# Business Intelligence for Expeditionary Advanced Base Operations (EABO) Shaping Flexible C2 Organizational Structure

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## Background and Needs

The U.S. Department of Defense (DoD), which has realized the importance of distributed operations, has conducted research as part of the modern warfare strategy. The DoD resources have gradually migrated to large, distributed, more mobile and wireless networks of networks. However, the U.S. DoD faces very sophisticated adversaries and has to operate in contested, degraded, and dangerous environments.

Needs are:

- The U.S. Navy and U.S. Marine Corps (USMC) need offensive power of individual platforms through networked firing capability over a wide geographic area, i.e., larger hybrid fleet, consisting of manned and unmanned platforms and also the composition of the fleet and the right mix of platforms.
- The DMO and EABO requirements need the state-of-the-art peer-to-peer system capabilities to manage capabilities, manpower, maintenance, and supply among distributed units using the right data strategy, distributed infrastructure, and deep analytics including business intelligence, artificial intelligence, machine learning, optimization and game theory.

The researcher maps the need of lowering operation signatures to a load balancing problem and applies lexical link analysis (LLA) for CLAs. The researcher further applies the principle of quantum entanglement and superposition into a framework of LLA quantum intelligence game (LLAQIG). LLAQIG helps a peer simultaneously achieve the Nash Equilibrium for itself and the optimal total social welfare for its peer-to-peer network.

## Data Set

The Transportation Capacity Planning Tool, which is a centralized client-server system integrated with the Global Combat Support System-Marine Corps. The sample data contains 37,449 TMRs from 01-OCT-20 to 25-MAR-21 for 287 units and 15 pieces of equipment. The capabilities of a unit are associated with the equipment it operates.

Goals of the use case

- Use a single CLA to represent the data set from the centralized model to discover patterns of units' collaboration, and prioritize the units based on the capabilities (e.g., equipment) and characteristics of the requests (e.g., people or cargo),
- Apply the data mining results to design peer-to-peer networks, whose goals are to self-organize, load balance, avoid being detected, targeted, and shape flexible C2

