Approaches and Concepts of Self Optimization in Autonomic Computing Systems

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Abstract- As earlier software systems were inefficient, frail, and incapablein resource utilization and allocation and also increase in complexity and size of software systems, thus made an adverse impact on software development process. Also large enterprise system consisting a lot of software, devices, tools and these are difficult to manage, so a new paradigm was introduced for managing, optimizing and maintaining systems, named "Autonomic Computing". Self-optimization is one of major characteristics of autonomic computing, which is self capable in resources utilization, allocation, and tuning of resources without increasing overload for satisfying user needs. Thus, increase in complexity of software systems has highlighted the need for maintaining and developing self optimizing autonomic systems.

Keywords- Autonomic computing, self-optimization, software systems, utility function, control theory, genetic algorithm.

I.　INTRODUCTION

The increase in complexity, size of software systems, advancement in software systems and computing techniques had a great impact on software development process. Thus this will led to investigate new approach named "autonomic computing" which is inspired from human nervous system. Autonomic Computing was first introduced by Paul Horn in 2001[1].In general terms autonomic computing is system that manages, configure and optimize itself without or with least human intervention. Now –a-days, enterprise software system consisting of hundreds to thousands of software, networked devices and all are managed under different enterprise standards. As more and more devices such as PC's, notebook etc are being added to systems, thus this increase the complexity of systems and make it difficult for skilled person to configure, optimize, maintain and integrate systems [2], so to overcome this problem we need autonomic computing approach . Autonomic computing having four major self-properties: self-configuration,self-healing, self-optimizationand self-protection, called self-CHOP [3]and four minor self-properties: context-aware, self-aware, open and anticipatory. Self-configuration means an autonomic system that configures and reconfigures itself under changing environments.Self-healing means an autonomic system that detects diagnose and repair problem without disturbing any system. Self-optimization means an autonomic system that improves resource utilization, tune its resource autonomously, reduce management overhead and try to satisfy user's requests, and also improve execution process. An autonomic system must identify attack i.e. active and passive attacksand protect its resources while maintaining system security. Self- aware means that autonomic system must be aware of its available resources, current status, components and also about which resources are being shared or used, it is also called self-knowledge. An autonomic system must be aware about its environment in which it executes; sometimes it is called environment- awareness. An autonomic system must operate in heterogeneous environmenti.e. system should run in different platform. Finally an autonomic system should anticipate its resources while hiding its complexities[4]. The increases in complexity in computer systems highlight the need for developing and maintaining self-managing and optimizing autonomic systems.This paper presents overview of self-optimization, evolutionary process of autonomic computing, methods for self-optimization and techniques for making decision in self-optimization autonomic systems.

II.　SELF-OPTIMIZATION: AN OVERVIEW

Self-optimization refers to an ability of systems or an environment that manages resources allocation and its utilization. As optimization means "an process of making any system, design or decision fully functional, efficient and effective. In general term, self-optimization means finding the best optimal way or solution autonomouslyfor software system improvement [5]. Self-optimization manages the complexity of system and with this ability it observes and tune resources(tuning means responding to dynamic changes for improvement)[6].There is two main challenges or issue of self-optimization: resource utilization and workload management[3]. The main aim of self-optimization is to maximize the value of system. Finally in more precise word, an autonomic system must optimize its operation and components with high level guidelines from IT experts for satisfying user requirements. Quality factors for self-optimization are efficiency, maintainability and functionality [7]. As many industry and academics have developed several software system with self-optim   ization property such as Optimal grid, Anthill, AutoMate,Autonomia, OceanStore, Storage Tank,Oceano,

Smart DB2, AutoAdmin, N1, Adaptive Enterprise [4],[7],[8].In self-optimization, the elements for Database management system are autonomic statistic management, query optimization, performance examining and so on are discussed by Shanta et.al [2] –

- Well known and good statistic are very important factor for enhancing performance of systems and providing accurate query execution plan, otherwise inessential statistics led to performance degradation.
- Now-a-days, database systems provide perception by examining system parameter, component, current events and statistic by using different devices like SQL server's performance monitor, DB2's performance expert and Oracle automatic database diagnostic monitor [9].And also database management optimizer like Oracle query optimizer, SQL query optimizer and DB2's Leo used for creating good query execution plan automatically[2].

