Recommendations for Network- and Internet-based Synchronized E-activities for Location- and Time-dependent Information

Paul Labbé* (P. Engineer), Zakaria Maamar (Ph. D.), Elkadhi Abdelhamid*** (MSc.), Bernard Moulin*** (Ph. D.), René Proulx**** (Senior Analyst), and David Demers* (Scientist)**

*Defence R&D Canada - Valcartier (DRDC Valcartier) /
R & D pour la défense Canada - Valcartier (RDDC Valcartier)
2459 Pie-XI Blvd. North
Val-Bélair (Québec), Canada, G3J 1X5
Tel.: (418) 844-4000 X 4479 FAX: (418) 844-4538
paul.labbe@usa.net
David.Demers@drdc-rddc.gc.ca

**Zayed University
College of Information Systems
PO Box 19282
Dubai, UAE,
Tel.: (971) 4 2082 461
Zakaria.Maamar@zu.ac.aeAddress

***Laval University
Département d'informatique et Centre de recherche en géomatique
Ste Foy (Québec), Canada, G1K 7P4, Canada
Tel.: (418) 656 5580 FAX: (418) 656 2324
bernard.moulin@ift.ulaval.ca
elkadhi@ift.ulaval.ca

****Neuring Inc.
7 rue de Laval
Québec (Québec), Canada G1R 3T8
Tel./FAX: (418) 692-3878
Rene.Proulx@drdc-rddc.gc.ca
NEURING@usa.net

Abstract

Seeking advances in infrastructure for e-activities over networks requires the projection of the utility (either profit or satisfaction) of such activities for organizations and individuals. Studies of defense-information systems that manage spatial- and time-dependent data for which we have assumed a decision process applied by cybernetic models with a bi-dimensional function for effector's effectiveness revealed emergent properties that must be considered in defining future e-activities over dedicated networks, intranets and the Internet. We address two aspects of improving the value of shared information for spatial- and time-dependent data for synchronized actions: (1) architecture changes, and (2) strategy adaptation to dynamic data for geographically distributed fix or mobile participants.

1 Introduction

Defense [1, 2] and Internet [3, 4] infrastructures exemplify the basic underlying frameworks or features of geographically distributed large and complex systems that manage e-activities for location- and time-dependent information. These infrastructures include the permanent installations required for military and Internet objectives such as e-commerce [5] that can be subjected to malicious attacks. Improved information systems architectures exploiting unified coherent structures allow streamlining these complex systems and make them more robust and maintainable. Consequently, architectural changes and information strategies that improve information value to end users and increase decision and action success rates impose on future military and Internet infrastructures.

Exploring the impacts on organizations' and clients' objectives of changes in architectures and strategies offers opportunities of observing emergent properties that most of the times were expected though not quantitatively demonstrated. However in a few cases conclusions are quite counterintuitive. To observe the impacts of changes in terms of organizations' effectiveness, appropriate modeling of the business processes at stake must be carefully constructed and validated with the end-users. Furthermore, advances in technologies must be selected and adapted appropriately to evolved processes since architecture and strategy changes require

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2002		**00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Recommendations for Network-and Internet-bassed Synchronized E-activities for Location- and Time-dependent Information	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defence R&D Canada -Valcartier,2459 Pie-XI Blvd North,Val-Belair (Quebec), Canada G3J 1X5, ,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**27**	

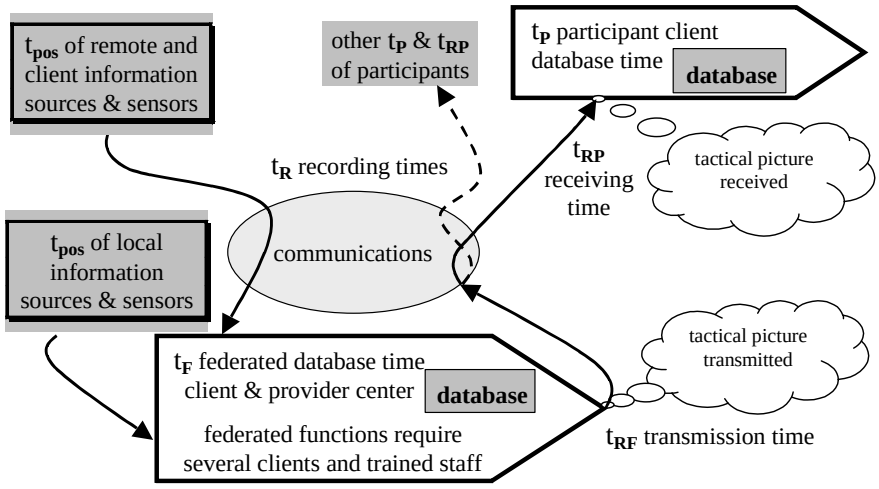

Fig. 1. Information flow of the systems (baseline architecture) studied where each participant does not use their local sensor information locally for improving the received federated information. Each participant sensor data are sent to the central node of the federation.

adaptation in the manner of conducting business in the future. In the defense sector this means that technology insertions require the development of appropriate standard operating procedures (SOPs) and training of personnel.

