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# Introducing a Cluster-Based Location Aided Reactive Greedy Reactive (CBLARGR) in Unmanned Aerial Vehicles (UAVs)

Anuradha[1], Renu Singla[2],

M.Tech Student, Department of CSE & Shri Ram College of Engg. & Mgmt, Palwal, Haryana, India[1]

Asst. Professor, Department of CSE & Shri Ram College of Engg. & Mgmt, Palwal, Haryana, India[2]

**ABSTRACT:** With the wide applications of unmanned aerial vehicle (UAV), there is an immediate requirement for making UAV fleet networks to improve the total operational efficiency, in which the mobile Ad Hoc network (MANET) architecture should be followed. In this paper, we introduce a new routing protocol to approach the routing issues in UAV fleet networks, known as Cluster-Based Location- Aided Reactive Greedy Reactive(CBLARGR). CBLARGR makes stable cluster architecture of UAV fleet as the basis and then performs route discovery and route maintenance by utilizing the UAVs geographic location. The clustering mechanism uses Node-Weight heuristic algorithm to choose cluster heads and build clusters, while the routing mechanism is an integration of Inter Cluster Routing and Intra Cluster Routing, which uses long-range transmission and short-range transmission respectively. Results of simulation have explained that CBLARGR performs better than RGR importantly in average end to end delay, successful delivery ratio as well as in dynamic performance and scalability, which build it more appropriate to be used in UAV fleet networks.

**KEYWORDS***:* UAV Fleet Networks, Clustering Algorithms, MANET, Scalable Routing, Routing Protocols.

## I. INTRODUCTION

In recent years, with the benefits of small size, light weight, low price, high flexibility, zero casualties, etc., unmanned aerial vehicles (UAVs) have been widely used in military fields, as well as in national economy. As shown by the U.S. Army Unmanned Aircraft Systems Roadmap 2010–2035, the US Air Force uses UAVs primarily for surveillance, reconnaissance, direct attack missions and battle damage assessment. Since, the short transmission range, limited energy and simple functions of single UAV limits its further applications, not enough to fulfill the several needs of the Army. Thus, there presents an immediate requirement for making UAV fleet networks to enhance the total operational efficiency through the cooperation of several UAVs. UAV fleet network obtains information sharing and data exchange through the real-time, reliable and high speed communication among UAVs. The building up of UAV fleet network would efficiently improve the work controllability, efficiency, survivability, and anti-jamming capacity of UAV fleet, hence enhance the tactical efficiency and explore the applications scope. UAVs often work in complicated and changing atmosphere with reliable operational ways and high mobility; thus, it is essential to apply the mobile Ad Hoc network (MANET) architecture in the UAV fleet network design.

Unmanned Aerial Vehicles (UAVs) are an evolving technique that can be harnessed for public, military and civil applications. Military usage of UAVs is more than 25 years old mainly consisting of border surveillance, strike and reconnaissance. Public usage is by the public agencies i.e. public safety, police and transportation management. UAVs can offer timely disaster warnings and guide in speeding up recovery and rescue operations when the public interaction network gets disabled. They can carry medical supplies to fields rendered inaccessible. In conditions i.e. wildfires, poisonous gas infiltration and wild animal tracking UAVs could be utilized to frequently envelope a huge region without safety risk of the personnel include. UAVs come in different sizes. Huge UAVs may be utilized singly in missions whereas small ones may be utilized in swarms or formations. The latter ones are proving to be quite helpful in civilian applications. As explained by Daniel and Wietfeld in [1] they are likely to become priceless inclusions in the operations of fire brigades, police departments and other homeland security organizations in the coming future.

