2022

COTS AI/ML Technology for Data Fusion and Track Management

Garza, Victor R.; Wood, Brian; Gallup, Shelley; Mun, Johnathan

Monterey, California: Naval Postgraduate School

NAVAL RESEARCH PROGRAM
NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

NETWORKED AIRBORNE ISR&T LONG ENDURANCE - COMMUNICATIONS ARCHITECTURE (NAILE-CA)

EXECUTIVE SUMMARY

Principal Investigator (PI): Mr. Victor R. Garza, Information Sciences (IS)

Additional Researcher(s): Mr. Brian P. Wood, IS; Dr. Shelley P. Gallup, IS; Dr. Douglas MacKinnon, IS

Student Participation: LT Samuel Deck USN, Computer Science

Prepared for:
Topic Sponsor Lead Organization: N9 - Warfare Systems
Topic Sponsor Organization(s): Warfighting Assessments & Requirements, Surface Warfare Division (N96F1), Chief of Naval Operations
Topic Sponsor Name(s): Mr. Stephen G. Conroy; OPNAV N2N6F22 USMC UAS Liaison Officer
Topic Sponsor Contact Information: Stephen.G.Conroy.civ@us.navy.mil (703) 695-2370

This research is supported by funding from the
Naval Postgraduate School, Naval Research Program (PE 0605853N/2098).

Project Summary

The Networked Airborne ISR&T Long Endurance - Communications Architecture (NAILE-CA) concept provides a long-haul unmanned aircraft system (UAS) sensor constellation for intelligence, surveillance, reconnaissance and targeting (ISR&T). NAILE-CA does not have network specifics to provide determination of the bandwidth, data links, apertures, compute, security, and autonomy requirements. Through analysis of current radio and networking technologies, we simulated how to optimize network traffic for the NAILE-CA concept. We found by completing a thorough analysis of sensor network traffic and correlation of data we were able to proffer recommendations on optimizing network links. These recommendations include: The NAILE concept can essentially be called a Flying Ad Hoc Network (FANET), which has a specific topology and can be modeled and analyzed. We have found that four common routing algorithms can be used to connect the unmanned aerial vehicles (UAVs) in the FANET and maintain the necessary communication links. To improve the performance of the FANET in NAILE, we recommend using a directional antenna and adding location and direction information to the routing algorithm. We also need an efficient and reliable routing algorithm that can find the best routes between the UAVs and recover quickly when a UAV is replaced due to flight endurance limitations. We have found that certain algorithms are better at building and maintaining routes quickly, according to our models. In addition, the UAVs in NAILE will need to be able to carry large payloads and have good power efficiency to extend their flight endurance. Using a directional antenna on the UAVs will help conserve power and improve the performance of the FANET in NAILE.

Keywords: *network; intelligence, surveillance, reconnaissance and targeting; ISR&T; target; targeting; command and control; data link; bandwidth; autonomy; surface warfare; data management; swarm*

Background

For OPNAV N96 to determine if the NAILE-CA concept should continue in the Joint Capabilities Integration and Development System process, the communications architecture technical requirements needed to be defined.

The NAILE-CA concept is designed to use long-endurance UASs, acting autonomously as sensors, to spread out ISR over a large area, reducing the need to launch sensors from an afloat asset. This concept is designed to provide organic ISR&T of surface targets to forward units. This network constellation of UASs can accomplish ISR&T visibility with different types of sensors—including Multi-Int, Electro Optical and InfraRed—and correlation of data afloat or ashore, or broadcast raw data to assets, so they can accomplish their own correlation of sensor data.

While the NAILE-CA concept has been advanced, issues with network communications and UAS size, weight, power and cost specifics needed to be evaluated, such as radio payloads, increased gain on antennas, increased power on radios, and reduced data rate, all to increase airborne ISR&T range.

A thesis student analyzed opportunities that were proposed for NAILE-CA applications and determined their value added in the context of surface warfare.

Examples of several airborne networking topologies have been effective in providing promising results. We reviewed previously proposed solutions, identified potential future applications, and evaluated their utility for the Navy.

Our research focused on the requirements for construction and maintenance of the links and routes between the UAV nodes in such an aerial network. We conducted a survey of previous related work and used a network model developed with the network modeling application Network Simulator 3 (NS3) as the primary means for discovering the routing requirements of NAILE networks.

Findings and Conclusions

NAILE has been proposed to provide to warfighters a persistent ISR&T capability that comes with no overhead to the units. NAILE is to be an airborne network of interconnected UAVs that collect information via various onboard sensors and then pass it to the connected customers via UAV-to-UAV multi-hop routing.

In summary, our findings suggest that:

- The NAILE concept is essentially a FANET with a more predictable and rigid topology and can be modeled appropriately and successfully.
- We found that four of the common routing algorithms that used FANETs are sufficient to build and maintain the necessary links and routes between aerial nodes.
- With the transmission distances necessary for NAILE, we recommended to use a directional antenna scheme, and to implement the addition of location and direction information into the routing algorithm route-finding packets.
- We see that NAILE will require an efficient and dependable FANET routing algorithm that can find and build network routes between nodes with the highest throughputs and must also be capable of fast recovery of broken network routes as UAVs are routinely swapped out due to flight endurance limitations.
- We determined that some algorithms build and maintain routes more quickly than others, according to the models. With the NS3 model, it was found that all four algorithms behaved similarly with the Destination-Sequenced Distance Vector routing protocol performing slightly better than the other three due to the faster build time of initial routes.
- NAILE will require advanced UAVs that can carry large payloads. Even so, conservation of power will still be of upmost importance, since the UAV flight endurance will enable the persistence envisioned for NAILE.
- The most efficient use of power to achieve the transmission ranges necessary in NAILE will require an airborne platform-based directional antenna scheme so that NAILE may function as a directional antenna-FANET.
- The implementation of a directional medium access control configured with ready to send circular directional medium access control to broadcast packets across sequential sectors will

greatly increase the transmission range of NAILE and give a more efficient use of battery power on the airborne platform.

Recommendations for Further Research

Further research is necessary to determine the realistic antenna characteristics necessary for the operational deployment of the Networked Airborne ISR&T Long Endurance (NAILE) network. This includes assessing the antenna aperture, size, weight, gain, and directivity to support the desired distances between unmanned aerial vehicle (UAV) nodes while also considering the size, weight, and power limitations of the potential UAV platforms.

Evaluation of several unmanned aircraft system (UAS) platforms have been modeled for applicability, but more research is needed to find current and upcoming UAVs that may satisfy NAILE's requirements.

A datalink mechanism is also necessary to enable nodes to find and track each other using directional antennas instead of omnidirectional broadcast.

The research conducted used the Network Simulator 3, which is a powerful tool for network simulation. However, it has limitations when it comes to modeling aerial networks with moving nodes. To more accurately model NAILE, a network simulator that allows for the removal and addition of nodes during a simulation run, and the ability to model frequencies other than the current limited ones, would be more suitable for NAILE modeling.

Additional ground to air topologies for networking UAS platforms also needs to be further evaluated for potential implementation by the sponsor.

Also, another item for consideration is determining where to complete intelligence, surveillance, reconnaissance and targeting data correlation, whether in the air, or afloat/ashore, and how that data can be safely and securely passed to ship/shore.

Acronyms

CA	communications architecture
FANET	Flying Mobile Ad Hoc Network
ISR&T	intelligence, surveillance, reconnaissance and targeting
NAILE	Networked Airborne ISR&T Long Endurance
NS3	Network Simulator 3
UAV	unmanned aerial vehicle
UAS	unmanned aircraft system