Fault Detection for Mobile Agent System Using Immunity-Based Diagnosis

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Abstract. In this paper, we apply the immunity-based diagnosis to fault detection for an information gathering mobile agent system. The diagnosis inspired by the immune system metaphor is a fully distributed diagnostic model. The advantage of the distributed diagnosis for mobile agent system is that no agent needs to gather at a centralized voting booth. To verify the feasibility of our diagnosis, we carry out some simulations. The result shows that the credibility of trusted agents and hosts increases gradually, otherwise decreases, and then the faulty ones are identified.

1 Introduction

Mobile agent can move around host computers network in order to accomplish its task. Many mobile agent systems have been proposed (e.g. [1, 2]). However, some security issues are particular to the mobile agent systems [3]. One of them is that both host computers and agents may not be trusted. For the task of information gathering, mobile agent cannot always gather correct information not only by its own bug or corruption but also by hosts mistakes. It is necessary to discern which hosts and agents can be fault-free. An approach to solve the problem is fault-tolerant software where some replicated agents are independently executed on each host and then vote on their results [4]. The vote system, however, requires waiting and gathering process at a centralized voting booth. In other words, it may spoil the distributed characteristic of mobile agent system.

The biological 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 network metaphor have been proposed [5, 6]. The immunity-based diagnosis is performed by the mutual tests among units and the dynamic propagation of active states.

In this paper, we apply the immunity-based diagnosis to fault detection for an 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 applicability of our diagnosis, we carry out some simulations. The result shows that the credibility of trusted agents and trusted hosts increases to 1 gradually, otherwise decreases to 0, and then the faulty ones are determined.

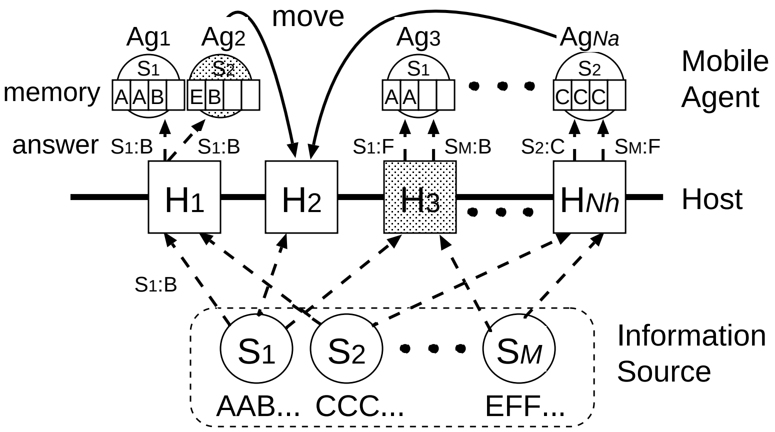

Figure 1: Model of information gathering mobile agent system.

2 Model of Information Gathering Mobile Agent System

In order to examine the feasibility of the immunity-based diagnosis, we apply it to a modeled mobile agent system rather than practical systems. Figure 1 illustrates the model of information gathering mobile agent system. There are N_a mobile agents on N_h host computers. Each agent can move from host to host in order to collect information. When the agent finds a host to provide necessary information, it stays at the host for a short while and saves the answer into its memory.

In this model, the assume that the host's answers are delivered from common information sources, which would exist implicitly in real world. (If explicitly, only by comparing with them, faults would be detected trivially.) For example, if some hosts announce the 2002 World Cup champion, their answers would be the same under neither misunderstanding nor lie. Another example is that supposing some hosts predict the 2006 World Cup champion, the distribution of their answers would be formed with probability. The information source S_i is represented by discrete information source, where the appearance probability for m symbols (answers) $\{a_1, a_2, \cdots, a_m\}$ is defined by $p_i(a_j)$ $(j = 1, 2, \cdots, m)$. According to the probability distribution, each information source sends the pair of label and symbol (e.g. S_1:B) to hosts.

If all hosts and agents are credible, each agent can easily gather correct information. However, it is assumed that accumulated answers in agent's memory probably contain false answers delivered from another information source. The error results not only from the agent bug but also from host computers mistake. In this model, there are false agents that mishear and save false answers just as agent 2 in Fig.1. In addition, false host, host 3 in Fig.1, can transmit the wrong pairs (S_1:F and S_M:B). The fraction of false agents and hosts is defined by f. The aim of the diagnosis detailed in next section is to detect the false agents and hosts.

