International Journal of Advances in Computer Science & Its Applications
Volume 6 : Issue 2 [ISSN 2250-3765]
Publication Date : 31 August, 2016

An Efficient 2-hop Weight-based Clustering Algorithm

Ariane Caine, Dr. Thomas Edward

***Abstract*—Mobile Ad Hoc Networks (MANETs) allow mobile nodes to communicate without a need for a fixed infrastructure. Nodes within MANETs move about arbitrarily, dynamically changing their connectivity and possibly partitioning the network. In this paper, we consider weight-based clustering as a viable approach to alleviate these issues. However, many of the existing weight-based clustering algorithms suffer from a high re-clustering rate resulting in the production of relatively unstable clusters. Therefore, we propose a 2-hop weight-based clustering algorithm, RPMW in the view that it will minimize the re-clustering rate of the network and thus preserve its lifetime. RPMW takes into consideration the weight factors of PMW along with the node degree in calculating the weight of a node. We provide a comparative analysis of these two algorithms in which RMPW is shown to outperform PMW in cluster stability thus maximizing the lifespan of clusters.**

Keywords— ***MANETs, weight-based clustering, re-clustering rate, CHs, RPMW, PMW***

I. Introduction

In recent years, the growing popularity in mobile devices and wireless networks has captivated the research community with much focus being placed on the Mobile Ad Hoc Networks (MANETs). A MANET is an infrastructureless, multi-hop network which uses wireless links to support a collection self-configuring mobile nodes. This network type is easily deployable and is used in many social, commercial, military and search and rescue applications[1].

Clustering was introduced in MANETs with the goal of improving the efficiency of the network [2, 3]. Clustering is a technique which involves the grouping of nodes into zones or clusters. A cluster comprises of one or more cluster heads (CHs), cluster members (CMs) and possibly gateway nodes (GNs) [4]. CHs assume the managerial role of a cluster like the coordinating cluster activities and discovering new routes. GNs enable communication among clusters whereas CMs are all the nodes beside the CHs or GNs. The clustering operation is characterized by a cluster formation and cluster maintenance phase. Cluster formation phase involves the CH election process and the affiliation of nodes to these clusters. During the cluster maintenance phase the re-clustering and re-affiliation of nodes take place. Re-clustering should only be invoked on demand to avoid excessive computation and communication overhead.

In this paper, we have proposed enhancements to PMW (Power, Mobility and Workload) algorithm [5] and named it RPMW (Revised Power, Mobility and Workload). Firstly, we included the node degree in the calculating the weight of a node, since a node with a high degree of neighbors tend to be more stable than a node with a low degree of neighbors. Next, we extended the CH radius to 2 hops. Our goal is to form and maintain stable clusters in MANETS thus maximizing the lifetime of this network.

The rest of this paper is laid out follows. Section 2 provides the related works. The proposed algorithm, RPMW is presented in Section 3. Section 4 gives the performance analysis of RPMW. Finally, Section 5 concludes the paper and points out future works.

II. Related Works

Numerous clustering approaches exists for the CH election in MANETs, namely identifier-based, connectivity-based, mobility-aware, power-aware and weight-based [3, 6, 7]. In this section, we review previous works on weight-based clustering approaches.

The authors of [8] pioneered works in weight-based clustering. They proposed a 1-hop weighted clustering algorithm (WCA) [8] for the production and maintenance of stable clusters in MANETs. WCA utilizes node degree, transmission power, battery power and node mobility for the election of a CH. An optimization of WCA named Flexible Weight Based clustering algorithm (FWCA) was presented in [9]. The authors of FWCA purport that the features used by WCA are necessary for the election of CHs during the cluster formation phase but the link lifetime should be used in determining the CHs in the cluster maintenance phase. In [5], authors postulated that power, workload and mobility of a node is crucial to the choosing of a CH hence, they proposed a 1-hop weight-based clustering algorithm, PMW based on these factors. A 1-hop weight-based clustering algorithm for MANETs which considers neighborhood contribution and average minimum power in CH selection was proposed in [10]. In [11], a 1-hop virtual links weight-based clustering (VLWBC) algorithm was presented to improve the stability of clusters in MANETs where the weight of a node is based on features of its adjacent nodes. A d-hop secured weight-based clustering algorithm (SCA) which allows for the effective performance and protection of MANETs by using a trust value and some system parameters for determining which nodes are elected as CHs was described in [12].