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Besides, advancement in sensor and electronics technique have increased the UAV network applications [2] scope to involve applications as wind estimation, diverse as traffic monitoring and remote sensing [3].
In this paper, we introduce a new routing protocol for UAV fleet networks by utilizing the location information of UAV nodes depending on the cluster architecture of UAV fleet, known as Cluster-Based Location-Aided Recative Greedy Reactive(CBLARGR). In brief, our technique is to make stable cluster architecture of UAV fleet network as the basis for routing and then to perform route discovery and route maintenance by utilizing the UAV nodes geographic location. The cluster head (CH) election depend on Node-Weight heuristic algorithm, which allocates node weights according to the suitableness of nodes behaving as CHs, by taking the relative speed, connectivity degree, residual energy, and weapon and equipment into account. After the cluster architecture has been made, the introduced routing protocol is performed. In CBLARGR, CHs use Location-Aided Recative Greedy Reactive(LADSR) for Inter Cluster Routing utilizing long-range transmission, while cluster members (CMs) take on roles of Intra Cluster Routing utilizing short-range transmission. With the cluster architecture and restricted forwarding domain, nodes included in route discovery and route maintenance are decreased dramatically, which results in less end to end delay and routing overhead. Theoretical analysis and simulation results indicate that the introduced clustering algorithm and routing protocol are highly scalable, efficient and appropriate for UAV fleet networks.

## II. MOTIVATION AND CHALLENGES OF UAV NETWORKS

Promising though it may be, this field is comparatively new and less explored. There are several problems to resolve before efficient usage of UAVs can be built to offer reliable and stable context-specific networks. As we shall look later, while it provides the promise of enhanced capacity and ability, setting up and managing effective communications among the UAVs is challenging. All the components of the UAV communication networks introduce challenging problems that require resolution. Unlike several other wireless networks, the UAV networks configuration remains fluid with the no. of nodes and connections changing and also the nodes relative positions is changing. UAVs may move with different speeds based on the application, this would cause the connections to be set up in an intermittent manner. What challenges would such a nature pose? Firstly, some architectural design aspects would not be intuitive. The fluid configuration, the vanishing nodes and finicky connections would all challenge the designer to go beyond the general ad hoc mesh networks. Second, the routing protocol cannot be a simple implementation of a reactive or as proactive technique. The inter-UAV backbone has to iteratively reorganize itself when UAVs fail. In some situations, the network may get divided. The challenge would then be to forward the packet from a source node to a destination node while analysing the selected metric. The third challenge would be to manage subscriber's sessions by transmitting them continuously from an out of service UAV to an active UAV. Lastly, there is requirement to be ways of conserving energy of power starved UAVs for increasing the network lifetime. In the next section we explain all of these problems in more detail.The UAV networks area is challenging to researchers due to the outstanding issues that offers motivation for research. In vehicular and mobile networks the nodes join and leave from the network quickly and, thus, ad hoc networks have been detected to be appropriate in most conditions. Additionally, for frequent and flexible communication among nodes, mesh network configuration is quite suitable. Does this apply to the UAV networks as well? In UAV networks, the nodes could almost be fixed and hovering over the operation or scouting area around at a fast pace. Nodes could die out for several causes and may be substituted by novel ones. Some similarities motivate researchers to explore the applicability of the work performed for Vehicular Ad hoc Networks (VANETs) and Mobile Ad hoc Networks (MANETs), but works in these fields do not completely approach the unique features of the UAV networks.

## III. RELATED WORK

In last few years, to schedule the network into hierarchical structure, some clustering algorithms have been introduced for MANET. Lowest-ID with Adaptive ID Reassignment (LIDAR) [2] makes clusters depending on the time and cost-effective lowest-ID mechanism, and re-allocates node IDs according to energy status and node mobility during the cluster maintenance stage. MOBIC [3] is a distributed clustering algorithm where every node computes relative mobility values in terms of the neighbouring nodes for the CH selection. Weighted Clustering Algorithm (WCA) [4] is a weight metric-based clustering method which takes into account the transmission power, ideal degree, battery power and mobility of mobile nodes. As a modification recommended to WCA, Weight Based Adaptive Clustering for Large Scale Heterogeneous MANET (WACHM) [5] incorporates scalability and node heterogeneity in the algorithm design.

