System Models with Threshold Cryptography for Withdrawal of Nodes Certificate in Mobile Ad hoc Networks

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Abstract. Achieving security in mobile ad-hoc network (MANETs) is somewhat difficult compare to wired network because in ad-hoc network malicious nodes can freely move from one location to another location and thus able to launch attacks against different nodes. In our previous work, we have explained a simple method to identify the malicious node that is collect information from, N nodes present in MANETs but, in that approach it is difficult to achieve efficient and secure key management as well as it is difficult to differentiate between valid and false accusation made by well-behaving and malicious nodes. As an extension to our previous work, this paper will help to achieve more security by using efficient key management technique. In this technique, we are dividing the functionality of the certificate authority. Threshold sharing techniques is used for distributing CA functionality. In this mechanism every node present in the network will holds a piece of certificate authority signing key and multiple nodes in a one hop monitoring range will jointly provide complete service. This paper also clarifies how to distinguish between legal and false accusations messages, as well as different system models will help our planned scheme for revoking the certificate of malicious node efficiently, and for avoiding false accusation attack which can occurs due to inside malicious node.

Keywords: MANET Network, Threshold Cryptography, Digital Certificate

1 Introduction

A mobile ad hoc network (MANETs), is a group of collection of more than one, low volume calculating devices such as laptops, PDA etc. These devices are connected to each other through wireless links and do not depend on the predefined infrastructure to keep the network connected. Mobile will act as a node in MANETs. Each and every node present in the MANETs can work as a sender, a who is responsible for sending data, as a receiver who is responsible for receiving data or as a router who sends data to specific destination.

There are 2 main types of network architectures are present those are wired network and wireless network. MANETs is type of wireless network. Every network, such as wired network, wireless network, local area network will have their own features which makes them unique from other types of networks. Likewise, MANETs also has their own characteristics which make it different from wired network [5, 10] and these unique characteristics of Ad-Hoc network itself will create opportunities and challenges for achieving security in network. Following are the some of the problems which can arise due to MANETs unique features:

1.1 Absence of centralized entity or server

Following are the some of the task to fulfill these tasks successfully and efficiently centralized entity or server is required that are as follows:

- To establish better trust management

Difficult to establish better trust management because in traditional network generally this trust management task gets done by the centralized entity. Every node which is available in MANETs needs to cooperate with the operation which get performed inside network.

- Issuing and Revocation of certificates to nodes

Difficult to perform certificate issuing and certificate revocation task because; certificates are get issued by centralized entity. Storage of certificates and Retrieval of certificates In MANETs it's difficult to perform storage and retrieval of certificates because; in traditional network the information about valid and revoked certificate get stored at some central repositories such that it will get accessed by all the nodes that are present in the network but in MANETs there is no centralized server is present so in the proposed system the information about valid and revoked certificates needs to be preserved towards every node present in MANETs [0][4].

1.2 Infrastructure support absence

The absence of infrastructure support, makes it impossible from making use of any traditional security method such as, DC for achieving security in MANETs [0]. Mostly, the DC method get used for achieving security in wired types of network but when it comes to wireless communication network at that time these wired network security methods will not be useful for MANETs for achieving security because it will create

different problems.

1.3 Dynamically change in network topology

The nodes in MANETs are permitted to link, to dispensation from the network at any time. This unrestricted mobility feature of the wireless network makes always some changes in topology, with each and every single movement of nodes. This change in the network formation will affect into some route change, loss of packet from sender to receiver.

1.4 Nonexistence of secure boundaries

In wired network, when any outside employer want to enter into the network for performing malicious activity then first that node needs to go through different security medium such as firewall, gateway before they can perform any malicious actions to the target nodes by using these all security medium that particular node which is adversary get found easily and next time, it will not allow that adversary node to enter inside the network and thus target node get protected from malicious activity.

In MANETs the adversary node does not require to go through different security medium to access the network because once the adversary node will come within the radio range if any other node present in network then that adversary node will be able to connect with the nodes which are presents within its radio range and thus join the network immediately [1]. Once adversary node gets entered into the radio range of other node, then that respective node will be able for performing false accusation attack and try to prove genuine node as an enemy node.

These are the different challenges that can occur in ad hoc network while achieving security due to its unique characteristics. The MANETs helps to set up a temporary network which will allow the user to perform instant communication due to this, the focus on MANETs has increased lot of attention in the recent years and due to this increased focus on MANETs, the security related issues are considered as important and brought to front position.

