

TEA-CBRP: Distributed cluster head election in MANET by using AHP

U. Venkanna · R. Leela Velusamy

Received: 21 February 2014 / Accepted: 26 November 2014 / Published online: 16 December 2014
© Springer Science+Business Media New York 2014

Abstract Mobile Ad hoc Network consists of a set of mobile nodes that are communicating in a wireless channel. In this network, the number of nodes and their mobility have an impact on the routing performance. In order to improve the routing performance of large scale Mobile Ad Hoc Networks, clustering is one of the solution. When clustering is implemented, an unconditional cooperation among the intra cluster and inter cluster nodes is necessary. In the event where a malicious or selfish node is elected as a cluster head, the routing performance gets significantly affected. In this paper, the key decision factors such as the trust value, remaining energy, and the time of availability of the mobile node is explored to elect a cluster head. Further, these three decision factors are incorporated into the Analytical Hierarchy Process technique in order to elect the most cooperative node as the cluster head. An enhancement to the existing Cluster based Routing Protocol, is proposed in this paper and then enhanced work, is termed as Trust Energy Availability based Cluster Based Routing Protocol. A network based on the proposed protocol is simulated. The important routing performance parameters such as packet delivery ratio, end to end latency, routing packet overhead, and the number of times cluster head changes are discussed for the simulated network and the results are compared with AODV and CBRP routing protocols. The simulation

results have shown that the proposed cluster based routing protocol improves the network performance by eliminating malicious and selfish nodes from being elected as cluster head.

Keywords Trust value · Remaining energy level · Availability · Cluster head election · CBRP · AHP · TEA-CBRP

1 Introduction

In the last decade, the advances in wireless communication network has opened up new research opportunities. Wireless communication is becoming increasingly popular since it can be deployed without infrastructure. Mobile Ad hoc Network (MANET) [1] and [2] is an autonomous system and infrastructure less system that consists of mobile devices such as PDA, Laptops, and mobile phones communicating using wireless channel. These networks are widely deployed in situations where the infrastructure is unavailable or deploying the network is impractical. Scenarios such as disaster recovery, military communication [3], and distributed collaborative communication uses MANET for communication [4]. In MANET every mobile node moves independently and establish communication with a new mobile node. An effective communication among nodes is achieved in MANET when there is an unconditional cooperation of nodes.

The routing in MANET is basically classified as flat and hierarchical routing. In flat routing, every mobile node has a dual role as a host (it is generating its own data packets and control packets) and as a router (it forwards packets from its neighbour nodes). The network performance of flat

U. Venkanna (✉) · R. Leela Velusamy
Department of Computer Science and Engineering, National
Institute of Technology, Tiruchirappalli, Tamil Nadu 620015, India
e-mail: uvrao4u@gmail.com

R. Leela Velusamy
e-mail: leela@nitt.edu

routing protocol degrades as the routing overhead increases with an increase in number of nodes and their mobility [5] and [6]. In hierarchical routing, the nodes are divided into small groups called clusters and one of the nodes in the cluster is elected as a cluster head [7]. This cluster head has the information about all its cluster nodes and plays the role of establishing communication with other cluster head by using the cluster gateway. The cluster head acts as a local coordinator and maintains the intra-cluster routing information and is responsible for forwarding the control and data packets. In this hierarchical routing a node having one or more neighbour nodes as cluster head will act as the cluster gateway. The routing between two clusters is processed by cluster gateway. Clustering in MANET has the following advantages:

- 1 Decreases the routing table overhead and the control packet flooding, thereby minimizing energy consumption.
- 2 Improves the routing performance as well as the scalability.

Electing the cluster head in a MANET is an important task. The cluster head is the node which will be more vulnerable to various attacks by misbehaving nodes [8] and [9] or non-cooperative nodes. The misbehaving behaviour of a node in MANET classifies it as malicious or selfish node. The malicious node intentionally misbehaves and performs attacks such as Blackhole [10], and Grayhole [11] and [12]. The selfish node due to its energy constraints intentionally drops the packets.

In the event of selecting the misbehaving node as a elected cluster head, the network performance is severely affected. Hence it is necessary to elect a cooperative node as the cluster head, in order to increase the network performance. In this paper the key decision parameters namely the Trust value (TV), Remaining Energy Level (REL), and Time of Availability (ToA) are used to elect a node as the cluster head. The TV parameter completely eliminates the possibility of electing a malicious node. While REL parameter helps in eliminating selfish node election and the ToA parameter is used to stabilize the cluster formation. The major contributions in this paper is as follows:

- 1 A methodology is proposed to elect a cooperative node as the cluster head by using key decision parameters TV, REL, and ToA value of nodes.
- 2 Furthermore, an enhancement to the above methodology is proposed to achieve cluster stabilization in which a Secondary Cluster Head (SCH) is elected to take the role of the Primary Cluster Head (PCH) whenever the latter moves out of the cluster.

This paper henceforth is organized as follows. Section 2 explains an overview on CBRP and AHP technique.

Section 3 introduces the various cluster head election methods from the existing literature. A cluster head election method using key decision parameters of the node proposed in this paper is explained in Section 4. This is followed by an illustration of the TEA - CBRP with an example in Section 5. Section 6 discusses the results obtained from simulation. Finally the paper concludes in Section 7.

2 Background

2.1 Overview on CBRP

CBRP [13] is designed for cluster based communication in MANET. CBRP divides the nodes into small groups called clusters and these clusters may be disjoint or overlapping. Each cluster has the cluster head elected by cluster members. The cluster head is elected based on lowest-ID mechanism [13]. The nodes in the cluster have bi-directional link to its cluster head. Every node in the cluster maintains a neighbouring table having information about its neighbour nodes namely, neighbour node-ID, link state information (bidirectional/unidirectional) and role of node in the cluster (head/member/undecided). Each node in the cluster broadcasts its neighbouring table as a HELLO message at regular HELLO-INTERVAL. The HELLO message consists of MY_OWN_ID, MY_MEMBERSHIP_STATUS, and Neighbour Table. The CBRP routing is strict source routing protocol such as DSR.

2.2 Analytical Hierarchy Process (AHP)

AHP [14] and [15] was developed by TL- Saaty in the 20th century. AHP is defined as an approach to decision making that involves structuring multiple criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives. AHP decomposes complex problem into sub problems, these sub problems are called decision factors and weighted according to their relative importance to the given goal. Finally, AHP synthesizes their importance to the given goal and finds optimal solution. The AHP method consists of the following three steps

1. Structuring hierarchy
2. Calculating the local weight of each influencing factor
3. Synthesizing the results for global weights.

