NETWORK AND DATA POLICY CONSIDERATIONS FOR EFFECTIVE NETWORK CENTRIC OPERATIONS

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Introduction

- **Change to network centric operations (NCO) is placing unprecedented demands upon the US military and its capability to rapidly adopt new technologies**
  - **NCO places a premium on information timeliness**
  - **Information as force multiplier**
- **Technology, policy, and doctrine under development**
- **However, lacking in ability to effectively knit advances together to maximize effectiveness**
  - **Unclear how to translate policy into resource allocations**
    - **Network resources**
    - **Data**

Need an overall systems engineering approach, point solutions are not likely to be scalable or sufficient

Introduction (cont.)

- We examine network and data policies and issues to achieve effective NCO
  - Technologies and policies
- Network and data control and management policy are critical
  - Address NCO needs
  - Manage and make effective use of network and control information flow
- Policies should be driven by needs and capabilities of users of NCO data
  - Also consider bandwidth, communication alternatives, priorities, and data security
- Changes in policy must be made rapidly
  - Placing a premium on cyber situation awareness and tools for translating decisions into policy
- But, lack metrics

Factors to Consider

- **Mission for each organization**
- **Battlespace state**
- **Available communication channels**
- **User and commander data needs**
- **User and commander security demands**
- **These factors define the required veracity, timeliness, truthfulness and data verification requirements**
- **Need for speed and complexity point to need for intelligent agent assistance and tools**

Network and Data Policy Requirements

- Capabilityof a NCO force correlates with ability of data to move to where it is needed
  - Effectively & efficiently
- Need to understand data volume requirement imposed
  - Let $I_{r_a} \leftarrow I_{s_b}$ be the instantaneous data volume between any source and recipient
  - Then, total data volume need for an organization is defined as:
    - $I_1 = \left(\Gamma_{i=1}^{n} I_{r_i} \leftarrow \Gamma_{j=1}^{m} I_{s_j} \right)$
    - An effective NC organization must have as large an I_1 as possible

Data Velocity and Data Traversal

- ω
- **At a given time, T, the data velocity is defined as:**
  - $(I_{1\tau} - I_{1\tau-1}) / I_{1\tau-1}$
- **Data traversal is defined as I_2, which is**
  - $I_2 = \left(\left(\underset{i=1}{\overset{n}{\Gamma}} I_{r_i} \leftarrow \underset{j=1}{\overset{m}{\Gamma}} I_{s_j} \right) \right) \div \sum \left(\Delta t (r_i \leftarrow s_j) \;\; \forall \;\; (r_i \leftarrow s_j) \neq 0 \right)$
- **I_2 must be minimized**
  - **No contention for bandwidth**
  - **Data moves promptly**
- **Must consider time required for priority data to arrive at its destination**
  - **Call this priority data *y***

Priority Data Considerations

- I_{3_p} is the average time for priority data to move all sources to all recipients of data of a given priority, *p*
  - P_y is the set of priority data of a given priority in movement at any time
  - P_y, y=1,x is the set of all priorities for data
  - I_{3_p} at time y is defined as:

$$\left(\left(\prod_{i=1}^{n} I_{r_i} \leftarrow \prod_{j=1}^{m} I_{s_j}\right)\right) \div \sum \left(\Delta t(r_i \leftarrow s_j) \ni \left[\left((r_i \leftarrow s_i) \neq 0 \wedge (r_i \leftarrow s_j) \subset p_y\right)\right]\right)$$

  - Allowing I_3 to be defined as

$$\sum_{y=1}^{x} \mathrm{I}_{3_{p_y}} \div \mathrm{x}$$

Need Differential

- I_4 is defined as the difference between when the data is needed and when it arrives at a recipient
  - For a given time period
  - Must be minimized for each recipient and the organization
- I_4 for a recipient *r* is defined as:

$$\sum_{j=1}^{m}\left(t_{a_r} - t_{n_r}\right) \forall \left(I_r \leftarrow \prod_{j=1}^{m} I_{s_j} \ni \left(r_r \leftarrow s_j\right) \neq 0\right)$$

- For the organization, I_4 can then be defined as:

$$\sum_{r=1}^{n} \mathrm{I}_{4_r}$$

- I_3 for a recipient must be minimized in order to minimize I_4

Need Differential for Data of a Priority

- I_5 is defined as the time differential between when the dat of a given priority is needed by a recipient and when it arrives
- I_5 for a recipient is then defined as follows:

$$\sum_{j=1}^{m}\left(t_{a_r} - t_{n_r}\right) \forall\ I_r \leftarrow \mathop{\Gamma}_{j=1}^{m} I_{s_j} \ni \left(\left(\left(r_r \leftarrow s_j\right) \neq 0\right) \wedge \left(\left(r_i \leftarrow s_j\right) \subset p_y\right)\right)$$

- Should approach zero for data of highest priority for each data recipient

Data Movement Efficiency

- Ψ
- **Defined for each recipient at a given time**
- **Data efficiency is based on performance as measured by I_4**
- Ψ **for a given recipient for a given time is defined as:**
  - $\psi_{r\tau} = (I_{4r\tau} - I_{4r\tau-1})/ I_{4r\tau-1}$

Further Considerations on Data Transport

- Data transport time, I_2, is based upon
  - Time spent in transit in a medium
  - Time spent in computing devices
  - Time spent in sensor systems
  - Time spent in releasibility decision making
  - Time spent in analysis
- Transit, computing, and sensor times are nearly constant
- Key is minimizing releasibility and analysis time
  - Argues for automation of these critical but sensitive tasks
    - Intelligent agents
      - For prioritization as well as information overload management
  - Same conclusions appear to hold for I_3, I_4, I_5

Need an overall systems engineering approach, point solutions are <u>not</u> likely to be scalable or sufficient

Major Metrics Redux

Metric/ Variable	Definition
I_1	The volume of data moving from all sources of data to all recipients of data within an organization at any given time
I_2	The average time for data to move from all sources to all recipients within a time period
I_3	The average elapsed time for priority data of a given priority to move from all sources to all recipients of data of that priority at any given time.
I_4	The time differential between the time when data is needed by a recipient and when it is received.
I_5	The time differential between the time when data is needed by a recipient and when it received by the data recipient for a given time period for data of a given priority.
$\varpi\ \tau$	Data velocity within an organization at a time τ
ψ	The efficiency of the movement of data.

Policy Implications

- Lacking tools and instrumentation to make required measurements in real time
- Lack insight into details, components, and placement of the metrics
- Must be able to deal with rapid changes in data transport requirements
- Intelligent agents are critical
- Technology preparedness is crucial
  - No alternative but to be at cutting edge of communication and computing technologies
  - Tools
- Simulation to gain understanding of metrics and their components is critical
  - No one solution for all situations, further complicating the challenge
  - Tools

Conclusions and Future Work

- NCO places a premium on network and computing technologies and policies
- We presented metrics to assess effectiveness of technologies and policies
- Need more detailed representations of the metrics
  - Experimentation and theoretical
  - Topologies, bandwidth, cyberwarfare, coalition, other factors
- Susceptibility to cyberoperations will determine effectiveness of a NCO force
- Coalition complicates NCO challenges
  - The metrics we propose can be used to assess effectiveness of coalition communication

Future Work

- **Extend metrics proposed here**
  - Develop component representations
- **Need real-time network instrumentation to enable management of network**
  - Sensors, data needed, dissemination
- **Need training to prepare for cyberattacks**
- **Need insight into systems engineering for NCO networks**
  - Better end-to-end engineering to insure efficient, prioritized data transport
- **Better insight into user needs for data**
  - Proper prioritization