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RESEARCH ARTICLE

ENHANCING SECURITY WITH LOW COMMUNICATION AND PROCESSING OVERHEAD FOR MULTI-HOP WIRELESS NETWORKS

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Abstract---- A multi-hop wireless network is a network in which a packet traversed in multiple successive wireless links to reach its destination. It is similar to mobile adhoc networks, but nodes in multi-hop wireless network are fixed. Multi-hop wireless networks can be deployed at less lost and it enlarges the coverage area with limited transmit power, enhance the spectral efficiency and network throughput. But the multi-hop wireless networks are vulnerable to different types of attacks. The selfish nodes in the multi-hop wireless networks do not relay other packets and by utilizing the cooperative nodes to transfer their packets to other nodes. So that the cooperative nodes are overloaded due to the high traffic. In this paper a trust based method is proposed to provide reliable route. Another method is Hybrid cryptographic has been proposed for improving security and reducing the complexity. Finally the SVM classification algorithm is proposed to efficiently classify the fair and cheating reports.

Key Words--- Multi-hop wireless network, Trust based method, Hybrid Cryptography, SVM

I. INTRODUCTION

In multi hop wireless networks (MWNs), the traffic originated from a node is usually relayed through the other nodes to the destination for enabling new applications and enhancing the network performance and deployment [3]. MWNs can be deployed readily at low cost in developing and rural areas. Multi hop packet relay can extend the network coverage using limited transmit power, improves area spectral efficiency, and enhance the network throughput and capacity. MWNs can also implement many useful applications such as data sharing [1] and multimedia data transmission. For example, users in one area (residential neighborhood, university campus, etc.) having different wireless-enabled devices, e.g., PDAs, laptops, tablets, cell phones, etc., can establish a network to communicate, distribute files, and share information. However, the assumption that the nodes are willing to spend their scarce resources, such as battery energy, CPU cycles, and available network bandwidth, to relay others' packets without compensation cannot be held for civilian applications where the nodes are autonomous and aim to maximize their welfare.

Selfish nodes will not relay others' packets and make use of the cooperative nodes to relay their packets, which degrades the network connectivity and fairness. The fairness issue arises when the selfish nodes make use of the cooperative nodes to relay their packets without any contribution to them, and thus the cooperative nodes are unfairly overloaded because the network traffic is concentrated through them. The selfish behavior also degrades the network connectivity significantly, which may cause the multi hop communication to fail.

A Report-based payment scheme which is called RACE for MWNs [4]. The nodes submit lightweight payment reports (instead of receipts) to the AC (Accounting center) to update their credit accounts, and temporarily store undeniable security tokens called Evidences. The reports contain the alleged charges and rewards of different sessions without security proofs, e.g., signatures. The AC (Accounting Center) verifies the payment by investigating the consistency of the reports, and clears the payment of the fair reports with almost no cryptographic operations or computational overhead. For cheating reports, the Evidences are requested to identify and evict the cheating nodes that submit incorrect reports, e.g., to steal credits or pay less. In other words, the Evidences are used to resolve disputes when the nodes disagree about the payment. Instead of requesting the Evidences from all the nodes participating in the cheating reports, RACE can identify the cheating nodes with submitting and processing few Evidences. Moreover, Evidence aggregation technique is used to reduce the storage area of the Evidences. Evidences are submitted and AC applies cryptographic operations to verify the payment only in case of cheating. But the disadvantage of this method is fewer throughputs, less packet delivery ratio, high latency, less security and high complexity so we have proposed trust based system, Hybrid cryptographic method and SVM classification to make the payment scheme in an effective manner. Therefore, reducing the communication and the payment processing overhead is essential for the effective implementation of the payment scheme and to avoid creating a bottleneck at the AC and exhausting the nodes' resources.

II. RELATED WORKS

Jianping Pan Et.al proposed Identity-based secure association method in wireless adhoc networks. In the wireless adhoc networks, the latest technique named as a method of identity-based cryptography is used in 2007. Actually, in the public-key cryptography schemes, the certificate authorities stored the identity and public key of the entities. This kind of central authorities is eradicated in the identity-based cryptography method. In this method, the public-key of an entity can be derived from its identity directly. This feature is crucially significant for ad hoc networks, where public-key infrastructures (PKIs) or CA hierarchies are also luxurious to build and susceptible to preserve in general. Identity-based cryptography is used to make possible asymmetric encryption/decryption and signature/verification procedure. It is suggested to utilize Identity-Based Broadcast Encryption Scheme for better efficiency [2].

