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A Novel Technique and Analysis for Efficient Packet Routing in FANET

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Abstract— Conventional routing protocols which are designed for wired networks generally fail to satisfy the requirements of wireless networks. These facts lead to invention of new routing protocols specifically for operation in wireless sensor networks. Due to the limited resources and dynamics, building efficient and scalable protocols for wireless sensor networks is considered to be a very Challenging task. Many routing protocols have been designed and implemented for this aim. Geographic Routing, which performs routing based on the geographic location of sensors is proposed for large scale and highly dynamic sensor network. In the recent years techno- logical advances on electronics and communication technology, unmanned aerial vehicle (UAV) has been evolved. A Flying Ad hoc Networks (FANETs) is a kind of network that consists of a group of small UAVs connected in ad-hoc manner. Lot of research has been devoted to extend position-based packet routing proposals to three dimensional environments. When flying objects are considered, a mobility model specifically designed for UAVs movement is needed.

Index Terms: Mobile MANET, FANET, UAV-Communications, Position-based Routing.

1. INTRODUCTION

Mobile ad-hoc Networks (MANETs) are autonomous, dis-tributed and self-configuring networks comprised of mobile wireless nodes [1], [2]. This type of networks can poten-tially operate without a fixed infrastructure or centralized administration and this flexibility makes them suitable to a wide range of operational scenarios such as rescue, disaster or hard to reach environments, military, underwater networks etc. The main characteristic of the MANET paradigm, differ-entiating it from traditional wired networks, is the potential of nodes to move around by fol-lowing (un)planned trajec-tories. This makes route discovery and maintenance a very challenging task. Evolution of MANETs have considered vehicles (VANETs - Vehicular Ad-hoc Networks) [3], [4] and sensors (WSN - Wireless Sensor Networks) [5], [6]. More recently, the growing capability in the production chain to miniaturize complex electronic systems has produced a wide range of gadgets capable to move and fly autonomously. These devices are commonly referred to as unmanned air- borne vehicles (UAVs, or even micro-aerial vehicles, quad- copters, swinglets, drones, etc.) [7], [8], [9]. The use of UAVs has paved the way to new and innovative application scenarios, introducing a new kind of networking paradigm, named Flying Ad-hoc Network (FANET) [10], [11], [12]. These net- works differ from traditional MANETs in terms of degree of mobility, connectivity, applications areas etc. In

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This respect, a FANET generalizes the topology from a 2D topology to a 3D one with a free movement scheme, due to the capability of drones to move autonomously in a 3D space.

A. FANET Characteristics

As in MANETs, the FANET architecture is a network without infrastructure, using multiple nodes to transmit data packets. The other characteristics are self-organized abilities, self-managed data in a distributed manner, the nodes com- munications and cooperation that are used to deliver data. FANETs, however, have some specific features as well that makes them differ from MANET and VANET [4]:

1) Network connectivity: FANET network connectivity has higher intermittent degree than in MANETs or VANETs. It is caused by UAVs mobility. The com-munication interruption can be critical when important information (control/command traffic) is transmitted. Moreover, UAV failure may result in connectivity failure with a following routing failure, and subsequent com-munication failure or worse delay.

2) Nodes number: When a UAV with a relatively high velocity is deployed in a specific mission, a restricted mission area can be covered. In this case, a large number of UAVs is not necessary.

3) Suf fi cient energy: It is usually supposed that de- pending on their size and type, FANET nodes have sufficient energy and computing power if compared to MANET nodes. The reason is that the amount of energy needed to move an UAV is much greater than that required to compute data.

4) Mobility (3D): The mobility model is of importance when network protocols are designed for ad- hoc networks. The mobility patterns of UAVs and other vehicles differ. UAV can move in all three dimensions.

5) Environment: Since FANETs consist of flying nodes, they are usually used in large free spaces. Therefore, to model the physical layer one often uses the free- space path loss model. Still large obstacles, ground reflections or weather conditions and other factors can affect UAVs connectivity.

B. FANET application scenarios

In this section, we explore different application scenarios in which a potential FANET could be deployed in order to provide communication support.

- Disaster scenario. During or after a catastrophic event (earthquake, hurricane, tsunami, etc.), the tra-ditional network infrastructure may suffer damages. A FANET could be deployed in order to restore or provide a self- sufficient communication network in isolated areas [18]. UAVs could be equipped with cameras and a variety of sensors, providing a birds eye view for the ground rescue teams in that re-gion(s) [12].

- Civilian scenario. A typical application of FANETs in the urban environment is urban monitoring and surveillance. Traditionally, these operations are achieved through the use of fixed cameras or special-ized mobile vehicles. However, UAVs seem to be a perfect match for the context, enabling information exchange amongst UAVs from/to infrastructure in order to have an accurate picture about the e.g., traffic conditions in a specific area by integrating data from multiple UAVs. Another popular application in a civilian context is the search and rescue of victims in dangerous or difficult to reach areas. A FANET could deployed in order to speed up the search operations providing, amongst other things, an autonomous and distributed coordination system. In this context, the area of interest could be divided into regions, and the system adopts a divide et impera approach speeding up the operations. This distributed UAV platform is capable of autonomous coordination through infor-mation exchange.

