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Management Architectures and Approaches for Ambient Networks

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***Abstract*— Network Management Systems of Ambient Networks must work in an environment where heterogeneous networks cooperates and composes, on demand and transparently, without the need for manual (pre)-configuration or offline negotiations between network operators. To achieve these goals, ambient network management systems must become dynamic, distributed, self-managing and responsive to the network and its ambience. This paper discusses the different management approaches taken within ambient networks to enable efficient management of ambient networks as well as how these approaches relate to each other.**

***Index Terms*—Ambient Networks, Network Management, Self management.**

INTRODUCTION

As the border between datacom and telecom is vanishing new requirements are imposed on network and system management. The increased dynamicity in inter-network connectivity introduces new challenges for these networks and their management systems, these systems must be able to automatically negotiate and agree on their working conditions without any prior knowledge of each others capabilities and requirements. Users will have access to different applications, multiple devices with different capabilities and requirements, they will have access to multiple access types, and the users will be used to and require connectivity that well suits their requirement at the moment they need it. The EU FP6

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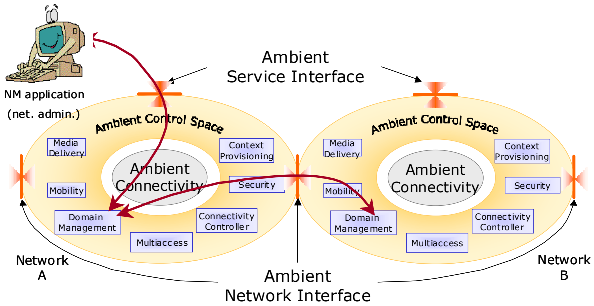

Fig. 1. Ambient Control Space, ASI, ANI And how network management works over the ANI and ASI.

program Ambient Networks (AN) aims at enabling different networks and network operators to automatically negotiate and agree on inter-working conditions ad hoc [1]—[3].

Network management is a vital part of Ambient Networks and will explore new management concepts of how network management will cope with the increased dynamicity [4]. The rest of this paper is organized as follows: firstly a short introduction to the characteristics of Ambient Networks and Ambient Network Control Space is presented. Then this paper discusses the main different network management concepts being explored to enable autonomous network self-management, i.e. Pattern-based approach, Peer-to-peer approach, Plug'n'play approach and closed loop optimization approach. This paper will also discuss what challenges and opportunities will come out of this work. Finally this paper will outline some implementation aspects of the different concepts.

AMBIENT NETWORKS CHARACTERISTICS

Ambient Networks (ANs) are based on and extends All-IP mobile networks by introducing network composition, advanced mobility and effective support for Heterogeneity in networks [1]. The notion of Ambient Control Space is introduced to encompass all control functions within a certain network domain. The ambient control space together with a (possibly legacy) connectivity network is called an Ambient Network. The ACS consists of a set of control functions supporting multiradio access, connectivity, mobility, smart media routing context management, security, and network management. The ACSs of different ANs communicate over the Ambient Networks Interface (ANI) and over the Ambient Service Interface (ASI) towards applications and services [1]—[4], see Figure 1.

NETWORK MANAGEMENT IN AMBIENT NETWORKS

The challenges in developing management systems for ANs are to build systems that on the one hand are simple and low cost (specifically for end-user networks), and on the other hand are scalable and robust. The appearance of novel wireless technologies, and the concept of network composition where netowrks agree to (partially) share a common control space, represents a challenging scenario from a network management perspective. To meet these challenges management systems of ambient networks have to become more dynamic, more self-managing, and they have to participate more actively in (inter)-networking. Novel protocols and approaches has to be researched and developed to go beyond existing network management paradigms in order to respond these challenges, see Figure 2.

Furthermore, since network management is part of the ACS, and the goal is to build self-managing management systems, most of the management communication between different instances of the management system will go though the ANI, see figure 1. Of cource, the network operators will communicate with the Ambient networks Management System (AMS) through the ASI, but this communication will mostly contain high-level instructions and feedback while the daily management operation will be performed by the AMS autonomously.

When two separate networks compose, one crucial challenge is to join the management systems of both networks into a consistent management system for the composed network. Similarly, when a network separates into two networks, the management system has to separate in a consistent and predictable way. Two novel approaches will be analysed to deal with the network management aspects of (de)-composition, the pattern-based management

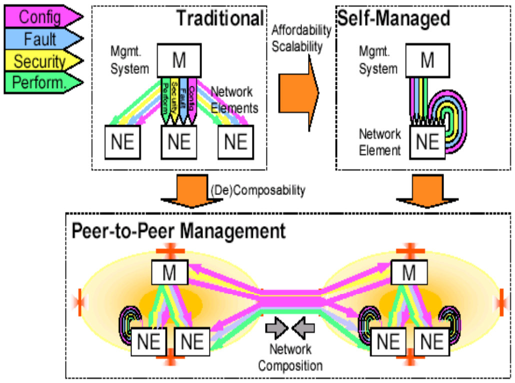

Fig. 2. Going beyond existing NM paradigms

and the peer-to-peer technologies.

