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Cluster Head Selection in Mobile Ad-hoc Network (MANET) Using ART1 Neural Network

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ABSTRACT

Mobile ad-hoc network or simply MANET is one of the better choices for communication in various fields like military, environment, tracking etc. due to its cost effectiveness. Limited battery power is a major challenge in MANET for many applications. Hence, to handle this problem, we more often work on routing technique like DSR, AODV, DSDV, OLTP. Therefore it consumes less power during data transfer from mobile nodes to the respective base stations. In today's research artificial neural network has become one of the most promising real time problems solving technique which is being used widely in many real time applications. It is also best suited for the cluster head selection in MANET. In this paper, ART1, an unsupervised learning technique of artificial neural network has been implemented to select the cluster head in routing. Simulation result shows that 58% network lifetime enhancement is achieved.

Keywords- MANET, cluster head, ART1 neural network, unsupervised learning.

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1. INTRODUCTION

Basically mobile ad hoc network (MANET) [18-20] is the combination of different network nodes which are able to communicate among themselves. These mobile ad hoc networks are without any predefined infrastructure, multi-hop, dynamic networks established by a collection of mobile nodes. Wireless nodes can communicate independently at it own in such networks without any fixed infrastructure or centralized administration. MANET nodes can receive their network packets from their respective neighbors. Nodes during their movement theses nodes change their topologies time to time. This type of communication in MANET is helpful for large scale infrastructure. These nodes usually establish their connections and share information along with the access of many specified resources.

Generally, there is no centralized network and it only consists of mobile nodes on which the entire network depends. Each node use limited battery power consumption and it forwards the data into the form of packets from source location to destination. MANET typically uses distributed system environment and a fixed infrastructure. As we know mobile nodes consist of radio range by which they communicate. In case if one station can communicate with other station but it doesn't in their range they can communicate via their intermediate nodes. Some of the important characteristics of MANET are:

1.1. Distributed Operation:
Every mobile node has individual functionality. They are communicate as per own various configurationally setups. Every node must communicate with each other for information transmission. Each node may act as a relay for implementation of specific functions such as routing and security.

1.2. Multi-hop Routing
When a node tries to send information among other nodes which are out of its connectivity area, then packet must be forwarded via one or more existing intermediate nodes.

1.3. Autonomous
Every mobile node is an individual entity, which acts as host as well as router.

1.4. Dynamic Topology
The network topology may change randomly in MANET. Some of nodes are free to move throughout specified network having different speeds.

1.5. Neighbour Discovery
The neighbouring node is discovered by transmitting and receiving hello packets.

1.6. Data Routing
Data packets can be routed from one source node to other destination node using a specific path.

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1.7. Resource Constraints
Limited bandwidth is available for communication between intermediate mobile nodes.

1.8. Diversity in Nodes as well as Protocols
Various nodes are available like ipods, palm handheld computers, PCs, smart tablets, smart sensors. Nodes can use different protocols such as IrDA, Zigbee, 802.11, GSM ot TCP/IP etc.

1.9. Light-Weight Mobile Nodes
The nodes configuration is mobile with less CPU capability, low power storage and small memory size.

2. PROBLEM DESCRIPTION

As we know that MANET is an infrastructure-less system, mobile nodes communicate with each other with the help of radio signals. One-to-one communication happens throughout the network at a particular time span. If a node wants to send its data to other node which is placed outside its coverage area then multi-hop routing is strictly needed. In that case, intermediated nodes act as routers having data forwarding properties to make communication complete and possible. During the movements of nodes energy is a very important issue and it should be handles carefully. Therefore, our main objective from the existing scenario is to make system energy efficient. To overcome this problem, we need to work over clustering of various nodes available in a MANET. Clustering means grouping of various nodes. Presently, clustering mechanisms are being used for MANET in various areas, such as building automation and home networks, and ubiquitous applications. Clustering strongly influences communication overhead, latency, congestion, inter-cluster and intra-cluster formation.

In MANET, clustering of various available nodes is done based on residual energy. So many clusters can be created using residual energy concept. Out of these formed clusters we choose one node. This one selected node is called cluster head (CH) node (fig 1).

