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A Trust-Based Framework for Information Sharing Behavior in Command and Control Environments

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***Abstract*—Information in tactical networks is being generated at an ever increasing pace. This is requiring networks to distribute the information processing in an efficient and intelligent way. Command and control (C2) theory suggests that the performance of such networks or organizations is dependent on the overall topology of the network and other parameters or characteristics of the constituent nodes, such as their ability to filter information. Traditional information sharing policies use static approaches and operate on a "need-to-know" basis. The more network-enabled approach is to "share-before-process", which introduces more dynamism and robustness to the system. However, no model exists to this day to appropriately study the trade-offs introduced by these different organizational structures. This paper proposes the use of an agent model in which agents consider two constructs, willingness and competence, when deciding with whom to share information. We show that these two constructs are general enough to capture organizational structures based on strict as well as shared governance rules. Furthermore, these constructs have clear analogues in cognition psychology, which allows us to incorporate trust into the agent models in a seamless manner. Through simulation, we study an information sharing scenario based on this agent model in different organizational structures. We illustrate the trade-offs between situation awareness (SA) gained and network overhead in terms of communications and time required to reach a steady-state SA.**

I. Introduction

In this paper, we introduce an agent-based model of team behavior that allows us to compare the decision making effectiveness of hierarchical vs. less-structured organizational structures. We investigate the impact of organizational structure in team effectiveness through a model that encompasses agent behavior along two axes: willingness and competence of team members. This model allows us to investigate the impact of various factors on the effectiveness of the team, e.g., connectivity among the team, the characteristics of individual team members, the complexity of the problem being solved, and the team size. With the help of an information sharing scenario that incorporates cognitive load on each agent, we study both the ability of the team to distribute information to each other and also the speed with which information travels. In particular, we study scenarios in which team members have different personality traits and illustrate the impact these have on the overall team performance.

Vast amounts of information are generated, shared, and processed in tactical networks. In such networks, human cooperation is a crucial requirement for effective processing of information. The primary goal in command and control (C2) environments is to get the right information to the right people at the right time to enable efficient and effective decision making. This need is addressed in the United States Intelligence Community information sharing strategy report [1], which highlights the evolving needs for information exchange rules and decision making models. There are various trade-offs involved in using different organizational structures for the task of sharing information within the team. For example, a hierarchical structure may enforce the information traveling up the hierarchy, but limit the access to information at lower levels. Plus, the bottlenecks created at decision nodes may lower the speed of decision making and increase the vulnerability of the network in case of communication delays. Less structured organizations such as edge networks are not prone to these problems, but this improvement comes at the cost of increased communication and noise. To date, there is no model that allows us to compare the two types of organizations and study the various trade-offs involved in each type of organizational structure. In traditional hierarchical networks, the interactions between agents are almost completely determined by organizational rules, e.g., need to know and need to report. However, in less structured organizations, interpersonal relationships and trust play a larger role. Our model captures both with the help of two main constructs: willingness based on trustworthiness or obligations, and competence based on information filtering ability.

The information sharing scenario we study in this paper is present in a wide range of organizations, in both domain and scope. In particular, the edge organizational structure is often cited as providing the agility necessary for quick decision making. For example, Company Intelligence Support Teams (COIST) [2] are company-level teams responsible for providing intelligence to the commander. The commander is required to perform intelligence analysis and fusion on many sources of information (e.g., documents, reports, debriefs, SITREPs). Small teams of soldiers (e.g., COIST) gather information in order to enable the commander to understand and effectively make tactical decisions. Performance and the quality of decisions in COIST environments can be greatly influenced by how quickly and widely information can be made available to the team. This networking scenario also reinforces the idea that every soldier is a sensor, given that every soldier is generating data and in some cases also processing, interpreting or exploiting the data.

Coalition networks are another example of complex networks in tactical environments that handle a wide range of information flows. Members within the coalition must make decisions based on information from entities that they may not be familiar with or they may not have complete trust. These networks may be comprised of other military branches, non-governmental agencies, other militaries, or foreign nationals. Given the diversity of entities and necessity to exchange information, it is vital to understand how to maximize information sharing among the interactions with other coalition members. In tactical network environments such as COIST or coalition networks, the overriding problems involve the ability to handle immense amounts of data, to deliver the information to those who need the information to make informed decisions, and to maximize the decision-making performance of these networks. Collaborative organizational structures found in these cases mix hierarchical relations with those based on inter-agency relationships.