Mohamed Elsalih Mahmoud et.al proposed a method which is called practical incentive system to motivate the support of the nodes in the multi-hop wireless networks in 2010. While the communication sessions may arise without concerning an infrastructure, the communicating nodes provide digital receipts for the intermediate nodes, which submit the receipts to the accounting center (AC) to maintain their payment. The decisive point of the practical completion of incentive systems is the receipts' submission and high overhead because of the high frequency of low-value transactions. If there is a huge number of receipts is submitted for the node clarification, there are high computation overhead and high complexity. It is suggested that the Practical Incentive System for multi-hop cellular networks could be proposed [4].

Linu Ann Joy et.al proposed Trusted and Attacker Free Credit Based System called TACS to provide node cooperation, efficient data transmission, low storage overhead and high performance in 2013. In the new system all the attacker nodes are removed before beginning the communication and a trust value is assigned to all the nodes. TACS can be used with any source routing protocol such as Trust based routing protocol, which establishes an end to end connection before transmitting the data. The results clearly showed that the data transmission in network was fully secured. It improved the security of the system and it has low communication overhead, processing overhead. It is suggested to replace the hashing techniques with any other encryption algorithm AES, DES etc for avoiding the attacker to hack the details [7].

Mohamed Taher Nashnosh et.al proposed LESIPT: Lightweight Enhanced Secure Incentive Protocol with Trusted value for multi-hop wireless networks in 2014. LESIPT signs the digital signatures by the Accounting Center AC and the mobile nodes require verifying only. The participated nodes save the digital signatures of the sender and then the receiver require using one-way hash function only. LESIPT reduces the cryptography operations in mobile nodes by the use of conventional digital signature, and one-way hash function. The results revealed that LESIPT can secure the payment, and improve the network performance significantly because the verification operation require less time and energy compare to the signing, and the hashing operations dominate the nodes operations [8].

Mohamed M.E.A et.al proposed Report based payment scheme is used in multi hop wireless networks to motivate node cooperation, organize packet transmission and implement fairness in 2013. RACE is the payment scheme use the concept of evidences to protect the payment and need cryptographic operations in clearing the payment only in the case of cheating. The AC can process the payment reports to know the number of relayed/dropped messages by each node and verify the payment by investigating the consistency of the node's reports without submitting and processing security tokens and without false accusations The results demonstrate that RACE can significantly decrease the communication and processing overhead comparing to the existing receipt-based payment schemes with acceptable payment clearance delay and Evidences storage area.It is suggested to implement Hybrid Cryptography for enhance the security and SVM classification algorithm is used for improving the classification of accuracy [6].

III. Trust Based Method

A node trust value is defined as the degree of belief about the node's behavior, the expectation, or the probability that a node will act in a certain way in the future based on the node's past behavior [5]. Based on sending the packet successfully a trust value is assigned for each node. The highest trust value is assigned for the nodes that relay messages more successfully. Similarly, if a node has broken a large percentage of routes in the past, there is a strong belief that this node will break routes with high probability in the future, and thus the trust based system should avoid it. The trust values are computed to depict the nodes' reliability and competence in relaying packets. Based on these trust values, a trust-based system is proposed to route messages through the highly trusted nodes (which performed packet relay more successfully in the past) to minimize the probability of dropping the messages, and thus improve the network performance in terms of throughput and packet delivery ratio.

