THE QUEST FOR SELF-MODEL IN SELF-MANAGING NETWORKS

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Abstract: Although autonomic networking has been discussed in related research activities in the last few years, there is neither a commonly accepted model nor a common understanding of the necessary components of an autonomic networking environment, which are also practically applicable. We present a simple model based on the notion of self that is perceived by human beings and deduce its components from the originating point which is the need for autonomic behavior. We also introduce three use cases that we implemented for solving different problems of IEEE 802.11e networks.

1 INTRODUCTION

Autonomy and self-awareness are gaining momentum in computer science, mainly because of the ever growing complexity of computer systems and networks. New approaches tend to support or even eliminate the human operator by moving the control intelligence towards the inside of the system. Entities no longer are 'dummy' objects or components that are completely managed from 'outside', they become self-aware and even self-managing meaning that the own behavior is understood and changed or adapted to meet certain criteria respectively (Sterritt and Hinchey, 2005).

Started some years ago, research activities try to answer the question, how computer systems and networks have to be designed and build in order to provide capabilities that fulfil the requirements of existing but also emerging requirements, such as ad-hoc structures, increasing management complexity, dynamic on-demand service composition and ever growing quality of service (QoS) expectations. Big vendors like SUN, HP and IBM on the one side and the research community on the other side have come up with different answers to those problems. Autonomic computing and utility computing or autonomic communications respectively have been proposed as solutions (Kephart and Chess, 2003), (Smirnov, 2004), (Rappa, 2004). Although the issues covered in these approaches are basically different (Abbas, 2003), their underlying concepts point at the same direction; the increasing system complexity can only be managed by making the systems aware of their own operations. This is referred to self-management. Therefore, it's not surprising to see that all novel principles are centered around 'self', e.g. self-configuration, self-healing, self-organization.

Despite the similarity of the mentioned proposed solutions, there exists neither a common understanding of the notion of self nor a framework for the development of self managing systems. Approaches so far also do not explain the intersecting issues of those systems with the already existing artificial intelligence methods. Therefore, it is difficult to figure out the innovative sides of these approaches, except the eight key elements of an autonomic-computing system (Horn, 2001) which do not go beyond being requirements for self managing environments. Hence, although theoretically the concept of autonomic computing has been stated expressly, practical issues are still far from being mature.

Being aware of this issue, this paper is dedicated to the presentation of a self model that we have used for managing QoS over IEEE 802.11e networks. In

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this way, we fill in the empirical gap of autonomic communications and enable focusing more on problem specific issues.

In the rest of the paper, we summarize the notion of self as perceived by human beings and induce our self model based on these perceptions. In doing this, we take into account the requirements and characteristics of today's communication environments and correspondingly reduce the self model down to a set of *sine qua non* enabling high scalability and comprehensiveness, which are essential for practice. We clarify points intersecting with the classical artificial intelligence methods and explain how this self model can be extended with respect to problem specific situations. In the third section, we present three problems of the IEEE 802.11e standard in order to illustrate the introduced properties of the model, and build corresponding self managing systems which we already implemented using network simulation tools. We conclude our discussion with the summary of the handicaps we encounter during the modeling of autonomic networks and our contribution for overcoming those handicaps.

2 SELF MODEL

The dichotomy of self and non-self is the basis of an entity which is said to be self-aware (Mulhauser, 1998). It is not easy to define what self is. In philosophy and psychology 'self' is the mental and conceptual awareness an individual holds with regard to his/her own existence. It refers to the conscious, reflective personality determining his/her identity (Tauber, 2002). Although we cannot describe the term 'self' for non-human living things in the same manner, we still impose on them the notion of self based on our perception of their possessions. Consequently, the notion of self has a relatively large spectrum, from being self-aware or autonomous to self-unaware or allonomous[2] . This is also the crucial distinction between intelligence and unintelligence.

One can argue that there is no need for defining the so called 'self's (Metzinger, 2003). The fact that we call the entity being developed 'self' is not the crucial point here at all. The goal is also not the creation of 'self' as in the case of some artificial intelligence techniques, but building methods which would decrease the complexities of the management and the utilization of the systems that we already built up. In these terms, the issue of 'self' is rather deduced from the need for autonomy. Considering this fact, we will try to figure out the structure of the self based on our needs for autonomic behavior in the following subsections.

