shows a simplified view of the DEN-ng PBSM architecture. In DEN-ng, ManagedEntity is the superclass for Products, Resources and Services, and it defines business as well as technical characteristics for each. A PolicyApplication is a type of Application, which is a type of ManagedEntity. PolicyApplication defines three principal subclasses. A PolicyController corresponds to the functionality found in a "Policy Server". This term is not used in DEN-ng due to its ambiguity (i.e., any PolicyApplication could be implemented as a server in the DEN-ng architecture).

A PolicyControllerComponent is a fundamental building block of a PBSM. It represents both a set of core functionality for implementing policy as well as a unit of distribution in a distributed implementation. A PolicyController is built from a set of specialised PolicyControllerComponents (not all are shown in Figure 5) – this enables application-specific functionality of a PolicyController to be built based around the use of a standard set of reusable components (since they are DEN-ng objects, developers can build reusable libraries of these objects).
DEN-ng Policy Decision Points (PDPs) are similar to traditional PDPs, except that they are specifically designed to answer requests from policy-aware and policy-enabled network elements, as well as from an operator of the PBNM system. This enables a PDP to serve as an interface between the network and higher level business processes (the difference between a policy-aware and a policy-enabled entity, as well as the ability to serve as an interface, is a longer discussion that is beyond the scope of this paper). A DEN-ng Policy Enforcement Point (PEP) is split into two different entities to disambiguate its functionality. The DEN-ng PolicyExecutionPoint (PXP) is used to execute a prescribed set of PolicyActions on a particular set of PolicyTargets. A DEN-ng PolicyVerificationPoint (PVP) is an entity that observes how a set of PolicyTargets respond to a given PolicyAction. The PVP will inform the PDP as to the status of the Policy Targets after (and optionally during) the execution of the PolicyActions. The combination of a PXP and a PVP enable the act of executing a decision (made by a PDP) to be separated from the act of ensuring that the executing actions were performed correctly, and had the desired results. Other entities shown in Figure 5 are beyond the scope of this paper; please see [16].

3.3 DEN-ng Formal Language

This section describes the research work towards formalising the terms and creating the necessary concepts to represent the semantics of the DEN-ng policy model. One of the main requirements in the complex task of context-aware services support is the interoperability of the information between the different abstraction layers running services in next generation networks, such as the business, system, and network layers. We use formal language(s) to make the context information extensible and interoperable along and among the different applications that use it.

A simple representation of terms and relationships is not enough when we are trying to link the concepts related in different abstractions levels (e.g., services, middleware and networks) for the creation, customisation, deployment, execution and maintenance of the services in multiple technologies (e.g., wireless and fixed networks). The use of a formal language is required in order to accommodate the need for sharing and reusing context information, as well as to support the development of applications that can take advantage of context information.

The advantage of using a formal language is that its lexicon can be structured so that the concepts, definitions, and relationships of an ontology are all expressed in a clear and consistent manner. Furthermore, software tools can be used to automate maintenance and editing of the ontology. In particular, one or more reasoners can be used to infer knowledge according to different constraints. The same lexicon can support the building of ontologies in different forms, where each form is a result of the language-specific features used. A number of different languages can be used, each of which has different hardware, software, and platform tradeoffs. For example, Ontolingua uses an internal KIF language [20], and provides an integrated environment to create and manage ontologies; KL-ONE, CLASSIC and LOOM are different systems that use their own unique ontology language. The Open Knowledge Base Connectivity (OKBC) model and languages like KIF-Knowledge Interchange Format and CL-Common Logic are examples that have become the bases of other ontology languages. There are also languages based on description logics, for instance DAML+OIL. OWL is the W3C standard that captures most of the power of DAML+OIL, and has been extensively used for representing different types of knowledge capture and achieved high acceptance levels for representing Web services and semantic applications, such as the Semantic Web [21].

The use of formal languages provides the best opportunity for sharing and reusing information contained in different applications. In addition, it can be used to create and manage new knowledge, providing better support to pervasive applications. The extensive use of ontologies defined by formal languages creates a promising panorama for context-aware applications, due to the inherent extensibility that it provides for supporting high level applications.

Most proposals in the communications area use ontologies in ubiquitous computing applications, where context data is compared and related to the needs of the applications. In contrast, the use of ontologies in network management operations has been largely ignored, both for integrating
context data as well as for defining the relationship between context data and communications networks. We believe that using OWL [22] to represent the semantics of the context information will enable context data to be integrated into the communications systems and furthermore into the definition and management operations of communication services.

3.4 DEN-ng Context Model Using Ontologies

As described in previous sections, even an extensible, robust UML model of context information is not sufficient to represent the relations and concepts that define required context data, due to the inability of UML to represent formal logic. Since Entity is largely characterised by its EntityData, and we use policies to govern ManagedEntityRoles, the synergy coming from entity roles and policies can provide both an abstract as well as a rich view of the entity’s performance and behaviour that characterise each Context.

An ontology describing a subject domain can and should be used for more than just representing information; it also provides a formal way to integrate diverse data describing that subject domain. This enables ontologies to provide a formal mechanism for dynamically formalizing and updating knowledge, which is mandatory if the knowledge base of the system is to be kept updated with context changes. This also means that ontologies can be used to dynamically add knowledge to one or more abstraction layers in one or more knowledge bases.

