On Some Method for Intrusion Detection Used by the Multi-agent Monitoring System

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Abstract. In this paper an original method for intrusion detection used by the multi-agent monitoring system is proposed. Due to the complexity of the problem of the network security maintaining it is a good idea to apply the multi-agent approach. The multi-agent system is used in the tasks of computer network monitoring in order to detect the security policy violations. In this paper the algorithm for detecting some type of attack is proposed. This algorithm is based on the network traffic analysis.

1 Introduction

In this paper an original method for intrusion detection used by the multi-agent monitoring system is proposed. The problem of the network security is taken up since eighties [9] and is developed up today [5, 8, 20]. A comprehensive survey of anomaly detection systems is presented in [16].

A comparison of different approaches to intrusion detection systems is given in [4]. The general challenge of the current intrusion detection systems is to find the difference between the normal and abnormal user behaviour. Intrusion detection system (IDS) should not only recognise the previously known patterns of attack, but also react in case of appearance of the new events that violate the network security policy. The first models of IDS systems were centralised namely data were collected and analyzed on a single machine. However, the distributed nature of the task of the network security monitoring requires applying of the distributed tools for network security maintaining. Many examples of the distributed IDS systems are given in [1].

The most important postulate addressed to the intrusion detection systems is that, such systems should automatically react in case of detecting the security policy breach to prevent the attack execution or to reduce the potential loss in the network systems. IDS systems should be equipped with the components responsible for the permanent observation of the states of monitored nodes and components that integrate the results of these observations and diagnose the security level of the system. It is reasonable to apply the agency for solving the tasks of the network security monitoring. A multi-agent approach in a network monitoring system was used in works [7, 3, 10, 19] where the general system architecture was proposed.

In our approach we also apply the agency to solve the tasks of network security monitoring. In work [11] the framework of an original proposal of the intrusion

detection system based on the multi-agent approach was presented. In particular, the architecture of such system and the task of agents were specified. Proposed ideas were further developed and in the work [14] the problem of anomalies detection on the basis of the nodes traffic analysis was discussed. Then in the work [17] the agents' knowledge organisation and the general idea of the algorithm for detecting the distributed denial of service (DDoS) attack was proposed. In this work we develop the algorithm for detecting the distributed denial of service attack.

2 The General Agents' Knowledge Structure

It is assumed that two types of agents are in the monitoring system: managing agents and monitoring agents. Each monitoring agent ma is responsible for one monitoring region mr consisted of the set of nodes V . Managing agents may modify the size of the monitoring regions by adding or removing nodes from the set V . It is assumed that the monitoring regions may overlap.

2.1 The Characteristic of the Monitoring Agents

The agent ma observes the states of the nodes from his monitoring region mr with a reference to the some properties from the set P . ma stores all the observations in his private database DB .

Definition 1. A single observation of agent ma is a tuple:

$$O(v, (p, x), t) \in DB \quad (1)$$

where $v \in mr$, $p \in P$, $t \in T$, T is the universe of the timestamps and DB denotes the database of the agent ma .

Single observation $O(v, (p, x), t)$ refers to the situation that at the timestamp t the agent ma has observed in the node v the value of the parameter p equals x [17].

DB consists of the *set of observations* (see definition 1) and *communication data*. *Communication data* consists of the communication matrix CM of the timestamps in which the communication between the nodes took place.

The second module embodied in the monitoring agent is *the anomaly detection module* that is supplied by the observations from *the set of observations*. This module is responsible for data analyzing to detect the security policy violation in the network system [17].

Definition 2. An *anomaly detection module* of agent ma is defined as a triple:

$$AD = \langle DB_{[t_{b'}, t_{e'}]}, AT, AC \rangle \quad (2)$$

where:

- $DB_{[t_{b'}, t_{e'}]}$ is a subset of DB restricted to time interval $[t_{b'}, t_{e'}]$ and is defined as:

$$DB_{[t_{b'}, t_{e'}]} = \{O(v, (p, x), t) : p \in P, v \in mr; t \in [t_{b'}, t_{e'}]\} \quad (3)$$

For a chosen time interval $[t_b, t_e]$ each tuple $O(v, (p, x), t) \in DB$ that fulfils the following condition: $t \in [t_b, t_e]$ is sent into the *anomaly detection module AD*.

