SPMA-NETS: SECURITY PROTOCOL BASED MOBILE AGENT IN MANETS

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ABSTRACT

The security in the communication process is an important issue since the days of homing pigeons, where the people accustomed to send encrypted messages. In nowadays, with the technologies development, this issue is considered as a research field, which take a great part of attention. The mobile ad hoc network is aspect of the evolution of communication technology; it is defined a collection of mobile nodes, with no fixed infrastructure, resource constraints, communicate with each other using the radio medium, and dynamic creation and organization. The security issue is becoming a main concern in the applications of mobile ad hoc network.

In this paper, we propose a security protocol for a mobile ad hoc networks based mobile agent, where the network is consisting of a set of nodes, each node has node agent for resources estimation of the node and communicate with others agents. The network is divided into a set of clusters; each cluster has to elect a node to be the head cluster, where the monitor agent will be reside. This monitor agent controls the communication inside cluster by collecting and analysing the data from the others nodes, it creates an inspector agent, which can move from one node to another to act like a local IDS in the visited node.

KEYWORDS: Mobile Ad Hoc Network, Mobile Agent, Security Protocol, Trust, IDS, Aglets.

1 INTRODUCTION

A mobile ad hoc network (MANET) is a collection of wireless mobile nodes (or routers) dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration. Thus, the network's wireless topology can be formed anywhere, at any time, may change rapidly, and unpredictably [1]. Nodes (e.g. laptop computers, PDAs, mobile phones, or even sensors) two or more are connected and communicate with one another either directly when they are in radio range of each other or via intermediate mobile nodes [2].

In fact, MANET has attracted considerable attentions due to variety of services and applications have been developing in military tactical, commercial, educational, nomadic computing, facilitate of communication in catastrophic disaster areas and during terrorist attacks, and so on. However, security design in mobile ad hoc network has to face the lack of clear line of defense. Each node in an ad hoc network may function as a router and forward packets for other peer nodes. There is no well-defined place where the traffic monitoring or access control mechanisms can be deployed. This makes the separation of inside from outside network domain obscure [3]. Moreover, different applications have different security requirements, where each application focus on parts of the problem [4]. A multitude of proposals vary between trust and key management, secure routing and intrusion detection, availability and cryptographic protocols.

According to the first classification base, MANET routing protocols are proactive, reactive, or hybrid. According to the role-based classification, MANET routing protocols are either uniform when all network nodes have the same role or non-uniform when the roles are different and dedicated. To optimize the communication in MANETs, which is an important source of resource consumption, one solution is to structure the network into clusters [5]. Each cluster represented by a particular node called cluster head. A node elected cluster head according to a specific metrics vary of application to another. Multiple clustering solutions have been proposing.

The mobile agent has received considerable attention in recent years for its wide applications in various areas of computing technology. This has led to deal more efficiently and elegantly with the dynamic, heterogeneous, and open environment like the mobile ad hoc network.

Therefore, in this paper we propose a security protocol based mobile agent for mobile ad hoc networks that aims to improve the level of security. This protocol based on network organization at three levels (node level, cluster level, and network level) for hierarchical management of the security services. Our contribution is the use of an optimization function of five parameters to evaluate node resources and the formula to estimate the trust ability of the node, a network topology based on the concept of clusters with the mobile agent technology. We use three agents; Node Agent (NA) manages node resources depending on

the capacity and the proposed conditions. Monitor Agent (MA) who considered a representative of the cluster; it has information about all communication inside the cluster and participates with its counterparts in the security network completely, it creates inspector agent(s) and sends to all nodes of the cluster for surprise inspections (i.e. it gets on the operations carried out during the previous period of the node agent, analysis this operation, back to the monitor agent, and deliver it a report that includes is there a threat or not in a node.

The remainder of the paper is organized as follows. The following section presents the related work. Section 3 describes our proposed protocol. Results and tests are show in section 4. Section 5 concludes this paper by summarizing our protocol and outlining some future research directions.

2 RELATED WORKS

The different directions of progressing research in ad hoc networks are based on security challenges that cover various classes of security attacks and how ad hoc network can defend against those attacks. Various other approaches are proposed in the last few years based on existing mechanism, one of this mechanism discussed in [6], where the network is splitted into a power two number grid clusters, respecting to the available battery level a node in the cluster is elected to be the cluster head and the rest nodes become cluster members, in each cluster there is a dedicated mobile agent consist of four modules: Registration Module (RM), Service Agreement (SA), Detection Module (DM) and Prevention Module (PM).

All the node in the cluster including the cluster head have to be register with mobile agent, and the MA store the list of all cluster nodes in the RA, the Detection Module of the mobile agent analyse the packets exchanged between nodes, if any mismatch is found, the MA informs the CH to drop the packet and to block the node. The communication inter-cluster is possible with the same supervision of the MA, but the packets have to be transmitted from CH to the other CH.

A new approach called securing DSR with mobile agents in wireless ad hoc networks proposed in [7]. The authors try to secure Dynamic Source Routing (DSR) protocol of an ad hoc network by using mobile agents. There are three types of mobile agents used in this routing protocol: discovery/reply of mobile agent, maintenance of mobile agent, update/approve for symmetric key mobile agent. Hybrid encryption technique (symmetric key encryption/public key encryption) is used to improve performance; where symmetric keys are used to encrypt routing data to authenticate and authorize node sending data, while, public keys are used for the exchange of symmetric keys between nodes.

