AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Detection and Revocation of Misbehaving Vehicles from VANET

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ARTICLE INFO

Article history:
Received 25 April 2014
Received in revised form
8 May 2014
Accepted 20 May 2014
Available online 17 June 2014

Keywords:

ABSTRACT

The present work is the detection and revocation of misbehaving vehicles in vehicular ad-hoc network. In the present work vehicles are within the coverage area of base stations and the base stations are within the coverage area of certifying authority. Each vehicle detects misbehaving vehicles from its neighbors, creates a certificate revocation list by mentioning the identification of the misbehaving vehicles and sends this list to its parent base station. Each base station creates a certificate revocation list after receiving the certificate revocation lists from the vehicles within its coverage area and sends it to the certifying authority. The certifying authority creates a final certificate revocation list after receiving the certificate revocation lists from the base stations within its coverage area and broadcasts it among the vehicles within its coverage area. The qualitative and quantitative performance of the proposed scheme outperforms the existing schemes.

To Cite This Article: Atanu Mondal and Sulata Mitra, Detection and Revocation of Misbehaving Vehicles from VANET. ***Aust. J. Basic & Appl. Sci.,*** *8(21): 87-92, 2014*

INTRODUCTION

The vehicular ad-hoc network (VANET) consists of a group of independent vehicles which are moving throughout the wireless network freely. The potential threat and road accident are increasing due to high velocity of vehicles in VANET. Several types of messages are exchanged among vehicles such as traffic information, emergency incident notifications and road conditions to avoid road accidents and congestion. It is important to forward message correctly in VANET. However, attacker nodes or misbehaving vehicles may damage the messages. The misbehaving vehicles are authentic vehicles but their behavior deviates from the required standard behavior. These vehicles may jeopardize the safety of other vehicles, drivers, passengers as well as the efficiency of the transportation system. Hence the critical part of any security mechanism in VANET is to identify and revoke misbehaving vehicles.

Several revocation schemes have been proposed so far. In (Aslam and Zou, 2009) the service provider issues certificates for the vehicles with a limited temporal/spatial scope. These certificates are usable by the vehicles within a particular geographic area or within a certain time or both. The certificates are not tied to the vehicle's registration and can be changed periodically during one service period. But it has a lot of overhead for the creation and revocation of certificates for each new coming and leaving vehicle.

The certificate revocation techniques and privacy-protection techniques are proposed in (Papadimitratos, *et al*., 2008; Kargl, *et al*., 2008). A security architecture for vehicular communication systems is developed in (Papadimitratos, *et al*., 2008). The authors identify threats and models of adversarial behavior as well as security and privacy requirements that are relevant to the vehicular communication context. A SeVeCom baseline architecture is presented in (Kargl, et al., 2008). The various implementation and deployment-specific aspects such as flexible integration in existing communication-stacks, use of a hardware security module and secure connections of vehicular communication on board units to in-vehicle bus systems are also highlighted in (Kargl, *et al*., 2008). But the authors discussed the concept of certificate revocation list (CRL) distribution without considering high vehicle traffic densities.

In (Nowatkowski and Owen, 2010) the scalable methods of distributing CRL and other large files over VANET using vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications while taking advantage of the multi-channel operations in IEEE 1609.4 is proposed. The size of the CRL increases with vehicle density. Hence it is difficult to distribute the CRL over the entire network with minimum delay and network congestions.

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In (Papadimitratos, *et al*., 2008) the authors consider the distribution of CRL across a large-scale and multi-domain vehicular communication system in a timely manner. A collaboration scheme between regional certificate authorities (CAs) that allows CRLs to contain only regional revocation information is proposed in (Papadimitratos, *et al*., 2008). Moreover it uses erasure codes to enhance the robustness of the CRL distribution. The scheme does not require any communication and cooperation between road side units (RSUs) during CRL distribution. It minimizes CA-RSU and vehicle-CA-RSU interactions thus limiting congestion in the network. The CRL size is reduced by using regional CA and short lived certificates for travelling vehicles. But the distribution time of CRL is tens of minutes which is too long for a high and dense network like VANET.

