**KimonoNet  
Enabling Efficient and Reliable Inter-UAV   
Fluid Data Communication Link**

Project Proposal

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*Authors*  
Bollens, Eric <ebollens@oit.ucla.edu>   
Hung, James <james400mhz@yahoo.com>  
Khalapyan, Zorayr <zkhalapyan@oit.ucla.edu> Norris, Wade <wade.norris@ucla.edu>

# 1. Introduction

## 1.1. Abstract

This proposal addresses a peer-to-peer network research topic related to routing and transport control issues that arise in ad hoc communication between autonomous peers such as unmanned aerial vehicles (UAVs). Under such scenarios, limited external uplinks exist, and these uplinks may lie beyond the network horizon of an individual node; this motivates the need to establish routing across a fluid peer network. Traditional routing algorithms are not suited for such a topology given the high mobility and high churn of network peers and thus a rapidly shifting set of routes.

The project described herein will provide (1) a description of necessary protocols and algorithms and (2) an implementation of an ad hoc peer-to-peer network based on the above description that performs routing with consideration for the position and velocity of relays in order to improve efficiency and reliability.

## 1.2. Background Information

The military has significantly increased the computing power it places in the field in recent years; however, the increase in network coverage has not followed suit. One option to increasing coverage relies on the development of an ad hoc peer-to-peer network whereby network-enabled devices in the field may form routes from remote operational zones back to a secure base station.

Rather than providing the route via stationary relays that make easy targets, unmanned aerial vehicles (UAVs) and other mobile equipment already equipped with basic network capabilities may be configured to provide such a network.

However, a network of this type would likely form a very sparse graph with limited routes to any endpoint. Further, given changing positions of nodes in the network and possible calamities that might befall the nodes, the network would suffer high churn. Consequently, an implementation to cover this use case must both adapt quickly to topological changes and also provide reliable data delivery even when route reliability is tenuous.

Beyond military application, this sort of research topic may provide insight into broader ad hoc networking issues. To address the dynamics of ad hoc networks, some protocols including AODV and DSR have taken the approach of on-demand routing, ascertaining a path at send-time rather than predetermining routes. These suffer from disadvantages including inconsistent, unreliable data routing and extra control overhead. Other ad hoc protocols such as OSLR employ table-driven approaches, many reminiscent to traditional distance-vector protocols.

# 2. Problem Definition

## 2.1. Overview

This project shall address routing and transport in ad hoc peer-to-peer networks where constituents form a sparse, fluid network, prone to shifting network horizons due to both movement and failure. Traditional routing protocols do not adequately handle this, befallen to delays in convergence or a need to understand global network topology. In this void, several ad hoc protocols have been developed. Some use on-demand routing to ascertain a route at send time, while others use more traditional table-driven approaches for determining route. This research shall extend the table-driven ad hoc approach, introducing velocity as a predictive factor upon the distance-vector routing.

## 2.2. Routing & Data Delivery

Conventional routing protocols are unsuitable for ad hoc network conditions:

1. IGP distance-vector algorithms rely on delays that stunt convergence and thus cannot cope with high churn.
2. IGP link-state algorithms require global knowledge of the network topology, which is not possible in a fluid network with mixed horizons.
3. EGP algorithms better deal with route fluidity, but do not provide the quality of service required.

In order to combat these problems, a series of ad hoc routing protocols have been proposed, including some similar to traditional distance-vector IGPs, while others attempt to instead build routes on-demand.

While peer-to-peer research has had some success with ad hoc routing, little work has been done to date in accounting for velocity. As per §1.2, this is a key factor in describing churn, as it leads to changing network horizons for peers. While traditionally velocity is considered a detriment, this project proposes a solution that extends the traditional distance-vector routing model by considering geolocation and velocity vector data explicitly to help determine short-lived packet routes across a fluid peer-to-peer network.

Further, this solution shall seek to aggregate data, reduce duplication and minimize control signal pollution, while still ensuring timely and accurate data delivery based on quality-of-service metrics.

## 2.3. Quality of Service

Within military operations, quality-of-service (QoS) describes packet reliability requirements. This same sort of metric might be useful within other scenarios as well.

This solution shall consider four QoS grades:

1. **Control Data**: Extremely time-sensitive with priority over all other traffic.
2. **Communication Data**: Time-sensitive but loss-tolerant such that no duplication or alternate routing is required, but timely delivery should be paramount.
3. **Surveillance Data**: Not time sensitive, but also not loss-tolerant. This data should be protected from loss, duplicated into local buffer storage in case the data is not successfully delivered to the endpoint.
4. **Standard Data**: Data without specific QoS requirements. This data should be routed with best-effort delivery. Data aggregation, duplication and alternate routing will proceed according to prioritization at a specific node.

# 3. Scope

Based on the requirements described in the Problem Definition (§2), this research project involves a routing and transport implementation over OSI Layers 3 and 4. It will also provide a demonstrable application of the peer-to-peer network developed forthwith. In accomplishing this overlay, the project may leverage existing protocols such as IP and UDP.

# 4. Approach

This project will produce both a description of necessary protocols and algorithms and a prototypical implementation. At the current time, the authors believe that this implementation will leverage Java, capable of running within a JVM on any device with a wireless NIC. In addition, the authors will also provide a test suite for the purpose of evaluating the algorithm.

The phases of this project are detailed forthwith.

## 4.1. Ad Hoc Neighbor Registration

This phase will implement the communication necessary to register a node with neighbors within its ad hoc network horizon. It is anticipated that UDP broadcast may provide this without requiring an implementation directly atop Layer 3.

## 4.2. Transport within Ad Hoc Network

This phase will implement transport, likely also atop UDP broadcast, sending a data packet from one node to another node within its ad hoc network horizon. This phase will not focus on quality of service metrics, but instead on addressing and delivery to ensure that the intended destination receives the message.

## 4.3. Data Relay across Ad Hoc Networks

This phase will implement relay capabilities between two ad hoc networks that share a common node. At this point, routing will not yet be paramount, but rather proper reception and retransmission with minimal work on behalf of the intermediate node.

## 4.4. Routing between Ad Hoc Networks

The cornerstone of this project, and the portion that distinguishes it as different from current ad hoc protocols, this phase will implement routing using an extended version of distance-vector that uses velocity-vector information in order to anticipate topological changes.

## 4.5. Quality of Service Transport

Within the problem definition, §2.3 describes four quality of service grades that this peer-to-peer network should provide. Essentially, these grades are all the combinations of speed and reliability. This phase shall handle the implementation of these grades.