Furthermore, in order to reduce the cost of network deployment, configuration and reconfiguration, as well as to increase scalability and affordability of Ambient Networks, innovative self-managing technologies will be researched and explored. Two approaches will be analyzed to enable AN self management, plug'n'play configuration of nodes and networks that compose and closed-loop traffic engineering on network level.

The interaction between the proposed approaches, see Figure 3, will be investigated in order to verify how they can interact with each other in an optimal way, to achieve an adaptive, distributed self-managing management system.

In the following sections we will go through the different approaches a little more in detail, before we describe how they relate to each other and makes a first attempt on how they can be fit together into one management system.

Peer-to-peer approach

The distributed approach of peer-to-peer (P2P) realizes interaction between individual Ambient networks Management Systems (AMS) to establish a consistent management system for the composed network by defining interaction between managers as well as between (self-managed) network elements. Furthermore, a key design goal is to minimize management costs, so simple transport protocols should be used.

Despite these advantages P2P requires enhancement in the following areas of control in order to deploy P2P techniques on

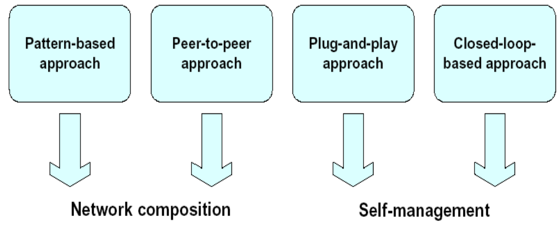

Fig. 3. Novel management approaches for composition and self-management

information sharing between AMSs [5][6]:

- Security, authentication and authorization – management information is valuable,
- Adaptive topology control – P2P overlay connections within and between AMSs are established and broken ad hoc,
- Traffic engineering – to distribute traffic within the overlay network, and if necessary prioritize certain traffic flows over other flows
- Resource management – how to utilize shared resources in an ever-changing environment.

Additionally, consider an AN environment in which two networks are composed, where the former networks offer different levels of QoS. Here the nodes with the lower QoS service should be reconfigured to better suit the new environment. This dynamic reconfiguration can be achieved with P2P technologies in combination with programmable techniques [7].

Furthermore, network composition imposes the following main areas as being relevant for P2P:

- Network Architecture for control and data plane – how to enable easy (de)-composition,
- Address allocation – how to ensure a consistent addressing structure,
- Routing – in dynamically changing environment,
- Policies – different networks contains different rules set.

A main feature of P2P is the immediate interaction among equal partners (peers), the nodes are highly autonomous – peers may join and leave P2P networks arbitrarily. Similarly, in an AN environment nodes and networks move across different ANs, resulting in dynamic network (de)-

composition.

Pattern-based approach

The pattern-based management paradigm aims at addressing the well-known drawbacks of centralized management [5][6] by investigating a distributed management approach based on graph traversal algorithms to control and coordinate the processing and aggregation of management information inside the network. A key feature of the approach is the separation of the distribution and computation/aggregation of information from the semantics of the management operation. The paradigm achieves this through the development of two important concepts: the navigation pattern, that implements the graph traversal algorithm, and the aggregator, that implements the computations required to realize the task. The main benefits of pattern-based network management is that it separates the semantics of the task from its flow control, it enables building scalable, distributed management systems and it facilitates management in dynamic environments.

Previous work on pattern-based management has identified the *echo* pattern to be useful for distributed monitoring [6], which characteristics is its two-phase operation:

- Expansion phase – where the flow is propagated from the management node through all nodes, upon receiving a packet the node forwards this packet on all links except the link which the packet arrived at.
- Contraction phase – a node waits for a reply on al links it sent out the packet before it replies with the answer on the link it originally received the request.

During the time between expansion and contraction the node can perform some aggregation of the results. This allows for distributed processing.

Pattern-based management has a strong potential to provide near-realtime information from dynamic, composed ANs. However, some of the areas that must be investigated in order to use pattern-based management in ANs are:

- Dynamic reconfiguration of management systems – to work in (de)-composing ANs,
- Robust patterns – how to adapt to topology changes
- Wireless networks – how to adapt patterns to mobile, wireless networks
- Inter-domain management – how to adapt patterns to be used in inter-domain management,
- Media overlays – how can patterns be used to support overlay networks.