In C2 environments, while each team member is tasked with consulting various sensors and other means of communication to gather and forward information, the underlying interactions are effectively inter-personal interactions dictated by a combination of personality traits, organizational rules and the need to achieve mission objectives. For example, cooperation games often show that people choose to cooperate, i.e., share information with those who reciprocate [3]. However, in an organizational context, rules may also play a role in how information is shared, in particular through the connectivity patterns imposed by the organizational structure. Personality patterns may also determine how often and with whom individuals choose to share data first. A person may be willing to share data only to improve their own standing, leading to slower rate of data sharing. We model this aspect of data sharing as the trustworthiness aspect of team members, which impacts their willingness to share data. We contrast this with organizational scenarios where team members share data based predominantly on organizational obligations and study the impact of both types of willingness scenarios.

In addition, we also consider a second aspect of team members' characteristics as their ability to accomplish a task. In our scenario, this corresponds to the ability to distinguish valuable information from noise. This aspect is rarely studied in trust models. Many cooperation scenarios are based on simplistic games in which competence plays no role. In controlled experiments, players either choose to contribute money or keep it for themselves. However, in most military scenarios involving information processing, competence is a major factor. Furthermore, cognitive psychology research shows that competence and trustworthiness are two universal factors used in when forming opinions of other people [4]. A willing team member is not very valuable if they are not competent. In this context, a soldier is not only a sensor, but also a filter. Better filters reduce the amount of noise in the network and improve decision making ability. However, competence is not simply a factor of ability, but also their situation awareness (SA). In our model, the competence of a team member improves as he has access to more pertinent information about the given problem domain. We study what effect this assumption has on the overall team performance.

To summarize, our paper makes the following unique contributions:

- We introduce a novel agent model that incorporates behavior based on both organizational rules and interpersonal relationships. Our model also captures the ability of the team members to make decisions as a function of their own abilities and the amount of information they have about the problem domain. Furthermore, we incorporate into our model the notion of cognitive load and adaptive intelligence based on past information processed.
- With the help of our agent model and an information sharing scenario, we study the impact of various factors in team performance and decision making, such as organizational connectivity (e.g., coordinated, collaborative and edge) and the amount of information required to process.
- Through simulation, we show the impact of different C2 approaches in the amount of SA an organization can gain. Also, we compare the information sharing strategies and study the settings where one approach results in superior performance in terms of SA, communication overhead and time required to attain maximum SA.
- We compare the performance of the organizations under the three C2 approaches (coordinated, collaborative, and edge) and identify tradeoffs between the choice of approach. We also observe the benefit of having redundancy in information flow patterns within an organization. To compare the collaborative with the coordinated C2 structure, we show how collaborative organization can cope with lower willingness in subordinate-superior communications by taking advantage of increased redundancy.

II. Related Work

A. Information Sharing, Trust, and Decision Making

The impact of trust on the effectiveness of teams or organizations has been studied in many different domains: organizational management [5], psychology, network science [6], [7], team studies [8], human automation interaction [9], and networking and telecommunication [10]. A common observation from the above research is that trust can introduce efficiency in task performance. That is, without relying on control mechanisms, entities may make autonomous decisions based on perceived trust. However, decision making solely based on perceived trust may introduce risk. Decision makers may not have access to sufficient information to handle challenges due to lack of resources [6], [7] or physical constraints such as network unavailability [10]. Team studies investigate the impact of such factors by simulating experimental settings [8], but to scale such studies to a large set of parameters requires the development of realistic simulation models.

Endsley [11] defines SA as a critical aspect of dynamic human decision making process. This work explains the role of SA in tactical and/or strategic systems where military command personnel rely on SA to make decisions. In addition, Bolstad and Endsley [11], [12] emphasize the role of SA in military operations as individual or shared SA enhances collaboration across teams for military missions. In this work, we consider SA as the ability to enhance decision-making ability through the sharing of information in tactical environments.