Literature on weight-based clustering has focused almost exclusively on 1-hop clustering schemes or algorithms for the maintaining cluster stability. In the next section, we are going to explore the impact of 2-hop clustering on the lifetime of MANETs. We hypothesize that 2-hop clustering schemes pose a lower probability of re-clustering than 1-hop clustering schemes thus prolonging

Ariane Caine, Dr. Thomas Edward
University of the West Indies, Cave Hill
Barbados

III. Revised Power Mobility Work Algorithm

A. Network Model

A MANET can be modeled by an undirected graph G = (V, E), V represents the set of all nodes (vertices), and E denotes the set of links (i, j) where i, j ∈ V. The link establishment between two nodes indicates that the nodes are within transmission range of each other. Note that all nodes are connected by bi-directional links.

Further, each node i has unique positive identifier (N_ID), a positive CH identification (CH_ID) and its current status (state) which is denoted by an integer. The following are possible states of node i: unknown, CH and CM In addition, each node i has a weighted value (w_i) which is calculated periodically and is denoted by a real number. Node i has a degree counter (D_i) which is used to ensure that a cluster does not exceed its maximum capacity of members (n_{max}). Each node i stores information about its 1 and 2-hop neighbors. We make the assumption that the network topology is static during cluster formation and re-clustering phase.

B. Messages Used by RPMW

The messages used by RPMW are listed in Table 1, and are of the following format: M(Type, N_ID, CH_ID, state, weight, RP, source, destination).

TABLE I. MESSAGES

Type	Description
HELLO	To identify 1 and 2 hops neighbors of a node
CLUSTERHEAD	To notify neighbors of a self_elected *CH*
J_REQ	To notify a CH of a node wish to join a cluster
L_REQ	Used by a CH to notify CMs of a cluster that its current CH is resigning
J_ACK	Used by a CH to inform a node of its successful membership to a cluster
J_NACK	Used by a CH to notify a node of its unsuccessful membership since its cluster size id n_{max}

C. Clustering Criteria of RPMW

We believe that factors necessary for CH election are residual battery power, node degree, mobility, and power decrease rate. The definitions and expressions of the mobility, residual battery power and power decrease rate are given in [5]. However, in subsequent paragraphs, we define node degree and weight of a node.

Node Degree: The node degree of node i is determined by the number of 1 and 2-hop neighbors with which node i can communicate.

Weight: Node i is considered the best CH candidate among its neighbors, if it has the lowest relative mobility (MP_i) and power decrease rate (PDR_i), and the highest residual battery power (RP_i) and node degree (D_i). In other words, the node i with the highest weight value (w_i) is elected as CH and w_i is calculated using

$$w_i = \sum_{i=1}^{k} \alpha_i S_i. \quad (1)$$

Where S_i represents the weighted factors MP_i, PDR_i, RP_i and D_i correspondingly, and α_i is a system constant such that

$$\sum_{i=1}^{k} \alpha_i = 1 \quad (2)$$

We have used α_i as the following 0.3, 0.3, 0.2 and 0.15 respectively.

D. Cluster Formation

The cluster formation of RPMW is described below:

- Initially, each node i broadcasts HELLO messages to build its list of neighbors and determine D_i. In addition, each node i on receiving two successive HELLO messages from neighbor j records its remaining power levels (rp_i1 and rp_i2) and its receive signal strength ($rss_{ij}1$ and $rss_{ij}2$) at time t_1 and t_2.
- Every node i calculates its w_i
- Every node i broadcasts the value of w_i to all its neighbors in a HELLO message.
- On receiving the HELLO messages from all 1-hop and 2-hop neighbors, the node with the highest weight among its neighbors declares itself a CH to its neighbors through a CLUSTERHEAD message.
- Any non-CH node which receives one or more CLUSTERHEAD messages will do one of the following:
  - If the non-CH node receives exactly one CLUSTERHEAD message, it sends a J_REQ message to the source of the received message.
  - If a non-CH node receives CLUSTERHEAD message from more than one CH, it sends a J_REQ message to the CH with the least number of hops:
    - If the hop counts are the same, the CH with the highest weight is elected.
    - Else if the weights are equal, a CH is chosen randomly.
- The elected CH sends a J_ACK to indicate successful cluster membership assignment and the non-CH node declares itself as a CM; otherwise CH sends a J_NACK to notify the responding node that its cluster is of maximum capacity.
- However, if node i does not receive any HELLO messages, it declares itself a CH (i.e. a Singleton Cluster).