2.1 Notion of Emotion

It is a wonder of the nature that each existence has its reasons or more strongly said 'defined targets'. The target is intrinsically tied with the existence itself. This makes it crucial to regard the target as the highest order feature of the 'self'. Based on this fact, most of the artificial intelligence techniques are built on the definition of targets (Ferber, 1999), (Keiblinger, 2000). Nevertheless, the introduction of targets poses many obstacles.

The questions, how to tell the 'self' about his targets and how these targets should be reached proved to be extremely difficult to answer leading to difficulties in the implementation of those techniques. For this reason, ontology based languages are proposed and corresponding evaluation algorithms are developed (Bratko, 2000), (Muggleton, 1999). Nevertheless, in practice the use of these languages also proved to be extremely awkward (Scott, 2000).

If we have a look at the animal world, instead of targets, we witness the existence of instincts that automatically tell animals what to do next as some triggering factors emerge. In fact a leopard does not think about his targets, which may be for him to survive. Or how do his babies know where the milk is coming from and why at all? Targets enriched with possessions such as the ability to run or eat are already there as they are born. This is a start-up process (bootstrapping) in the lives of all living things.

In (Damasio, 2005) emotion is defined as

> ' an intense mental state that arises automatically in the nervous system rather than through conscious effort, and evokes either a positive or negative psychological response.'

Taking this definition of emotion as the basis, we can say that the impulses occurring in the form of emotions are directly coupled with all the actions of the living things following their births (Damasio, 2005), (Glasser, 1999).

The initial emotions give them a taste of what a satisfaction would mean and autonomic reactions to the sensed emotions show the initial solution proposals to these impulses (pleasure and pain). With time and experience the causalities behind the possessed functions, new ways of satisfaction and how to get rid of dissatisfaction are learned.

The phenomenon which results emotions is the state being sensed by the 'self'. Targets are also defined as states. Therefore, targets of a self can be di-

[2] governed by external stimuli

rectly coupled with a mechanism of emotion. If there exists a measurable emotion for each state, on which the behaviour of 'self' depends and if it is also possible to manage the level of emotion at each state, then it is also possible to lead the self to its targets by only using emotion levels. This eliminates the need for defining targets separately, which would otherwise require additional definition, semantics, representation and interpretation mechanisms (Levesque et al., 1998).

Consequently, it is possible to model the 'self' without explicit targets, but with a well defined emotion map over a state space by introducing the primary target as the willingness to maximize satisfaction.

2.2 Embedded Notion of Emotion

The sense of emotions is solely a triggering factor for the functioning of the self. A deeper mechanism, which exists in the core of the self is responsible for the birth of the self. It has exclusively only the capability to 'trigger' some functionality of itself with respect to its feelings. In fact this entity or mechanism is what the philosophers have been trying to find out (Glasser, 1999). Instead of speculating about what this entity might be for different living things, we just try to model its functional properties that are crucial to the formation of the self. We call this mechanism 'Embedded Notion of Emotion' (ENE).

Although ENE is the core element of the self model, it is an complete abstract entity. Its program is simply based on the desire to maximize its reward function and the ability to trigger the possessed functionalities. Its existence gives birth to a living self but has no direct influence on the possessions of the self. These possessions are rather given. It might be the case that, ENE is enriched with possessions which enable the self to reach higher rewards by gaining new possessions. This however defines the intelligence level of the self which is not a necessary characteristic for its existence.

Creating intelligent systems is in itself very interesting, but this sound should not deflect one from the actuator point that we should try to minimize the complexity within highly entangled systems. Although intelligence is a desired characteristic, it is most of the times not true that the intelligent systems decrease complexity. For this reason what we are searching for is autonomy more than intelligence. Autonomic systems can be composed of system management methodologies, which are defined to be static. However, the 'self' model can also cover artificial intelligence methodologies in order to make 'learning' possible so that knowledge and functions of the system are adapted to new environments gradually and become self-aware resulting in autonomous environments.

2.3 *Sine Qua Non* of Self

Based on the discussion of Sections 2.1 and 2.2, we define three necessary components for the existence of a 'self'. These are the reward mechanism defined over a state space, a primary triggering function reflecting a targeted incentive running over the reward mechanism (ENE) and a possession which can be an abstract or a concrete one. Although these three components are sufficient to build the very basics of 'self' regardless of what kind of possessions the self has or how its reward map is designed, the notion of autonomy needs the definition of properties that enable the perception and evaluation of the possessions by the self. An illustration of this model can be seen in Figure 1 We define those properties in the following section.