We have recently investigated trust within organizations using a C2 experiment platform called Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust (ELICIT). We examine how quality of service (QoS) in communication networks adversely affects overall user performance or trust relationships in the scenarios of dynamic information sharing in the networks [13]. In addition, [14] proposes an agent model for an information sharing scenario in tactical networks to examine how trust relationships between agents affect decision making behavior. This paper extends this prior work by introducing various dimensions of trust into information sharing behavior within various C2 environments.

Trust is a multi-dimensional concept embracing diverse aspects of an entity's reliability. In social cognition research, two types of trust are discussed according to time and effort. First, people use warmth, friendliness and trustworthiness to assess trust towards another person without much time or effort. Second, people may take more time and effort to assess competence or ability [4]. Social psychologists observed the similar trust dimensions in friendship and arm's length relations [6]. In organizational management, Mayer et. al. [5] adds integrity to evaluate the ethics or beliefs of the other person. Levin *et. al.* [7] disregard integrity because it does not have a moderating effect in the behavior dynamics. However, it is likely to serve as a precondition for all cooperation. Prior trust models treat trust as a binary concept: trusted vs. untrusted. For example, in e-commerce, when a person will carry out a specific transaction successfully, the system is trusted [15]. Similarly, on the internet, we trust correct information [16]. In such models, trust is accumulated as a function of evidence collected either from interactions or from a social network. These notions of trust are meaningful in simplified contexts of applications. However, in complex networked environments, various types of trust may play an important role in decision making at the same time. Research on composite trust models using multiple dimensions of trust has recently received considerable attention [10]. Our work also adopts the concept of composite trust considering the multidimensional aspects of trust.

B. Information Sharing vs. Organizational Structure

Information sharing in an organization is affected by the structure of the organization which dictates the approach taken to share information. Stinchcombe [17] defined an organization as "a set of stable social relations, deliberately created, with the explicit intention of continuously accomplishing some specific goals or purposes." Jacobides [18] viewed the organizational structure as "the viewing glass or perspective through which individuals see their organization and its environment." This work is mainly interested in investigating the idea that organizational structure is critical to how information is shared and how each individual is part of the decision making process.

In the C2 research community, Alberts and Hayes [19] propose C2 Maturity Model in order to understand how to better operate in a complex network environment. The C2 Maturity model [19] presents a C2 approach space model to reflect potential operating environments of organizations in information flow and decision making rights. The main C2 approach space dimensions [19] are: patterns of interactions among entities, distribution of information among entities, and allocation of decision rights to the collective. One of key features of edge organizations is *self-synchronization* [20]. Dekker [21] experimented the effectiveness of self-synchronization under various circumstances in terms of network capacity, problem complexity, and time-pressure using computer simulations. The comparison of centralized networks networks to organizations without a commander was made here in terms of performance. Our work considers the impact of trust in these two organizational structures: hierarchical and edge.

Edge and Remus [22] examined the impact of hierarchical and egalitarian organizational structure on group decision making and attitudes in a simulation experiment. They found that the egalitarian organization outperforms the hierarchical organization by showing high return on investment with speedy decisions and high work motivation. However, they observed that less incentivizing organizations with egalitarian communication do not necessary perform better than hierarchical organizations. Joglar-Espinosa *et al.* [23] compared problem solving capability of edge organizations and that of hierarchical organizations when knowledge sharing is encouraged. The authors observed that the edge organization outperforms the hierarchical organization, particularly when knowledge sharing is implemented. Entities in the edge organization interact more closely and share information since they have the freedom to collaborate. Leweling *et al.* [24] showed that edge organizations perform better than hierarchical organizations under certain environmental contexts using the ELICIT multiplayer intelligence game. Like other existing work dealing with comparative analysis between traditional hierarchical organizations and edge (or flat) organizations, this work also did not consider trust as a factor to facilitate information sharing or to enhance decision making.