– *AT* is a table of discovered anomalies defined as:

$$AT = \{A(v, p, \alpha, [t_b, t_e]) : p \in P, v \in mr; [t_b, t_e] \subseteq [t_b', t_e']\} \quad (4)$$

A single anomaly $A(v, p, \alpha, [t_b, t_e]) \in AT$ is interpreted as the agent *ma* believes at the level α that in the time interval $[t_b, t_e]$ in the node v an anomaly connected with the property p occurred.

– *AC* is an *anomaly archive* consisted of discovered anomalies that are sent from *AT* after attack detection. However only anomalies connected with discovered attack are sent to the archive *AC*. In this way the time interval of discovered anomalies is not a criterion of sending given tuples $A(v, p, \alpha, [t_b, t_e])$ into *anomaly archive*.

Anomaly table AT is created for each monitoring region independently. On agents' autonomy assumption it is quite possible that one agent may discover anomaly state of the node v with reference to some property's value, while other agent having the same node in its monitoring area will not observed any anomaly with reference to this property's value.

The third module closed in internal agents' knowledge structure is *ontology module* that consists of the attack patterns. Each monitoring agent subordinates only to one managing agent.

2.2 The Characteristic of the Managing Agents

Managing agents are responsible for coordination and management of the monitoring system. The internal structure of the managing agents is as follows. Each managing agent is equipped with: *data storage module*, *data analysis module*, *attack detection module*, *queue task module* and *communication module*. In the *data storage module* two types of data are stored: data received from the monitoring agents and knowledge about the pattern of attacks. Data sent by monitoring agents are derived from their *anomaly detection modules*. In the *data analysis module* conflicts of inconsistent knowledge incoming from distributed resources are solved applying consensus methods. Many a time managing agent after receiving the *warn* message from a one agent, asks other agents about their opinions. Also the new patterns of attacks are discovered in the data analysis module.

The *attack detection module* is responsible for the attack detections. In the *attack detection module* there are embodied two algorithms: the algorithm for determining of the sources attack and the algorithm for determining of the attack propagation scenarios. In this paper the attention to the first algorithm is paid, see Section 4 for details. The *Queue task module* consists of the tasks that must be executed or delegated by managing agent [17].

3 The Language of Communication

The agents communicate with each other to exchange knowledge about the states of monitored nodes or send the requests. They use a *communication language* compatible

with standard ACL (Agent Communication Language) proposed by FIPA (Foundation of Intelligent Physical Agents) [15]. The ACL like KQML (Knowledge Query and Manipulation Language), developed by DARPA knowledge Sharing Effort, rely on speech act theory [2, 18]. These languages base on the performatives. The messages might be sent to one or more receivers. From the number of receivers point of view two types of performatives are considered: *peer-to-peer* and *multicast*. In the algorithm for determining the set of *Masters* following types of messages are used: *warn* messages, *multi_query_if* messages, *confirm* (*disconfirm*) messages and *multi_request* performatives with *inform* action execution. A monitoring agent *ma* sends the *warn* message to the managing agent as a warning of the anomaly detection in his monitoring region. There must exist a tuple $A(v, p, \alpha, [t_b, t_e])$ in the agent's *ma anomaly table*. The message with *query_if* performative is sent if the sender wants the receiver to ask about the anomaly appearance, i.e. the value of the parameter p in a given node v is higher than a given value x . *Multi_query_if* is used to send a query to a group of the agents. For example the managing agent may ask, if in the given time interval the value of the parameter p in a node v was abnormal i.e. higher than x : *multi_query_if*($A(v, (p > x), \alpha, [t_b, t_e])$). The *confirm* (*disconfirm*) message is send by the managing or monitoring agent if they want to confirm (*disconfirm*) the true of some proposition. If the managing agent sends *confirm* (*disconfirm*) message to more than only one agent then we have the *multi_confirm* (*multi_disconfirm*) message. The *multi_request* performative is sent by the managing agent to a group of monitoring agents. In this kind of message also the type of action must be specified. In the algorithm proposed in this paper an *inform* action is considered. In case of *multi_request* performatives with *inform* action execution the managing agent sends to the group of the monitoring agents a request of sending information about the discovered anomalies. If the managing agent requests of sending information about a state of a single node v with the reference to the one parameter p in the time interval $[t_b, t_e]$ then the message content is as follows: *send_information*($O(v, p, [t_b, t_e])$). The managing agent may also ask about the nodes that have been communicated wit a given node. In this case the *communication matrix* is analyzed.