E. Cluster Maintenance

The dynamic nature of MANETs gives rise to highly dynamic cluster membership resulting in the need for cluster maintenance. Cluster maintenance involves re-clustering and node re-affiliation. Here, we defined re-clustering as the election of a new CH when an old CH resigns or fails. Re-clustering is invoked only on demand. The process whereby a node disassociates from a cluster and joins another is termed as re-affiliation. The primary reasons for cluster maintenance are outlined subsequently:

- ***Two CHs become 1-hop neighbors:*** If two CHs (singleton or non-singleton) become 1-hop neighbors for a predefined Cluster Contention Interval (CCI) (Basu et al 2001) the CH with the minimum weight to become a CM of the other, if n_{max} of the cluster is not reached. Thus, any CM that is out of range of the new CH sends a J_REQ to the nearest CH in its list. If no CH is present in its list, and its weight and battery are above Low Battery Threshold (LBT) and Low Weight Threshold (LWT) respectively, the node declares itself as a CH forming singleton cluster. Else it changes its status to unknown.
- ***CH Resignation****:* If the present remaining battery power or weight of a CH is less than LBT and LWT respectively and there exists at least one CM whose power and weight are higher than LBT and LWT, the CH resigns and elects the best fit CM as the new CH. The resigned CH then sends a J_REQ message to the new CH. Upon receiving a J_ACK from the new CH, the old CH sends a L_REQ message to its members. Thus, any CM of the old cluster that cannot be affiliated with the new CH and must join the nearest CH. If no cluster is within its neighbor, and the CM meets the criteria of a CH, it declares itself a CH. Else it declares it changes it status to unknown.
- ***Failure of Nodes:*** If after three successive broadcast intervals (BIs), a node does not receive any HELLO messages from a CM, each member of the cluster to which is CM is affiliated (CH and other CMs) will remove the CM from its list of neighbors. However, if a CM does not receive any HELLO messages from its CH after three successive BIs, it removes the CH from its list of neighbors. The CM then sends a J_REQ message to the nearest CH in its list if any. If no CH is available in its list but the node fit the criteria of CH, it declares itself a CH forming a singleton cluster. Otherwise it declares its state as unknown.

IV. Implementation and Simulation

A. *Simulation Parameters*

The primary objectives of our simulation are: (1) to establish a performance bench mark, and (2) to show the performance of RPMW against PMW with respect to the average number of non-singleton clusters formation, non-singleton CH duration and the average cluster size. The algorithms are implemented using the Network Simulator-2 (NS2) [13] with similar simulation parameters described in [5] see Table 2.

For RPMW to have real world value, we adopted the Random Waypoint mobility model (RP). RP model is characterized by a mobile node which moves to a random destination with constant speed. The node then pauses for a specified time period before moving to its next destination. In addition, we used the traffic-scenario generator to randomly produced 25 constant bit rate connections. Each node sends a 512 byte packet through UDP at a rate of one packet per second.

TABLE II. SIMULATION PARAMETERS

Parameters	Value
Network Area	670 m X 670 m
Number of Nodes (N)	50
Battery Power (BP)	Random (30 – 100)%
Maximum speed of nodes	5, 15, 25 m/s
Transmission Range (TR)	10 -250 m
Pause Time (PT)	0s, 30s
Broadcast interval (BI)	1s
Cluster Contention Interval (CCI)	3s
Low Power Threshold (LPT)	30%
Low Weight Threshold (LWT)	10
Simulation Time	150s

B. *Simulation Results*

The results are illustrated in the Fig. 1, 2 and 3 below.