The distributed trust based framework presented in [8] to protect the agents and the host platforms against threats of the environment like the kill of the agents while visiting some hosts, the authors propose a threat model, where they assume that any node in the network can be malicious node, which kill or misrouting the arrived agent. Due to the nature of MANET nodes can only have an opinion about its neighbours, this opinion in defined as the degree of trust between nodes. The authors define a model of trust as a reputation system, where they defined three concepts: belief (how much trustworthy a host is) or disbelief (how much suspected a host is) as well as uncertainty, this expressed mathematically as: $b + d + u=1$. Here b, d, u designate belief, disbelief and uncertainty respectively. They claimed that nodes can detect all the malicious nodes and eventually prevent themselves and their agents from network hostilities.

Another work proposed new approach in [9], where mobile agents collect information about the nodes of a cluster by visiting them one by one, until it returns to the cluster head, this information is used by the cluster head to process of key deactivation, common leader election and key serving nodes selection one way hash function protects the code of the mobile agent against any malicious modification. A secret key of cluster nodes is generated based on a distributed private key generation scheme, used for validate the identity of the cluster head and cluster's members. The paper presents the behaviour of the proposed protocol against several scenarios like: Masquerading, Eavesdropping, Unauthorized access and alteration, and Denial of service. The simulation of the proposed protocol is carried on using the ns-2 simulator because it is very used in such problems. The authors claim that the proposed schema is effective and provides a high packet delivery ratio and low delay compared to the cluster based routing protocol CBRP

The authors of [10] define a new composite key management technique for key management in ad hoc network. A network is partitioned into clusters based on the dominator concept, in each cluster a node considered the most trusted and active is elected as a cluster head. A fuzzy logic controller calculates the degree of trust of nodes, which represent the degree of belief about the future behavior of other entities. In addition to the public key, each node has also a private key generate by a specific cluster called the Primary Key Generation, which are a number of cluster head with high value of trust.

Agent based trusted on-demand routing protocol for mobile ad-hoc networks is presented in [11], authors propose a protocol called ATDSR. It selects the most trusted as well as the minimum hop count route from different possible routes with minimal overhead in terms of extra messages and time delay. This protocol uses a multi-agent system (MAS) that consists of two types of agents that cooperate with each other to achieve the required task; specifically monitoring agent (MOA) and routing agent (ROA). MOA is responsible for monitoring its hosting node behavior in the routing process and then computing the trust value for this node. ROA is responsible for using the trust information and finding out the trust worthiest route for a particular destination.

3 THE PROPOSED PROTOCOL

In fact, we divide the network into clusters where each cluster has a dominator. The construction of clusters are a distributed manner, a self-organisable, and under the proposed conditions. There are three kind of agents: Node Agent, Monitor Agent, and Inspector Agent.

3.1 Organization of the Network

In our model, the security is carried out in three levels (Node Level, Cluster Level, and Network Level) by a set of agents, which communicate with each other a secure manner.

3.1.1 Node Level

The node agent is installed in each node to estimate available resources to better manage the resources of the node (battery, degree node, CPU and memory,) in order to satisfy application security requirements. We take into account the parameters TL, EL, DN, CL, and ML, to calculate the full capacity C_{ni} of the terminal, whereas:

$$C_{ni} = f\,(TL, EL, DN, CL, ML)$$

Knowing that:

TL: Trust Level

EL: Energy Level

DN: Degree Node (i.e. the highest number of neighbors)

CL: CPU Load

ML: Memory Load

To simplify our protocol, we assume that these parameters are independent and we introduce the following equation to measure the capacity of a node:

$$Cni = aTL + bEL + cDN + dCL + eML$$

Where:

a, b, c, d, e : are the security management parameters to favor a resource or a terminal compared to the other depending on the role of the agent will play or the proposed conditions, while: a + b + c + d + e =1.

3.1.2 Cluster Level

This level describes the interactions between nodes within the same group to manage local of various security features. Here the node takes the state: Member or Cluster Head.

3.1.3 Network Level

A network organizes as a set of clusters, each cluster is a set of nodes. We proposed a mechanism of mobile agent to manage security interactions between different clusters. The following figure illustrates the general architecture of our protocol.

