Overview

Network Optional Warfare (NOW)

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Motivations

- **Naval forces do not have to be engaged in constant centralized communication.** Deployed Navy vessels have demonstrated independence of action in stealthy coordinated operations for hundreds of years.

- Littoral operations, deployable unmanned systems, and a refactored force mix for surface ships pose a growing set of naval challenges and opportunities.

- Four Network-optional warfare (NOW) precepts for deliberate, stealthy, minimalist tactical communications:

  Efficient Messaging, Optical Signaling, Semantic Coherence, Ethical Human Supervision of Autonomy

Network Optional Warfare (NOW)

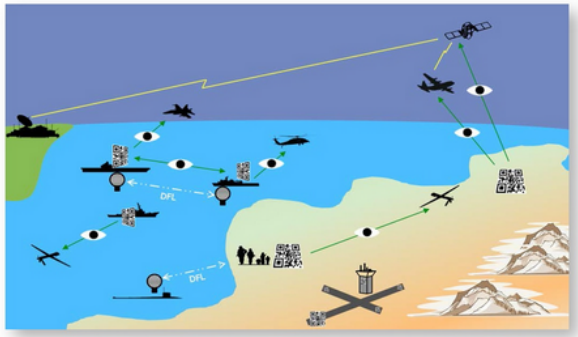
Network-Optional Warfare (NOW)

- ***Major vulnerabilities:*** naval forces conducting constant communications lack stealth and become dependent on continuous data exchange.
- ***Agile EMCON:*** "Radio silence" emissions control with judicious use of low-probability of intercept (LPI) communication channels, such as optical.
- ***Messaging maturity:*** efficient compression and a coherently defined signal book, aiding remote command initiative and operational freedom of action.
- ***Ethical Human Supervision of Autonomy:*** allow unmanned systems with potential for lethal force to operate reliably at a distance, directed by humans to follow same tasking + constraints as any other trusted participant.

Network-Centric Warfare (NCW)

- "Seeks to translate an information advantage, enabled in part by information technology, into a competitive advantage through the robust networking of well-informed geographically dispersed forces."
- "This networking—combined with changes in technology, organization, processes, and people—may allow new forms of organizational behavior."
- Source: Network-Centric Warfare, Wikipedia

Operational emphasis: opportunity to restore naval covertness and potential for tactical surprise, enabling fluid operations by fleet and marine forces across NCW and NOW.



Operational View (OV-1) shows line-of-sight (LOS) optical signaling via Quick Reaction (QR) codes and Digital Flashing Light (DFL). Only two radio frequency (RF) lightning bolts!