Plug’n’play approach

The basic purpose of PnP is to configure an AN entity automatically, without any user interaction. This means that when an AN entity (practically an new core router or a router with wireless access point) is to join an AN domain, the AN PnP system should detect this case and starts its methods to configure both the new AN entity and the existing and working AN domain the get the new AN entity to be integral and working part of the domain [6].

Today routers and base stations are configured manually when they are being installed. However, within AN automatic configuration and reconfiguration of routers and base stations are a necessity. Hence, methods for detecting and establishing IP connections to the rest of the network are needed. This connectivity is practically set up to the routers’ direct neighbors.

A flexible and self-organizing plug’n’play configuration has to be developed and integrated with the AMS. This configuration will partly be based on P2P technologies to allow a new router to communicate directly with its neighbors to identify its configuration parameters or where further information can be found. Furthermore, the use of mobile code with an attractive programming environment [7] seems to be an attractive solution to some of the important problems.

Traffic engineering approach

Traffic engineering (TE) encompasses performance evaluation and performance optimization of operational networks. An important goal is to avoid congestion in the network and to make better use of available network resources by adapting the routing to the current traffic situation.

However, existing intra-domain routing protocols such as OSPF (Open Shortest Path

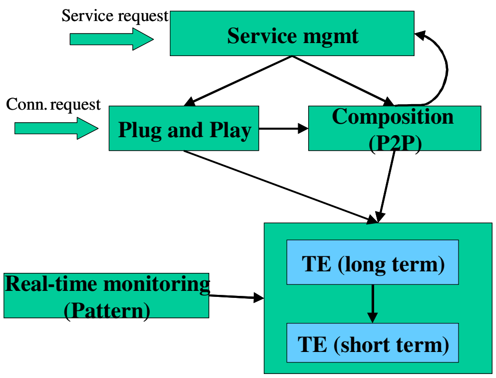

Fig. 4. Relation between the different AN management approaches

First) and IS-IS (Intermediate System to Intermediate System) are simple, highly distributed, and scalable. But these protocols do not consider network utilization and do not always make good use of network resources. More specifically, in these protocols, traffic is always routed though the shortest path, even when the path is overloaded, and alternative paths are not considered [4].

The main challenge for traffic engineering in Ambient Networks is to cope with the dynamics of both topology and traffic demands. Mechanisms are needed that can handle traffic load dynamics in scenarios with sudden changes in traffic demand, e.g. a large moving network suddenly composing with an access network before moving on, and dynamically distribute traffic to benefit from available resources.

The proposed areas of reseach within AN regarding TE is to analyse and simulate how near the optimal traffic distribution proposed methods can achieve. The general problem of finding the best way to route traffic through a network can be mathematically formulated as a multi-commodity flow (MCF) optimisation problem. A long-term research goal would be to construct a new multi-path routing protocol based on flow optimisation [8]. Based on the same scenario and traffic distribution the difference between having global respectively local information of the current traffic load and distribution, how close to the theoretical, optimal solution can these proposed methods get?

Integration of management approaches

During the first phase of two years of Ambient Networks the management groups will research and analyze the novel approaches described above, to investigate what their pros and cons are, and leave it for the second phase of the project to, based on the results from the first phase, integrate the different approaches into one management system. However, we already see how the different approaches relate to each other on a high level, see figures 4 and 5.

Service management provides support for service management and overlay setup when requested. Depending on the request service management asks the plug'n'play management and/or P2P management to adapt the current network configuration to the new requirements imposed on the network. Service management uses patterns to define and detect preferred routes depending on the requirements from overlays and services. Service management only occasionally triggers plug'n'play or P2P mechanisms, as can be seen in figure 5.

Plug'n'play management is responsible for configuring connectivity between nodes and networks. Triggers for plug'n'play might come from lower layer information (i.e. from layer 2 when a new radio connection is within range) or from service management requesting a new connection being setup. As can be seen in figure 5, plug'n'play management is the first instance of composition, and triggers P2P management to execute the composition when basic connectivity is provided. Plug'n'play also triggers TE when topology changes are imposed on the network.

