S-PAC : A Novel Hard Index based Cluster Validation Technique for Ad Hoc Network

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Abstract: - Gone are the days that transmission media are physically established to transmit the data from one location to another location. As of now, the transmission by air has been an indispensable step to conserve the resources and also to make the investments cost effective. The ad hoc network has come up as a solution provider to set up the communication process. The supportive mechanism like clustering will increase the efficiency of the network functionality which has been known very well. These clusters need to be fine-tuned on the process of maintaining an efficient network. Thus, this work proposes S-PAC as a validation technique to measure the cluster stability. This stability of clusters are measured in terms of their strength of inter and intra cluster communication. This strength factor decides the proper time to make the re-cluster event to occur in the ad hoc network. This work has been experimentally shown using OMNET++ simulator.

Key-Words: - S-PAC, W-PAC, Silhouette.

1 Introduction

The network places an essential role in this real world has been well experienced by the people who stay at nook and corner of this globe. To say further, wireless has been playing a substitution for wire based networks in this fast paced world.

The wired and wireless networks are making use of infrastructure in their communication process. The situation will be slightly overburdened in terms of space as well as resources when networks are infrastructure based. Having the present scenario in our mind the networks with functionally integrated nodes are coming up. These networks are dynamic in nature and nodes are having multi-functional capabilities. Thus, this paper work has put focus on the ad hoc scenario and mechanisms which are supportive to the efficient functionality of the network. The existing clustering algorithms will form clusters but lacks in identifying an efficient clusters by means of the strength of bonding between the nodes and cluster head. To get rid of this situation this paper has come up with S-PAC(Silhouette based Partitioned Around Cluster head) procedure as a cluster validation mechanism. This will identify the good clusters from the bad ones which are needed on the path towards maintenance of clusters. The good clusters will have strong intra cluster communication. This will help to sustain the clusterhead of the clusters to continue in their role. The downside of the intra cluster strength indicates the re-clustering at the global level in the ad hoc network.

This paper has been organized as follows. Section.1 comes as introductory part. Section.2 describes the related work on clustering mechanism. Section.3 puts down the existing W-PAC(Weighted Partitioning Around Clusterhead) algorithm on

forming clusters. Section.4 proposes the S-PAC procedure on top of the W-PAC. Section.5 gives out the experimental results. Section.6 specifies the future direction of this study. Section.7 points out the concluding remarks.

2 Literature study

The fact says that clustering concept hasn't been a new concept to get the focus. The fruitfulness of this mechanism has been felt over the period of time. The non clustered protocols when added up with the clustering mechanism gives a noticeable improvement in their performance have been understood.

The clustering has been used in showing the network functionality a tremendous success. This has been understood based on the works carried out so far on this mechanism. The clustered network benefits over nonclustered has been experimentally shown[1]. The real world applications are making use of the clustered networks[2].

The purpose of clustering on ad hoc network has been realized after performing research and simulations on clustered routing protocol[3]. This also deals with the intention of the cluster routing protocol in ad hoc network and shows the routing protocol functionality on ad hoc network.

The AODV[4] protocol integrated with clustering mechanism reveals that a noticeable change in bandwidth consumption and routing table size.

The clustering protocol with scalability[5] will make a significant benefit of AODV_clustering technique. This deals with the logical level of clustering the network which differs from having distinguished clustering technique.

The k-means and fish-school algorithm[6] describes the cluster formation. This brings out the cluster formation techniques restricted to few parameters .

The cluster classification methods[7] are of numeric, discrete and partitioned types. This helps to find out the clustering method preferable for a given data set.

The cluster validation[8] procedures using various indices play essential role in evaluating the clusters and gets the conclusion about the clusters formed.

The hierarchical clustering[9] using k-means procedure shows the cluster formation and also the silhouette validation to understand the nature of the clusters formed.

The k-means approach on different scenarios[10] says that the simple k-means won't give better results. Thus, k-means with silhouette has been suggested to achieve the best results.

The clustering has been illustrated with the help of graph[11]. This takes the indices to fine tune the graphical results to produced best cluster as a results.

The CLPSO[12] states that swarm intelligence techniques are extremely outperforming in finding the optimum number of clusters. Thus, the resources of the networks can be managed efficiently.

The CBTRP[13] creates the one hop clusters and puts the focus on cluster head. The cluster head has been considered as highly trustworthy node to transmit the data towards the destination.