III. Agent Model

In this section, we describe the data model used in our simulations. Our model builds on the concept of data sharing between team members in an organization. We assume agents are working to optimize their problem solving ability. To do so, they need to make the best use of the resources that they have available to them. In this case, the main resource is the other team members. Team members sense and share information. When deciding who to share information with, there are two main considerations: availability and access to data from a specific team member, and the quality of the data obtained from a specific team member. These two considerations must be balanced: highly available information is not valuable if it is too noisy, and high quality information is not useful if there is no access. As a result, we summarize these two concerns into the following two constructs:

- *Willingness* of the team member to share data contributes to the availability of the data, and
- *Competence* of the team member contributes to the quality of the data obtained from the team member based on his ability to filter out irrelevant data.

These two constructs have different meanings based on the relationships between team members in different organizational contexts as we describe below.

A. Willingness

We consider two types of relationships:

- Organizational relationships define who reports to whom.
- Interpersonal relationships define to which degree one considers another person trustworthy. In an organizational context, the trustworthiness implies that a person may be relied on to cooperate in accomplishing tasks.

We note that both types of relationships imply an asymmetric willingness to cooperate. If A reports to B, then B can rely on A to be willing to pass on all information that he has to B. Furthermore, A will send information only to those individuals he reports to.

In the case of interpersonal relationships, there is a general expectation of reciprocity. A will report information to B only if B reciprocates. If B does not reciprocate due to inability to communicate or lack of time, A will eventually choose to dedicate his energy to cooperating with another team member. This notion of trustworthiness is operationalized in our model as the willingness to cooperate. In cases where individuals have limited cognitive resources either due to lack of time or the sheer size of data they have to process, this type of conditional reciprocation can play an important role in how information is routed in the network.

In an organizational setting, the hierarchy defines who can communicate with whom. Even in the hierarchical setting, team members may choose to use backchannels based on interpersonal relationships. In less structured organizations, almost all data sharing is based on interpersonal relationships. Note however that many other constraints, e.g., communication connectivity may define who may be able to share information with whom. For example, in traditional C2 organizations, the typical mode of operation is to adhere to static strict rules to share information. Information is shared out of obligation. Entities are expected to forward information without any ability to make decisions regarding the information, regardless of their competence. Subordinates send all information *up* to their superior, their superiors send all of this information to the commander, or whomever is responsible for decision making. Their willingness is a measure of their ability or motivation to share information with their superior. In addition, teams may be able to share information with other teams directly by communicating *across* teams through similarly ranked team members. In the recent proposed approaches to C2, we consider more distributed approaches where each entity can exchange information with any other entity within the organization, regardless of role or position in the organization. Interactions are guided by trust in the other entity, which we define as being a function of willingness and competence.

B. Competence

As discussed earlier, team members also need to take into account not only the availability of the data, but also its quality. In a hierarchical reporting scenario, it might be expected that individuals must pass all the information available to them, as information is processed only at the decision nodes to avoid possible loss of information. However, if the lower level nodes are given processing power, i.e., ability to filter information, they can reduce the amount of noise transmitted by only sending information deemed valuable. However, this presumes that team members can in fact distinguish valuable information from noise. The capability of the individuals to accomplish a task depends on two factors:

- The inherent expertise of the team member based on his familiarity with the problem topic, and
- The situational expertise of the team member based on his access to the relevant facts and cognitive resources available, *i.e.*, situation awareness.

We assume that the inherent expertise of an individual is a human capital and impacts to which degree he can process and make sense of the facts he receives. As a result, situational expertise is a function of both the facts available to the team member and his inherent expertise.

IV. Computational Framework

In this section, we describe how the agent framework is implemented and the different tunable parameters available to the framework. We will then discuss the setup for experiments. The results of different tests are given in the next section.

The scenario that we insert our trust model into is one where agents are responsible for sending information to a decision-making node. All of the agents are initial given a set of facts, and they must decide whether or not to forward information to other nodes in their organization. Not all the facts are valuable. The ability to distinguish valuable information from noise is the main determinant of competence. Suppose, an agent A receives a fact that they consider valuable from another agent B. A will consider this as a positive evidence of B's competence. However, the fact that B is sending information to A is positive evidence of their willingness to cooperate.