Different methods such as symmetric key cryptography, digital certificates are existing for achieving security in wired network. These all methods are not able to provide security for MANETs because of the absence of central authority (CA), absence of physical connection presents between nodes, mobility. Certificate revocation theatres a vital role for achieving sufficient amount of security in MANETs. Revocation of certificate issue in wired network is easy because; once certificate of malicious node gets revoked, then certificate authority stores this revocation information into certificate revocation list (CRLs). The CRLs is either stored on some accessible repositories or else broadcast to all the existing nodes in MANETs. Handling of certificate revocation problem in MANETs is difficult task compare to the wired network because the wired security methods are not able to provide security in MANETs. The planned system, makes use of threshold based cryptography method to revoke certificate of malicious node quickly and correctly and try to achieve security as well as protect legitimate

nodes from malicious nodes in MANETs.

This paper is get break into different section where Section II analyses and compares the proposed system with the already available techniques, next Section III gives the idea of system models and finally Section IV describes proposed threshold based cryptographic method with their design.

2 Related Work

This section will describe numerous approaches which are already present for MANETs and their limitations.

2.1 URSA

URSA [6] technique makes use of, certified tickets based approach. Using this approach, it provides the tickets for the node and then the node who is consuming legal ticket those nodes it allows to go in MANETs. Remaining node, who are not having tickets those nodes are not allowed to by URSA [6] for entering into network. All the tickets of nodes in URSA [6] get managed locally inside the network itself for removing adversary and malicious node form's network. The ticket of malevolent node gets cancelled, when it exceeds the number of votes of its fellow citizen beyond the predefined threshold value.

2.2 Voting Based Scheme

This Scheme [7] is a transformed format of the URSA. The main modification amongst URSA, voting scheme is it this scheme permits the nodes presents in MANETs to vote through different weightiness. weight of nodes vote, get calculated form node consistency as well as nodes previous performance. To revoke the certificate of malevolent node, it estimates weights of all the polls which are received in contradiction of a particular node and after calculating sum if this reaches to a predefined threshold value then it will remove the certificate of that particular node.

2.3 Decentralized Suicide Based Approach

Voting Based Scheme [7] is a modified version URSA. The foremost variance amongst URSA and Decentralized Suicide Based Approach is that this approach permits the nodes present in MANETs to polls with different weight value. Nodes reliability and nodes historical performance get taken into consideration for calculating weight of the nodes.

2.4 Working of existing methods with proposed methods in comparative analysis form

Below **Table** 1 indicates different features and also explains the brief working of the existing methods. First column indicates the name of the existing method with its reference number in bracket. Second column indicates whether that particular excising method will make use of CA for issuing and revoking of certificate and fourth column gives information about who is going to issue certificate to nodes and revoke certificate of malicious node. Fifth column indicates the mechanism used by the existing methods

Existing Methods	Mechanism to Revoke Certificate	Time required to revoke certificate
URSA [6]	Takes opinion from multiple neighbouring nodes which are present within 1-hop Monitoring [12]	Less compare to [7]
Voting Based scheme [7]	Allows all nodes to vote with variable weight and if sum of weight wi of all nodes votes against particular node exceeds, a predefined threshold [14]	More compare to [6]
Suicide for the Common good [8] or Decentralized Suicide Based approach	Even if only one has made accusation against another node then certificate of accused as well as accuser get revoked [12]	Very Less compare to [6] and [7]

to revoke the certificate of node and last column gives information about the period required for revocation of nodes certificate by these existing methods.

Table 1. Working of CA and effect of attack on existing methods

Existing Methods	CA	False Accusation Attack
URSA [6]	Not used	Robust for single node
Voting Based scheme [7]	Not used	----------
Suicide for the Common good [8] or Decentralized Suicide Based approach	Not used	Not able to differentiate between valid and false accusation messages

Table 2**.** Working of existing methods for certificate revocation task

Above **Table** 2 gives comparative analysis of the existing method with our new proposed methods. It gives information about advantages and limitations of the existing method whose name is indicated in first column of this **Table** 2 and last column of Table II indicated the advantages provided by planned approach. The relative study of third and fourth column indicates that, the new proposed method tries to solve the limitations of these existing methods. **Table** 1 and **Table** 2 shows the working of the existing methods with different parameters.