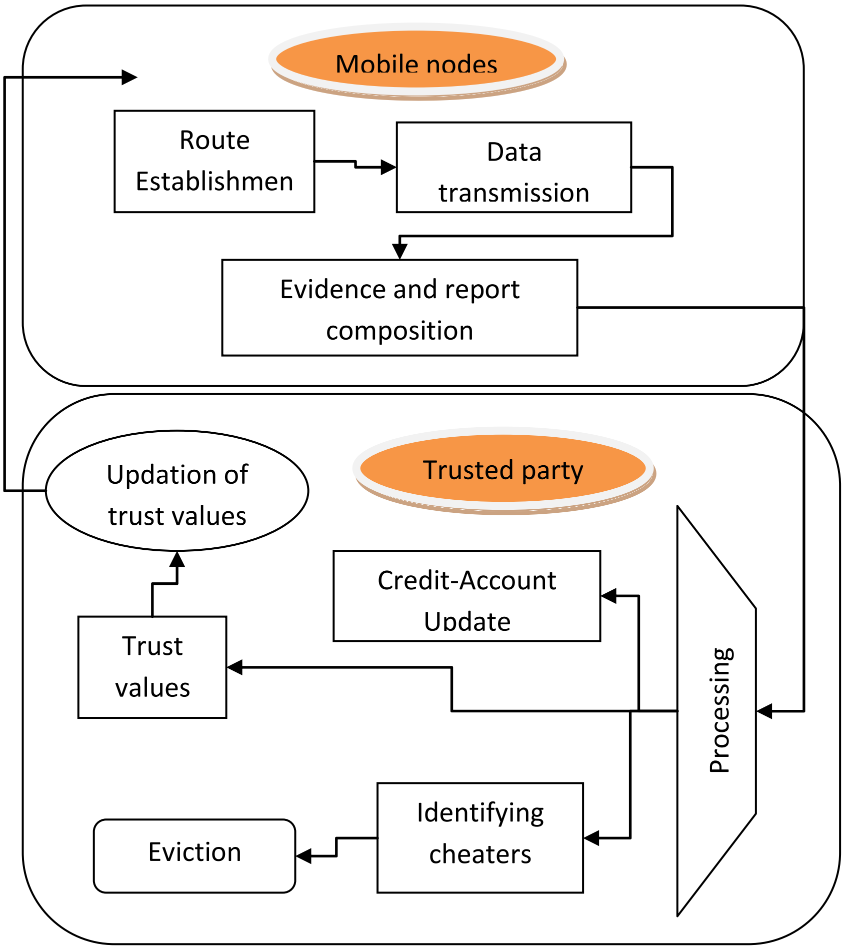


Fig 1: Trust Based System

As shown in the above figure 1 the trust based payment system includes five phases,

- The first phase is communication phase. The Communication phase has four processes: route establishment, data transmission, Evidence composition, and payment report composition/submission. In the route establishment process, the route is identified and the data is transmitted in the route. In the data transmission process, the source node sends data packets to the destination node through the established route and the destination node replies with ACK packets.
- In the Evidence composition, and payment report composition process, the nodes accumulate the payment reports and submit them in batch to the TP. This evidence is given to the processing for classify the cheating nodes and normal nodes.
- For the Classifier phase, the TP classifies the reports into fair and cheating. For the Identifying Cheaters phase, the TP requests the Evidences from the nodes that are involved in cheating reports to identify the cheating nodes. The cheating nodes are evicted and the payment reports are corrected.
- In the Credit-Account Update phase, the AC clears the payment reports.

- In the trust value phase, the TP computes the trust values and given the route establishment process. The trust values are updated at every time interval. These values are given to the route establishment process. Based on the trust values, the route is selected.

