Self-Configuring and Optimizing Mobile Ad Hoc Networks

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Abstract

We present the design and implementation of a working system that enables self-configuration and self-optimization in mobile ad hoc networks (MANETs) by exploiting context awareness and cross-layer design principles, combined with simple network management policies and network programmability. We propose the collaborative management of the MANET through a proactively constructed body of nodes in order to overcome the inherently dynamic nature of MANETs.

1. Introduction

The concept of mobile ad hoc networks (MANETs) has brought a new paradigm in communication networks and acts as an enabler for pervasive computing and communication environments being highly dynamic. This way of dynamically creating a network often requires the ability to rapidly create, deploy and manage services and protocols in response to user demands in an equally dynamic manner.

There has been no previous research on deploying autonomic communication solutions in MANETs, but such an aspect is important in ad hoc networks due to their inherent nature. Autonomic communication principles can assist in the self-management of MANETs and enable network self-configuration and optimization by utilizing context information. The latter can be used to establish the need for automatic changes (self-configuration) in accordance to high-level rules. Pre-specified optimization rules are used to infer the need for changes in the MANET in order to achieve relevant objectives. This paper provides conceptual and practical design, implementation and deployment issues regarding a self-configuring and optimizing autonomic platform targeted to MANETs.

The structure of the paper is as follows. After this brief introduction, Section 2 gives an overview of the proposed system's design and architecture. Details on the implementation of the platform and its deployment on our experimental MANET testbed is the subject of Section 3, with initial results also presented. Finally, Section 4 concludes the paper and discusses our future research directions.

2. System design and Architecture

The SCOMAN platform (Self-Configuring and Optimizing MANets) operation is the following. By monitoring the MANET, management decisions are conceived and configuration and optimization enhancements are accordingly and autonomously deployed. Each of these aspects of the platform is implemented as a different, yet open and interoperable entity and deployed on the mobile nodes (MNs).

Cross-layer context gathering is the basis of our autonomic platform that exploits this information in order to self-configure and self-optimize the network and the participating MNs accordingly. Each MN is responsible for collecting its own low-level context and processing it to higher-level context information that have an impact on the management plane of the MANET (MMC - Monitored Management Context). The MANET autonomic communications platform will build on the MMC collected from all MNs to reach to management decisions for the MANET as a whole. These decisions will then be implemented as (re-) configuration changes.

A set of nodes in the MANET will form a Management Body (MB) that will be responsible for identifying the need for possible configuration changes in the MANET. The management entities will collect the MMC from all MNs, process it and based on predefined policies translate it into configuration changes. The management entities of the MANET are placed on a Connected Dominating Set (CDS) of the graph that describes the MANET connectivity. This set of MNs is constantly being updated and maintained. The idea of using a virtual backbone to serve as a management entity in a MANET is not new. There have been several approaches in the literature that take this under consideration [1], [2], [3]. The management entities after having collected the MMC from all the MNs, calculate MANET-wide management properties, as for example the future topology of the MANET as this is predicted from the individual mobility predictions of the MNs. The management properties are validated against the policies and rules defined and exploited by the management entities in order to infer if any special conditions are being met and configuration changes are thus necessary. We consider that the functionality of all MNs, regardless of the heterogeneity of the available platforms, is employed by means of software plugins that allow their activation, de-activation or reconfiguration according to management demands. The autonomic aspects of SCOMAN are thus implemented through the use of these software plugins that can be implemented in Java or C/C++ in our experimental prototype.

We require thus that the MNs forming the MANET are collectively the set of MNs with the highest computational resources in the MANET. Every MN is calculating a value that denotes it capability to host the MB Service. In our approach the capability function considers the following attributes: memory requirements (MEM), processing power (PP), battery power (BP), mobility ratio (MR) and current load (CL). These 5 variables need to be combined in a single equation, the Capability Function (CF) that is used for the MB formation.

$$CF(x) = \frac{(w_1 \times MEM(x)) \times (w_2 \times PP(x)) \times (w_3 \times BP(x))}{(w_4 \times MR(x)) \times (w_5 \times CL(x))}$$

Where, $\sum_{i=1}^{5} w_i = 1$, and x is the mobile node and

$$MR(x) = \left(\frac{Number\_of\_movements(x)}{Time\_Period} \right) \times \left(\frac{Number\_of\_link\_breakages(x)}{Number\_of\_neighbors(x)} \right)$$

3. Usage scenario and testbed evaluation

To test SCOMAN performance and efficiency as well as to examine its operation in a real environment we deployed it on our experimental MANET testbed that comprises 3 laptops and 4 PDAs. The SCOMAN platform is implemented using J2ME and the CDC framework. The context is modeled with the use of XML. The communication protocols among the mobile nodes are based on the lightweight XML-RPC protocol (www.xmlrpc.com).

The scenario we chose to test includes the dynamic change of the routing protocol used in the MANET from AODV to OLSR in respect to changes in network mobility. The scenario serves the purpose of presenting both the self-configuration and self-optimizing aspects of the platform, as well as the platform functionality. The self-configuration aspect is apparent from the scenario itself, while in this case the self-optimizing aspects refer to the fact that by changing the network protocol we achieve better performance of the network by means of bandwidth consumption (proactive and reactive routing protocols consume different amount of bandwidth and work better in different network states). Results from testbed measurements prove first of all that SCOMAN functions properly. The SCOMAN platform as evaluated in our testbed seems to fulfill its goal as being lightweight and deployable on devices with limited resources, such as PDAs.

4. Conclusions

We presented the foundations and major design principles of SCOMAN, an autonomic platform that enables self-configuration and optimization in MANETs. The platform has been implemented and successfully deployed on our experimental testbed, with encouraging initial results. Our future work focuses on further expanding the SCOMAN architecture to take into account more elaborate management policies and undertaking more extensive measurements to test its performance.

5. References

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