# F-PAC: A Novel Soft Index Based Cluster Head Validation & Gateway Election Mechanism for Ad Hoc Network

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*Abstract:* - In this dynamic scenario the communication no longer happens in predetermined manner. The network as a platform for communication comes with high infrastructure may likely to waste the resources. Thus, the ad hoc scenario network came into existence. This network functionality has been enhanced through clustering mechanism. These clusters need to be perfect to sustain the efficient functionality of the network. Thus, this paper proposes F-PAC as a fuzzy logic based cluster validation technique to authenticate the cluster head identified by the existing cluster formation mechanisms. This procedure also helps to elect the gateway node for each cluster. This study has been shown using OMNET++ as simulator.

*Key-Words:* - F-PAC, W-PAC, Fuzzy.

## 1 Introduction

It is well known that the ad hoc network stands uniquely as a tentative network in the communication process. The network functionality never remains constant since the number of nodes is not constant always. There is an expectation upon the network functionality to be stable irrespective of the change happens in network size. Unfortunately this couldn't happen due to the inadequate maintenance of the network. If this setback on the network hasn't been set right then this may cause colossal damage on the performance of the network. This issue can be addressed and solution can be attained with the help of some unique mechanism on the ad hoc network. The clustering has been realized as one such mechanism which can provide the expected results**.** The cluster formation algorithms are used in hard way of forming clusters. There should be some soft approach which would be helpful to decide the degree of closeness of nodes in a cluster. The F-PAC(Fuzzy based Partitioning Around Cluster head) will apply soft method to ascertain the cluster head identified by WCA[1] and W-PAC[2] procedure.

This paper has been organized as follows. Section.1 deals with the introduction. Section.2 gives out the literature study. Section.3 tells about existing approaches. Section.4 speaks about W-PAC procedure. Section.5 puts down the proposed F-PAC procedure. Section.6 shows experimental results and analysis. Section.7 specifies the future direction of this work. Section.8 ends up with the concluding remarks.

## 2 Literature study

The power level of nodes decided the sustainability of the cluster head role. The transmission power alone is not sufficient to calculate the weight of the node. The power reward[3] based weight calculation ensures the uniform power distribution.

The clustering can also be formed based on the signal strength[4] between the cluster head and nodes belong to cluster. The cluster head has been computed using the signal strength expression. The cluster head will select the nodes for the cluster on the basis of signal strength.

The dominating sets are identified in the clustered network. In which the minimum independent set[5] can be constructed and the tree structure of the same can be formed later. The connected dominating set algorithm has been a backbone to form the clusters.

The cluster head functionality can be tampered by the malicious node which behaves like cluster head. The SWCA[6] proposed a secured weighted clustering algorithm to keep the network away from such malicious nodes.

The NWCA[7] has been proposed to improve the weight based algorithms through changing methodology of parameter calculation for weight. The degree computation has been changed to mean connectivity degree. This novel method also considers the energy level of the nodes to play the role of cluster head.

The DWCA[8] considers the cluster formation based on weight, mobility factor and cluster maintenance. The new node addition to cluster has been handled through distinct approach by this protocol.

The weight based clustering has been improved[9] on the basis of reducing the load of the cluster head with the help of threshold value. This limits the cluster size to ensure the cluster head to last longer.

The role of clustering in ad hoc networks has been realized when AODV[10] incorporates the clustering mechanism. This added mechanism enhances the functionality of the network.

The application of the clustering mechanism[11] with AODV as a routing protocol in the real world scenario has been indispensible. This shows that clustering technique makes the network to be suitable for various applications. The clustering mechanism PAC[12] over the k-means approach tells the purpose of parameters in cluster formation. These parameters decide the efficiency level of clusters. This study also confirmed that k-means takes more time when the number of nodes are high in count. This work lacks in implementation and also the sample set of nodes are small in size.

The PAC has shown good results when the number of nodes are less. It leaves many nodes as non clustered nodes. The Ex-PAC [13] came out as an extension to PAC which takes entire nodes and produces the maximum clusters. The cluster formation process ultimately improved in Ex-PAC procedure. This approach concludes that Ex-PAC has outperformed k-means in terms of computational speed.

The multi-parametric swarm intelligence based clustering mechanism PSO-PAC[14] takes the necessary parameters to identify the cluster head of the cluster. This parameter optimization will suit specific application.

