# Towards a framework for network management applications based on peer-to-peer paradigms

## The CELTIC project Madeira


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***Abstract* — The Madeira project addresses a novel approach for the management of network elements of increasing number, heterogeneity and transience. As next-generation networks exhibit major challenges for today's centralized network management systems, we investigate the feasibility of a peer-to-peer (P2P) approach, facilitating self-management and dynamic behavior of elements within networks. In this short paper we give an overview of the system architecture developed in Madeira and describe the key concepts, like Madeira platform services, Adaptive Management Components and policies that provide the base for building distributed network management applications.**



***Keywords – P2P technologies; self-managing networks; policy based management; Model Driven Architecture (MDA)***


## I. Introduction

In the past, telecommunication networks could often be characterized by a static, relatively small-scale environment with homogeneous network elements. For such networks, today's centralised, hierarchical network management architectures work quite well, but with the increasing scale, dynamicity and heterogeneity foreseen in next-generation networks the traditional approaches will reach their limits (e.g. in terms of performance, scalability, flexibility, maintainability and reliability).

We need to find methods that are more self-managing and support distributed network management, to cope with future environments. Peer-to-Peer (P2P) technologies are one promising approach to enable distribution and scalable techniques in Network Management. Our strategy in the Madeira project, part of the CELTIC Initiative [1], is to build a prototype system using the P2P paradigm [2] and to demonstrate how this architectural technique can be used to solve challenging management problems in next-generation networks. Exploiting P2P characteristics such as self organisation, symmetric communications and distributed control [3][4], this approach is expected to lead to a more adaptive network control than in today's systems, and ultimately to a significant reduction in Operational Expenses (OPEX).

This paper is organized as follows: we introduce the basic concepts in section II, give a brief overview of the conceptual system architecture – as it has been developed in the first phase of the project – in section III, and then come to a more detailed presentation of the main ingredients of our system: the Madeira Platform (section IV) and the Adaptive Management Components (AMCs, section V). Finally we give some insight into the ongoing tasks within a case study, where we are going to validate and improve our concepts.

## II. Basic Concepts

### *A. Madeira Platform, Framework and Management System*

In order to define terms, we distinguish between the *Madeira Platform*, a set of software components that can serve as a core for a Network Management System for highly distributed, heterogeneous and transient networks, the *Madeira Framework*, including the Madeira Platform, additional framework code / libraries, rules and guidelines for component and interface implementation, and finally the *Madeira Management System*, an implementation of a Network Management System based on the above. Within the Madeira project we are developing a prototype implementation, based on a concrete scenario and focusing on configuration (CM) and fault management (FM) for a meshed network.

## B. P2P overlay management network and AMCs

In typical "classical" Network Management (TMN, e-TOM), there is a (more or less) clear distinction between *Element Management* (performing network element specific management functions on one or more instances of a defined type of network element) and *Network Management* (performing management functions with the view of the whole network).

Madeira investigates a different approach, based on a flatter structure and on the peer-to-peer (P2P) paradigm which is helpful in addressing scalability and interoperability issues. Our approach encapsulates management functions in P2P-aware components called Adaptive Management Components (AMCs – for a more detailed description refer to section V), directly corresponding to the network elements. A well-defined east-west (P2P) interface allows the AMCs to not only perform specific element management functions, but also communicate with other AMCs resulting in an overlay management network. Given these capabilities, the scope of the Madeira Management System covers both the element management and the network management layer of the traditional TMN approach.

Management functions (and corresponding management information) will therefore be distributed and implemented in the Network Elements as far as possible. By making use of the east-west interface introduced with the P2P paradigm, both AMCs residing on each NE and AMCs on dedicated Network Management nodes become part of the Overlay Management Network. Such a configuration is shown in Figure 1.