These cluster head nodes are responsible to communicate over the network. The non-cluster head nodes selected the cluster head node using cluster head id by sending a confirmation packet to get in a particular cluster's vicinity. Then at a particular round, a node in a particular cluster sends its data to cluster head node. These cluster head nodes afterward forwards these collected information to the base station (BS). Then again cluster head is selection is done for another round. It goes on till nodes are shut down their battery life more than minimum nodes required for the communication in the network. This is the brief overview of clustering process and transmission of data packets from nodes to base station. Also this is one of the energy saving procedure for a MANET.

Now we need to modify the existing system for making the system more energy efficient. We have used adaptive resonance theory (ART1) neural networks to find the cluster head. ART1 is an unsupervised learning clustering algorithm which can be used for where competition among nodes or any other type of entities happens. This works well for solving the real time problems [1]. We have implemented this ART1 technique over the cluster head part in MANET. Here, clustering is done over various parameters of MANET and ART1. As a result of it has performance is achieved at a greater extent and at a greater rate.

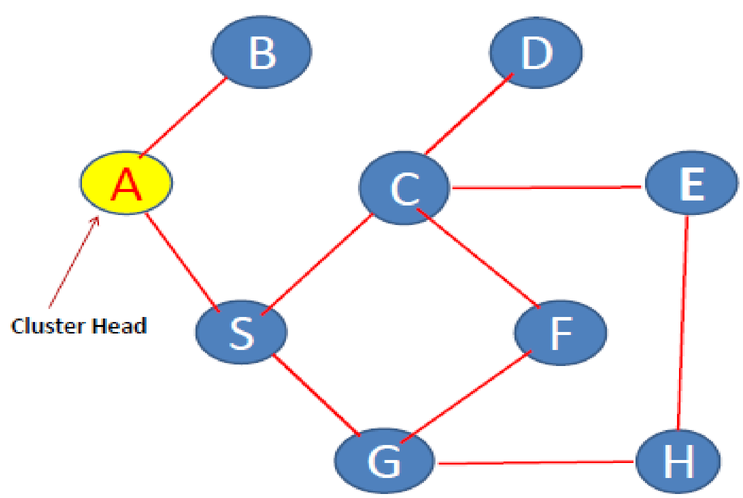

Figure 1: Basic Scenario of Cluster Formation

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3. REALTED WORK

Amis et al. have discussed about the clustering in wireless ad hoc network. They have proposed a d-clustering heuristic technique which is modified of 1-hop clusters as traditionally generated. Under this election of cluster head is done an even network configuration change. Krishan Kumar et al. have proposed routing protocol to control power based on coverage using neural network. The main objective is to maximizing the network lifetime. In this paper, the cluster head selection procedure has been modified using adaptive learning in neural network. There are many clustering schemes available. But there is need to modify them according to the problem. As energy efficiency is one of the main constraints in MANET. Other is the heterogeneity in the network. These two major problems is to solve as much as possible. A practical approach is needed to analyze the existing routing protocols and modify using artificial neural network to get a better network communication and energy efficient.

Ratish Agarwal et al. have surveyed on several clustering algorithms. After survey completed, it is observed that a cluster-based MANET consists many issues such as the control overhead of cluster, cluster structure stability, the energy consumption of mobile nodes, load distribution in clusters, and the fairness of serving as cluster heads for a mobile node [15].

4. BASIC CLUSTERING CONCEPT

Clustering in MANETs can be considered as the virtual partitioning of dynamic nodes in the flat structure or distributed network structure into several clusters [22]. Clusters of the nodes in the flat structure or distributed network structure are made with respect to their closeness to each other. Such nodes are considered neighbors when all neighboring nodes are located within their transmission range and set up a bidirectional link between them. Typical algorithms for clustering in the flat structure or distributed network structure are known as one-hop clustering and multi-hop (d-hop) clustering algorithms [22].

In the one-hop clustering, every member node is at most 1-hop distance away from a central node that is called the cluster head. Thus, all member nodes remain at most two hops distance away from each other within a cluster category. On the contrary, in multi-hop clustering [22,23], the management of neighboring nodes to the cluster head is performed by allowing the nodes to be presented at most d-hop distance away from each other to form a cluster. A typical wireless MANET structure consists of flat and hierarchical structures as shown in Figure 2(a,b).

