Some Issues of Future Autonomic Networks

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Abstract

Autonomic networks seek to improve the ability of networks, terminals and services to cope with the unpredicted changes. However, some problems can also be brought by the introduction of the self-* characteristics in the dynamic environment. This document analyses some problems involved in the current autonomic networking technologies and systems and proposes some requirements aiming at enhancing current autonomic networks.

1. Introduction

Increasing complexity of the IP-based networks is a growing challenge for network designers, network operators and network users. Current IP networking technologies perform reactive adaptation by responding to changes in the environment after a problem has occurred. Autonomic networks seek to improve the ability of networks, terminals and services to cope with the unpredicted changes, including changes in topology, load, tasks, the physical and logical characteristics of the networks that can be accessed, and so forth. It enables users to focus on things other than configuring and managing networks by introducing some self-* characteristics.

However, some problems can also be brought by the introduction of the self-* characteristics in the dynamic environment, such as the convergence rate of the autonomic control-loop, especially in the heterogeneous and mobile environment, the lack of the learning ability of the policy-based control-loop, the security and cost-effectiveness of the intrinsic monitoring techniques in the current autonomic networking technologies. In addition, some factors have not been considered as criteria in the self decision makings process in the autonomic networks, such as context information for routing decision etc. All these may restrict the autonomic capability of the networks.

This document analyses some problems involved in the current autonomic networking technologies and systems in the context of some basic networking technologies, intrinsic monitoring system and mobility management. Some requirements have been proposed aiming at enhancing the current autonomic networking technologies and systems.

2. Problem statement

2.1 Basic networking technologies

Through introducing a series of autonomic features into current internet architecture, the future internet is enabled to gain autonomic capacities such as self-management, self-organization, self-optimizing, etc. However, current autonomic networking technologies are still insufficient to adapt to heterogeneity and variety of future network environment:

（1） At the aspect of control/decision plane, the current designs of control loop only provide primary autonomic functions: the policy-based autonomic control loop lacks for learning ability, which restricts the autonomic capability of the network. Optimized decision is often difficult to achieve when decision element make a decision according to end-to-end performance goal.

（2） More generalized context aware technologies. Contexts provide essential information to autonomic network nodes to make decisions. Network contexts acquirement technologies have received a lot of attentions. However, user behavior model, contents of applications and service features are also important context information for autonomic nodes to optimize network performance and QoS/QoE of user. For example, due to the restricted data transmission capacity, packet loss rate is relative higher in wireless networks. When autonomic nodes decide to drop some packets, users will expect the “un-important” packets in the application packet streams to be dropped firstly whereas “important” packets to be protected. The generalized context aware technologies will enable this feature by acquiring and analyzing the context information of network, users and applications.

（3） At the same time, we believe in the critical importance for future autonomic networks to be compliant, meaning that "Business-Awareness", "Goal-Awareness (for injectable goals)" and "Application-Awareness" are to be essential properties of Self-Managed Networks.

2.2 Intrinsic monitoring

The Autonomic networks and services are context-aware and can sense the environments. Consequently, the status about the network itself should also be sensed by the autonomic systems. Various status information form a large amount of data flow, and are handed out to the autonomic systems. How do the monitoring infrastructures provide local/global performance information reliably and efficiently without security issues and performance degradation is a big problem faced by the current autonomic systems.

In order to build the monitoring infrastructures securely with high performance, the security of the underlying monitoring mechanism should be carefully studied and the costs of large-scale monitoring activities should be evaluated. Furthermore, the large scale monitoring activities will produce massive data that need further processing and aggregating into the global performance information for the autonomic networks and services.

2.3 Mobility management

Future heterogeneous wired/wireless environments will provide ubiquitous coverage and seamless mobility to support more and more users with multi-mode mobile terminals. Therefore, mobility management becomes more complicated. It is a big problem for a mobile terminal to aware

various changes accurately and timely and take proper measures automatically among heterogeneous access environments. Moreover, in order to achieve efficient resource utilization, load sharing, bandwidth aggregation and other advantages, mobility management with different granularity, such as interface-level mobility and flow-level mobility, should be supported.