Trust Based System Algorithm

1. Initialize N number of nodes in the network i=1,..N
2. // Route establishment phase
3. S broadcasts RREQ packet to all the nodes //S=source, RREQ includes $Source\ ID\ (ID_s), Destination\ ID\ (ID_D)$, time stamp Ts, Time-to-live (TTL)
4. TP compute the trust value of each node in the network
5. // Establish stable route based on trust value
6. $\tau_i^{(1)} = \frac{No\ of\ packets\ that\ are\ relyed\ in\ the\ last\ \omega\ sesions}{Total\ no\ of\ incoming\ packets\ in\ the\ last\ \omega\ sessions}$ // $\tau_i^{(1)}$= depicts the probability that $\mathcal{N}_k$ will relay a packet successfully, ω=session
7. $\tau_i^{(2)} = 1 - \frac{No\ of\ sessions\ broken\ by\ \mathcal{N}_k\ in\ the\ last\ \omega\ sessions}{\omega}$ // $\tau_i^{(2)}$= depicts the probability that $\mathcal{N}_k$ will not break a route.
8. $\tau_i^{(3)} = \frac{No\ of\ sessions\ that\ \mathcal{N}_k\ relayed\ at\ least\ \delta\ packets}{\omega}$ // $\tau_i^{(3)}$=depicts the node's ability to keep a route connected for a minimum number of packets.
9. $\tau_i^{(4)} = \frac{No\ of\ sessions\ \mathcal{N}_k\ participated\ in\ the\ period\ t}{\mathcal{M}}$ // Where $\tau_i^{(4)}$= is the total number of sessions $\mathcal{N}_k$ participated in, in the last period.
10. $\tau_{WXYZ}^{(a)} = \tau_W^{(a)} \times \tau_X^{(a)} \times \tau_Y^{(a)} \times \tau_Z^{(a)}$ // the probability that a packet will reach the destination node through the intermediate nodes Ex: WXYZ=Intermediate nodes
11. If (nodes that relay messages more successfully)
12. Highest trust value
13. Else
14. Lowest trust value
15. End if
16. Select the highest trust nodes
17. Based on the highest trust value select the route and Update the trust values
18. S selects the stable route
19. D composes RREP packet for the first received RREQ packet and reply to S // D=Destination node
20. D create produce the hash chain root $h^{(i-1)} = H(h^{(i)})$ //h=hash value
21. // Data transmission phase
22. if (n_i is the source node) then
23. $P_X \leftarrow$ [R,X, M_X, Sigs(R,X, T_s, H(M_X))];
24. Send (P_X); // send P_X to the first node in the route
25. Else
26. if(R,X, T_s are correct) and verify (Sigs(R,X, T_s, H(M_X))) == TRUE) then
27. if(n_i is an intermediate node) then
28. Relay the packet;
29. Store Sigs(R,X, T_s, H(M_X));
30. End if
31. if(n_i is the destination node) then
32. Send($h^{(X)}$);

End if
Else
Drop the packet;
Send error packet to the source node;
End if
End if
// Evidence and report composition
if(P_X is last packet) then
Evidence = {R, X, T_s, H(M_X), $h^{(0)}$, $h^{(x)}$, H (Sig_s(R,X, T_s , H(M_X)), Sig_D (R, T_s, $h^{(0)}$))};
Report = { R, T_s, F,X);
Store Report and Evidence;
end if
// Cheating report identification phase
$n_i \rightarrow$ TP: Submit (Reports[t_{i-1}, t_i));
TP$\rightarrow$ n_i: Evidences Request (Ses_ID_s[t_{i-2} , t_{i-1}));
$n_i \rightarrow$ TP: Submit (Req_Evs[t_{i-2} , t_{i-1}));
TP: Identify_ Cheaters ();
TP: Clear the payment of the reports;
if (n_i is honest) then
TP $\rightarrow$ n_i: A renewed certificate
end if

IV. HYBRID CRYPTOGRAPHY

There are two main phases in the hybrid cryptography method

1. Key generation Phase

In the key generation process, the RSA algorithm is used to generate the keys for all the nodes in the network. After that the Diffie Hellman algorithm is used for exchanging the keys.

2. Encryption/ Decryption Phase

- The RC4 and AES algorithm is used for encryption/decryption process.

- **AES Algorithm**

Sender encrypts the original message by using the AES encryption algorithm. At the receiver side, the message is decrypted by using the AES algorithm. Again, the hash value is computed for the decrypted message.