A flexible, simple and scalable design for VANET certificates and new methods for efficient certificate management is proposed in (Samara, *et al*., 2010). It reduces channel overhead by eliminating the use of CRL. It also protects the system from adversary vehicles by distributing information about adversary vehicles among the whole network and by revoking the certificates of malicious nodes. But the performance of the scheme is not evaluated on the basis of overhead and delay.

An adaptable method to detect packet forwarding misbehavior based on the principal of flow conservation of messages and the application of policy-based management (Boutaba and Aib, 2007) is proposed in (Duque, *et al*., 2009). The message is forwarded to those vehicles which are moving towards the location of the event. In the proposed scheme the different tasks are assigned to a vehicle at different instant of time depending upon the certain policy for identifying the misbehaving vehicles which increases the complexity of each vehicle.

The present work is the detection and revocation of misbehaving vehicles in VANET. The proposed VANET is a hierarchy having CA at the root level, base stations (BSs) at the intermediate level and vehicles at the leaf level.

Each vehicle has an electronic license plate (ELP) in which its vehicle identification number (VIN) is embedded in encrypted (E_VIN) form. The ELP of a vehicle broadcasts the E_VIN after entering into the coverage area of a new BS. The BS verifies the authentication of the vehicle after receiving its E_VIN and assigns a digital signature (D_Sig) to the vehicle if it is authentic (Mondal and Mitra, 2012). The CA maintains a CRL (CA_CRL) to store the E_VINs of the misbehaving vehicles and broadcasts it for the vehicles within its coverage area.

Each vehicle receives beacon message periodically and service message (S_MSG) after the occurrence of an event from the vehicles which are within its coverage area. The steganography method is used to protect S_MSGs from the access of intruder. The S_MSG consists of D_Sig of the sender vehicle, hidden message (H_MSG), E_VIN of the sender vehicle and the operational part (O_MSG) to retrieve the message (MESS) from H_MSG.

Each vehicle switches on a timer. It receives a S_MSG from a vehicle within its coverage area, and searches CA_CRL for the value of E_VIN field of S_MSG. If found it discards S_MSG. Otherwise it stores the S_MSG in a FIFO queue, triggers ALGO_MESS to retrieve MESS from H_MSG field of S_MSG and inserts a record in the form (E_VIN, MESS, REMARK) in a data table (DT). It repeats the same steps of operation for the other received S_MSGs till the timer expires. Initially the value of the REMARK field of all the records in DT is null. Each vehicle triggers ALGO_V algorithm to detect the misbehaving vehicles using the records in the DT after the expiry of the timer and inserts the E_VIN(s) of the misbehaving vehicle(s) in a CRL. The algorithm repeats the same steps of operation for all the records in the DT and finally sends the CRL to its parent BS.

Each BS switches on a timer and triggers ALGO_B algorithm. The algorithm receives CRLs from the vehicles within its coverage area and stores them in a FIFO queue. It performs union operation among the received CRLs in the queue for generating a new CRL. It repeats the same steps of operation till the timer expires and sends the new CRL to CA after the expiry of the timer.

The CA switches on a timer and triggers ALGO_C algorithm. The algorithm receives CRLs from the BSs under it and stores them in a FIFO queue. It performs union operation among the received CRLs in the queue for generating CA_CRL. It repeats the same steps of operation till the timer expires and broadcasts CA_CRL among the vehicles within its coverage area after the expiry of the timer.

Unlike (Aslam and Zou, 2009; Nowatkowski and Owen, 2010; Samara, *et al*.,2010) the present work uses steganography to protect S_MSGs from intruder in VANET. The use of encryption/decryption algorithm for secure message transmission consumes a considerable amount of time due to their computational hardness. Moreover the length of message may increase during encryption which increases storage overhead along with communication overhead. In the present work CA_CRL consists of E_VIN of the misbehaving vehicles instead of their IP address like (Papadimitratos, *et al*., 2008). So only the E_VIN of a vehicle is sufficient to identify, detect and revoke misbehaving vehicles from VANET. Unlike (Papadimitratos, *et al*., 2008) the present work performs well in high density of vehicles. In (Papadimitratos, *et al*., 2008) CA distributes pieces of CRL among vehicles via RSUs. So in the worst case a vehicle needs to encounter all the RSUs for collecting all the pieces of CRL. Hence the performance of CRL generation degrades if congestion occurs, if vehicles move slowly and if the distance between RSUs increase. The misbehaving vehicles are identified by their E_VINs during V2V communication in the present work. So no extra task is required to assign to a vehicle for identifying

misbehaving vehicle like (Duque, *et al*., 2009). There is no requirement of reporting the reason of revocation to CA in the present work like (Kherani and Rao, 2010) which helps to reduce the delay in revocation.

