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Combining Social Network Analysis and the NATO Approach Space to Define Agility

Topic 2: Networks and Networking

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Abstract

This paper takes the NATO SAS-050 Approach Space, a widely accepted model of command and control, and gives each of its primary axes a quantitative measure using social network analysis. This means that the actual point in the approach space adopted by real-life command and control organizations can be plotted along with the way in which that point varies over time and function. Part 1 of the paper presents the rationale behind this innovation and how it was subject to verification using theoretical data. Part 2 shows how the enhanced approach space was put to use in the context of a large scale military command post exercise. Agility is represented by the number of distinct areas in the approach space that the organization was able to occupy and there was a marked disparity between where the organization thought it should be and where it actually was, furthermore, agility varied across function. The humans in this particular scenario bestowed upon the organization the levels of agility that were observed, thus the findings are properly considered from a socio-technical perspective.

Introduction

The NATO SAS-050 approach space "is intended to serve as a point of departure for researchers, analysts, and experimenters engaging in C2-related research" (NATO, 2006, p. 3). As such, whilst the approach space is a useful and well accepted basis for thinking about command and control there are a number of possible extensions or enhancements that spring to mind. These centre round the following:

The first is that the model is "interested in the actual place or region in this [approach] space where an organization operates, not where they think they are or where they formally place themselves" (Alberts & Hayes, 2006, p. 75). The extension that flows out of this is for metrics to define, quantitatively, the position that live command and control organizations adopt on any one of the approach space's three axes. If live command and control can be fixed into the approach space then it can be benchmarked.

Secondly, the observation that "An organization's location in the C2 approach space usually ranges across both function and time" (p. 76) brings a further requirement to capture and understand the underlying dynamics of NCW. If the underlying dynamics can be captured and understood, then useful aspects of agility can be revealed.

Finally, "Identifying the crucial elements of the problem space and matching regions in this space to regions in the C2 approach is a high priority". Command and control is contingent. Fixing and understanding the dynamics of it in the approach space increases the accuracy of the mapping that can occur between approach and problem.

Part 1 of this short paper deals with the innovations that have been directed towards these three 'missing links' and which enable the NATO approach space to be transformed from a typology (i.e. a non-numerical process by which C2 can be classified into 'types') to a taxonomy (i.e. a 'systematic', numerical classification). An explicit strategy for achieving this is derived from social network analysis and is put to the test with theoretical data. Testing the hybrid social network/NATO approach space with live data in Part 2 provides an opportunity to observe 'the actual place or region where an organization operates', how that location varies 'according to function and time', and aided by theoretical data, tentatively 'match regions of the problem space to the approach space'.

Part 1: Extending the NATO SAS050 Model

Social Network Analysis

At the heart of all the missing links presented above is the ability to provide quantitative measures or metrics that relate meaningfully to decision rights, patterns of interaction and dissemination of information. Social network analysis (SNA) is used to overcome this.

In general terms a social network is "a set of entities and actors […] who have some type of relationship with one another" whereas social network *analysis* represents "a method for analyzing relationships between social entities" (Driskell & Mullen, 2005, p. 58-1). A social network is created by plotting who is communicating with whom on a grid-like matrix. The entries into this grid denote the presence, direction and frequency of a communication link. The matrix can be populated using information drawn from organization charts and standard operating procedures so that it describes where an organization formally places itself. Much more consistent with the approach space is that the matrix can be populated with live data that describes where an organization is actually placed.

The matrix of agents and links is what enables a social network diagram to be created. This is a graphical representation of the entities and actors who are linked together. Apart from very simplistic networks, any underlying patterns extant in this graphical representation are difficult to discern by eye alone. Thus, graph theoretic methods are applied to the matrix in order to derive a number of specific social network metrics (e.g. Harary, 1994). These form the basis of a comprehensive diagnosis of the network's underlying properties, which include several that map across to decision rights, patterns of interaction and distribution of information. This mapping of social network metrics to the NATO model axes is one of the key innovations of the work and is described below.