III.   EVOLUTIONARY PROCESS

Autonomic computing is an evolutionary approach that will provide self-managing value of IT environments and it consists of 5 levels: Basic, Managed, Predictive, Adaptive and Autonomic[2], [6] -

Level 1- Basic: At this level,system components are managed separately by IT experts or high skilled person and these high skilled person monitor, manage, set up and replace system components. This level requires manual computing.

Level 2- Managed: At this level, management tools used to collect data from different systems and IT administration should manage and analyze data. This level provides benefits such as greater system awareness and improved productivity.

Level 3- Predictive: At this level, new methods are introduced to monitor the system, analyze changes and predict optimal configuration and actions plan that are approved by IT experts. Benefits at this level are faster decision making and low dependency on high skilled person.

Level 4- Adaptive: At this level, system should monitor, analyze and also take actions according to business policies and also help IT companies for developing balanced relation between system and human interaction. It improves flexibility of system.

Level 5- Autonomic: At this level, system component should manage them dynamically by using business policies set by IT experts.

IV.   APPROACHESFOR SELF-OPTIMIZATION IN AUTONOMIC COMPUTING SYSTEM

Now-a-days, some software needs proper performance improvement, complete resource utilization and workload management. Some techniques are being discussed by as follows:-

- **Control Theory**- Control theory is self-optimization techniques for dynamic system. This method requires canonical models i.e. discrete time linear model and discrete event system and apply standard control methods such as proportional integral controller and proportional integral and derivative controller [10].Self-optimization techniques based on learning discussed by MARKL, LOHMAN AND RAMAN [11]. MARKL et.al [11], apply self-optimization in query optimizer and query optimizer itself optimize, manage and update the query execution plan according to feedback provided by previous execution plan, and this techniques identify the errors during execution and then re-optimize the query.
- **Adaptive Control Theory**- Adaptive control method is also one of method for dynamic systems. It needs a mechanism for identification of parameter and the ability to adjust the parameter. Adaptive control method requires modification in control theory law used by controller of system. This technique is complex as compared to control theory. It is based on dynamic system or environment and acquires its characteristics using input/output information and also identifies errors on time. And according to certain changes, it modifies parameter and makes decision for automatically adapting to control signal to maintain optimal performance of system. Although, feedback control theory [2] also used for optimization, it analyses the implementation result and then recognize the reason and give corrective measures for development. Thus, both adaptive control theory and feedback control theory used to build autonomic computing system [2]. The model for adaptive control theory method is :
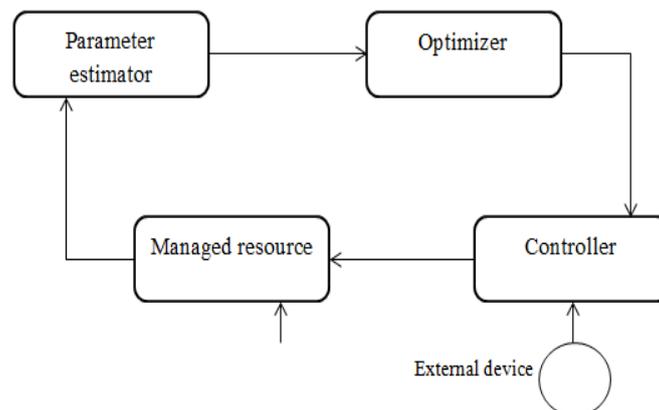

Fig 1: Model for Adaptive Control Theory Method

- **Heuristic Methods**- Heuristic method is common technique for making decision in self-optimization autonomic system. This method uses guess about software needs and then adjust these guess according to need and then make decision. This techniques do not require any model, basically is designed for computational performance [10]. Disadvantage of this technique, is not guarantee performance improvement.