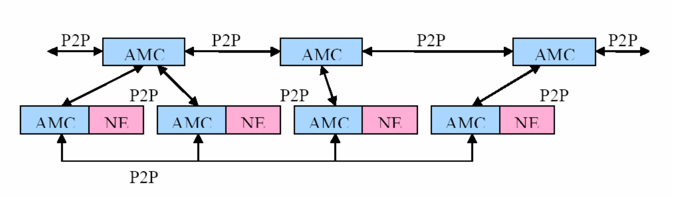


Figure 1. Overlay Management Network using AMCs.

## C. AMCs and their relationship to the Madeira Platform

As mentioned before, we are aiming at a framework that is based on the Madeira platform and supports building of truly distributed management applications. This is achieved by introducing the concept of AMCs.

An AMC is responsible for the network management functionality on a peer in a peer-to-peer network, based on the Policy-Based Management paradigm. An AMC has the ability to exchange and export network management information.

The AMC requires an execution environment (a *Container)*, plus a variety of services to perform its tasks. The Madeira platform provides both this Container and the services required by AMCs.

Considering the functionality split between AMC and platform in an actual instance of the Madeira Management System, the AMC covers the application specific parts for a particular scenario, whereas the platform provides all the generic functionality required for network management tasks in a P2P environment.

This separation within the system ensures the feasibility of a model driven approach, using OMG's Model Driven Architecture (MDA) principles [5], for AMC development, in order to adapt to changing scenarios and requirements in a very efficient way. The application of MDA can solve the problem of heterogeneity introduced by the different network technologies and applied standards as it allows the specification of shared / distributed behaviour (logic) and state (data) to happen *once* in a *technology-neutral* way and then it can automatically transform the models into numerous technology-specific formats as required by the various network elements and platforms. Particularly, we are using MDA in a twofold way in Madeira: First to model NM application logic and transform it to formats that can be executed on different platforms and second, to model information which can then be transformed to different data models supported by the elements it will be deployed on [6].

# III. CONCEPTUAL SYSTEM ARCHITECTURE

## A. Layered structure of services

Let us look at the architecture of the Madeira Management System intended to run on "Madeira NEs" on a high level. Considering an AMC and its relation to the platform, the following layered structure can be defined – see Figure 2.

The *Platform Services* layer reflects the direct dependencies of AMCs on the platform, whereas the *Peer to Peer Services* of the platform will not be accessed directly by AMCs. The *Life-cycle Management Services* shown on the same layer as the *Platform Services* might be accessed directly by an AMC for the purpose of logging and tracing; these lifecycle services will also be responsible for starting, stopping and monitoring services running on these AMCs. The *AMC Specific Services* layer, which is application specific and in the responsibility of AMCs, provides the base for the actual *network management applications* (e.g. CM, FM). The *Northbound Interface* layer communicates with external entities like operation support systems (OSS) by means of Web Services.

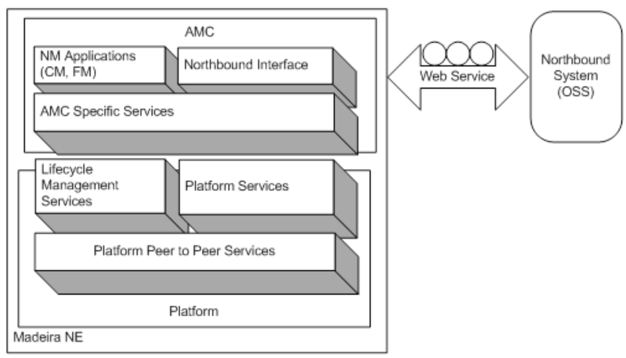


Figure 2. Layering concept on a Madeira Management Network element.