The cluster maintenance technique[14] helps to maintain the clusters created to sustain the stability of the network. When two cluster heads are getting closer to each other may put them under over lapping region. One of those two cluster head will have to resign and the clusters will merge. The cluster head re-election can happen while the battery energy of cluster head runs down below the threshold value.

The token based clustering algorithm[15] ensures the proper resource sharing mechanism by solving mutual exclusion problem. The clustered network makes the resource utilization in an efficient way.

The EWCA[16] states that clustering mechanism can be put into two steps namely cluster set up and cluster maintenance. The threshold places the vital role as limiting factor to the cluster head to keep themselves away from energy completely drained out. To reduce the burden of the cluster head node the role of playing as cluster head will be rotated among the nodes. This may solve the energy [17] imbalanced problem.

The clustering method requires to minimize the energy to set up cluster, maximize the life time of cluster and make sure the stable structure[18]. The power level of nodes decided the sustainability of the cluster head role. The transmission power alone is not adequate to calculate the weight of the node. The power reward[19] based weight calculation guarantees the uniform power distribution.

The clustering can also be created based on the signal strength[20] between the cluster head and nodes belong to cluster. The cluster head has been decided using the signal strength expression. The cluster head will elect the nodes for the cluster on the basis of signal strength.

The cluster heads are considered as dominating sets in clustered network. The minimum independent set[21] can be built and the tree structure of the same can be produced later. The

connected dominating set algorithm has been a backbone to form the clusters.

The clustering mechanism should incorporate security to make the network as highly reliable. The SWCA[22] proposed to add up the security measures to the clusters formed. This will keep the malicious attack away from the network.

The WCA makes to understand that there are several parameters in deciding the weight of the node to be elected as cluster head. An improved protocol NWCA[23] replaces the degree computation to mean connectivity degree. It considers the energy factor to decide the cluster head.

The DWCA[24] takes the cluster formation based on weight, mobility factor and cluster maintenance. The new node addition to cluster has been handled through distinct approach has been affirmed by this protocol.

The weight based clustering has been improved[25] on the basis of minimizing the load of the cluster head with the help of threshold value. This confines the cluster size to guarantee the cluster head to retain their role for long period.

The modified DSECA[26] has been an enhanced algorithm to diminish the burden of the cluster head. The cluster head breakdown can be handled using proxy node acts as cluster head. This approach eliminates frequent re-clustering and minimizes the reaffliation.

The re-clustering should be based on identifying the strength of the existing clusters. The role of various indices[27][28] on evaluating the cluster should be understood very well. The cluster classification[29] also plays key role in determining the perfectness of the clusters. Those classifications are of numeric, discrete and partitioned types. It also finds out the preferred clustering method for a given sample set of nodes.

3 W-PAC

The PAC[30] forms the clusters through iterative process. The manhattan distance saves time in finding the distance between pair of nodes. The results obtained are not sufficient to find out the suitable cluster for all nodes. This has been improved through Ex-PAC algorithm which is built on top of PAC. The experimental results show that Ex-PAC outperforms K-means[31] algorithm in forming clusters. But this algorithm lacks in considering various parameters to decide the cluster head. The W-PAC algorithm takes multiple parameters together in the name of weight to identify the cluster head.

W-PAC Cluster Creation Procedure

(1) Initialize set of nodes as M.
(2) Compute the degree of node Ni.
(3) Deg (Ni) = 0.
(4) j = 1.
(5) If (i not equal to j)
begin

MDist (Ni, Nj) = $\mathrm{MOD}\{(X_2 - X_1) + (Y_2 - Y_1)\}$

If (Manhattan Dist(Ni , Nj) < Radious)
begin
Add (Ni , Cm) // add to cluster
Deg(Ni) = Deg(Ni) + 1
j = j + 1
end
else
Add (Ni , NCn) // add to Non cluster
end
(6) Repeat the step 5 until j = M.

