International Journal of Software Engineering and Its Applications
Vol.8, No.7 (2014), pp.133-148
http://dx.doi.org/10.14257/ijseia.2014.8.7,11

Proposition of a new approach to adapt SIP protocol to Ad hoc Networks

I. Mourtaji, M. Bouhorma, M. Benahmed and A. Bouhdir

Computer and Communication Systems Laboratory
Abdelmalek Essaadi University
Tangier Morocco
imourtaji@gmail.com, bouhorma@gmail.com, med.benahmed@gmail.com, hakim.anouar@gmail.com

Abstract

Through this paper we propose a new approach to fix the problem related to the deployment of SIP protocol in Ad Hoc Networks. In fact in an Ad hoc network context, there is no available centralized architecture to accommodate different key servers for SIP operations.

The main idea of this new approach, which we have named VNSIP (Virtual Network for Session Initiation Protocol), is to self-organize the ad hoc network using a virtual backbone, and then this virtual network will be used as architecture to ensure dierent roles of SIP entities. We have evaluated performances of our technique using comparison with TCA approach, which is considered as one of the most satisfying solution to adapt SIP to Ad hoc networks.

During this paper we have treated the notion of QoS in MANET (Mobile Ad hoc Networks) as well. In fact we will explain, at the end of the comparison, that despite the fact that our solution offers overall better results than TCA, it nevertheless suffers from a high consumption of bandwidth, which forced us to enhance VNSIP performance regarding this constraint of bandwidth. Therefore we have designed a new algorithm to enhance QoS inside MANETs. We have named this algorithm MCAC (MANET Call Admission Control). This algorithm counts the number of simultaneous calls or sessions inside the MANET, and refuses the establishment of new sessions when a maximum number of simultaneous calls is reached. By this manner we can control the bandwidth of the MANET and consequently guarantee a good QoS.

Keywords: *MANET, SIP, QoS*

1. Introduction

Ad Hoc Networks provide a real opportunity to design flexible networks, very simple to deploy. However they remain a particular computation environment, characterized by the deficiency of pre-existed and centralized infrastructure. In the other hand, SIP protocol [ROS 02], which knows a huge booming in internet networks, requires centralized entities, like proxy server (PS), registrar server (RS) and location service (LS). Consequently SIP is not adapted to Ad Hoc networks.

In this chapter we will present a new solution that we have designed to resolve the problem related to the constraints of SIP deployment in Ad Hoc network. We have named this solution VNSIP (Virtual Network for SIP). The main idea of this technique is to create a virtual infrastructure, enabling SIP to proceed in a distributed architecture inside the Ad hoc

ISSN: 1738-9984 IJSEIA

Network. Using this technique, we will be able to design a virtual sub-network, which will be used by SIP [ROA 02] in a high mobility Ad Hoc network. VNSIP allows decentralization of SIP proxies, specially registrar, proxy and location servers, by integrating those server functionalities in each MANET node. VNSIP node contains a supervisor module which we called Virtual Network Algorithm (VNA), and which is responsible of activating and deactivating server functionalities depending on the position of the node in the MANET (Mobile Ad Hoc Network) [COR 99]. This chapter is organized as follows. In the second paragraph we'll introduce VNSIP solution. In the third paragraph we'll illustrate VNSIP design. Afterward in the next section, we will evaluate VNSIP performance using comparison with TCA approach [BAN 06]. In the next paragraph we present MCAC algorithm which improves VNSIP performances. In the end, we will achieve this chapter with a conclusion, with future works and perspectives.

2. Presentation of VNSIP Solution

The main idea of VNSIP is to deploy SIP over Wireless Mobile Ad Hoc networks. Thus our approach will be able to decentralize all proxy server (PS), registrar server (RS) and location Service (LS) functionalities. This will be achieved through the integration of these modules to each MANET terminal. In this way we delete the need of a centralized infrastructure which must in principal assumes proxies roles. VNSIP approach will be able to manage and maintain in totally distributed manner a virtual topology, which will be used to assign roles to the different nodes of the MANET, and to optimize SIP location service. We have tried to adapt VNSIP algorithms to be able to respect MANET constraints especially energy and bandwidth limitation and mobility of nodes.

The presence of Proxy Server (PS), Registrar Server (RS) and Location Service (LS) is a prerequisite for SIP operations. Thus it's necessary to decentralize those servers to enabling SIP integration in Ad Hoc network. The most evident solution, to fix this problem, is to include all SIP servers' functionalities in each node of the ad hoc network [LEG 05]. (However this solution consumes a lot of energy when broadcasting messages to find a node location [ROB 02] [BAN 06], and generates many failure connections because of message collisions.

VNSIP solution tries to define a dynamic virtual network inside the MANET, to be exploited by nodes, to adequately choose which one will be in charge to execute SIP server tasks. VNA (Virtual Network Algorithm) will be the entity in charge to activate or deactivate SIP server functionalities in each MANET node. A VNSIP node (see Figure 1) consists of several entities, when interacting between them; they allow communication in MANET using SIP protocol. These entities are:

- User Agent: it assumes UAS and UAC functions. It initiates and responds to SIP requests.
- PS: it assumes Proxy server functions.
- RS: It assumes Registrar server functions.
- LS: It realizes Location service roles.
- VNA: is the algorithm in charge of the construction of the Virtual Network and the affectation of node roles.