- Tactical and military scenario. As in the urban sce- nario, there is also an increasing demand for UAVs systems in the tactical context. Differently from the urban or civilian scenario, UAV usage in this context has strict requirements with respect to communi- cation and coordination delay. This affects also the complexity

Traditional topology-based routing algorithm is not well adjusted for highly dynamic and low density networks like FANETs due to the large amount of packet overhead gen-erated. The overhead tends to increase proportionally with the number of nodes and the mobility degree. On the other side, position-based routing protocols (or geographic-based protocols) try to address the issues by employing a differ-ent mechanism for path discovery. This class of protocols leverages on the geographic positions of nodes to perform the forwarding decision using Global Position System (GPS) receivers. In this context, each node determines its own geographic position, and makes the forwarding decision rbased on the destinations position and those of neighbors nodes. This local decision making, makes position-based routing protocols suitable in scenarios of large and highly mobile networks; nodes do not have to explore the status of the whole network, store routing tables or exchange control messages in the entire network.

C. THE ROUTING PROBLEM

Generally, MANETs characteristics such as frequent topol-ogy changes, energy constraints and limited bandwidth, pose various challenges to the routing process. To this end, various MANET routing protocols have been proposed during the years [10].These protocols into two main categories: topol-ogy and position-based. Topology-based routing protocols exploit link information to route the packets, while position- based ones use location information of nodes to make the forwarding decision.

D. Topology-based Routing Protocols

Topology-based protocols consider the network topology and maintain up-to-date routing tables, specifying the path or the next-hop where to route a packet from a source to a destination. In this context, there are three strategies that exploit topology information: proactive, reactive and hybrid. A protocol is considered proactive when each node keeps an up-to-date information reflecting the state of the network each node can determine its position (longitude, latitude and altitude), the position of its neighbors (usually 1 hop); the destinations location information is assumed known a- priori (e.g., acquired through external means); nodes store the information about their neighbors (e.g., position, speed, direction) in a neighbor table; the next-hop decision can be made based on the location of the current node (the node holding the packet), its neighboring nodes and the destination node.

E. Position-based Routing Protocols

Position-based Routing Protocols Position-based (or geo- graphic) routing protocols use the position of the nodes in the network to make the forwarding decision. The first proposed protocols using geographic information were intended to be adopted in support to the topology-based protocols, limiting the propagation of route request packets into a determined area. Position-based routing protocols exploit local knowl-edge; a node makes the forwarding decision replying on its position information, the position of the destination and the position of its neigh-bors. To obtain location information, nodes use a location service such as GPS, or other types of location services. To acquire the position of the neighbors, nodes make use of a beaconing mechanism in which each node sends a beacon to its neighbor nodes, containing its position [9].

2. DESCRIPTION OF 3D ROUTING ALGORITHMS

A. Greedy

Greedy is a simple progress-based forwarding strategy [7]. A node *(n_c)* forwards the packet to the neighbor node that minimizes the distance to the destination node *(n_d)*. In general, if there is no neighbor node closer to the destination (i.e., there is a void), the algorithm fails and the node storing the packet is called local minimum. There are two classes of forwarding algorithms that adopt a greedy strategy, which differ from one another based upon the nodes considered as part of the neighboring set.

Greedy : n_c forwards the packet to one of its neighbors that is closer to n_d than n_c and any other neighbor.

Geographic Distance Routing (GEDIR): n_c forwards the packet to one of its neighbors that is closer to n_d than any other neighbor, but not necessarily closer to n_d than node n_c itself. In *GEDIR*, all neighbors are considered. So, even the nodes that are in backward direction can be chosen.

B. Projective Face

The Face algorithm works on the connected planar sub-graph of UBG, called Gabriel Graph (GG), which contains only non-crossing edges [7]. The packet is routed over the faces of a *GG* that are intersected by the line n_s, n_d. Each *face* is traversed using the right-hand rule, unless the current edge crosses n_s, n_d at an intersection point *p*. At this point, the algorithm switches to the next *face* sharing the edge. This process is repeated until the packet arrives to n_d.

Since the face strategy cannot be performed directly on a

3D graph, a proposed solution is to project the nodes onto a plane to perform the face algorithm. The first extension of *face* based strategy in 3D space uses two orthogonal planes intersecting at the line connecting source and destination. In this context, the nodes of the network are projected onto one plane that contains the segment n_s, n_d and a third point chosen randomly. Then, *Face* is performed on this projected graph. If the routing fails, the nodes are then projected onto a second plane, orthogonal to the first one which contains the segment. Then, *Face* is again performed. The algorithm makes use of a local threshold value, *TTLF* (Time to Live Face), in order to terminate the algorithm in case it does not reach the destination within *TTLF* hops.

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