2.2.1 Structuring hierarchy

Figure 1 represents the basic AHP hierarchy structure. The AHP hierarchy structure consist of different levels. Top

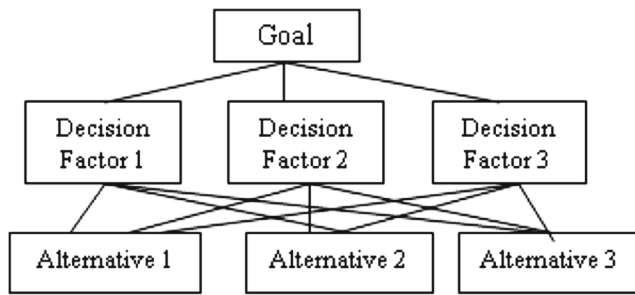


Fig. 1 AHP structuring hierarchy

most level consists of the goal (objective) of a decision problem, the subsequent level consist of various decision factors, and bottom level consist of solution alternatives.

2.2.2 Calculating the local weight of each influencing factor

The second step in AHP process is calculating local weight for each influencing factor within the same parent. The local weight represents two things: the weight of each decision factor towards goal, and the weight of each candidate to each factor. The local weight calculation of each influencing factor consists of three parts: making a pairwise comparison, calculating the weight vector, and checking for consistency.

1. Making a pairwise comparison: A pair wise comparison matrix is developed by comparing the decision factors against each other under the topmost goal. These preference values ranging from 1 to 9 represent the intensity of preference among the decision factors at the same level. A preference value 1 expresses "equal importance" and a preference value 9 expresses "extreme importance". Table 1 [16] represents the fundamental preference values among the decision factors.

For example in Matrix-A which is a simple pair-wise comparison matrix consisting of three decision factors DF_1 , DF_2 , and DF_3 are compared against each other. The Decision factor DF_1 is compared with DF_2 and a

value of 3 is assigned since it is regarded as moderately important.

$$\text{Matrix A} = \begin{matrix} & DF_1 & DF_2 & DF_3 \\ DF_1 & \begin{pmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 1/3 \\ 1/5 & 3 & 1 \end{pmatrix} \\ DF_2 & \\ DF_3 & \end{matrix}$$

2. Calculating the weight vector: For the given nxn comparison matrix called A, its Eigen value equation is written as $AW = \lambda_{\max}W$. where W is a non zero vector called Eigen vector, and λ_{\max} is a scalar Eigen value. After standardizing, the Eigen vector W is called local weights of each decision factor(j), which can be represented as $W_j^T = \{W_1, W_2 \dots W_n\}$.
3. Checking for consistency: Consistency of comparison matrix is calculated by Consistency Ratio (CR), after the local weight of each decision factor and alternatives are calculated. Consistency Ratio of comparison matrix is the ratio of Consistency Index (CI) to Random Index (RI) as given in Eq. 1.

$$CR = CI/RI \tag{1}$$

where CI can be calculated using Eq. 2 and 3.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

$$\lambda_{\max} = (1/n) * \sum_{i=1}^n \frac{(AW)_i}{W_i} \tag{3}$$

where n is rank of Matrix A and RI is a Random Index value as given in Table 2 [16]. If $CR \leq 0.1$ then the estimated comparison matrix is accepted, otherwise new matrix must be constructed until $CR \leq 0.1$.

2.2.3 Synthesizing the results for global weights

The global weight of each alternative is computed by multiplying the local weight and the weight of its corresponding parents. The final weight of the matrix is calculated using following (4).

$$W_{ni} = W_{ni/j} * W_j \tag{4}$$

The final weight of each alternative is calculated using following (5).

$$W_{ni} = \sum_{j=1}^n W_{ni/j} * W_j \tag{5}$$

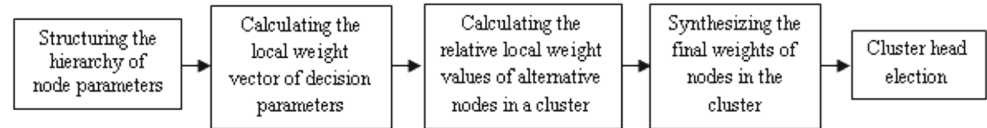
Table 1 The fundamental scale 1 to 9

Scale value	Description
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values
Reciprocal	Values for inverse operation

Table 2 Standard Random Index values

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Fig. 2 Proposed CH election model



where W_{ni} is final weight value of node i , $W_{ni/j}$ is weight value of i^{th} node with respective decision factor j , and W_j is weight value of decision factor j .

3 Existing work

During the past few years, researchers have extensively investigated many approaches to improve the cluster head election process. The existing cluster head election process is mainly based on the mobile node parameters such as identifier based, mobility aware, connectivity based, power aware, and weighted sum based.

Yanqing Zeng et al. [17] proposed cluster based intrusion detection mechanism for electing cluster head. In this method a node having more remaining energy will be elected as cluster head and also provides incentives for selfish nodes to be a cluster head.

Chang Li et al. [18] proposed Enhanced Weighted Clustering Algorithm (EWCA). In EWCA, cluster head is elected based on the weighted sum of a node parameter, namely, the degree differences (Δ_i), sum of the distances (D_i), mobility (M_i) of the node, and consumed energy (E_i). After computing the weights of every node in the topology, the node having the less weight value is elected as cluster head.

Haowo et al. [19] proposed a Type based Cluster forming Algorithm (TCA). The TCA algorithm employs a stability factor (S) to elect a cluster head. This considers the diverse range of node parameters into a single factor such as the relative speed of node, average distance, the degree of node connectivity, and the remaining battery power. The node with the lowest stability factor (S) is elected as the cluster head and reassigned lowest ID.

Zouhair El-Bazzal et al. [20] proposed an algorithm termed EMAC, which stands for Efficient Management Algorithm for Clustering. To manage cluster efficiency and cluster head election EMAC considers the weighted sum of the node parameters such as node degree, remaining battery power, transmission power, and node mobility.

Javad A Kbari Torkestani et al. [21], proposed Mobility based Cluster Formation Algorithm (MCFA) by using weighted learning automata and assumes mobility parameters are random variables with unknown distributions. The relative mobility of each host with respect to all its neighbours is defined as a weight. The weight of each host is

estimated by sampling the mobility into various epochs and the highest expected weight host is elected as a cluster head.

In the above methods, the limitation is that, the dynamically changing node behaviour is not considered into account to elect CH. To the author's knowledge, election of CH by considering this important aspect is an unsolved problem. The following section describes the enhanced cluster head election algorithm which determines the node behaviour in terms of TV, REL, and ToA parameters.