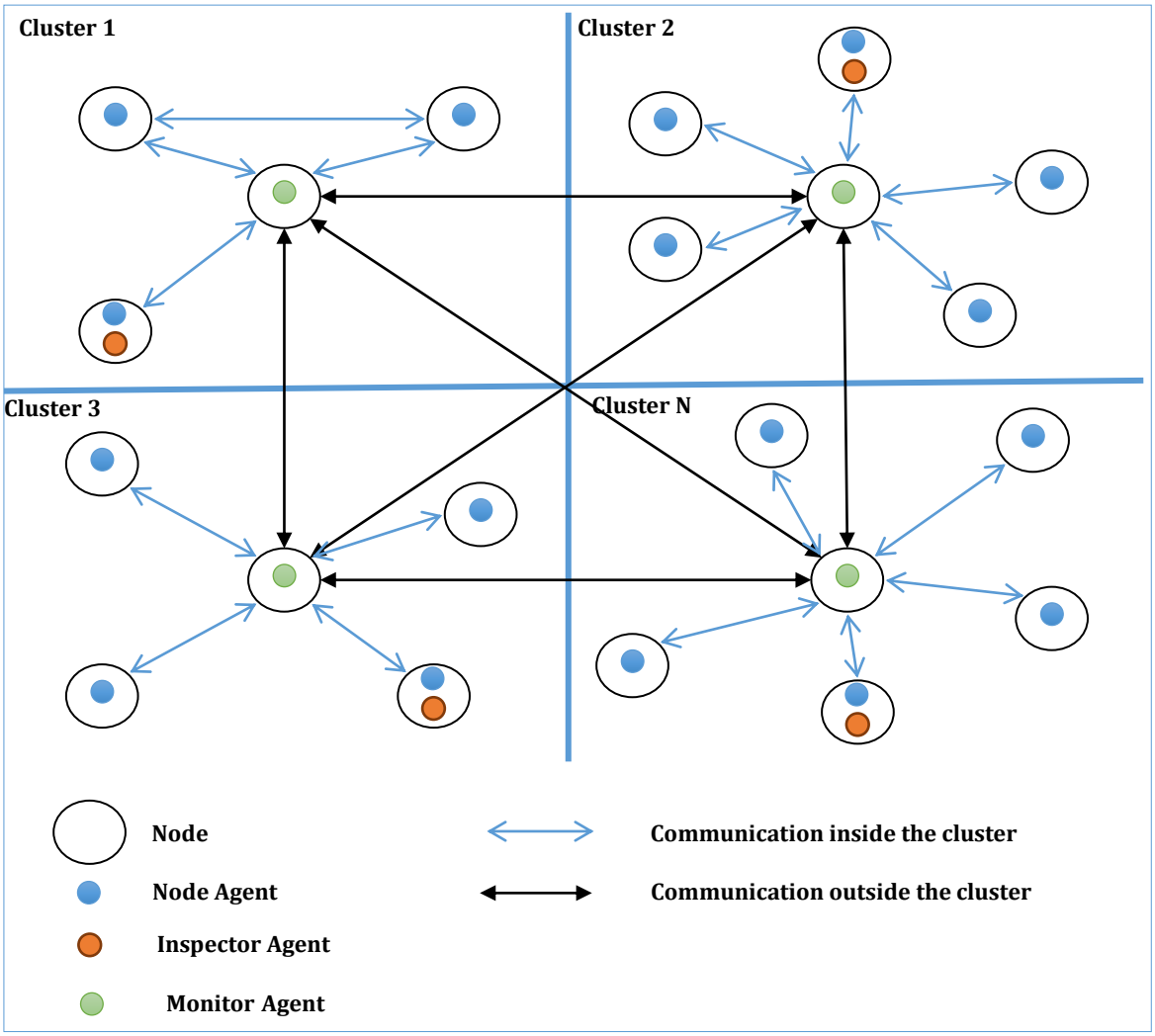

Figure 01: Our proposed architecture for security protocol based Mobile Agent in MANETs

3.2 Modeling of the Trust Level

The aggregation of mistake and malicious behavior generated by the node is an important element in the elaboration of a final decision as estimating the trust that can grant to an entity (node). Let P = {p_1, p_2,….., p_i,….,p_n} the set of parameters involved in the evaluation of the trust. For example, a message/agent dropped, a message altered, a message delayed, a message repeated, and wrong password, etc. Let W_i is represent the weight assigned to the parameter P_i. The introduction of a weighting of different parameters to aggregate proposed. The Trust (T) formula is as follows:

$$T = 100 - \sum_{i=1}^{n} |P_i| * W_i$$

Where: $|P_i|$ is the number of occurrence of the error Pi, the following function shows how to determine the level of trust.

```
Function   getleveloftrust
(int T)
{If 80 ≤ T ≤ 100 then
  Trust_Level:   =   'Fully
Trusted'
Else If 60 ≤ T < 80 then
  Trust_Level: = 'Normal'
Else If 40 ≤ T < 60 then
  Trust_Level: = 'Average'
Else If 20 ≤ T < 40 then
  Trust_Level: = 'Low'
Else If T < 20 then
  Trust_Level:    =    'Not
Trusted'
Return Trust_Level
```

Algorithm 01: Determine the Level of Trust

The definition of the trust parameters and weightings made by the network administrator. These two operations very linked to the service security criteria. If the ratio between the number of success operations and the number of all operations is greater than a defined threshold, we update the value of trust level by adding the average of weights assigned to mistakes and malicious behaviors. Therefore, the Trust Level will increase as follows:

$$T = T + \frac{\sum W_i}{|W_i|}$$

3.3 Architecture of the Mobile Agent

In our protocol, there are three agents: Node Agent (NA), Inspector Agent (IA), and Monitor Agent (MA). We present in the following the internal architecture of these agents. This architecture based on components where every component implements some functions of the agent.

3.3.1 Architecture of Node Agent

The node agent is installed in each node, it maintains routing table that represented by conceptual data structures with the necessary information. The structure of the routing table is the following:

Table 01: Structure of the Routing Table

Neighbor_ID	Cluster_ID	State	C_{ni}	Threshold
@ IP_N	@ IP_C	M/H	%	%

Knowing that:

Neighbor_ID: is an identifier of a neighbor, we use the IP address of a node to identify it.

