Design and Analysis of Quality of Service on Distributed Fault-tolerant Communication Networks

by

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Abstract

Fault-tolerant distributed systems are designed to provide reliable and continuous service despite the failure of (one or more faults within) some of its components. In such systems, failure detector is a basic block and also is at the core of many fault-tolerant algorithms and applications. It can be found in many systems, such as ISIS, Ensemble, Relacs, Transis, Air Traffic Control Systems. Fault-tolerant systems are designed to provide reliable and continuous services for distributed systems despite the failures of some of their components [4-8]. As an essential building block for fault-tolerant systems, failure detector (FD) plays a central role in the engineering of such dependable systems. Therefore, ensuring quality of service of failure detector is very significant for ensuring fault tolerance of distributed systems.

The goal of this thesis is to explore and present novel failure detectors and an Active Queue Management (AQM) scheme to improve quality of service (QoS) of communication networks.

On the one hand, I present three novel failure detectors: Tuning adaptive margin failure detector (TAM FD), Exponential distribution failure detector (ED FD) and Self-tuning failure detector (SFD) and analyze their implements. For the proposed TAM FD, it can effectively adjust its safety margin to achieve satisfactory quality of service in communication networks, especially, in unstable and frequently changeful networks. For ED FD, it is an optimization over existed methods. In ED FD, Exponential Distribution, instead of Normal Distribution in [18, 19], is used for estimation of the distribution for inter-arrival time. Experimental results demonstrated that ED FD over-performs the existed methods from the view of quality of service of failure detector. So far, a lot of failure detectors are designed to try to satisfy different QoS requirements. However, there are no any self-tuning scheme presented. That is, for a given QoS requirement, how do the parameters of failure detectors are tuned by itself to satisfy such requirement? Therefore, in this thesis we address this problem and present a self-tuned failure detector.

Furthermore, the κ failure detector [3] is an instance of accrual failure detector [19]. This allows for a clearer separation between the monitoring of the system and the interpretation of suspicion information by applications. Hayashibara in [3] gave the original idea and definitions about the κ FD. While the performance evaluation and analysis is not enough. Therefore, a question then arise: what is the performance characteristic of κ FD compared with the existed failure detectors? In this thesis, we analyze quality of service of κ failure detector based on a lot of experiments.

On the other hand, failure detection is generally based on distributed communication networks. Reversely, the performance of communication networks also affects quality of service of failure detector. Therefore, it becomes very necessary to improve the performance of communication network. The another goal of our research is to design and analyze new schemes for active queue management to support TCP flows. AQM is an effective method used in Internet routers for congestion avoidance, and to achieve a tradeoff between link utilization and delay. The de facto standard, the Random Early Detection

(RED) AQM scheme, and most of its variants use average queue length as a congestion indicator to trigger packet dropping. We proposes a novel packet dropping scheme, called Self-tuning Proportional and Integral RED (SPI-RED), as an extension of RED. SPI-RED is based on a Self-tuning Proportional and Integral feedback controller, which considers not only the average queue length at the current time point, but also the past queue lengths during a round-trip time to smooth the impact caused by short-lived traffic dynamics. Furthermore, we give theoretical analysis of the system stability and give guidelines for selection of feedback gains for the TCP/RED system to stabilize the average queue length at a desirable level. The proposed method can also be applied to the other variants of RED. The simulation results have demonstrated that the proposed SPI-RED algorithm outperforms the existing AQM schemes in terms of drop probability and stability. Thus, the presented active queue management schemes improved the communication performance of networks, so as to ensure good quality of service of failure detection.

In all, the contributions of this thesis are composed of two parts. First we presented several FD schemes to improve the performance of the existed failure detector. Then we design and analyze a new active queue management, called SPI-RED, to support TCP flows, thus it achieves smaller queuing delays and higher throughput by purposely dropping out packets.

keywords Failure detector, Fault tolerance, Distributed system, Computer networks, Communication system traffic, Communication networks, Feedback systems, Load flow analysis, Load flow control, Real time systems, Traffic control (communication).