A. Agent Trust Evaluation

We represent the evolution of competence and willingness by using Bayesian updates of the Beta and Gaussian distributions, respectively. Estimates of competence and willingness based on the expected value of each of the distributions and their variance are an evaluation of the uncertainty of the assessment of the parameter. A more detailed explanation of this formulation can be found in [14].

For competence, we use beta-binomial conjugate distributions with prior distribution $B(\alpha_0, \beta_0)$, where α_0 and β_0 are the initial prior positive and negative evidence, respectively. Given the new positive and negative evidence (r and s, respectively) based on the perceived number of valuable or non-valuable information received from an entity, the posterior trust distribution is given by $B(\alpha + r, \beta + s)$. The expected (mean) value of trust, $E(t_c)$, and its uncertainty (variance), $\sigma^2(t_c)$ are given by:

$$E(t_c) = \frac{\alpha + r}{\beta + s + \alpha + r} \quad (1)$$

$$\sigma^2(t_c) = \frac{(\alpha + r)(\beta + s)}{(\alpha + r + \beta + s)^2(\alpha + r + \beta + s + 1)} \quad (2)$$

For willingness, we use Gaussian-Gaussian conjugate distributions with a prior of $\mathcal{N}(\mu_0, \sigma_0^2)$ and evidence $\mathcal{N}(\mu, \sigma^2)$, where $\mu = t_w$ and σ^2 is the variance of the past willingness t_w for that node. The posterior distribution is $\mathcal{N}\left(\left(\frac{\mu_0}{\sigma_0^2} + \frac{\mu}{\sigma^2}\right) / \left(\frac{\sigma_0^2 + \sigma^2}{\sigma_0^2 \sigma^2}\right), \left(\frac{\sigma_0^2 \sigma^2}{\sigma_0^2 + \sigma^2}\right)\right)$. The simulations use the following prior distribution values: $\alpha, \beta = (10, 1)$ and $(\mu_0, \sigma_0^2) = (0.5, 1)$.The expected (mean) value of willingness trust, $E(t_\omega)$, and its uncertainty (variance), $\sigma(t_\omega)$, are given by:

$$E(t_\omega) = \left(\frac{\mu_0}{\sigma_0^2} + \frac{\mu}{\sigma^2}\right) / \left(\frac{\sigma_0^2 + \sigma^2}{\sigma_0^2 \sigma^2}\right) \quad (3)$$

$$\sigma(t_\omega) = \frac{\sigma_0^2 \sigma^2}{\sigma_0^2 + \sigma^2} \quad (4)$$

In terms of competence, the behavior that the agents exhibit is a function of the valuable facts that they have processed. We assume initial competence of c_0 and then for every fact f of the total number of factoids F a node has been able to process, it behaves with increasing competence. As a result of being able to obtain and process the facts, it will gain $\gamma f(t)/F$ competence. The learning process is determined by:

$$c(t) = \min\left(c_0 + \gamma\left(\frac{f(t)}{F}\right), 1\right) \quad (5)$$

At each point in time, the agent considers the current fact that he has processed and decides whether or not to share it with another agent. The order is determined by their relative trust in their neighbors. As only one fact is processed at each point, this models a type of cognitive limit (and overload).

B. C2 Structure

We consider the C2 approaches in which one organization is operating, potentially the case where there are several teams working towards the same goal. There is a varying degree of connectivity within these organizations. In [19], we consider the coordinated (C3), collaborative (C4) and edge (C5) organizations as three C2 approaches.

The coordinated and collaborative organizations (C3, C4) are hierarchical structures, where we assume that there is a single commander node and several team leader nodes who are supported by sets of teams. We model an organization about the size of a platoon where the teams are represented by squad-level sized groups. Within the organization, nodes can either send information up their hierarchy or, if possible (in C4), they can share information between team members of different teams. In C4, each team has 2 nodes that are able to communicate with team members of other teams. The probability this link is used is ω_x. For C3 and C4, team members are not capable of assessing value of the information so they send all information up. The team leaders are able to filter the valuable information from the non-valuable information. Also, the willingness and competence of the nodes are fixed over the time simulation. We also consider edge topologies (C5), where every node is able to share with any other node. The interactions are guided by the trust established between the pairs of nodes. The trust is based on a prior estimate that is initialized at the beginning of the simulation, and changes as a result of the observed behavior of the nodes. Simple examples of the hierarchical and edge approach are shown in Figure 1.