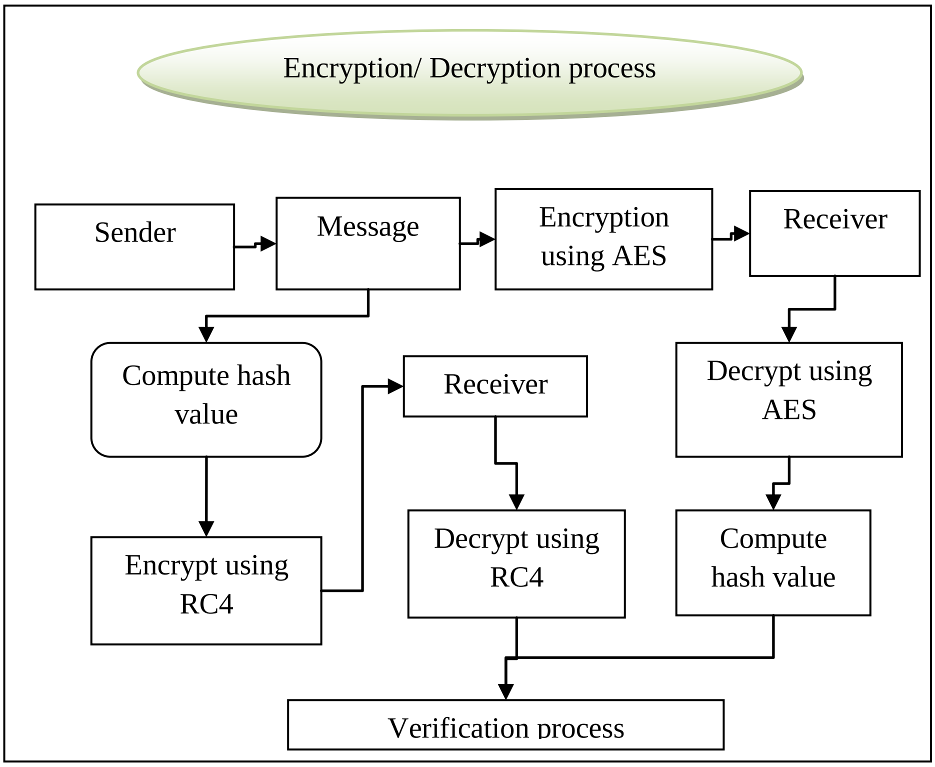


Fig 2: Hybrid Cryptography Architecture

- **RC4Algorithm**

  Hash value of the message is computed. After that, the hash value of the message is encrypted by using RC4 encryption. At the receiver side, the encrypted hash value of the message is decrypted by using the RC4 algorithm

- Finally these two hash values obtained from AES and RC4 are compared and verified. .

Hybrid Cryptography Algorithm

1. Initialize N number of nodes in the network
2. // Key generation process using RSA algorithm
3. Select the two distinct prime numbers p and q. The integers p and q should be chosen at random, and should be of similar bit-length.
4. Compute $n = p \times q$. // n is used as the modulus for both the public and private keys. Its length, usually expressed in bits, is the key length.
5. Compute $z = (p - 1) \times (q - 1)$
6. Choose a prime number k, such that k is co-prime to z, i.e., z is not divisible by k
7. The values n and k is the public key
8. // Secret key computation process
9. k * a = 1 (mod z) // a is the secret key
10. The key is generated for all the nodes in the network

11. // Diffie Hellman Key exchange algorithm
12. Sender and receiver agree to use a prime number p and base g (which is a primitive root modulo 23).

13. Sender chooses a secret integer a and compute $A \equiv g^{a}(mod\ p)$ // Sender and receiver
14. Receiver chooses a secret integer b and compute $B \equiv g^{b}(mod\ p)$
15. Sender and receiver exchange the values
16. Sender compute the value $s = B^{a} mod\ p$
17. Receiver compute the value $s = A^{b} mod\ p$
18. Sender and receiver share a secret value
19. // Encryption and decryption process
20. // AES encryption
21. Sender gives the plain text and change to state
22. Sub-bytes: This is a byte-by-byte substitution. The substitution byte for each input byte is found by using the same lookup table. The size of the lookup table is 16×16.
23. Shift Rows: The Shift Rows transformation consists of (i) not shifting the first row of the state array at all; (ii) circularly shifting the second row by one byte to the left; (iii) circularly shifting the third row by two bytes to the left; and (iv) circularly shifting the last row by three bytes to the left.
24. Mix Columns: This step replaces each byte of a column by a function of all the bytes in the same column. More precisely, each byte in a column is replaced by two times that byte, plus three times the next byte, plus the byte that comes next, plus the byte that follows.
25. Add Round Key: Round key is added to the State using XOR operation
26. // RC4 Encryption
27. Compute the hash value for the message
28. H(M)=hash(M) // Hash value for the message
29. Create two string arrays
30. for (k = 0 to N-1) {
31. i = (i + 1) mod 256;
32. j = (j + S[i]) mod 256;
33. swap S[i] and S[j];
34. t = S[(S[i] + S[j]) mod 256]
35. C= H(M[k]) XOR t} // Cipher text
36. Where H (M [0...N-1]) is the input message consisting of N bits.
37. // RC4 decryption process
38. For the decryption, XOR the cipher text with the key stream.
39. H(M)=C XOR t
40. // AES Decryption
41. Inverse shift rows: For decryption, the corresponding step shifts the rows in exactly the opposite fashion. The first row is left unchanged; the second row is shifted to the right by one byte, the third row to the right by two bytes, and the last row to the right by three bytes, all shifts being circular.
42. Inverse Sub-bytes: This is a byte-by-byte substitution. The substitution byte for each input byte is found by using the same lookup table. The size of the lookup table is 16×16.
43. Add Round Key: Round key is added to the State using XOR operation
44. Inverse Mix Columns: This step replaces each byte of a column by a function of all the bytes in the same column. More precisely, each byte in a column is replaced by two times that byte, plus three times the next byte, plus the byte that comes next, plus the byte that follows.
45. The original message is recovered by AES decryption
46. // Compute the hash value of the decrypted message
47. $H'(M) = hash(M)$ Hash value for the decrypted message
48. // Verification process
49. If(H(M)= $H'(M)$)
50. Successfully verified
51. Else
52. Not successfully verified
53. End if

