The Systems Thinking Approach of Beyond-Line-Of-Sight Command and Control

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ABSTRACT

Effective command and control (C2) is necessary to achieve and maintain superiority in military engagements. C2 is well documented in the literature and is a major focus in the military arena; however, the conventional military network topology is increasingly becoming a liability and ineffective in the new age of asymmetric warfare. The beyond-line-of-sight command and control (BLOS C2) concept is a radical shift towards a seamless joint network topology, which will dramatically increase tactical C2 across military service branches, equipment types, and geographical locations. Though BLOS C2 is still in its testing phase, this paper examines the systems thinking approach of BLOS C2 with respect to layered models, adaptation, and synergy. The implementation of the BLOS C2 "tactical Wi-Fi" concept helps fill a Central Command (CENTCOM) capability gap in support of a Contingency Plan (CONPLAN) that provides Navy Forces Central Command (NAVCENT) with a robust force protection system.

Keywords

BLOS C2, Command and Control, Beyond Line of Sight, Tactical Wi-Fi, Systems Thinking, Adaptation, Synergy, Layered Models.

INTRODUCTION

The term command and control (C2) has its origins in the Industrial Age and has been used in its current state for over 50 years (Alberts and Hayes, 2005). Many definitions for C2 exist in the literature depending on the context to which it is being applied. The official U.S. Department of Defense defines it as, "responsibility for effectively using available resources, planning the employment of, organizing, directing, coordinating and controlling military forces for the accomplishment of assigned missions" (*Department of Defense*, 2011).

According to Alberts and Hayes, command and control is the need to recognize and act on the realities of complex operations, along with the necessity to capitalize on shared situational awareness. Command is scalable and driven by those functions listed below (2006):

- Establishing goals or objectives (intent);
- Determining roles, responsibilities, relationships;
- Establishing rules and constraints; and
- Monitoring and assessing the situation and progress.

Alternatively, control has emergent properties which are limited by the initial conditions established by command (Alberts and Hayes, 2007).

Although C2 is recognized as an important facet of military function and is instrumental in achieving and maintaining tactical advantage, inherent design limitations of current military network topologies fall short of achieving Pareto efficiency. Implementation of the BLOS C2 concept expands the Pareto boundary (*Pareto efficiency*, 2011) of the tactical network and will enhance levels of nodal connectivity without degrading network fidelity.

Networks within and without each branch of the military are relentlessly restrained (Hoffman, 2011), resulting in Pareto deficient C2 while enduring difficulty sharing information across service boundaries during joint military endeavors. Although this communication deficiency has been acknowledged for some time now, the problem has escaped attempts at finding a practical solution. The BLOS C2 concept is a systems thinking approach to bridging the gap of disparate military communication networks that share a similar mission but are unable to share the information necessary to effectively execute joint military operations.

This short paper is a systems thinking analysis of the BLOS C2 concept that is currently in the experimental phase. The following sections will address these systems properties as they relate to BLOS C2: Layered models, Adaptation and Synergy. An overview of the BLOS C2 concept is provided in the next section as the foundation for the remainder of this paper.

BACKGROUND

Beyond-Line-Of-sight Command and control (BLOS C2)

The objective of BLOS C2 is to provide pervasive battle space awareness through improved communication. Communication will be improved, not just simply via the relay of analog voice communications, but via the implementation of a high-bandwidth, Internet protocol (IP) based, battlefield network. This network will support air-to-air, air-to-ground, and air-to-surface transmission of real-time, bi-directional full-motion video (FMV), as well as collaborative command and control (C2) via voice over Internet protocol (VoIP), chat, images, and track information.

The network is distributed among and via a number of military assets, including: satellites, U-2 aircraft, MQ-9 Reaper Unmanned Aerial System (UAS), Bombardier Global Express aircraft modified as Battlefield Airborne Communications Node (BACN), tactical jet aircraft, maritime operation centers (MOC) aboard destroyer (DDG) ships, Tactical Operations Centers (TOC), and mounted/dismounted troops (note that the integration with sea-based MOC and terrestrial TOC make this a truly joint initiative).

Providing ubiquitous connectivity between common-mission nodes that currently utilize disparate communication systems is the key to BLOS C2. This transparent connection to the combat end user has come to be known as "tactical Wi-Fi". Interoperability is needed to increase battle space awareness through improved communication without degrading mission effectiveness by imposing onerous requirements for network establishment and maintenance.

A key component of BLOS C2 is the Tactical Pod (TACPOD), which is carried (normally in pairs) on the wing of the Reaper UAS. The TACPOD acts as a hub / relay / translator for a variety of communication streams. As a component of BLOS C2, TACPOD will help to satisfy a Central Command (CENTCOM) capability gap in support of a Contingency Plan (CONPLAN) that provides Navy Forces Central Command (NAVCENT) a robust system for force protection.