This paper addresses the challenging problem of assessing the value or impact of information systems architecture changes and of strategy adaptation to dynamic inputs (attribute-, location-, and time-dependent information) and network capabilities for mobile and fixed participants geographically distributed, e.g., a change may include using intelligent agents in military or industrial e-activities [6].

Throughout this paper, readers will find useful information on experiments conducted, measurement methodologies, results obtained and their interpretation in terms of strategy, architecture and infrastructure requirements for future systems that would better support current and new e-activities.

2 Infrastructures and Cybernetic Models at Play

Reference infrastructures and architectures (Fig. 1) of this paper were used in coalition live and simulated exercises where the decision-making process at command centers (CEOs in non-military operations) can be interpreted as an adaptive-control system represented by a cybernetic model such as [7] including the following activities:

1- monitor the situation;

2- assess the situation and estimate adversarial intent;

3- develop alternative courses of action;

4- predict their consequences for both sides;

5- decide a course of action (COA); and

6- direct its execution while monitoring the evolving situation in the environment.

Furthermore, the model must interact with external processes and agencies to inform and query, through direct and monitor functions respectively. In such cybernetic models, the decision-making process recursively steps through a six-staged cycle. By using cybernetic models to interpret data and information collected during experiments consisting of simulated or real business operations, the properties of a business activity can be evaluated in terms of the adequacy or inadequacy of performance of each of the model stages or systems' functions (MOPs). We evaluate the stages through a set of measures of performance (MOPs). Similarly, measures of effectiveness (MOEs) can provide an assessment of the resulting degree of mission accomplishment in scenarios (operations or market campaigns) to scale MOPs relatively to the MOEs.

DRDC -Valcartier model-based measures (MBMs) [8, 9] are evolving into more systematic methodologies where experiments with appropriate statistical replication allow estimating the effects of a technology insertion accurately. Such experiments require a set of systematically replicated scenarios played by trained personnel organized in decision-making teams. For each experiment, realistic and insightful critical scenarios are replicated, both with and without a particular architecture change. The selected scenarios specify the operational parameters of interest. Decisions and plans made with uncertain and incomplete information force actions and strategies that result in much less than optimal outcomes. The productivity of an outcome is computed using a utility function that factors in 1- the cost of using resources, and 2- the closing towards the objective(s). For an experiment with sufficient observable events, it is possible to draw statistical inferences on the causal effects or cause-and-effect of the particular technical insertion or architectural change studied on systems' MOPs and mission's MOEs.

Our early MBM cybernetic model took the following form:

1- Find the data available to a decision-maker at the time of engagement for each opportunity to engage a given contact.

2- Build the data history at the same command node during the preceding 15-min period (or longer, depending on the sampling rate during the original data collection). Techniques accounting for missing data points may be required.

3- Determine the geographical sub-area to be used to evaluate the quality of the tactical data for this particular decision, e.g., a fixed radius around the aimed position.

4- Calculate the information quality and quantity for this sub-area for the conditions imposed by 1 and 2 above. This requires searching for the corresponding ground-truth data.

5- Determine possible causes of variation, if the calculated values at time of engagement in 4 are much different from those calculated by searching the best and worst values according to the combination of 1 to 4.

6- Accumulate the portion of the above measures that are consistent with the scenario's rules of engagement and with an appropriate cybernetic model.

7- Calculate the correlation between results using counts and rates of corresponding engagement success or failure.

8- Deduce possible causal relationships and calculate their empirical probabilities using sets of correlation values and alternative rules.