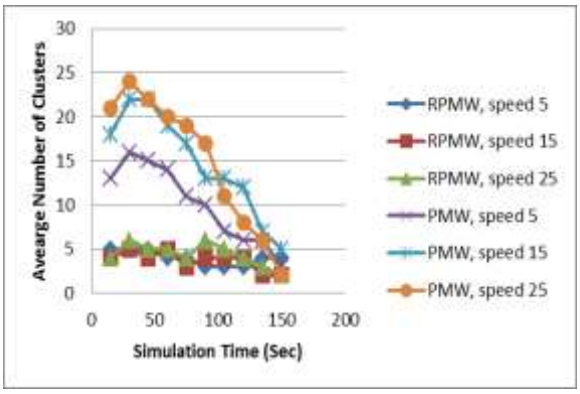

Figure 1. Average number of clusters per interval time.

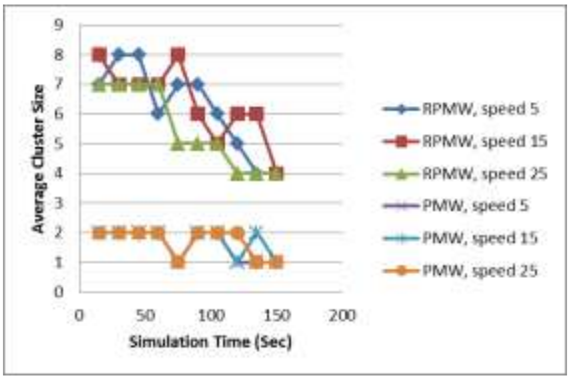

Figure 2. Average Cluster size per interval time.

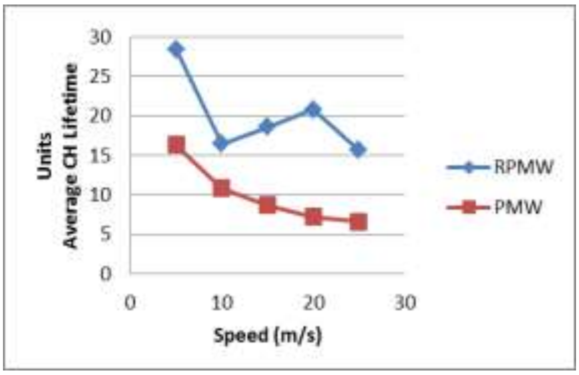

Figure 3. Cumulative average CH lifetime.

1) Average Cluster Size

We recorded the average number of non-singleton clusters and average cluster size at 15 seconds interval for our algorithm, RPMW and PMW and the results are depicted in Fig. 1 and 2. From Fig. 1, we observed that RPMW algorithm creates less than 50% of non-singleton clusters when compared to PMW. That is RPMW has an average 4 non-singleton clusters per time interval while PMW has 13. In addition, Fig. 2 illustrates the average cluster size with respect to different speed. We noted that RPMW has a significantly larger variation of cluster sizes than PMW where the average cluster size of RPMW is 6 and PMW is approximately 2. A possible justification for these results is that a CH in RPMW tends to cover a larger area of the network because of its 2-hop nature thus resulting in the decrease in the average number of clusters formed and an increase in the cluster size as oppose to PMW which has a 1-hop radius. Furthermore, the average distance between CHs is shorter in PMW than in the RPMW resulting in more clusters with fewer cluster members.

It was further observed that there was a declined in the number of non-singleton clusters towards the latter of the simulation. This decline can be attributed to one of the following: (1) two CH nodes becoming 1-hop neighbors, and (2) the battery power (or weight in case of RPMW) of a CH node falls below its threshold.

2) CH Lifetime

Fig. 3 illustrates the cumulative CH lifetime against varying speeds for 10 runs of the simulation. For PMW, CH lifetime span 5 -16 seconds while RPMW lasts about 15 -29 seconds. In contrast to PMW, the 2-hop nature of RPMW does not allow for two CHs to readily become 1-hop neighbors, triggering re-clustering hence, is the reason for a larger lifespan. We also noted that an increase in speed results in the shortening of CH life in PMW but causes fluctuations in the CH lifespan of RPMW.

3) Summary of Results

So far, we have shown that RPMW outperforms PMW in forming the least number of non-singleton clusters, and having larger cluster size and longer lifetime. However, a tradeoff of RPMW is that takes twice as much time as PMW to complete the cluster formation phase. This is due to nodes in RPMW having to broadcast HELLO messages to their 1 and 2-hop neighbors which covers a greater distance than PMW whose neighbors are within a 1-hop radius.