Present Work:

In this section the function of vehicle, BS and CA are elaborated for vth vehicle (Vv) within the coverage area of Bth BS (BSB) under CA. The number of BSs under CA and the number of vehicles under BSB are assumed as NO_OF_BS and NO_OF_VB respectively.

Function of Vv:

The function of Vv is elaborated for jth S_MSG (S_MSGj) that it receives from jth vehicle within its coverage area. S_MSGj is of the form of (D_Sigj, E_VINj, H_MSGj, O_MSGj). D_Sigj is the digital signature of the jth vehicle, E_VINj is the E_VIN of the jth vehicle, H_MSGj is the hudden message and O_MSGj is the operational part to retrieve the message (MESSj) from H_MSGj. O_MSGj field contains the bit pattern corresponding to the different bitwise operators (AND, OR, XOR). Each bitwise operator is represented by Size_BWO number of bits and the size of O_MSGj (Size_O_MSGj) is exact multiple of Size _BWO. The ALGO_MESS algorithm is used by Vv to retrieve MESSj from H_MSGj by performing (Size_O_MSGj/Size_BWO) number of bitwise operations (Number_BWOj) among H_MSGj and E_VINj.

Vv switches on a timer and initializes it to v. It receives S_MSGj, increases a counter (NS_MSGv) by 1 and searches CA_CRL for E_VINj. If E_VINj is in CA_CRL or if (Size_O_MSGj%Size_BWO≠0) it discards S_MSGj. Otherwise it stores S_MSGj in a FIFO queue (Qv), triggers ALGO_MESS algorithm to retrieve MESSj from H_MSGj and inserts a record (Rj) in the form (E_VINj, MESSj, REMARKj) in a data table (DTv) for S_MSGj.

```
/*Retrieval of MESSj from H_MSGj*/
        {   i ← 1
            k ← 1
while (k<Number_BWOj){
 if (O_MSGj (i, i+Size_BWO-1) represents AND bit wise operator)
   {MESSj←H_MSGj    E_VINj
      Go to L1}
else if (O_MSGj (i, i+Size_BWO-1) represents OR bit wise operator)
     {MESSj←H_MSGj    E_VINj
      Go to L1}
else if (O_MSGj (i, i+Size_BWO-1) represents XOR bit wise operator)
   {MESSj ← H_MSGj    E_VINj
    Go to L1}
else
       Go to L1
L1: { i ← i + Size_BWO
    k ← k + 1}  } }
```

It repeats the same steps of operation for the other received S_MSGs till the timer expires. The maximum number of S_MSGs in Qv and the maximum number of records in DTv is NS_MSGv.

It triggers ALGO_V algorithm to detect the misbehaving vehicle after the expiry of the timer. The function of this algorithm is elaborated for S_MSGj in Qv. It compares MESSj of Rj with the value of the MESS attribute field of all other records in DTv. In case of match it increases Matchj counter and in case of mismatch it increases Mismatchj counter by 1 after each comparison. If Matchj = Mismatchj it ignores Rj. If Matchj > Mismatchj the Algo_V inserts TRUE in the REMARKj attribute field of Rj. Otherwise it inserts FALSE in the REMARKj attribute field of Rj, inserts E_VINj in a CRL (CRLv) and increases a counter (NEVIN_CRLv) by 1. The Algo_V repeats the same steps of operation for all the records in DTv to generate CRLv. Vv sends CRLv to its parent BS. The maximum number of E_VINs in CRLv is NEVIN_CRLv.

Function of BSB:

BSB triggers ALGO_B algorithm for generating a CRL (CRLB) and for sending CRLB to CA. The algorithm switches on a timer and initializes it to B. It receives CRLs from the vehicles within its coverage area of BSB, stores them in a FIFO queue (QB), increases a counter (NB_CRL) after receiving each CRL by 1 and assigns the first received CRL to CRLB. It starts to update CRLB by performing union operation among the existing CRLB and the received CRLs in QB as soon as NB_CRL becomes equal to 2 till the timer expires. The ALGO_B algorithm sends CRLB to CA after the expiry of τB. The maximum value of NB_CRL is NO_OF_VB and the maximum number of E_VINs in CRLB is assumed as NEVIN_CRLB.