Table 3**.** Comparative analysis of existing methods with new proposed method in this paper

Existing Methods	Advantages of Existing Methods	Limitations of Existing Methods	New Proposed Methods
URSA [6]	Strong for False Accusation Attack generated by single node	The subject of spotting false accusation attack generated by more than one nodes present in MANETs are still not resolved	Able to detect false accusation attack caused by one node as well as by more than one node
Voting Based scheme [7]	Improves the accuracy of certificate revocation	Increases the time required to revoke certificate of malicious node.	Certificate of node get revoked when it will detect the first misbehaviour of that node

3 Planned System Models

In this unit we will discourse about the net model; the trust model, the attack model and the mathematical model which will be used in the proposed system.

3.1 Network Model

We consider a wireless mobile ad hoc network (MANETs) as shown in below Fig.1. Where; the network is made-up from 'N' nodes and N>0.

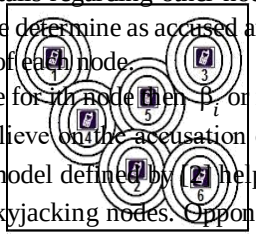


Fig. 1. MANETS with 6 nodes

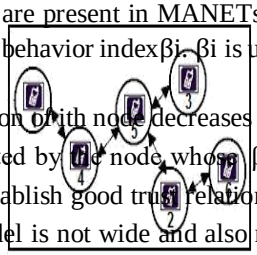


Fig. 1. Accusation Graph

Once the network gets created with specified number of nodes 'N', then from that network our proposed system draws accusation graph G= (V, E) where; G represents "Directed Graph", V represents "Nodes" and "E" represents "Edges" as shown in Fig.2.

In **Fig.1.** Nodes in the network communicate with each other if they present inside the radio or else it gets performed in multihop or ad hoc manner where more than one hop is requiring to send data from source to destination. The value of, 'N' changes dynamically as new node joins or leave the network. Each node has a unique ID which is used to identify the node. Due to absence of structure support the, nodes present in network need to get prepared with some additional net functionality those includes packet forwarding, need to be fortified with a local one-hop intensive care apparatus. The one-to-one monitoring technique helps for finding neighboring nodes between its straight neighbors.

3.1 Trust Model

To achieve security in MANETs, every node which is present in the network, that node needs to be genuine. This model helps to determine on which node user can keep trust and on which not. In every security design, "trust" is very basic and important element. Basically, there are 2 main trust models are available that are trusted third party model (TTP) [9] and the PGP "web-of-trust" model [10].

Crepe and Davis [2] proposed a trust mechanism which will help to establish a good trust relationship among the nodes that are present in MANETs as follows: All the nodes in the MANETs maintain "Profile Table" (PT). This table maintains different information details regarding other nodes that are present in MANETs such as nodes which they have determine as accused and their behavior index βi. βi is used to calculate the reputation of each node.

If A_i is large for ith node then β_i or reputation of ith node decreases Supplementary nodes don't believe on the accusation completed by the node whose β_i value get decreased. This model defined by [2] helps to establish good trust relationship but the β_i handles only skyjacking nodes. Opponent model is not wide and also not stated, how the nodes are authentic, what is to be done with the malicious node as well as, the

process of exchanging PT each time is time consuming.

A. Distributed Trust Model:

We define a scattered trust model. This model gets used to validate the nodes preset in the MANETs. It is also called as a "Trusted third party model" where "Certificate Authority" (CA) will play the role of trusted third party. We are using the concept of "Secret Sharing", which is based upon Shamir's "secret sharing model" [3, 4] through threshold cryptography.

Shamir's secret sharing model helps for key management and also provides privacy among a set of nodes N. To protect message generally we make use of encryption algorithm and encrypt that message to protect it but, what about the key protection which get used for encrypting message? What will happen with it if it the attacker obtained it? If attacker will succeed to obtain the encryption key using which the message gets encrypted then that attacker can easily obtain our message and misuse it. So, to avoid damage and to protect message securely we need to use efficient key management technique. Threshold scheme helps to manage encryption key so that message get protected. In our proposed scheme, we need to protect CA signing key.