Decision Rights Mapped to Sociometric Status

Decision rights can be mapped to the social network metric called 'sociometric status' which is given by the formula:

$$\textit{Sociometric status} = \frac{1}{g-1}\sum_{\mathrm{j=1}}^{\mathrm{g}}(\chi\mathrm{ji} + \chi\mathrm{ij})$$

where g is the total number of agents in the network, i and j are individual agents, and χ_{ij} are the number of communications extant between agent i and j (Houghton et al., 2006). Sociometric status gives an indication of the prominence that each agent has within the network in terms of their ability to communicate with others. The hypothesis, therefore, is that unitary networks would generally posses fewer high status agents (corresponding to unitary decision rights) compared to peer-to-peer networks. Specifically, the number of agents scoring more than one standard deviation above the mean sociometric status value for a given network will be higher for edge type organizations by virtue of their peer-to-peer configuration than for classic C2.

Patterns of Interaction Mapped to Network Diameter.

Patterns of interaction can be mapped to the social network metric ‘diameter’, which is given by the formula:

$$\textit{Diameter} = \max_{uy} d(u, v)$$

where d(u, v) is “the largest number of [agents] which must be traversed in order to travel from one [agent] to another when paths which backtrack, detour, or loop are excluded from consideration” ($\max_{uy}$; Weisstein, 2008; Harary, 1994). Generally speaking, the bigger the diameter, the more agents there are on lines of communication. The hypothesis is that an edge organization facilitates more direct and therefore distributed communication (and thus has a smaller diameter), compared to a hierarchical network with more intermediate layers in between sender and receiver (and a higher diameter score).

Distribution of Information Mapped to Network Density

Distribution of information can be mapped to the social network metric ‘density’, which is given by the formula:

$$\textit{Network Density} = \frac{2l}{n(n-1)}$$

where l represents the number of links in the social network and n is the number of agents. It is hypothesized that an edge organization will be denser than a hierarchical one, meaning that (all things being equal) broader dissemination of information will be rendered possible because there are more direct pathways between sender and receiver (compared to a hierarchically organized counterpart).

Testing the Metrics Using Network Archetypes

The hypothesis that diameter, density and sociometric status can be used as metrics for decision rights, patterns of interaction and distribution of information can be tested with reference to several theoretical network archetypes. Four of these are based on early social network research by Bevelas (1948) and Leavitt (1951) who defined the following: the ‘Chain’, the ‘Y’, the ‘Star’ and the ‘Wheel’ (shown in Figure 1).

The value to be obtained by plotting Bevelas and Leavitt’s archetypes into the approach space is consistent with the wider goal of identifying crucial elements of a problem space and matching regions in this space to regions in the C2 approach. Specifically, the four archetypes enable a body of empirical evidence concerning their efficacy under different task conditions to be deployed. For example, the problem space might be suggestive of a task context that is complex, i.e. dynamic rates of change, low familiarity and a weak information position. The corresponding fix within the approach space, again, for example, might be in close proximity to the ‘Star’ archetype. On the basis of Bevelas and Leavitt’s work it becomes possible to not only make a crude judgment about this particular configuration being less than optimal but to outline more precisely why. Networks exhibiting the properties of a ‘Star’ often overload the heavily connected high status node(s) in complex, dynamic situations.

It is important to note, however, that the transition from typology to taxonomy currently awaits the NATO ‘problem space’. This renders judgements about the essential nature of ‘problems’ somewhat crude and informal. Unfortunately, this issue lies within the purview of future work.