https://wiki.nps.edu/display/NOW/Network+Optional+Warfare

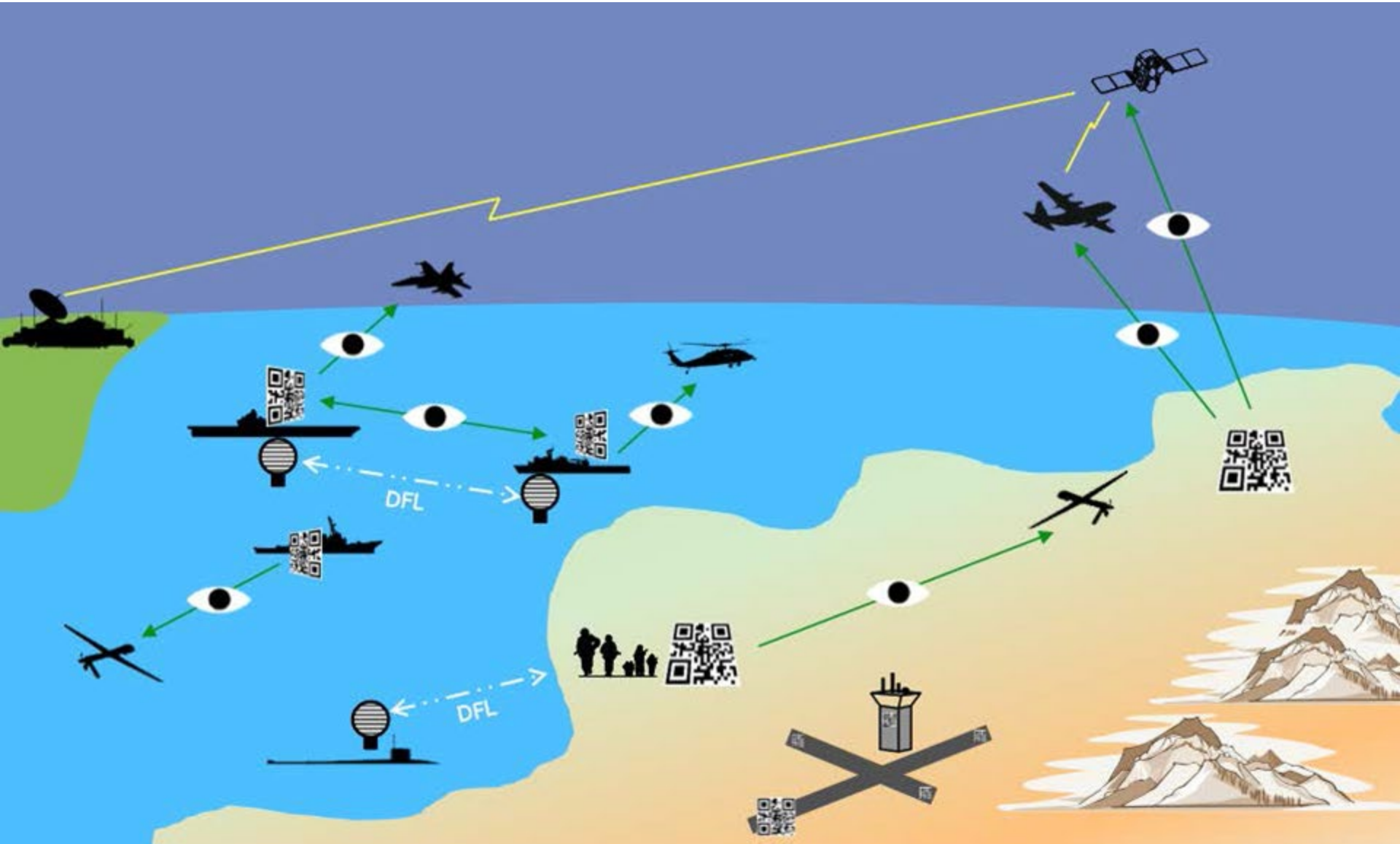
Working definition: NOW

Network Optional Warfare (NOW)

- Vulnerabilities arise for naval forces conducting constant communications due to lack of stealth and dependence on continuous data exchange.
- Emissions control (EMCON) and judicious use of low-probability of intercept (LPI) data channels can restore naval covertness and tactical surprise.
- Data compression and a well-defined signal book can enable fluid operations across NCW and NOW, aiding command autonomy and freedom of action.

https://wiki.nps.edu/display/NOW/Network+Optional+Warfare

Optical communications operational concept



Sea change in naval strategy is under way

Imminent threats, especially in **Littoral Operations**

- Freedom of maritime operations, South Pacific
- Budget pressures simply preclude status quo

Major strategic response: **Distributed lethality**

- Bimodal fleet provides selective presence where needed, only use blue-water ships when decisive
- Bimodal fleet supports maritime collaboration and gradated response in naval operations
- Must broadly integrate use of unmanned systems

Strategic benefits as well

Low-cost escalation becomes practical rather than destabilizing reliance on high-stakes forces

- Leading with carriers and submarines carries risk of immense economic, political costs if one is lost
- … U.S. might win battle but lose the longer war

Flotilla + NOW conops can change the playing field

- Shift economics of gradual escalation in our favor
- Stabilizing: allies hold the asymmetric advantage

Net-Centric plus Network Optional Yields Mission-Agile EMCON

NOW blog

Brutzman, Donald (Don) (CIV) posted on Jun 24, 2015

CC4913 Class Project report and briefing, April 2015

Point of Contact: Professor Dan Boger, dboger@nps.edu, 831.656.3671

CC4913 Policies and Problems in C2 is a capstone course for NPS Command and Control students. Study of the fundamental role C2 systems fulfill in operational military situations, including the full range of military operations. Topics include analysis of the changing role of organizational structures and processes, as well as technologies and impacts on C2 systems requirements and designs. Considerations include the complexities imposed on C2 systems as the force structure becomes more heterogeneous. Case study of selected incidents and systems provide a focus on current problems.

This year's class was divided into RF and non-RF groups and asked to explore C2 issues in a scenario where we were trying to prevent conflict by "holding at risk" aggressors in a complex political and geographic situation described above. In last year's scenario, high power jamming only originated from the mainland. Developments in the past few months caused a change in that assumption: all SATCOM uplinks are at risk within 300 miles of fixed bases and large surface ships. This was how our simple communications wargame transpired: Aggressive action by nation X; Send in UAV to support ROL (Predator-Global Hawk); Lose UAV SATCOM link; Send in missile boats; Missile Boats tracked via omni-MF and VHF; Send in UAV (Shadow-Scan Eagle); Lose UAV CDL; Patrol boats to visual range – all RF comm jammed; Patrol boats exfil to establish link; Picture gone. This led us to consider a combined RF/non-RF solution.

Network Optional Communications (NOW) is comprised of the following potential methods: lasers, flashing light in various bands, underwater/acoustic, QR codes, and data muling. What we rediscovered was this is not a question of RF vs non-RF. There is a spectrum of options, and we may decide to operate at some level of EMCON to avoid detection. Or the enemy and weather may conspire to reduce the availability of our network. We found situations where there did not appear to be a viable and elegant RF solution but a hybrid combination of techniques could meet user requirements. We refer to this as Mission Agile EMCON and is shown on slide 32 of the accompanying presentation. Slide 34 presents our recommendations.