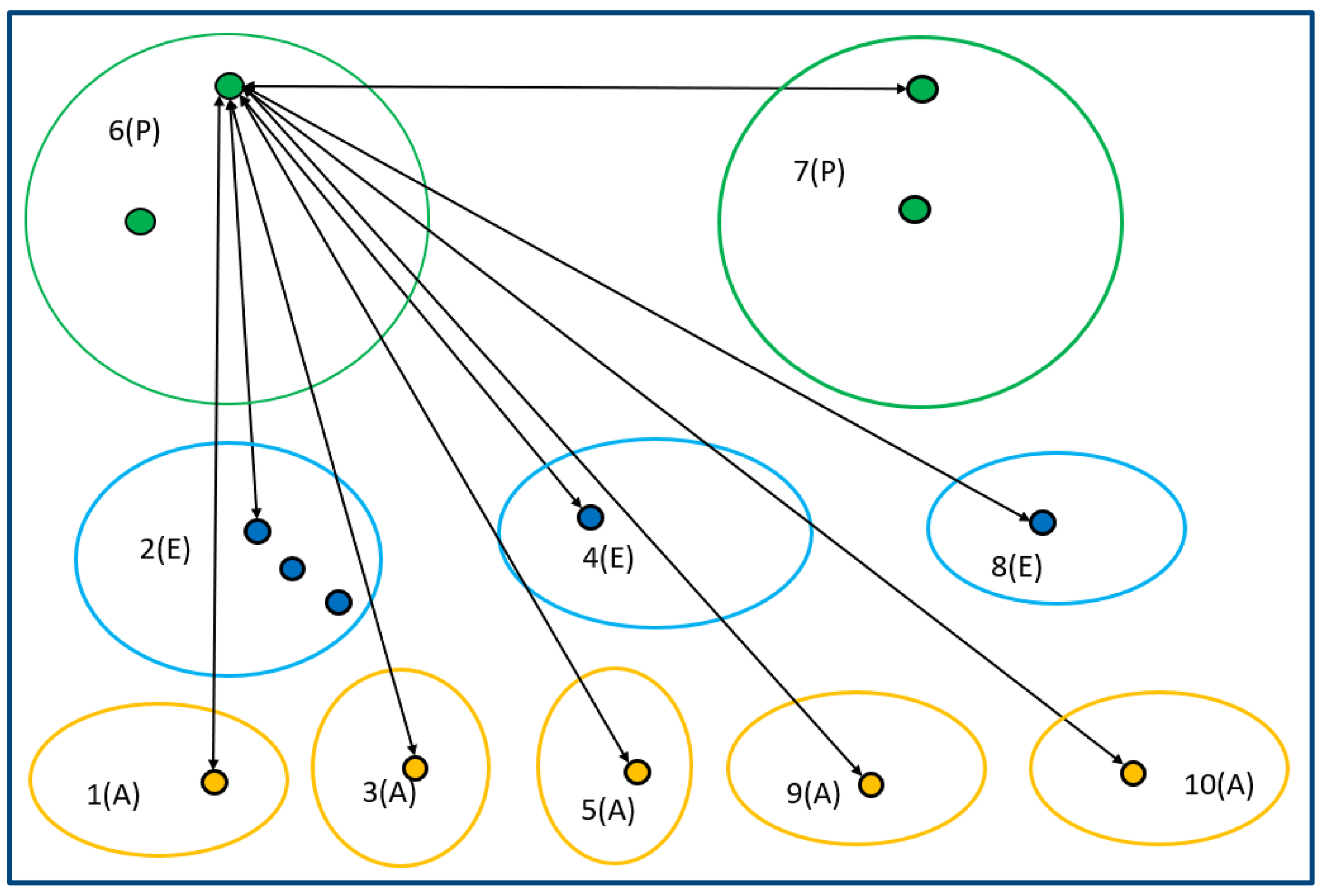


Figure 2: Tactical units in the data are grouped into ten Groups using CLAs and LLAQIG, based on which 10 new peer groups are generated to achieve the goals.

## Recommendations and Future Work

- The researcher recommends to work with the Transportation Capacity Planning Tool stakeholders to design new peer groups to distribute the capabilities and load as even as possible for better counter-detection based on the Result #1, #2, and #3
- Future work is needed to validate the methodologies to different domains of distributed operations.

**Publication**

Zhao, Y. (2021). Developing A Threat and Capability Coevolutionary Matrix (TCCM) – Application to Shaping Flexible C2 Organizational Structure for Distributed Maritime Operations (DMO). In the *Proceedings of 18th Annual Acquisition Research Symposium, Virtual*, 404–417. https://dair.nps.edu/bitstream/123456789/4399/1/SYM-AM-21-092.pdf

Zhao, Y., Mata, G. & Zhou, C. (2021). Self-organizing and load balancing with quantum effect for peer-to-peer collaborative learning agents and flexible command and control and organizational structures [Manuscript submitted for publication].

## Methods

**1. Collaborative learning agents (CLAs):** CLAs include distributed, networked, and peer-to-peer agent architecture and analytics. A single agent ingests local data, indexes, catalogs them, and separates patterns and anomalies. Multiple CLAs work collaboratively using peer lists.

**2. Lexical link analysis (LLA)**: Unsupervised machine learning to discover links and groups from structured and unstructured data.

**3. LLA quantum intelligence game (LLAQIG)**:CLAs employ unsupervised LLA that can be set as a LLAQIG. The higher the LLAQIG quantum effect impact factor associated with a unit, the more likely its load can be balanced towards the group average. The social welfare of a whole peer system is optimized while a peer's individual value is optimized as well.