Based on the cluster architecture, there has been a no. of hierarchical routing protocols introduced for MANET. Cluster Based Routing Protocol (CBRP) [6] partitions nodes into overlapping or disjoint 2-hop-diameter clusters in a distributed way, by which the protocol speeds up the route discovery procedure and decreases the flooding traffic. Virtual Structure Routing (VSR) [7] depends on a virtual configuration including both clusters and a backbone; VSR integrates the assets of both flat methods: inter-cluster routing is reactive while intra-cluster routing is proactive. There are some hierarchical routing protocols introduced to increase the network scalability by decreasing the control overhead [8], [9]. Routing protocol has been a major research field in Ad Hoc networks [10]–[13]. Location-aware routing, also called geographic routing, which depends on mobility and location information, has also obtained much attention in recent years [14]–[16]. Since, the research of location-aware routing based on hierarchical structure is still in its early stage of growth. Cluster Based Location-Aware Routing Protocol for Large Scale Heterogeneous MANET (CBLARHM) [17] incorporates location-aware routing and cluster architecture to obtain high success delivery ratio, low routing overhead and low average end-to-end delay. Location-Aided Hierarchical Cluster Routing (LHCR) [18] considers location factor into consideration to make n-level cluster structure, then performs reactive inter-cluster routing and proactive intra-cluster routing, which are taken attention of by the node of the highest level in every cluster.

## IV. ROUTING ISSUES

The UAV networks built for several applications may change from slow dynamic to the ones that fly at considerable speeds. The nodes may go out of service because of failure or power restraints and get substituted by new ones. In green networks, radios in the nodes may be automatically switched off for power conservations when the load is low. Connection interruption may quickly take place due to the UAVs and ground stations positions. In addition, the connections could have high bit error rates because of disruption or natural conditions. The reliability needs from the UAV networks are also different. For instance, while forwarding earthquake data may need a 100% flexible transport protocol, forwarding pictures and earthquake video may be performed with lower flexibility but limited delay and jitter needs. Bandwidth needs for data, voice and video are different. The UAV networks, thus, have all the needs of mobile wireless networks and more. Node mobility, intermittent connections, network partitioning, restricted resources and changing QoS needs build routing in UAV a challenging research issue.
Additionally, the needs available in the generic wireless mesh networks, e.g., determining the most effective route, permitting the network to scale, assuring reliability, controlling latency, taking care of mobility and assuring needed QoS; routing in airborne networks needs energy-awareness, location-awareness and increased robustness to intermittent connections and changing configuration. Designing the network layer for UAV networks is still one of the most challenging issue [3]. There still available a requirement for a routing protocol tailored to the specific requirements of airborne networks that follows to high mobility, dynamic configuration and various routing abilities [30]. Routing protocols attempt to increase delivery ratio, decrease resource consumption and delays. In addition, one has to assume issues related to loop freedom, scalability, energy conservation, and effective usage of resources also requires to be resolved [31].

## V. CLUSTER-BASED UAV FLEET NETWORK ARCHITECTURE

According to the needs of battlefield applications, UAV fleet conducted missions in the formation form, which contains two kinds of UAVs: task UAV and lead UAV. Task UAV performs particular tactical tasks i.e. electronic countermeasure, reconnaissance, and direct attack; whereas lead UAV takes the responsibility of coordinated interaction and the formation management as well. In comparison of task UAV, lead UAV has less relative mobility, more initial energy and longer transmission range, which builds it more appropriate to be CH. Thus, the CH election is mainly conducted among lead UAVs. Depending on the battlefield atmosphere and operational needs, in the CH election process, four system parameters of UAV nodes should be considered into account: (*a*) connectivity degree $C$, which shows the no. of one-hop neighbours; (*b*) relative speed $S$, which shows UAV's relative mobility to the formation; (*c*) residual energy $E$, which shows the UAV energy situation; (*d*) weapon and equipment $T$, which shows the UAV tactical value. In this paper, we build a reasonable consideration that all UAVs are fitted with GPS or other

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positioning systems. With the location information offered by GPS, UAV nodes learn the local network configuration, and distributed determine the above system parameters through the information exchange and sharing within the formation. In the clustering mechanism, only lead UAVs play role in CH election, except for the condition that there are no lead UAVs in the formation. On the assumption of satisfying the residual energy threshold, the candidate UAV with the highest weight in the formation becomes CH and floods CH declaration message, whereas other UAVs in the formation response to the CH and become CMs. Because of the high risk and complexity of battlefield atmosphere, the candidate UAV with the second highest weight, if available, is selected as backup CH, which will frequently take the roles of CH when current CH is not applicable. In the formation without lead UAVs, which is rare case, task UAVs will play role in CH election and may become local CH until lead UAVs enter the formation. To record basic information and essential data, every UAV manages a cluster information table.