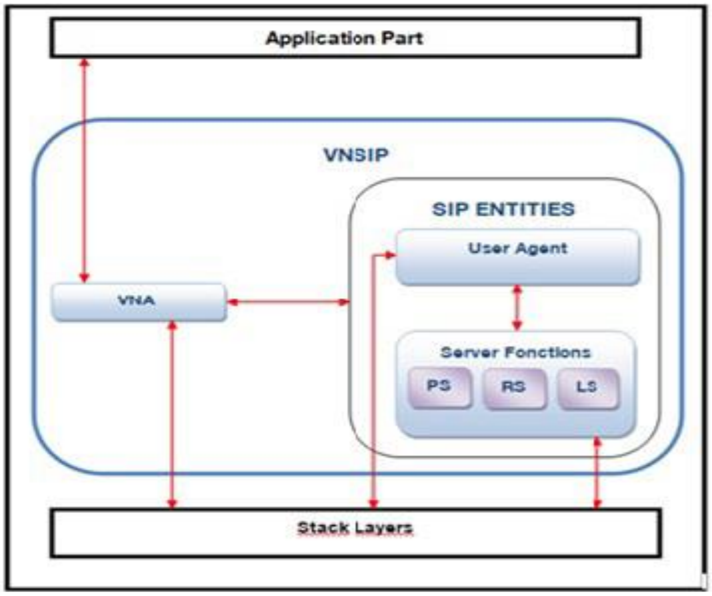

Figure 1. VNSIP Node Architecture

3. VNSIP Design

The first step is the construction of the Virtual Network (VN), which will be used by VNSIP to affect SIP server functionalities to the different nodes.

3.1. Virtual Network Algorithm (VNA)

VNA starts by the construction of neighbor tables. Thus each node of the MANET broadcasts a HELLO message [PER 03]. When receiving this message for the first time, each node can populate its own neighbors table with its 1-hop neighbor's number information. HELLO message is then sent for a second time, including the 1-hop neighbor's number information. When receiving the second HELLO message, each node upgrades its neighbors table with its 1-hop neighbor's number and 2-hop neighbors number information. VNA defines a flag "VN_membershi_flag" which shows if a node belongs to the VN or not. When executing VNA, the VN will include all nodes having VN membership flag=1. VNA is characterized by two conditions (see Figure 2):

- **Condition1:** if a node doesn't belong to the VN and the number of its neighbors which belong to the VN is lower than the number of its neighbors which don't belong to the VN then the VN membership flag of this node is set to 1.
- **Condition 2:** if a node belongs to the VN and the number of its neighbors which belong to the VN is higher than the number of its neighbors which don't belong to the VN then the VN membership flag of this node is set to 0.

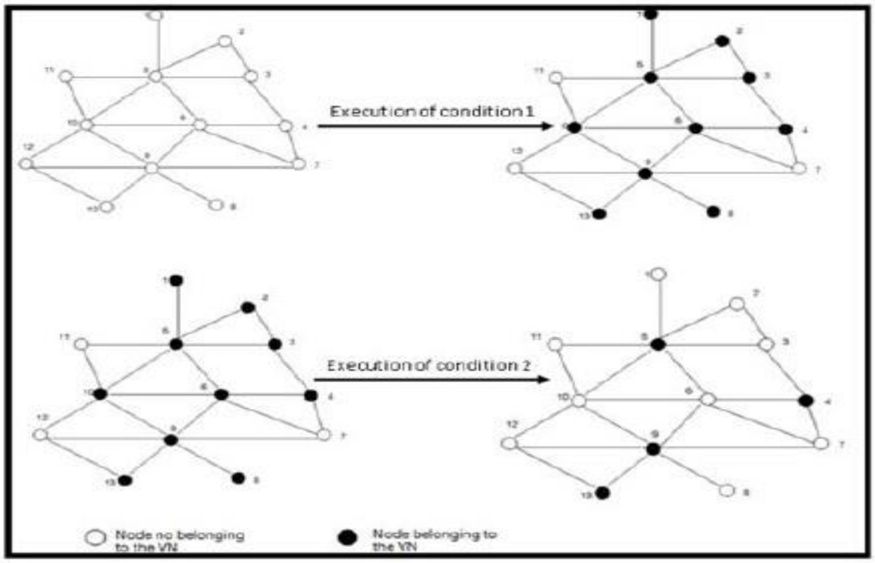

Figure 2. Generation of Nodes Belonging to the VN

To complete the construction of a connected VN, we define Gateway nodes to ensure connections between all nodes belonging to the VN. Gateways are generated using the execution of the two rules below:

Rule 1: if two nodes belonging to the VN, and don't have a connection between them, and have a same neighbor node which doesn't belong to the VN, then this node is considered as Gateway.

Rule 2: if two neighbor nodes, which don't belong to the VN, and their neighbors are respectively belonging to the VN, then those two nodes are considered as Gateways.

When finishing the selection of gateway nodes the construction of the VN is completed (see Figure 3).

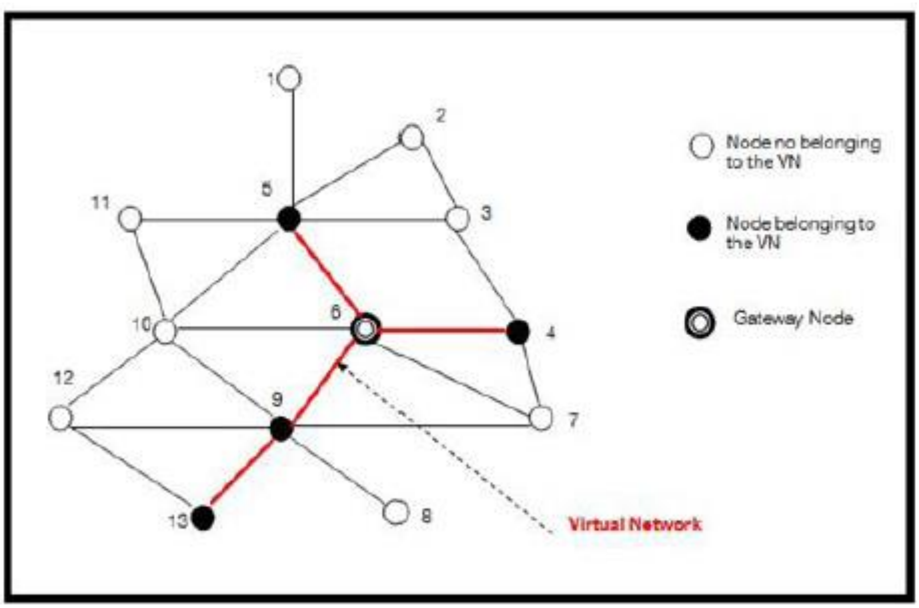

Figure 3. VN Construction

3.2. Interaction between VNA and SIP Entities

As it shown in Figure 3, when finishing the construction of the VN, three kinds of nodes are defined:

- If a node belongs to the VN, then it plays SIP User Agent role and all its SIP server's functionalities (Proxy server (PS), Registrar (RG) and location service (LS)) are activated,
- If a node is a gateway, then it plays SIP User Agent role and PS role. RG and LS are deactivated.
- If a node doesn't belong to the VN, then it plays only SIP User Agent role and its SIP server's functionalities are deactivated.