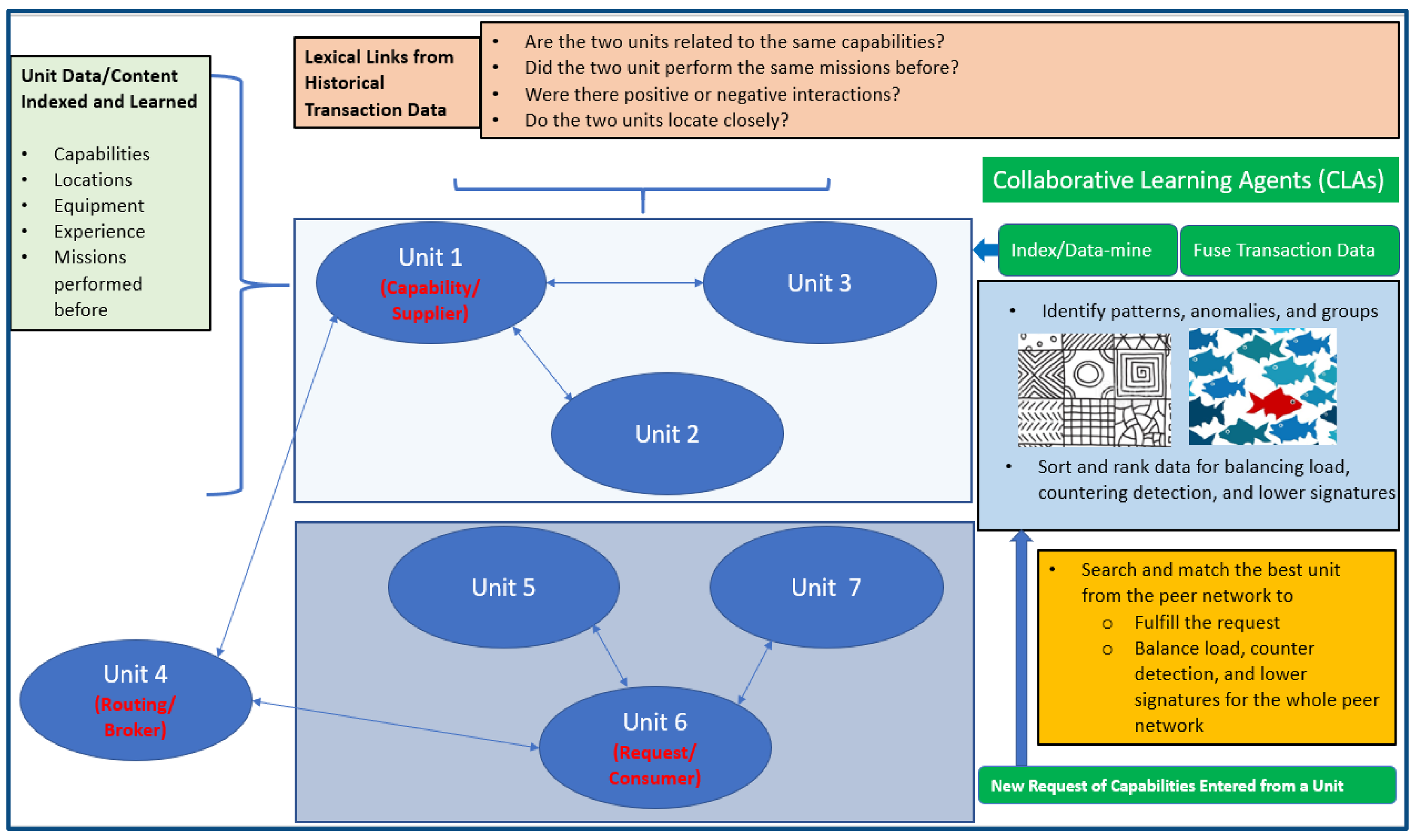


Figure 1: Distributed Operations and CLAs: Each unit or node is represented as a single CLA. A unit can be a capability supplier, consumer, or broker. The patterns of content, data, links in each unit are indexed and learned from historical transaction data. When using CLAs, each unit first builds a content and peer network to index, data-mine, and fuse data locally and from its peer network, then to identify behavior patterns and groups of units and capabilities. When a unit receives a new request of capabilities, it searches its peer network for the best match to fulfil the request, meanwhile balances the load to lower the signatures and avoids detection.

## Results and Findings

**Result #1**. The data mining results show the top 26% (75 units) have 80% of all the workload (i.e., number of transactions). These units that have higher loads than others, so they may be detected and targeted by the adversaries.

**Result #2**. If the LLA groups are used directly for load balancing 63% (182 out of 287) of the units would cover 80% of the total load.

**Result #3**. If the LLA groups, strategy in Figure 2, and LLAQIG are used combined, 74% (213 out of 287) of the units would cover 80% of the total load.