4 Proposed solution for cluster head election

The modules involved in the proposed solution are shown in Fig. 2. The first module identifies the key parameters used to select the cluster head and structuring the hierarchy. According to the hierarchy in the first module, the local weight values are calculated in the second module. The third module calculates the final weight value of nodes by using the local weight values obtained from the second module. The last module selects the best cluster head in the cluster based on the highest weight value. Section 4.1 to 4.4 describes in detail the working of four modules involved in the proposed solution.

4.1 Structuring the hierarchy of node parameters

The first step in the proposed cluster head election consist of structuring the problem as a hierarchy, as described in Section 2.2.1. The proposed AHP hierarchy model is given in Fig. 3. From Fig. 3, electing the cooperative CH is set as

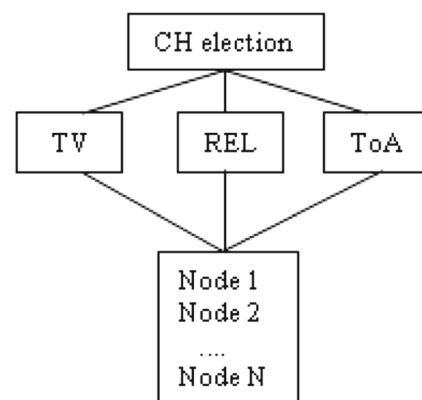


Fig. 3 Proposed AHP hierarchy model for CH election

goal at the top level, the subsequent level consist of key decision parameters namely TV, REL, and ToA, and the bottom level consist of n alternative nodes in the cluster.

4.2 Calculating the local weight vector of decision parameters

The second step is used to calculate the relative local weights of key decision parameters namely TV, REL, and ToA towards the goal. The evaluation Matrix B will be obtained by making pair-wise comparison among the three key decision parameters. To compare these parameters, the scale value 1 to 9 is used as given in Table 1. The Matrix B is as follows:

$$Matrix B = \begin{matrix} & \begin{matrix} TV & REL & ToA \end{matrix} \\ \begin{matrix} TV \\ REL \\ ToA \end{matrix} & \begin{pmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 1/2 \\ 1/3 & 1/2 & 1 \end{pmatrix} \end{matrix}$$

It can be observed from the Matrix B that, the priority of the three decision factors decreases respectively. The Eigen vector $W^T = [0.54, 0.30, 0.16]$ of this Matrix B gives the the local weights of key decision parameters. The parameters TV, REL, and ToA have local weights 0.54, 0.30, and 0.16 respectively. Equation 3 is used to calculate the maximum Eigen value λ_{max} i.e. 3.004. Subsequently, CR = 0.0034 is calculated using Eq. 1. The obtained CR for Matrix-B satisfies the condition $CR < 0.1$, therefore the Matrix-B satisfies the consistency check.

4.3 Calculating the relative local weight values of alternative nodes in a cluster

The third step is to calculate relative local weight of each node in the cluster with respective to each decision factor. To calculate relative local weights, nodes in the cluster need to compare each other and construct the pair-wise comparison matrix. This comparison is based on the values stored in Neighbour Node (NN) table using Table 1. For example if cluster consist of K nodes, we can get three pairwise comparison matrix having the order of $K \times K$ i.e. $ATV = (a_{ij})$, $REL = (a_{ij})$, and $ToA = (a_{ij})$. where $i, j = 1, 2, 3, \dots, K$. After calculating the pair-wise matrix, the steps given in Section 2.2.2 are executed. Finally, the local weight vectors are calculated as follows $TV = [TV_1, TV_2, \dots, TV_k]^T$, $REL = [REL_1, REL_2, \dots, REL_k]^T$, $ToA = [ToA_1, ToA_2, \dots, ToA_k]^T$.

Section 4.3.1 to 4.3.3 explains the procedure to calculate node behaviour with key decision factors namely TV, REL, and ToA. The calculated values of nodes are updated in its NN table. The format for NN table is given in Table 3. The TV of a node represents the packet forwarding behaviour.

Table 3 NN table

Neighbour Node-ID	TV	REL	ToA
N_1	T_{12}	E_1	T_{Sec}
N_2	T_{23}	E_1	T_{Sec}
...

If a node relays the packets received from its neighbouring nodes then the TV of a node is high, hence it is cooperative node otherwise the node is malicious or non cooperative node. The REL value of node represents the selfish behavior of a node, i.e. if the node has more REL value then it acts as a cooperative node, otherwise it is considered to be a selfish node. The ToA of node represents link stability of nodes, i.e if ToA of a node is more then the stability of the cluster increases.

4.3.1 Calculating TV of neighbour nodes

The node behaviour is dynamically monitored by its neighbour node to calculate the trust value of a node. A nodes trust value depends on both Direct Trust Value (DTV) and Indirect Trust Value (IDTV). The algorithm-1 shows calculation of trust value for a node in MANET. Equation 6 represents the Trust Value (TV) of node B calculated by node A.

$$TV[B/A] = \alpha * DTV[B/A] + \beta * IDTV[B/A] \quad \alpha + \beta = 1 \quad (6)$$

- DTV calculation Each node in the network maintains the direct trust value of its neighbour nodes. The sender node after the transmission of any packet places itself in promiscuous mode to receive passive acknowledgement from immediate neighbours within the communication range of the wireless channel. Using this passive acknowledgement the sender node can calculate direct trust value of its neighbour node. Consider the topology given in Fig. 4, node A can calculate direct trust value of neighbour node B for fixed time intervals and updates the direct trust value of the neighbour node B at a regular interval time (ΔT) using the following two cases as given below:

Case 1: When $F(B) > D(B)$ $DTV_i[B/A] = DTV_{i-1}[B/A] + (1 - DTV_{i-1}[B/A])/20$.

Case 2: When $F(B) \leq D(B)$ $DTV_i[B/A] = DTV_{i-1}[B/A] - (1 - DTV_{i-1}[B/A])/10$.

For i varying from 1 to (Simulation time / ΔT) and DTV_0 is initialized to 0.5. F represents the number of successfully forwarded packet ratio to neighbour node, D represents the dropped packet ratio, $DTV_i[B/A]$ represents direct trust value of neighbour node B calculated

by node A at time instant i. In case-1 if the forwarded ratio is greater than the dropped ratio then the direct trust value of the neighbour node will be within the range of 0.5 to 1 and direct trust value of the neighbour node keeps increasing monotonically. In case-2 if the dropped ratio is greater than the forwarded ratio then the direct trust value of the neighbour node will be within the range of 0.5 to 0 and direct trust value of the neighbour node keeps decreasing monotonically.