Attached. Class Project Report and Class Project Briefing.

This work was presented at the Littoral Combat Ship (LCS) Wargame Planning and Innovation Workshop hosted by the NPS Littoral Operations Center (LOC), 23-24 April 2015.

Supporting technologies for NOW

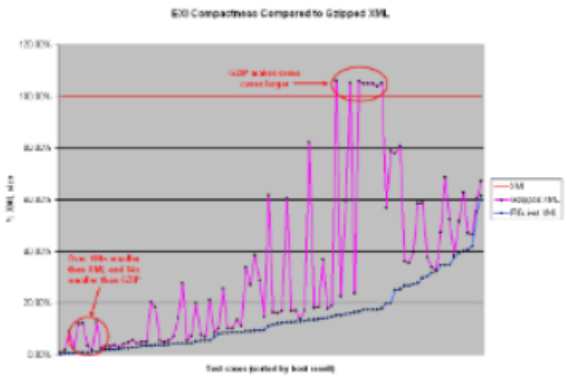
- Efficient Messaging
  - Efficient XML Interchange (EXI), WAN optimization
- Optical Signaling
  - QR code streaming, Digital Flashing Light (DFL)
- Semantic Coherence
  - Structured vocabularies, Navy/allied “signal book”

Efficient Messaging

Navy networks afloat are very different than networks ashore. Bandwidth is a precious and finite resource, latency can be huge, connectivity can be intermittent, environmental effects dominate, channels are limited in varying ways, and mobile relays are rare. Manned and unmanned naval systems need efficient messaging for networks afloat - but rarely have it. Failing to properly utilize communications capacity directly limits tactical effectiveness.

Efficient messaging is needed to take maximum advantage of severely constrained data links. The key to our strategies for achieving efficient messaging is first to use of Extensible Markup Language (XML) for structured data languages, and then use EXI for compressing XML. Since XML provides a flexible and validatable way to define regular data structures for any language, it provides a practical opportunity to compatibly capture and convert all manner of diverse data formats used for military messaging. The economics of Web technologies are undeniable and usually provide industry-wide best practices as well. As a result, this use of open standards is scalable and repeatable, avoiding the "stove pipes" which commonly prevent system-wide interoperability between Navy platforms and coalition partners.

"Efficiency" means both size and speed. EXI has demonstrated compaction that *always* meets or beats the most commonly used compression techniques (zip and gzip). Additionally, because EXI decompression goes straight into memory rather than string characters, which then require significant additional parsing, decoding EXI is many times faster than other techniques. This approach also reduces memory requirements and power consumption on small devices. Because Navy tactical traffic is usually highly structured and highly numeric, EXI provides major advantages that might well impact all afloat Navy communications. Alternative bit-centric compression schemes cannot take full advantage of those characteristics.