IV. SVM CLASSIFICATION

Support vector machine (SVM) classification method is used to classify the fair and cheating reports. There are two phases are

- ✓ Training phase
- ✓ Testing phase.

In the training phase, the nodes behavior is computed by using the parameters like packet delivery ratio, signal strength, traffic flow, time-to-live and compare with the threshold. Then the class labels are assigned to the nodes like cheating and normal.

In the testing phase, the behavior are analyzed for all the nodes present in the network and find out the cheating nodes by learning the rules present in training phase. Sometimes, the nodes resources are reduced due to some problems like network failure, less resources and so on. So, the SNMP (Simple Network Management Protocol) is used to monitoring the network performance and classify the cheating and normal nodes correctly.

SVM Classification Algorithm

Input: Number of nodes

Output: Classification of cheating and normal nodes

1. Initialize N number of nodes in the network $N = n_1, n_2, \dots n_i$
2. // Training phase
3. While $i \leq N$
4. Set the SNMP nodes
5. SNMP nodes calculate the energy level
6. // Compute the energy level
7. Calculate transmission energy for all nodes
8. $E_{tx}(p.i) = I.v.t_b$ Joules // , I is current in ampere, V voltage in volts, t_b is time taken to transmit a packet
9. E (p, i) = $E_{tx}(p,i) + E_{rx}(p,j)$ //
10. Residual energy = Available energy-(Transmission energy +reception energy)
11. $E_{res}(i) = E_{ave}(i) - (E_{tx}(p,i) + E_{rx}(p,j)$ // $E_{res}(i)$ = residual energy of node i $E_{ave}(i)$= Available energy in node i, $E_{tx}(p,i)$ = Amount of energy spent to transmit the packet from node i to node j , $E_{rx}(p,j)$ = Amount of energy spent to receive the packet at node j.
12. Compute the metrics such as packet delivery ratio, signal strength, traffic flow, time-to-live.
13. // Packet delivery ratio –PDR
14. $PDR_i = \frac{Number\ of\ packets\ receive}{Number\ of\ packets\ send}$
15. // Signal strength-SS
16. $SS_i = T_x - (L_{LS} + L_{MS} + L_{SS})$ // Where SS=signal strength, T_x=Transmitted signal strength, L_{LS}=Signal degradation caused by large-scale propagation, L_{MS}=signal degradation caused by medium-scale propagation, L_{SS}=signal degradation caused by

small-scale propagation
//Traffic flow-TF
$TF_i = \frac{Amount\ of\ data\ transfer}{Time}$
//Time-to-live-TL
$TL_i = \frac{Data\ in\ network}{Time\ interval}$
If $(PDR_i < Th\_PDR || SS_i < Th_{SS} || TF_i < Th\_TF || TL_i < Th\_TL)$ then //
$Th_{PDR} =$ Threshold for PDR, $Th_{SS} = Threshold\ for\ signal\ strength, Th_{TF} = Threshold\ for\ traffic\ flow, Th_{TL} = Threshold\ for\ time - to - live$
If $(E_{res}(i) < E_{Th})$ then $//E_{Th}$=Threshold for energy
Consider as normal nodes
Else
Consider as cheating nodes
End if
End if
End while
Construct classifiers
// Testing phase
For i=1 to N
Compute PDR, SS, TF,TL
Learn the rules in the training phase
Classify the cheating and normal nodes
End for

V. EXPERIMENTAL RESULTS AND DISCUSSION

The performance metrics considered in this work to show the effectiveness of packet delivery ratio, throughput and end-to-end delay.