Algorithm 1 Algorithm for total trust calculation

```

FTV_cal[B/A] ( )
begin
  For every node in the topology initialize DTV value as 0.5.
  Calculate DTV using the function DTV[B/A] ( );
  if (DTV[B/A] ≥ 0.5) then
    | α =1 and β=0
  end
  else
    | α =0.5 and β=0.5 Calculate IDTV using the function IDTV[B/A] ( );
  end
  FTV[B/A] = α *DTV[B/A] + β*IDTV[B/A];

  DTV[B/A] ( )
  begin
    if (no interaction between node A and node B) then
      | The DTV value of node B is fixed to be 0.5
    end
    else
      if (F(B) > D(B)) then
        | DTVi[B/A] = DTVi-1[B/A] + (1 - DTVi-1[B/A])/20.
      end
      else
        if (DTVi[B/A] ≤ 0) then
          | DTVi[B/A]=0.
        end
        else
          | DTVi[B/A] = DTVi-1[B/A] - (1 - DTVi-1[B/A])/10.
        end
      end
    end
  end
end

  IDTV[B/A] ( )
  begin
    | IDTV[B/A] =  $\sum_{i=1}^n \frac{RTV_i(B/n_i)}{N}$ 
  end
end
    
```

- IDTV calculation The IDTV of a node is calculated when a node does not have a DTV value greater than equal to 0.5. The node request recommendations from its neighbour nodes. The following equation is used for calculation of IDTV value for a node.

$$IDTV[B/A] = \sum_{i=1}^n \frac{RTV_i(B/n_i)}{N} \tag{7}$$

where $RTV_i(B/n_i)$ represents Recommended Trust Value (RTV) of node B by the neighbour node n_i . N represents the total number of recommendations received for node B.

4.3.2 Calculating REL of nodes

Every mobile node in MANET Consumes energy(C) for Transmit a packet(Tr), Reception of a packet(Recep) and

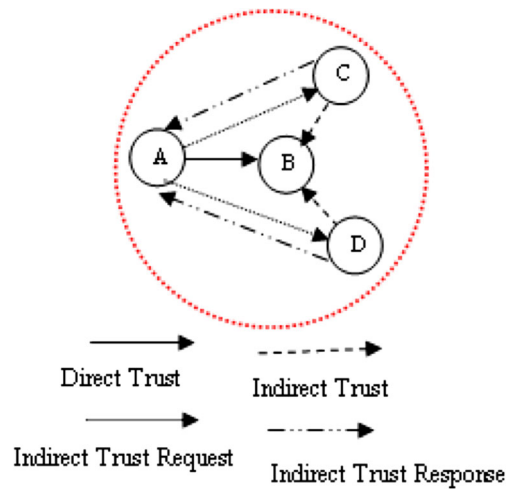


Fig. 4 Trust Relationship types

overhearing the neighbour nodes. The energy consumed at a particular node (n_x) is calculated as follows:

$$E(n_x)C = E(n_x)Tr + E(n_x)Recep + (N-1) * E(n_x)overhearing \tag{8}$$

$$E(n_x)Remainingenergy = E(n_x)Initialenergy - E(n_x)C \tag{9}$$

$$E(n_x)Remainingenergy_ratio = \frac{E(n_x)Remainingenergy}{E(n_x)Initialenergy} * 100 \tag{10}$$

where N is number of neighbouring nodes of n_x . The energy value of a mobile node is calculated at regular intervals to determine the remaining energy and in turn calculate the remaining energy ratio. If the remaining energy ratio for a node is greater than equal to 50 the node energy level is assigned with a value of 1 else 2. Once the mobile node energy level gets reduced to 2, it will broadcast an Energy_Level message. The format of the message is given Fig. 5.

4.3.3 Calculating ToA of nodes

The ToA of two nodes for communication depend on the following parameters of mobile node such as radio propagation range, speed, and moving direction [22]. Let two mobile nodes A, B have the coordinators (X_A, Y_A) , (X_B, Y_B) , communication range r, also V_A, V_B are speed, and θ_A, θ_B ($0 \leq \theta_A, \theta_B \leq 2\pi$) be the moving direction.

Node-ID	Energy Level
---------	--------------

Fig. 5 Format for Energy Level message

Table 4 Weight_Table

Node-ID	Weight-value
---------	--------------

Then, the amount of time available for two nodes communication is calculated using Eq. 11.

$$ToA = \frac{-(ab + cd) + \sqrt{(a^2 + c^2)r^2 - (ad - bc)^2}}{(a^2 + c^2)} \quad (11)$$

where $a = V_A * \cos \theta_A - V_B * \cos \theta_B$, $b = X_A - X_B$
 $c = V_A * \sin \theta_A - V_B * \sin \theta_B$, $d = Y_A - Y_B$

If two mobile nodes move in the same direction with same speed then the ToA is assigned a value of infinity (∞) without applying the above formula.

4.4 Synthesize the overall weight value of nodes in the cluster

The fourth step is to calculate the overall weight value of each node in the cluster. The final weight value is calculated using Eqs. 4 and 5 and stores the resultant weight value is stored in Weight_table at CH. The format of the entries in Weight_table is given in Table 4. The CH elects the highest weight value as PCH and next highest weight value as SCH. This process is repeated in MANET topology to elect PCH and SCH in different clusters to achieve better cooperation and network performance.

4.5 CH Election

Finally, clustering in the proposed TEA-CBRP algorithm consists of two parts, viz., CH election and cluster maintenance. In the cluster head election procedure, the node with the lowest ID is initially selected as the cluster head for T seconds duration, as shown in Algorithm 2. After the time T seconds duration, the cluster head is then elected based on the three parameters described earlier, namely the TV, REL, and ToA. These parameters are considered as inputs to the AHP process to calculate the weight values for every node

in the cluster. The node having the highest weight value is selected as the PCH and the next highest weight value as Secondary cluster Head (SCH). Table 5 lists the different type of messages used in TEA-CBRP.

Algorithm 2 Cluster Head(CH) election

```

Lowest-ID.CH.election ( )
begin
  Every node in the topology broadcast HELLO packet with node ID.
  Neighbour node receives HELLO packet and creates entry in neighbour node table.
  Broadcasts neighbour node table to its neighbour nodes.
  Initial T Sec., select the node having lowest -ID as the CH.
  Selected CH, send the CH_elect message.
  The remaining nodes send the Join_request message.
  if (CH send a Join_accept meegage) then
    | The node will be the member of the cluster
  end
  else
    | CH send a Join_reject meegage, then the Node sends a Join_request message to next CH.
  end
  if (Node receives packet from more than two CH) then
    | the node act as Gateway.
  end
  if (T expires) then
    | CH_election-process ( );
  end
end

CH.election-process ( )
begin
  CH collects TV,REL, and ToA of its neighbouring nodes within the cluster.
  Execute AHP process to calculate weights of its neighbouring nodes.
  if (lowest ID has more weight value) then
    | Send the PCH_elect-message.
  end
  else
    | Node having more weight value is the elected as a PCH, Send PCH_elect-message.
    | Select the node having next highest weight value as SCH. Send the SCH_elect message.
  end
end
end

