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# Mobility analysis and Framework proposal on Clustering and Validation Mechanisms for Ad Hoc Network

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**Abstract**

The mobility of the nodes affects the compactness of the clusters. This ends up with the decline in the performance of the clustered ad hoc networks. Thus, while the clusters move to worst state in their performance, re-clustering should be suggested. But this process will be considered as overhead of the network if the re-clustering time hasn't been decided properly. The validation mechanisms should be applied to decide the re-clustering time of the ad hoc network. This research work shows the analysis of the clusters periodically where the nodes are dynamic in nature. This analysis has been done for 10 nodes as a sample set. The measures are done for time periods $T_1$, $T_2$, $T_3$ and $T_4$. The results are tabulated to make a decision on the re-clustering. This work also incorporates a framework for the clustering and validation mechanism.

***Keywords:*** *DB Index, Dunn's Index, Silhouette Index*, *W-PAC.*

## 1. Introduction

Over the decades, the communication system has grown up tremendously in an unprecedented manner. The wired mode can no longer dominate the communication system. The wireless mode comes here not merely as a supportive instead this has begun its revolution to replace the wired communication system. This trend stands as a fair and cost-effective approach. The wireless network refers to any type of computer network that uses wireless (usually, but not always radio waves) for network connections. It is a method by which homes, telecommunications networks and enterprise (business) installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. Wireless telecommunication networks are generally implemented and administered using radio communication. This implementation takes place at the physical level of the OSI model [1] network structure. This wireless networks may or may not be based on the infrastructure. Wi-Fi with access points and mobile phone communication with base stations are some of the examples for infrastructure based networks.

The field of wireless and mobile communications has experienced an extraordinary growth during the past decade. Current Second-Generation(2G) cellular systems have reached a high penetration rate enabling worldwide mobile connectivity. Mobile users can use their cellular phone to check their email and browse the internet. Recently, an increasing number of wireless local area network hot spots are emerging, allowing travelers with portable computers to surf the internet from airports, railways, hotels and other public locations. However, all these networks are conventional wireless networks, conventional in the sense that as prerequisites, a fixed network infrastructure with centralized administration is required for their operation, potentially consuming lot of time and money for set-up and maintenance. These limitations made us to understand the need of the ad hoc networks [2].

The performance of ad hoc networks could be maintained to some extend while the nodes are on move. There should be some mechanism to improve this situation. The clustering is one such mechanism to ensure frequency reusability and handling modular growth. There are various clustering algorithms [3][4] proposed to handle this situation. Apart from clustering, validation has been suggested to decide the re-clustering time.

## 2. Literature Review

In the literature, many authors have proposed single and multi-parametric cluster creation algorithms. Lowest ID [5], Highest Degree [6] [7] and k-means [8] are proposed under single parameter category. K-means has been accepted as a well-known single parameter based algorithm. In the case of multi-parametric category several

algorithms are proposed. They are WCA [9], EWCA [10], EBC [11], WBCA [12] and FWCA [13]. WCA has been considered as well accepted multi-parametric algorithm.

The validation of clusters has been done by validation indices namely silhouette index [14], Dunn's index and Davies-Bouldin index [15]. Based on the existing research works, the following drawbacks are observed. They are: (i) Single and Multi-parametric algorithms are taking more time to form the clusters. (ii) There is no procedure to test the strength of the clusters formed. (iii) These algorithms lack in specifying the sustainability of the clusters which obviously determines the re-clustering time of ad hoc network. To overcome those aforementioned drawbacks, the cluster formation methods and validation techniques have been proposed. The mobility analysis which is making use of clustering and validation mechanism helps us to decide the re-clustering time of ad hoc networks.

## 3. Clustering and Validation Indices

In this study the clusters have been created using multi-parametric algorithm(W-PAC)[16]. The validation on the clusters has been done using the following indices.

Davies –Bouldin Index

$$\frac{1}{n}\sum_{i=1}^{n} \max_{i \neq j}\left\{\frac{Cn(Ni) + Cn(Nj)}{C(Ni, Nj)}\right\}$$

Dunn's Index

$$Min_{\,p=1..nc}\left\{Min_{\,q=i+1..nc}\left[\frac{dis(Cp, Cq)}{Max_{r=1...nc}\, dia(Cr)}\right]\right\}$$

Silhouette Index

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

## 4. Mobility analysis

This analysis has been divided into several stages with respect to time factor. The results obtained based on this analysis decides the re-clustering time of the ad hoc networks to sustain the performance of the network.