In addition, our work uses ontologies to share and reuse information. This takes advantage of the formalisms that ontologies provide to represent and integrate the various relationships and terms in the context model. We use these properties to build relationships between managed Policies and Context information to formally support the semantics of management operations. This in turn enables context to define the set of policies that are applicable for that context, which in turn control the functionality that an Entity has during the time that this particular Context is active.

ManagedEntity has three main governance relationships: EntityData, ManagementInfo and ManagedEntityRoles. These relationships enable specific semantics to be attached to how a given EntityRole uses particular EntityData to enforce Context-Aware Policy Management.

Figure 6 presents the ontology for the context-aware policy model. This depicts interactions between the classes of the DEN-ng information model and the context information model for management purposes. The structure shown relates DEN-ng information model classes to corresponding concepts in the ontology using relationships that are named in a manner consistent to the model elements of DEN-ng. For instance, an “Noperator” is a “Person” that isDefinedAs a “ContextEntity” and also isLocatedAt a “Place”; note that all of these concepts describing context information are part of the DEN-ng “Context” information model. This approach enables us to augment the rich (but static) information model with concepts that add behaviour and semantics.

3.5 DEN-ng Ontology

The ontology for expressing the terms of the DEN-ng model (DENON-ng) is used to express the underlying semantics of management information to be shared and reused for different management operations and applications; this promotes integrated management in NGN. A model compliant with DENON-ng defines the semantics for policies that the autonomic frameworks require to operate. The objective of this paper is not to show how to build this ontology; rather, we only address our research work for describing the advantages of using a formal language for defining and exchanging information between different abstraction layers and views in the policy continuum with the objective to support context-aware services.

DENON-ng defines a set of dialects using OWL as its formal lexicon that is used for supporting the integration and interoperability of context information in service management operations. As previously explained, context variations change the set of policies that are active, which in turn change the functionality of the system; hence, system functionality adapts to changes in context, which is the promise of autonomic communications systems. This adaptation is a critical feature in all NGN proposals [1]-[9], and promotes integrated management in NGN. DENON-ng is being driven by a set of pervasive service use cases enabled by a policy-based management architecture described in [23].

Figure 7 shows the DENON-ng Upper Ontology. Concepts are represented as classes with associated relationships symbolised as arrows; brief descriptions under the arrows are the functions that represent the operations necessary for
managing the classes containing the parts that compose the policies that manage the services. For example, a context variation means a change in the set of attributes in the Context class, and this change can be detected using an Event that is related to one or more ManagedEntityRoles, which are in turn enabled by a set of policies that was enabled by the Context change. The Event can trigger the Policy that controls the ManagedEntity operations using the Condition and Action clauses of the Policy; this can be used for performing other Policy-based management operations related to the values of the ManagementInfo retrieved.

![DENON-ng Upper Ontology Representation](image)

3.6 W3C Representation and Earlier Work

The **W3C** [21] defined the Semantic Web, which provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries. It is based on the Resource Description Framework (RDF), which integrates a variety of knowledge using XML for syntax and URIs for naming. The core is the XML Language as a result of its enormous advantages and applications. An approach dealing with Policy Based Service Management (PBSM) using these representation frameworks is the TEQUILA project [24]. Its overall objective is to specify, implement and validate a set of service definition and traffic engineering tools to obtain quantitative end-to-end quality of service guarantees through careful planning and dynamic control of scalable and simple qualitative traffic management techniques within Internet services.

Another interesting proposal is the CONTEXT project [18]; this proposal uses a Policy Model in XML that supports the complete service life cycle. The policy model is extensible and contains parts defined as context information. This approach follows the business-oriented scope based on the context information that the active networks requires to operate. The service lifecycle is managed by a set of policies that contain such context information and it is used as trigger events, however this proposal lacks in the formalism level for sharing the context information and then supports the reuse of the information promoting the extensibility and interoperability.

We use ontology for expressing different types of meaning for a concept that needs to be interpreted by computers. Therefore, DEN-ng Ontologies not only define vocabulary for the interoperability, they also define one or more definitions and relationships for a concept. This enables different applications to use different meanings for the same object, in service and networks management operations which helps integrate the cross layers in NGN systems. Due to the inherent influence of the Internet, most of initiatives for representing context information must be track elements such as schema extensions for Web Services and others [21] and then under this perspective is DENON-ng initiative acquire importance. In DEN-ng, ontologies are used to augment data represented by information models, so that the system can reason about the modelled information.

4. Deployment & Operations - Scenario Approach

People want to stay connected whenever and wherever they are, accessing and using information that they need through a set of gadgets that deliver this data. This scenario is based on a seamless mobility system for Digital Video IP Broadcasting to handheld devices. Digital Video IP Broadcasting provides opportunities to marketing, government and other agencies. A user capable of receiving multimedia content (digital contents) is able to receive sports, news, entertainment and so on, according personal preferences and with certain quality of service dependent of certain contextual conditions or events.