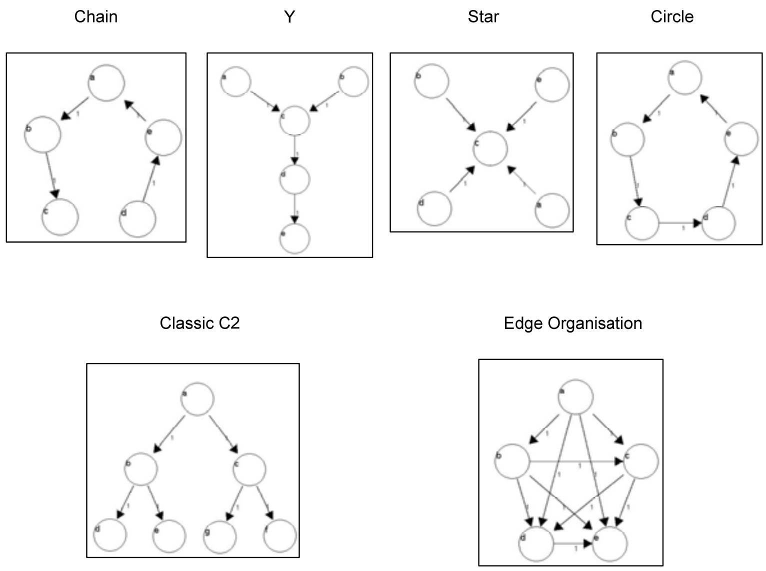

Figure 1 – Illustration of archetypal networks. Associated with each is empirical evidence concerning its performance on simple and complex tasks.

Bevelas and Leavitt’s various archetypes, and their empirically derived performance characteristics, can be joined in the approach space by two further network structures. These are derived explicitly from the NATO approach space: the hierarchical ‘classic C2’ organization and the fully connected ‘edge organization’ (also shown in Figure 1). The approach space proposes that these network archetypes should in theory fall into the bottom left and top right corners respectively. The hypotheses that diameter, density and sociometric status can be used as metrics for decision rights, patterns of interaction and distribution of information can thus be subject to a direct test: if the metrics work as expected, these two network archetypes should occupy positions in the approach space predicted by the model.

Reference to Figure 2 shows this to be the case. The classic C2 and edge organization, more particularly, the mapping of the relevant social network metrics to the model’s main axes, leads these two archetypes to fall broadly into the areas of the approach space predicted. Interestingly, although classic C2 is not pushed hard into the bottom/left/front position of the space that is predicted, it is positioned in the correct ‘octant’. Further investigation of this phenomena (e.g. Walker et al., 2009) reveals hierarchical networks to be much more scale dependent than comparable edge organizations, which means in practice that more realistically sized hierarchies do indeed tend to push further into the ‘correct’ part of the approach space.

Broadly speaking, then, the mapping hypotheses described above are supported: diameter, density and sociometric status can be legitimately used as metrics for decision rights, patterns of interaction and distribution of information. Using these quantitative measures to plot Bevelas and Leavitt's network archetypes into the approach space also helps to fulfil the high priority goal of 'identifying the crucial elements of the problem space and matching regions in this space to regions in the C2 approach'.

Part 2: Testing the Extended Model with Live Data

Live NCW Exercise

Having defined a set of social network metrics that map onto the NATO SAS-050 approach space, and subjected those metrics to a test with theoretical data, an opportunity now arises to scale up the analysis considerably and test their efficacy and usefulness with realistically sized 'actual' C2 organizations. This occurs by embedding the approach developed in Part 1 above into a bigger analysis based on a large scale military exercise. The military exercise in question had the purpose of trialling a digital tactical communications and mission planning system. The current analysis formed part of a much wider effort in respect to this and spoke towards the following exploratory hypotheses:

- Exploratory Hypothesis #1: Echoing the earlier statements of Alberts & Hayes (2006) the interest remains firmly directed towards where a live NCW organization 'actually' places itself. This exploratory analysis relies on deploying the social network metrics with live data to model the organization both statically and dynamically. The aims and aspirations of the military exercise (combined with the concept of operations and standard operating procedures) are consistent with realising a fully net-centric force. The alternative hypothesis is that where the organization 'actually' places itself will be different to that anticipated.
- Exploratory Hypothesis #2: The number of locations that a particular organization is able to adopt within the approach space is a reflection of the organization's agility, degrees of freedom or variety (Alberts & Hayes, 2006; Waldrop, 1992; Ashby, 1956). It is anticipated that this varies according to function and that different parts of the C2 organization will exhibit different levels of agility.

Data Collection

Data collection took place at a fully functioning Brigade level headquarters (BDE HQ) deployed in an army training area for the purposes of evaluating a particular instantiation of NCW. The social network analysis itself focuses on 'inter-organizational' and 'inter-cellular' communications. Inter-organizational communications took place between the BDE HQ and live, geographically dispersed Battlegroup headquarters (BG HQ's). Additional data, such as further BG HQ's and enemy units was simulated from an Experimental Control centre (EXCON) which, once again, was geographically disperse from both the live BDE and BG HQ's.