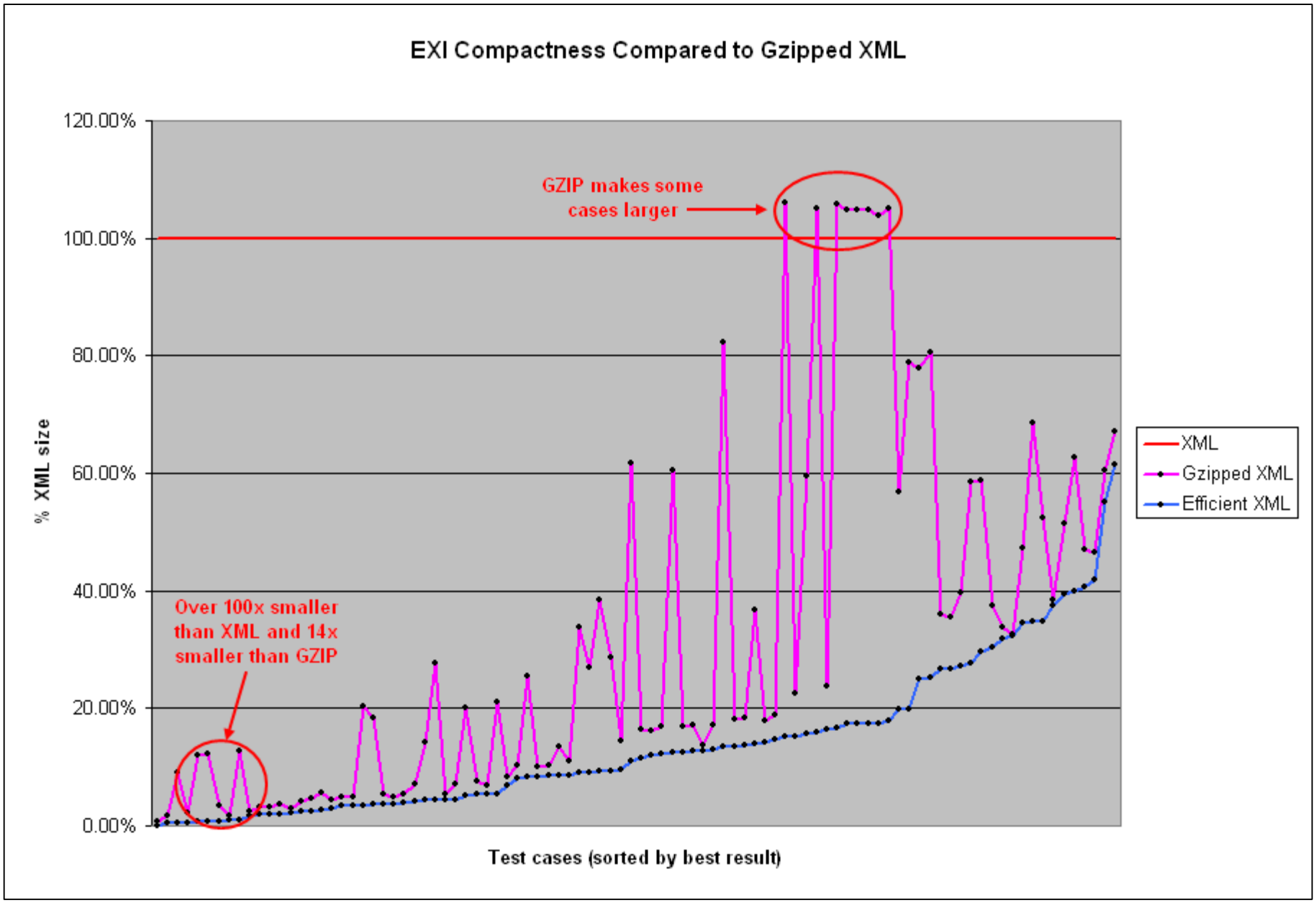
EXI Compactness
compared to Gzipped XML

Open EXI
A Quick Introduction

OpenEXI overviews: video and whitepaper

Multiple theses have provided in-depth analysis that Efficient XML Interchange (EXI) compression of XML/Web data can have major impacts on afloat communications.

EXI compression superior in all cases



USNI PROCEEDINGS article

Proceedings Magazine - July 2014 Vol. 140/7/1,337

Being Efficient with Bandwidth

By Lieutenant Commander Steve Debich, Lieutenant Bruce Hill, Captain Scot Miller (Retired), U.S. Navy, and Dr. Don Brutzman

Naval information dominance hinges on three fundamental capabilities: assured command and control (C2), battlespace awareness, and integrated fires. None of these are possible without effective communications links. Networks—and more specifically, the information flowing through them—are now a center of gravity for the Fleet. 1 Maritime tactics and operational plans rely on levels of synchronization only possible through high-bandwidth communications. Satellite communication (SATCOM) is the Fleet's primary path for high-bandwidth C2. However, afloat units may be denied access due to equipment failure, technical problems, weather phenomenon, or enemy actions, forcing reliance on lower-bandwidth alternatives.

For afloat units, bandwidth has become a critical but painfully finite resource that must be conserved. SATCOM carries data from a large number of disparate systems often referred to as "stovepipes." These systems vary in function from tactical to administrative, and the data formats for each application vary greatly. The result is communications only occurring vertically within a system, but not across the breadth of different systems. When many such stovepipes contend for access to the same ship-to-shore transport path, even the largest SATCOM channels can become congested. Future assured C2 requires interoperability between stovepipes and better prioritization of network traffic.

Before identifying the solution, we must understand the factors that impose constraints on the transmission path: bandwidth, latency, and throughput.

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NOW blog

Debich thesis: Navy WAN optimization

THE ROLE OF EFFICIENT XML INTERCHANGE (EXI) IN NAVY WIDE-AREA NETWORK (WAN) OPTIMIZATION

Created by Brutzman, Donald (Don) (CIV), last modified on Jun 12, 2015

THE ROLE OF EFFICIENT XML INTERCHANGE (EXI) IN NAVY WIDE-AREA NETWORK (WAN) OPTIMIZATION

Steven Debich, Lieutenant Commander, United States Navy

Thesis, Master of Science in Network Operations and Technology, March 2015

Advisor: Don Brutzman, Department of Information Sciences. Co-Advisor: Scot Miller, Department of Information Sciences. Second Reader: Don McGregor, MOVES Institute.