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### *B. Interfaces*

An overview of the four different types of interfaces, indicated by arrows, is given in Figure 3. We have to specify the following interfaces of an AMC:

- P2P interface (for communicating with other AMCs),
- Northbound interface (for communicating with OSS),
- Southbound interface (accessing NE application specific functionality), and
- Interface(s) to the platform (both the interface to the services an AMC is depending on, and the interface for lifecycle management by the platform)

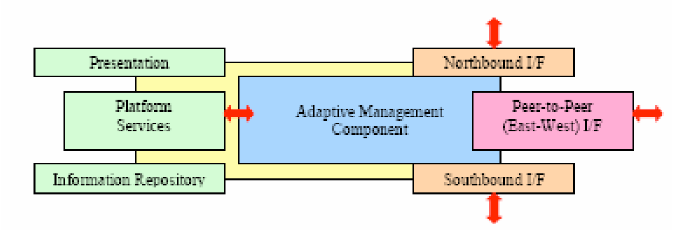


Figure 3. Four different types of interfaces

## IV. MADEIRA PLATFORM REALIZATION

This section presents some details of those services supplied by the Madeira platform, which form the building blocks for the more specialized AMC services and network management applications based on those. The services provided by the platform fall into two distinct categories; 1) Container Management services and 2) Core Utility services. The partitioning of these services is illustrated in Figure 4. In the following we give a brief overview of the responsibilities of each of the services provided by the platform.

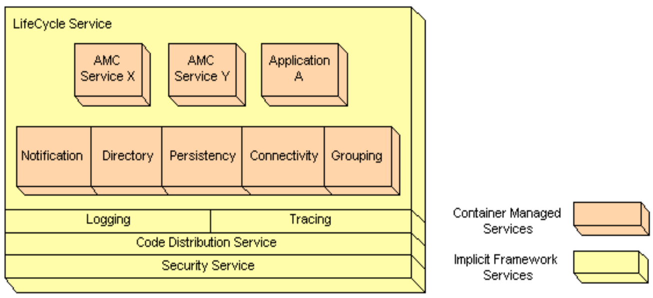


Figure 4. Madeira Platform services categorization

### *A. Container Management Services*

The Container Management services provide the environment in which the other platform services and AMC services will run, and provide functionality common to all dependent services. The following list details the proposed set of Container Management services to be provided by the platform.

- *Lifecycle Service* – this service is responsible for all aspects of the AMC containers lifecycle management. It provides start/stop/restart operations on all modules loaded by the AMC. The logging and tracing services are an integral part of this service in order to provide a single point of contact for all monitoring/control functionality, such as logging the start/stop/restart of modules, which events triggered them, when they were started etc.
- *Code Distribution Service* – the architecture of the Madeira framework supports the notion of AMC containers, which have a minimum “Bootstrap” configuration for the particular role in the network. Application logic/data or NE specific adapters are dynamically loaded into the AMC as required. This responsibility falls to the code distribution service, which utilizes distribution mechanisms to search the peer network for the implementation of the API and cache it in the registry for future requests.
- *Security Service* – this service provides all aspects of security and authentication from a platform perspective.

### *B. Core Utility Services*

The second set of services are categorized as Core Utility services which are responsible for enabling the development of peer-to-peer management applications within the Madeira framework and thus provide the basic mechanisms for any distributed system. These services include:

- *Notification Service* – a basic event notification service based on a standard publish subscribe service. AMCs subscribe to specific event types and are informed via registered handlers when those particular events occur.
- *Directory Service* - provides a directory of AMCs and their associated roles and capabilities. This service allows AMCs to be looked up, and caches information about known AMCs within the peer overlay network.
- *Connectivity Service* – provides reliable point-to-point connectivity between two AMCs. This will be realized in the form of a P2PPort. This is analogous to a socket or similar point-to-point connection, but will transparently support the multihop P2P communication semantics.
- *Persistency Service* – a local persistence service per AMC Container. It allows AMCs to persist data to storage for retrieval across restarts etc.
- *Grouping Service* – allows the dynamic formation of AMC groups for a given management function and provides clean application partitioning for AMCs of similar roles or capabilities.

Having outlined these components of the Madeira platform, we will highlight the modeling point of view for AMCs in the next section.