Pareto Set Criteria

For any network system, there exists a theoretical limit (also known as a Pareto boundary) that defines the trade space between capacity and performance; as capacity approaches the upper limits of a given network, performance is degraded.

In this section the number of connected nodes is contrasted with network fidelity as a Pareto set. For this paper fidelity is defined as reliability and throughput in which case BLOS C2 essentially expands the Pareto boundary from that which is available from a traditional C2 system. The result is an increased number of nodes that can be connected without degradation of network fidelity. Taking advantage of this new capability amounts to a significant Pareto improvement (*Pareto efficiency*, 2011).

Figure 1 illustrates these theoretical boundaries (note: Pareto boundaries aren't necessarily as smooth as depicted). Point A represents a stage which may still undergo Pareto improvements, that is, more nodes may be added without degradation of network fidelity. Point B represents a system state that lies on the traditional network Pareto boundary, therefore assuming the system is not altered (e.g., equipment or software changes that result in capability improvements) the number of connected nodes cannot be increased without degrading network fidelity. Conversely, the network fidelity cannot be improved without decreasing the number of connected nodes.

Point C lies on the theoretical limit of the BLOS C2 Pareto boundary which is beyond the realm of traditional C2 networks. Note the increased number of nodes which can now theoretically share information with increased network fidelity. Under the traditional C2 network topology paradigm, this level of Pareto efficiency would not be possible.

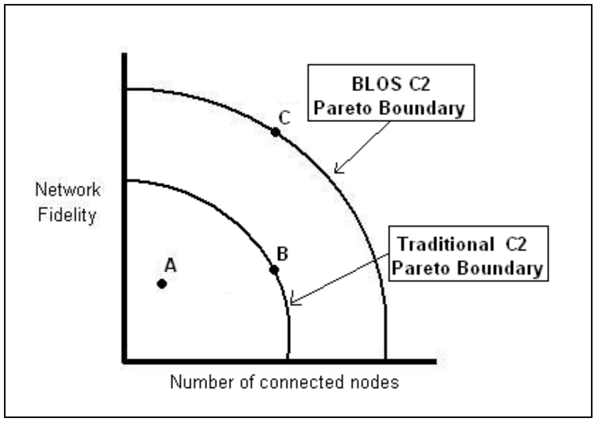

Figure 1. Theoretical BLOS C2 Pareto boundary: network fidelity versus number of nodes.

Systems Thinking

While traditional analysis uses the "divide and conquer" approach to solving problems, systems thinking embraces an holistic assessment of the requirements within their environment (Capra, 1996) which often leads to a different result than one obtained from a reductionistic analysis. Systems thinking has proven valuable in the following areas (Aronson, 2011):

- Complex problems that involve helping numerous individual actors "see the big picture" and not just their part of it.
- Recurring problems or those that have been made worse by past attempts to fix them.
- Issues where an action affects (or is affected by) the environment surrounding the issue: either the natural environment or the competitive environment.
- Problems whose solutions are not obvious.

While analytical methods have their place in solving simple and/or very specific problems, their use in complex problem solving can introduce undesired side-effects (Aronson, 2011). Systems thinking enables holistic problem conceptualizations that help us understand the interaction of variables within complex problems (Skyttner, 2005). Although the concept has been around for millennia, Senge helped to frame systems thinking as we know it today with eleven laws which capture the spirit of systems thinking philosophy (2006).

SYSTEMS THINKING APPROACH OF BLOS C2

The BLOS C2 concept is built upon a systems thinking approach that attempts to answer the need for a seamless joint military network. The network will be evaluated against the system attributes of layered models, adaptation and synergy in the following sections.

Layered Models

The ability of BLOS C2 to enable seamless, joint network connectivity is based in the multi-layered design of the architecture (Hitchins, 2003) as data is passed through multiple layers of the system enroute to its destination. Consider the geographically isolated and tactically disadvantaged network user; a soldier located on the side of a mountain in Afghanistan who needs to send FMV to headquarters (HQ) in Washington, DC. While the possible paths of data packets to the desired destination may exhibit equifinality, they are likely to traverse multiple layers of the BLOS C2 system, trailing across equipment types, frequency ranges and service boundaries.

One possible path for data packets could be: hand-held radio to UAS, UAS to BACN, BACN to U-2, U-2 to Satellite, Satellite to TOC, and finally TOC to Washington, DC HQ. Clearly this path has several layers which, depending on the circumstances, may cross service boundaries, require frequency conversions, and include multiple equipment types. The layered aspect of the BLOS C2 model offers customized, bidirectional connectivity to the most geographically disadvantaged user. This system thinking attribute enables nodes buried deep in the catacombs of the battlefield network to be reachable by virtually all other BLOS C2 nodes.