The re-clustering should be based on identifying the strength of the existing clusters. The role of various indices[15] on evaluating the cluster should be understood very well. The cluster classification[16] 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.

The cluster formation procedure will not confirm the perfectness of the clusters. The validation[17] process confirms the perfectness of the cluster to determine the stability factor of the cluster. This factor helps in finding out the re-clustering time based on the measured value.

## 3 Existing Approaches

The highest degree algorithm[18] considers only degree of the node to form the clusters. This doesn't take other parameters into account to decide the members of the particular cluster. Thus, δ-degree clustering algorithm[19] has improved highest degree algorithm by considering speed and link factor into account. The stability of the link has been decided based on fuzzy membership degree. The fuzzy set has been considered with near, far and medium as fuzzy names to decide the membership of the nodes. The fuzzy logic based clusterhead election algorithm proposed[20] lacks in obtaining the experimental results instead specifies the fuzzy rules to elect the clusterhead. The multi-parametric algorithm WCA takes more time to form the clusters. Thus, W-PAC mechanism has been considered to form the clusters since this elects the clusterhead by considering multiple parameters.

## 4 W-PAC

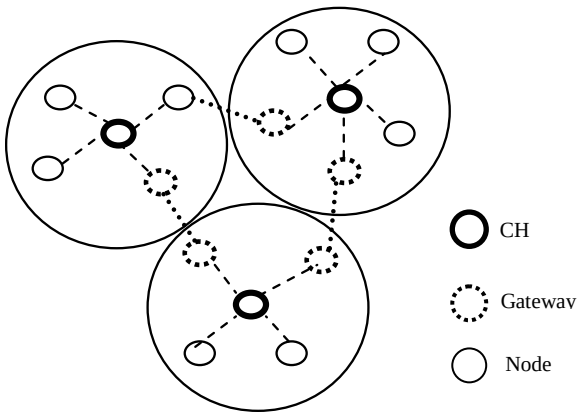


**Fig.1 Clustered Network**

The Fig.1 shows the clustered network structure of W-PAC procedure. 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

Manhattan Dist (Ni, Nj) = $\mathrm{MOD}\begin{Bmatrix}(X_2 - X_1)\\ +(Y_2 - Y_1)\end{Bmatrix}$

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 = Max { $W(N_1), W(N_2), W(N_3) \ldots W(N_M)$ }.
(10) Repeat the step 2 through 9 for i = 1…..no of clusters.

W-PAC algorithm certainly improves WCA and shows performance improvement 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 confirm their identity within the specific clusters and their communication with the cluster head.

# 5 F-PAC

This procedure is based on fuzzy logic and fuzzy set. The Fuzzy logic deals with the possible value or truth value or approximate value rather than identifying the fixed hard values. The values are neither 1 and nor 0 which lies between 0 and 1.This approach is so called as soft approach on cluster formation. It is against the binary logic which says the value could be either 0 or 1. This fuzzy logic has been expressed in terms of fuzzy set construction comprise of nodes as set members.

A fuzzy set is a pair (M,K) where M is set of nodes and K is called the degree of membership of the nodes denote as
M : K → [0,1]. For a finite set contains the elements as shown(1).

$$\begin{cases} M = \{N1, N2 \ldots Nn\} \\ Dij = \{Di1, Di2 \ldots Din\} \\ i = 1,2 \ldots . Ci \end{cases} \quad (1)$$

The degree of the nodes Dij can have the following values as shown (2). When Dij value is either 0 or 1 then the node will not belong to the set or definitely contained in the set. But the value when lies between 0 and 1 then the node will become fuzzy member and value determines how far the node is truthful in its property.

$$\begin{cases} Dij = 0 & Dij \notin \text{Fuzzy set K} \\ Dij = 1 & Dij \in \text{Fuzzy set K} \\ 0 < Dij < 1 & Fuzzy\ member \end{cases} \quad (2)$$

The set { Ni ∈ M | Dij >0 } is called the support of (M,K) and the set {Ni ∈M | Dij =1 } is called its

kernel. The degree of node can take values between 0 and1 has been realized (3). These nodes are part of

$$\begin{cases} \text{Dij} \in [0-1], & \text{i} = 1,2 \dots \text{C}, \\ & \text{j} = 1,2 \dots \text{n} \\ \sum_{\text{i}=1}^{\text{C}} \text{Dij} = 1, & \text{j} = 1,2 \dots \text{n} \\ 0 < \sum_{\text{j}=1}^{\text{n}} \text{Dij} < n, & i = 1,2 \dots C \end{cases} \quad (3)$$

cluster, will have the membership degree. The sum of those membership degrees of all nodes within the cluster will not exceed the maximum value 1. This is not only true for intra cluster but also for inter cluster.