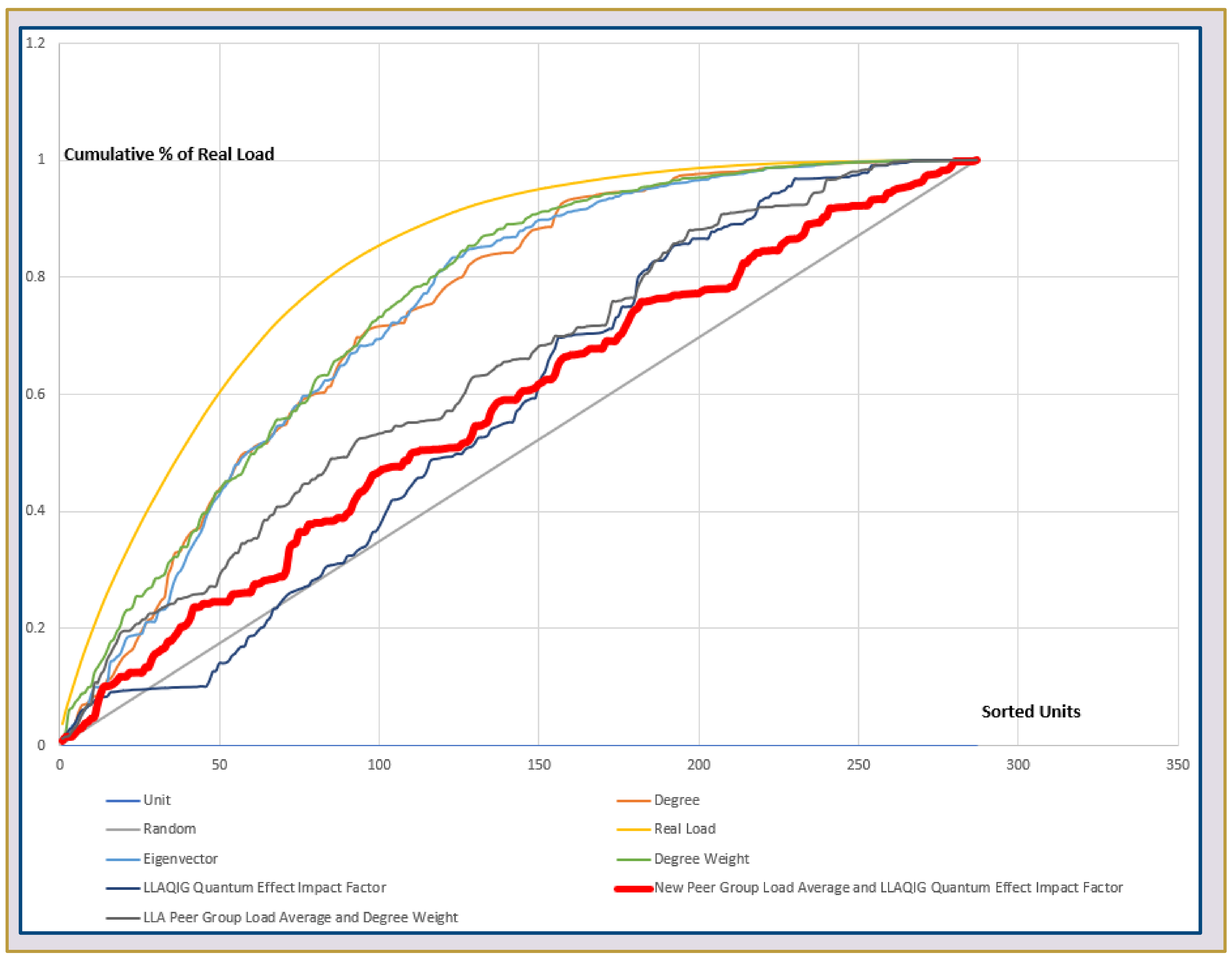


Figure 3: Unit cumulative percentage of real load based on different scores and load balancing methods. The best one is the one using LLA groups and LLAQIG quantum effect impact factor. The new peer-to-peer groups appear more random yet more likely to fulfill the same total load.

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