Cluster_ID: is an identifier of a cluster, we use the IP address and the name of a cluster head.

State: this field designs the state of a node agent it may be a member or a cluster head.

C_{ni}: represents the capacity of the node that calculated by the node agent.

Threshold: represents the degree of capacity, if the capacity of a terminal reaches a constant value, it is necessary to inform others to reduce their load, or can be removed or replaced. Figure 1 shows the architecture of the node agent, the main components that allow the agent implementation are the following:

Security component: this component has a function is to ensure the security agent against all malicious access, protect all information that is sent to other agents by well-defined mechanisms as symmetric and asymmetric key, etc.

Reception component: the reception's role is to receive information from other agents for evaluation or communication between them (e.g. information on the node resources, routing table, etc.).

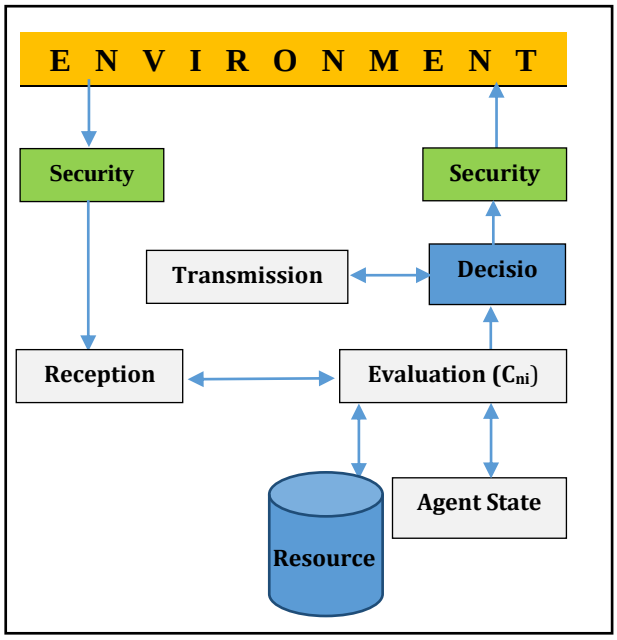

Figure 02: Architecture of Node Agent

Evaluation component: an agent is evaluate the resources of the node according to the optimization function that previously presented and proposed conditions.

Transmission: the transmission's role is to send message to other agents.

Decision component: it allows the agent to select the action to perform.

3.3.2 Architecture of Monitor Agent

The monitor agent is created in the node that called cluster head. This agent is the most important among other agents, where it is responsible for all operations within the cluster and outside with counterparts. The monitor agent maintains a table of confidence it contains the necessary information for the trustworthiness and authentication of each node in the cluster. The structure of the confidence table is:

Table 02: Structure of the Confidence Table

Node	ID	Trust Level	Public Key
1			
2			
..			
..			
N			

Knowing that:

ID: Is an identifier of a node, where each node has a unique identifier.

Trust Level: This field takes the following properties (Not Trusted, Low, Average, Normal, and Fully Trusted).

Public Key: A key generated by Monitor Agent.

The same status in the architecture of node agent, which based on components for simplicity, adaptability, evolution, and code reuse, etc., where every component implements some functions of the agent. The architecture of Monitor Agent is as follows:

Collection component: A collection component collects activity information (for instance, the process of sending and receiving agents, messages, agent log files, etc.), either in a single node from node agent or cluster level from inspector agent. Those data are gives as an input analyzer component.

Analyzer component: An analyzer implement a erification policy, which is a set of rules defined for a set of events related to the node system or/and agent system (e.g. changes in the execution context or behavior).

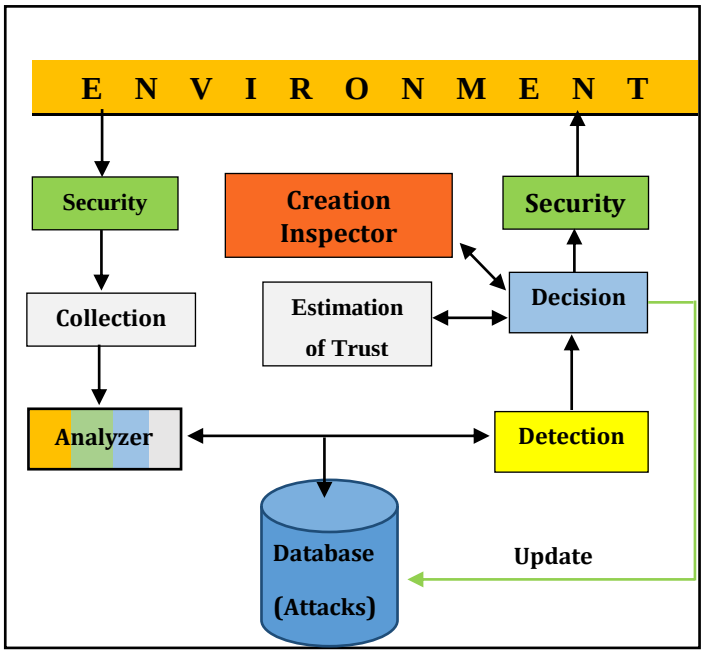

Figure 03: Architecture of Monitor Agent

Detection component: Their goal is a classification and detection. It uses results provided by Analyzer Component to detect the type of intrusions. It includes both a misuse detection, an anomaly detection, and specification detection. The procedure of a misuse detection used to determine the exact types of attacks by using the pattern matching algorithm. An anomaly detection procedure used to detect new or unknown attacks by using the classification techniques. Specification detection is a procedure where we defined a set of constraints that describe the correct operation of our protocol. The execution of the protocol should respect the defined constraints.