3 Immunity-based Diagnosis

3.1 Distributed Diagnosis Model

The mobile agent system has the iteration of two phases, the information gathering phase and the diagnosis one. The agent has the capability of testing other agents and hosts, and being

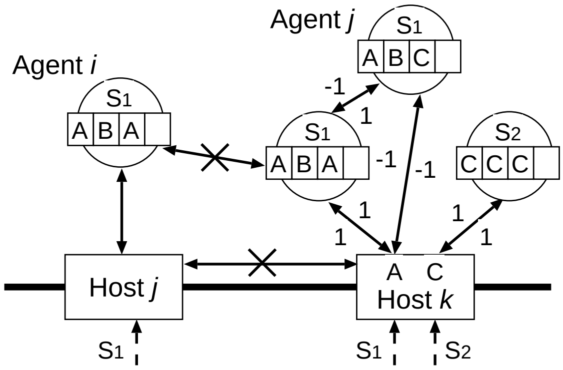

Figure 2: Mutual tests among host and agents at a step.

tested by the others as well. The diagnosis is based on the *skeptical model* that is one of the several different models elaborated in [6]. In the model, a state variable R_i indicating the *credibility of unit* is assigned to each agent and each host, and calculated as follows:

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

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

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

where the credibility $R_i \in [0, 1]$ is a normalization of $r_i \in (-\infty, \infty)$ using sigmoid function, and T_{ij} is the binary test outcome from unit i to j (detailed in *3.2*).

As represented by the differential equation (1), the credibility of tested unit is updated by the sum of the test value weighted by the credibility of testing unit. The weighted test value leads to neglect the test outcome of false unit with low credibility. Weighting the test and propagating active states, which are derived from the immune network metaphor, make the credibility of fault-free unit increase to 1 gradually, otherwise decrease to 0.

3.2 Test Method

It is necessary to describe how the agent and the host on the information gathering mobile agent system can produce their test outcome. Suppose 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 Figure 2. Note that there is no test among hosts, because the advantage of mobile agent system is generally caused by the reduction of communication between hosts.

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

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

where $p_{k,i}(a_l)$ $(l = 1, 2, \cdots, m)$ is the appearance probability of symbol a_l in the memory of unit 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 unit i to j is decided as follows:

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

where θ denotes the threshold for unit i to decide whether unit j is fault or not. The proposed diagnosis can detect fault-free or fault unit based on the distance between the probability distributions, just as the immune system can identify self or non-self by mutual pattern recognition.

The equations (1)-(5) lead to a complete set of computations of credibility R_i. According to equation (3), when both T_{ij} and T_{ji} become 1, the credibility of unit i is activated by the unit j, that is, the unit i is considered credible by the unit j. In Fig.2, the agent j has the symbol C in the memory concerned with A and B, and as a result it seems faulty to the others. However, the insertion of false symbol is not always caused by the fault of agent j. At the beginning of information gathering, even a fault-free agent can receive false symbols from faulty hosts, for no one knows which agents and hosts can be credible. If the diagnosis detects false units correctly, the fault-free agent can ignore faulty hosts. The exact diagnosis would be fulfilled by the iteration of both information gathering and mutual test.

4 Simulation

4.1 Simulation Conditions

To confirm the feasibility of the immunity-based diagnosis, we carry out some simulations on Java-based simulator. For simplicity, simulation conditions are set as follows:

- 3 information sources S_1, S_2 and S_3 can send 4 symbols $\{A, B, C, D\}$. The probability distributions for 4 symbols in S_1, S_2 and S_3 are defined by $\{0.74, 0.24, 0.01, 0.01\}$, $\{0.01, 0.01, 0.74, 0.24\}$ and $\{0.01, 0.97, 0.01, 0.01\}$, respectively.

- Each host transmits symbols from selective 2 information sources to agents. There are 3 combinations of sources (${}_3\mathrm{C}_2 = 3$).

- 3 kinds of agents must save symbols into the memory from S_1, S_2 and S_3, respectively. Needless to say, fault agents and hosts cause the insertion of fault symbols from another information source.

- All agent are located on one 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 whose credibility drops below 0.1. This 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 faulty to the others.

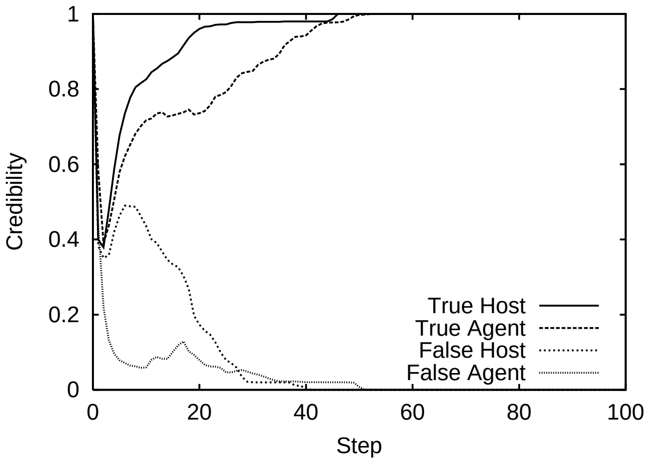

Figure 3: Transitions of average credibility over 50 trials for hosts and agents.

4.2 Results

Figure 3 illustrates the transitions of average credibility over 50 trials for true host, true agent, false host and false agent. In this simulation, the parameters are fixed: $N_h = 30$, $N_a = 60$, $f = 0.2$ and $\theta = 1.0$. From the result, although all hosts and agents seem faulty until 5 steps, the credibility of true agent and true host gradually increases, otherwise decreases, and finally the false units are identified.

5 Conclusions and further work

In this paper, we applied the immunity-based diagnosis to fault detection for the information gathering mobile agent system. The simulation result shows 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.

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