Abstract. Navy afloat units become disadvantaged users, once disconnected from the pier, due in part to the high latency associated with SATCOM. Unfortunately recent gains in SATCOM capacity alone do not overcome throughput limitations that result from latency's effect on connection-oriented protocols. To mitigate the effect of latency and other performance inhibiting factors, the Navy is improving its current WAN optimization capabilities by implementing Riverbed Steelhead WOCs. At-sea testing has shown Steelhead increases effective SATCOM capacity by 50%. Laboratory testing demonstrates that by encoding structured and semi-structured data as EXI rather than XML, compression ratios can be further improved, up to 19 times greater than Steelhead's compression capability alone. Combining EXI with Steelhead will further improve the efficient use of existing SATCOM capacity and enable greater operational capabilities, when operating in a communications constrained environment. Not only does EXI improve compactness of traffic traveling over relatively high capacity SATCOM channels, it also expands net-centric capabilities to devices operating at the edge of the network that are restricted to lower capacity transmission methods. In order to achieve these substantial improvements the Navy must incorporate the already mandated DISR standard, EXI, as the single standard for all systems transferring structured and semi-structured data.

Received Outstanding Thesis Award from NPS Information Sciences Department.

Keywords: EXI, Efficient Xml Interchange, EFX, efficient XML, Riverbed, Steelhead, WAN optimization, compression, long fat network LFN.

Links: catalog, slideset (.pdf), thesis.

Briefed to RADM Lewis, Command SPAWAR on 27 March 2015

NOW blog

Hill thesis: EXI compression for large datasets

EVALUATION OF EFFICIENT XML INTERCHANGE (EXI) FOR LARGE DATASETS AND AS AN ALTERNATIVE TO BINARY JSON ENCODINGS

Created by Brutzman, Donald (Don) (CIV), last modified on Jun 12, 2015

EVALUATION OF EFFICIENT XML INTERCHANGE (EXI) FOR LARGE DATASETS AND AS AN ALTERNATIVE TO BINARY JSON ENCODINGS

Bruce Hill, Lieutenant, United States Navy

Thesis, Master of Science in Network Operations and Technology, March 2015

Advisor: Don Brutzman, Department of Information Sciences. Co-Advisor: Don McGregor, MOVES Institute.

Abstract. Current and emerging Navy information concepts, including network-centric warfare and Navy Tactical Cloud, presume high network throughput and interoperability. The Extensible Markup Language (XML) addresses the latter requirement, but its verbosity is problematic for afloat networks. JavaScript Object Notation (JSON) is an alternative to XML common in web applications and some non-relational databases. Compact, binary encodings exist for both formats. Efficient XML Interchange (EXI) is a standardized, binary encoding of XML. Binary JSON (BSON) and Compact Binary Object Representation (CBOR) are JSON-compatible encodings. This work evaluates EXI compaction against both encodings, and extends evaluations of EXI for datasets up to 4 gigabytes. Generally, a configuration of EXI exists that produces a more compact encoding than BSON or CBOR. Tests show EXI compacts structured, non-multimedia data in Microsoft Office files better than the default format. The Navy needs to immediately consider EXI for use in web, sensor, and office document applications to improve throughput over constrained networks. To maximize EXI benefits, future work needs to evaluate EXI's parameters, as well as tune XML schema documents, on a case-by-case basis prior to EXI deployment. A suite of test examples and an evaluation framework also need to be developed to support this process.

Received Outstanding Thesis Award from NPS Information Sciences Department.

Keywords: Extensible Markup Language (XML), Efficient XML Interchange (EXI), JavaScript Object Notation (JSON), Compact Binary Object Representation (CBOR), Binary JSON (BSON), data serialization, data interoperability.

Links: catalog, slideset (.pdf), thesis.

Briefed to RADM Lewis Commander SPAWAR on 27 March 2015

Optical signaling

QR Codes

Digital Flashing Light (DFL)

Covert modalities

Optical Signaling for Network Optional Warfare (NOW)

https://wiki.nps.edu/display/NOW/Network+Optional+Warfare

Optical Signaling refers to Line of Sight (LOS) information transfer using visual means. Each of these techniques has the potential to significantly reduce vulnerability to detection of electromagnetic (EM) radio emissions.

Quick Reaction (QR) Code Streaming

Quick Reaction (QR) Codes can be used for single messages of various sizes or to create a streaming data channel.

Thesis work

- Lucas, Andrew, Digital Semaphore: Technical Feasibility of QR Code Optical Signaling for Fleet Communications, Master's Thesis, Naval Postgraduate School, June 2013. Received NPS Outstanding Thesis Award.
- Richter, Stephen P., Digital Semaphore: Tactical Implications of QR Code Optical Signaling for Fleet Communications, Master's Thesis, Naval Postgraduate School, June 2013. Received NPS Outstanding Thesis Award.
- Sokol, Christopher R., "A Study on Using Quick Reference Codes in Airport Surface Operations to Reduce Accidents and Incidents While Taxiing," capstone project, Embry-Riddle University, 18 June 2013.

QR Code on King Hall

NPS thesis work in 2013 investigated the possibility of viewing QR codes as a data-signaling mechanism to aircraft. Here are pictures of the completed QR Code on King Hall.

