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Fuzzy Logic Based Dynamic Clustering and Adaptive Gateway Management in Heterogeneous Wireless Network

Kadhiravan D[1], Pradeepa J[2], Diviya Bharathi S[3], Rathidevi M[4] & Kalaiyarasi M[5]

[1,2]Lecturer, Department of Electronics and Communication Engineering, UCET, Tindivanam.
[3,4,5]Scholar, Department of Electronics and Communication Engineering, UCET, Tindivanam.

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ABSTRACT

In the recent years, there subsist a continually rising demand for widespread connectivity which necessitates unblemished integration of Vehicle Ad hoc Network (VANET), Wireless LAN and Cellular networks. Integration of these networks results in a Heterogeneous Wireless Network (HWN) architecture which is capable of providing high data-rate, end-to-end connectivity, utilizing the higher bandwidth of multi-hop networks, improved reliability, Spectrum Efficiency and the extensive range communication of 3G networks. In this manuscript, an Adaptive Gateway Management (AGM) which comprises an efficient gateway assortment mechanism to decide on a most favourable Gateway from the Gateway Candidate nodes by clustering is proposed by considering metrics such as Signal Strength, Energy, distance from base station and Mobility. Every cluster has Cluster Head and it take steps as a relay point for Cluster members and members of neighboring clusters. From available cluster heads optimal numbers of gateways are chosen by foundation by means of Fuzzy logic. Thus the formed VANET clusters are evaluated by means of Silhouette Value and other parameters.

Keywords: *Heterogeneous wireless Network, Adaptive Gateway management, dynamic clustering, VANET, Fuzzy Logic and end to end connectivity*

1. Introduction

Most recent few years have seen an augmented concentration in the prospective use of Wireless Sensor Networks (WSNs) in a variety of fields similar to disaster management, battle field observation, and border security observation [1]. VANET is rising wireless communication technology developed to accomplish safety and intellectual transport emergency vehicles like ambulances, fire truck, police car plays essential responsibility in natural disaster like earthquake, Tsunami and storms etc. When this kind of confrontation occurs wired communication may possibly get spoilt and for this reason VANET kind of network would facilitate because of its ad hoc nature [2]. HWN have suit foremost explore subject in wireless networks which integrates numerous wireless systems to afford wherever anytime data access and connectivity. **Fig. 1** shows a typical Heterogeneous Wireless Network. The enhancement of WLAN (e.g. IEEE 802.11p) combined with 2G, 2.5G, 3G and the Internet can afford a widespread connectivity

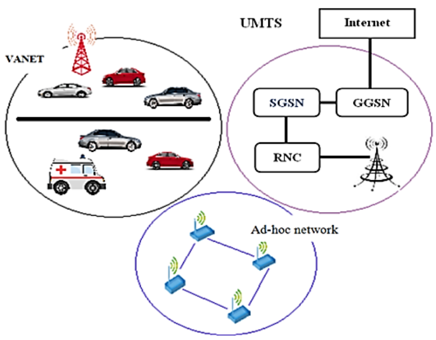

Fig.1. Heterogeneous Wireless Network

VANET is complimentary because it allows short medium range of communication, less deployment cost, support short message delivery, minimum latency of communication link. However shortcomings similar to high mobility, dynamic topology are unpredictable because of road constraints, self-organized nodes, and fragmented network makes maintenance of network critical. Universal Mobile Telecommunication Systems (UMTS) network provide data services up to 8 to 10 km with data transfer rate of 2 Mbps to 7 Mbps and 1.925 GHz band allocated for uplink and 2.115 GHz band allocated for downlink. UMTS is broadly deployed and used nowadays in tremendous applications. This manuscript proposes the conception of Clustering in VANET based on a variety of metrics [4].

2. Cluster Head / Gateway election Fusion Fuzzy architecture

The Cluster head Selection Algorithm projected here is based on the following metrics. The receivedSignal Strength (S_i) from the base station measured in ***dBm*** which typically varies from a maximum of -50 ***dBm*** to a minimum of -120 ***dBm*** fade margin. Mobility speed (MS_i) measured in Kilometer/hour scale is expected to be low for a node to be selected as Cluster Head (CH_n)/(GW_n). Distance (DS_i) from the Base Station (***BS***) measured in meters, anticipated to be minimum such that it is easy for the node being selected as CH_n to communicate. Residual Energy (RE_i) of the battery backup in the mobile node measured in joules. A higher battery backup means more life time as (CH_n)/(GW_n). Position (X_i) is a parameter that defines the geographical position of the mobile node with respect the base station. Concentration (CO_i) is a parameter that defines the number of neighbouring nodes near to the current node. In other words it refers to the density of neighbouring nodes. Centrality (CE_i) is a parameter that defines how centre a node is with respect to its neighbour such that it is easy to communicate with the neighbouring nodes if being selected as (CH_n)/(GW_n). Queue Capacity (QU_i) if the buffer capacity of the node i.e., (CH_n)/(GW_n), which is expected to be high such that it can process the packet forwarding without congestion. Relative Mobility (RM_i) is parameter that defines the nodes relative velocity with respect to the neighbouring nodes. This parameter is expected to be of a low value such that if the node is elected as a (CH_n)/(GW_n)would be maintaining its status for considerable prolonged interval of time.