## V. ADAPTIVE MANAGEMENT COMPONENTS

The AMC Modelling approach follows the levels of abstraction as defined in Modelling Driven Architecture. The approach also incorporates concepts from the TMF NGOSS modelling initiatives, which strives to include behavioural aspects in future OSS models. Further, one of the major challenges was to provide a model supporting P2P characteristics as outlined before.

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The first objective addressed in this modelling approach is the provision of a minimum as well as generic set of semantics (also known as the meta-model) that is used to build the AMC model. The next objective was to build, using the semantics of the meta-model, an AMC Model that is neither specific to Middleware or Management. The AMC will be technologically independent.

For a Network Management solution, it is important that the model represents the static and dynamic behaviour associated with an AMC. The model should capture the peer and network distribution requirements associated with an AMC.

### *A. Meta-Model*

The meta-model or meta-language defines what can be expressed in a valid model, it is itself defined in UML. The Meta-Model for Madeira attempts to introduce concepts relating to network management of a P2P network such as behaviour & distribution.

These issues are addressed by including specific classes in the meta-model such as:

- Network Management: (Half-) Connection, Transaction
- Distribution: Distributed Application, Application Module
- Behaviour: Policy, Notification

### *B. AMC Model*

A model defines what elements can exist in a system. The AMC Model uses the elements defined in the Meta-Model to describe the structure and behaviour of an AMC.

The AMC Core is the primary component or 'brain' of the AMC and, based on notifications and policies, orchestrates the services and applications to facilitate the required network management function.

Services are components that provide some service or functionality requested by the AMC Core in order to facilitate network management. Applications provide the actual management functionality specific to the device.

A simplified clipping of the current AMC model is given in Figure 5.

### *C. Policy Approach*

Policies provide the generic management functionality shared by all AMCs within the same management domain. The main advantages of such a policy-based approach are:

- Scalability: We can apply the same policy to a large set of devices and objects.
- Flexibility: Policies can be changed dynamically as a result of separating them from the implementation of the managed system.
- Simplicity: As policies define the overall system performance, the elements do not have to be configured individually. Instead they are configured automatically by means of the actions defined within the policies.

The main function of the Policy-Based Management System (PBMS) will be to react to the different notifications received by the AMC. The arrival of a notification can trigger, where the conditions stated by the policy are met, the enforcement of a policy. In such cases the action of the policy will then be executed.

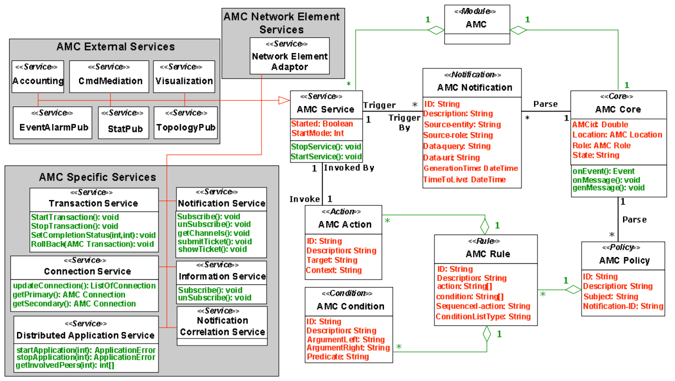


Figure 5. Madeira AMC Model (simplified).

## VI. Conclusion and Further Work

In this paper we have sketched our approach and presented a high level architecture of a distributed, logically meshed Network Management System. Further we have outlined the key concepts for Madeira platform and Adaptive Management Components, as they have been developed in the first half of this research project.

These concepts shall now come to life, by implementing prototype applications for configuration (CM) and fault management (FM), realizing a concrete example scenario of a wireless meshed network that has already been specified earlier [7]. As both the platform and the AMC services are currently being implemented in an iterative approach, and the modelling approach has been extended to describe the CM and FM applications in detail, we are ready to build the prototypes in order to test and validate the concepts for distributed network management as described here.

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