QR Chat

As part of our building an open-source application, here is a video demonstration of our open-source QR Visual Chat application that works without a network. Working nickname: *"Digital Semaphore"* for use in Network Optional Warfare (NOW).

Interested in learning more, or reporting that you've seen the rooftop QR code? Your feedback is welcome at qr@nps.edu, thanks!

Additional references

- **Digital Flashing Light (DFL).** New project referring to automation of classic Flashing Light signaling through use of QR Code (Digital Semaphore) streaming techniques.
- TODO: we are interested in obtaining a pair of Navy signal lamps for use in ongoing experimentation.
- Flag Semaphore display and recognition also appears to automatable using digital image analysis techniques.
- Laser and Free-space optical communication

http://qr.nps.edu

QR Code on King Hall

QR Visual Chat demo

Stay tuned, lots more to follow!

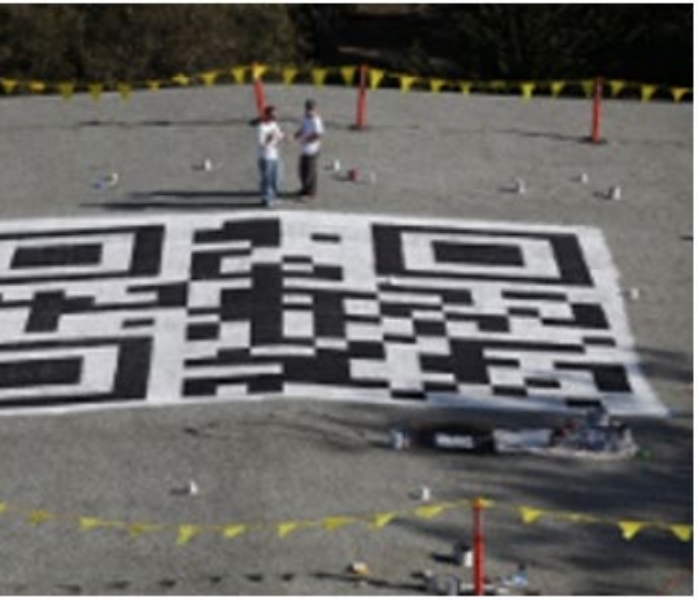
- Examining correspondences and corollaries between radio and optical domains
- Radar-absorbing, carbon-fiber clouds, aka "electronic smoke" (7th Fleet Tests Innovative Missile Defense System)
- Ongoing work comparing Network-Centric Warfare (NCW) and Network-Optional Warfare (NOW) approaches

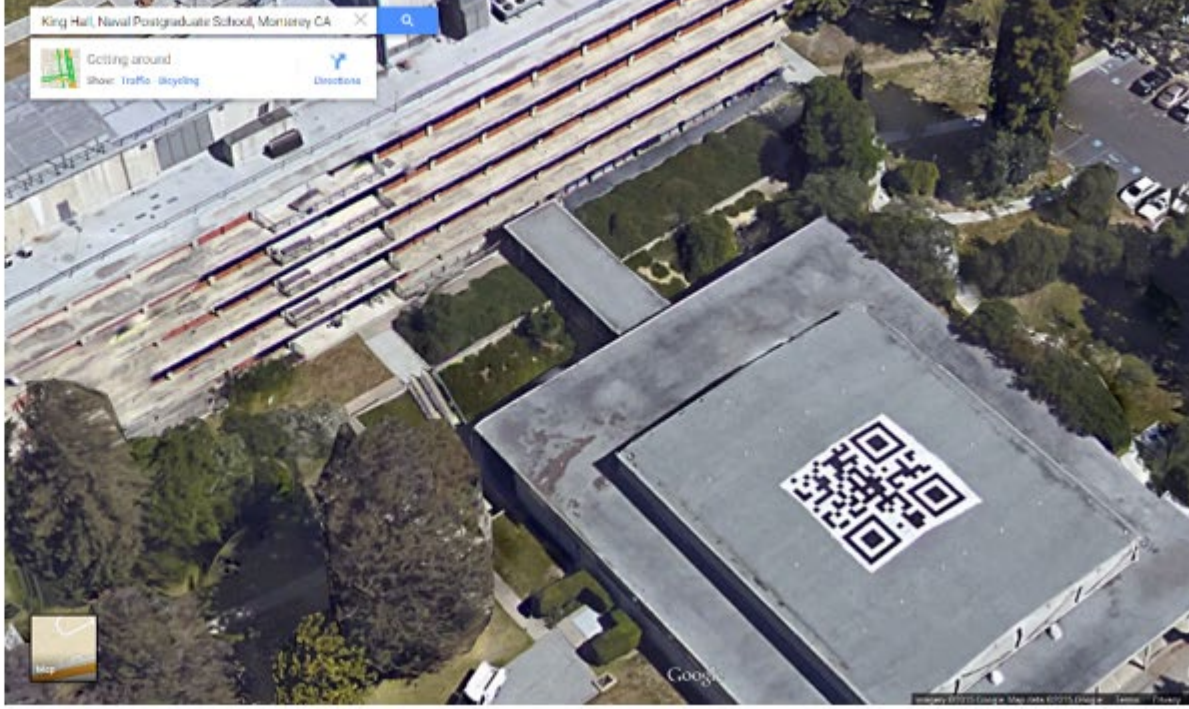
Contact

All questions and comments are welcome, please let us know what you think.