```

Algorithm 3 CH_relection-process

```

CH_relection-process ( )
begin
  if ( weight value of PCH < Th) then
    | Set SCH as PCH and send a CH_change-message.
  end
  if (weight value of SCH < Th) then
    | CH_election-process ( );
  end
end
end

```

The Algorithm 3 shows the re-election process of PCH and SCH considering the dynamically changing nodes

Table 5 Different type of messages used in the algorithm

Message	Description
HELLO(N_ID, Neighbour_Table, CAT)	A node broad cast every HELLO.INTERVAL
CH_elect(N_ID)	Lowest ID elected as cluster head
PCH_elect(N_ID)	The node set as PCH
SCH_elect(N_ID)	The node set as SCH
CH_change(N_ID)	The cluster head change notification
Join_request(N_ID CH_ID)	Node request to join in the cluster
Leave_request(N_ID CH_ID)	Node leaving from the cluster
Join_accept(N_ID CH_ID)	Accept as a cluster member
Join_reject(N_ID CH_ID)	Reject as a cluster member

weight value. If the weight value of PCH node becomes lesser than the threshold value (T_h), the SCH will be promoted as PCH. The node which is having, the next highest weight value will now take the position of SCH. Under the circumstances where the weight of this newly promoted PCH node (the earlier SCH node) becomes less than the threshold value (T_h), the execution of the CH election algorithm is invoked as illustrated in Algorithm-2. Cluster maintenance in MANET is necessary by considering the dynamic changing topology. The Cluster maintenance algorithm explained in Algorithm 4 is executed under the following conditions:

- The CH node moving out of the cluster
- The CH of two neighbouring clusters move closer to each other such that they will be at 1- Hop distance.

Algorithm 4 CH_maintenance

```

CH_maintenance ( )
begin
  if (join_request from new neighbor node) then
    Create an entry in CH_neighbour table and initialize weight value as 0 in CH_weight table.
  end
  if (number of cluster members > N_threshold) then
    Drop the Join_request.
  end
  if (leave_request from cluster member node (or) Hello_message not received within HELLO_interval) then
    Delete the entry in CH_neighbour table and CH_weight table then update CH_neighbour table and CH_weight table.
  end
  if (two CH's are one hop away) then
    Wait for  $T_x$  amount of time.
    if ( $T_x$  expires) then
      Compare weight values each other. Node having more weight values as a PCH and other node converted as CH member.
    end
  end
end
end

```

5 Illustration of CH election in TEA-CBRP routing algorithm

The illustration for cluster head election in the TEA-CBRP routing algorithm is described with an example in this section. To illustrate the routing algorithm, the topology shown in Fig. 6a–c is used. There are eight nodes, with node IDs from 0 to 7. Each node maintains a Neighbour Node

table and cluster head maintains CH_weight table. Initially all the nodes in the cluster broadcast a HELLO packet with node ID to its neighbouring nodes. For the initial T Sec duration, the node ID with 0 is selected as CH (based on lowest-ID). This elected CH (Node-ID 0) sends CH-elect message to its neighbour nodes. The CH sends Join-request message to remaining nodes in the cluster having node-ID's 1, 2, 3, 4, and 5. The CH sends the reply message Join-accept. The cluster has been thus formed with CH as node-ID 0 and nodes with Ids 1, 2, 3, 4, 5 as its cluster members. After time T expires, a cluster - election process is initiated. The CH executes an AHP process as shown in Section 4.3 and 4.4 to calculate weight values of its neighbour nodes. If the node-ID 0 has the highest weight value it is then automatically selected as PCH. If this condition is not satisfied, among the remaining nodes, the node having highest weight value is elected as PCH. Subsequently, the node with next highest weight value is elected as SCH. The application of CH-election process algorithm to the topology in Fig. 6a shows that nodes 1 and 5 are elected as PCH and SCH, respectively. The cluster topology with the elected PCH and SCH is shown in Fig. 6b. The application of CH-Maintenance process algorithm to the topology in Fig. 6b shows that nodes ID 0, and 2 moving out of the cluster and the nodes 6, and 7 joining to the cluster. The resulting new cluster is shown in Fig. 6c.

6 Simulation and result analysis

The proposed TEA-CBRP routing algorithm was developed and tested using the Ns-2 simulator [23]. The algorithm was simulated using the parameters listed in Table 6.

6.1 Performance parameters

To analyse the performance of the proposed algorithm two different simulation scenarios and five different metrics were considered. Table 7 lists the various scenarios for which the simulation study was done. In the first scenario

Fig. 6 Example of CH election in TEA-CBRP

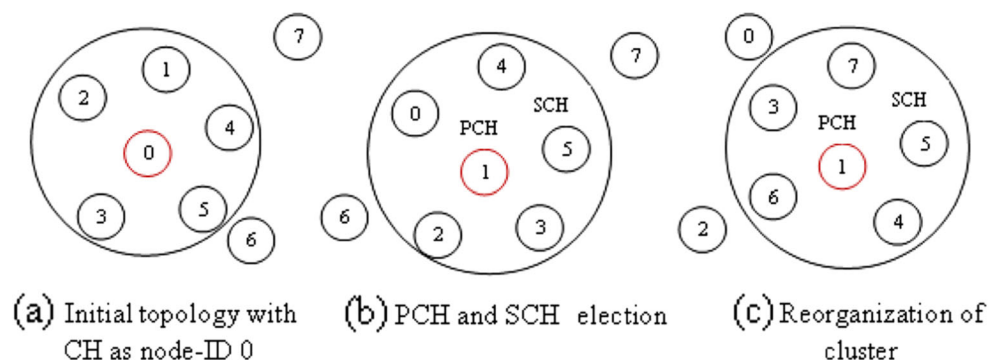


Table 6 Simulation parameters

Parameters	Value
Area	1000 m X 1000 m
Total no of nodes	50,100,150,200
Simulation time	600 s
Transmission range	250 m
Mobility model	Random waypoint
Maximum speed	30 m/s
Mobility direction	Random
Pause time	10 ms
Traffic type	Constant Bit Rating (UDP)
Number of connections	20

speed of node was varied from 0-30 m/s and number of nodes and malicious nodes were fixed to be 100, and 20 respectively. In the second scenario the number of nodes was varied from 50 to 200 and correspondingly the number of malicious nodes was varied from 20 to 50. The speed of node was fixed to be 10 m/s. The performance metrics considered for the various test cases are listed below:

1. Packet delivery ratio: the ratio of packets received by destination node to those sent by the source node.
2. Average end to end latency: the average time taken by data packets to reach destination which includes buffer delay during a route discovery, queuing delay at the interface, retransmit delay at the MAC layer, and propagation delay.
3. Routing packet overhead: Ratio of control packets generated to the total number of data packets sent.
4. Number of times CH changes: Count the number of times CH changes in the network.