Function of CA:

CA triggers ALGO_C algorithm for generating CA_CRL and for broadcasting CA_CRL among the vehicles within its coverage area. The algorithm switches on a timer and initializes it to C. It receives CRLs from the BSs within the coverage area of CA, stores them in a FIFO queue (QC), increases a counter (NC_CRL) after receiving each CRL by 1 and assigns the first received CRL to CA_CRL. It starts to update CA_CRL by performing union operation among the existing CA_CRL and the received CRLs in QC as soon as NC_CRL becomes equal to 2 till the timer expires. The ALGO_C algorithm broadcasts CA_CRL among the vehicles within the coverage area of CA after the expiry of τC. The maximum value of NC_CRL is NO_OF_BS and the maximum number of E_VINs in CA_CRL is assumed as NEVIN_CA_CRL.

Simulation:

The performance of the proposed scheme is evaluated qualitatively and quantitatively. In this section the simulation parameters, qualitative analysis and quantitative analysis of the proposed scheme are considered for discussion.

Simulation Parameters:

The size of E_VIN (Size_E_VIN) is 17 characters (Mondal and Mitra, 2012) and the size of each character is assumed as 8 bits (extended ASCII format) in the proposed scheme. Hence Size_E_VIN is 136 bits. The bit wise operation is performed among H_MSG and E_VIN to retrieve MESS from H_MSG. Hence the size of H_MSG (Size_H_MSG) is 136 bits. The size of D_Sig (Size_D_Sig) is 160 bits (Mondal and Mitra, 2012). The size of S_MSG (Size_SMSG) is (Size_D_Sig + Size_E_VIN+ Size_H_MSG + Size_O_MSG) bits. The value of v ,τB, τC, NO_OF_BS, NEVIN_CRLv, NEVIN_CRLB, NEVIN_CA_CRL, NO_OF_VB, NS_MSGv and Size_SMSG are assumed as 30 secs, 20 secs, 20 secs, 3, 400, 400, 1200, 144, 400, and 3232 bits. The data transmission rate (Data_TR) is assumed as 6Mb/s (Vehicular Technology).

Qualitative Analysis:

The qualitative analysis on the basis of communication overhead (COMM_OH), storage overhead (STO_OH) and computation overhead (COMP_OH) is reported in this section. The qualitative performance is evaluated by considering the maximum length of Qv, QB, and QC i.e. Qv has NS_MSGv number of S_MSGs, QB has NO_OF_VB number of CRLs and QC has NO_OF_BS number of CRLs. The qualitative performance of the proposed scheme is compared with (Towards Effective Vehicle Identification, 2004) on the basis of STO_OH.

Communication Overhead. The COMM_OH of the proposed scheme is /Data_TR sec where COMM_OHB is the communication overhead of BSB in bits.

Computation of COMM_OHB. BSB receives CRLs from NO_OF_VB number of vehicles within its coverage area. The size of CRLv is (NEVIN_CRLv×Size_E_VIN) bits. Hence COMM_OHB due to the reception of NO_OF_VB number of CRLs is (NEVIN_CRLv × Size_E_VIN) bits.

BSB sends CRLB to CA. The size of CRLB is NEVIN_CRLB×Size_E_VIN bits. Hence COMM_OHB due to the transmission of CRLB is NEVIN_CRLB×Size_E_VIN bits.

BSB receives CA_CRL from CA. The size of CA_CRL is NEVIN_CA_CRL ×Size_E_VIN bits. Hence the COMM_OHB due to the reception of CA_CRL is NEVIN_CA_CRL ×Size_E_VIN bits.

BSB sends CA_CRL to NO_OF_VB number of vehicles within its coverage area. Hence COMM_OHB due to the transmission of CA_CRL is NO_OF_VB× NEVIN_CA_CRL ×Size_E_VIN bits.

Hence COMM_OHB = Lv×Size_E_VIN)+ Size_E_VIN×(NEVIN_CRLB + NEVIN_CA_CRL (1+ NO_OF_VB)) bits.