The small circle in the figure represents the nodes in MANET. The lines joining the circles denote connectivity among the nodes. Every node is identified with an ID number (*i.e.*, 1–10) along with a number within parenthesis. The numbers in the parenthesis are the weights of the nodes. These weights are measured with respect to various node parameters and apply the selection of cluster heads. Every node in the flat structure shares equal responsibility to act as a router to route the packets to every other node. However, to achieve better routing efficiency, this structure requires an amount of message flooding. Occasionally, such message flooding has the merit of reducing overhead of the MAC layer. On the other hand, nodes in the hierarchical structure are assigned with different functionalities while acting as a cluster head, gateway, or a cluster member as shown in Figure 1(b).

The cluster head in the hierarchical structure plays an important role in inter-cluster and intra-cluster communication. Thus, the cluster head works as the local coordinator for its member nodes and manages the cluster members. A gateway node is a node that connects the bridge between the inter-cluster and intra-cluster communication. On the other hand, a gateway works as the common or distributed access point for two cluster heads. Both of the distributed gateways provide the path for inter-cluster communication. The ordinary nodes of the cluster are the immediate neighbours of the cluster heads. They have the capability of serving as either a head or a gateway whenever selected to do so.

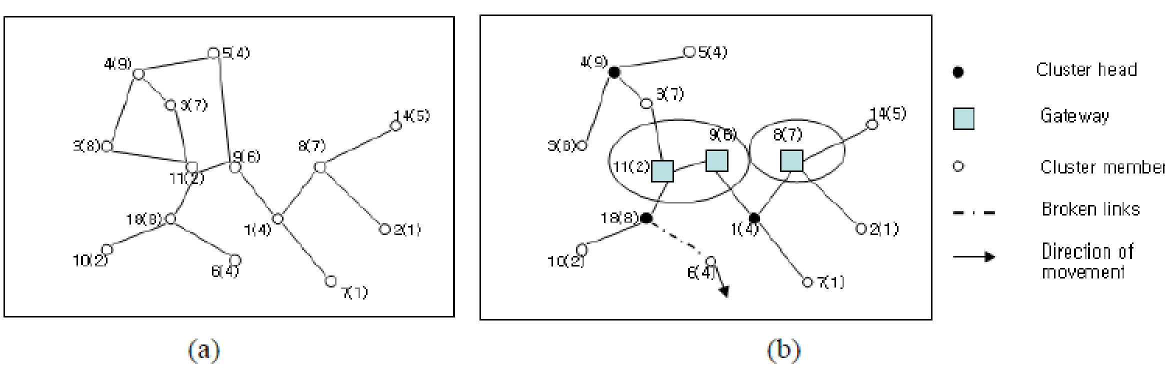

Figure 2: Flat Structure & Hierarchical Structure of Cluster formation [21]

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5. ART1 NEURAL NETWORKS

Adaptive resonance theory (ART), an unsupervised learning neural network method, was given by Carpenter A Grossberg in 1987 [17]. It was divided in two categories, first one i.e. ART1 for the binary pattern and the second one ART2 for the continuous values. ART1 consists of basically two layers, an input layer and an output layer. ART1 receives only binary input vectors. It expands if new input has not been categorized with the existing neuron. It maintains two matrices one is bottom-up matrix and other is top-down matrix. ART1 main forms clusters as an output depend on given input. The clusters size is fixed and depends on vigilance parameter (ρ). A vigilance parameter describes the tolerance of matching process.

5.1 Training Algorithm

A discussion of the choice of parameter values and initial eights follows the training algorithm [1]. The used notations follows:

n **-** number of components in the input vector.
m **-** maximum number of clusters that can be formed.
bij **-** bottom-up weights (from F1(b) unit Xi to F2 unit Yj).
tji **-** top-down weights (from F2 unit Yj to F1 unit Xi).
ρ **-** vigilance parameter.
s **-** binary input vector (an n-tuple).
x **-** activation vector for F1 (b) layer (binary).
$\|x\|$ - norm of vector x (defined as the sum of the components xi).

The training algorithm an ART1 net is presented next. A discussion of the role of the parameters and an appropriate choice of initial weights follows.