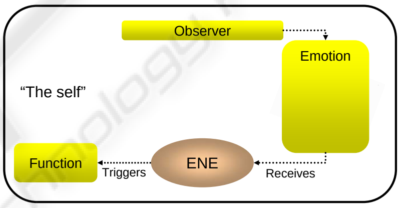

Figure 1: A simple illustration of ENE.

2.4 Observer

Self-awareness, the most fundamental requirement for a self-managing system, is the continuous recognition of the own possessions, their states and functionalities abstracted from the environment in which self exists. Correspondingly, the process of observing the changes in own possessions, their states and functionalities relative to the environment of existence is called self-monitoring. During the process of self-monitoring, the observer and the observed are one in a process that recursively gives rise to each.

In the area of social sciences self-monitoring is not a new issue. Human beings are self-aware by nature. Psychology, sociology, medicine and even sport deal with the monitoring of 'self' But psychology and sociology use the term 'moitoring' with a different meaning. Monitoring is not only dealing with measuring and observing properties, according to the literature, self-monitoring involves three major and somewhat distinct grounds (Baron and Greenberg, 1990):

- the willingness to be the centre of attention

- sensitivity to the reactions of others;
- ability and willingness to adjust behaviour to induce positive reactions in others.

Along these points, monitoring does not only deal with observation, but also includes behavioural control tendencies. However, in the technical literature these are two separate issues. In a technical sense self-management is rather perceived to be the subsequent use of the recognized possessions for controlling, preserving and changing the recognized states and functionalities.

Entities performing self-monitoring are separated into two distinct types. High-monitors are aware of their own presentation within their environment, keeping track of external cues to regulate their behaviour. In contrast to that, low monitors are sensitive and aware of their 'inner' states resulting in a low degree of public awareness. They pay 'less attention to appropriate behaviour in social situations and try to maintain consistent behaviour across all situations' (Snyder, 1986). High-monitors deal mostly with public awareness. The environment is monitored more than themselves. These entities are concerned about each situation and how to fit to it and choose the right 'face'. Low self-monitors focus on internal states and cues as an indication of behaviour modification. Primarily, these care for a consistent behaviour across different situations.

Although monitoring within ENE is not a must, its existence is necessary during implementations in order to generate corresponding emotion stimuli. Additionally, in case of the need for behavioural intelligence it is also necessary that the 'self' is aware of its state. Depending on the environment in which the 'self' exists, both high and low monitoring must be made available. The generation of corresponding emotion stimuli is a problem specific issue. Although low monitoring takes a role in generating emotion stimuli always, high monitors are generally used during decision making as additional information. Only in case of social 'self's it might be required to include high monitoring for emotion stimuli generation.

3 A SIMPLE SELF MODEL USING IEEE 802.11E

The amendment IEEE 802.11e extends the existing IEEE 802.11 standard by adding new functions targeting both differentiated and integrated services. In this way, IEEE 802.11e enables QoS enhanced access points (QAP) to cope with real-time traffic that is delay-sensitive, jitter-sensitive and error-prone, such as voice and video streams (see (Chalmers and Sloman, 1999) for a detailed overview).

New primitives of IEEE 802.11e, such as MAC Layer Management Entity ADD Traffic Stream request (MLME-ADDTS.request) allow negotiations between a QAP and a QoS enhanced station (QSTA) such as required maximum MAC Service Data Unit (MSDU) size, data rate, burst size and average delay. Additionally the QoS enhanced basic service set (QBSS) load element being advertised within beacon frames periodically gives information about the situation of an access point. This enables decision making prior to attachment using parameters other than signal strength. Furthermore, there is a number of new QoS related parameters used by a central control mechanism, the hybrid coordinator (See 1 for more detail on those parameters). Hybrid coordinator (HC) is responsible for managing those parameters in order to assure the best possible QoS over the QAP.

The number of available parameters that can be reconfigured during run time, the definition of a clear target, which is the maximization of QoS offered to the attached mobile stations and the existence of corresponding negotiation and control mechanisms make IEEE 802.11e a very good candidate for the deployment of a self managing wireless network. Therefore we adapted our model ENE to the IEEE 802.11e implementation of the ns2 network simulator. In the following sections we introduce three problems of IEEE 802.11e and corresponding ENE models to solve those problems.

Within our simple scenario there exist a QAP, a number of stations already connected with the QAP and a QSTA which has a new traffic stream to transfer. There are three problems for the establishment and preservation of the connection with the QSTA.

3.1 The Scenario

Within our simple scenario there exist a QAP, a number of stations already connected with the QAP and a QSTA which has a new traffic stream to transfer. There are three problems for the establishment and preservation of the connection with the QSTA.

