Improving the user experience through adaptive and dynamic service management

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***Abstract*- Current management systems make it difficult and often prohibitively expensive for Service Providers to offer value-added services to large numbers of subscribers with a concern for each individual's unique experience. Furthermore, many Service Providers do not clearly understand what services will attract subscribers, in order to maximise long-term profitability and growth.**

This paper discusses the concept of *Quality of Experience* as a means to come to a greater understanding of emotive user behaviour and each individual's *purpose* and *needs*. We combine this understanding with the use of Policy-based Network Management to build more automated, adaptable and evolvable management systems that can respond dynamically to needs. However, there is still a great deal that must be done to architect management systems that can handle millions of users. This is because high performance and availability are essential but service complexity and user demands will continue to increase, putting these non-functional qualities at risk.

I. Introduction

Service Providers, faced with increasing competition, find it hard to differentiate themselves from competitors, turning many telecommunication services into commodities and driving down profit margins [1]. Whilst IP-based Next-Generation Networks (NGNs) have promised to reduce costs and increase convergence of services, it is often found that value-added services are too difficult to operate profitably due to their additional complexity and an equivalent increase in operational costs. It is evident that Service Providers need to become more agile through management systems that can (1) react to the short, medium and long-term needs of the stakeholders, (2) minimise the burden on operators, and (3) allow new services to be added or changed incrementally. We believe that this can be done through adaptable, automated and evolvable management systems. However, to build services that maximise growth and profitability of the subscriber base, more needs to be done in terms of understanding and improving individual user experiences through increasing personalisation and diversification, and making the services respond to user needs in a dynamic, on-demand fashion. Improving the next-generation of management systems is a suitable mechanism to achieve these goals.

Our UTS-Alcatel research group seeks to understand and manage complex networks with millions of users: through the exploration of Policy-Based Network Management (PBNM) to reduce complexity and increase adaptability and evolvability, and through exploring Quality of Experience (QoE) to better understand and accommodate user needs, wants and expectations. We are also modelling, visualising, simulating and developing the system using Architecture-based Engineering to ensure that the system realisation will achieve its functional and non-functional qualities.

This paper is organised into three parts: (II) discusses the existing management problems, the requirements for future management systems, and how *Quality of Experience* might help in selecting profitable services. (III) discusses how policy-based management might be helpful and (IV) discusses some of the areas of our current and future work.

II. A way forward for Service Providers

A. Existing management problems

The operational management of a heterogeneous, multi-service network is a complex undertaking, and by its nature a number of significant problems have arisen. (1) There is *disparity* amongst the numerous management components, with 'stovepipe' systems, forcing operators into 'swivel-chair management' [2]. Thus, consistent, error-free end-to-end management is difficult. (2) The focus is on managing individual devices rather than logical services, burdening operators with service-related issues. (3) There is increasing management burden as services become more complex and more devices need to be managed. Management of the user's devices (such as the Customer Premises Equipment, Integrated Access Devices or Set Top Boxes) and other service-related components becomes more crucial as multiple services contend for the access network. (4) There are high operational costs because management systems are human-driven and configuration processes are error-prone. (5) Few systems allow service performance measurement, and Service Level Agreements (SLAs) are not standardised across systems. (6) Multi-way Service Provider partnerships for more complex services are not supported by management system peering. (7) Management systems are not reactive, and rely heavily on operator involvement to ensure network availability and SLA-compliance. Furthermore, network resources are not managed to ensure adequate service quality levels.

All of these problems are barriers to offering new services profitably, and often the business case for many new services cannot be justified. Service Providers wish to ascertain which services will drive revenues with maximum Return on Investment (ROI). Thus, it is essential for Service Providers to understand which services are the most desirable and valuable to the users, and the suitable prices to make them affordable, attractive and profitable. It is necessary to understand how these services are used to assist in meeting each individual's needs and purpose in communicating and collaborating with others.

B. Understanding the user: Quality of Experience

The advent of the NGN and value-added services has necessarily introduced an increased awareness of the user perspective. Customers do not purchase technologies for their own sake but instead have a purpose or need to which a technology may apply. Thus, services need to provide for specific and individual end-user needs at price-points that align with the customer's perception of the value to them [3].