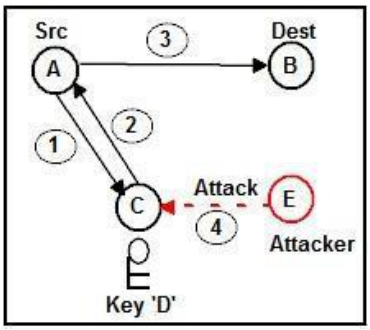


Fig. 3. Without threshold cryptography and Secrete sharing

Where, A'→Source 'B'→Destination 'C'→Provider 'E'→Attacker 'M'→Message

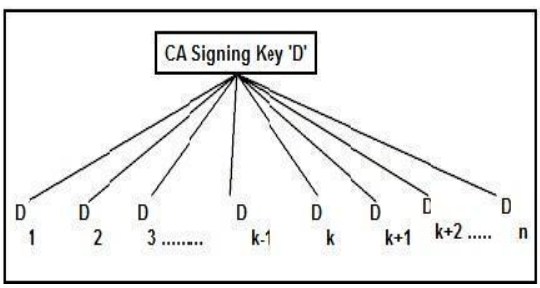
1- 'A' makes request to 'C' for obtaining CA signing key 'D'

2- 'A' makes request to 'C' for obtaining CA signing key 'D'

3 - 'A' makes request to 'C' for obtaining CA signing key 'D'

4 - 'A' makes request to 'C' for obtaining CA signing key 'D'

Generally, the key is kept at a central location as shown in above Fig.3 As shown in above **Fig.3.** if attacker 'E' is able to access 'C' provider then that attacker can easily obtain the CA signing key 'D' and then by making use of obtained CA signing key, the attacker is able to listen the communication which is done between source 'A' and destination 'B' and thus security get break. This will happen because the secrete key 'D' is stored at a central location and so this scheme is highly unreliable. To avoid this and to protect secrete key threshold scheme get used. Threshold scheme was introduced by Shamir in [5,8].



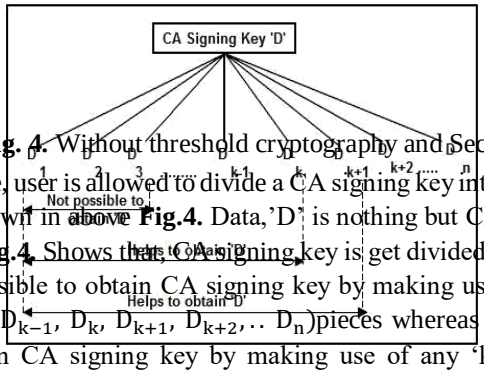


Fig. 4. Without threshold cryptography and Secrete sharing

Using this scheme, user is allowed to divide a CA signing key into 'n' different shares such that k<n as shown in above **Fig.4.** Data,'D' is nothing but CA signing key in our proposed system. **Fig.4.** Shows that, CA signing key is get divided into 'n' parts. **Fig.5.** shows that, it is possible to obtain CA signing key by making use of any 'k' or from more D_i (D_1, D_2,.. D_{k-1}, D_k, D_{k+1}, D_{k+2},.. D_n)pieces whereas **Fig.5.** shows that, it is possible to obtain CA signing key by making use of any 'k' or from more D_i (D_1, D_2,.. D_{k-1}, D_k, D_{k+1}, D_{k+2},.. D_n)pieces whereas it is not possible to obtain CA signing key by making use of k-1 or fewer D_i (D_1, D_2, D_3..) pieces.

Fig.5. Obtaining Data 'D'

This type of structure is called a (k, n) threshold scheme. For efficient key management and to avoid the drawbacks occurred in Fig.3. We make use of threshold cryptography. Consider for example, there is one Ad-Hoc network in which CA private key get used to sign the certificates of each and every node which are present in the network. In this situation, there are 2 options are available to keep CA private key secure that are:

If we are given a copy of the private key to all the nodes in MANETs so that each node is able to protect their encryption key, then in this situation the system is convenient but there are lots of chances of misuse of key.

If we make use of teamwork mechanism then to protect CA signing key the cooperation is required among all the node's which are existing in MANETS for signing the certificate of each node. This option will keep our system safe but it is not convenient because every time the cooperation among all the network node is required to sign the certificate of newly entered node. Threshold cryptography (k, n) allows us to develop standard solution for example if (k, n) = (3, n) then for each node a small piece D_i of CA signing key 'D' is given then to generate a temporary copy of the actual CA signing

key ‘D’. At least 3 secretes of signing key ‘D’ are required and after using this temporary copy it get destroyed and in this situation, if any malicious node want to perform any malicious activity such as obtaining CA signing key then that malicious node requires at least 2 node’s which also want to perform malicious activity and which will help him to obtain CA signing key.