W-PAC Cluster Head Election Procedure

(1) Create Clusters using W-PAC cluster creation.
(2) Cluster = Ci, P = Number of nodes in Ci.
(3) j = 1; Ni = (U_t, V_t); Nj = (U_{t-1}, V_{t-1});
(4) If (i not equal to j)
begin
If (Manhattan Dist(Ni,Nj) < Radious)
begin

Compute the Mobility speed of Node Ni of Ci.

$$M(Ni) = \frac{1}{T}\sum_{t=1}^{T} \mathrm{MOD}\{(U_t - U_{t-1}) + (V_t - V_{t-1})\}$$

Compute the Distance between Ni and Nj.

$$D(Ni) = \sum_{t=1}^{T} \mathrm{MOD}\{(U_t - U_{t-1}) + (V_t - V_{t-1})\}$$

j = j + 1

end
end
(5) Repeat the step 4 until j = P.
(6) Assume the Energy of nodes E(Ni) for all the nodes.
(7) The weight of node Ni computed as follows,

W(Ni) = q1*Deg(Ni) + q2*M(Ni) +
q3*D(Ni) + q4*E(Ni)

(8) Repeat the step 7 for all nodes belong to Ci.
(9) CHk = Min { $W(N_1), W(N_2), W(N_3) \ldots W(N_M)$ }.
(10) Repeat the step 2 through 9 for i = 1…..no of clusters.

W-PAC algorithm certainly improves Ex-PAC and shows performance slowdown in obtaining effective results while the number of nodes and their mobility level is high. The nodes which are identified as part of clusters have to be confirmed their identity within the specific clusters.

This algorithm has been bounded by drawback. The weight co-efficient are fixed with respect to the chosen scenario. This should be variable in accordance with real world application. This is possible with the help of artificial intelligence based approach specifically neural networks will stand this way to provide meaning solutions.

4 S-PAC

This algorithm has been devised to study strength level of the intra cluster communication. This takes the clusters formed through W-PAC as an input. The parameter silhouette identifies closeness of the nodes to their cluster. The formula (1) tells the calculation of silhouette parameter.

$$S(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}} \qquad (1)$$

The above mentioned formula can be written based on constraints as given in (3),

$$S(i) = \begin{cases} 1 - \frac{a(i)}{b(i)}, & \text{if } a(i) < b(i) \\ 0, & \text{if } a(i) = b(i) \\ \frac{b(i)}{a(i)} - 1, & \text{if } a(i) > b(i) \end{cases} \qquad (2)$$

From the above definition it is obvious that,

$$-1 \leq s(i) \leq 1 \qquad (3)$$

In the formula (2) , the variable b(i) will be computed by taking the average dissimilarity of node to the nodes belong to the clusters other than the cluster where the node appears. This is also called as inter cluster dissimilarity.

b(i) = d(i,C) { Average dissimilarity of i to all nodes in cluster C }

The variable a(i) could be computed by calculating the average dissimilarity of a node to the nodes belong the same cluster.

a(i) = d(i,A) { Average dissimilarity of i to all nodes in Cluster A }

The lower value of a(i) tells the nodes closeness with the cluster. This indicates stability level of clusters formed. The higher value of b(i) points out the nodes dissimilarity from being the member of cluster. The silhouette value lies between -1 and 1. The positive value indicates either the dissimilarity within the cluster or dissimilarity with other clusters.

Table.I Types of Cluster

Silhouette	Types of Cluster
0.0 - 0.49	Simple
0.50 - 0.75	Good
0.75 - 1.0	Perfect
Less than Zero	Bad

Table.I gives out the type of clusters based on the silhouette range. The clusters can be of type simple, good, perfect and bad. These types identify the closeness of member nodes to the clusterhead. This is decided based on the average index value measured. The silhouette index for each value obtained says that existence of the node in a specific cluster. The positive result indicates the node's closeness to the clusterhead in the cluster and negative measures indicate the non-existence of node in the specific cluster.

S-PAC Procedure

1. Input the clusters formed through W-PAC algorithm.
2. Choose N[i] from Cluster C[i].
3. Find the average dissimilarity of N[i] within C[i].
   A = Avgdissimilarity(N[i],C[i])
4. Find the average dissimilarity of N[i] to remaining Clusters C[j].
   B = Avgdissimilarity(N[i],C[j])
5. Compute silhouette,
   Silhouette = B – A / Max [A,B]
6. If silhouette is between 0.75 and 1.0
   then Perfect Cluster.
   Else
   If silhouette is between 0.5 and 0.75
   then Good cluster formation
   Else
   If silhouette is negative
   then Bad cluster formation.
7. Repeat the steps 2 through 6 for all nodes in each cluster.

The silhouette is calculated based on the value of A and B. This value will be checked for their occurrence on the specific range. This range of silhouette will ascertain the cluster type as perfect, good and bad.