The proposed (CH_n)/(GW_n) election architecture considering all the above mention parameters elects the (CH_n)/(GW_n) in a three step process. The step one is a fuzzy module 1 shown in **Fig. 2** which considers the parameters such as Signal Strength (S_i), Mobility speed (MS_i), Distance (DS_i) from the base station and Residual Energy (RE_i). The fuzzy module produces a statistical value which is termed as the Cluster Head Eligibility (CHE_i) parameter. Higher the value conveys that the node is more likely to be selected as the (CH_n). **Table 1** shows the sample rule base for the fuzzy module 1, where a node is more likely to be selected to be a cluster head when it's S_i, RE_i are found to be maximum and DS_i, MS_i should be minimum.

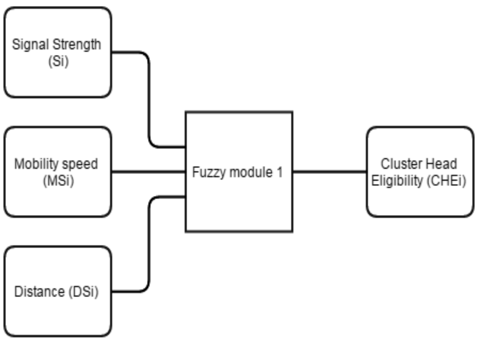

Fig. 2 Fuzzy Module 1 Cluster Head Eligibility (CHE_i) parameter Calibration

Table 1 Rule Base for Fuzzy Module 1

S_i	RE_i	DS_i	MS_i	CHE_i
L	L	Near	H	No
L	L	M	L	No
L	L	Far	M	No
M	M	Near	L	Little
M	H	M	M	Little
M	M	M	M	Little
H	H	Near	L	Perfect
H	H	Near	M	Perfect
H	H	M	M	Perfect

The step two fuzzy module 2 shown in **Fig. 3** considers the parameters such as Position (X_i), Concentration (CO_i) and Cluster Head Eligibility (CHE_i) parameter that is obtained from the fuzzy module 1. The fuzzy module produces a statistical value which is termed as the Gateway Eligibility (CWE_i) parameter. Higher the value conveys that the node is more likely to be selected as the (CH_n)/(GW_n). **Table 2** shows the sample rule base for the fuzzy module 2, where a node is more likely to be selected to be a (CH_n)/(GW_n) when it's X_i is Near, CO_i, CWE_i found to be maximum. This then leads to the third and the final step which is again a fuzzy module 3 shown in **Fig. 4** which considers the parameters such as Queue Capacity (QU_i), Relative Mobility (RM_i), Centrality (CE_i) and Gateway Eligibility (CWE_i) parameter obtained from the fuzzy module 2. This fuzzy module 3 produces a statistical value which is termed as the Cluster Head / Gateway Eligibility (CWE_{Fi}) parameter. Higher the value conveys that the node is more likely to be selected as well as maintained as the (CH_n)/(GW_n). Table 3 shows the rule base for the fuzzy module 3 where a node is selected and maintained as a (CH_n)/(GW_n) considering the parameters mentioned in **Fig.4.** If a node that has been elected as a gateway and is the current gateway fails the decision making of the fuzzy module 3, then that node is taken off from its status as gateway immediately and a new gateway node is elected based on all the three fuzzy modules combined together. The so formed clusters are analysed and evaluated by means of Silhouette width parameter.

Silhouette refers to a means of elucidation and justification of uniformity inside clusters of VANET. The method presents a concise graphical depiction of how well each cluster member node lies within its cluster. It was originally portray by Peter J. Rousseeuw in 1986.The Silhouette value is a measure of how alike a cluster member is to its own cluster compared to other clusters. The silhouette ranges from -1 to 1, where a elevated value specifies that the cluster member node is well coordinated to its own cluster and defectively coordinated to nearest clusters. If most cluster members have an elevated value, then the clustering arrangement is appropriate. If many nodes have a low or negative value, then the clustering arrangement may be inappropriate. The silhouette value can be calibrated with any distance metric, such as the Euclidean distance or the Manhattan distance [5]. The silhouette value can be calibrated as follows in equation (1)

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}} \quad (1)$$

Where *a(i)*is the average dissimilarity within the same cluster and *b(i)*is the average dissimilarity between the other clusters.