BDE HQ in itself is a reasonably sized organization divided up into the conceptual equivalent of 'departments' (or 'cells'). Inter-cellular communications refer to those that took place between different parts of the BDE HQ and these too placed heavy reliance on the communications capability of the NCW system as various documents, templates, graphics and other comms. traffic flowed around it. Unfortunately, due to several hard operational constraints, inter-personnel communications (by non technologically mediated means, i.e. face to face comms.) were not subject to analysis. This we readily acknowledge as a limitation in terms of possible adaptations to the new digital NCW system. Having said that, these issues were captured in the wider analysis of which this study is a part (see Stanton et al., 2009) and are available to be introduced later if appropriate.

In all respects the Net Enabled command and control infrastructure was set up and staffed as it would have been if deployed. There were a total of 73 active agents in the scenario, 17 of whom were located in and around the BDE HQ. Agents, in this case, refers specifically to 'role' and the NCW system terminals provided to support any given role. More than one person can use a system terminal or be performing a particular role at different times. In any case, this number of agents and this degree of geographical dispersion creates a complicated, large scale and realistic scenario.

The various planning and operations phases took place over the course of three weeks and this study came near to the end. It thus represents a situation in which a considerable amount of adaptation to the new system had already taken place. The military operation observed took place over a single day (with plans and so forth being prepared the day previously) and took four hours and twenty minutes to complete. In broad terms it was comprised of a rapidly approaching enemy from the west who had to be steered, through a combination of turn and block effects, to the north east of the area of operations into a region where a 'destroy' effect would be deployed. Any remaining enemy units would then continue into the next area of operations which was not under the control of the present BDE HQ.

It is important to note that the explicit aim of this field trial was to put this particular NCW system to the test; it was not a test of the military effectiveness of the BDE and BG headquarters (or any other sub-unit). In fact, it was acknowledged that the simulated enemy was probably rather more 'compliant' than that normally encountered. That said, the scenario would not be described as in any way leisurely in nature nor was it predictable in terms of ultimate outcome. Overall levels of complexity, tempo and realism were high.

Data Sources

Digital Data

Two sources of data were used to inform the analysis. Firstly, comprehensive telemetry was extracted from the NCW system. The sampling rate of the telemetry varied but reached a maximum of approximately 10Hz and yielded a total of 2866 data points pertaining to who was communicating to whom, as well as the broad category of 'what' was being communicated. This 'system log' data all resided at a 'digital' level in so far as it presented itself to the user through the NCW system's data terminals.

Voice Data

The second source of data was voice communications, which were transmitted over the encrypted radio embedded within the NCW system. Data collection here relied on a formal log of those communications kept by the incumbent of the Watch Keeper role. Every communication, its time, from who it derived and to whom it was directed, and its content, was recorded. This formed the basis of an analysis of inter-organizational 'voice' comms. Although mediated by a digital radio technology the presenting modality of the communication, from the user's point of view, was 'voice'. A total of 158 discreet events of this type were extracted from the scenario.

Results: Digital Communications

Static Characterization

The data from the scenario that shows who is communicating to whom was broken down into 34 time slices, with each stage being subject to a social network analysis. This involved constructing a matrix (identifying who was communicating to whom and how often), producing network diagrams, and from them, computing various network statistics which in turn map on to the NATO approach space's three main axes as per Part 1.

In order to perform a static characterization of what could be regarded as the organization's centre of gravity within the approach space, the space itself is divided into eight 'octants'. By this reckoning social networks can either be broad or tight (in terms of decision rights), distributed or hierarchical (in terms of patterns of interaction), unitary or peer to peer (in terms of dissemination of information), or any combination thereof.

The 34 separate social network analyses performed on the digital comms. layer produced 34 separate diameter, density and sociometric status figures. These were then divided into upper and lower 50th percentiles to create a total of six categories, as shown in Table 1 below. The raw data was then transformed into category data (1 = a value that falls into the upper percentile, 2 = one that falls into the lower percentile). The number of data points that fell into each category was then subject to a simple modal analysis to derive an 'average' network type.