1. The QSTA should decide if the QAP is the right choice for making the connection in terms of QoS.
2. The QAP must decide on accepting the new request coming from QSTA or not.
3. During the data transfer from QSTA, QAP has to make sure that its parameters are configured in a way that the negotiated QoS level is preserved.

The first two problems deal with the interaction between two different 'self's (high monitoring), whilst the last one only deals with a problem within a self (low monitoring). In order to implement these scenarios, we used network simulator ns2. We present here only the models, since this paper aims at presenting the model ENE. Real implementations and their results are referred after each problem.

3.2 Problem 1

In the first problem, the QSTA has to decide whether it would want to connect to the candidate QAP or not. The choice of the QAP over which the QSTA sends its frames is left to vendors within IEEE 802.11e. However the unit responsible for making this decision is the station management entity (SME). For making this decision, the SME is supposed to use the QBSS load element. It includes three parameters: *station count*, *channel utilization* and *available admission capacity*. The station count is the total number of stations currently associated with the access point. The channel utilization gives the percentage of the time the channel is sensed to be busy using either the physical or virtual carrier sense mechanism of the access point. The available admission capacity gives the amount of time that can be used by explicit admission control. We refer to (Simsek et al., 2006a) for a detailed study of the QBSS load element and its usage during decision making.

As we described in Section 2.2, the ENE is an abstract entity which has no direct influence on the possessions of the self. These possessions are rather given to it. Within the first problem, the ENE is embedded into the QSTA with four interfaces. One interface is at the SME, where the decision about the access point selection is given. The second interface is for monitoring purposes. Parameters regarding the characteristics (priority, burst rate, mean data rate and delay bound) of traffic stream are visible to the ENE. ENE regards both the function responsible for candidate access point selection and the parameters of the traffic stream, hence the traffic stream itself as its own possessions. The third interface that the ENE has is the point where the QBSS load element advertisements are received by the QSTA. ENE regards QBSS load element as the 'other' which is the QAP.

ENE is responsible for making a decision with respect to the state which it perceives as a result of the monitoring at the second and third interfaces and applies its decision on the first interface. The last interface is indirectly bound with ENE. The QoS of the traffic being transmitted is observed and satisfaction level is calculated using mean opinion score (MOS). This MOS level is then given to the ENE as the satisfaction mechanism.

As can be seen from figure 2, the original ns2 implementation is not changed except the point where the selection decision is given. This is true regardless of the problem. This property is the reason for the name 'embedded notion of emotion', since ENE is embedded into an existing system partially or entirely, without modifying the system. As described in Sections 2.1 and 2.2, the functionality of ENE is simply based on the desire for having more satisfaction and on the ability to trigger the possessed functionalities of the system in which it is embedded. We refer to our previous study (Simsek et al., 2006b) for the implementation of this model and its results.

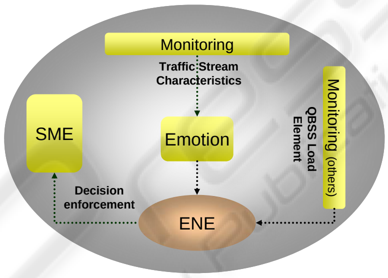

Figure 2: Representation of ENE within Problem 1.

3.3 Problem 2

Following the decision of QSTA for initiating the transmission with a QAP, the QAP has to decide whether it should admit the request or not, depending on the characteristics and if existing on the corresponding service level agreements with the mobile user. During the first problem, the QSTA had only limited information for making its decision, which is the QBSS load element of the QAP. However, the QAP has all the capacity related information (channel utilization of each priority and each traffic stream, corresponding QoS metrics such as delay and loss rates of each priority) and also its own admission control policy (service level agreements done with other mobile users) (See Figure 3). Although, both problems are very similar in nature, namely, if the QAP will be able to satisfy the QoS requirements of the traffic stream or not, the amount of available information in the second problem is significantly higher and the point of view is different. This allows us to compare behavioural differences of both parties (QSTA and QAP) for the same problem. This is especially interesting when learning is enabled, since the experiences of QSTA and QAP and also the monitoring of the behaviours from different perspectives are completely different. Furthermore, we can also analyze the consequences of using different amount of information.