6.2 Result analysis

In the simulation scenario, under the condition that the number of nodes were randomly scattered in 1000 m X 1000 m rectangle area, the total simulation time was set to 600 seconds. The transmission range of every node in one hop was fixed at 250 m. The random waypoint mobility model was chosen in which each packet starts its journey from random source to random destination with maximum speed of 30 m/s and mobility direction was also set at random. The IEEE 802.11 Distributed Coordinate Function (DCF) was used as the Medium Access Control (MAC) protocol. Some nodes

Table 7 Varying Simulation parameters

Scenario	Number of nodes	Number of malicious node	Speed
1	100	20	0-30 m/s
2	50-200	20-50	10 m/s

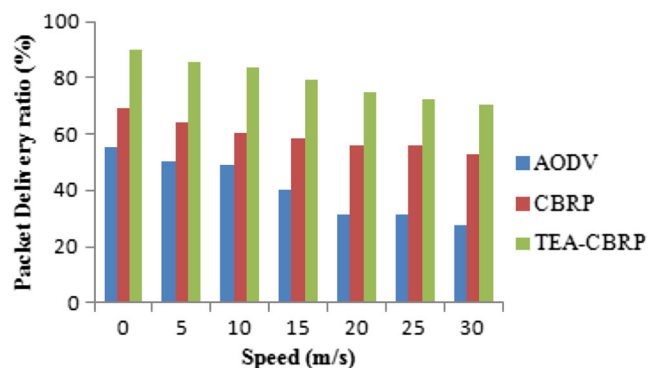
were randomly selected as malicious nodes to launch the Blackhole attack or Grayhole attack.

Section 6.2.1 and 6.2.2 discusses the performance of the proposed TEA-CBRP routing algorithm with respect to packet delivery ratio, the average end-to-end latency, routing packet overhead, energy consumption, and number of times cluster head changes. The performance of the TEA - CBRP is compared with AODV [24] and CBRP routing algorithms.

6.2.1 Scenario-1 with varying speed

In this scenario the speed of mobile node was varied from 0 and 30 m/s. The effect of the speed of mobile nodes on performance parameters was observed and plotted as graphs shown in Figs. 7, 8, 9, and 10.

Figure 7 represents the graph plotted for node speed versus packet delivery ratio for the CBRP, AODV, and TEA-CBRP routing algorithms. From Fig. 7, it can be observed that the packet delivery ratio for TEA-CBRP remains higher across the varying speed of mobile nodes in comparison with CBRP and AODV. In TEA-CBRP, the CH is elected as a cooperative node by considering the node behaviour decision factors namely TV, REL, and ToA. This improves the cooperative communication among the clusters and also between source and destination node. Hence the packet delivery ratio is improved by eliminating malicious and selfish nodes as a CH. In case of AODV, there is a possibility of selecting malicious and selfish nodes as intermediate nodes, because node behaviour is not considered while establishing path between source and destination node. Hence, more number of packets are dropped by malicious and selfish node if a path uses them. Therefore the packet delivery ratio considerably reduces compared with TEA-CBRP. In case of CBRP, cluster head is elected based on Lowest-ID available in the cluster. There is a possibility that the elected CH can be either malicious or selfish node, thereby more packets are dropped. Hence packet delivery ratio remarkably degrades when compared with TEA-CBRP.

**Fig. 7** Packet delivery ratio

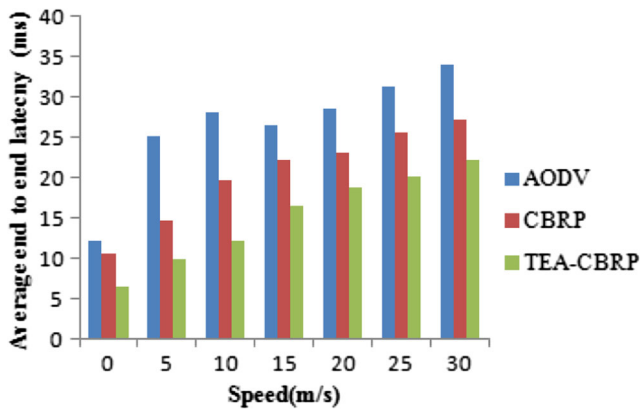


Fig. 8 Average end to end latency

Figure 8 represents the graph plotted for the node speed versus average end to end latency for AODV, CBRP, and TEA-CBRP routing algorithms. It can be observed from the figure average end to end latency of packet to transmit in MANET is directly proportional to the speed of the node. This is due to frequent changing route entries in the routing table. In TEA-CBRP electing the highest weight value (more cooperative node) as a CH, reduces the number of packets dropped. It decreases the average end to end latency marginally when compared with AODV and minimal reduction when compared with CBRP. In case of AODV, the average end to end latency keeps increasing when compared with TEA-CBRP, and CBRP. This is due to malicious and selfish node in the path found by AODV. The cluster based communication between source and destination node reduces average end to end latency in CBRP compared with AODV. But, in CBRP there is a possibility that the elected CH has a malicious or selfish node, it drops packets, thereby increases retransmission of packets. Hence CBRP is having more average end to end latency compared with TEA-CBRP.

Figure 9 represents the graph plotted for the node speed versus routing packet overhead for CBRP, AODV, and

