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Joint Fires in Support of Distributed Maritime Operations

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NPS NRP Executive Summary

Title: Joint Fires in Support of Distributed Maritime Operations

Report Date: 16 October 2019 IREF Project ID Number: NPS-19-N191

Naval Postgraduate School / School: (GSEAS/SE)

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JOINT FIRES IN SUPPORT OF DISTRIBUTED MARITIME OPERATIONS

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EXECUTIVE SUMMARY

Project Summary

As the Distributed Maritime Operation (DMO) concept continues to evolve, the idea of Joint Fires (JF) in support of DMO is gaining traction. This study explored options and concepts for employment of joint assets in support of maritime operations and enabled maritime calls for fire, supported by air- and land-based assets in the degradation and denial of Red Force reef island outpost capabilities. Specifically, we explored how well a small adaptive force composed of the Army, Air Force, Navy, and Marines can synchronize and coordinate a limited strike to destroy key enemy assets and how the utilization of the wireless mesh network affects those operations. The aim was to determine whether a mesh network will help or hinder the speed and accuracy at which the nodes can communicate. This research addressed and quantified potential benefits to mission success through the employment of a specific type of network. The mission success for this project was defined as the ability to effectively send and receive the voice, video, and data transmission necessary to support a joint fires limited strike. We suggest that further research include examination of scalable SATCOM networks to support larger user bases, possibly into the thousands.

Keywords: *joint fires, distributed maritime operations, mesh networks*

Background

The maritime domain is described by the Joint Maritime Operations as consisting of "oceans, seas, bays, estuaries, islands coastal areas, and the airspace above these, including littorals" (Joint Chiefs of Staff 2018b, x). It is in this environment that this research explores, through model and simulation, the effectiveness of a mesh network and how the type of communications network can influence mission success. In an article titled, "Hiding Comms in Plain Sight," the authors specifically mention the littoral operational environment as one being a challenge due to the physical geography and congested waterways (Bordetsky, Benson, and Hughes 2016b). Operating in a crowded environment or an environment where the geography physically constrains operations adds an increased layer of complexity to the effectiveness of a network. In these types of environments, "where defensive and offensive measures are much harder to carry out" success often relies on an ability to stay mobile and flexible (Bordetsky, Benson, and Hughes 2016b).

Networks that can automatically adapt to dynamic situations and still provide robust capability are critical to mission effectiveness. Mesh networks are potentially a solution to the complexity that complicates the congested maritime environment. The inherent characteristics of a mesh network allow for each node within the network to act as a router. Each node is self-aware and can create a path depending on the message type and the intended target (Herzig 2005). As a result of these self-healing and autonomous links, these "undetectable mesh networks can deliver a significant amount of time-sensitive information while platforms and operators rapidly change locations" (Bordetsky, Benson, and Hughes 2016b).

Our systems analysis focused on modeling the impact of different communications network configurations on reliability and the effectiveness of a JF DMO. The models and simulations were created to determine how well each network configuration could support similar data types. Our hypothesis is that mesh networks would provide clear benefits versus star networks in a littoral environment.

Findings and Conclusions

The backdrop of this study was a series of three JF DMO scenarios designed to degrade the radar capabilities on a Country Red reef island outpost. The scenarios used a combination of air and sea assets with varying capabilities. Scenario #1 was a direct assault on the target radar by a SEAL squad in cooperation with a Combat Craft Medium (CCM), a Navy Littoral Combat Ship (LCS), an Air Force MQ-9, and a Scan Eagle. Scenario #2 removed the MQ-9 but inserted an Army Logistics Support Vehicle (LSV) outfitted with Containerized Missile Systems (CMS). Scenario #3 combined all assets of Scenarios #1 and #2.

The purpose of the scenario models developed for this study was to help give the reader a better understanding of how the tightly coupled data type, data rate, and desired network capabilities impact the network design. This helps highlight the design constraints of the implemented network. The simulation results were used to define a baseline reference and traceable data requirements to support a tactical network designed for a JF DMO.