3.3. Implementation of SIP Operations

3.3.1. Registration

When a node of the ad hoc network decides to registrar to the SIP network generated by VNSIP, two possibilities are treated:

- **The node belongs to the VN:** in this case, SIP servers for this node are activated. Thus its User Agent sends a Registrar message to its own RG, making a local registration (see Figure 4), this registration is realized exactly in the same manner as in wired network.
- **The node doesn't belong to the VN:** in this case, the User Agent of this node broadcasts a Register message to all its 1-hop neighbors (Replication Mechanism), each neighbor register this node to its own RS if it belong to the VN (see Figure 5).

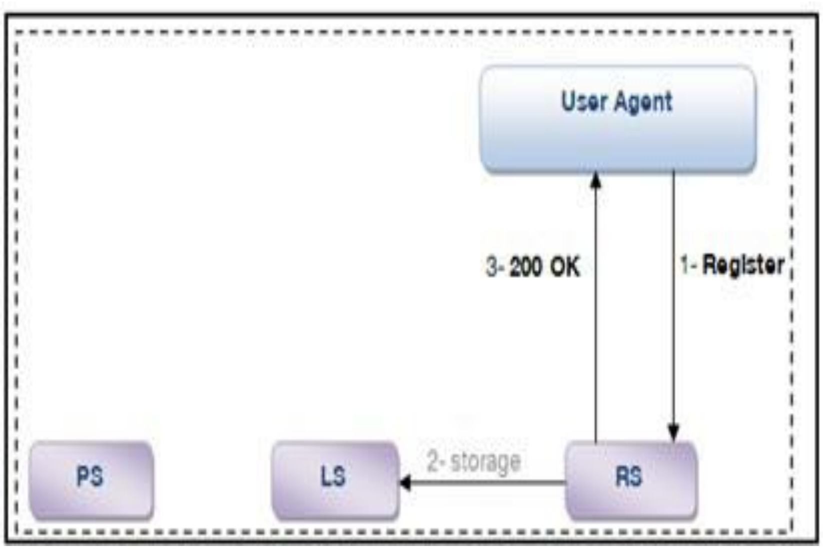

Figure 4. Registration for a Node Belonging to the VN

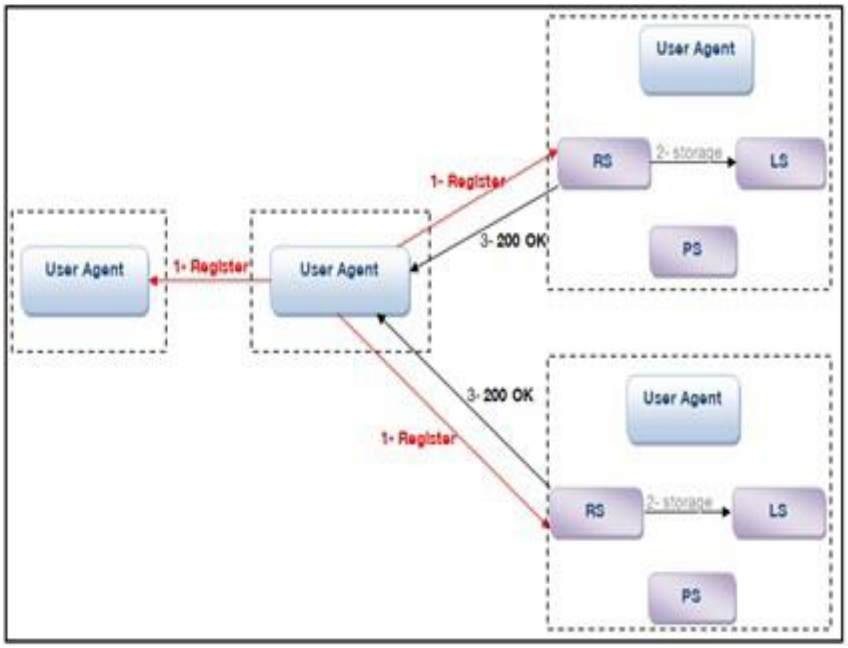

Figure 5. Registration for a Node don't Belonging to the VN

3.3.2. Session Initiation

When a node A decides to initiate a session with a node B. if SIP servers of A are activated then it sends INVITE message directly to its own PS (see Figure 6). Or if its SIP servers are deactivated, in this case, it broadcasts the INVITE to its 1-hop neighbors (see Figure 7).

