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Assessment of Global Information Network Architecture in Support of C2 Interoperability and Sensor Fusion (Summary Technical Report, Oct 2019–Sep 2020)

by Timothy Gregory, Michael Lee, and James Michaelis

NOTICES

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14. ABSTRACT
The Global Information Network Architecture (GINA) is a semantic modeling framework designed to facilitate integration of ad-hoc sensor assets and command and control systems as they become available to the operators in the battlespace using the implementation known as Vector Relational Data Modeling. A proof-of-concept assessment was developed to evaluate the interoperability and inference capabilities of GINA and tested on real-world sensor data.

15. SUBJECT TERMS
Summary Technical Report, STR, interoperability, Cursor on Target, GINA, sensor fusion, command and control, C2, Internet of Things, IoT, Military Information Systems

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1. Summary

As stated in the US Army's Multi-Domain Operation (MDO) concept,[1] our nation's adversaries seek to achieve their strategic aims, short of conflict, by use of layered standoff in the political, military, and economic realms to contest both US forces and coalition partners. Further, the MDO concept states that adversaries may employ multiple layers of cross-domain standoff—spanning land, sea, air, space, and cyberspace—to threaten US and coalition forces in time, space, and function. The central idea in countering these strategies is rapid and continuous integration of all domains of warfare (i.e., convergence) across time, space, and capabilities to overmatch the enemy.

Toward enabling MDO execution, interoperability across joint military services, government agencies, and multinational partners represents a key requirement. Tactical operations have become increasingly dependent on information networks for sensing, communication, coordination, intelligence, and command and control (C2). Accordingly, the US Army continuously seeks to improve its ability to integrate networked systems and synchronize effects at varying levels of operational tempo. Historically, such integration has posed technological challenges in evolving networked battlespaces featuring ubiquitous Internet of Things (IoT) and military C2 systems due to an inadequate capability to support both existing and emerging technologies and processes. This limitation is further exacerbated by silos of disparate systems, limiting both cross-system usage of tactics, techniques, and procedures as well as supporting hardware and software components. These limitations leave Warfighters with inconsistent and missing mission-critical data, driving warfighting functions to operate in isolation. For example, data exchanged between operations and intelligence is limited and constrained in scope, increasing risks and delays in the commander's decision-making process.

Toward the Army Network Modernization, the Army Futures Command Network Cross Functional Team (N-CFT) is investigating disruptive approaches to network interoperability through innovative, holistic, and adaptive information technology solutions that meet established C2 interoperability challenges. Per direction of N-CFT, US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) researchers evaluated a technology called Global Information Network Architecture (GINA) as a system-of-systems solution for multisource sensor data fusion intended to support decision making.[2] According to its software specifications, GINA aims to reduce technical challenges present in interoperability and integration and support for just-in-time common intelligence/operating pictures and intelligence analysis for decision-making.

Currently, semantic interoperability is an active area of research; a number of military technology solutions have been developed in the recent decade. Semantic interoperability provides means to facilitate rapid integration of information from ad-hoc sensor assets and heterogeneous C2 systems as they become known to the operators in the battlespace. This initial evaluation demonstrated that GINA enabled integration of disparate sensor systems, and homogenized and orchestrated the data to provide interpretation, analysis, and inference under the experimental scenarios for this evaluation. Drawing upon this assessment, further evaluations at a field exercise and/or experimentation, matching in scale and complexity of MDO, may be of interest. Specifically, the capabilities for further evaluations are 1) interoperability between sensors and communication devices from multiple services in a timely manner; 2) bridging the systems of allied, partner, or commercial data streams from various structures and standards; 3) enrichment, data analysis, inference, and/or augmenting other decision support C2 systems; and 4) comparison with other technology solutions.

Comprehensive analyses of this evaluation have been documented and published in the DEVCOM ARL technical report ARL-TR-9100.[3]

2. Overview of Evaluations and Results

2.1 Interoperability Model Testing on TTCP-CUE 2019 Data

The Technical Cooperation Program (TTCP) is an international cooperative science and technology effort jointly held by organizations from Australia, Canada, New Zealand, United Kingdom, and the United States. TTCP provides a venue to member nations to demonstrate and extend their research and development capabilities. The TTCP Contested Urban Environment (CUE) 2019 Exercise was held in New York City.