V. Conclusion

In this paper, we have proposed a 2-hop weight-based clustering algorithm, RPMW in the view that it will preserve the lifetime of MANETs. RPMW added node degree to the weight factors of PMW.

From the results, we observed that RPMW creates and maintains more stable clusters than PMW since CHs in RPMW tend to have a relatively longer lifetime. This supports our hypothesis that 2-hop clustering schemes pose a lower probability of re-clustering than 1-hop clustering schemes. Therefore, we conclude that the enhancements made to PMW were necessary in prolonging the lifetime of MANETs.

As a future extension, we intend to include intrusion detection systems in this clustering scheme.

Acknowledgment

We the authors, acknowledge with sincere gratitude the University of the West Indies, Cave Hill, Barbados for their support in this research.

References

[1] C. E. Perkins, "Ad hoc networking: an introduction," *Ad Hoc Networking*, vol. 40, pp. 20-22, 2001.

[2] H. Safa, O. Mirza, and H. Artail, "A dynamic energy efficient clustering algorithm for MANETs," in *Networking and Communications, 2008. WIMOB'08. IEEE International Conference on Wireless and Mobile Computing*, 2008, pp. 51-56.

[3] J. Y. Yu and P. H. J. Chong, "A survey of clustering schemes for mobile ad hoc networks," *Communications Surveys & Tutorials, IEEE*, vol. 7, pp. 32-48, 2005.

[4] T. Ohta, S. Inoue, and Y. Kakuda, "An adaptive multihop clustering scheme for highly mobile ad hoc networks," in *Autonomous Decentralized Systems, 2003. ISADS 2003. The Sixth International Symposium on*, 2003, pp. 293-300.

[5] Z. Xing, L. Gruenwald, and K. Phang, "A robust clustering algorithm for mobile Ad-hoc networks," *Handbook of Research on Next Generation Mobile Networks and Ubiquitous Computing*, vol. 2008, pp. 187-200, 2008.

[6] R. Agarwal and D. Motwani, "Survey of clustering algorithms for MANET," *arXiv preprint arXiv:0912.2303*, 2009.

[7] A. Bentaleb, A. Boubetra, and S. Harous, "Survey of clustering schemes in mobile ad hoc networks," *Communications and Network*, vol. 5, p. 8, 2013.

[8] M. Chatterjee, S. K. Das, and D. Turgut, "WCA: A weighted clustering algorithm for mobile ad hoc networks," *Cluster Computing*, vol. 5, pp. 193-204, 2002.

[9] Z. El-Bazzal, M. Kadoch, B. L. Agba, F. Gagnon, and M. Bennani, "A flexible weight based clustering algorithm in mobile ad hoc networks," in *Systems and Networks Communications, 2006. ICSNC'06. International Conference on*, 2006, pp. 50-50.

[10] S. Balaji and V. Priyadharsini, "A ROBUST CLUSTER HEAD SELECTION BASED ON NEIGHBORHOOD CONTRIBUTION AND AVERAGE MINIMUM POWER FOR MANETs," *ICTACT Journal on Communication Technology*, vol. 6, 2015.

[11] A. Karimi, A. Afsharfarnia, F. Zarafshan, and S. Al-Haddad, "A novel clustering algorithm for mobile ad hoc networks based on determination of virtual links' weight to increase network stability," *The Scientific World Journal*, vol. 2014, 2014.

[12] B. Kadri, A. M'hamed, and M. Feham, "Secured clustering algorithm for mobile ad hoc networks," *International Journal of Computer Science and Network Security*, vol. 7, pp. 27-34, 2007.

[13] T. Issariyakul and E. Hossain, *Introduction to network simulator NS2*: Springer Science & Business Media, 2011.

About Author (s):

Image	**Ariane Caine** is a PhD candidate at the University of the West Indies, Cave Hill, Barbados. Her research interests include Mobile Ad-Hoc Networks, Artificial Neural Networks, Fuzzy Logics and Bayesian Networks. **Thomas Edward** is currently a lecturer in Computer Science at the University of the West Indies Cave Hill Campus. He obtained a PhD in Computer Science from this same University in 2006. His research interest includes security of Mobile Networks, Distributed Systems and High performance computing.