**F-PAC algorithm: Cluster Head Identification**

1. Input the clusters formed using WCA or W-PAC algorithm.
2. Input the Cluster Ci
3. Compute the degree $D_{ij}$ of the node $N_i$.

$$\text{Dij} = 1/\text{dist}(\text{CH}, \text{Ni})$$

4. Compute the cluster Center based on membership degree Dij.

$$\text{Center} = \frac{\sum_1^{\text{N}} \text{Dij} * \text{dist}(\text{CH}, \text{Ni})}{\sum_1^{\text{N}} \text{dist}(\text{CH}, \text{Ni})}$$

5. Repeat the steps 2 and 3 for all the nodes in the cluster.
6. { To Find the number of nodes from cluster head less than or equal to Computed Center }
For i = 1 .. n { n – number of nodes in Cluster Ci}

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If ( dist (CH,Ni) < Center)
   Count[i] = Count[i] +1
```

7. {To find the Max count in a cluster }

```
For i = 2 …n
    Max=Count[1]; { tentative maximum }
    If ( Count[i] > Max)  Max = Count[i];
```

8. Repeat the steps 2 through 6 for i = 1…..No of clusters.
9. Identify the cluster head for maximum count.
10. If the cluster head = cluster head identified in the case of WCA or W-PAC then cluster head is valid.

This algorithm takes output from WCA or W-PAC as input for further processing. It finds the degree of each node and then Center for each cluster. The Center will be taken as a reference to find the number of nodes within the cluster. This Center signifies the maximum distance the cluster head and nodes can have while their existence in the same cluster. The Count[i] finds the maximum number of nodes in a cluster based on Center value. The cluster head of the cluster which has max Count[i] will be chosen. If the cluster head identified by this fuzzy procedure is same as cluster head identified by the WCA or W-PAC procedure then say cluster head validation has reached success.

**F-PAC algorithm: Gateway Election**

1. Input the clusters formed using WCA or W-PAC algorithm.
2. Find the distance between node N and cluster head CH

$$\text{Dist(CH,Ni)} = \sum_{\text{i}=1}^{\text{n}} |\text{xi} - \text{yi}|$$

3. Compute the degree Dij of the node $N_i$.

$$\text{Dij} = 1/\text{dist}(\text{CH}, \text{Ni})$$

4. Repeat the steps 2 & 3 for all nodes in cluster.
5. Gateway = least (Degree of node Dij).
6. Repeat the steps 2 through 5 for each cluster.

This Procedure considers the non overlapping clusters to construct distributed gateways. These gateways will be identified based on their degree values. Higher the degree values indicate the closeness of the node towards the cluster head. Thus, the lower value nodes will be near to the edge of the cluster boundaries to act as gateway nodes. The maximum membership value lies between 0 and 1.

# 6 Experimental Results

The F-PAC algorithm has been implemented using OMNET++ Tool and the results are tabulated. This work has been carried out with the system configuration of 64bit AMD processor, 2GB RAM and windows XP as an operation system. This simulation has been done for 10 nodes and 25 nodes.