## VI. DESIGN ISSUES OF CBLARGR PROTOCOL

Depending on the cluster architecture explained in the prior section, we introduce a new CBLARGR protocol to approach the routing issues in UAV fleet networks. CBLARGR is an integration of Inter Cluster Routing and Intra Cluster Routing, thus a hierarchical routing protocol. Intra Cluster Routing is performed depending on the Neighbour Table of every node, thus a Table-Driven routing technique. When a node wishes to forward packets to another node in the same cluster, it simply views the Neighbour Table to learn the information of location, and directly forwards packets towards the target node utilizing short range transmission. Inter Cluster Routing uses the introduced LADSR, which is a location-aware protocol depending on DSR. When the target node is available in a different cluster, the source node forwards packets to its CH utilizing short-range transmission. Source CH view its CH Table to learn the information of location of CH which the target node belongs to, and forwards packets towards the adjacent CH which is the closest to the destination CH utilizing long-range transmission. If destination CH is away from source CH by more than two clusters, in which case the information of location is not precise enough, the source CH forwards a route request packet to all CHs in the direction of destination CH. On obtaining the route request packet, the destination CH forwards back a route response packet to report source CH. On reception of the route reply packet, source CH forwards data packets along the found route. At last, destination CH sends data packets to the target node utilizing short range transmission, hence completes the Inter Cluster Routing procedure. Figure 1 shows the routing procedure of CBLARGR protocol, which shows both the Inter Cluster Routing and Intra Cluster Routing.

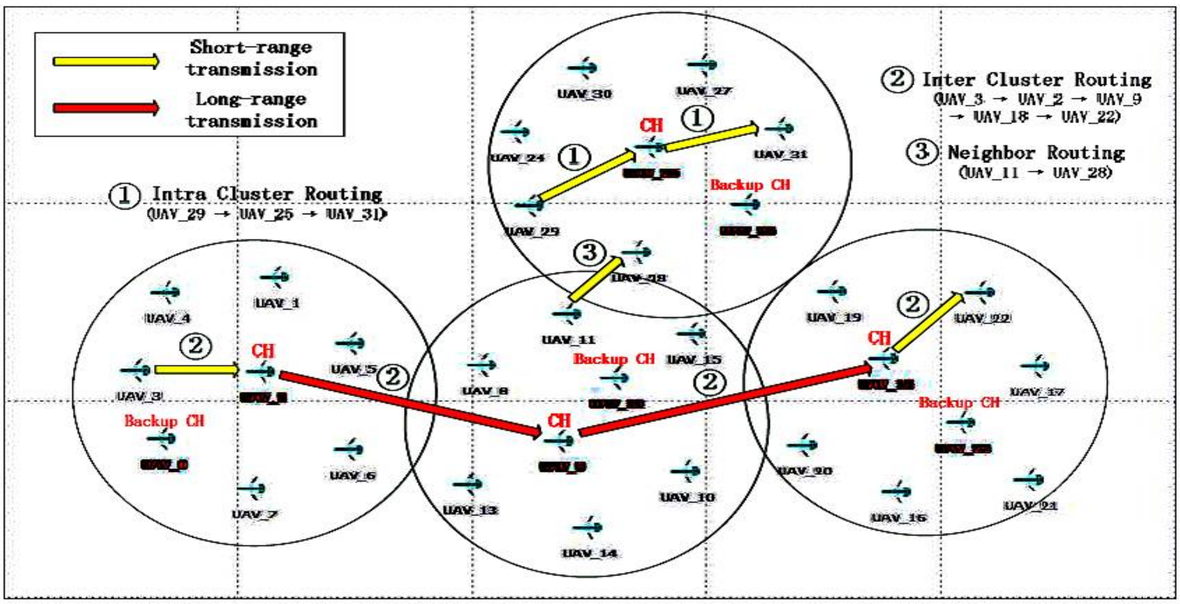


**Figure 1. The routing process of CBLARGR protocol**

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## VII. SIMULATION SETUP AND RESULT ANALYSIS