Step0. Initialize parameters:
$L > 1$,
$0 < \rho \le 1$.
Initialize weights:
$0 < b_{ij}(0) < L / L- 1 + n$,
$t_{ji}(0) = 1$.
Step1. While stopping condition is false, do
Steps 2-13.
Step2. For each training input, do steps 3-12.
Step3. Set activation of all F2 units to zero.
Set activations of F1 (a) units to input vectors.
Step4. Compute the norm of s:
$\|s\| = \Sigma s_i$
Step5. Send input signal from F1 (a) to the F1 (b) layer: $x_i = s_i$.
Step6. For each F2 node that is not inhibited:
If $y_j \neq -1$, then
$y_j = \Sigma b_{ij} * xi$.
Step7. While reset is true, do step 8-11.
Step8. Find J such that $y_J \ge y_j$ for all nodes j.
If $y_j = -1$, then all nodes are inhibited and this pattern cannot be clustered.
Step9. Recompute activation x of F1 (b):
$x_i = s_i * t_{ji}$.
Step10. Compute the norm of vector x:
$\|x\| = \Sigma x_i$.
Step11. Test for reset:
If $\|x\| / \|s\| < \rho$, then $y_j = -1$ (inhibited node J) (and continue executing Step 7 again)
If $\|x\| / \|s\| \ge \rho$,
Then proceed to Step 12.
Step12. Update the weights for node j (fast learning):
$b_{ij}(new) = L*xi / L-1 + \|x\|$, $t_{ji}(new) = x_i$.
Step13. Test for stopping condition.

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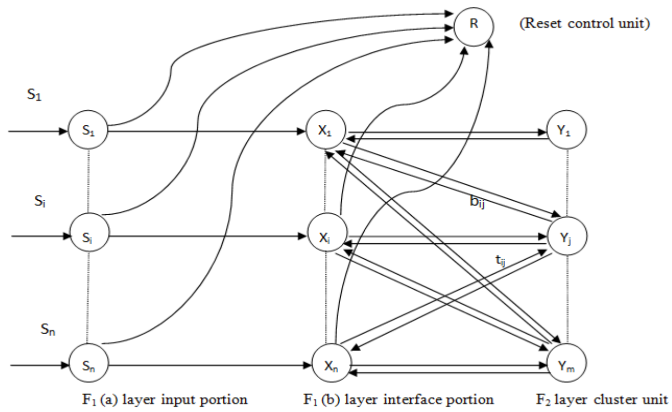