5 Experimental Results

This S-PAC algorithm has been implemented using OMNET++ as a simulation tool. This work has been done for 10 nodes, 25 nodes and 300 nodes.

Table.II Simulation Parameters

Parameter	Values
N (Number of Nodes)	10 , 25 & 300
Space (area)	100 ×100
Tr (Transmission range)	20m
Threshold (Re-clustering)	50%

Table.II shows the simulation parameters considered for implementation.

Table.III Results of W-PAC

Number of Nodes	Cluster1	Cluster2
10	5	5
25	18	7
300	128	172

Table.III shows that the number of nodes used in experimental study. In the scenario of 10 nodes the cluster1 and cluster2 have 5nodes each.
In the case of second scenario considered 25 nodes for the study. It splits the nodes into 18 under cluster1 and 7 under cluster2.

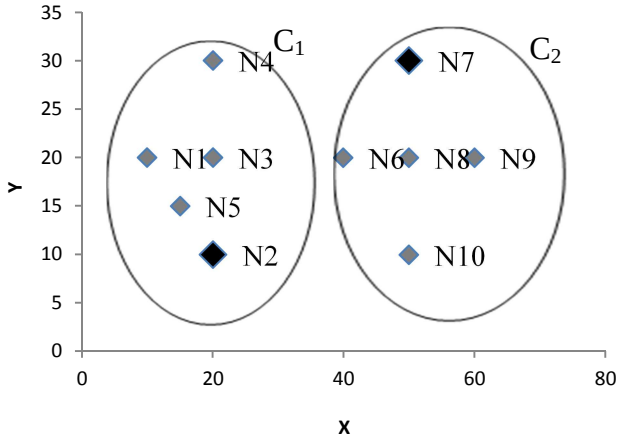

Fig.1 Cluster Creation results – 10 Nodes

Fig.1 shows the result of cluster creation for the sample of size 10 nodes. These clusters need to be validated using the validation indices.

Table.IV Results of Cluster

Nodes	Cluster	Silhouette			Type
		0.76-1.0	0.50-0.75	0.0-0.49	
10	1	0	5	0	100% Good
	2	0	4	1	80 % Good + 20% Simple

Table.IV shows the tabulated experimental results of 10 nodes scenario. The clusters formed using W-PAC has been validated using Silhouette parameter. The result shows that the clusters formed have been rated as good. This goodness indicates the strength of intra cluster communication between clusterhead and the member nodes of the cluster. This also reveals that the clusters formed were stable and the re-clustering might not be required for some time period T.

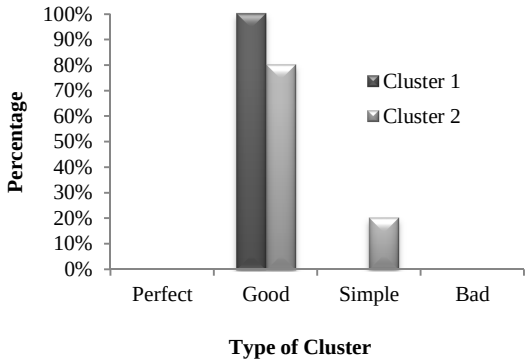

Fig.2 Graph - Cluster Validation

Fig.2 shows the results of cluster validation process using Silhouette index for 10 nodes. This obviously ushers that the clusters formed by W-PAC procedure were good.

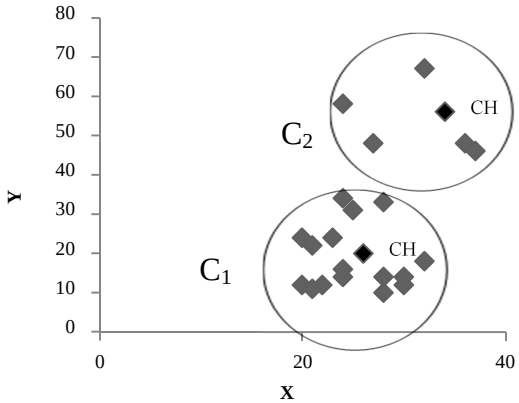

Fig.3 Cluster Creation results – 25 Nodes

Fig.3 shows the result of cluster creation for the sample of size 25 nodes. These clusters need to be validated using the validation indices

Table.V Results of Cluster

Nodes	Cluster	Silhouette			Type
		0.76-1.0	0.50-0.75	0.0-0.49	
25	1	2	13	3	11% Perfect + 72% Good +17% Simple
	2	0	6	1	86% Good + 14% Simple

Table.V puts down the results of 25 nodes used in cluster formation. This validation using silhouette reveals that the clusters type fall in perfect, good and simple. This analysis makes us to understand that the results are not based on the number of nodes. It is based on the place where the node exists. Both cluster1 and cluster2 have 72% and 86% goodness respectively at time T1. If this percentage gets reduced below 50% after time T2 due to mobility property of the nodes then the re-clustering need to be considered. This re-clustering is based on the threshold of 50% goodness in cluster.