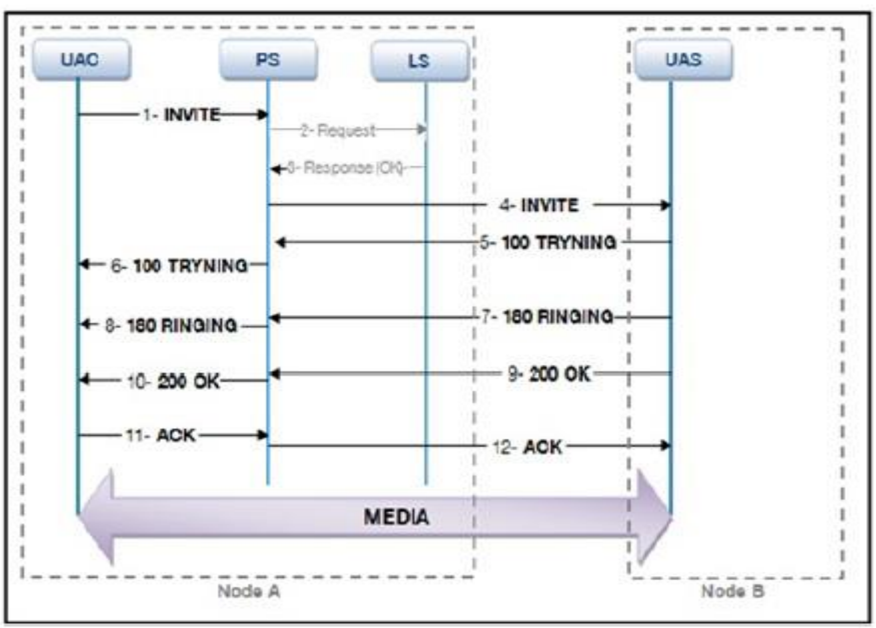

Figure 6. Example of Session Establishment when PS of Node A Knows Location

When a PS receives the INVITE, it sends a request to its LS to verify in the database if he knows the route to B. if it does then the PS redirects the INVITE directly to B (see Figure 6). If not, it broadcast the INVITE to its 1-hop neighbors (see Figure 7). When the User Agent of B receives the INVITE, its answers by a 200 OK message, which will follow the reverse path of the INVITE.

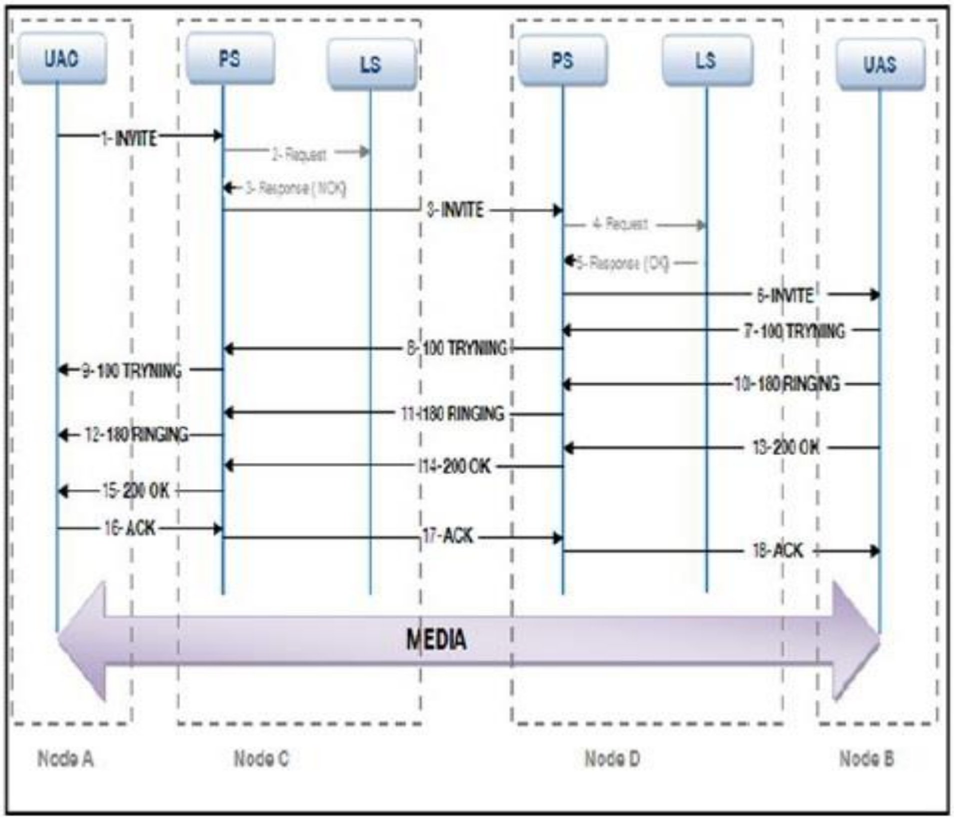

Figure 7. Example of Session Establishment when PS of Node C doesn't Know

4. Simulations and Evaluation of Performances of VNSIP Approach

4.1. Configuration

Simulations scenarios were achieved using the network simulators NS2 [NS 02] and SIPp [SIPp]. The simulation area was 1000m by 1000m. The node number was between 10 and 50 nodes. The movement speed of nodes was between 0 and 18 m/s, and times of simulations were 180 seconds.

4.2. Scenarios of Simulations

To define the difference between VNSIP behavior and TCA behavior [BAN 06], we achieved many types of simulations, and we analyzed the behaviors when node speeds and node numbers are increased.

4.2.1. Session Setting Time

The Figure 8 illustrates session setting time, for TCA and VNSIP, according to nodes mobility.

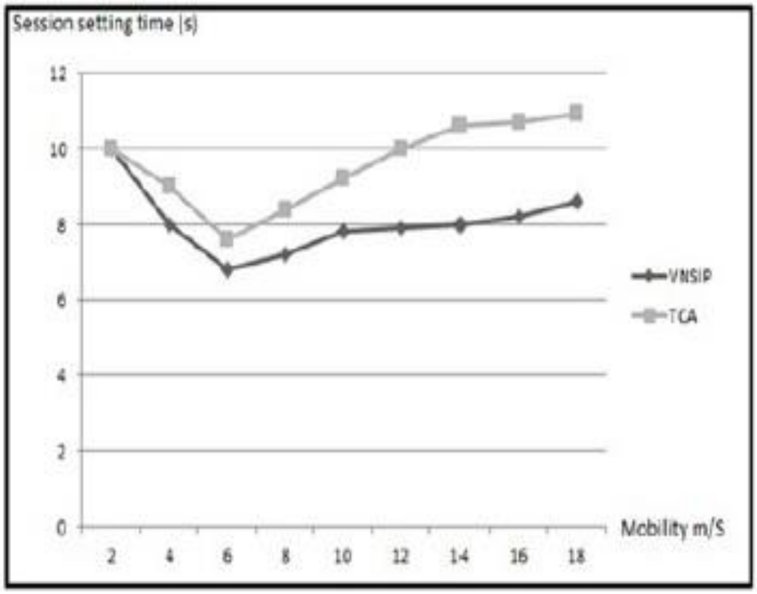

Figure 8. Session Setting Time According to Mobility

After analyzing the graph above, we can note that our approach guarantees a better time, than TCA solution, to establish sessions between nodes. We can justify this behavior by the fact that our solution VNSIP uses, to forward SIP messages, a higher number of nodes than TCA. And we can add that, replication mechanism used by VNSIP, allows performing many research on different SIP proxies on the same time, which helps to receive responses on shortest time.