A persistent online data integration scenario was executed at the 2019 TTCP-CUE, and the collection of commercial IoT sensors was leveraged, which were operating as part of use cases tied to Forward Operating Base perimeter monitoring and vehicle tracking. For GINA's evaluation, a key objective involved successful ingest of data from the set of deployed sensors on site, integration of data, and visual display of the data stream in a common operating picture visualization.

During the exercise, GINA received and subsequently parsed, assembled, ingested, and visualized the sensor data in real time over satellite imagery. After the completion of the exercise event, further evaluation was conducted at DEVCOM ARL on GINA's handling at increased scalability. The TTCP-CUE 19 exercise generated 25,224 observations from 50 disparate technology assets of 9 sensing technology types, such as passive infrared, unmanned aerial systems (UAS), LiDAR, and IoT sensors. Further, the data were generated by four different nation owners. There were 73 data objects in Open Standards for Unattended Sensors XML (OSUS). GINA was able to ingest these sensor data in both OSUS and Java Script Object Notation (JSON). Once the data schema is learned in GINA, incoming JSON and OSUS streams were parsed into a common data component using the interoperation model to enable user applications like RaptorX to read the integrated data.

2.2 Sensor Fusion Testing

Initial research into sensor fusion was conducted on a scenario designed to demonstrate a basic fusion application capable of performing a simple task autonomously. The scenarios simulated relationships between multiple sensors and moving targets in White Sands Missile Range, New Mexico, where the task was to categorize the movement direction or path belonging to the correct target.

Vector Relational Data Model (VRDM), the GINA analytics, was tested on three simulated sensor data streams in the lab. There were 24 seismic unattended ground sensors (UGS) that sent alerts as they detected movement, where two sets of 12 sensors were positioned along the roads that intersected. Additional sensors were carried by a UAS. The sensors on the roads sent the position information of the sensor using different data schemas, Cursor on Target (CoT) and OSUS, as they were triggered by the moving targets. Some of the sensors along the roads were positioned closely so that more than one sensor was triggered for the same target. In other words, multiple events were generated for one target, and this required entity resolution for the targets before path analysis could be performed. The sensor from the UAS sent its position information in JSON. The simulated data were received and ingested into the sensor fusion model in GINA.

After the sensor fusion analysis completed the path track determination for the three moving objects, two vehicles and one UAS, the results were published to RaptorX, which in turn visualized the tracks created by the model. First testing of VRDM was on whether the model would be able to identify the tracks across two different UGS types. One object was moving from east to west, triggering the UGS with OSUS alerts, and then turning northwest, triggering UGS with COT alerts. The other object was moving northeast, triggering the UGS with COT alerts, and then turning east, triggering the UGS with OSUS alerts. Another testing result from the target model implementation was the two moving objects on the ground triggered UGSs with COT alerts and OSUS alerts in addition to the sensor on UAS sending its position data in JSON. The Sensor Fusion model received and ingested these three disparate data streams, resolved multiple events referencing the same movement, created a unique track, and ran path analysis to correctly infer the tracks belonging to each of the moving targets based on the sensor alerts within close proximity and time at the intersection. These results indicated the model implemented the relationship inference analysis and orchestrated actions between the sensors as intended.

3. Conclusions

The initial objective in using GINA modeling was to integrate a wide range of sensors and platforms not designed to work together and provide a common operating picture. The technical assessment in this effort demonstrated GINA's ability to support semantic interoperability without the need for system specification conformity, the need to change system configurations, or the need to integrate additional software. The modeling efforts were conducted only on needed key information of interest from standards used by target systems. This information, rather than the systems themselves, became interoperable from the existing systems.

4. References

1. The U.S. Army in Multi-Domain Operations 2028. U.S. Army Training and Doctrine Command; 2018. TRADOC Pamphlet 525-3-1.

2. Dolk D, Anderson T, Busalacchi F, Tinsley D. GINA: system interoperability for enabling smart mobile system services in network decision support systems. IEEE; 2012.

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List of Symbols, Abbreviations, and Acronyms

ARL	Army Research Laboratory
C2	command and control
COT	Cursor on Target
CUE	Contested Urban Environment
DEVCOM	US Army Combat Capabilities Development Command
GINA	Global Information Network Architecture
IoT	Internet of Things
JSON	Java Script Object Notation
MDO	Multi-Domain Operation
N-CFT	Network Cross Functional Team
OSUS	Open Standards for Unattended Sensors
TTCP	Technical Cooperation Program
UAS	unmanned aerial systems
UGS	unattended ground sensors
VRDM	Vector Relational Data Model

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