Immunity-based diagnosis in information gathering mobile agent system

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Abstract

In this paper, we apply the immunity-based diagnosis to fault detection in information gathering mobile agent system. The diagnosis inspired by the immune system metaphor is a fully distributed diagnostic model. In our system, the credibility of each agent and each host computer is evaluated by the iteration of local mutual tests and the dynamic propagation of active states, just as the population of cell in the immune system is activated by antigens and other immune cells according to mutual pattern recognition. The advantage of the distributed diagnosis in mobile agent system is that no agent needs to gather at a voting booth, that is, there is no centralized process required by the existing vote systems. To verify the feasibility of our system, we carry out some simulations on Java-based simulator. The result shows that the credibility of trusted agent increases gradually, otherwise decreases, and then the faulty units are identified.

Keywords
Mobile agent system, immunity-based diagnosis, information gathering, fault tolerance

1 Introduction

Mobile agent is the program or process that roams around the host computers network in order to accomplish its task. Many mobile agent systems have been proposed from programming language level to practical system [1, 2]. Mobile agent systems, however, raise new security issues that overturn some of the assumptions in most traditional security implementations [3]. One of the overturned assumptions is that the basis of trustworthiness is not securable. For the task of information gathering, mobile agent cannot always gather correct information not only by its own bug or corruption but also by host computers mistake. It is necessary to discern which agents and hosts can be credible. An approach to solve the problem is fault-tolerant software in which replicated agents are independently executed on each host and then vote on their results [4, 5]. The vote system, however, requires waiting and gathering process at a credible voting booth. In other words, it may spoil the distributed characteristic of mobile agent system.

On the other hand, the immune system can be regarded as a fully distributed diagnosis, where a large number of immune cells detect and eliminate non-self by circulating through the body, recognizing antigenic molecular pattern, reproducing the clones, and interacting with one another. The diagnostic models inspired by the immune system metaphor have been proposed [6]. The distributed diagnosis is performed by the mutual tests among units and the dynamic propagation of active states.

In this paper, we apply the immunity-based distributed diagnostic model to fault detection in information gathering mobile agent system. The advantage of the distributed diagnosis is that no agent needs to gather at a voting booth. To verify the feasibility of our system, we carry out some simulations on Java-based simulator. The result shows that the credibility of trusted agent and trusted host increases to 1 gradually, otherwise decreases to 0, and then the faulty units are determined.

2 Information gathering mobile agent system

2.1 Model of mobile agent system

We examine the applicability of the distributed diagnosis by applying it to a modeled mobile agent system rather than a practical system. Fig.1 shows the model of information gathering mobile agent system. There are N_a mobile agents on N_h host computers network. An agent moves from host to host in or-

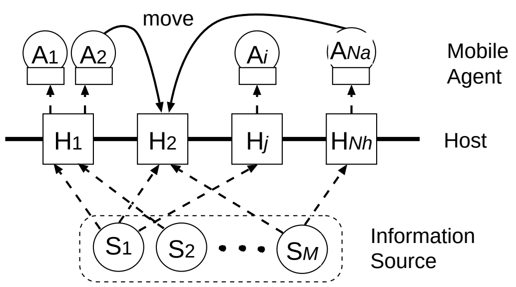

Figure 1: Model of information gathering mobile agent system.

der to collect answers to a question. When the agent finds a host to provide necessary answer, it stays at the host for a short while and saves the answer into its memory. We assume that the answers of hosts are delivered from common information source as detailed in 2.2. The role of host is telling the information to the agent without mistaking.

2.2 Information source

We explain the above assumption, namely, common information source, using the following examples. If some hosts announce the today's weather of Tokyo, their answers would be the same under neither misunderstanding nor lie. Another example is that supposing some hosts forecast the tomorrow's weather of Tokyo, the distribution of their answers would be formed within a range by a today's weather chart and knowledge of meteorology. Based on this fact, the information source S_i is represented by discrete information source, where the appearance probability for m symbols $\{a_1, a_2, \cdots, a_m\}$ is defined by $p_i(a_j)$ $(j = 1, 2, \cdots, m)$. According to the probability distribution, each information source can send a sequence of symbol to hosts.