The Figure 9 illustrates session setting time, from TCA and VNSIP, according to the number of nodes.

Comparing curves above, we observe that VNSIP gives better performance than TCA. In fact when the number of nodes, which are in charge to forward SIP messages, is increasing, it directly involves that session setting time decreased. Unlike TCA mechanism, which uses only one cluster-head to manage cluster members by forwarding SIP messages, generating largest queue and consequently the session setting time is increased.

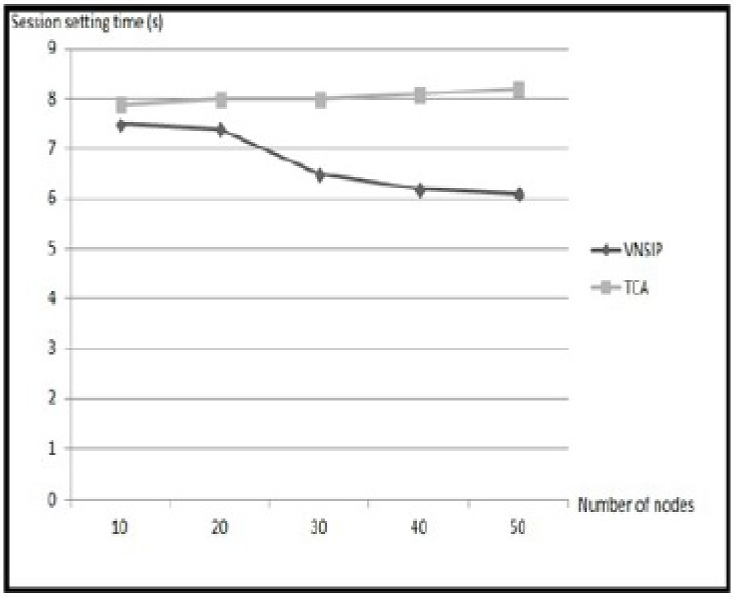

Figure 9. Session Setting Time According to Number of Nodes

4.2.2. Failure Rates

The Figure 10 illustrates the failure rates of session setting according to nodes mobility for TCA and VNSIP methods.

When we compare failure rates to establish SIP sessions between both methods, we observe that VNSIP performs better results in terms of successful sessions setting. This result can be easily justified by the difference between VNSIP and TCA architectures. VNSIP uses replication mechanism, which allows forwarding SIP messages by several nodes, unlike TCA which uses only cluster-heads to forward SIP messages, this involves that there is only one registration for each node. Therefore TCA mechanism is very sensitive and vulnerable to Cluster-heads moves.

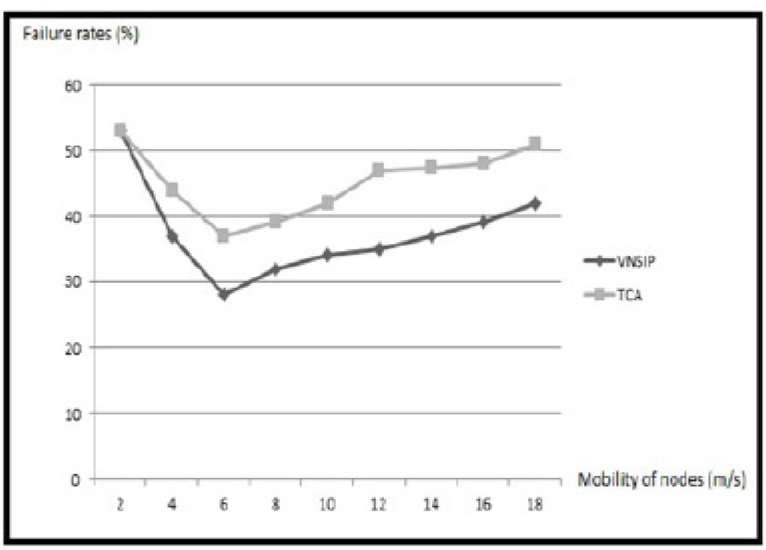

Figure 10. Failure Rates by Mobility of Nodes

4.2.3. Bandwidth Consumption

The Figure 11 illustrates bandwidth consumption when establishing SIP sessions according to number of nodes. When we compare both graphs, we note that VNSIP gives lower results than TCA; in fact consumption of bandwidth is higher and increases when number of nodes is rising. This behavior can be warranted by the high number of message sent when applying our replication mechanism, which consists of achieving several registrations and locations in the same time for the same node.

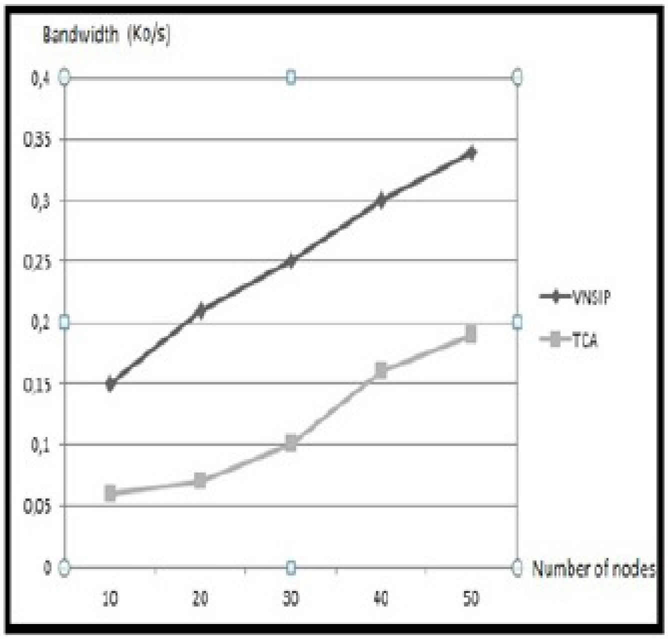

Figure 11. Bandwidth Consumption by Number of Nodes

5. MCAC: MANET Call Admission Control

The purpose of this paragraph is to describe our solution, MCAC (MANET Call Admission Control), This feature allows to limit VoIP calls in ad hoc networks. The need of MCAC for VoIP communications is mainly because the bandwidth of the access network of a MANET is not sufficient to accept all communications simultaneously. The purpose of the MCAC solution is to allow the establishment of a number of communications in line with the available bandwidth on the network access of a MANET. Its vocation is to reject the establishment of communications when the bandwidth is no longer sufficient and thus not disrupt communications already established.