Figure 3: Basic Architecture of ART1

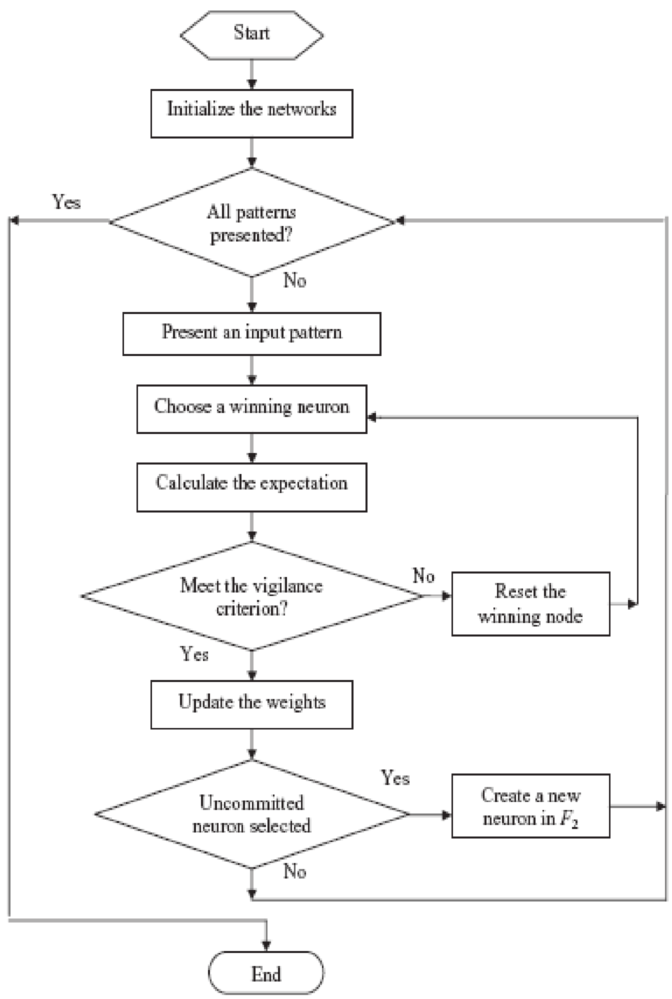

Figure 4: Flowchart of ART1 Neural Network

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5.2 Actual Parameters

n: number of components in the input vector.
m: maximum number of clusters that can be formed.
b_{ij}: bottom-up weights (from F1(b) unit Xi to F2 unit *Y*j).
Used to store different clusters values.
Permissible range is given by
$0 < b_{ij}(0) < L / (L - 1 + n)$
Sample value 1 /(1 + n).
tji: top-down weights (from F2 unit *Y*j to F1 unit *X*i).
ρ - vigilance parameter.(For deciding the learning node).
s - binary input vector (an n-tuple). Input array to store different input values.
Output array to decide the learning node.
$\|x\|$ - norm of vector x, defined as the sum of the components *x*i.
Initialize parameters:
L =50
ρ=0.5
Initialize weights:
$b_{ij}(0)$ =0.2
$t_{ji}(0) = 1$

6. RESULT ANALYSIS

Cluster head selection in MANET depends on residual energy which is left to each mobile node. The location-based algorithm decides the cluster using location information and residual energy power. This algorithm affects the problem of determining the lifetime of nodes in advance. Thus, if the nodes are managed in a distributed manner or flat structure without the cluster, the clustering performance is heavily affected by overheads. If the nodes are at the stage of critical energy then it cannot be the part of cluster head selection. Therefore ART1 neural network is used for selection of cluster head in MANET routing protocol and it is found that it is suitable for it. ART1 algorithm helps in cluster formations based on residual energy of mobile nodes. Cluster head selection is done on the basis of high energy residual cluster formed in ART1. Here we may have more than one cluster formed after setting up of the appropriate parameters of ART1. First of all the nodes are converted in binary patterns on the basis of their id (Table-1).

Table 1: Binary Vectors for Input Patterns

Node Number	Vector Pattern	Input Number	Vector Pattern
Node-1	(0,0,0,0,0,1)	Node -11	(0,0,1,0,1,1)
Node -2	(0,0,0,0,1,0)	Node -12	(0,0,1,1,0,0)
Node -3	(0,0,0,0,1,1)	Node -13	(0,0,1,1,0,1)
Node -4	(0,0,0,1,0,0)	Node -14	(0,0,1,1,0,0)
Node -5	(0,0,0,1,0,1)	Node -15	(0,0,1,1,1,1)
Node -6	(0,0,0,1,1,0)	Node -16	(0,1,0,0,0,0)
Node -7	(0,0,0,1,1,1)	Node -17	(0,1,0,0,0,1)
Node -8	(0,0,1,0,0,0)	Node -18	(0,1,0,0,1,0)
Node -9	(0,0,1,0,0,1)	Node -19	(0,1,0,0,1,1)
Node -10	(0,0,1,1,0,0)	Node -20	(0,1,0,1,0,0)

Among these clusters one winner will be of the highest energy. This clustered node with highest energy can be the part of cluster head in routing for next round of data transmission. Rest of ART1 neural network clusters elements act as intermediate mobile nodes. Simulation result of total energy consumption has been shown in table-2 & table-3. Comparison of results of energy and payload is represented in figure 5. Consequently It is observed that cluster node consumes more energy/power (Tx and Rx) when we increase payload data.

Table 2: Cluster Head Formed after Clustering By ART1 Neural Network

Sector/ class	Input classification in different sectors	Vector Pattern
1	2,8,26,27,29,30,35,41	(0,0,0,0,0,1)
2	14,21,4,5,34,43,31,40	(0,0,0,0,1,0)
3	3,6,12,17,19,23,25,28,37	(0,0,0,0,1,1)
4	7,9,11,15,16,22,32,33,42	(0,0,0,1,0,0)
5	1,24,10.13.18,39,20,44,38,45	(0,0,0,1,0,1)

7. CONCLUSION

We can say that MANET is the choice for cheap communication now-a-days. However this has few limitations which make it less preferable. One of the major challenges is battery life of MANET. During communication process whole system consume battery lives of mobile nodes. To reduce this power consumption; we have worked on routing techniques which lower the power consumption at a greater extent. We have implemented ART1 neural network over the cluster head selection as a part of the routing technique which selects the cluster head depending on residual energy of the mobile node after the completion of every data transmission. After simulating the results in table-3 and figure-5 we found that ART1 algorithm or simply ART1 has optimized the problem of cluster head selection and consequently optimized residual energy. And the network lifetime is increased up to 58% as compared to traditional routing techniques.

