Architectural Resiliency in Distributed Computing

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ABSTRACT

Cellular organisms have evolved to manage themselves and their interactions with their surroundings with a high degree of resiliency, efficiency and scalability. Signaling and collaboration of autonomous distributed computing elements accomplishing a common goal with optimal resource utilization are the differentiating characteristics that contribute to the computing model of cellular organisms. By introducing signaling and self-management abstractions in an autonomic computing element called Distributed Intelligent Managed Element (DIME), the authors improve the architectural resiliency, efficiency, and scaling in distributed computing systems. Described are two implementations of DIME network architecture to demonstrate auto-scaling, self-repair, dynamic performance optimization, and end to end distributed transaction management. By virtualizing a process (by converting it into a DIME) in the Linux operating system and also building a new native operating system called Parallax OS optimized for Intel-multi-core processors, which converts each core into a DIME, implications of the DIME computing model to future cloud computing services and datacenter infrastructure management practices and discuss the relationship of the DIME computing model to current discussions on Turing machines, Gödel's theorems and a call for no less than a Kuhnian paradigm shift by some computer scientists.

Keywords: *Cloud Computing, Configuration, Distributed Computing, Distributed Intelligent Managed Element (DIME) Network Architecture, Fault Configuration Accounting Performance and Security (FCAPS) Management, Signaling, Turing Machine*

1. INTRODUCTION

As recent advances in neuroscience throw new light on the process of evolution of the cellular computing models, it is becoming clear that communication and collaboration mechanisms of distributed cellular information processing elements and end-to-end distributed process management played a crucial role in the development of self-resiliency, efficiency and scaling which are exhibited by diverse forms of life from the cellular organisms to highly evolved human beings. According to Damasio (2010), managing and safe keeping life is the fundamental premise of biological value and this biological value has influenced the evolution of brain structures. "Life regulation, a dynamic process known as homeostasis for short, begins in unicellular living creatures, such as bacterial cell or a simple amoeba, which do not have a brain but are capable of adaptive behavior. It progresses in individuals whose behavior is managed by simple brains, as in the case with worms, and it continues its march in individuals whose brains generate both behavior and

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mind (insects and fish being examples)….” Homeostasis is the property of a system that regulates its internal environment and tends to maintain a stable, constant condition of properties like temperature or chemical parameters that are essential to its survival. System-wide homeostasis goals are accomplished through a representation of current state, desired state, a comparison process and control mechanisms.

The governance of life’s processes is present even in single-celled organisms that lack a brain and it has evolved to the conscious awareness which is the hallmark of highly evolved human behavior. “Deprived of conscious knowledge, deprived of access to the byzantine devices of deliberation available in our brains, the single cell seems to have an attitude: it wants to live out its prescribed genetic allowance. Strange as it may seem, the want, and all that is necessary to implement it, precedes the explicit knowledge and deliberation regarding life conditions, since the cell clearly has neither. The nucleus and the cytoplasm interact and carry out complex computations aimed at keeping the cell alive. They deal with the moment-to-moment problems posed by the living conditions and adapt the cell to the situation in a survivable manner. Depending on the environmental conditions, they rearrange the position and distribution of molecules in their interior, and they change the shape of sub-components, such as microtubules, in an astounding display of precision. They respond under duress and under nice treatment too. Obviously, the cell components carrying out those adaptive adjustments were put into place and instructed by the cell’s genetic material.” This vivid insight brings to light the cellular computing model that:

1. Spells out the computational workflow components as a stable sequence of patterns that accomplishes a specific purpose,
2. Implements a parallel management workflow with another sequence of patterns that assures the successful execution of the system’s purpose (the computing network to assure biological value with management and safekeeping),
3. Uses a signaling mechanism that controls the execution of the workflow for gene expression (the regulatory network) and
4. Assures real-time monitoring and control (homeostasis) to execute genetic transactions of replication, repair, recombination and reconfiguration (Stanier & Moore, 2006).

The managing and safekeeping life efficiently are evident at the lowest level of biological architecture that provides the resiliency that von Neumann was discussing in his Hixon lecture in 1948 (von Neumann, 1987). “The basic principle of dealing with malfunctions in nature is to make their effect as unimportant as possible and to apply correctives, if they are necessary at all, at leisure. In our dealings with artificial automata, on the other hand, we require an immediate diagnosis. Therefore, we are trying to arrange the automata in such a manner that errors will become as conspicuous as possible, and intervention and correction follow immediately.” Comparing the computing machines and living organisms, he points out that the computing machines are not as fault tolerant as the living organisms. He goes on to say “It’s very likely that on the basis of philosophy that every error has to be caught, explained, and corrected, a system of the complexity of the living organism would not run for a millisecond.”

The connection between the design of autonomic systems and computing models is succinctly summarized by Samad and Cofer (2001). Any attempt to design automation systems with humanlike autonomous characteristics requires designing in some elements of being aware of one’s multiple tasks and goals within a dynamic environment and of adapting behavior accordingly. They point to two theoretical limitations of formal systems that may inhibit the implementation of computational awareness of self and surroundings and hence limit our ability to design human-like autonomous systems.

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