5.1. MCAC Algorithm

The MANET is related to a set of Getaways which are responsible to provide connectivity of MANET with the internet network (figure 12). On each Getaway we integrate MCAC Application Server, which contains MCAC process and MCAC database. Each Getaway, via its Application Server, defines an MCAC group, and associates this MCAC group to a list of MANET nodes and a number of simultaneous calls [JIA 99] [LIN 97]. When a part of the MANET, subscribes to a MCAC group, a call between two nodes of this group will be recognized by the MCAC process. To create MCAC groups, Getaways (Application Server) determines MANET nodes with which it is directly linked, and automatically associates them to MCAC group.

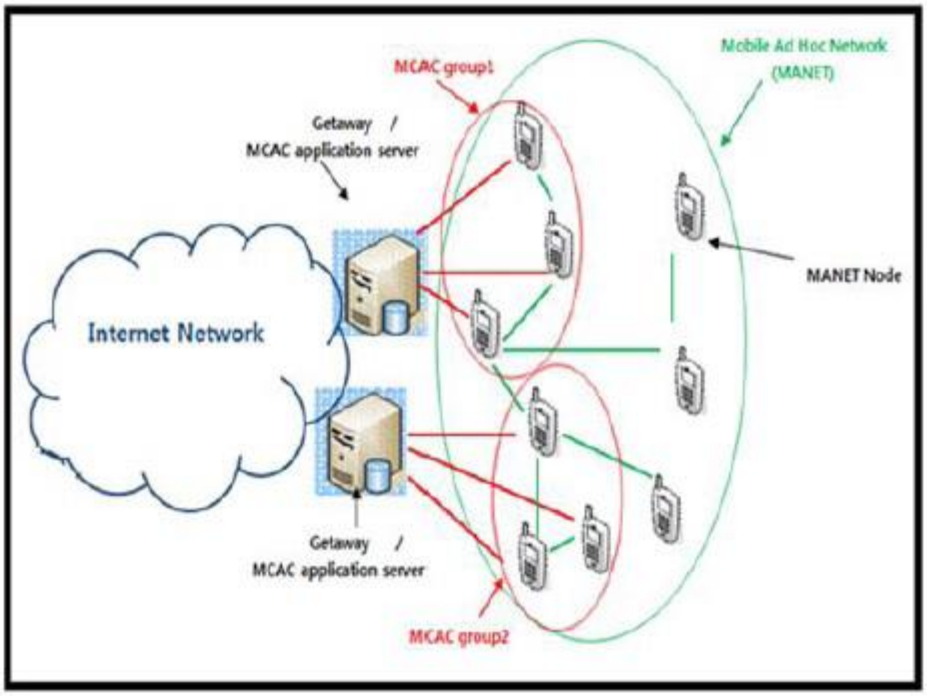

Figure 12. Architecture of MANET Connectivity to Internet

Each node can be associated with one and only one MCAC group (see Figure 13). When a network node is associated with a MCAC group, all calls, and incoming or outgoing, concerning this node are supervised by the MCAC algorithm. If the threshold of the MCAC group associated with this line is reached, MCAC algorithm rejects any new calls, by sending the specific SIP error code 503 (service unavailable), when receiving this error, the node is assumed to play a congestion tone.

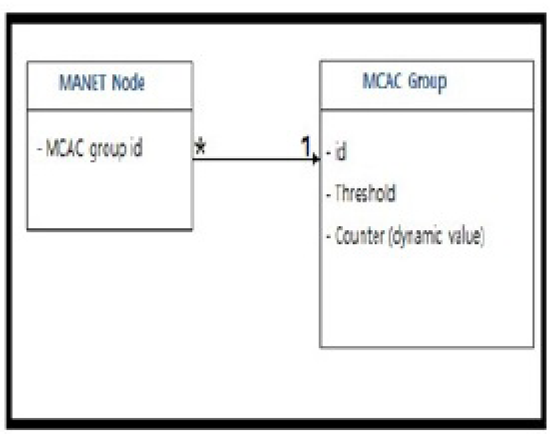

Figure 13. MCAC Data Model

When a Node A decides to communicate with a node B, several scenarios to increment and decrease the MCAC counter are defined, according to if A and B belong to an MCAC group or not. The Table 1 shows different possible use cases of increasing and decreasing the MCAC counter.

If a node of the MANET, associated to a MCAC group, decides to perform a call to another node of the MANET, the MANET routing protocol must ask authorization from MCAC algorithm, before routing the call to destination node. The Figure 14 shows an example of Scenario, in this case A and B are belonging to the same MCAC group.