**Time $T_1$**: Time $T_1$ represents the state immediately after the clusters have been created using multi-parametric (W-PAC) algorithm.

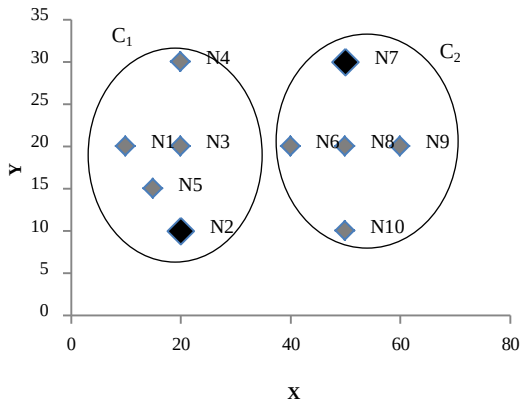


Figure 1 Results of W-PAC

Figure.1 shows the clusters $C_1$ and $C_2$ of network comprised of 10 nodes. These clusters are formed based on the various parameters using W-PAC algorithm. This also shows the nodes initial position under the clusters at time $T_1$.

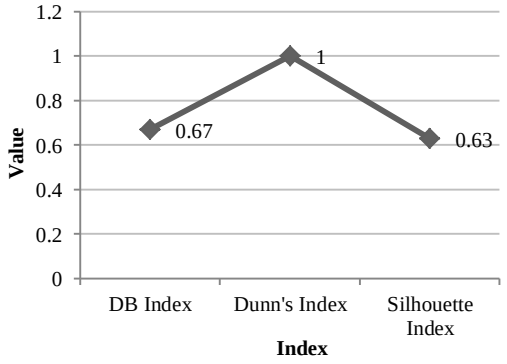


Figure 2 Cluster Validation at time $T_1$

Figure.2 graphically shows the results of cluster validation at time $T_1$. The low DB index and high Dunn's index indicates the perfectness and compactness of the clusters formed. The average silhouette index value also shows the clusters compactness level. These results at time $T_1$ tells that the clusters are in good condition. Thus, re-clustering of the ad hoc network is not recommended at this time.

**Time $T_2$:** Time $T_2$ represents the structure of the ad hoc network after the node $N_5$ makes a move from Cluster $C_1$ to Cluster $C_2$.

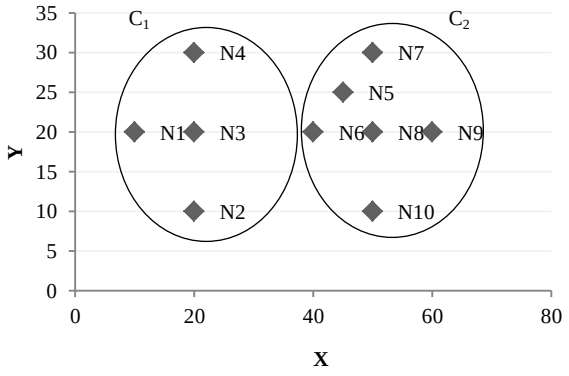


Figure 3 Result of clusters at time $T_2$

Figure.3 shows the clusters and member nodes at time $T_2$. These results are obtained after the mobility of node $N_5$ from Cluster $C_1$ to Cluster $C_2$.

Figure.4 shows the graphical results of validation at time $T_2$. This obviously tells that the value of DB index and Dunn's index remain same as $T_1$. Silhouette index value has down by 2%. This reduction indicates the decline in compactness of the clusters which means the member nodes are moving away from clusterheads. This reduces strength of communication signal between members and their respective clusterhead.

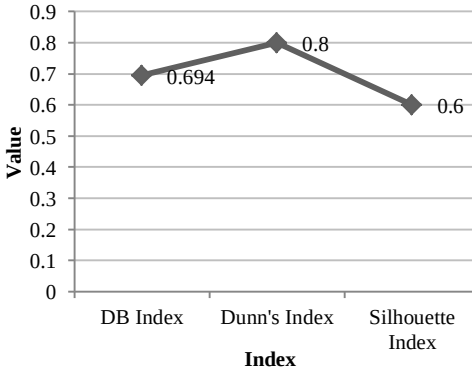


Figure 4 Result of validation at time $T_2$

**Time $T_3$:** At this time node $N_1$ has moved from cluster $C_1$ to cluster $C_2$. This mobility further reduced the size of the cluster $C_1$ and increased the size of cluster $C_2$. The clusterhead of cluster $C_1$ handles less number of nodes. As a result of this, the burden of clusterhead of $C_1$ gets down. This is because of very few number of nodes initiates the data transfer operation with the clusterhead of cluster $C_1$. In the case of Cluster $C_2$, the number of data transfers increases proportionately as the number of affiliation of nodes increases. The threshold may limit the number of nodes of clusterhead. This situation makes the clusters to reach imbalance state.