Table.I shows the simulation parameters. The cluster heads identified using WCA and W-PAC have been mentioned. These clusterheads need to be validated using F-PAC to confirm their place within each cluster. If F-PAC results are showing different clusterheads then the clusters are imperfect in their existence.

**Table.I Simulation Parameters**

| Parameter | Values |
|---|---|
| N (Number of Nodes) | 10 , 25 |
| Space (area) | 100 ×100 |
| Tr (Transmission range) | 20m |
| WCA ,W-PAC Cluster heads (10 nodes) | N2, N7 |
| WCA, W-PAC Cluster heads (25 nodes) | N3,N19 |

**Table.II Cluster heads of F-PAC , WCA and W-PAC**

| Nodes | Cluster | Existing Methods | | Proposed |
|---|---|---|---|---|
| | | WCA | W-PAC | F-PAC |
| 10 | C1 | N2 | N2 | N2 |
| | C2 | N7 | N7 | N7 |
| 25 | C1 | N3 | N3 | N3 |
| | C2 | N19 | N19 | N19 |

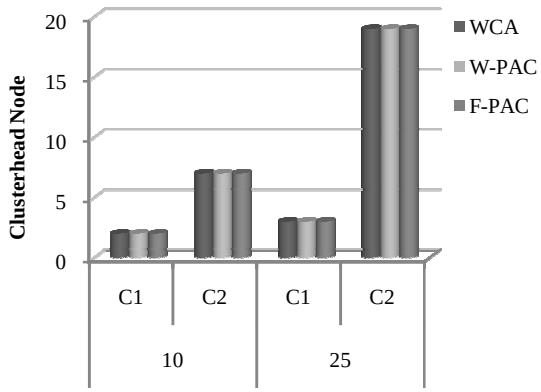


**Fig.2 F-PAC Vs WCA and W-PAC results**

Table.II shows that the cluster head elected using WCA and W-PAC procedure and validated using F-PAC procedure at time T1. This validation process confirms that the cluster heads are properly identified by WCA and W-PAC procedure. But WCA takes more time to form clusters than W-PAC.

Fig.2 shows the clusterheads elected for the existing methods and proposed methods. WCA and W-PAC give the same results as for as the clusterheads are concerned. These two algorithms differ on time what it takes to identify the clusterheads . This study has considered two sets of sample for the results. The first sample of 10 nodes forms two clusters C1 and C2 with the clusterhead nodes N2 and N7 respectively. The sample of size 25 nodes contains two clusters with the clusterhead nodes N3 and N19 respectively. These clusterheads are elected by the WCA and W-PAC algorithms. The results are same since the two algorithms are applying same methodology in identifying clusterheads but they differ in cluster formation time. These clusterheads need to be validated to confirm the proper selection of clusterhead at time T1. The proposed F-PAC procedure has identified the clusterhead of each cluster. These clusterheads are same as WCA and W-PAC clusterheads. Thus, the clusters formed can sustain without any changes. The change of clusterhead is needed while the clusterhead makes a move. This may end up with the re-election of clusterhead.

## Fuzzy logic based Clusterhead Re-election:

Fuzzy logic based Validation decides the perfectness of the clusterhead selected by multi-parametric clustering algorithms. The forthcoming analysis describes the validation results at time periods T1 and T2. Time T1 has been initial validation of the clusterhead selected by the cluster formation procedures. Time T2 has been validation after the mobility of the clusterhead elected.

### Time T1:

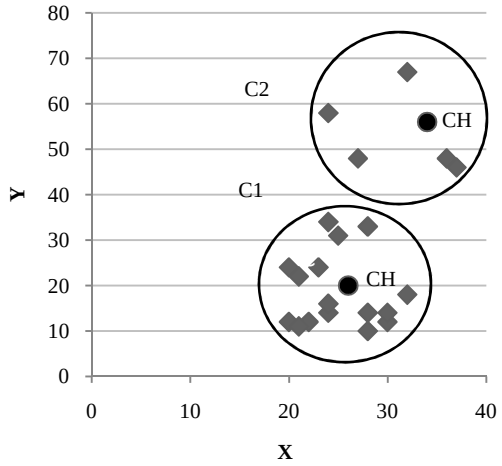