Adaptation

The systems thinking attribute of adaptation is of a cyclical nature as systems and their environments are very closely related. A system that adapts to its environment, changes its environment - which effectively initiates another adaptation. The ability to adapt is a factor of the stability of a system. Systems that possess increased capability to harmonize with dynamic environments also have improved survivability rates (Skyttner, 2005). Nodes on the BLOS C2 network are constantly in motion and the circumstances of military engagements are highly dynamic. Typically, traditional networks are challenged to maintain connectivity due to their relatively fixed nodes in rapidly shifting mission environments. The BLOS C2 architecture was designed to adapt and ensure nodes maintain connectivity by capitalizing on unpredictable mission dynamics to extend and increase the fidelity of the network. Simply put, BLOS C2 manipulates uncertainty and chaos to its advantage.

The BLOS C2 architecture also has the capability to ensure alternate paths for data packet transmission are used if primary nodes become congested. This adaptation method helps reduce packet loss and increase network fidelity. If any node leaves the network bubble (e.g., a soldier is repositioned behind a mountain), UAS or other network assets can be programmed to automatically adjust flight patterns to ensure connectivity is maintained.

This continuous morphing is an important factor in the fidelity of the system. While system adaptation is generally good for survivability, passive adaptation in a deteriorating environment can lead to disaster (Gharajedaghi, 1999) and is analogous to the old adage "if you want to boil a fish to death, don't place it in hot water because it will jump out. Place it in cool water and slowly turn up the heat". Without proper feedback loops, systems can slowly self-destruct.

While the BLOS C2 is a powerful and robust system, there are scenarios that must be addressed to avoid system failure. One such scenario is the continual addition of outlying nodes, each connecting directly to a hub with no alternative paths for packet transmission. If no limits are placed on nodal connections to a single hub, a self-inflicted denial-of-service (DoS) attack could result, bringing down that branch of the network. Incorporating a *connection count* variable into a negative feedback loop could avoid DoS by denying additional connections as nodal connections approach predetermined upper limits.

Synergy

The BLOS C2 network consists of many assets which when working together, define its system properties as a whole. Each of those parts work together to enable network bi-directional connectivity between geographically (in some cases, globally) distributed users; without any one of them the BLOS C2 system will exhibit diminished network effectiveness.

Instead of focusing on individual components as is typically done in reductionist techniques, the BLOS C2 concept takes the holistic approach to bridging the communications gap by viewing disparate military networks as components of a single system. Achieving synergy among the dissimilar components located on diverse networks highlights the primary advantage of the BLOS C2 system. The BLOS C2 synergy approach connects the unconnected and breathes systemic life into otherwise inert, disconnected and ineffective network parts.

The interoperable nature of the BLOS C2 network is revealed as the network is traversed. The overall system is made up of smaller sub-systems, and drilling deeper into the network reveals even smaller sub-systems. Acknowledging this fractal pattern (Mandelbrot, 1983) of systems gives the appreciation that systems can never be known completely as alluded to by the darkness principle (Skyttner, 2005). This being the case, sub-systems of BLOS C2 architecture are better understood if placed in the context of the overall system as opposed to isolated analysis. Optimizing interaction and maximizing synergy among sub-systems in the BLOS C2 network is a major factor which enables the expansion of the Pareto boundary for nodal capacity and network fidelity.

CONCLUSION

BLOS C2 is a systems thinking approach to solving a complex and long-standing command and control dilemma. By visualizing traditional, stove-piped communication network topologies as sub-systems of a larger over-arching system, the BLOS C2 network enables different branches of the military to share information seamlessly and has potential to become a Revolution in Military Affairs (RMA). Just as the establishment of ubiquitous cellular networks spawned the smart phone and innumerable "apps", BLOS C2 may enable the exponential acceleration of command and control technology. As a layered network that can adapt in real-time, the synergistic combination of multiple, disparate capabilities into a single information stream constitute an RMA.

BLOS C2 extends the benefit of global information sharing to even the most isolated areas of military engagement. With proper analysis and application of information assurance, the challenges of effective C2 are both alleviated and secured. As an expansion of the Pareto boundary of C2, more nodes can be connected without degrading network fidelity. This systems thinking approach to a deeply rooted, complex networking problem has unbounded potential as technology capabilities continue to improve. As the BLOS C2 network takes root, command and control will undoubtedly enter a new era of information and data sharing across US military services and coalition members.

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