Self-organizing and Load-balancing via Quantum Intelligence Game for Peer-to-Peer Collaborative Learning Agents and Flexible Organizational Structures

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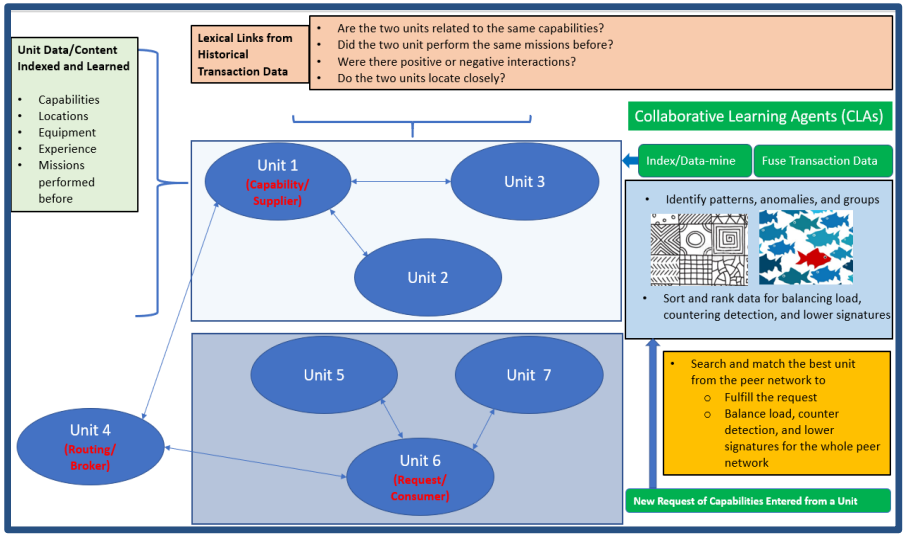
Background and Needs

- The U.S. Department of Defense (DoD)
  - Faces very sophisticated adversaries
  - Needs to operate in contested, degraded, and dangerous
  - Needs distributed operations
    - Networked firing capability over a wide geographic area, peer-to-peer system capabilities to manage capabilities, manpower, maintenance, demand, and supply among distributed units
      - The Distributed Maritime Operations (DMO)
      - Expeditionary Advanced Base Operations (EABO
  - Needs to lower operation signatures

Method: Model Supply and Demand Networked Agents to "Game" to Their Own Values



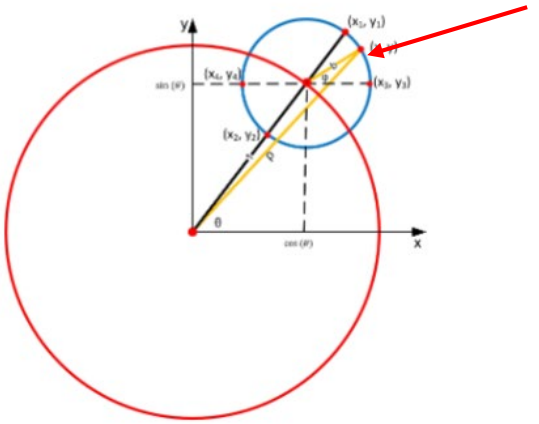
$$|X\rangle = c_0 |C\rangle + c_1 |D\rangle \tag{9}$$

where the coefficients c_1, c_2 are complex numbers.

$$\begin{aligned} c_0 |C\rangle &= e^{i\theta} \\ c_1 |D\rangle &= be^{i\phi} \end{aligned} \tag{10}$$

The magnitude of the superposition as a total reward, i.e., total social welfare ρ, for the LLAQIG is

$$\rho = \langle X|X\rangle = 1 + b^2 + 2b\cos(\theta - \phi) \tag{11}$$



- **Collaborative learning agents (CLAs):** CLAs include distributed, networked, and peer-to-peer, learning agents
- **Lexical link analysis (LLA)**: Unsupervised machine learning to discover links and groups from structured and unstructured data
- **LLA quantum intelligence game (LLAQIG)**:CLAs employ unsupervised to optimize its own value and the social welfare of the whole peer system