2.3 False host and mobile agent

We suppose that accumulated answers in agents memory are not always correct, that is, they probably contain false answers delivered from another information source. For example, if the question is how the weather of Tokyo is, false answers are the weather of Kyoto, the temperature of Tokyo, and so on. The errors result from not only the bug or corruption of mobile agent but also host computers mistake. False host and mobile agent are illustrated in Fig.2. Faulty host tells a lie at error rate e_h. Faulty agent mishears

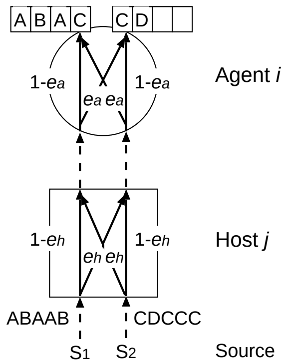

Figure 2: False host and mobile agent.

at error rate e_a. The aim of our system is to detect false host and agent.

3 Immunity-based diagnosis

3.1 Distributed diagnosis model

The information gathering mobile agent has the capability of testing other agents and hosts, and being tested by the others as well. The proposed system consists of repeated execution of two phases, the information gathering phase and the diagnosis one. The latter is based on the *skeptical model* that is one of the several different diagnosis models elaborated in [6]. In the model, a state variable R_i indicating the *credibility of agent* is assigned to each agent, and calculated as follows:

$$\frac{dr_i(t)}{dt} = \sum_j T^+_{ji} R_j(t) \tag{1}$$

$$R_i(t) = \frac{1}{1 + \exp(-r_i(t))} \tag{2}$$

$$T^+_{ij} = \begin{cases} T_{ij} + T_{ji} - 1 & \text{if tests between agent } i \\ & \text{and } j \text{ exist} \\ 0 & \text{if no test between agent} \\ & i \text{ and } j \text{ exist} \end{cases} \tag{3}$$

where the credibility $R_i \in [0, 1]$ is a normalization of $r_i \in (-\infty, \infty)$ using a sigmoid function. In equation (3), T_{ij} denotes the binary test outcome from agent i to j. As represented by the differential equation (1), the credibility of tested agent is updated by the sum of the test value weighted by the credibility of testing agent. The weighted test value, which is one of different points from the graph-theoretical self-diagnosable model [7], leads to neglect the test outcome of false agent with low credibility. Weighting the test and propagating active states, which was derived from the immune network metaphor, makes the credibility of fault-free agent increase to 1 gradually, otherwise decrease to 0.

3.2 Test method

It is necessary to describe how the agent and the host in the information gathering mobile agent system can produce their test outcome. We assume that the agent on a host can evaluate the host and the other agents on the host, and be evaluated by the others as shown in Fig.3. Note that there is no test among hosts, because the significance of mobile agent system is generally maintained by the reduction in the amount of communication between hosts.

The test outcome is assigned to 1 or -1 based on the difference between the agent i and j. The difference is computed using the following Kullback-Leibler (KL) divergence:

$$D_k(P_i||P_j) = \sum_{l=1}^{m} p_{k,i}(a_l) \log \frac{p_{k,i}(a_l)}{p_{k,j}(a_l)} \qquad (4)$$

where $p_{k,i}(a_l)$ $(l = 1, 2, \cdots, m)$ is the appearance probability of symbol a_l in the memory of agent i in terms of information source S_k. The KL divergence can be considered as a kind of a distance between the two probability distributions P_i and P_j, and $D_k(P_i||P_j) = 0$ only if $P_i = P_j$. For $D_k(P_i||P_j)$, the test value from the agent i to j is decided as follows:

$$T_{ij} = \begin{cases} 1 & \text{if } V_k(P_i, P_j) < \theta \\ -1 & \text{if } V_k(P_i, P_j) \geq \theta \end{cases} \qquad (5)$$

The above equation leads to a complete set of computations of credibility. According to equation (3), when both T_{ij} and T_{ji} become 1, the credibility of agent i is activated by the agent j, that is, the agent i is considered credible by the agent j. In Fig.3, the agent i has the symbol C in the memory concerned with A and B, and as a result it seems incredible to the others. However, the insertion of false symbol is not always caused by the fault of agent i. At the beginning of information gathering, when no one knows which agents and hosts can be credible, even a fault-free agent can receive false symbols from faulty hosts. The exact diagnosis would be fulfilled by the iteration of both information gathering and mutual test. The proposed system can detect fault-free or fault agent