Don Brutzman, brutzman@nps.navy.mil +1.831.656.2149

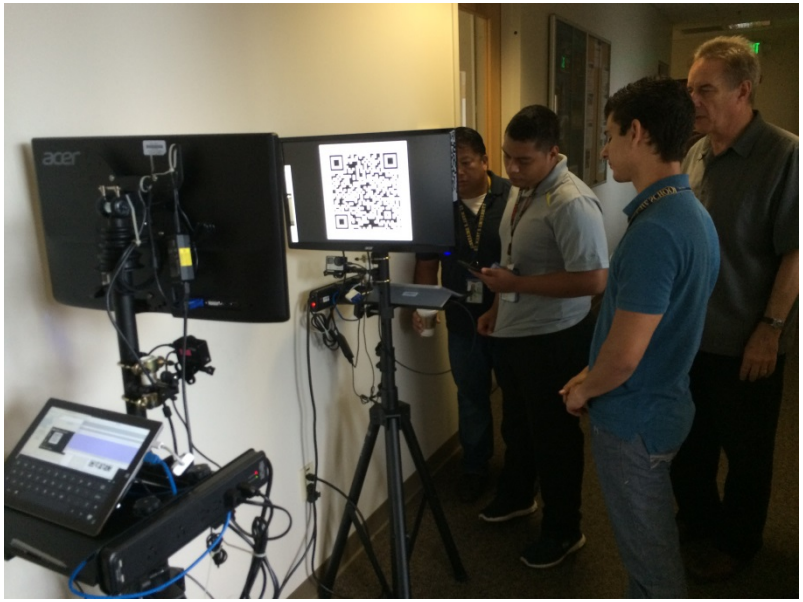
PS King Hall (overhead) and
panagel Hall (oblique view)

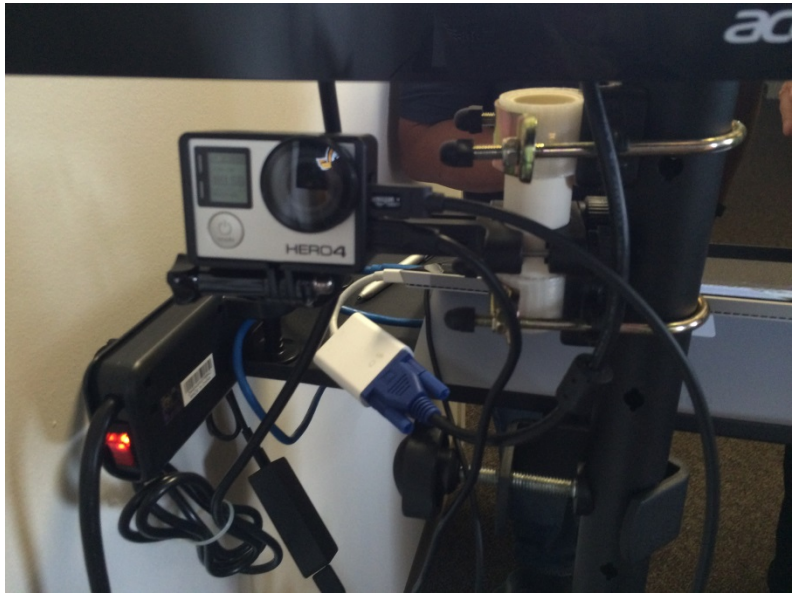


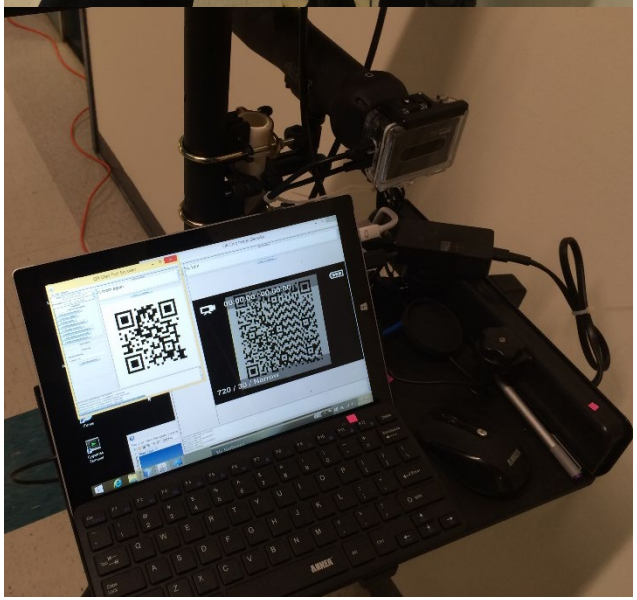


R pixels, initially unreadable

Open-source QR TDA software, test rig







Now can stream QR data 13-20m, proposed work to test across-campus signaling

Next steps for optical signaling

- Increase range: optics and displays
- Digital Flashing Light (DFL) experimentation
- Develop, establish streaming protocols
- Deploy and test capabilities at sea
- IO thesis student CAPT Stephen Philips USMC

Semantic coherence

QR Codes

Digital Flashing Light (DFL)

Covert modalities

Semantic Coherence

Military command and control (C2) systems often function similarly, but diverse message systems are not interoperable.