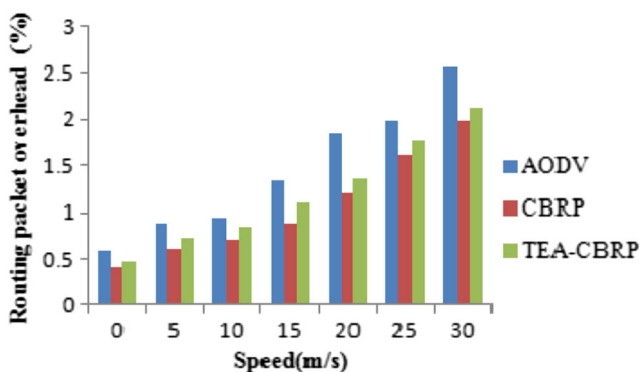


Fig. 9 Routing overhead

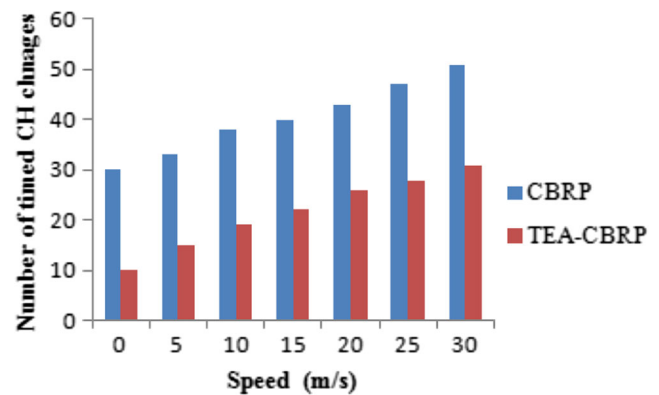


Fig. 10 Number of times CH changes

TEA-CBRP routing algorithms. From the figure it can be observed that, the routing packet overhead for AODV is more compared with CBRP and TEA-CBRP. This is due to more transmission of RREQ and RREP control packets to establish a path between source and destination node. The CBRP and TEA-CBRP routing overhead is less when compared with AODV, due to cluster based communication between source and destination node. From Fig. 9, the average routing overhead for CBRP and TEA-CBRP are 1.06 % and 1.19 % respectively. It can be seen that there is a marginal increase of 0.13 % in the TEA-CBRP compared with CBRP. This is due to exchange of messages to elect cooperative CH.

Figure 10 represents the graph plotted for the node speed versus number of times CH changes for CBRP and TEA-CBRP routing protocols. The number of times CH changes in CBRP is more compared with TEA-CBRP while increasing of speed. In CBRP, the CH elect based on Lowest-ID, there is a possibility the elected CH moves out of the cluster. In case of TEA-CBRP cluster stabilization achieved by selecting PCH and SCH among the cluster members, it reduces CH changes in the clusters.

6.2.2 Scenario-2 with varying number of nodes

In this scenario the number of mobile node was varied from 50 and 200. The effect of the speed of mobile nodes on performance parameters was observed and plotted graph shown in Figs. 11, 12, 13, and 14.

Figure 11 represents the graph plotted for number of nodes versus packet delivery ratio for AODV, CBRP, and TEA-CBRP routing algorithms. It can be seen from Fig. 11, that the packet delivery ratio of proposed TEA-CBRP remains higher compared with AODV and CBRP by varying number of nodes. This is due to following reasons:

- CH elects based on the calculated weight value
- Elimination of all malicious and selfish nodes from being a CH.

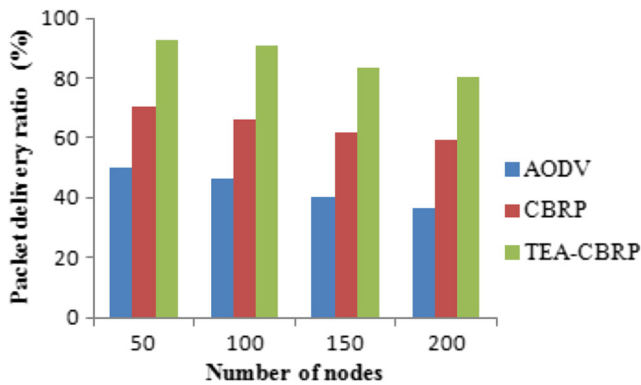


Fig. 11 Packet delivery ratio

In case of AODV packet delivery ratio decreases gradually when compared with CBRP and TEA-CBRP. This is due to the fact that as the number of nodes increases in the network, proportionately length of the routing path also increases, thereby increasing the number of dropping packets. In CBRP, since CH is elected based on lowest-ID, there is a possibility for elected CH to be a malicious or selfish node. Due to this the packet delivery ratio is less compared with TEA-CBRP.

Figure 12 represents the graph plotted for number of nodes versus end to end latency for AODV, CBRP, and TEA-CBRP routing algorithms. In AODV, latency increases with varying number of nodes. This increase is mainly due to more packet retransmission when the length of routing path increases as the number of nodes in the network increases. In case of CBRP end to end latency is less when compared with AODV. This is due to less packet retransmission in CBRP because of cluster based communication. From Fig. 12, it can be observed that the end to end latency is less for TEA-CBRP. In TEA-CBRP, the elimination of malicious or selfish nodes as CH, reduces the number of retransmissions, thereby decreasing the average end to end latency when compared with AODV and CBRP.

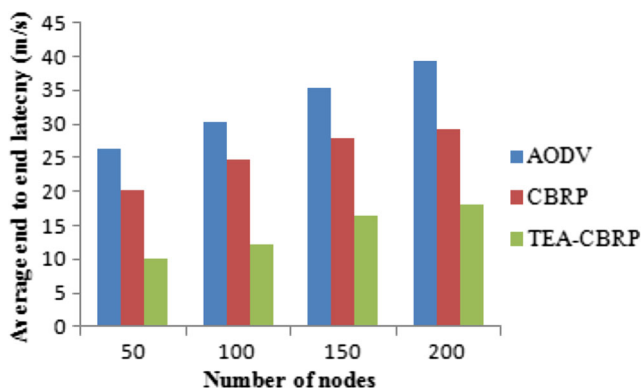


Fig. 12 Average end to end latency

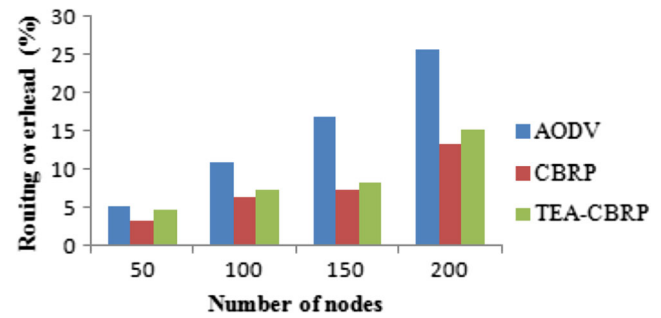


Fig. 13 Routing overhead

Figure 13 represents the graph plotted for number of nodes versus routing overhead for AODV, CBRP, and TEA-CBRP routing algorithms. In AODV, increase in network size has an impact on the routing overhead. This is because when the network size increases, the average routing path length also increases, due to this frequent route updates are required. Hence it is necessary to broadcast RREQ/RREP packet to establish a routing path. However in CBRP and TEA-CBRP the impact of routing overhead due to increase in network size is minimum due to cluster based communication. Hence routing overhead is less for CBRP and TEA-CBRP when compared with AODV. From Fig. 13, the average routing overhead for CBRP and TEA-CBRP are 7.44 %, and 8.76 % respectively. It can be seen that there is a marginal increase of 1.32 % in TEA-CBRP. The reason for this increase is due to the switching over of SCH to PCH, when PCH is out of the cluster, SCH broadcasting the elected message to neighbour nodes.