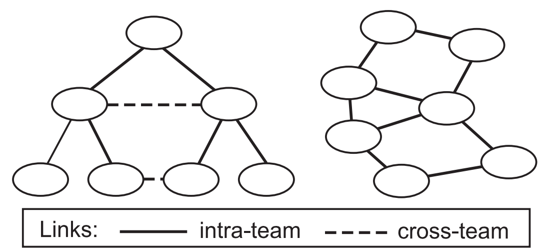

Fig. 1. Hierarchical (coordinated C3, collaborative C4 on the left) vs. Edge topologies (C5, on the right), showing both intra-team and cross-team communication links. A C3 organization has no intra-team communication links.

C. Experimental Setup

At the start of each simulation, we seed all of the facts randomly to the nodes in the network. At each time, a node will take a fact from its inbox (message buffer), determine the value of the information, and decide with which, if any, of its neighbors to share the information. At each time slot, a node is able to send information to one of its neighbors. The most trusted node has the highest priority, valuing willing and competent nodes higher than all, then prioritizing competence over trustworthiness based on preset thresholds. The nodes perform this process until it has no messages in its inbox until the simulation is finished. We also consider initial values of the nodes in terms of the behavior that they will exhibit throughout the course of the experiment. Initial willingness ω and cross-team willingness ω_x.

V. Simulation Results

We have run several sets of simulations to study the impact of organizational structure on organizational performance. In this section, we first define metrics by which we measure the performance of the organizations. From these simulations, we can see the difference in performance for the C2 approaches and observe how the organizations perform in the presence of varying behavior of the constituent nodes.

A. Metrics

We use three metrics to study performance, efficiency and resource cost. To measure performance, we look at the SA of the commander node as shown in (6). This node is responsible for decision making and needs all of the information. Failure for the subordinate nodes to forward this information to the decision making node will cause significant effectiveness of the organization. On the other hand, it is not as crucial if the nodes lower in the hierarchy do not receive all of the information.

$$\overline{SA}(t) = S_{cn}(t) \tag{6}$$

For the edge, we consider the performance of the organization to be a function of the maximum SA attained by any of the nodes, so (7) defines the SA of the commander to be the SA of the node that has attained the greatest SA within the organization.

$$\overline{SA}(t) = \max_i S_i(t) \tag{7}$$

For resource cost, we look at the total communications $C(t)$ performed over the course of the simulation in (8).

$$\overline{C}(t) = \sum_{ij} C_{ij}(t) \tag{8}$$

For efficiency, we consider the time taken for the commanding node to achieve final SA for the particular simulation, regardless if it has reached full shared SA. This is described in (9):

$$t_f = t|min_t \text{ s.t. } \overline{S}_{cn}(t) = S_{cn}(T). \tag{9}$$

B. Performance vs. Organization

We compare the performance of the organizations under the three C2 approaches and identify tradeoffs between the choice of approach. Figures 2, 3, and 4 are average results of 20 runs of an organization of 20 nodes, running the information sharing scenario for $T = 5000$ time units. These simulations have used three of the C2 approaches: coordinated (C3), collaborative (C4) and edge (C5). For this set of experiments, we consider a set of $F = 200$ facts with $f_v = 100$ of them being of value. To study the impact of willingness in the organization, we look at each of the C2 approaches and have run a set of simulations that varies willingness ω and cross-team willingness (ω_x). We note that C5 only uses ω to determine sharing with other nodes, regardless of any team affiliation.

Figure 2 shows that C4 and C5 are superior to C3 when willingness is low to moderate. The team leaders in C3 and C4, all members in C5 may incorrectly drop information. Due to the redundancy provided by the greater connectivity in C4 and C5, this does not result in reduced SA even in the case of lower willingness values. Figure 3 and 4 show the communication cost and time required to attain maximum SA. Overall, C5 has higher communication cost and takes longer to attain maximum SA.