4 The Algorithm for the DDoS Attack Detecting

The algorithm for the sources of *DDoS* attack detecting is embodied in the managing agent's *attack detection module*. It is assumed that network traffic should be analyzed in order to detect anomalies. The main purpose is to detect the attack before blocking the chosen goal. In order to detect the *DDoS* attacks the anomalies in traffic characteristics and anomalies in communication schemes must be observed. In the *DDoS* attack it is assumed that *Attacker* is the source of attack and initializes the overall attack in a computer network by putting a maliciously software in chosen computers (nodes). These nodes become *Masters*. In the next step each *Master* starts to infect other nodes that become *Demons*. Next *Demons* infect other nodes and those next ones etc. and in this way spreading stage is expanded. When sufficient number of nodes is infected or

at the fixed time point final attack or on earlier chosen computer (attack goal) is carried out. Due to the numerous numbers of requests sent simultaneously from different *Demons* at the same time interval to the *attack goal* all his resources are allocated and blocked [13].

4.1 The Idea of the Algorithm

The goal of applying the algorithm for the sources attack detecting is to determine the node $v^k \in V$ that is an *Attacker*. This algorithm consists of two main steps. In the first step the set of *Masters* is detected and in the second one on the base of *Masters'* input traffic analysis the *Attacker* is trailed. In this work the first Step is discussed in detail. The idea of the algorithm is as follows [17]:

- Step 1. Determine the set H of *Masters*.
- Step 2. If the cardinality of the set H is higher than threshold value τ then go to Step 3 else go to Step 1.
- Step 3. Apply the *procedure of the Attacker detection*.

4.2 The Algorithm for Determining the Set of the Masters

Let us assume that the set of managing agents is one-element and we detect the anomaly with reference to one monitored property.

The algorithm for determining the set of the *Masters* is divided into two parts: *Preliminary part* and *Principal part*.

Preliminary part

- Step 1. The monitoring agent *ma* detects the anomaly in the node $v \in mr$ with the reference to the property $p \in P$. It means that there exists the tuple $(v, p, \alpha, [t_b, t_e])$ in his anomaly table *AT*.
- Step 2. The agent *ma* determines the node $v_k \in mr$, in which the anomaly of the value of the parameter p appeared at earliest.
- Step 3. The monitoring agent *ma* affirms the *local anomaly* in his monitoring region, indicates the node v_k and sends a *warn message* to the managing agent.
- Step 4. If the node v_k is monitored by the other monitoring agents, then Go to the Step 5, else Go to the Step 8.
- Step 5. The managing agent asks other monitoring agents about their opinions about the state of the node v_k in a given time interval $[t_b - \Delta, t_e]$. The managing agent sends to them the message with *multi_request* performative with *inform action* execution.
- Step 6. The managing agent collects the answers and obtains consistent opinion about the state of the node v_k . In this step, the procedure for verification of the node state is carried out, in which the consensus methods are applied. The aim of this procedure is to obtain the agreement of the node state.
- Step 7. If anomaly exists then Go to Step 8 else send into the *queue task module* the task of the node state verification in some time.
- Step 8. The managing agent initializes *Principal part* of the algorithm.

Principal part

- Step 1. The managing agent asks monitoring agents which nodes communicated with the node v_k in the time interval $[t_{b-\Delta}, t_b]$. The managing agent sends the message with *multi_request* performative with *inform action* execution.
- Step 2. Monitoring agents on the basis of their communication matrixes determine the nodes that communicated with the node v_k in the time interval $[t_{b-\Delta}, t_b]$ and send the answers.
- Step 3. The managing agent obtains the set K of the nodes that communicated with the node v_k in the time interval $[t_{b-\Delta}, t_b]$.
- Step 4. The managing agent commissions the monitoring agents to verify if in the nodes from K the anomaly of the value of the parameter p in the time interval $[t_{b-\Delta}, t_b]$ appeared. For each $v \in K$ the managing agent sends the message with *multi_guery_if* performative.
- Step 5. Monitoring agents on the basis of their anomaly tables send the answers to the managing agent.
- Step 6. The managing agent determines the set of infected nodes K' . If the nodes from K' are monitored by more than one monitoring agents, then the managing agent obtains the consensus opinion about the anomalies.
- Step 7. If the set K' is not empty then go to Step 8 else go to Step 9.
- Step 8. From the set K' managing agent selects the node v' that communicated with the node v_k at earliest and applies for the node v' the *Principal Part*. Go to the Step 1.
- Step 9. The node v_k is a *Master*. Include v_k into the set H . Stop.