However during the course of our compute-intensive analyses of collected data we have refined and simplified this generic approach to the case of over-the-horizon targeting for ships identified in a decision-maker database as hostile. In such a case the cybernetic models collapse into the following:
for all units in a task force (allied friendly forces) that have effectors (weapons) available, for each report of hostile platforms at position within effectors' range, hypothetically (or with an

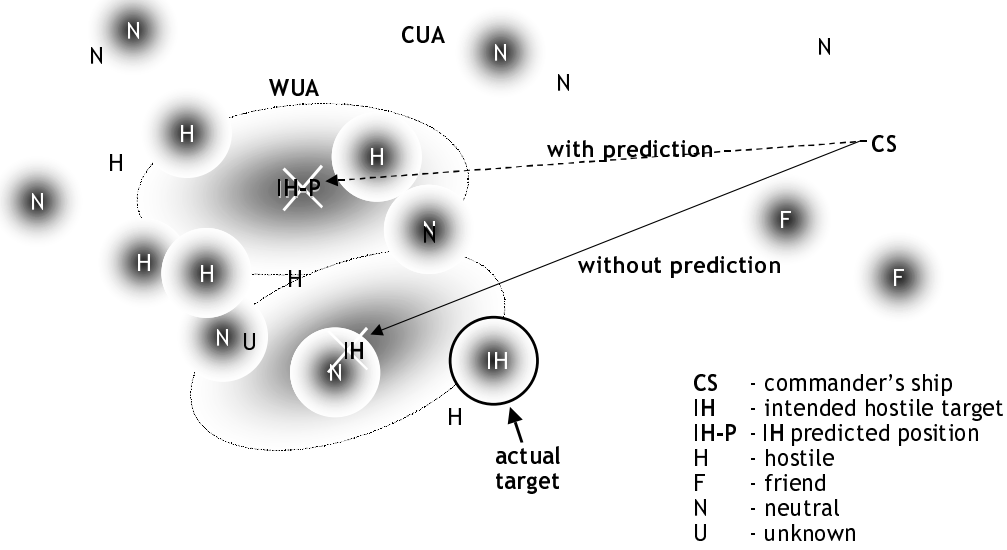

Fig. 2. Two effectors' opportunities for a perceived hostile ship. Black letters identify ground-truth positions. White letters identify the uncertain positions displayed to decision-makers.

artificial delay) immediately or with a delay intercept hostile according to the latest received rules-of-engagement For these cybernetic decision models we have characterized various types of uncertainties observed in real situations for the reference coalition infrastructure of Fig. 1. Positional reports provide t_{pos} the time of an observation, its creation time t_F in the source database, its arrival time t_P in a participant database and the record times of its transmission t_{RF} and reception t_{RP} at participant locations with $t_F < t_{RF} < t_{RP} < t_P$.

Due to a lack in coherently reporting positional areas-of-uncertainty (AOUs) in coalition, a circular-uncertainty area (CUA) is applied to the real position (ground truth) of each ship for computation and assessment purposes. A truncated-bivariate-normal distribution was used for the results presented. Consequently, the probability of a ship being outside its CUA centered at its ground-truth position is zero and inside its CUA that probability follows a bi-normal density function. Our generic effectors' footprint (weapon-uncertainty area, WUA) for the results presented used an ellipsoid with a triangular weight function reaching its maximum at the center and null at the edge and outside the footprint area. This weight indicates the likelihood of intercepting (*LI*) something if it is at a given position within the WUA. Centering the effectors' footprint on the reported position or a predicted position provides two measure opportunities as illustrated by Fig. 2. Details are beyond the scope of this paper and can be found in [8, 10]. However we need an indication in this paper of how MBMs use utility functions to combine interception value (*IV*) and effectors' cost (*EC*) in progressing towards organizations' and clients' mission goals, e.g., the success rate measure (*SRM*) is:

$$SRM = (IV \otimes LI) \oplus EC. \quad (1)$$

3 Success as Function of CUA and WUA Parameters

Applying MBMs to collected data from coalition exercises with the reference architecture for over-the-horizon targeting opportunities of hostile ships we have obtained results that can be used for assessing the impact of architecture changes. Extensive computation of MBMs to explore the effect of varying the CUA and WUA parameters for various input data sets provided