It will be noted from Table 1 that none of the categories are strongly biased towards any one network type, so this high level characterization is undeniably of a broad brush nature.

Table 1 – Overall characterisation of the network type extant at the digital comms layer compared to a number of social network archetypes.

		Diameter	Density	Status
Digital Layer	Upper Percentile	16	17	18
	Lower Percentile	18	17	16
	Modal Point	Hierarchical	Broad/Tight (Tied)	Peer to Peer
Archetypes	Peer-to-Peer	Distributed	Broad	Peer to Peer
	Hierarchical	Distributed	Tight	Peer to Peer
	Circle	Hierarchical	Broad	Peer to Peer

Chain	Hierarchical	Tight	Unitary
Y	Hierarchical	Tight	Unitary
Wheel	Distributed	Broad	Unitary

* Shading denotes closest match

The modal network type derived from the above analysis was able to be compared against the earlier network archetypes, the Circle, the Chain, the 'Y' and the 'Wheel'. The results of this comparison are also shown in Table 1.

Bevelas (1948) and Leavitt's (1951) prototypical networks (and the performance characteristics associated with each) can now be used to draw out the implications of the digital comms. network observed at BDE HQ. Here it can be seen that the static characterization of the BDE digital comms. network approximates most closely to the 'Circle' network archetype, which is to say that the centre of gravity for this layer of comms. is located in that vicinity. Leavitt says of this network that it possesses a certain "active, leaderless, unorganised, erratic" character, at least compared to some other network configurations. In situations of high task complexity its decentralized nature helps to avoid bottlenecks and the overloading of just one, or of a few, heavily connected agents. Consider also that performance characteristics described by terms such as 'erratic', 'active' etc. seem at face value to be far more relevant to agility than 'stable' and 'fixed'. As for exploratory hypothesis #1 this is undoubtedly where the organization 'actually' places itself, and in this context represents a match with where the organization, as a decentralized net-enabled force, aspires to be.

Despite achieving a match to organizational aspirations there still appears to be a fundamental mismatch between 'approach' and extant problem. Plotting the archetypical networks directly into the NATO approach space as shown in Figure 2 locates the 'Circle' archetype in the bottom/right/back octant. The problem, i.e. the scenario, was an overtly cold-war style of engagement characterized by high familiarity (of enemy doctrine), fairly static rates of change (to the extent that the dynamics are more or less linear and in sequence) and a high strength information position (a lot is known about enemy capability and position). The corresponding octant in the problem space is, therefore, in the region of the bottom/*left*/*front* octant. In this situation, the attributes of a circle network are less optimal than hierarchies, chain or Y networks. This is because as the resultant problem complexity decreases, the time taken to collate information begins to negate the benefits of decentralization. In fact, this precise phenomenon was clearly in evidence during the exercise and partly one of the reasons why users reverted to the unexpected use of simplistic, relatively unconstrained free text facilities in an attempt to bypass the more bureaucratic aspects of the interface, which often acted as an unwelcome constraint. People in the NCW system were observed to undertake these types of behavioural adaptations in an attempt to align themselves more to the nature of the problem they were facing (Stanton et al., 2009).

Dynamic Characterization

If the communications network was stable then the high level static characterization described above would be sufficient. Unfortunately, as the category data suggested by not revealing a strong bias towards any one network type, the network is far from stable. This dynamism is clearly evident when all 34 sequential social networks from the observed exercise are plotted into the approach space along with the archetypal networks. What results is a form of 3D scatter plot or 'phase space' that illustrates the dynamical behaviour of the network over time.

Although the circle network archetype represented something of the desired or doctrinal definition of the organization, the 'actual' region in the approach space adopted by the organization proved to be quite different as a function of time. The extent of the organization's agility can be seen in that the network for digital comms. had a density value that varied about its mean of 0.84 by +/- 0.5. Similarly, the number of high status agents in the network varies from zero to four, and likewise, diameter varies around 4.38 by +/- 3.5. These are pronounced changes in the structure of the social network as illustrated by Figure 2.