Network setups are often depicted by their topology, which is the physical way in which the nodes within that network are arraigned and can communicate (U.S. Army Engineering Division 1984, 7). This research compared a traditional Star network, against a multilayered Mesh communications network and quantified how the arraignment of those links might affect operations.

The most widely used topology for a wireless network is that of a star geometric pattern. A star topology consists of a central node through which all information flows. In the star format, all information must be sent and received from each participating asset and routed through the central hub. The central node in this configuration represents a single point of failure. If the central node is taken offline, the entire network will go down.

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A multilayered tactical wireless mesh network refers to the process through which information is shared within a network. A mesh network describes a configuration where each node has the capability to communicate and can both send and receive messages to one another. In a mesh, the nodes are self-organizing and automatically establish on an as-needed basis (Shillington and Tong 2011).

There were two communication architectures modeled that were based on line of sight (LOS). To be LOS, there must be little to no obstructions between the transmitter and the receiver. Geographic features like mountains and the curvature of the Earth along with natural features like trees that block the transmission path create a connection type that is called beyond line of sight (BLOS).

BLOS architectures were used for over the horizon communications and have the advantage of poor detectability by near-peer LOS detection systems. Two types of BLOS communications architectures were implemented using bent-pipe or hub-relay structures. Both architectures were represented in the model to account for the time delay inherent in each for a message to reach its intended target node or hub.

For evaluation, both LOS and BLOS threshold models were created in Microsoft Excel. The simulation results were then used to determine the desired message completion rates (MCR) and network parameters for ExtendSim simulations. Excel modeling was also used to validate and modify position reporting rates, based on the type of platforms used in the mission scenarios. ExtendSim was used to model discrete network performance and evaluate user demands introduced by changing network and parameters. Finally, MATLAB was used for post processing and analysis of the data-logs generated by the ExtendSim simulations.

Network configurations had the most impact on the overall performance based on the application data requirements for interfacing with dependent joint assets. Delay and network reliability for both unicast and broadcast traffic were performances measured in the network configurations. Critical design factors that impacted the system performance were related to the data transition requirement, message transmission unit sizing, messaging overhead for network control, encryption, and emission controls.

Network design considerations need to support the data requirements for applications and services to be effective. To enhance JF DMO, strong consideration should be given to the messaging between assets to optimize the amount of data that needs to be transmitted. The message size directly impacts the network configuration performance. Network responses are based on how it handles messaging transmission, data rates, location of network controllers, and how external data is injected and distributed over the network.

Recommendations for Further Research

We recommend that future researchers address the following:

- Determine optimal battlefield reporting for higher confidence in human decision making based on situational awareness.
- Research scalable SATCOM networks to support larger user bases into the thousands.
- Research in the predictive algorithms to predict position reporting with minimal data reporting from users.
- Research into benefits of moving network routing capabilities from RF communication systems into warfighting computing devices using software-defines networking technologies.

References

Bordetsky, Alexander, Stephen Benson, and Wayne Hughes. 2016b. "Hiding Comms in Plain Sight." Signal. June 1, 2016. https://www.afcea.org/content/Article-hiding-comms-plain-sight.

Joint Chiefs of Staff. 2018b. Joint Maritime Operations. JP 3 32. Washington, DC: Joint Chiefs of Staff. https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_32.pdf?ver=2019-03-14-144800-240.

Shillington, Luke, and Daoqin Tong. 2011. "Maximizing Wireless Mesh Network Coverage." *International Regional Science Review* 34(4) (March). 419–437. https://doi.org/10.1177/0160017610396011.

U.S. Army Engineering Division.1984. *Reliability Report for Communications Networks.* HNDSP-84-096-ED-ME. Https://apps.dtic.mil/dtic/tr/fulltext/u2/a153764.pdf.

Acronyms

Beyond Line of Sight	BLOS
Combat Craft Medium	CCM
Containerized Missile System	CMS
Distributed Maritime Operations	DMO
Joint Fires	JF
Littoral Combat Ship	LCS
Logistics Support Vehicle	LSV
Line of Sight	LOS
Message Completion Rate	MCR
Satellite Communications	SATCOM