Estimation component: This component evaluates the trust level of a node by the formula that is already proposed. Therefore, the agent takes a decision (e.g.it will elect as cluster head, exclusion of the cluster and the network, or attempt to repair if it is possible).

3.3.3 Architecture of Inspector Agent

The Inspector Agent (IA) is created periodically by the Monitor Agent, it roles is to inspect each node locally and send the results to the monitor agent. Therefore, it travails from node to another to examine the actions history of each node agent to detect any suspect behaviour (like sleep deprivation…. or the black hole). If the node agent is not trusted, the inspector agent can compare its history action with the history actions of its communication partners. The life cycle of a transporter agent initialized to be active, waiting, suspended, move, and dispose.

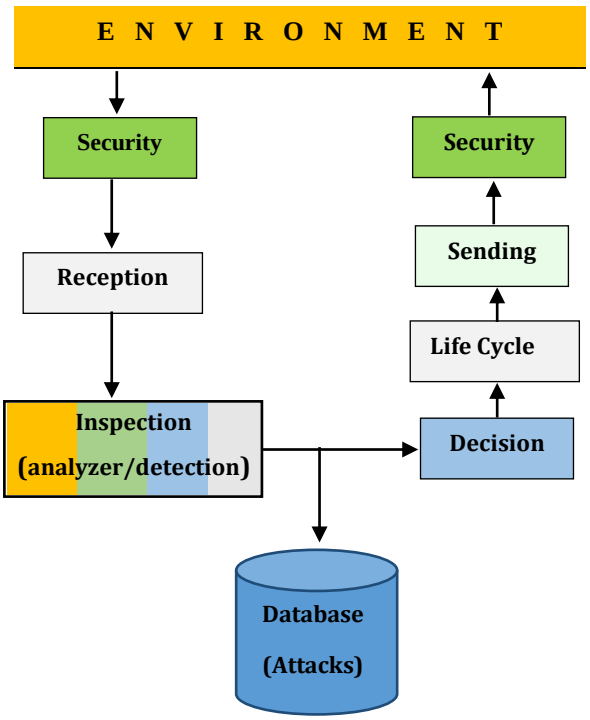

Figure 04: Architecture of Inspector Agent

3.4 Class Diagrams of Protocol

Here we show the class diagram of our protocol, which contains a Node Agent, an Inspector Agent, and a Monitor Agent.

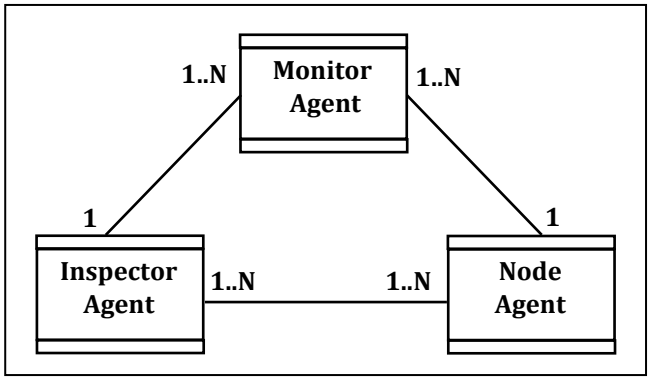

Figure 05: Class Diagrams of our protocol

3.5 Communication Protocol

When a source node wants to send a message to the destination node, it creates a message contains information about source and destination node, table 3 shows the whole structure of this message:

Table 03: Structure of the Message

Node	ID_SN	ID_DN	ID_TA	Hash
1				
2				
..				
N				

Knowing that:
ID_SN: is the unique identifier of the Source Node.
ID_DN: is the unique identifier of the Destination Node.
Data : is the continent of the message.
Hash: hash value is useful for verifying the integrity of data sent through the nodes of network. The hash value of sent data of the source node must be compared between the hash value of received data of the destination node to determine whether the data was altered. In our protocol, we used Secure Hash Algorithm 1 (SHA-1).

After the formation of the clusters, the node agent of cluster head change its state to Monitor agent of the cluster. The monitor agent creates the inspector agent(s) and sending periodically to all nodes in the cluster. The role of inspector agent is to move from node to another, in each node it collects, analyses, and inspects the behavior of node agent to detect any malicious actions. In other words, the inspector agent works like an IDS at the node level. When a source node A wants to send data to a destination node B. There are two cases, the first one, where node B and D are in the same cluster. The process of sequence diagram shown in Fig 6: Sequence Diagram (a).

1. Node Agent A (NAA) requests from its Monitor Agent is the node B trust?

2. Monitor Agent (MA) sends the trust level of the node B to the Node Agent A, if the trust level of the node B is greater than 'Not Trusted'.

3. NAA encrypted a Message, if the node B is neighbor of node A, we use low technic of encryption ( ), if the node B is not neighbor of A but in the same cluster, we use medium technic of encryption ( ).