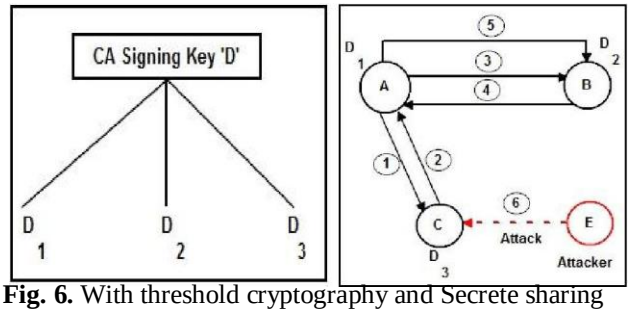


Fig. 6. With threshold cryptography and Secrete sharing

Suppose (k, n) = (3, n)

Where, ‘A’→Source ‘B’→Destination ‘C’→Provider ‘E’→Attacker ‘M’→Message

1- ’A’ request to ‘C’ for obtaining one piece of CA signing key ‘D’, D3
2- ‘C’ gives D3 piece of key ‘D’ to ‘A’ after verification and authentication
3- ‘A’makes request to ‘B’ for obtaining other piece of CA key ‘D’ that is D2
4- ‘B’ gives D2 piece of key ‘D’ to ‘A’ after verification and authentication.
5- ‘A’ will generate temporary key and communicate with ‘B’
6- Although ‘E’ is able to access ‘C’, ‘E’ will not be able to perform malicious Activity

Above Fig.6. shows that, if attacker ‘E’ is able to perform attack on provider ‘C’ then also attacker ‘E’ is not able to obtain CA signing key because it will obtain only one part of signing key ‘D’ and due to this attacker ‘E’ is not able to perform malicious activity.

3.2 Attack Model:

This paper focuses on false accusation attack and to some extent with misbehaviors that can occur in network layer. The main feature of network layer is, sending the data towards destination that is, routing and packet forwarding so our attack model tries to solve false accusation attack, packet forwarding that is send packet to well-behaving destination. In this we are not considering other attacks that can occur at other layers.

Initially all the ‘N’ nodes using which the ad-hoc network get created that ‘N’ nodes are considered as well-behaving nodes so initially the attack can be initiated by a single node. Once the attack gets initiated then again accusation graph G= (V, E) get updated which will help to find out A_i and β_i depending on the attack that get occurred and then certificate revocation module which is discussed in our previous work [11] get invoked to determine the value of α_i and ω_i and from all of these values R_j get calculated. This calculated R_j will helps to find out whether it is needed to revoke the certificate of jth node or not. Single or more than one malicious node can also target other well-behaving node then false accusation attack get occur. When attack gets occurred due to multiple

misbehaving nodes then it is called as joint accusation against well-behaving node.

In this paper our focus is more towards the insider attacks which can occur due to malicious or selfish nodes. We consider malicious or selfish nodes are already present in the system. We are considering the attacks caused by single node, as well as by multiple nodes which works within collaboration.

Incorrect allegation attack means; the malevolent node drive to show the well-behaving, nodes as attacker and owing to this the well-behaving node gets removed from MANETs. Below **Fig.7**. Demonstrate that, user has designed MANETs with 4 nodes that are i, j, k and L where well-behaving nodes are indicated by white color and malicious nodes by red color. Initially all the nodes are considered as a well-behaving node and initially attack get initiated by single node suppose that node is 'j'. Then in this situation, if node j will try to prove any well-behaving nodes from the available well-behaving nodes i, k and L as malicious node by generating and sending fake accusation message to other nodes except to the node to which he is trying to prove as malicious node then we can say that the false accusation attack get occurred. Here we are considering that, malevolent node j is trying to show genuine node L, as malevolent node then the **Fig.7.** For this will look like as shown in **Fig.8.**below:

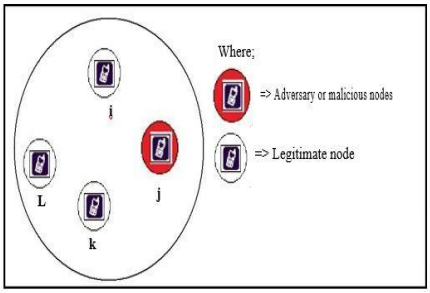


Fig. 7. Original Network

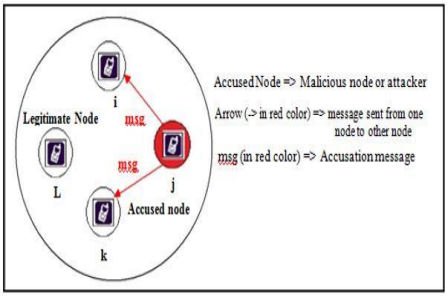


Fig. 8. False accusation attack

Above **Fig.8.** Shows the network when malevolent node j, will try to prove well-behaving node L, as malevolent node. Node j is generating fake accusation message and then sends this fake accusation message to node i and node k to tell them that node L is malicious node and by doing this the malicious node j in this example is trying to show well-behaving node L, as malevolent node in such situation we can say that "False Accusation Attack" get occurred in the network and this will result in the revocation of well-behaving node L from the MANETs network while malevolent node leftovers in the network as shown in below **Fig.9.**

Below **Fig.9.** Shows the effect of false accusation attack on network shown in **Fig.7.** It shows that, due to false accusation attack generated by malicious node j for legitimate node L; the well-behaving node L, gets detached from MANETs however the malevolent node j will present in the network. The original network shown in **Fig.7.** Now look like as shown in **Fig.9.** Due to false accusation attack.

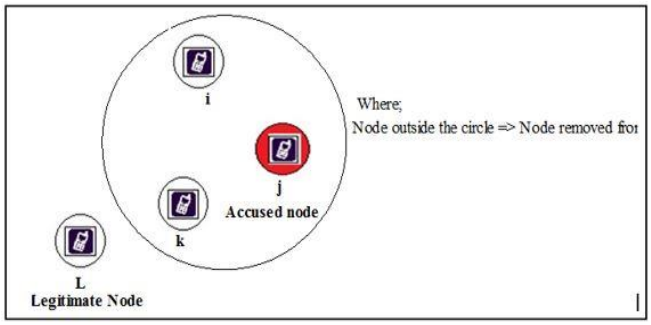
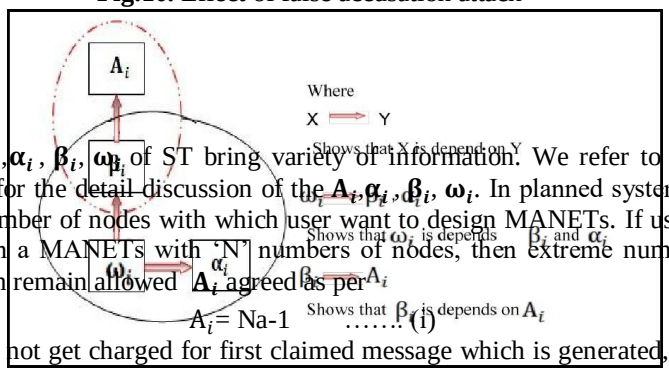


Fig. 9. Effect of false accusation attack

3.2 Planned System Mathematical Model:

Below **Fig.10.** Demonstrates, the mathematical model of planned system.

Fig.10. Effect of false accusation attack



Parameters $\mathbf{A_i}$,$\boldsymbol{\alpha_i}$, $\boldsymbol{\beta_i}$, $\boldsymbol{\omega_i}$ of ST bring variety of information. We refer to recent publication [11] for the detail discussion of the $\mathbf{A_i}$,$\boldsymbol{\alpha_i}$, $\boldsymbol{\beta_i}$, $\boldsymbol{\omega_i}$. In planned system, 'N' represents the number of nodes with which user want to design MANETs. If user has decided to design a MANETs with 'N' numbers of nodes, then extreme number of claim posts which remain allowed $\mathbf{A_i}$ agreed as per

$$A_i = \text{Na-1} \quad \ldots\ldots \text{(i)}$$

The node does not get charged for first claimed message which is generated, in the planned system. Depending on this situation, amount of claim message aimed at node gets exciting, becomes Na-1. Other important bit is that, none of the node present in the MANETs will not produce claim note in contradiction of themselves. Finally, reduce 1 from Na-1, for obtaining worth aimed at total amount of claim messages aimed at node charges thus

$$\alpha_i = \text{Na-1}$$
$$\alpha_i = \text{Na-1-1}$$
$$\alpha_i = \text{Na-2} \quad \ldots\ldots \text{(ii)}$$