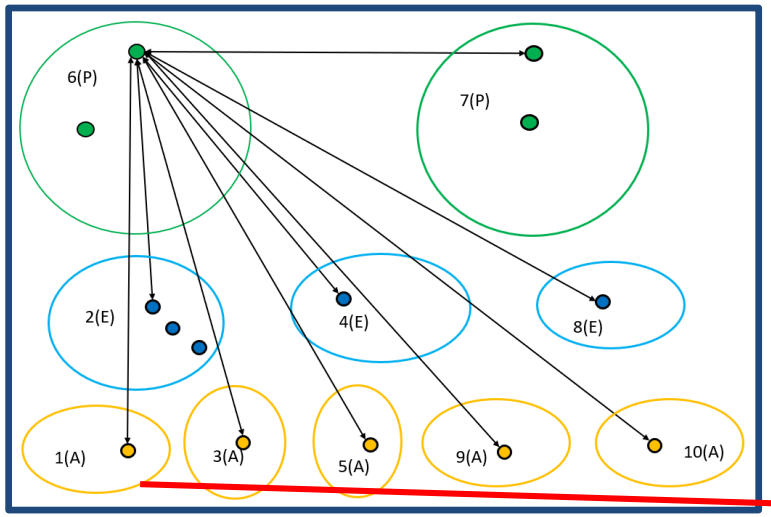
(x1,y1) is the unique Nash Equilibrium

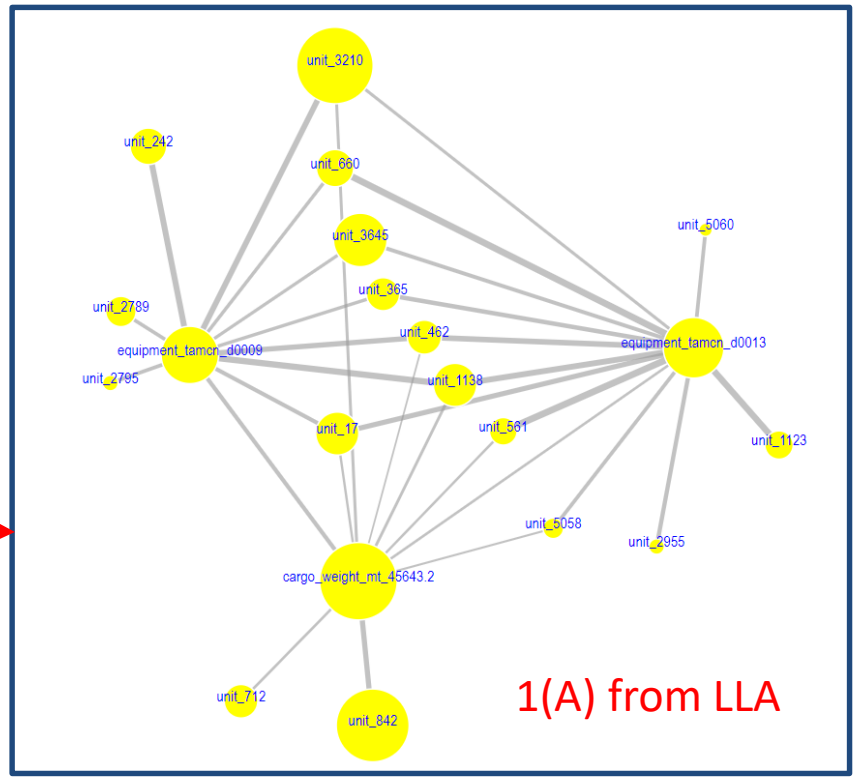
- Maximized individual unit value
- Maximized social welfare/collaboration value