However, previous attempts to understand which services might be most desirable and valuable to the users have been limited in their effectiveness. There is little consensus on what QoS is [4], and existing definitions proclaim QoS to simultaneously be 'a state, a cause, an effect, a measurement, and a subjective experience' [5]. Amidst a plethora of explanations in the literature of the user-network relationship, the commonly held view is that if performance

quality is high, then the user is satisfied. Inherent in this view is a blurred distinction between the user and the application [6]. The literature discusses the term Quality of Experience (QoE) [7], but provides no clear or precise definition and in actual fact, adopts this same view. This myopic tendency neglects to address the full problem. It fails to separate the user from the application, and consequently, attempts to quantify the user experience in terms of how big and well-formed the bit-pipe is. Accordingly, a QoE perspective needs to go beyond the application to first consider the experiences of the user, and then design the applications to reflect this experience.

We understand QoE to be service quality as understood from the user's viewpoint. Their experience may be partially influenced by QoS parameters, but the defining factor is expected to be the *purpose* for which they engage with the technology. Currently, there is no consistent and adequate understanding of QoE from this viewpoint. Further work needs to be done to come to attain this understanding of QoE, which is being done as part of the Management of Enriched-Experience Networks (MEEN) project at UTS. An overview of this work is necessary however, to explain what we have coined *Enriched-Experience Networks (EENs)*, and how we consider them to be fundamentally different from Next-Generation Networks (NGNs). An EEN is basically a recognition that *QoE resides with the people, not with the network*. The network can only influence and shape QoE, not create it.

Some factors that might significantly contribute to QoE include accessibility, usability and simplicity (the *anything, anywhere, anytime, anyhow* motto), increasing service convergence and integration (to make user tasks easier), and personalisation (to increase choice and suit individual user needs).

There are still many technical and managerial issues associated with implementing these services in a manner that positively shapes the QoE and thus, improved management systems play a fundamental role in enhancing the user experience.

C. *Improvements to management systems*

We believe that a number of key aspects of management systems need to evolve in order to support EENs. (1) Management must become *automated*, *adaptive* and *on-demand* so that services can be configured according to instantaneous user needs and the current environment. (2) Whole *logical services* need to be managed rather than individual devices. (3) Higher-level application layer components need to be managed. (4) The *end-to-end behaviour of the services should be consistent*, and network disruptions should be recovered appropriately. (5) More knowledge from Information Systems needs to be incorporated in decision-making processes (see Figure 1). The management systems also need to be more aware of the available resources and capabilities, and of details about the user from external credential, location and identity frameworks.

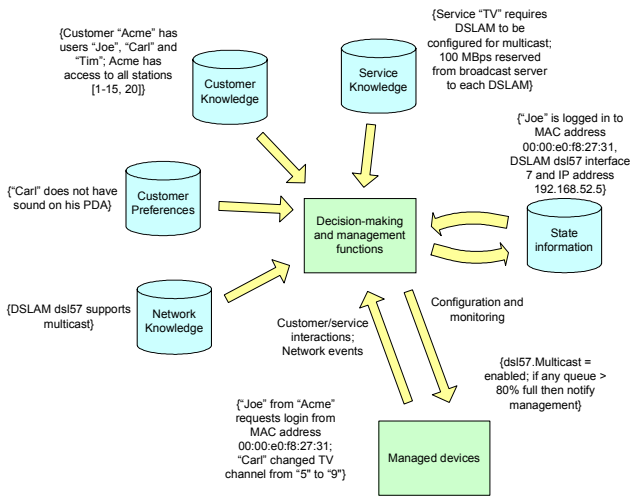

Fig. 1. The automated decision-making function

D. *Non-functional qualities of management systems*

These changes, however, increase the burden of meeting non-functional requirements. If management systems take a more active role in the day-to-day operation of services, then the availability and performance become increasingly important, because the management systems impact on the Quality of Experience of the users. Furthermore, the scalability of the management systems needs to be capable of supporting up to 10^7 users, services and devices.

It is not possible to achieve all non-functional qualities simultaneously since they must be balanced against one another. Thus, we seek to understand the trade-offs that exist between these qualities by using an Architecture-based Engineering approach [8]. By using abstract models of different views of the system, we can evaluate the most significant non-functional qualities of different architectures and designs at an early stage to understand the implications of different design decisions. We have conducted work to examine published management systems architectures and to understand the drivers in management system design. Using the Architecture Trade-off Analysis Method (ATAM), the crucial qualities have been elicited and ranked (see Figure 2).