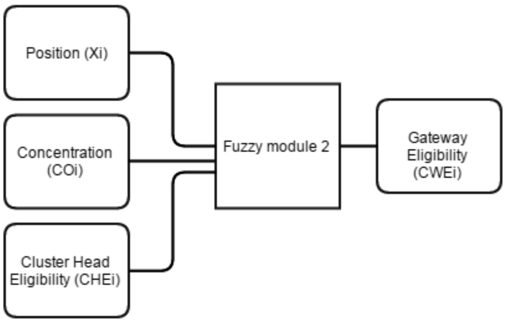

Fig.3 Fuzzy Module 2 Cluster Head / Gateway Eligibility (***CWE_i***) parameter Calibration

Table 2 Rule Base for Fuzzy Module 2

CHE_i	***X_i***	***CO_i***	***CWE_i***
No	Near	L	No
No	M	H	No
No	Long	M	No
Little	Near	L	Little
Little	M	M	Little
Perfect	Near	M	Perfect
Perfect	Near	L	Perfect

***Note: L- Low, High-H, Medium-M**

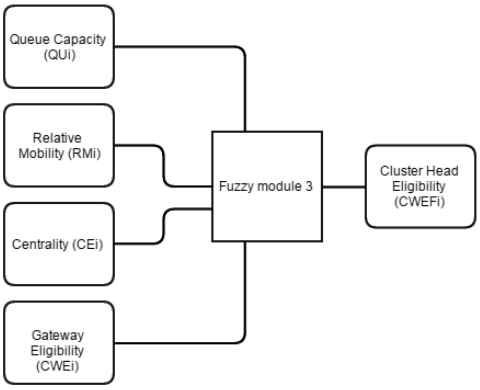

Fig.4 Fuzzy Module 3 Cluster Head / Gateway Eligibility (***CWE_{Fi}***) Calibration

Table 3 Rule Base for Fuzzy Module 3

CE_i	CWE_i	QU_i	RM_i	CWE_{Fi}
Not maintain	No	L	L	No
Not maintain	No	M	M	No
Not maintain	No	H	M	No
Maintain	Little	H	L	Little
Maintain	Little	H	M	Little
Maintain	Little	H	M	Little
Maintain	Perfect	H	L	Perfect
Maintain	Perfect	H	M	Perfect

3. Simulation Setup and Results

The simulations were carried out in Matlab 2009 Rb version environment with parameters as mention in **Table 4** below. The simulations were run for a time of over 200 seconds. **Fig. 5** shows the input and output membership function for fuzzy module 1, 2 & 3.**Fig. 6** shows the VANET clustering simulation run on matlab 1000 x 1000 environment. The total number of mobile nodes were 390. Nearly 10 to 12 clusters were formed depending upon various parameters as mention earlier in the context. The base station is located at the (x,y) co-ordinate (500,400), whereas the cluster heads position vary dynamically with respect to the change in the parameter variations. **Fig. 7** shows the number of clusters versus the number of nodes in each cluster. **Fig. 8** shows the silhouette value of each node in each cluster. **Fig. 9** shows the silhouette value histogram of all the nodes. It is found that most number of the nodes fall with a high silhouette value which infers that the clustering is done in a proper appropriate manner.

Table 4 Simulation Parameters

Parameters	Specification / Range
Simulation Tool	Matlab 2009Rb
Tool Box	Fuzzy Logic Tool box
Signal Strength (S_i)	-50 dBm to -120 dBm
Radio Propagation Model	Nagakami Fading Model
Mobility speed (MS_i)	0 to 140(kmph)
Residual Energy (RE_i)	600000 to 7200000(J)
Queue Capacity (QU_i)	100 packets in WFQ
MAC Type	MAC/802_11p
Topological Area	1000 * 1000
Number of Mobile Nodes	390

