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ABSTRACT

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Analysis of Network-Enabled ASW Concepts of Operation

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Analysis of Network-Enabled ASW Concepts of Operation

This paper presents a framework for the quantitative analysis of networked-enabled warfare concepts using Queueing Theory. This framework is useful for quantitatively analyzing the value added of network-enabled warfare over platform-centric warfare. Applications of this framework to Anti-Submarine Warfare (ASW) are presented. This work was funded primarily by the Naval Undersea Warfare Center in support of the international five-allied-country (Australia, Canada, New Zealand, United Kingdom, and United States) "The Technical Cooperation Program", Maritime Systems Group, Action Group 1, involving a study of "Network-Centric Maritime Warfare".

In recent years, numerous publications have promoted the benefits of network-centric warfare, but most provide no quantified justification. However, military decision makers need the results of quantitative analysis to support assessments leading to informed investment decisions for acquiring network-centric capabilities. Our research indicates that Queueing Theory can provide a useful framework for the quantitative analysis of warfare systems and tasks that can be characterized as a "demand-for-service" process. In such processes, the idea is that there are "customers" who demand "service." Examples of various maritime systems and tasks that we have examined include: anti-air warfare (including fighter interception and cruise missile defense), ship self-protection tasks such as anti-swarm attack, strike, command and control, intelligence gathering, maritime interception operations and ASW. This paper focuses on the application of Queueing Theory to quantifying the value-added of networking in selected ASW concepts of operation.

After a general description of the ASW search problem, two network-enabled ASW concepts of operation are described and analyzed. These concepts are:

1. Use network-enabled Shared Situational Awareness (SSA) to reduce false contact loading, thereby increasing the probability of finding threat submarines, and
2. Use a network-enabled collaborative environment to provide operator "reach-back" to ASW experts, thereby improving target classification performance.

For each of these concepts, a tactical situation is described and then metrics are defined and quantified by means of mathematical models. Some of the input data needed is derivable from first principles, but there is also a need for empirical data.

In the first tactical situation, a submarine conducts a barrier operation using passive sonar in a false contact environment comprised mainly of neutral fishing vessels. In the case where the submarine uses only organic sensors, it can be pulled off its search track for further investigation of a contact due to misclassifying the surface contact as a threat submarine. In a network-enabled environment, third-party sensors can be used to provide the submarine with the surface "picture", thereby eliminating some of the false contacts and the need to investigate them to resolve the contact classification issue. This network-enabled concept leads to missing fewer targets of interest during ASW search.

Interest in the second tactical situation arises because it is known that a large fraction of fleet sonar operators perform significantly poorer than a small fraction of expert-level sensor operators. Therefore it might be possible to use a communications network to link sensors, operators, experts (not co-located with forward operators) tactical decision aids, and commanders to improve ASW performance through distributed collaboration between operators and experts. The expert would be co-located with the Theater ASW Commander and he could provide “service” to one or more forward operators. The expert’s performance has queueing and workload aspects and these are examined.

The principal findings of this research and analysis are:

1. Queueing Theory can provide a framework for the analysis of ASW because ASW and its subtasks are “demand for service” processes.
2. ASW success can be increased by improving classification performance against both benign contacts and targets of interest. In effect improving classification performance against benign targets reduces their percentage arrival rate which thereby increases the probability of acquiring targets of interest.
3. An accurate surface picture, shared among the ASW units, could increase ASW success. Networking the force for information transfer is a key enabler of this aspect of shared situational awareness.
4. An alternative method for increasing ASW success is to employ more ASW units, i.e., increase the number of “servers.”
5. The Queueing Theory framework can be used to analyze the tradeoff in benefits between shared information and force size (“bits” vs. “bangs”).
6. A communications network enables distributed collaboration which, through the increase in probability of correct classification and improvement in other functions, could increase the probability of ASW success.