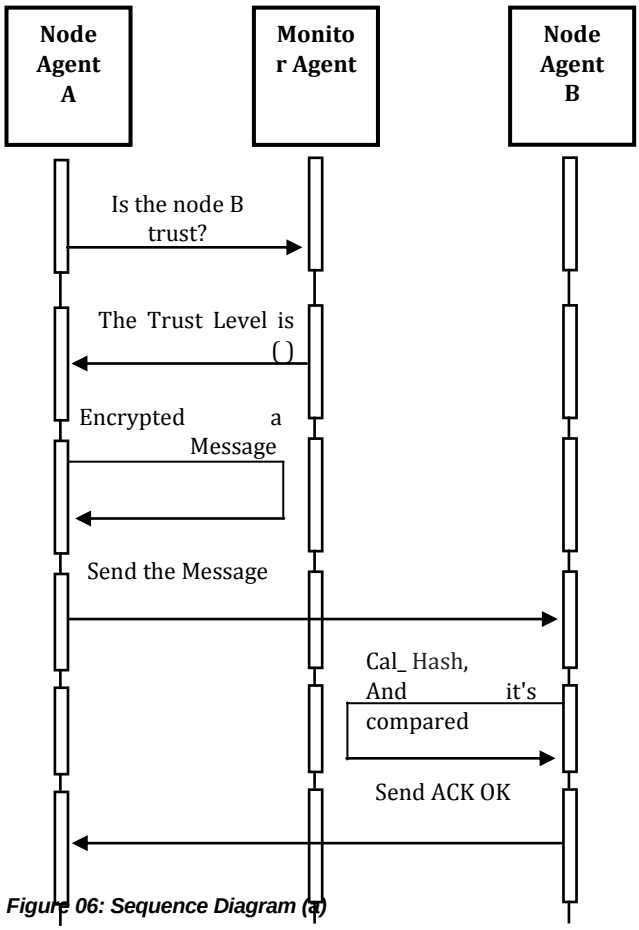

Figure 06: Sequence Diagram (a)

4. NAA sends the message to NAB.

5. NAB accepts the message, calculates the Hash to verify the integrity of the message.

6. If the hash is equal then, it is sends to the (NAA) ACK OK. Otherwise, it sends ACK not OK and alert message to Monitor Agent.

The second case (b), the source node B and destination node D are in different cluster. The process of sequence diagram shown in Fig 7: Sequence Diagram (b)

1. The NAA requests from the Monitor Agent of cluster which continent the node A (MAA), is the node D trust?

2. The MAA searches on the node D in its Confidence Table (CT) and did not find, it sends a request to all its counterparts, the MA of node D (MAD) response it and sends to it the trust level of the node D, if it is greater than 'Not Trusted', which resends the response to MAA.

3. The NAA encrypts message, it sends to its MAA, while the MAA resends this message to MAD.

4. The Node Agent D (NAD) accepts the message, calculates the Hash to verify the integrity of the message.

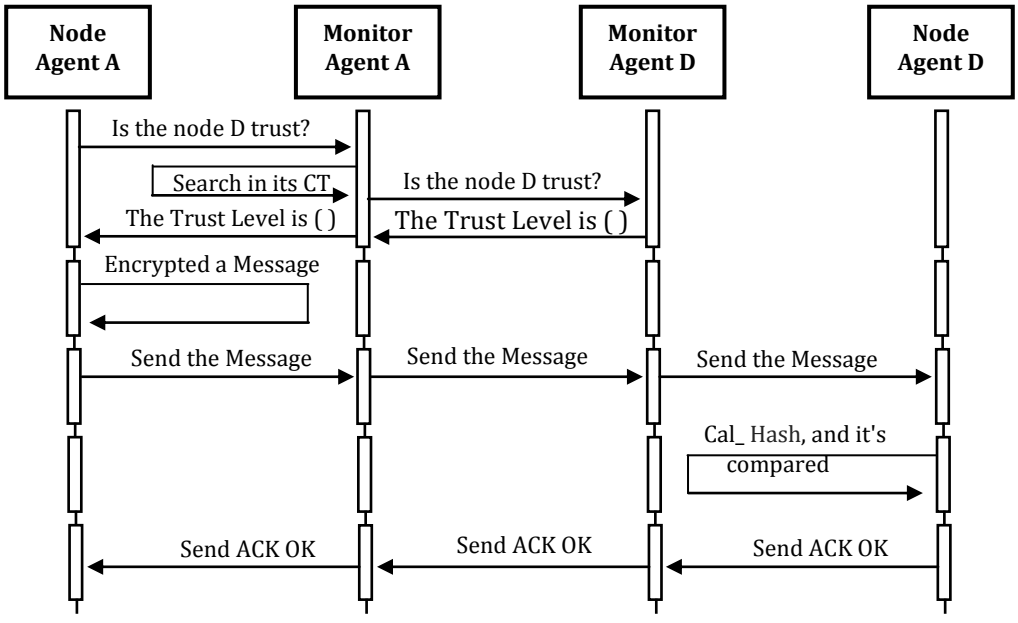

Figure 07: Sequence Diagram (b)

5. If the hash is equal then, it is sends to the (MAD) ACK OK, the MAD resends it to MAA until it reaches the NAA. Otherwise, it sends ACK not OK and alert message to its Monitor Agent, which turn sends this warning to all its counterparts in the network.