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Table 3: Total Energy Analysis with Vigilance Parameter

S. No.	Energy Tx	Energy Tx (ρ= 0.9)	Energy Tx (ρ= 0.6)	Energy Tx (ρ= 0.3)	Energy Rx
1	0.01216	0.01216	0.0216	0.01216	0.2183693
2	0.06336	0.02336	0.02336	0.02336	0.2183693
3	0.09576	0.03576	0.05576	0.03576	0.255674
4	0.2288	0.06288	0.06288	0.188	0.255674
5	0.3378	0.09288	0.1288	0.288	0.255674
6	0.5392	0.1292	0.2292	0.392	0.255674
7	0.6653	0.1755	0.3755	0.4755	0.255674
8	0.9344	0.1991	0.5891	0.7891	0.255674

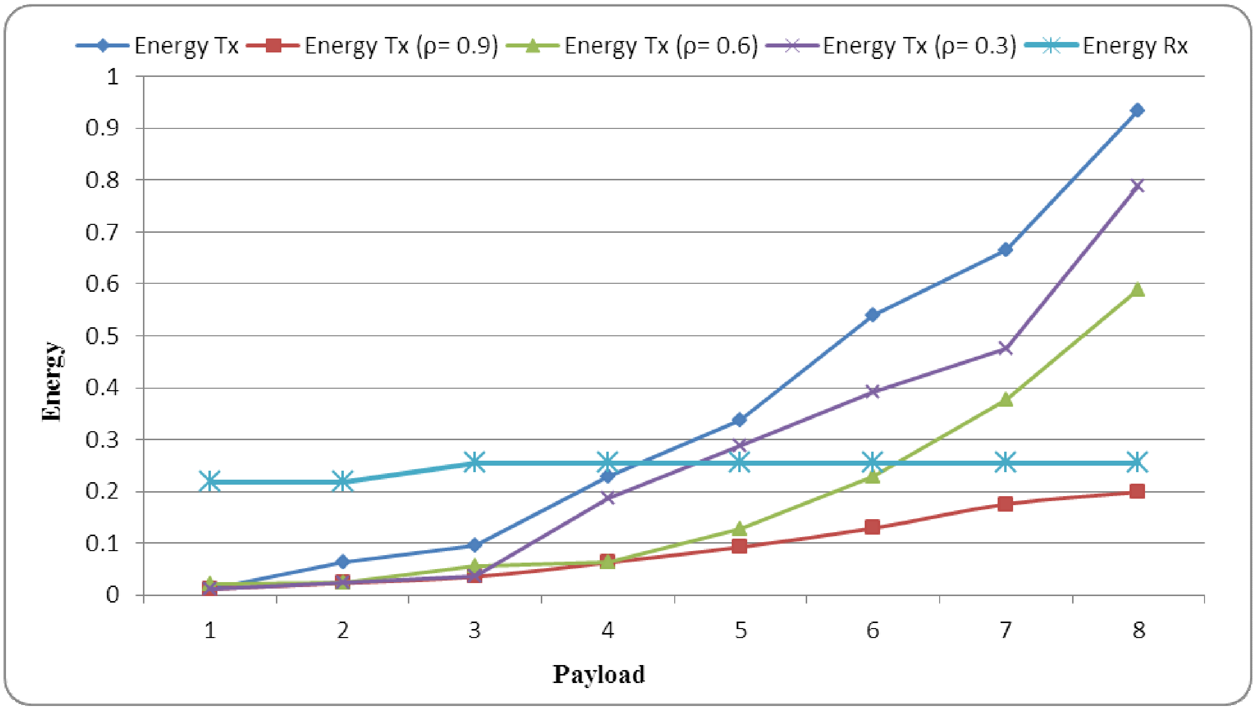

Fig 5: Comparison of Residual Energy with Different Vigilance Parameters

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