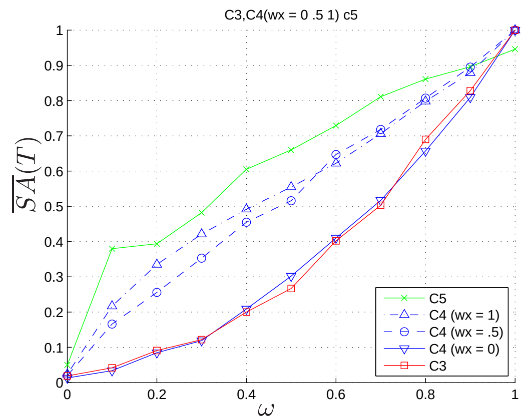

Fig. 2. SA vs. Willingness for coordinated (C3), collaborative (C4) with varying cross-team willingness, and edge (C5) topologies

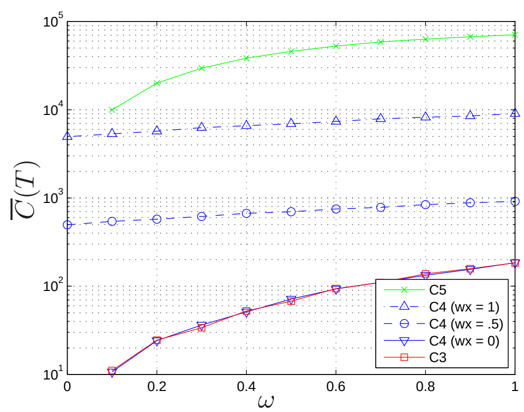

Fig. 3. Total communications vs. willingness for coordinated (C3), collaborative (C4) with varying cross-team willingness, and edge (C5) topologies

C. Performance vs. Dataset Size

The second set of simulations study the impact of the volume of data on performance. We considered network sizes $n = 20$, and $F = \{100, 500, 1000, 5000, 10000, 50000\}$ with $f_v = .5F$ using the three C2 approaches: coordinated (C3), collaborative (C4), and edge (C5). Each of these simulations use $\omega = 0.6$.

Our hypothesis is that the traditional approaches using a hierarchical approach will prove to be too rigid as higher nodes in the hierarchy become bottlenecks due to information overload, which will in turn have a negative impact on the

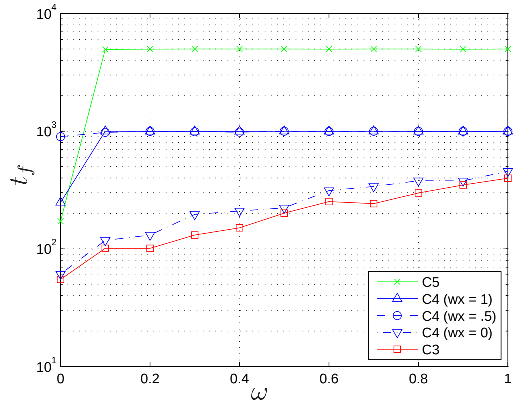

Fig. 4. Total communications vs. willingness for coordinated (C3), collaborative (C4) with varying cross-team willingness, and edge (C5) topologies

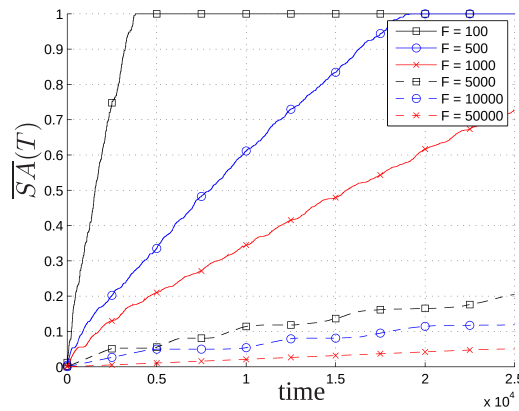

Fig. 6. Edge (C5) topology vs. F (Dataset size)

performance. In addition, reduced situation awareness is also a contributor to lower competence, which impacts the ability to filter information appropriately.