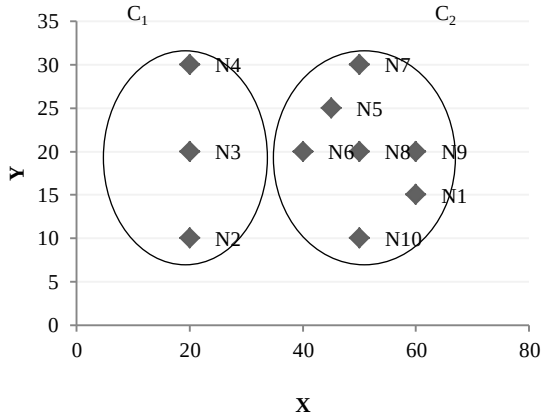


Figure 5 Result of clusters at time T3

Figure.5 shows the mobility of the node N1 from cluster C1 to C2 at time T3. This mobile node N1 gets affiliated under the new clusterhead by sending the 'hello' message to new clusterhead node.

Figure.6 shows the graphical representation of the measured validation indices at time $T_3$. These values show a decline in silhouette index value while this is compared with time period $T_2$. This silhouette index value when it goes down below the threshold the sustainability of the cluster reduces.

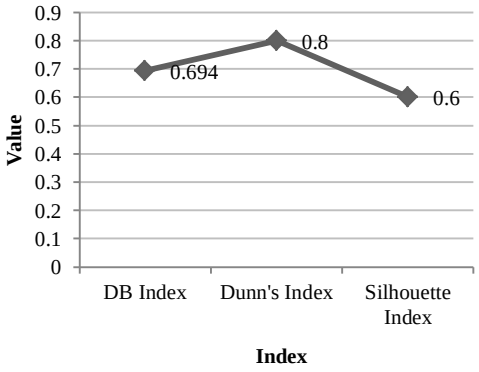


Figure 6 Results of validation at time $T_3$

**Time T4:** At this time period T4, the node N2 makes a move away from clusterhead of the cluster C1. As a result of this, the distance between node N2 and clusterhead of the cluster C1 has increased. The communication between the clusterhead and member node N2 breaks since N2 has crossed the boundary of cluster C1.

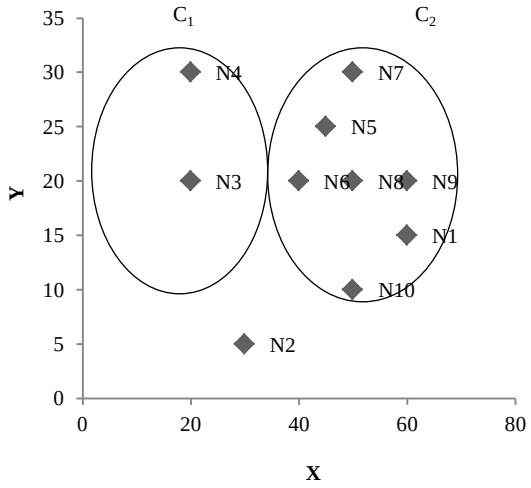


Figure 7 Results of Clusters at time $T_4$

Figure.7 shows the result of clusters at time T4 after the mobility of node N2. The cluster C1 has less number of nodes whereas C2 has more number of nodes.

Table 1 Consolidated results of cluster validation at time $T_4$

| Validation Index | Nodes | Index Value | Percentage |
|---|---|---|---|
| DB Index | 10 | 0.944 | 94.4% |
| Dunn's Index | 10 | 0.57 | 57% |
| Avg. Silhouette Index | 10 | 0.47 | 47% |

Table 2 Cluster validation results of 10 Nodes

| Time | Validation Index | Index Value | Percentage |
|---|---|---|---|
| $T_1$ | DB Index | 0.67 | 67% |
| | Dunn's Index | 1.0 | 100% |
| | Avg. Silhouette Index | 0.63 | 63% |
| $T_2$ | DB Index | 0.67 | 67% |
| | Dunn's Index | 1.0 | 100% |
| | Avg. Silhouette Index | 0.61 | 61% |
| $T_3$ | DB Index | 0.694 | 69.4% |
| | Dunn's Index | 0.8 | 80% |
| | Avg. Silhouette Index | 0.60 | 60% |
| $T_4$ | DB Index | 0.944 | 94.4% |
| | Dunn's Index | 0.57 | 57% |
| | Avg. Silhouette Index | 0.47 | 47% |

Table.1 shows the consolidated results of cluster validation at time $T_4$. It shows an increase in DB index value, decrease in Dunn's index value and decrease in Silhouette index value while this is related with the values measured at time $T_3$.