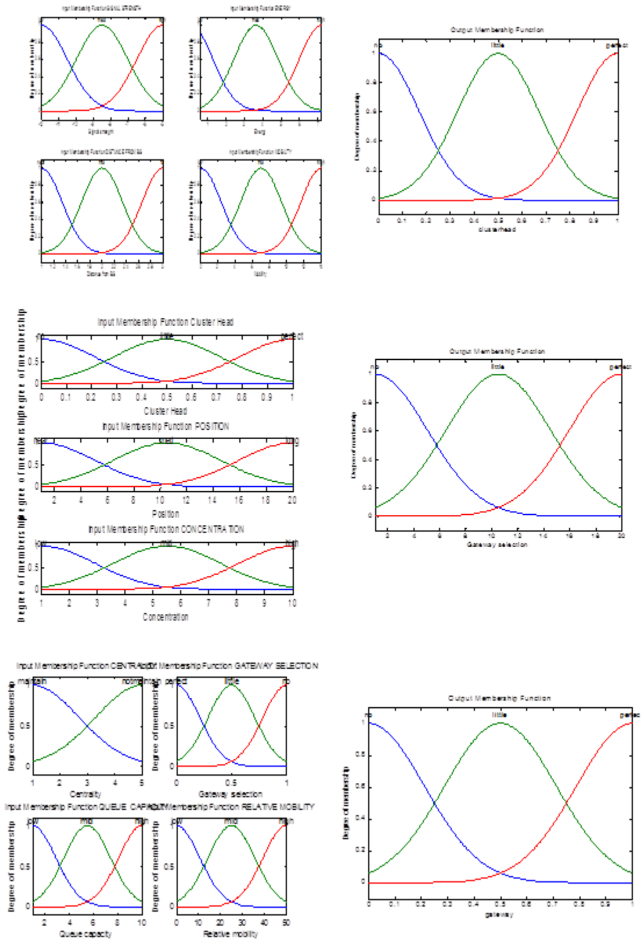

Fig.5 Input –Output Membership Function of fuzzy module 1-3

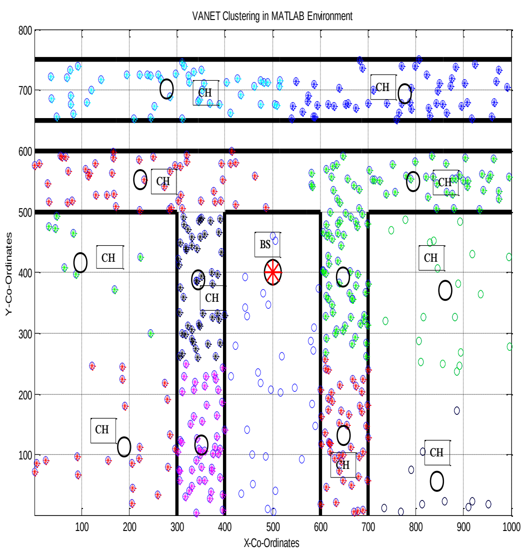

Fig.6 VANET Clustering in MATLAB Environment

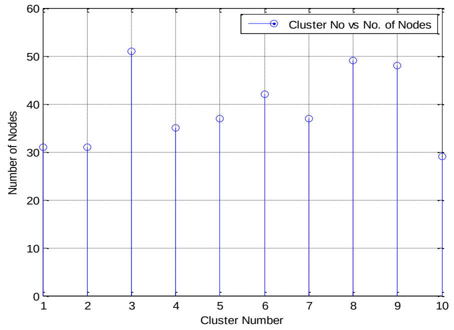

Fig.7 Cluster number. Vs. Number of Nodes

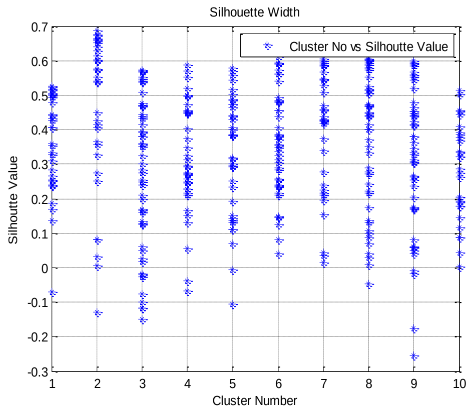

Fig.8 Cluster Number vs. Silhouette

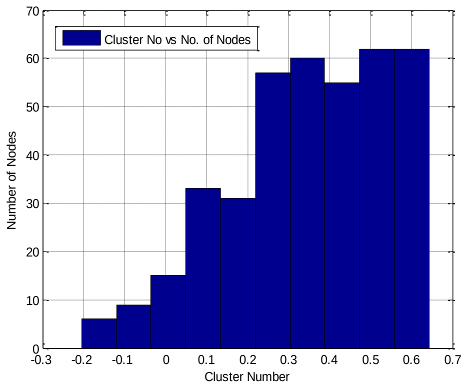

Fig.9 Silhouette value vs. Number of Nodes

4. Conclusion

This manuscript elucidates the necessitate for HWN for seamless data access. The Gateway issue in HWN have been analyzed and an Adaptive Gateway Management (AGM) Mechanism which comprises an efficient gateway assortment means to decide on a most favourable Gateway from the Gateway Candidate nodes by clustering is proposed by considering metrics such as Signal Strength, Energy, distance from base station and Mobility. The simulations were carried out in a Matlab environment under Nagakami Wireless fading conditions. The obtained clustering results were analysed using silhouette value and it is inferred that more than 75% of the nodes are placed in the most appropriate clusters.

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