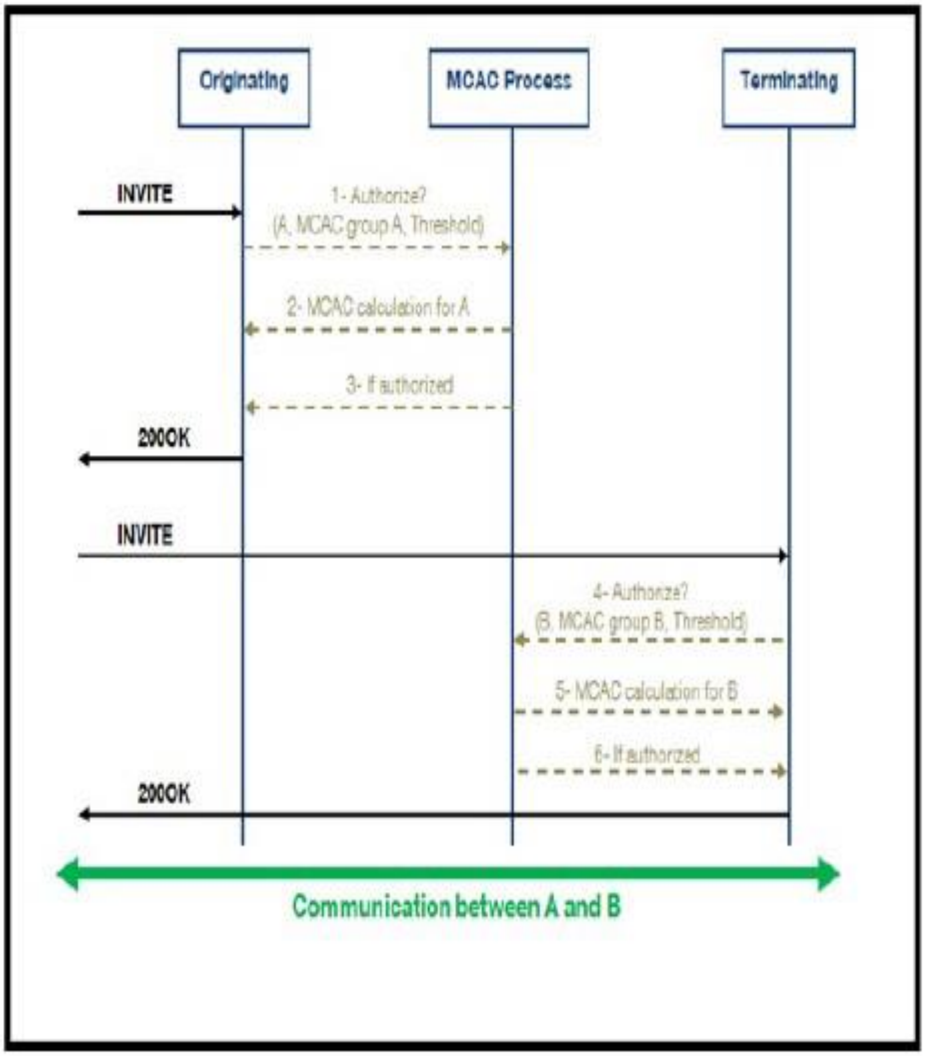

Figure 14. Example of Scenario of Communication between Two Nodes Controlled

5.2. Application of MCAC Algorithm to VNSIP Approach

As we have mentioned in paragraph 4, VNSIP approach, comparing to TCA approach performs good results concerning time of session establishment and failure rates, but in the other side it's suffering from a high consumption of bandwidth because of the mechanism of replication of SIP messages. To resolve this problem we deploy MCAC algorithm on VNSIP architecture (see Figure 15). MCAC will control SIP communication established by VNSIP, which involves controlling bandwidth consumption to be in line with the MANET capacity.

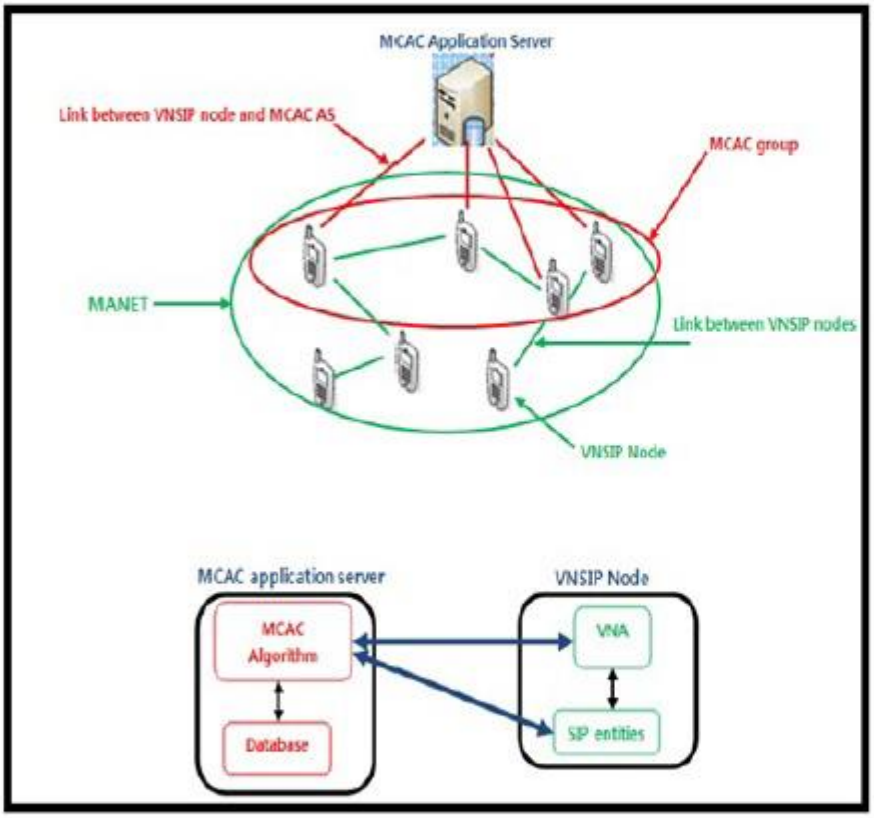

Figure 15. Deployment of MCAC on VNSIP Architecture

When a VNSIP node, which belongs to the MCAC group, decides to initiate a call with another VNSIP node, the VNA (Virtual Network Algorithm) of this node contacts the MCAC algorithm (see Figure 15), before redirecting the call to the PS (Proxy server) of the destination node, to ask if it's authorized to perform the call. If the counter of simultaneous calls is still lower than the threshold defined in MCAC database, then the call will be correctly redirected to destination and the counter will be incremented. If not, then the MCAC algorithm will send a specific SIP error. When the destination receives the call request, two cases are treated. Firstly, if the destination doesn't belong to the MCAC group then the MCAC algorithm will not be invoked and the call will be normally treated. Secondly, if the destination belongs to the MCAC group, then its VNA will also ask authorization from MCAC algorithm to treat the call. If the threshold is not yet reached then the call will be correctly treated. If not, the MCAC algorithm will send the SIP error. The Figure 16 illustrates an example of a call establishment scenario between two VNSIP nodes which belong to the same MCAC group.