Data Set and Use Case

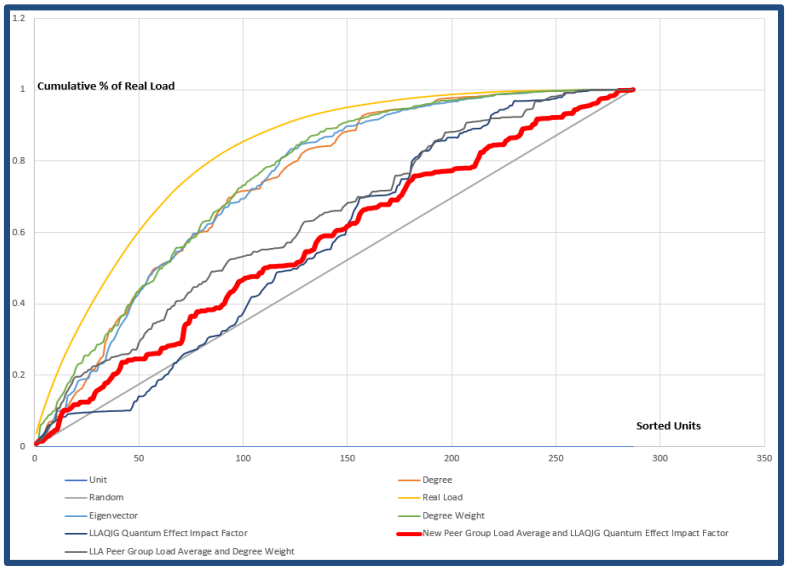
The Transportation Capacity Planning Tool

- A centralized client-server system integrated with the Global Combat Support System-Marine Corps.
- 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.

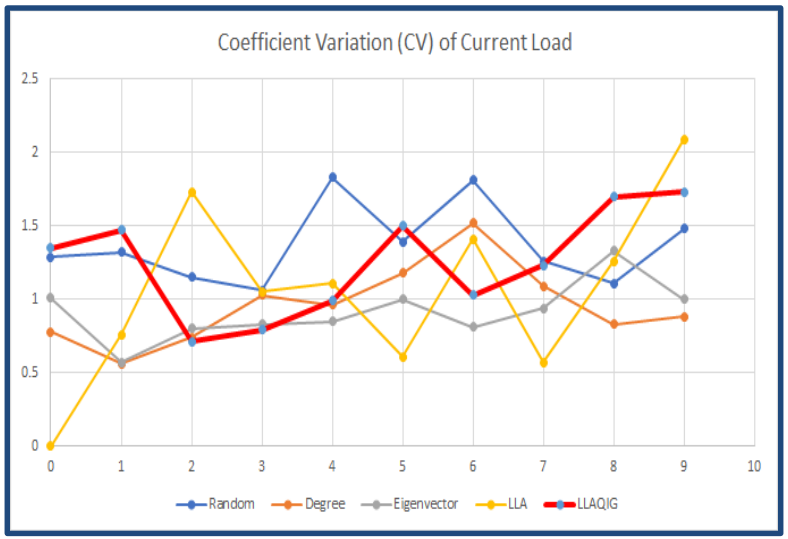




Results and Findings



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. If the LLA groups and LLAQIG are used combined, 74% (213 out of 287) of the units would cover 80% of the total load.



Result #2. The resulted newly formed peer groups based on each unit's equilibrium value from LLAQIG have the characteristics

- Smaller load mean range between groups
- Lower current load standard deviation within groups

than the random configuration and other methods, therefore, may maintain the lower operation signatures.

Summary and Future Work

- Quantum computing/game theory can help warfighters perform distributed operations lower operation signatures
- "Invisible Military"
  - Quantum adiabatic evolution for NP-hard combinatorial optimization leveraging quantum supremacy
  - Quantum stealth
  - ...

Disclaimer: The views presented are those of the authors and do not necessarily represent the views of the U.S. Government, Department of Defense (DoD), or their Components