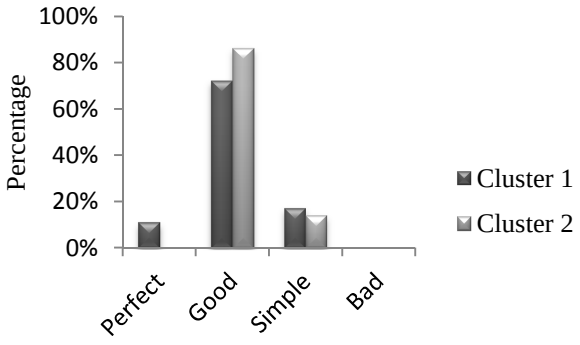

Fig.4 Graph - Cluster Validation

Fig.4 shows results of cluster validation process for 25 nodes. This obviously ushers that the clusters formed by W-PAC procedure are good as well as perfect.

Table.VI Results of Cluster

Nodes	Cluster	Silhouette			Type
		0.76-1.0	0.50-0.75	0.0-0.49	
300	1	72	30	26	24% Perfect + 10% Good + 9% Simple
	2	0	137	35	46% Good + 12% Simple

Table.VI puts down the results of 300 nodes used in cluster formation. This validation step identifies that the cluster1 has less perfectness. The cluster2 has zero perfectness. Thus, both the clusters have less perfectness. This is due to nodes mobility and size of the clusters. This has reduced the bonding between the clusterhead and member nodes within each cluster formed. The re-clustering will bring out some other clusterhead other than the one which played clusterhead role at the time of this cluster formation.

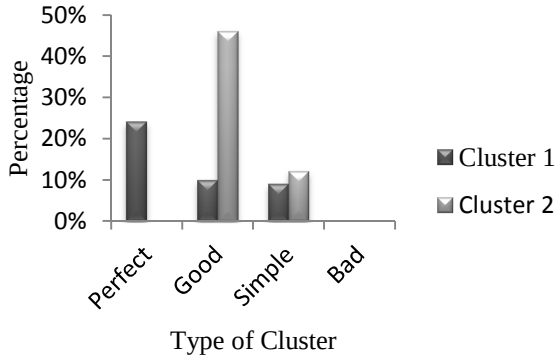

Fig.5 Graph - Cluster Validation

Fig.5 shows results of cluster validation process for 300 nodes. This obviously ushers that the clusters formed by W-PAC procedure are less perfect, good and simple.

6 Future Direction

This Silhouette metric could be applied for various real world applications where the clusters are playing vital role. They are as follows:

- To set up conference network within the Hall the inter cluster distance may likely to be maximum. Since the network will be constant for a while needs smooth communication across the clusters of the network.
- To set up field study(soil humidity) network the inter cluster distance should be as maximum as possible. Since this network would be fixed for the specific period.
- To set up network within the campus where the nodes are highly mobile deserves less inter cluster distances. This is to keep the re-clustering process to happen while it is desperately needed.

7 Conclusion

This study discloses the vital role of validation mechanism over clustering algorithms. This makes us to understand that mere clustering the nodes will

not solve the problem of ad hoc networks. Though this may provide tentative solution this can be prolonged with the help of validation. This research work reveals the purpose of S-PAC as a validation mechanism over the W-PAC procedure. This S-PAC procedure just identifies the nature of cluster at a specific time T1 after the clusters formed with the help of W-PAC. This nature decides inter and intra-cluster relationship in ad hoc networks. The Silhouette as a validation parameter decides the perfectness of the existing clusters. The validation process identifies the right time to re-cluster the ad hoc network based on the Silhouette value. This process comes as a part of cluster maintenance. This work has been supported with the implementation using OMNET++ simulator. This work has left the overlapped clusters to find the perfectness of clusters. The multi-hop clusters have not been considered for validation in this work. This work can be applied for large sample size.

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