4 IMPLEMENTATION AND TESTS

In order to implement our protocol we used a platform for developing mobile agents published by IBM called Aglets, accompanied with java development kit (JDK 7) and the NetBeans IDE version 8.0.2. For testing the prototype, we are using ad hoc network consisted of four node (laptop), where every node is configured to run the Aglet Agents.

Note1: We assume the values of coefficient (a, b, c, d, e) as follows: a = 0.5, b = 0.3, c = 0.2, d = - 0.05, e = - 0.05.

Note2: In the initial state, we gave the node that called maqbol and URL: atp://Node2:5002, the value =100 (Fully Trusted) of the trust level, while the other nodes takes the value = 59 (Average) of the trust level.

Note3: The degree of node = 60, i.e. the node has three neighbors, while the value = 40, i.e. the node has two neighbors.

The following figure illustrated an example of initial state of the node, the Tahiti of the Aglets platform where the node agent created and calculated the value of C_{ni}.

Figure 08: Illustrated an example of initial state of the node

The fig 9 indicates the process of election between four ad hoc nodes where the node that called maqbol and URL: atp://Node2:5002 elected as Monitor Agent because it has the more capacity C_{ni} that equal = 90.75%. While others nodes takes the Member states.

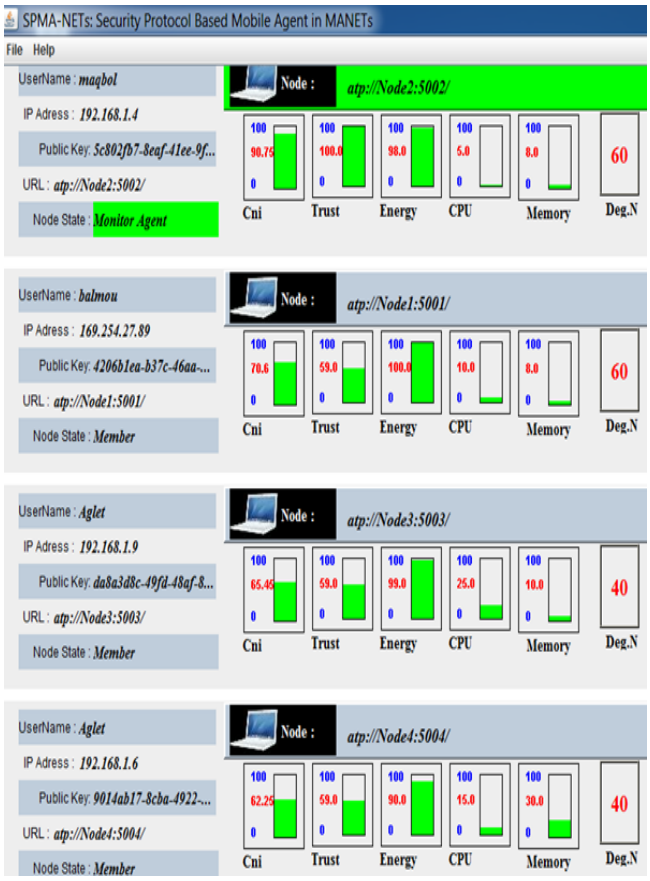

Figure 10: Explained the election process

After the election process, the Monitor agent creates the Inspector Agent as in fig 11, dispatch it to any node, which travels from one node to another for detect any attack or suspicious behavior, and it then returns to the original node (see the following figures respectively).