**Fig.3 Clusters C1 and C2 at time T1: 25**

Fig.3 shows the initial level of clusters formed using W-PAC algorithm excluding outliers at time T1. The clusterhead elected using W-PAC procedure has been validated using F-PAC procedure. This validation process confirms that the cluster heads are properly identified by W-PAC procedure. The cluster heads of clusters C1 and C2 have matched with the cluster heads of same clusters identified by

the F-PAC procedure at the time T1. The WCA results are same as W-PAC. This situation may prolong till the clusterheads are stationary.

**Time T2:**

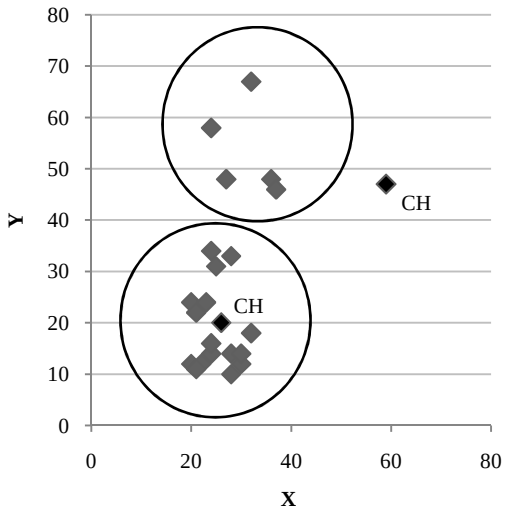


**Fig.4 Mobilty of Node N2 from C2 at time T2: 25 nodes**

The clusterhead N19 of cluster C2 has moved. Under this assumption the fuzzy logic based validation happens at time T2. Now, the position of clusterhead N19 has moved fromm (34,56) to new position (59,47). This drives the change to happen within the cluster C2. At this time T2 , F-PAC has been applied and new results are obtained. The node N20 has been considered as new center point(Clusterhead) of the cluster C2. This re-election has been achieved using F-PAC procedure.

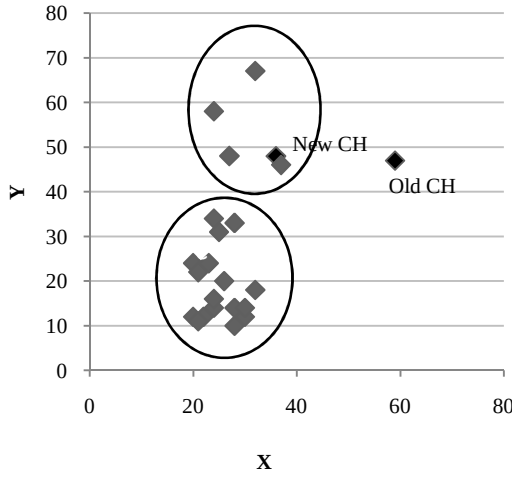


**Fig.5 Node 20 as new CH of C2 at time T2: 25 nodes**

Fig.5 shows the old and new clusterheads after applying the F-PAC procedure. The old CH has gone out of the communication range of the cluster C2. This node has lost its membership status of C2. It will be considered as outlier.

## 5.1 Gateway Election

Fuzzy logic based procedure not only finds the valid clusterhead and re-elect the clusterhead but also identifies the gateway node for each cluster of the ad hoc network. The gateway nodes are identified for each cluster to have inter-cluster communication between the clusters. To identify this gateway the fuzzy membership degree values have to be observed. The node which is far away from cluster and lies at the edges of the cluster boundary will have least degree. The node which is closer to clusterhead will have high degree while it is compared with other nodes degree. This gateway is known as distributed gateway. Since each cluster will fix its own gateway node. F-PAC produce places a key role in determining the gateway node.

**Table. III Elected Gateways**

| Nodes | Cluster | Gateway Node (WCA) | Gateway Node (W-PAC) | Degree of Node |
|---|---|---|---|---|
| 10 | C1 | N4 | N4 | 0.07 |
| | C2 | N8 | N8 | 0.06 |

Table. III shows the elected gateways of cluster C1 and Cluster C2 for the sample of 10 nodes. This gateway node of the W-PAC has been same as WCA. It differs in gateway node identification time. In cluster C1, the node N4 has the least degree value to be considered as gateway whereas for the cluster C2 node N8 holds the minimum membership degree value to be elected as gateway.

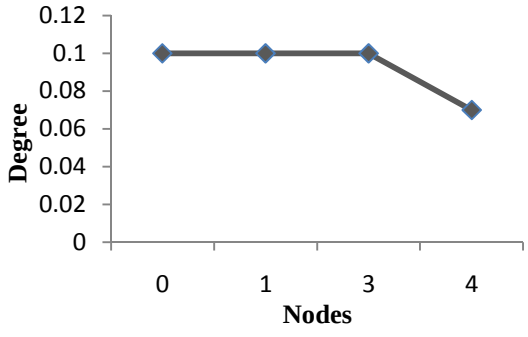