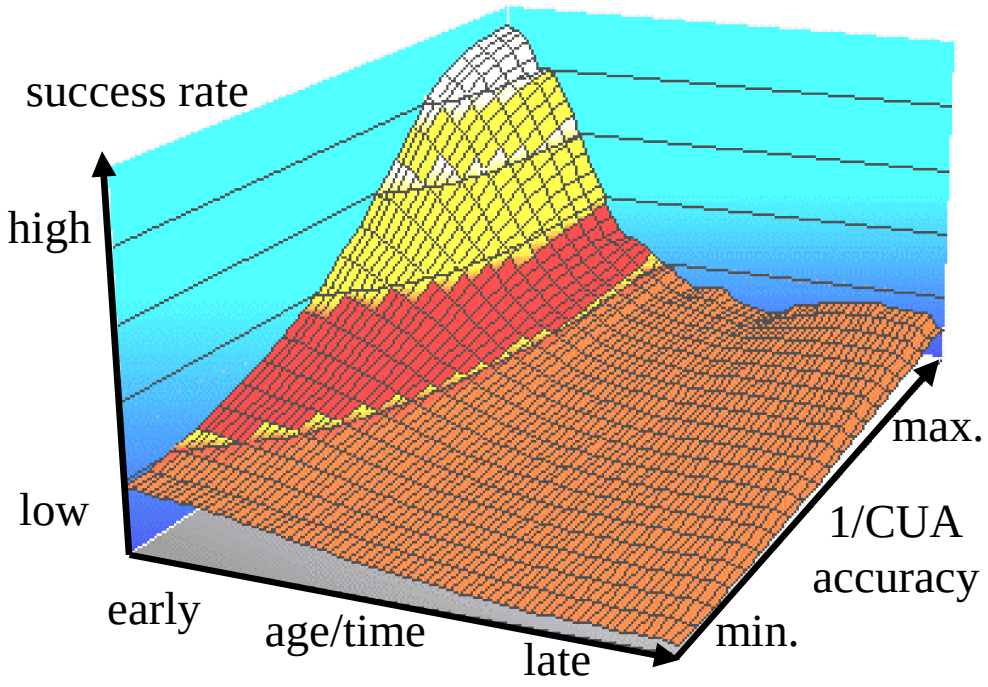

Fig. 3. Potential mission success rate as function of input information age and accuracy for a fixed effectors' strategy (fixed WUA parameters).

insightful results from which emergent properties can be identified. Next we present these results in the context of drawing a parallel between coalition activities and other e-activities that are imposing new requirements for the evolving Internet infrastructures and management strategies.

3.1 Success as Function of Accuracy and Age

If we assume that smaller CUAs are equivalent to higher accuracy then Fig. 3 shows that the success rate or mission effectiveness increases as a function of information promptness and accuracy (smaller CUA parameters). We can therefore infer that as uncertainties and their associated CUAs increase, mission effectiveness decreases. Similarly, as input information ages or timeliness decreases, mission success rate or effectiveness decreases. Though we have made a lot of assumptions and greatly simplified the extremely complex problems at stake, using such results allow the identification of coalition infrastructure properties.

In Fig. 3, a given effectors' strategy mission effectiveness (success rate) monotonically increases with information promptness and accuracy. This is a particular case where information promptness is equivalent to information timeliness because our models did not include detailed effectors' dynamics. If we add optimal times-to-go for describing effectors' behaviors, then maximum effectiveness would occur between the minimum delay and the optimal time-to-go, creating bell-shaped results along the age axis. The same would occur for a marketing campaign not initiated at an optimal-opportune time for a given objective.

A simple rule-of-thumb for assessing architecture changes is to use MBM metrics that express effectiveness as function of information promptness as in Fig. 4 for the scenarios and model assumptions made.

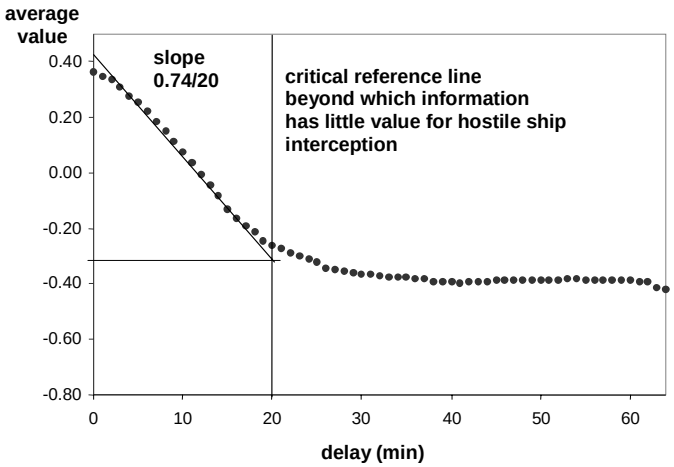

Fig. 4. Ship-engagement effectiveness as function of information age.

Someone said: "There is nothing better than an idea whose time has come." Being pertinent and timely is an emergent property. From the experimental results we infer that an improved architecture must include the notion of value of information and its timeliness for intended tasks or missions. Consequently, the infrastructure that supports such an architecture must provide means for prioritizing activities and services across the assets at play.