Figure 14 represents the graph plotted for number of nodes versus number of times CH changes for CBRP and TEA-CBRP routing protocols. In CBRP, CH is elected based on the lowest ID. As the size of the network increase the possibility of reelecting CH may also increase. In case of TEA-CBRP, number of times CH changes are less due to possibility of PCH and SCH moving out of the cluster is minimum.

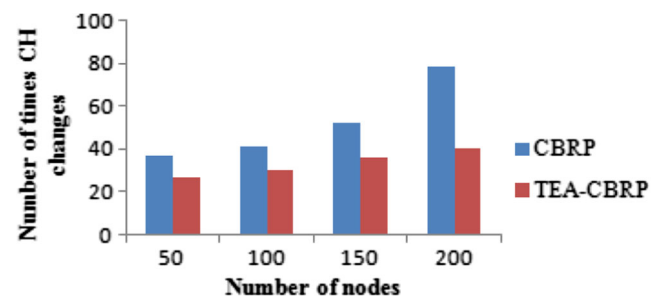


Fig. 14 Number of times CH changes

7 Conclusion

In this paper the routing mechanism in CBRP is improved by considering the dynamically changing node behaviour to elect CH. The TV, RE, and ToA key decision parameters are used to elect CH. This newly proposed CH election scheme is named as a TEA-CBRP. To analyse the performance of proposed TEA-CBRP routing algorithm, a simulation study was conducted with two different scenarios. The TEA-CBRP was compared with AODV and CBRP in terms of packet delivery ratio, end to end latency, routing overhead, and number of times CH changes. From the comparison, it was found that the TEA-CBRP performs better than the existing algorithms with respect to packet delivery ratio, end to end latency and number of times CH changes. However the marginal increase in the routing overhead is manageable. From the results we can conclude that the efficiency and routing performance of network can be improved by considering the dynamic behaviour of a node to elect CH.

References

1. <http://www.ietf.org/html.charters/manet-charter.html>. Accessed (2009)
2. Chlamtac I, Conti M, Liu JJ-N (2003) Mobile ad hoc networking: imperatives and challenges. *Ad Hoc Networks* 13–64
3. Burbank JL, Chimento PF, Haberman BK, Kasch WT (2006) Key challenges of military tactical networking and the elusive promise of MANET technology. *IEEE Communication Mag* 44(11):39–45
4. Duran A, Shen C (2004) Mobile Ad Hoc P2P file sharing. In: Proceedings of IEEE wireless committee and networking conference (WCNC). Atlanta
5. Hong X, Xu K, Gerla M (2002) Scalable routing protocols for mobile ad hoc networks. *IEEE Network* 16(4):11–21
6. Yu JY, Chong PHJ (2005) A survey of clustering schemes for mobile ad hoc networks. *IEEE Communc Surv Tutorials* 7(1):32–48
7. Baker D, Ephremides A (1981) The architectural organization of a mobile radio network via a distributed algorithm. *IEEE Trans Commun* 29(11):1694–1701
8. Li W, Joshi A, Finin T (2010) Coping with node misbehaviours in ad hoc networks: a multi-dimensional trust management. In: Proceedings of mobile data management, Kansas
9. Hollick M, Schmitt J, Seipl C, Steinmetz R (2004) On the effect of node misbehavior in ad hoc networks. In: Proceedings of IEEE international conference on communications, Paris
10. Djahel S, Na-abdessalam F, Zhang Z (2011) Mitigating packet dropping problem in mobile Ad Hoc networks: proposals and challenges. *IEEE Commun Surv Tutorials* 13(4)
11. Agrawal P, Ghosh RK, Das SK (2008) Cooperative black and gray hole attacks in mobile ad hoc networks. In: Proceedings of 2nd international conference on ubiquitous information management and communication (ICUIMC), Korea
12. Zhou L, Hass Z (1999) Securing Ad Hoc networks. *IEEE Netw* 13(6):24–30
13. Jiang M, Li J, Tay Y (1998) Cluster based routing protocol (CBRP). IETF Internet-Draft
14. Saaty TL, Katz JM (1990) How to make a decision: the analytic hierarchy process. *Eur J Oper Res* 48:9–26
15. Vaidya OS, Kumar S (2006) Analytical hierarchy process (AHP) an overview of applications. *Eur J Oper Res* 169(1):1–29
16. Saaty TL (2000) Fundamentals of decision making and priority theory with the analytic hierarchy process. RWS Publications, USA
17. Zeng Y, Chen Z, Qiao C, Xu L (2011) A cluster header election scheme based on auction mechanism for intrusion detection in MANET. In: Proceedings of international conference on network computing and information security (NCIS), China, pp 14–15
18. Li C, Wang Y, Huang F, Yang D (2009) A novel enhanced weighted clustering algorithm for mobile networks. In: Proceedings of international conference on wireless communications, networking and mobile computing, China, pp 24–26
19. Wu K, Hong ZZ, Hanzo L (2010) A Cluster-head selection and update algorithm for Ad Hoc networks. In: Proceedings of GLOBECOM, USA, pp 6–10
20. El-Bazza Z, Kadoch M, Agba BL, Gagnon F, Bennani M (2006) An efficient management algorithm for clustering in mobile ad hoc network. In: Proceedings of PM2HW2N '06, Spain, pp 2–6
21. Torkestani JA, Meybodi MR (2011) A mobility-based cluster formation algorithm for wireless mobile ad-hoc networks. *J Clust Comput* 14(4):311–324
22. Rahman KA, Tepe KE (2011) Mobility assisted routing in mobile adhoc networks. In: Proceedings of 4th IFIP international conference on new technologies mobility and security (NTMS), pp 7–10
23. <http://www.isi.edu/nsnam/ns/>. Accessed (2009)
24. Perkins C (2003) Adhoc on demand distance vector (AODV) protocol. RFC 3561



U. Venkanna obtained his degree in Computer science and Information Technology in 2005 from Kshatriya college of Engineering, J.N.T.U. Hyderabad and Post graduate degree in Software Engineering in 2009 from Rmappa Engineering College, J.N.T.U. Hyderabad, Andhra Pradesh, India.

He is currently doing research in National Institute of Technology (NIT), Tiruchirappalli, Tamil Nadu, India. His research interests Trust

management and Reliable routing for Ad Hoc Networks.



R. Leela Velusamy obtained her degree in Electronics and Communication Engineering in 1986 from REC Tiruchirappalli and Postgraduate degree in Computer science and engineering in 1989 from REC Tiruchirappalli.

She was awarded Ph.D. degree by the NIT Tiruchirappalli in 2010. Since 1989, she has been in teaching profession and currently she is a Associate professor in the Department of C.S.E, N.I.T. Tiruchirappalli, Tamil

Nadu, India. Her research interests include QoS routing, Adhoc Networks, Social Networks and Digital forensics.