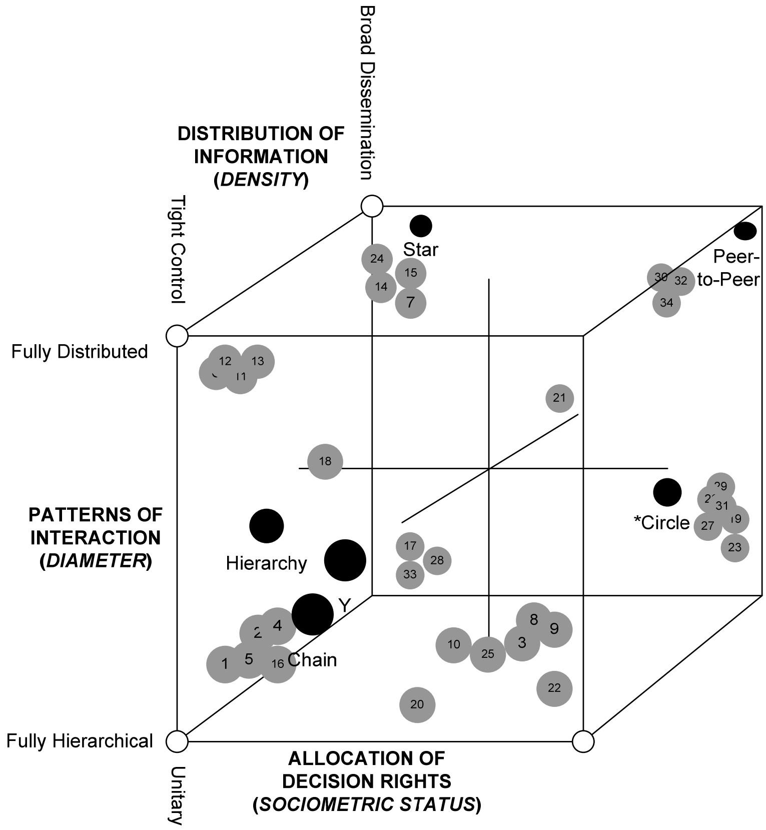

Figure 2 – Illustration of the 34 separate social network analyses plotted into the NATO SAS-050 approach space to show how the configuration of digitally mediated comms changes over time (grey numbered spots). The approximate position occupied by the network archetypes is also shown (black annotated spots). The 'modal' network configuration of the digital comms layer approximated to a 'circle' archetype (marked with an asterix).

Voice Communications

The analysis performed on the digital comms. data can now be repeated for voice comms. As a lot of the explanatory ground work has already been covered above, this section can be considerably briefer and to the point.

Static Characterization

The first stage of the analysis is to provide a static representation of the underlying voice comms. data by undertaking a simple form of modal analysis, as before. The results of this are shown below in Table 2:

Table 2 – Overall characterisation of the network type extant at the voice comms layer compared to hierarchical and peer-to-peer archetypes

		Diameter	Density	Status
Voice Layer	Upper Percentile	18	17	18
	Lower Percentile	16	17	16
	Modal Point	Hierarchical	Broad/Tight (Tied)	Peer to Peer
Archetypes	Peer-to-Peer	Distributed	Broad	Peer to Peer
	Hierarchical	Distributed	Tight	Peer to Peer
	Circle	Hierarchical	Broad	Peer to Peer
	Chain	Hierarchical	Tight	Unitary
	Y	Hierarchical	Tight	Unitary
	Wheel	Distributed	Broad	Unitary

* Shading denotes closest match

It can be seen that the static characterization of the BDE HQ voice comms. network, like the digital network, approximates most closely to the 'Circle' archetype. The advantages of this configuration under situations of high task complexity have already been noted and apply here. But again, this appears to be a relatively poor match to the extant situation, perhaps even to a slightly greater extent even than the digital comms. layer. In simple terms, for the scenario being faced by the organization it probably needs to be locating itself in the region of the hierarchy, chain and y archetypes which in practice does happen on several occasions as shown in Figure 3.