In addition, in the heterogeneous wireless environments, the different characteristics of the heterogeneous access technologies, together with the time-varying feature of wireless channels, result in a vibration during the information collection for the control-loops. In other words, the convergence rate of the control-loop in the autonomic networks can be low. This will affect the self-adaptation and self-configuration process in the heterogeneous wired/wireless environments. The correctness of the self-adaptation result should also be continuously evaluated.

3. Requirements

3.1 Context-aware networking technologies

In order to tackle the problems mentioned in 2.1, the researches in the following aspects are needed:

（1） Introducing the cognitive technology into autonomic networking architectures:

- The research on the cognitive network architectures design for end-to-end goals, which target to be self-adaptive, self-management, self-optimization
- cognitive routing research based on future networks which support mobility
- QoS autonomic management of cognitive networks
- Cooperation and communications among cognitive nodes

（2） Generalized context aware technologies:

- Constitute a packet prioritization strategy which orders application packets based on their contributions to guarantee the application’s QoS.
- According to the capability of the network and the receiving device, choose the most suitable transmittal strategy.
- Adaptively choose the route and the appropriate responder with less cost to satisfy the demand of the user and the content of request.

3.2 Secure, cost-effective and global-aggregating monitoring system for autonomic networks and services

The path to the aforementioned problems in section 2.2 can be decomposed into two parts: i) Improve security and performance for the monitoring mechanisms together with the monitoring infrastructures. ii) Develop new methods to process massive monitoring data in order to get global information.

（1） Study the performance and security of the monitoring infrastructures.

- The metrics will first be designed for evaluating the performance of the monitoring mechanisms (such as new monitoring protocols). Then the costs of the monitoring

mechanisms with the large-scale infrastructures are evaluated in various temporal/spatial granualities.

- The monitoring abilities added to the protocols should be carefully considered to avoid abuse and security issues. Therefore, new security features of the protocols on monitoring abilities should be designed and integrated by defining trust domains to distinguish different security levels of monitoring. Moreover, the openness and the security should be balanced so that sufficient monitoring abilities can be used by autonomic services while avoiding severe security holes.

（2） Develop new methods to process massive monitoring data. In order to provide global information for the decision process of the autonomic systems, the original monitoring data should be cleaned, converted and filtered. After that, the feature extraction is performed and the features are aggregated to form into the global information.

- Obtain the monitoring data, such as delay, loss and bandwidth through simulation or monitoring networks.
- Study the characteristics of the data with chaotic theory, fuzzy mathematics, digital signal processing etc.
- Provide the interfaces for the context-aware services so that they can use the global information.

3.3 Effective mobility management

To solve the aforementioned problems in section 2.3, the following studies are needed in the ubiquitous and heterogeneous mobile environments:

（1） Autonomic mobility management with different granularity support

- Because mobility management in multiple wired/wireless environments must be a multi-criteria based problem, key factors awareness and analysis is the important basic. Therefore, following problems should be solved to enhance the mobility management in the autonomic networks: (i) Awareness of interface status for a multiple access mobile terminal. (ii) Key factors analysis on multiple access networks selection and handoff.

- Mechanisms, protocols and policies are needed to be designed in the future autonomic networks to support mobility with different granularity.

（2） Fast control-loop convergence method for mobility management

- The changes of wireless channel is very fast, this results in that much attention must be paid to the convergence rate of the control-loop in the autonomic networks. Therefore mechanisms for increasing the convergence rate in the context of mobility management must be studied.

- In order to enhance the mobility management functions, especially to realize fast control-loop convergence, collaboration and interaction of multiple mobile nodes are needed. Hence, modelling and mechanisms for interaction, communication and collaboration among multiple nodes should be studied.