Table.2 shows the cluster validation results of 10 nodes as sample size. It shows the consolidated results of the measure of hard validation indices at various time periods $T_1$, $T_2$, $T_3$ and $T_4$. These results need to be observed in order to conclude the sustainability of the cluster based on threshold fixed by the application for which the clustered ad hoc network has to be formed.

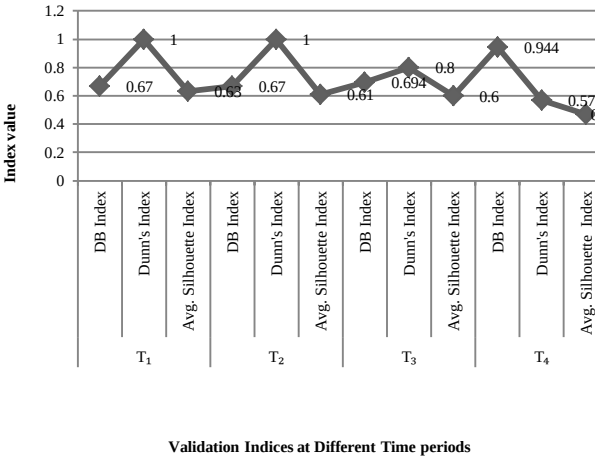


Figure 8 Results of cluster validation from $T_1$ to $T_4$.

Figure.8 shows the results by graphical representation. The following results are observed at various time periods $T_1$, $T_2$, $T_3$ and $T_4$.

At time $T_1$, the results show that the clusters are in good condition. They are well compact in nature.

At time $T_2$, the results show that the compactness sustains without noticeable change due to the movement of the node $N_5$. Silhouette index has got reduced slightly to indicate a negligible amount of reduction in clusters compactness.

At time $T_3$, the DB index value has increased to indicate the fall in the strength of intra-cluster relationship. This rise in DB index proportionately increases the intra-cluster distances. The Dunn's index value has reduced by 20% while it is compared with the previous value. This obviously shows the increase in overlap level of the clusters. Thus, compactness of clusters which is shown by silhouette index has reduced.

At time $T_4$, the rise in DB index and fall in Dunn's index value further shows the weak state of the clusters formed

using the cluster formation algorithms. This would be considered as the re-clustering time since the values are going down. This may also drive the re-election of clusterhead in the Cluster $C_2$ since the number of nodes has increased, which will exhaust the energy level of clusterhead.

This research work has emphasized on reducing the overhead of the network. The re-clustering has been procrastinated till $T_4$ since the re-clustering should not be done for a slight change in the structure. As the re-clustering process has been considered as overhead of the networks, this should be postponed to the maximum extent possible.

The following scenarios are considered to implement this cluster formation and validation.

- 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.