In this section, the performance of the introduced CBLARGR is measured and compared RGR on OPNET Simulator. We conducted two scenarios of comparative simulations: (*a*) Node no. scaling scenario, in which we scale up the no. of nodes while changing the network size to study the routing protocols scalability. We conduct four sets of simulations in geographic regions size 4, 000m × 4, 000m with 25 nodes, size 6, 000m × 6, 000m with 50 nodes, size 8, 000m × 8, 000m with 75 nodes, and size 10, 000m × 10, 000m with 100 nodes, while the node speed is static at 30m/s. (*b*) Node speed varying scenario, in which we change the nodes speed to study the dynamic features of routing protocols. We conduct six sets of simulations in a static region of size 3, 000m × 3, 000m with 50 nodes, whereas the node speed is set to 10, 20, 30, 40, 50, and 60m/s, respectively. We also assume the group mobility features of UAV fleet, such that nodes in the same geographic zone are provided with close velocity and direction of motion at the starting of simulation, and the change of direction and velocity when arriving the default destination will be carried out in similar ways. The simulation parameters are explained in Table 1.

**TABLE 1. SIMULATION PARAMETERS**

| Simulation parameters | Configurations |
|---|---|
| Network model | MANET |
| MAC protocol | IEEE 802.11 |
| Mobility model | Improved random waypoint |
| Pause time | 200 sec |
| Packet inter-arrival time | 1 sec, poisson |
| Packet size | 1, 024 bits, constant |
| Channel capacity | 4 Mbps |
| Task UAV. initial energy | 250 J |
| Lead UAV. initial energy | 400 J |
| Weight factors | $w1$=0.4; $w2$=0.2; $w3$=0.3; $w4$=0.1. |
| Short transmission range | 600 m |
| Long transmission range | 1, 400 m |
| Simulation time | 1800 sec |

To measure the routing performance of the introduced CBLARGR as well as RGR, we propose two key performance metrics: (*a*) Successful delivery ratio, which is the ratio of data packets provided to the destination node to those created by the source node. (*b*) Average end-to-end delay, which is averaged over all supporting data packets from the source node to target node. We perform four sets of comparative analyses for several scenarios and performance metrics, as follows.

Fig 2 presents the results of successful delivery ratio in the node no. scaling scenario. It shows that the successful delivery ratios of all three routing protocols reduce with the increase in no. of nodes, while the introduced CBLARGR performs better than RGR in networks of all sizes, particularly in large-scale networks. CBLARGR makes stable cluster architecture and performs location aided routing in a smaller estimated region, hence possesses good scalability and high successful delivery ratio. RGR is flat routing protocols with poor scalability, which yields to low successful delivery ratio when the size of network scales up.

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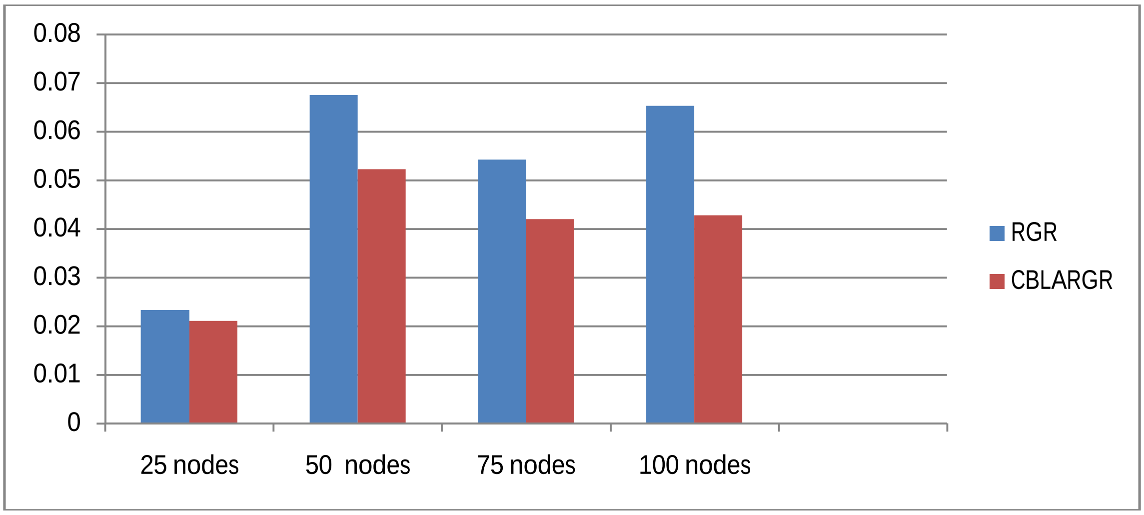