Dynamic Characterization

The reconfiguration of the voice comms. network over time is clearly evident when all 32 sequential social networks are plotted into the NATO approach space as shown in Figure 3. The reason for their being 32 instead of 34 time slices in this 'voice' data is because no voice communications took place during the first and last time intervals. In the case of the voice comms. network, the density varies about its mean of 0.26 by +/- 0.9. Similarly, the number of high status agents in the network varies from zero to two, and likewise, diameter varies around 1.06 by +/- 2.

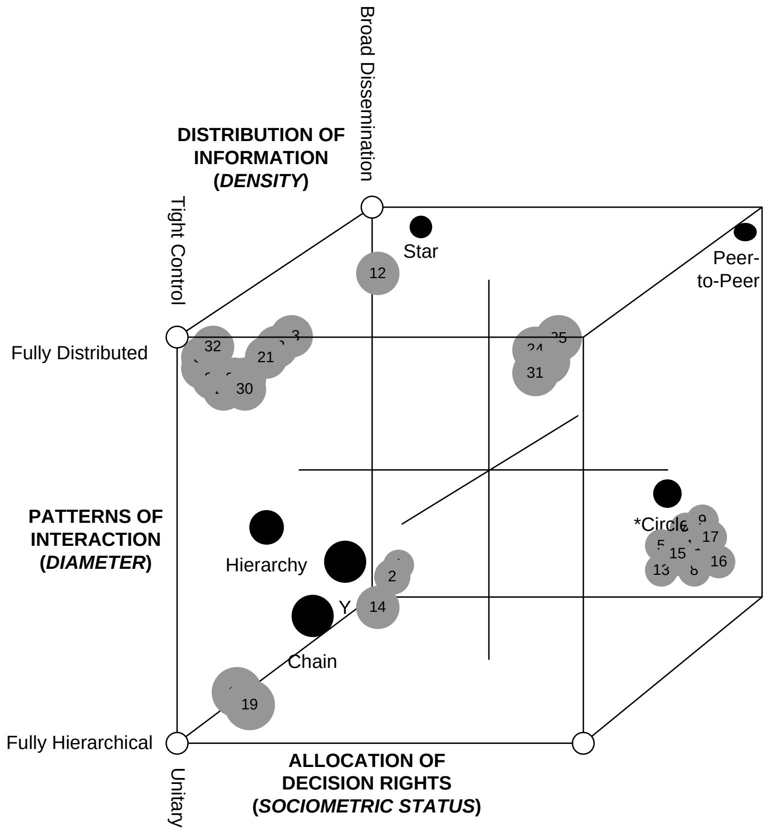

Figure 3 – Illustration of the 32 separate social network analyses plotted into the NATO SAS-050 approach space to show how the configuration of voice mediated comms changes over time (grey numbered spots). The approximate position occupied by the network archetypes is also shown (black annotated spots). The 'modal' network configuration of the voice comms layer approximated to a 'circle' archetype (marked with an asterix).

Agility

Further refinements are required to fully realise a vision of being able to compare levels of agility across an organization (i.e. across function). There is recognition of a raft of insights from complexity science and related fields which connect points in phase spaces which are conceptually and visually similar to the NATO model. Manifolds and convex hulls are just two examples. These may well prove to be a far more adequate way of representing this aspect of NCW than the present highly simplistic first attempt. But in so far as a simplistic comparison can be made, then the following is offered.

Figure 4 is a composite representation of the amount by which the organization varied about it's mean values on its three measured social network metrics across digital and voice functions. This simple measure of change represents the range of coordinates in the 3D space and says something about the number of locations in that space which were actually occupied. These three values were summed to reveal the digital layer scoring 12.46 compared to 13 for the voice layer. Although in raw terms both functional layers of the system can be said to exhibit almost identical levels of agility, the digital and voice networks are of vastly different size.

Because we do not fully understand at present how size or scale affects these measures, we have acted under the assumption that these changes are more impressive for the large digital network than for the small voice network. In the small network a far smaller number of agents can influence the subsequent network metrics compared to the large network. In order to achieve the same amount of change in the metrics many more agents have to be active in the larger network.