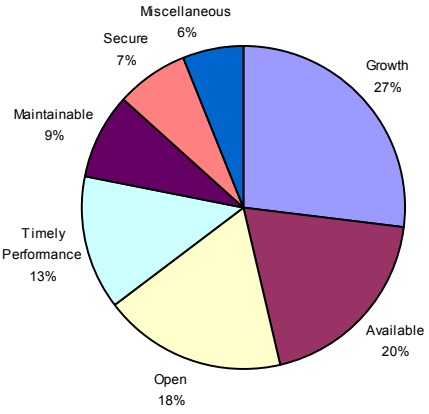

Fig. 2. Elicited qualities from ATAM process

III. Policy for Management of Enriched-Experience Networks

Policy-based Management is a method of guiding, constraining and enforcing the behaviour of managed entities. In particular, Policy-based Network Management (PBNM) refers to the use of policy in facilitating network management, and these systems have the potential to support automated, adaptive and reactive 'on-demand' management. In autonomous systems, *obligation* policies determine the responsibilities of management agents [9]. The major advantage of using policy is that management agents become effectively *programmable*, since the network behaviour can be adapted quickly at any time without disruption.

A. How does policy benefit EEN management

The key benefits of using policy in EEN management are (1) the *automation* of management tasks, (2) *adaptability* in delivering customised and diversified services (3) *on-demand* and *reactive* behaviour in response to user needs/demands and network conditions, (4) *evolvability* and *growth* of services over time, increasing Service Provider agility, (5) being able to capture *higher-level goals* such as SLAs with abstract policies and service descriptions, and (6) being able to specify *constraints* on how the network is utilised.

Policy may also help to capture network operator knowledge and improved security and configuration management of both management systems and networks.

B. Service modelling

In the past, many commercial and research PBNM solutions have been extremely limited. These systems are either focussed on managing individual devices, or have utilised fixed translation mechanisms that only support particular services or technologies. These systems have not been able to significantly reduce complexity or allow for evolvability in future services. We seek to remove these limitations by introducing the concept of *service definitions* (to describe what the services are and how they should be managed) and *service models* (identifying users, customers, service instances and resources and associating them together). By taking this approach, it is a simple matter to change who has access to the services, what services are available, and how those services may be controlled and monitored to satisfy each user's requirements.

A hypothetical example given here is for IP TV:

***Service model**: John.Services = {IPTV}*
***Service definition**: IPTV ⇒ {edge,dslam}.Multicast = True*
if (user.appliance.lowResScreen) then {user.IPTVservice.ch[1].port = 800} else {user.IPTVservice.ch[1].port = 801}

The management system can then use this information, as well as other user and network knowledge to ascertain how the management system should actually carry out its control and monitoring tasks over time. This could result in concrete policies:

{192.168.0.1, 192.168.0.2}.AllIPInterfaces.Multicast = True
{192.168.0.10}.IPTVApp.ServerPort = 800

These *service descriptions* could change over time, so that Service Providers can change the operation of the services over their lifetime or introduce additional value-added features as required. Furthermore, different events might lead to services being re-configured and managed in accordance with new user requirements or environmental conditions. This contributes immensely to adaptability and growth in the management systems.

C. How does policy need to be extended for EEN management?

Policy-based Management is not a *panacea* for all of the management woes of Service Providers, as there are many specific areas which are in need of improvement and further research: (1) The development of *service models* and *definitions* to capture individual user requirements. (2) The *translation* of high-level requirements to low-level device configurations whilst maintaining an understanding of *why* some network action is being done. (3) Taking advantage of more knowledge about the users and resources in automated decision-making. (4) The development of *policy representational models* to facilitate the specification of policies for each aspect of the services. (5) The development of *new policy languages* that are efficiently interpreted and have primitives that facilitate service management. (6) A greater emphasis of policies on *monitoring* the services and reacting to feedback. (7) *Policy conflict detection and resolution* that operates *dynamically* to maximise network cohesion. (8) *Increased scalability through management system distribution* and appropriate coordination across management nodes.

D. Will non-functional qualities be satisfied by PBNM systems?

The most common archetype of PBNM systems is the Internet Engineering Task Force (IETF) model [10], but this highly abstract and logical architecture provides only vague guidance in building policy systems. Thus, inter-operability of complete solutions will be a significant issue [11], along with the lack of a *service-oriented focus*. However, we wish to ask if this architecture has non-functional qualities that are suitable to carrier-class network management and EEN management?

The standards do incorporate some inherent architectural decisions that help performance, scalability and reliability (such as backup PDPs, both push and pull models, local decision caching). These simple architectural decisions have been somewhat helpful, but more needs to be done to ensure the architecture is *carrier-class*. Some researchers have also attempted to address these issues. Hamada, Czezowski and Chujo [7] provide limited guidance on scalability but have no experimental results. Law and Saxena [12] improved the scalability of the PDPs through load balancing. Ponnappan, Yang, Pillai and Braun [13] measured the response time of the COPS-PR and COPS-RSVP protocols. However, the results given do not give substantial clear guidance.