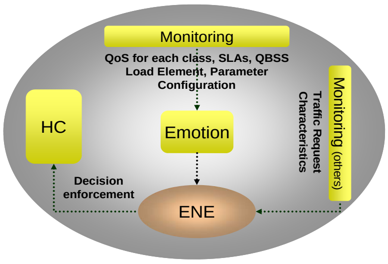

Figure 3: Representation of ENE within Problem 2.

3.4 Problem 3

Different than the first and the second problems, where the QSTA and the QAP had to make decisions following the request for a traffic stream, the QAP is responsible for preserving the promised QoS levels for each traffic stream in a continuous manner within the last problem. This requires permanent monitoring of QoS levels of each active traffic and modification of own parameters respectively.

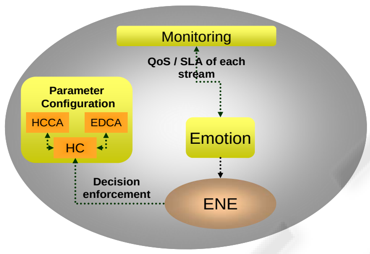

Figure 4: Representation of ENE within Problem 3.

As seen from figure 4, the IEEE 802.11e in its own has two functions, EDCA (Enhanced Distributed Channel Access) and HCCA (Hybrid Coordinator Controlled Channel Access). These functions are used by the hybridc coordinator (HC) for differentiated and integrated services respectively. The HC has full control over HCCA and its schedule, whereas it has only limited influence on the functioning of the EDCA. We are going to describe how different levels of control over the possessions of the 'self' can be managed in our next study. Nevertheless, although HC cannot control the transmissions over EDCA, it can restrict the use of some of the four priorities by requiring for explicit negotiation for those priorities. Additionally, it can change the contention window sizes of EDCA for each priority and also alter the TXOP limit. Hence, the HC can indirectly affect the QoS of traffic using EDCA. Table 1 shows a list of the most influential parameters of HCCA and EDCA that we found to be most significant for the functioning of IEEE 802.11e.

Within the third problem, ENE has two interfaces with the QAP. The first interface is used for monitoring the QoS levels of each traffic by the use of which satisfaction level is given to ENE. The second interface is with the parameters of table 1. ENE alters the parameters continuously with respect to the satisfaction level it expects. This problem is also known as algorithm configuration problem. We are going to present our implementation of the third problem and its results within our next studies.

Table 1: List of HC configuration parameters.

HCCA	% of time reserved for HCCA service interval
EDCA	CWmin CWmax TXOP Limit priority restriction

4 CONCLUSION

Although there are plenty of models proposed so far for building the intelligent environments of the future which should reduce system complexities, these models either could not bear down the conceptual planning phase like many bio-inspired models (Simsek and Albayrak,) or they proved to be inefficient in terms of performance like the agent technology (Keiblinger, 2000). In building such models, the research community ignored the following crucial points which constitute the igniting factors of our paper.

- The effort to build and preserve the self managing components should be significantly lower than traditional solutions. As mentioned above, the agent technology is a very good example for an unsuccessful effort in bringing this facility. Although in terms of conceptual planning the agent technology proved to reflect many requirements that one may expect from autonomic environments, its development, application and maintenance became to be a greater obstacle in reducing system complexity.
- The model for self managing components should be system independent and work generically in order to prove its ability to reduce system complexity. Otherwise it is an additional load to software developers and it makes more sense to use application specific solutions. Therefore, the self managing model should have the plug & play capa-

bility which starts functioning after it is embedded into the system being considered regardless of the application type. However previous models required the implementation of the systems from scratch.

- There must be clear metrics for defining self managing components, their states, targets and behavioural directions. However there is so far no such well defined metric for self managing components.
- It must be possible to define the behaviour of self managing components in a formal manner so that it becomes manageable. This behavioural management should be independent of the application and easy to define so that the course of the actions of the self managing components can be followed in a causal manner during runtime.

The points mentioned above show how our desire for a more intelligent computing environment can easily become a fallacy in terms of application efficiency. Hence, during the development of models for autonomic computing it is essential to consider the practical aspect primarily. This is especially important for the new trend 'autonomic networking'.

In this paper we presented a model for autonomic networking which is simplified down to the very basic elements of the 'self' as perceived by human beings. In doing this, we especially paid attention to our originating point, which is the need for autonomic behaviour. We kept the model as simple as possible by considering the above mentioned problems so that the model is scalable and applicable within the seven OSI layers even with scarce resources. For illustration purposes, we also summarized three implementations of ours using the introduced ENE model for solving three different problems of IEEE 802.11e. In this way, we opened the way for more problem specific studies in autonomic networking.

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