The results of the simulations show that the hierarchies are efficient with small datasets and they are able to attain SA quickly, but exhibit diminish performance when compared to the edge topology in terms of maximum SA attained. This is due in part to the initial value of ω, which would result in some valuable information not being forwarded to the commander node. The coordinated and collaborative topologies essentially have the same performance when studying these topologies from the perspective of the dataset size. Figures 5 and 6 show these results, which is the average of 20 runs for each value of F.

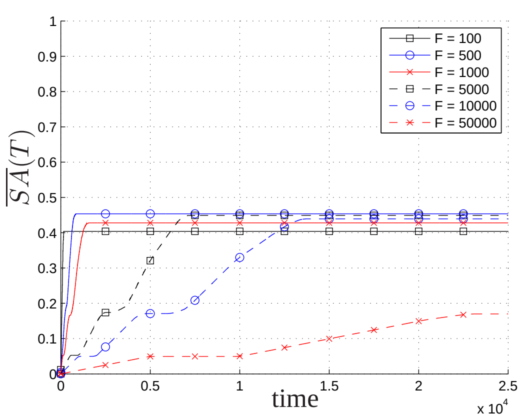

Fig. 5. Hierarchical (C3) topology vs. F (Dataset size)

Additionally, we see that the communication cost comparison of the edge versus hierarchical organizations is similar to previous results, where the edge performs better in terms of maximum SA, but requires more information exchange. This is shown in Figure 7. Lastly, we look at the rate that each topology gains SA in Figure 8. We see that this reflects the idea that the hierarchical topology can quickly gain SA, but is unable to gain as high final SA as the edge topology.

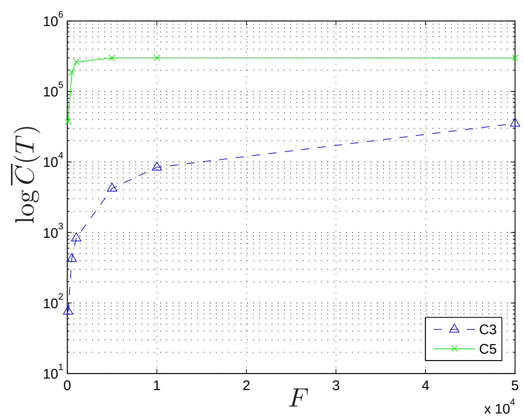

Fig. 7. Communications required for maximum SA for Coordinated (C3), Edge (C5) vs. F (Data size)

VI. Discussion and Conclusion

We have studied the problem of information sharing in tactical networks and considered the impact of trust-based information sharing to deal with the emerging issues of recent information networks. We introduced a novel agent model based on two constructs: willingness and competence, and showed that it can effectively capture the trade-offs between connectivity and decision making capability. We showed how both constructs can be implemented to reflect different organizational rules and tie performance to both individual ability and situation awareness. There are many factors that remain to be studied in our framework, such as the impact of various adjustable parameters on performance. We also would like to model more distributed decision making scenarios where the shared situation awareness contributes to team performance. We are currently working towards validating parts of our model against cooperation experiments, and further validation

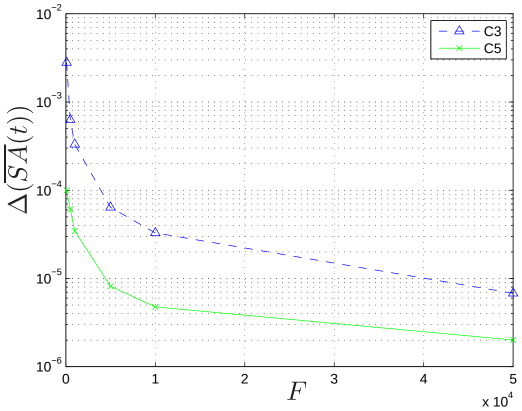

Fig. 8. Rate of SA gain for Coordinated (C3), Edge (C5) vs. F (Data size)

is an ongoing topic of study. The model is a useful step towards providing strategies to maximize information flow in future tactical networks.

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