Without well-known non-functional qualities and a lack of a service focus, it is doubtful whether PBNM systems can be used in carrier-class networks. For this reason, we are working on improving the capabilities of PBNM systems so that they will be suitable for EEN management.

IV. Current and Future work

A. Evaluation of PBNM systems

The strengths and weaknesses of over thirty PBNM systems and standards have been identified to see how well they suit the management of Enriched-Experience Networks, provide service-management functionality, and support non-functional qualities. Another paper is in preparation regarding this work and it will be published shortly.

B. PBNM languages and systems

Our experimentation with the Ponder policy framework [2] has shown that using generic Policy-based Management systems for network management is cumbersome, particularly for modelling of complex logical layering. We wish to write policies reflected in multiple logical service layers, and minimise management system modifications through using open, pluggable interfaces for the management components which are hard-coded. Work has begun on designing a new PBNM system that supports logical service management with our adaptable *service definition* concept. Service Providers will then be able to add and modify services at suitable business opportunities. Furthermore, the system will use external knowledge sources to make complex policy decisions that facilitate user QoE.

C. *Non-functional qualities*

Our Architecture-based Engineering approach requires the critical evaluation of existing management system architectures for non-functional qualities, and this information is fed into the design process, so that newly constructed or evolving architectures may benefit from previous design experiences. In addition, the design process is cyclic, with architectures refined over several iterations. The use of different simulation techniques help in the evaluation of performance and scalability, and potentially other quality attributes (e.g. reliability), well before the system is implemented. We are continuing with this process as the design of our PBNM system develops, so that it will be possible to predict some of the characteristics of our architecture.

One major concern with PBNM systems is *timely performance* which might be addressed by efficient policy models and algorithms for translation, evaluation and conflict detection/resolution.

D. *Policy distribution and co-ordination*

To improve scalability and throughput it is desirable to decentralise and distribute policy to several PDPs automatically, even as policies are changed in real-time. Potentially, some of the knowledge used in decisions could also be distributed to reduce decision-time latencies, although not all PDPs will have enough resources to do so. Ultimately, policies and knowledge may eventually be distributed to hardware devices for evaluation.

Whilst many policies can be simply partitioned, there is often a need for some co-operation for more complex inter-PDP policies [2] to ensure consistent behaviour across the whole network. In Figure 3, three policies overlap one PEP, thus requiring all four PDPs to coordinate their actions. If the policies are modified, then the changes should be effected simultaneously across the whole network to minimise inconsistency and service disruption.

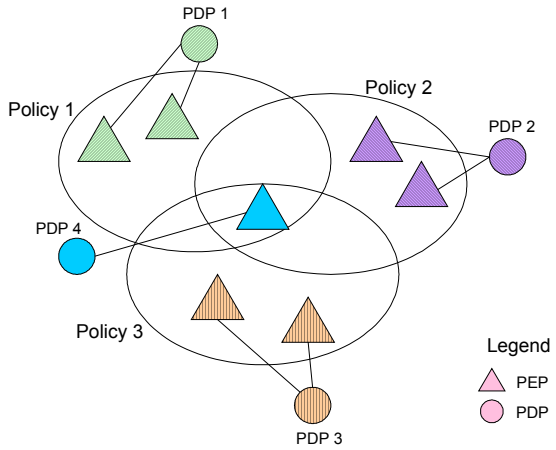

Fig. 3. Cross-PDP policies

V. Conclusions

At this juncture in the telecommunications industry it is necessary for Service Providers to find new ways to offer value-added services to users and differentiate themselves from competitors. Quality of Experience has the potential to improve the ability of Service Providers to predict which services will be most valuable to the users, through a deeper understanding of the *purpose* of user collaborations and the *needs* of individuals. Furthermore, the development of new management systems that are adaptable, automated and evolvable will help to minimise complexity, reduce costs and increase agility. However, in the near future, there will be an increasing reliance on management systems to cope with the demands of users on shortening timescales. Thus, the architecture of the system must be carefully constructed and evaluated so that quality attributes are suitably met.

Whilst Policy-based Network Management is a promising new approach, there are significant challenges which must first be overcome before they will be useful in a carrier-class network. In particular, PBNM systems must be generalised to support unique and evolvable management techniques. They must also have an increased focus on end-to-end *service management* to ensure that management activities are directed at specific user needs.

Acknowledgments

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URLs are given at http://www.eng.uts.edu.au/~nigelss/urls/ATNAC04.html.