To provide a rough order of magnitude analysis these raw scores were multiplied by the total number of agents in the respective networks and a simple percentage calculated. This is likely to be over cautious but by this reasoning the digital network exhibits greater agility (89.4%) than the comparable voice network (10.6%). The outright distance between these figures may be debatable but Figure 4 is suggestive of what we regard to be the direction of the main finding: that the digital 'info-structure' did indeed facilitate high levels of agility.

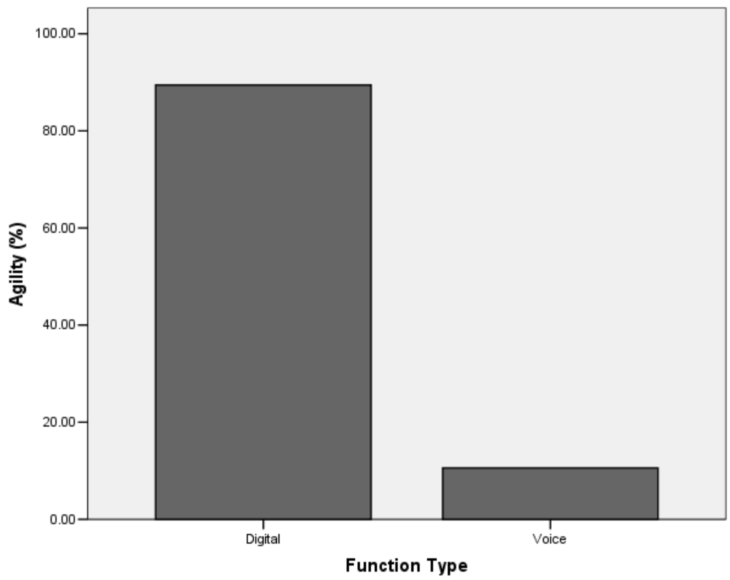

Figure 4 – A rough order of magnitude measure of total agility shows that the digitally based function of the NCW system exhibited greater agility than the voice based function.

Conclusions

The key innovation presented in this paper is to use social network analysis in order to define quantitative metrics for each of the NATO approach space's primary axes. It is this simple expedient that has provided a practical means to define the actual place or region in the approach space where an organization operates, to see how that ranges over function (digital and voice layers) and time (by taking numerous slices through the data). In addition, through the use of well understood network archetypes, a comparison between the approach and the problem to which it is directed has been facilitated. In summary, the use of both theoretical and live data demonstrates one approach to addressing the NATO model's missing links.

In Part 2 the findings go to the heart of the NATO approach space in that they show where a live C2 organization actually positioned itself in practice. Its static characterization clearly bore the hallmarks of a distinctly net-centric organization, as defined by procedures, doctrine and what we now know by considering Leavitt's (1951) theoretical archetypes. It was the users, in attempting to meet the challenges created by their 'problem', that pulled this organization into virtually all areas of the approach space. By and large it was down to them, and the way they interpreted and modified the system to suit their own purposes, combined with the constraints imposed on these unexpected adaptations, that gave the system its observed behaviour.

In the event the digital architecture was able to support high levels of agility but it is important to point out that this was only achieved through arduous effort. Indeed, the system itself imposed several unhelpful constraints that prompted adaptations and changes in agility in the first place. Fundamentally, though, there was a mismatch between approach and problem which seemed very hard to overcome. In the present case success in the mission to some extent occurred despite the presence of net-enabling technology rather than because of it.

If these unexpected user adaptations are a clue as to the type of interaction that users themselves demand from such a system, then at least now the extended NATO approach space can be used to test the effect of subsequent iterations which may reflect them. Of course, there is still much work to do on what is admittedly a relatively fresh innovation. Future work is directed into the following areas:

- further refinement of the mapping between the NATO approach space's axes and social network metrics,
- exploration of issues such as how these metrics behave at different scales,
- how concepts from complex systems research can help to understand and model the underlying dynamics of NCW systems,
- and how a similar quantification approach can be performed on the 'problem' space.

For the time being, this work is also offered up as a further point of departure for researchers, analysts, and experimenters engaging in C2-related research.

Acknowledgements

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