Description of performance metrics

1. Packet delivery ratio

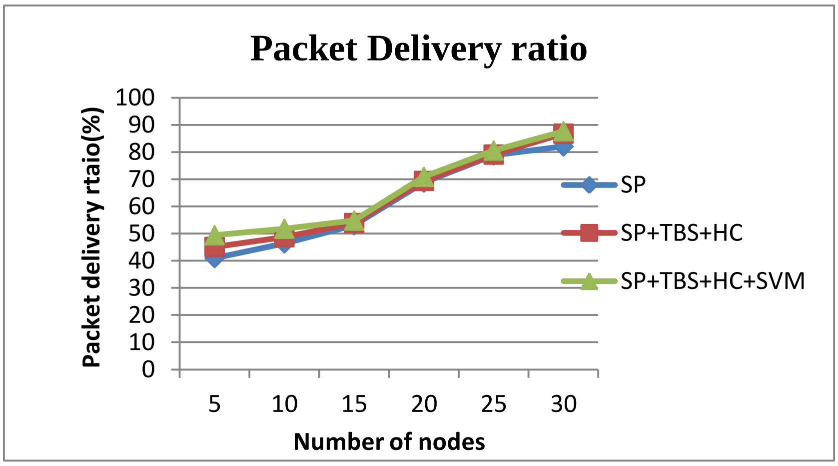
It is defined as the ratio of the number of delivered data packet to the destination. This illustrates the level of delivered data to the destination.

∑ Number of packet receive / ∑ Number of packet send

Table 1: Packet delivery ratio

Packet delivery ratio (%)			
Number of nodes	SP	SP+TBS+HC	SP+TBS+HC+SVM
5	41	45.1	49.4
10	46.4	48.7	51.8
15	53.1	53.9	54.8
20	68.8	69.4	70.9
25	78.8	79.1	80.6
30	82.1	86.8	87.7

Table 1 shows the statistical value for the packet delivery ratio. This shows that if the number of nodes are 30, the packet delivery ratio for SP is 82.1%, for SP+TSP+HC is 86.8 % and 87.7% for SP+TBS+HC+SVM.



Graph 1: Packet delivery ratio

The above graph 1 clearly shows the packet delivery ratio obtained by the Trust based system, Hybrid Cryptography and Support Vector machines that achieves higher packet delivery ratio than the Report based payment Scheme (RACE).

2. End-to-End Delay

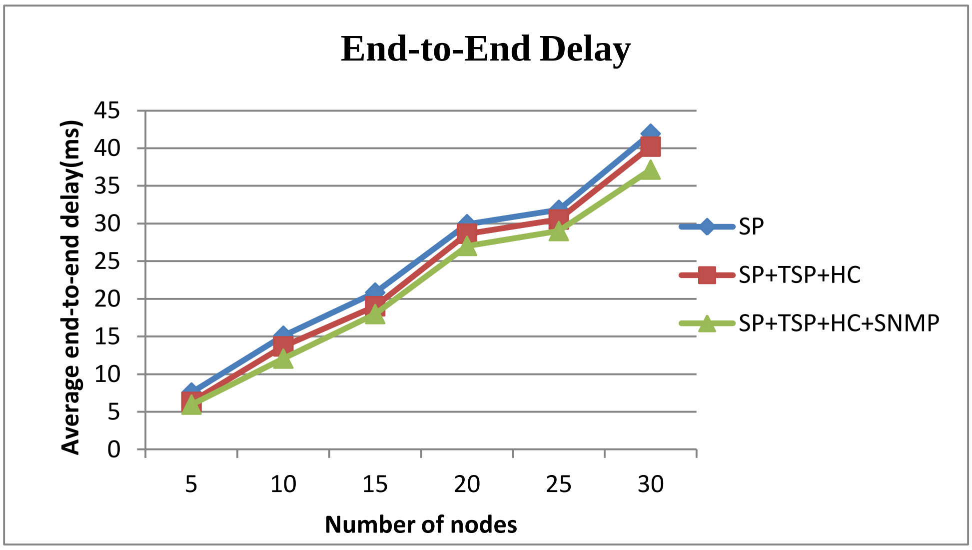
End-to-end delay is the time it takes a packet to travel across the network from source to destination. Delay jitter is the fluctuation of end-to-end delay from packet to the next packet.