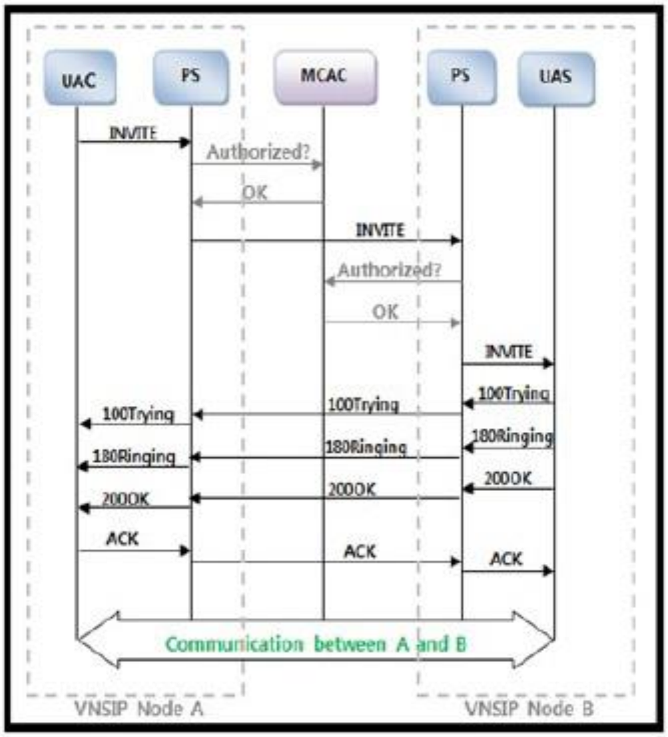

Figure 16. Call Ow between Two Nodes under MCAC Control

5.3. Simulations and Evaluation of Performances

To define difference between VNSIP behavior using MCAC and VNSIP behavior without using MCAC, we achieved many types of simulations, and we analyzed behaviors when node speeds and node numbers are increased.

Figure 17 and Figure 18 illustrate bandwidth consumption when establishing SIP communications according to number and mobility of nodes respectively.

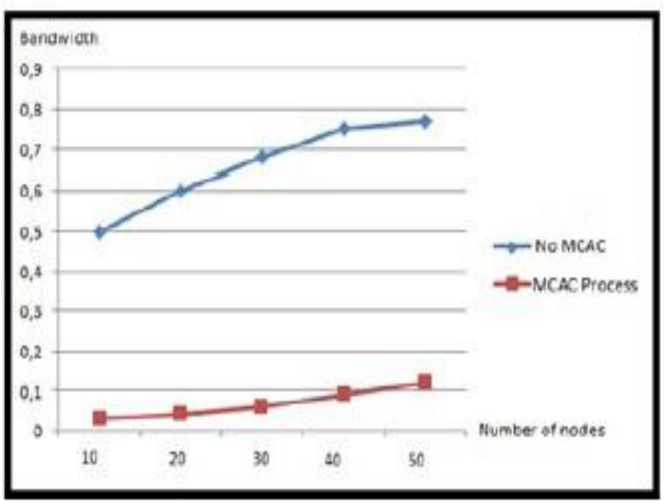

Figure 17. Bandwidth Consumption by Number of Nodes

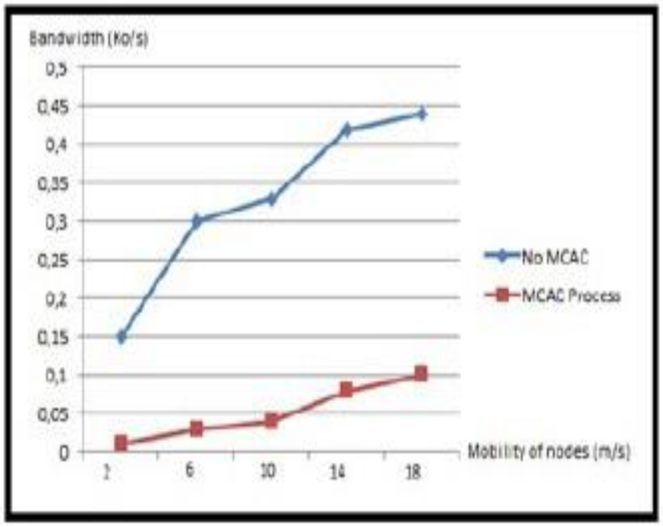

Figure 18. Bandwidth Consumption by Mobility of Nodes

When we compare both figures, we note that using MCAC process to supervise calls inside the MANET have considerably reduced the consumption of MANET bandwidth; which directly involves improvement of QoS. In fact even if the number of call attempts increases, the MCAC process keeps the number of simultaneous calls in line with the available bandwidth inside the MANET, which guarantees a good QoS for current calls.

6. Conclusion

In this first part of this paper we have presented, analyzed and evaluated the performance of a new approach VNSIP (Virtual Network for Session Initiation Protocol) for adapting SIP protocol to Ad Hoc Networks. To achieve this evaluation of performance, we have compared our solution to the TCA approach, which is consider as a solution giving a very interesting result to fix the problem of SIP adaptation to Ad Hoc Networks.

The simulation of both approaches has shown that our solution guarantees better results than TCA in terms of setting time and failure rates of SIP sessions. These good results were obtained thanks to VNA, the algorithm used to construct the VNSIP topology, and thanks to the mechanism of replication of SIP messages. On the other side, this mechanism has its own disadvantage, which involve that our solution proposes lower results than TCA in term of bandwidth consumption.

The second part of this chapter proposes a new algorithm to improve the QoS of calls in MANET. We have named this technique, MCAC (MANET Call Admission Control). It aims to ensure QoS by rejecting simultaneous calls in a MANET, when their number reaches a predefined threshold. We have used this technique to enhance performances of VNSIP approach which suffers from high bandwidth consumption. Simulations has shown that MCAC have considerably reduces bandwidth consumption in MANET, thanks to controlling number of simultaneous calls, which enables to adapt this number to the MANET , which involves to guarantee a good QoS of SIP calls.

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