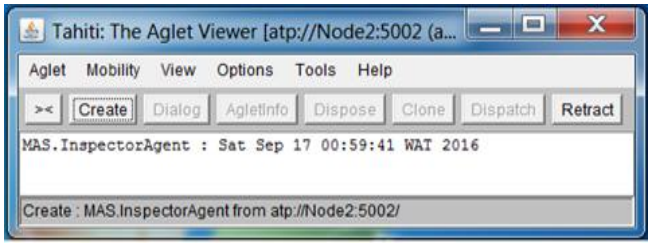

Figure 11: shows the creation of Inspector Agent

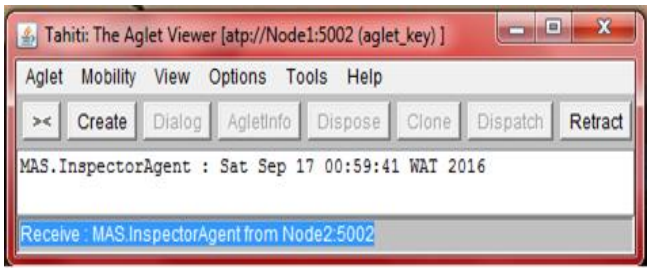

Figure 12: shows the travels of Inspector Agent from Node2 to Node1

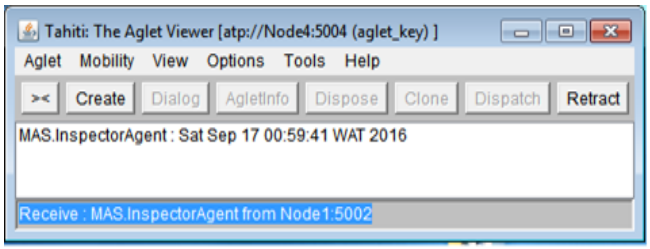

Figure 13: shows the travels of Inspector Agent from Node1 to Node4

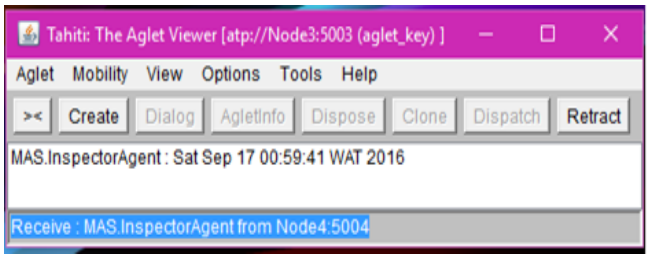

Figure 14: shows the travels of Inspector Agent from Node4 to Node3

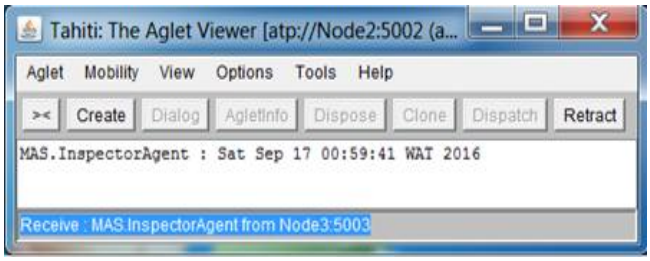

Figure 15: shows the returns of Inspector Agent from Node3 to Node2

In our experimental results, shows the proposed protocol is expected to perform better in all situations. For example, in the first scenario, we tested our protocol to detect Black Hole attack as in figure 13.

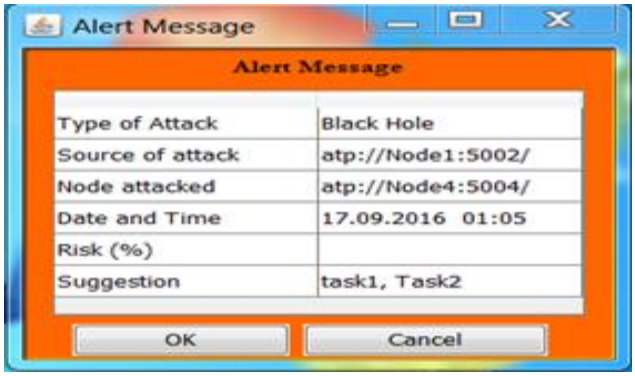

Figure 16: Illustrates the detection of Black Hole attack

In the second scenario, it is succeed to detect Denial of Service attack as in figure 14. The Inspector Agent sends or delivers to the Monitor Agent an alert message contains the necessary information such as: Type of Attack, Source of attack, Node attacked, Date and Time, Percentage of Risk, and Suggestion.

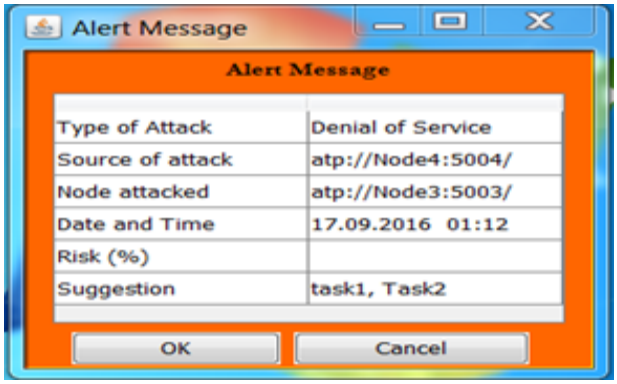

Fig ure17: Illustrates the detection of Denial of Service attack

5 CONCLUSION

In this paper we focused on the security in the MANET, therefore we proposed a security protocol based mobile agent in MANETs, we adopted a network structured as a set of cluster, these clusters are composed of a set of nodes, one of this node is elected as the cluster head (Monitor Agent), and the rest nodes as ordinary members. In our proposition we defined three types of agents: Node Agent (NA) exist in all the node of the cluster, after the process of cluster head election, the NA in the cluster head transform to be the Monitor Agent (MA), where it roles is to collects information about all operations in the cluster from the NAs, to detect any suspicious behaviour, it creates also the Inspector Agent (IA), which move from node to another to analyse and inspect the action in each node, and alert the MA if it detect any malicious or suspicious actions. To implement the proposed protocol we choose to use the Aglet platform, because it is appropriate for developing mobile agent.

Based on the obtained results, we can summarise that the implementation of our protocol satisfy the main objectives of the security.

Authentication: Where we used the Monitor Agent after the election process as trusted site.

Confidentiality: We used the mechanism of cryptography symmetric inside the cluster and asymmetric outside the cluster.

Availability: The Monitor Agent checks the presence of Nodes by it sends a message or by Inspector Agent.

Integrity: To realize the integrity we use the hash value for verifying the data sent through the nodes of network. In our protocol, we used Secure Hash Algorithm 1 (SHA-1).

Non-repudiation: The repudiation cannot appears in our

protocol because Node Agent records all sends and receives operations and the Inspector Agent has the ability to detect any repudiation through analysis and comparison.

In our future research, we addressed some attack especially the attack of masquerade, which appears if an agent pretend to be a very trustful entity for wining a main position in the network with evil intent.

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