**Fig.6 Graphical Illustration: 10 Nodes, Cluster C1**

The Fig.6 shows the nodes and their degree values. It is obvious that the node N4 carries lower degree while this is compared with other degrees. This least value degree represents the degree of closeness of the nodes towards the cluster boundary. The Higher

degree node will be closer to the cluster head. This will be helpful to decide the gateway node which would be closer to boundary of cluster and keep themselves away from the cluster head node.
The Fig.7 shows that node N8 has been the least degree node comparatively to the other nodes of cluster C2.

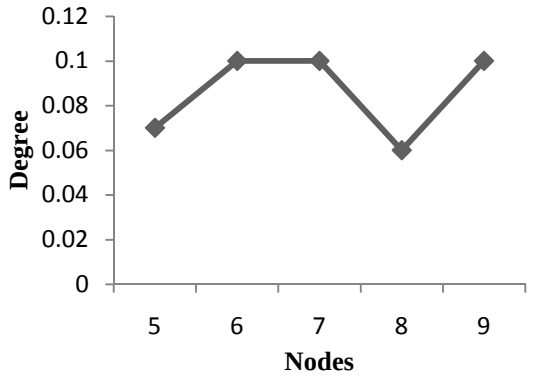


**Fig.7 Graphical Illustration: 10 Nodes, Cluster C2**

**Table. IV Elected Gateways**

| Nodes | Cluster | Gateway Node(WCA) | Gateway Node(W-PAC) | Degree of Node |
|---|---|---|---|---|
| 25 | C1 | N16 | N16 | 0.07 |
| | C2 | N23 | N23 | 0.04 |

The Table.IV shows the elected gateways and their respective degree values for each cluster where 25 nodes are considered as sample size. The node N16 has been considered as gateway since this holds the least membership degree value. The cluster C2 elects N23 as gateway node because of its minimum degree value.

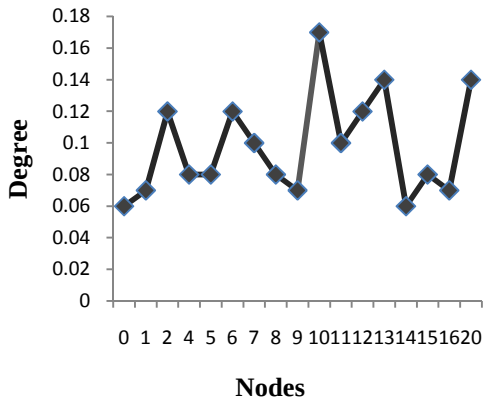


**Fig.8 Graphical Illustration: 25 Nodes, Cluster C1**

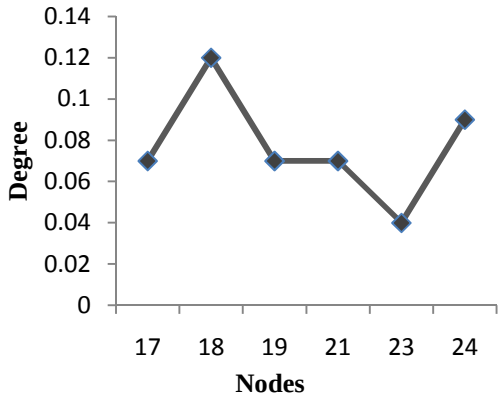


**Fig.9 Graphical Illustration: 25 Nodes, Cluster C2**

The Fig.8 pictorially shows that node N16 has been the least degree node belongs to the cluster C1. This node will be considered as gateway node as far as the cluster C1 has been concerned. The Fig.9 shows that node 23 has been the least degree node belongs to the cluster C2. This node plays the role of gateway for the cluster C2 to ensure inter-cluster communication.
The gateway nodes elected also changes based on their mobility property. This gateway re-election could be handled as separate task of F-PAC. While the gateways are going out of communication range of clusterheads then the clusterhead could be able to sense it since the absence of the periodic signal from gateway to clusterhead. This may invoke the F-PAC gateway election procedure to re-elect the gateway node.

## 7 Future Direction

The fuzzy logic can be further utilized on the ad hoc network to identify the nodes falling into the overlapping region. The common gateway node identification has to be done. The experimental results can be further enhanced with the help of more number of nodes.

## 8 Conclusion

This study clearly exposes the role of fuzzy logic in cluster formation in ad hoc network. It confirms the cluster head selected by the existing WCA and W-PAC procedure with the help of F-PAC procedure. In this way F-PAC has been highly helpful in validating the cluster head election. The purpose of F-PAC procedure has been clearly explained for clusterhead re-election and gateway election procedure to ensure inter-cluster communication in ad hoc network.

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