Storage Overhead: The STO_OH of the proposed scheme is the sum of STO_OH of CA (STO_OH_CA) and STO_OH of NO_OF_BS number of BSs under CA (STO_OH_BS).

STO_OH_CA is due to the maintenance of NO_OF_BS number of CRLB in QC. Hence STO_OH_CA = NEVIN_CRLB× Size_E_VIN bits.

STO_OH_BS is) bits where STO_OHB is STO_OH of BSB.

STO_OHB is due to the maintenance of QB and NO_OF_VB number of Qv.

Now QB has NO_OF_VB number of CRLs and hence size of QB (Size_QB) is bits.

Qv has NS_MSGv number of S_MSGs and hence the size of Qv (Size_Qv) is bits, where Size_SMSGj is the size of S_MSGj.

Hence STO_OHB = Size_QB + bits.

Computation Overhead: The COMP_OH of the proposed scheme is the sum of COMP_OH of CA (COMP_OH_CA) and COMP_OH of NO_OF_BS number of BSs under CA (COMP_OH_BS).

COMP_OH_CA is for updating NC_CRL and for performing union operation among the received CRLs from NO_OF_BS number of BSs.

Now COMP_OH of updating NC_CRL for NO_OF_BS times is O(NO_OF_BS).

The COMP_OH of performing union operation among NO_OF_BS number of CRLs is O(log (NO_OF_BS)).

COMP_OH_BS is where COMP_OHB is the sum of COMP_OH of BSB and NO_OF_VB number of vehicles under it.

COMP_OH of BSB is for updating NB_CRL and for performing union operation among the received CRLs from NO_OF_VB number of vehicles.

Now COMP_OH of updating NB_CRL for NO_OF_VB times is O(NO_OF_VB) and of performing union operation among NO_OF_VB number of CRLs is O(log (NO_OF_VB)).

The COMP_OH of NO_OF_VB number of vehicles is the sum of searching overhead of CA_CRL for E_VIN, execution overhead of ALGO_MESS and ALGO_V.

Now COMP_OH of Vv for searching CA_CRL for NS_MSGv number of E_VINs corresponding to NS_MSGv number of received S_MSGs in Qv is O(NS_MSGv × NEVIN_CA_CRL), for executing ALGO_MESS algorithm for NS_MSGv number of S_MSGs is O(Number_BWO × Size_H_MSG × NS_MSGv) and for executing ALGO_V algorithm for NS_MSGv number of records in DTv is O(NS_MSGv2).

Hence COMP_OH of NO_OF_VB number of vehicles under BSB is O((Number_BWO × Size_H_MSG × NS_MSGv) + (NS_MSGv2))).

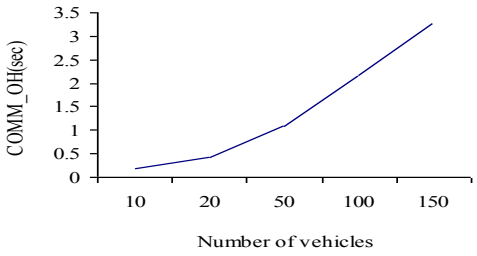


Fig. 1: COMM_OH vs. Number of vehicles

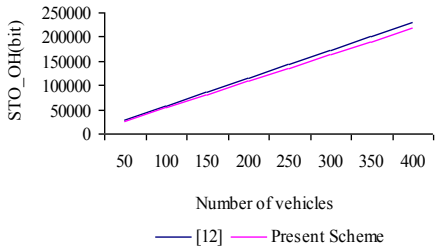


Fig. 2: STO_OH vs. Number of vehicles.