Calculation (i), (ii) stretches on the value for A_i as well as on the value of α_i , as Na-1, Na-2 respectively. In Fig.10 The projectile (X ⟹ Y) determination specify that, adjustable X is dependent on Y. It also gives information about 2 different relationship which are presents is amongst diverse variables by manufacture use of dotted and plain ovals. Unadorned ovals from the above Fig.10. demonstrate the β_i rest scheduled the A_i ; since β_i , get used for calculating the morality of the node. The nodes honesty is get intended by manufacturing the use total number of claim messages, which are made in contradiction of particular node ith, A_i.

If large number of nodes such as A_i= Na-1 , when Na is the number of node count

which are in MANETs has generated accusations message against any node n_i , at that time node n_i is in query that whether it is malevolent node or well-behaving node and due to this less weight get assigned to the claim messages that are generated by node n_i which is in question .So to assign weight to the accusation messages generated by any node n_i proposed system need to first determine the, morality of that node i that β_i which is depends on A_i. Therefore, from this obtained β_i is:

$$\beta_i = 1 - \lambda A_i \quad \text{..... (iii)}$$

Scattered oval in above **Fig.10.** Protests that ω_i is rest on β_i and α_i since; we know that, ω_i is used to assign weight to the claims memo made by the node i who has detected misconduct of another node j. Then to assign weight to the accusation we need to determine the honesty of that node i firstly that means β_i which will help to find out the honesty of the node So that depending on that weight is get assigned to claim message made by that node i. So above **Fig.10.** Shows that ω_i is depend on β_i which will help to find out behavior of node i. Therefore, from this gained ω_i is:

$$\omega_i = \beta_i - \lambda\alpha_i \quad \text{..... (iv)}$$

The value of λ in equation (3) and (4) got as shadow:

$$A_i = Na-1 \quad \text{..... (i)}$$
$$\alpha_i = Na-2 \quad \text{..... (ii)}$$
$$\beta_i = 1 - \lambda A_i \quad \text{..... (iii)}$$
$$\omega_i = \beta_i - \lambda\alpha_i \quad \text{..... (iv)}$$

Place value of A_i obtained in equation (i) into equation (iii)

$$\beta_i = 1 - \lambda A_i \quad \text{..... (iii)}$$
$$\beta_i = 1 - \lambda\,(Na-1) \quad \text{..... (v)}$$

Place value of α_i obtained in equation (ii) into equation (iv)

$$\omega_i = \beta_i - \lambda\alpha_i \quad \text{..... (iv)}$$
$$\omega_i = \beta_i - \lambda\,(Na-2) \quad \text{..... (vi)}$$

Place value of β_i obtained in equation (v) into equation (vi)

$$\omega_i = \beta_i - \lambda\,(Na-2) \quad \text{..... (vi)}$$
$$= 1 - \lambda\,(Na-1) - \lambda\,(Na-2)$$
$$= 1 - \lambda\,[(Na-1) + (Na-2)]$$
$$= 1 - \lambda\,[(Na-1 + Na-2)]$$
$$= 1 - \lambda\,[(Na + Na -1-2)]$$
$$= 1 - \lambda\,[(2Na-3)]$$
$$1 = \lambda\,[(2Na-3)] \text{ Thus } \quad \lambda = \frac{1}{2Na-3}$$

4 Conclusion

In this paper, we have extended our previous work on certificate revocation to achieve better security and efficient key management by distributing certificate authority's functionality through threshold secrete sharing. Our work is divided into 5 phases that consists of; creating ad-hoc network, establishing trust among the nodes, distributing certificate authority's functionality, generating attack and removing it. We used, Shamir's secret sharing model, with severance to reduce the effect of malicious node

because it states that by using less than (k-1) pieces it is not possible by attacker to recreate the certificate authority key and thus it will help to improve the integrity of the ad-hoc network. The proposed scheme achieves, removes window of opportunity problem, false accusation attack, improves reliability of network, achieve efficient key management and for certificate revocation, our proposed scheme takes the reliability of each nodes into consideration and depending on the nodes reliability it assigns weight ω_i to each accusation message A_i made by nodes which will help to take decision about, whether to revoke the certificate of node or no.

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