$$\sum \text{(arrive time – send time)} / \sum \text{Number of connections}$$

Table 2: End-to-End Delay

End-to-End Delay (ms)			
Number of nodes	SP	SP+TBS+HC	SP+TBS+HC+SVM
5	7.562	6.314	5.957
10	15.101	13.684	12.068
15	20.834	19.014	17.983
20	29.914	28.647	27.034
25	31.824	30.536	29.009
30	41.933	40.214	37.168

Table 2 shows the statistical value for the end-to-end delay. This shows that if the number of nodes are 30, the end-to-end delay for SP is 41.933 ms, for SP+TBS+HC is 40.214 ms and 37.168 ms for SP+TBS+HC+SVM.



Graph 2: End-to-End Delay

The above graph 2 clearly shows the end-to-end delay obtained by the trust based payment method, hybrid cryptography and Support Vector machines which decrease the delay than the Report based payment scheme (RACE).

3. Throughput

Throughput or network throughput is the rate of successful message delivery over a communication channel. Throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot.

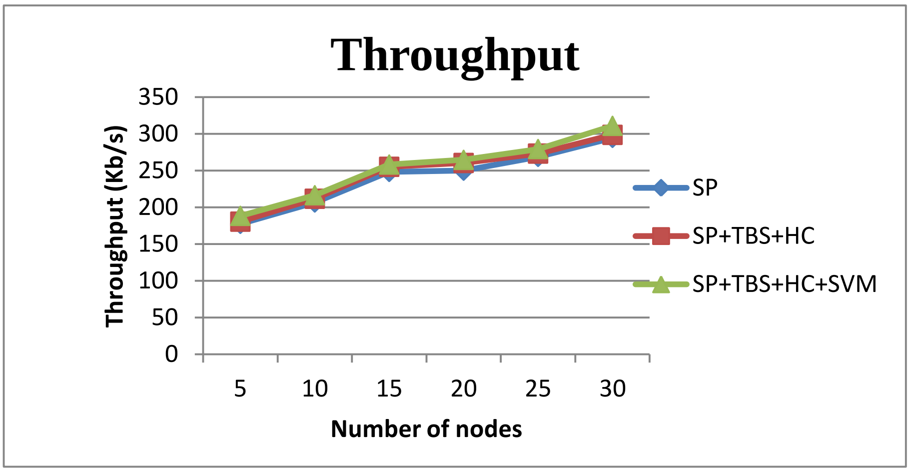
Transmission Time = File Size / Bandwidth (sec)

Throughput = File Size / Transmission Time (Kbps)

Table 3: Throughput

Throughput (Kbytes/sec)			
Number of nodes	SP	SP+TBS+HC	SP+TBS+HC+SVM
5	164.41	181.48	188.3
10	206.5	211.68	216.4
15	248.1	255.19	258.2
20	249.8	260.34	264.6
25	268.6	273.16	279.3
30	294.5	298.64	310.9

Table 3 shows the statistical value for the throughput. This shows that if the number of nodes are 30, the throughput for SP is 294.5 Kbytes, for SP+TBS+HC is 298.6 Kbytes and 310.9 Kbytes for SP+TBS+HC+SVM.



Graph 3: Throughput

The above graph 3 clearly shows the throughput obtained by the Trust based payment method, Hybrid cryptography and Support Vector machines which achieves the higher throughput than the Report based payment scheme.

VI. CONCLUSION AND FUTURE CONSIDERATIONS

A report-based payment scheme is used in multi-hop wireless networks. The nodes submit lightweight payment reports containing the alleged charges and rewards (without proofs), and temporarily store undeniable security tokens called Evidences. The fair reports can be cleared with almost no cryptographic operations or processing overhead, and Evidences are submitted and processed only in case of cheating reports in order to identify the cheating nodes. Based on these trust values, a trust based System is proposed to route messages through the highly trusted nodes (which performed packet relay more successfully in the past) to minimize the probability of dropping the messages, and thus improve the network performance in terms of throughput and packet delivery ratio. In order to enhance the security the Hybrid cryptographic method is used. SVM classification method is proposed to accurately classify the fair and cheating reports. In future, Energy consumption of communication systems is becoming a fundamental issue among all the sectors and wireless access networks are largely responsible for the increase in consumption.

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