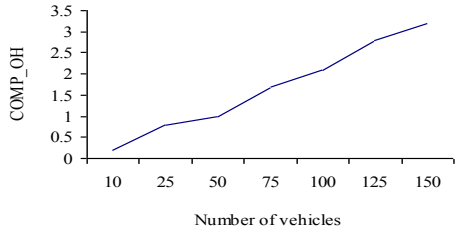


Fig. 3: COMP_OH vs. Number of vehicle

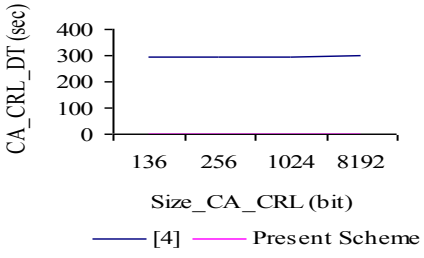


Fig. 4: CA_CRL_DT vs. Size_CA_CRL

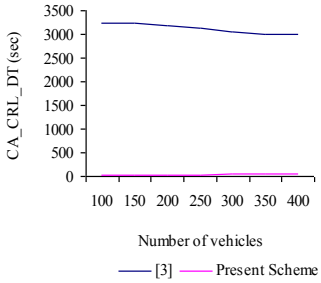
Fig.1, Fig.2 and Fig.3 show the plot of COMM_OH, STO_OH and COMP_OH vs. number of vehicles in VANET. STO_OH of the present scheme is less than that in as observed from Fig.2. The number of vehicles per BS increases with the number of vehicles in VANET which in turn increases COMM_OH, STO_OH and COMP_OH as observed from Fig.1, Fig.2 and Fig.3 respectively.

Quantitative Analysis:

The performance of the proposed scheme is studied quantitatively on the basis of CA_CRL distribution time (CA_CRL_DT) and it is compared with (Kargl, *et al*., 2008; Nowatkowski, *et al*., 2008). The CA_CRL_DT is the time which is required to broadcast CA_CRL by CA among the vehicles within its coverage area. It is determined during simulation. The quantitative performance of the proposed scheme is also studied on the basis of delay in detection of misbehaving vehicles (Delay_MV). Delay_MV for Vv (Delay_MVv) is computed as the sum of waiting time of S_MSGs in Qv, searching time of CA_CRL for E_VINs corresponding to the received S_MSGs in Qv, time to execute ALGO_MESS and ALGO_V. So, Delay_MV= .

Fig.4 shows the plot of CA_CRL_DT vs. Size_CA_CRL. The Size_CA_CRL is the size of CA_CRL and it is computed as NEVIN_CA_CRL × Size_E_VIN bits. It can be observed from Fig.4 that CA_CRL_DT increases with Size_CA_CRL both in the present scheme and in (Nowatkowski, *et al*., 2008). In (Nowatkowski, *et al*., 2008) Size_CA_CRL is 1 Mbyte and CA_CRL_DT is 300 secs. The curve is a straight line as Size_CA_CRL is constant to 1 Mbyte. In the present work Size_CA_CRL varies dynamically with

NEVIN_CA_CRL and hence CA_CRL_DT increases slowly with Size_CA_CRL. In the present work CA_CRL_DT is about 1 sec.



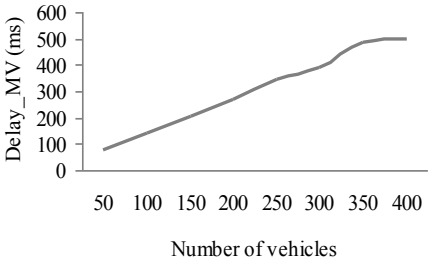


Fig. 5: CA_CRL_DT vs. Number of vehicles.

Fig. 6: Delay_MV vs. Number of vehicles.

Fig.5 shows the plot of CA_CRL_DT vs. number of vehicles in VANET. CA_CRL_DT depends upon the size of CA_CRL which in turn depends upon the number of misbehaving vehicles in VANET. Hence CA_CRL_DT increases slowly with the number of vehicles as observed from Fig.5. In (Kargl, *et al*., 2008) CA_CRL_DT is approximately 3000 secs whereas in the present work CA_CRL_DT is almost 3 secs.

Fig.6 shows the plot of Delay_MV vs. number of vehicles in VANET. It can be observed from Fig.6 that Delay_MV increases with the number of vehicles as per its definition.

Conclusion:

Each vehicle detects and revokes misbehaving vehicles from VANET during V2V communication. The CA_CRL is created by CA after collecting the CRLs from the BSs within its coverage area. Each BS creates the CRL after collecting the CRLs from the vehicles within its coverage area.

The CA may verify the revocation decision of the vehicles before creating CA_CRL. The performance of the proposed scheme may be studied by varying the value of the other parameters and by incorporating the fuzzy logic concept.

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