4.3 An Example

Fig. 1 shows the anomaly of the input and output traffic in the node $v_2 \in mr_3$. The node v_2 is monitored by the agent ma_3 . This agent has observed the anomaly of the input traffic in the following time intervals: $[t_3, t_7]$, $[t_{11}, t_{16}]$, $[t_{18}, t_{20}]$ and $[t_{20}, t_{25}]$ with the reference to the values of p_1 and p_2 . In the time intervals: $[t_9, t_{14}]$ and $[t_{19}, t_{23}]$ the anomaly of the output traffic has been observed. The nodes: $v_3, v_{13}, v_{17}, v_{16}, v_{15}$ communicated with v_2 while v_2 communicated with v_8 and v_{19} .

Fig. 1. Anomaly of the input and output traffic in the node v_2

Fig. 2. Graphic representation of the piece of the anomaly table created by the ma_3 .

- the anomaly of the parameter p_1 in the time intervals $[t_3, t_7]$ and $[t_{18}, t_{20}]$
- the anomaly of the parameter p_2 in the time intervals $[t_{11}, t_{16}]$ and $[t_{20}, t_{25}]$
- the anomaly of the parameter p_3 in the time interval $[t_9, t_{14}]$
- the anomaly of the parameter p_4 in the time interval $[t_{19}, t_{23}]$

Let us concentrate on the analyzing of the parameter p_3 . On the basis of the time intervals in which this anomaly occurred we deduce that the node v_3 is the local source of the attack in the region mr_3 . Let us assume the belief coefficient α equals 1 for all detected anomalies and the coefficient Δ equals 4.

The algorithm for determining the set of the *Masters* is as follows.

Preliminary part

- Step 1. The monitoring agent ma_3 detects the anomaly in the node $v_3 \in mr_3$ with the reference to the property $p_3 \in P$. It means that there exists the tuple $(v_3, p_3, l, [t_9, t_{14}])$ in his anomaly table AT .
- Step 2. The agent ma_3 determines the node $v_3 \in mr_3$, in which the anomaly of p_3 appeared at earliest.
- Step 3. The monitoring agent ma_3 sends *warn message* to the managing agent.
- Step 4. The node v_3 is monitored only by the one agent.
- Step 8. The managing agent initializes *Principal part* of the algorithm.

Principal part

- Step 1. The managing agent asks monitoring agents which nodes communicated with the node v_3 in the time interval $[t_0, t_4]$. The managing agent sends the message with *multi_request* performative with *inform action* execution.
- Step 2. Monitoring agents on the basis of their communication matrixes send the answers.

- Step 3. The managing agent receives the answers from two agents: ma_1 and ma_2 and determines the set $K = \{v_7, v_9, v_{12}\}$ (Fig 3).
- Step 4. The managing agent commissions the monitoring agents to verify if in the nodes from K the anomaly of the value of the parameter p_3 in the time interval $[t_0, t_4]$ appeared. The managing agent sends the message with *multi_query_if* performative.
- Step 5. Monitoring agents on the basis of their anomaly tables send the answers to the managing agent.
- Step 6. The managing agent determines the set K' of infected nodes: $K = \{v_7, v_{12}\}$
- Step 8. From the set K' managing agent selects the node v_7 and applies for the node v_7 the *Principal Part*. Go to the Step 1.

Fig. 3. The nodes v_7 , v_9 and v_{12} have communicated with the node v_3 and one of them has infected the node v_3 .

5 Conclusions

In this paper the problem of automatic intrusion detection was discussed. This paper is a continuation of the issues presented in previous works [11, 14]. In particular the ideas presented in [17] were here developed and the algorithm for automatic detecting of the *DDoS* attack was in detail described. This algorithm consists of two parts and the first part was here discussed. As a future work the second part of the algorithm must be developed and practical verification of presented results must be done.

Applying agency into the tasks of intrusions detection is the chance of building of the automatic intrusion detection systems that act in an incomplete, inconsistent and unpredictable environment. Agents as autonomous entities observe the nodes, take the decisions, communicate each other, integrate the results of their local activity and solve the global task of intrusion detection. In this paper we concentrate on the presentation of the algorithm for intrusion detection, and it was assumed that after discovering the anomaly of some parameter the agents apply the algorithm for the source of

DDOS attack detection. It must be pointed out that the anomalies discovering plays a crucial role in a whole system. This problem basis not only on measuring some parameters and comparing them with templates but also requires taking into account other individual nodes' characteristics. Undoubtedly the effectiveness of monitoring system depends not only on the applied intrusion detection algorithms but also on the input of these algorithms i.e. effectiveness of lower layers responsible for anomalies detecting.

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