## 5. GDPRS-C&V Framework

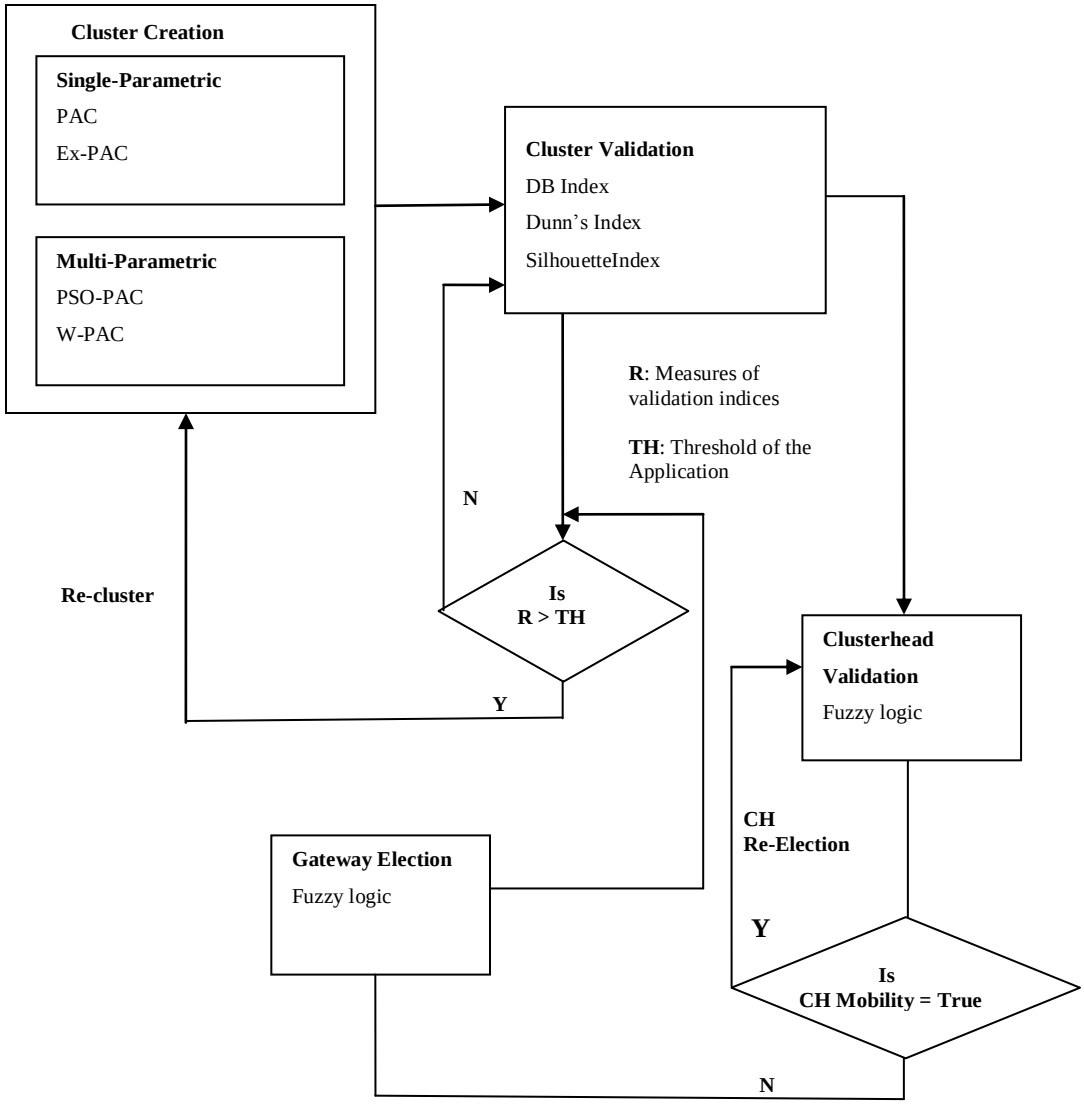


Figure 9 GDPRS – C&V : Framework for Ad Hoc Networks

The frame work for ad hoc network has been devised by Dr. **G**eorge **D**harma **P**rakash**R**aj and Mr. **S**homasundaramThirumurugan (**GDPRS**); **C&V** stands for **Cl**ustering and **V**alidation.

Figure.9 shows the Clustering and Validation Framework for Ad Hoc networks.

The cluster creation is the first phase of this framework tells about the options of cluster creating algorithms. These algorithms are divided as single-parametric and multi-parametric algorithm. The selection of algorithm depends on the real world scenario for which ad hoc network has to be set up.

The second phase of framework is covered by cluster validation process. The clusters which are created using cluster formation algorithms will reach this second phase as input to be processed further. This second phase just checks the cluster status to make some decision on those measurements. This second phase is subdivided into parts such as hard indices based validation and soft fuzzy logic based validation.

The hard validation indices periodically measure the cluster perfectness or compactness. It recommends for re-clustering while the validation measures R (Dunn's, Davies-Bouldin and Silhouette index) goes down below the TH (threshold) which depends on the specific application.

The soft fuzzy logic based validation procedure helps to confirm the elected clusterhead of the clusters of ad hoc network. In case of the clusterhead mobility this approach re-elects the clusterhead. This also procrastinates the re-clustering process by re-election of clusterhead locally. This also helps to elect the gateway to ensure inter-cluster communication among the clusters of the ad hoc network.

## 6. Conclusion

This study helps to decide the re-clustering time of the ad hoc networks. This has been decided with the help of clustering and validation on the mobility scenario of the network. The findings will ensure the sustainability of the network to strengthen the application for which the network has been utilized. A framework proposal aids on understanding the complete process of clustering and validation.

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