Consider such a user, employing his or her handheld device for receiving such information in digital video format, shown in Figure 8. The user subscribes for this service using a web service portal where he introduces his personal profile that defines basic context information for the user, as well as the required features of his device in order to use the service. The system creates a complete set of business rules that create and deploy the necessary components. The system also creates the policies for managing the service and the network according to the subscription details of the user, taking into account the specific context that the user is currently in. This also has the option to enable the user to roam. Wherever a hotspot is encountered, the user can receive his subscribed services (assuming that the requisite infrastructure, such as identity management and brokerage between providers, are in place). Even in presence of an emergency disaster where the TV broadcasting system is down, the user can still receive instructions telling him where to go to be safe, thanks to TV broadcasting using Internet Wireless Connectivity.
This kind of scenario highlights the necessary interaction of the data, control and management planes to provide a compelling set of digital video broadcasting services that match the user’s context information. Our approach uses the DEN-ng information model to represent the services and their management, and the DENON-ng Ontology for supporting the interoperability of the information and the integrated management activity. This combination enables the services to be a function of the user’s context. This depicts the importance/application of cross layered interoperability in autonomic environments on NGN.

4.1 DEN-ng Implications & Extensions

The context taxonomy for the scenario is related to the nature of the information. Four categories are relevant: User Object, Location Object, Network Object and Application Object. Each one of these categories is modelled as object classes that interact with the DEN-ng context policy model. Specifically, each of these object classes forms a class hierarchy, where a set of roles are used to identify a particular object. This enables both scalability and extensibility, as only roles are managed; it also provides a more easily managed system where the service operations can be executed.

In traditional autonomic systems, the control loop is static. This does not meet the needs of systems that change dynamically, since the nature of the control loop itself may need to change. In particular, we are concerned with detecting context changes, so that we can change offered services and resources in accordance with context-aware policies. The FOCALE [17] architecture, shown in Figure 9 below, adjusts the functionality of its control loop to meet changing business needs and environmental conditions. The FOCALE architecture uses context-aware policy to control the autonomic manager, which then controls each of the architectural components of the control loop. This enables the different control loop components to change the type of algorithm used, the type of function used, and even the type of data to use as a function of context. This is facilitated by enabling the detection of context changes to change the active policies that are being used at any given time. Note that the use of two different control loops, one for maintenance operations and one for reconfiguration operations, is fundamental to overcoming the limitations of a single static control loop having fixed functionality.

The FOCALE architecture associates one or more ontologies with its DEN-ng based data and information models, enabling ontologies to represent relationships and semantics that cannot be represented using UML. For example, even the latest version of UML doesn’t have the ability to represent the relationship “is similar to” because it doesn’t define logic mechanisms to enable this comparison. Note that this relationship is critical for heterogeneous end-to-end management, since different devices have different languages, programming models, and side effects [15].

The autonomic manager uses the ontologies to analyze sensed data to determine the current state of the managed entities being monitored. Often, this task requires inferring knowledge from incomplete facts. For example, consider the receipt of an SNMP alarm. This is a potentially important fact, especially if the severity of the alarm is assigned as “major” or “critical”. However, the alarm in and of itself doesn’t provide the business information that the system needs. Which customers are affected by the alarm? Which Service Level Agreements (SLAs) of which customers are effected? These and other questions are critical in enabling OSSs and BSSs to decide which problems should be worked on, and in what order, according to specific business goals.

Given the above example, FOCALE tries to determine automatically (i.e., without human intervention) which SLAs...
of which customer are impacted. Once an SLA is identified, it can be linked to business information, which in turn can assign the priority of solving this problem. FOCALE uses a process known as semantic similarity matching [25] to establish additional semantic relationships between sensed data and known facts. This is required because, in this example, an SLA is not directly related in the model to an SNMP alarm. Inferencing is used to establish semantic relationships between the fact that an SNMP alarm (context information considered as event) was received and other facts that can be used to determine which SLAs and which customers could be affected by that SNMP alarm.

5. Concluding Remarks

We have studied the user’s requirements, based on both, the next generation networks (NGN) demands on context information and the pervasive services, according to a set of service requirements as defined in Figure 2.

The integration of context information for managing service operations in a suitable and formal form appear to be, in terms of policy composition, management costs and application independence, the most suitable alternative for supporting interoperability in cross layer systems. We follow this premise and use the DEN-ng models, which also contain a policy-based paradigm. This combination has been shown to be a feasible alternative for meeting the convergence requirements of broadcasting systems making use of NGN.

The DEN-ng object-oriented information model contains a robust policy model to govern managed entities. We then extend this model to include a novel object-oriented context model to achieve cross layer interoperability.

The scenario depicted has shown the business opportunities and advantages in NGN services, using a novel combination of DEN-ng policy and context models with the DENON-ng ontologies. This supports cross layer interoperability of the systems within the FOCALE architecture described.

Our future work is based on integrating the DEN-ng information model with various ontology models. While ontology models have some drawbacks in their implementation (not in their functionality), as the analysis of this paper shows, they offer a very rich set of meanings that are not possible to represent in other ways. We are currently investigating overcoming these integration problems.

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