- **Machine learning techniques**- Machine learning techniques is also one of method for making decision in self-optimizing autonomic system. Are of two types: 1) Model based techniques 2) Model free techniques. Model based techniques need some structure to learn software systems behavior. Artificial neural network and genetic algorithm are model based machine learning techniques. Artificial neural network technique work by predicting system reaction to some different inputs and then give some pattern to build model. This is used to build model for control purposes[10]. Another model based technique is genetic algorithm. Genetic algorithm is stochastic global search methods for optimization and also it is an adaptive heuristic search algorithm which based on evolutionary concepts of natural selection and genetics. This technique is designed for simulating processes in system necessary for evolution [12]. Genetic algorithm also used for decision making in autonomic computing system in [10]. Andres et.al[13], given a concept that enable the system to dynamically adapt to reconfigure plan under various change in requirements of system, which maximize data reliability and minimizes cost. Model free technique is reinforcement learning algorithm such as SARSA and Q-learning and this do not require any model for making decision [10].

- **Utility Function**- Utility function is model for resource utilization in autonomic computing system. It provides a framework for maintaining and achieving self-optimization in autonomic system. Generally, utility function concepts used in artificial intelligence and economics [14]. With the help of utility function, utility i.e. business value [5] of heterogeneous system is calculated. Utility function in autonomic computing map the state (vector of attributes) of entity (component) to real value. And it can be provided by human experts and also obtain from other utility function [14]. William et.al [14], explain utility function in autonomic system, which enable the autonomic element to optimize the use of resources in disparate environment and also uses flexible two-level data center architecture of individual autonomic element and each of autonomic element control resources usage to optimize utility function and global arbiter assign resource among architecture environment based upon resources utility function which is obtained from manager. The model for utility function is given below [2] :-
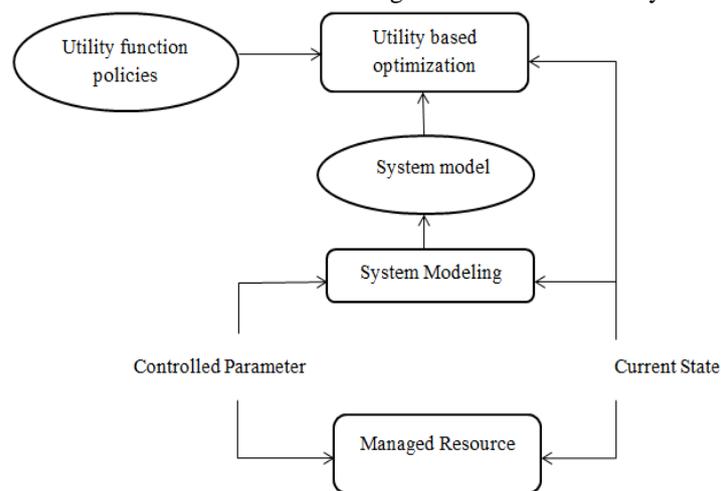

Fig 2: Utility function model

- **Service Self Optimization Algorithm (S²O_AC)-** Service self optimization algorithm in based on Autonomic computing. The approach identifies the self-optimizing function and executes the self-optimizing function, with the goal of minimizing optimization rate mode and maximizes service performance. S^2O_{AC} includes two functions: single dynamic optimization and static optimization prediction. When an internal environment changes, the optimizing function value is needed to findout, to identify the optimization rate mode. And when system internal environment does not change i.e. remain steady, the static optimization prediction is implemented and this static optimization prediction, optimizes the internal resources of system and also help in improving prediction accuracy[2],[15]. Finally, these two functions cooperate with each other to perceive service self-optimization performance.

V.   CONCLUSION

Self-optimization is one of major characteristics of autonomic computing. A self-optimized autonomic system is one which control or organize its various elements and resources itself and meet the expectations of user. Various industry, IT companies and large enterprise are developing a software system with self-optimization property, which will help in company growth and profit while satisfying user needs. In this paper, we give an idea of self-optimization and techniques for self-optimization that are used in autonomic computing system and also the techniques that are used for making decision in self-optimizing autonomic systems.

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