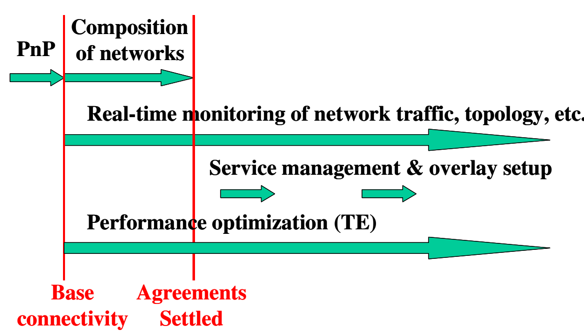

Fig. 5. Timeline of management mechanisms

P2P management allows AMSs of different networks to communicate and agree on the conditions directly with each other during their composition phase. As can be seen in figure 5 composition continues the work initiated by plug'n'play management when connectivity has been established. The composition management also feeds back information to the service management whenever a new composition has taken place as well as receives information from the service management whenever a composition is initiated by an operator. Finally, composition feeds information to TE regarding new compositions.

Realtime monitoring uses the pattern-based approach to monitor, poll and distribute information in the AMS. The state of the (composed) network is fed into the TE management.

Traffic Engineering is responsible for performance evaluation and performance optimization of operational networks. Based on input from the other approaches within the management structure TE tries to avoid congestion as well as to use the entire network resources in an optimal way based on the requirements of the network, the users, their applications and services as well as the available resources.

Furthermore, the AMS communicates with the rest of the ACS, receiving information regarding e.g. layer 2 connectivity, media overlay reservation requests, and QoS information, as well as the AMS feeds back information to e.g. QoS information and composition information. However, this AMS-external communication has to a large degree been left out of figure 5.

CURRENT STATUS AND FUTURE WORK

In this chapter we shortly list the current status of the different approaches, and what the current implementation plans are.

Plug'n'play

Currently a first prototype of the self-configuration of IP addresses for mobile nodes in ad-hoc networks is implemented, further more a preliminary prototype of configuring OSPF routing protocol as a representative for other control plane functions, which will be implemented in the future. The WLAN base station self-configuration is under development. Having finished all the parts we need to integrate them into a single plug and play demonstration setup.

Traffic Engineering

In order to facilitate the analysis of how much state information is needed, we divide the problem in two parts; the global view and the local view. The global optimization, utilize global information about the network state to make a coarse optimization of the routing. The state information is conveyed between nodes in the Ambient Network to perform the optimization. Since an Ambient Network is under constant change it will probably be infeasible to obtain a global view of the current traffic situation in the network. In particular, the trade-off between accuracy of the input information and signaling overhead is critical for the performance of the traffic engineering solution. To reduce the signaling between nodes, a local optimization is performed in each node to fine tune routing parameters using local information in nodes only

Currently common scenarios is developed that will be used for simulating network load and characteristics. These scenarios will then be used to see how close to the theoretical optimal solution the two approaches will perform, as well as providing some insight into the trade-off between accuracy of the input information and signaling overhead is critical for the performance of the traffic engineering solution.

Peer-to-peer

The P2P management system is currently being developed. There is a need to ensure certain level of security and QoS in this P2P management system. Thus, a secure and QoS assured management service overlay network (known as the Ambient Virtual Pipe) is also being developed based on a flexible and programmable infrastructure (i.e. DINA [9]). This management service overlay network is created dynamically between AN management entities and to provide secure and QoS assured means of communication channels between management entities in composed ANs or across different ANs.

Furthermore, a prototype is being

developed to visualize composition. The prototyped solution offers a distributed mean of network management in heterogeneous and highly dynamic networks, such as the Ambient Networks. The prototype also features a platform that implements basic Ambient Network Interface (ANI) functions. The prototype has been succesfully used to demonstrate various Ambient Networks composition scenarios. Currently we are are working to enhance the platform to support more complex tasks. The list of management functions are also extended to cover several AN scenarios

Pattern-based Approach

The concepts of pattern-based management have been implemented in Weaver [10], a decentralized management platform to execute patterns. Weaver is a scalable platform that facilitates the collection, correlation, and processing of information from very large networks. Weaver will be used to investigate pattern-based management in AN scenarios.

Furthermore, SIMPSON [11] is used to simulate how different patterns can be used to help setting up service specific overlay networks. SIMPSON [11] is also being evaluated to see if it can be enhanced to simulate wireless networks as well as some mobility in the networks.

CONCLUSIONS

In this paper we have presented the four different network management approaches taken within the Ambient Networks project [3] to provide a network management plane to the integrated Ambient Control Space. These network management approaches, the pattern-based approach, the peer-to-peer approach, the plug'n'play approach and the traffic engineering approach, will be researched individually during the first phase of Ambient Networks, to investigate and analyze how these approaches can provide and support an integrated approach to distributed, self-managing network management system.

Even though the integrated management approach will be taken in the second phase of Ambient Networks, this paper also outlines how these approaches can inter-work with each other, both on a time-scale basis as well as on a functional basis.

Finally, this paper provides an overview of the current status of network management within Ambient Networks, as well as what the future work will consist of.

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