Patchwork communication links are commonly called stovepipe systems which only work within specific systems, not broadly across multiple systems. These incompatibilities surprise many people: if trained experts can understand such correspondences, why can't systems translate them also? Data format incompatibility is the primary cause of non-interoperability in communications for robotics, command & control (C2), and Modeling & Simulation (M&S) systems.

Achieving clarity. A fundamental consideration in the design of programming and data languages is that they consist of two primary components: syntax (form) and semantics (meaning). If both challenges are solved, then a language is effective. NPS has performed several projects that explore coherent syntax and consistent semantics for tactical messaging in the robotics, C2, and M&S domains. The Extensible Markup Language (XML) is the basis for syntax, and definition of common terms can provide the semantics. A broad harmonization appears to be possible between diverse protocols in military-relevant contexts. Messaging might become compatible, stovepipe connections might become links to a common coherent communications bus. Most important data exchange that can benefit from interoperability: *contact track information*.

Historic example. Well-known fact: the English Navy's signal-flag book was a critical factor in the Battle of Trafalgar which enabled coordination despite melee and English victory. Lesser-known fact: each night for the previous two years Admiral Lord Nelson went to dinner aboard every ship in his fleet. After dinner they laid out the charts on the wardroom table and he explained the details of the battle plans, what each signal-flag hoist actually meant, and how forces should proceed if communications were interrupted. As a result, the officers on every ship understood both commander's intent and the specific semantic significance of each of the signal messages. These ships were able to act both independently and collectively, even amidst cannon fire and smoke and confusion and "fog of war," winning this critical major battle.

Reclaiming past strengths. Countless examples exist throughout naval history where commanders acted independently with only intermittent communications to achieve coordinated goals. We are examining how semantic coherence might produce a concise and effective "signal book" for Naval messaging that improves interoperability while reducing both size and stove-piped complexity of at-sea message traffic. Our research is now applying these concepts to help connect three important domains: robotics tasking interoperability, C2 protocol interoperability, and simulation protocol interoperability.

Robot Task, Mission Interoperability for Ethical Operations

- Unmanned systems must work together with human systems, not magically and uniquely.
- Task constraints and prerequisites provide a path for ensuring autonomous lethal systems correctly execute commanders intent.
- Simulation work to show that coordinated human-robot teams can operate ethically in accordance with Law of Armed Conflict (LOAC)
- Semantic Web ontology shows tractability is possible for a wide range of diverse systems.

Data dilemma: security

- Most computer security and cyber defense activity in Navy is oriented around networks
- Sheer variety of systems, networks and usages makes a coherent defense nearly impossible
- Nature of problem has become battleground between network offense and defense

- But: we care most about data, not transport

Data-centric security

- Focus first on the information being shared
  - Who needs what? When, where and why?
- Utilize PII CAC infrastructure already in place
  - Encrypt and authenticate, in any combination
  - Use alternate encryption for external partners
- Network transport becomes much simpler
  - Data not at risk, whether in motion or at rest
  - “How” data gets sent becomes much simpler

Data-centric security pilots

- Pick a cross-cutting category of data sharing
  - Unclassified, unrestricted
  - Navy, cross-service, public, international
  - Multiple Action Plans and blog entries relate
  - Walk the walk, repeat and scale to learn quickly

- Data Strategy for Unmanned Systems Field Experimentation (FX), Simulation and Analysis
  - https://wiki.nps.edu/display/NOW/Data+Strategy+for+Unmanned+Systems

Additional topics, Semantic Coherence

No need to “fix” giant sprawl of software systems

- Each deployed on independent timelines anyway

Connect the stovepipes

- C2 protocol mappings, packet bridges
- M+S protocol mappings, packet bridges
- Interoperability lets M+S be part of warfight

Terse “core” signal book gives new systems, agents, computational resources bigger & better impact

Many paths to explore

- Agile EMCON: extending network-centric paradigms for asymmetric advantage
- Semantic coherency: terser “signal book” to make sense out of disparate stovepipes
- Concept extrapolation for real world locales
  - What do operations among 30,000 islands really mean?
- Walk the walk
  - Theses, partners, wargames, fleet experiments, plans
- Evolve naval operations and defense strategies

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