**Figure 2. Successful delivery ratio with varying the number of nodes**

Fig 3 presents the results of average end-to-end delay in the node no. scaling scenario. The average end-to-end delay of all routing protocols increases when scaling up the node no., while CBLARGR performs better as compared to RGR in networks of all sizes. The cause is that CBLARGR performs Intra Cluster Routing depending on the Neighbour Table, and performs Inter Cluster Routing among CHs utilizing long-range transmission, which importantly decrease the network latency. CBLARGR decreases the delay caused by packets waiting for route discovery in comparison of DSR, while decreases the delay because of computing the route to next-hop node in comparison of GRP, which result in good scalability and lower average end-to-end delay.

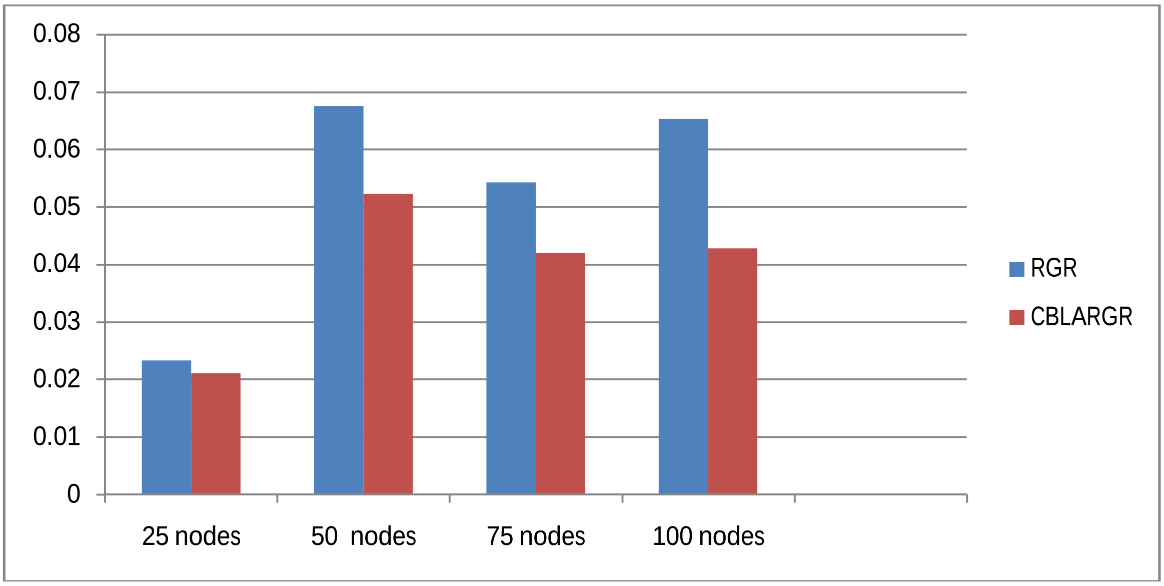


**Figure 3. Average end-to-end delay with varying the number of nodes**

## VIII. CONCLUSION

In this paper, we introduce a new CBLARGR protocol to approach the routing issues in UAV fleet networks. CBLARGR performs route discovery and route maintenance depending on the UAV cluster architecture with the aid of location information. The clustering mechanism depend on Node-Weight heuristic algorithm, which allocates node weights according to relative speed, connectivity degree, residual energy, and weapon and equipment as the basis for choosing CHs and making stable clusters. The routing mechanism is an integration of Inter Cluster Routing and Intra Cluster Routing, in which CHs use LARGR, a location-aware protocol based on RGR, to perform routing among the clusters by utilizing long-range transmission; whereas CMs route packets within the clusters depend on the Neighbour Table by utilizing short-range transmission. Simulation results have indicated that our introduced CBLARGR performs better as compared to RGR importantly in successful delivery ratio and average end-to-end delay, as well as possessing good dynamic performance and scalability, which build it more appropriate to be used in UAV fleet networks and other high-dynamic large-scale MANETs.

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