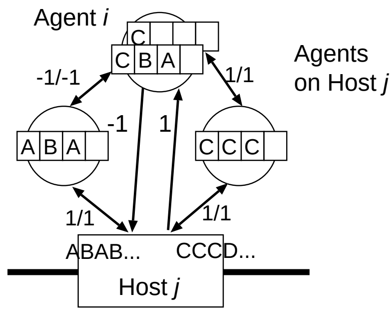

Figure 3: Mutual tests among host and agents at a step.

based on the distance between the probability distributions, just as the immune system can identify self or non-self by mutual pattern recognition.

4 Simulation

4.1 Simulation setup

To confirm the feasibility of our proposed system, we carry out some simulations on Java-based simulator. To start with, we clarify simulation setup. The conditions of information source are as follows:

- There are 2 information sources S_1 and S_2 which send 4 symbols $\{A, B, C, D\}$.
- The probability distribution for 4 symbols in S_1 is defined by $\{p_1, 1-p_1, 0, 0\}$, and S_2 by $\{0, 0, p_2, 1-p_2\}$.

Host and agent have the following conditions:

- All hosts transmit symbols from S_1 and S_2 to agents.
- Though all agents can receive symbols from S_1 and S_2 through host, they must save symbols only from S_1 into the memory. Needless to say, fault agents and hosts cause the insertion of fault symbols from S_2.
- Each agent is randomly located on host at the beginning of simulation, and then takes a random walk, staying at a host within random staying steps from 1 to 10.
- Agent should not accumulate the symbol from the host that makes its own credibility drop below 0.1.

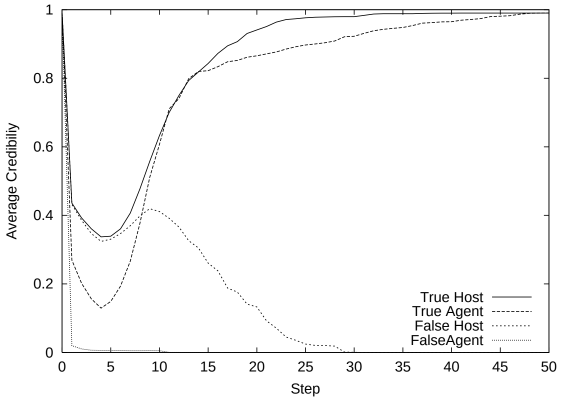

Figure 4: Transitions of the average credibility of 100 trials for hosts and agents.

Table 1: Parameters list.

	Description of variable
$R_i(0)$	Initial value of credibility
$r_i(0)$	Initial value of intermediate variable
N_h	Number of hosts
N_a	Number of agents
f	Rate of false units per total
$e = e_h = e_a$	Error rate
p_1	Probability of symbol A in S_1
p_2	Probability of symbol C in S_2
θ	Threshold for divergence

The latest term means a simple information filtering, that is, if there is no filtering, fault-free agents would always save false symbols from faulty hosts and look like incredible to the others.

4.2 Results

Fig.4 illustrates the transitions of the average credibility of 100 trials for true host, true agent, false host and false agent, respectively. In this simulation, the parameters listed in Table 1 are fixed: $R_i(0) = 1.0$, $r_i(0) = 0.5$, $N_h = 50$, $N_a = 100$, $f = 0.2$, $e = 1$, $p_1 = p_2 = 0.75$ and $\theta = 1.0$. From the result, although all hosts and agents seem incredible until 10 steps, the credibility of true agent and true host gradually increases, otherwise decreases, and finally the false units are determined.

5 Conclusions and further work

In this paper, we applied the immunity-based diagnosis to fault detection in information gathering mobile agent system. The simulation result show that the immunity-based diagnosis can identify false hosts and false agents by decreasing the value of credibility.

In further work, we must compare the proposed distributed diagnosis with the existing vote systems that require the centralized process, and incorporate it to practical mobile agent systems.

Acknowledgements

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