3.2 Success as Function of Strategy and Age

If we assume that smaller WUA parameters are equivalent to precision targeting and larger ones to lower-selectivity target destruction within large areas (mass destruction) then these parameters can be associated with effectors' strategy broadness. Fig. 5 shows that the success rate or mission effectiveness increases as a function of information promptness for fixed CUA parameters. Effectiveness as function of effectors' strategy broadness or total WUA footprint area increases from low effectiveness for narrower strategy (smallest WUAs) up to a maximum of effectiveness for some broader strategy (some larger WUAs) but effectiveness rapidly drops down after that point for even broader strategy (even larger WUAs). For prompt information (early age), effectiveness follows a wave shape (not exactly a bell shape but like a Rayleigh distribution envelope) that indicates that strategies must be tailored to what need to be accomplished. Because of the utility functions used, weapons that do not limit their effects to the intended targets are penalized for too large potential collateral losses. Precision weapons that are too demanding on the collected information on a target simply do not intercept targets often enough for their (firing) cost. Fig. 5 shows that strategy broadness for optimal effectiveness (the maximum value for a given age) increases slightly with the age of the information used in deciding to act.

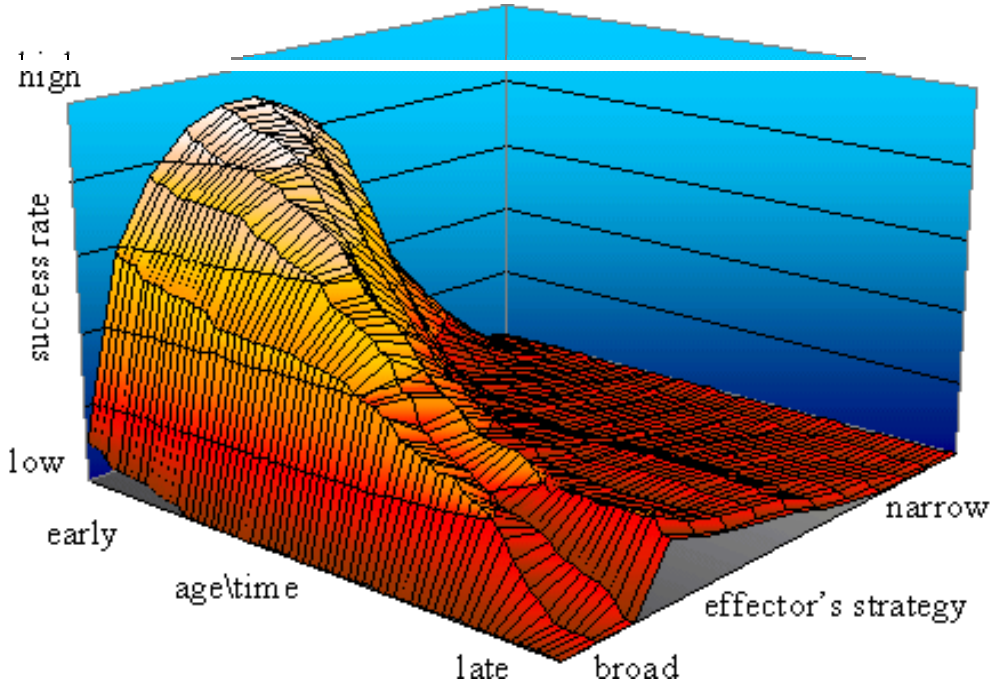

Fig. 5. Potential mission success rate as function of input information age and effectors' strategy broadness for fixed CUA parameters.

One interpretation of these results for effectiveness as function of strategy broadness and information promptness is the strong requirement for a certain level of adaptiveness for the effectors' strategy to maintain best results for desired decision outcomes. Only more detailed analyses will reveal the metrics for each type of e-activities and operations such as for e-medicine and e-commerce.

4 Architecture Changes

4.1 Baseline Architecture

The baseline architecture of the coalition exercises analyzed is best captured by the information flow diagram of Fig. 1. This architecture with a central node that broadcasts the information of one federated database was designed with the intent of offering the same information to all decision makers of a coalition. Unfortunately it has several drawbacks such as time-lateness due to non-optimal use of staff (those developing the information to be shared), computer and communications capacities.

4.1.1 Can it be improved?

For the observed experiments and hypotheses made in [10] assuming that perfect information management and sharing can occur with no loss and delays, and that sensor errors and uncertainties are null, then such architecture and infrastructure can be replaced by utopian ones that would score an effectiveness improvement of 63%. Next we present feasible changes and their corresponding effectiveness gain using the same MBMs' metrics.

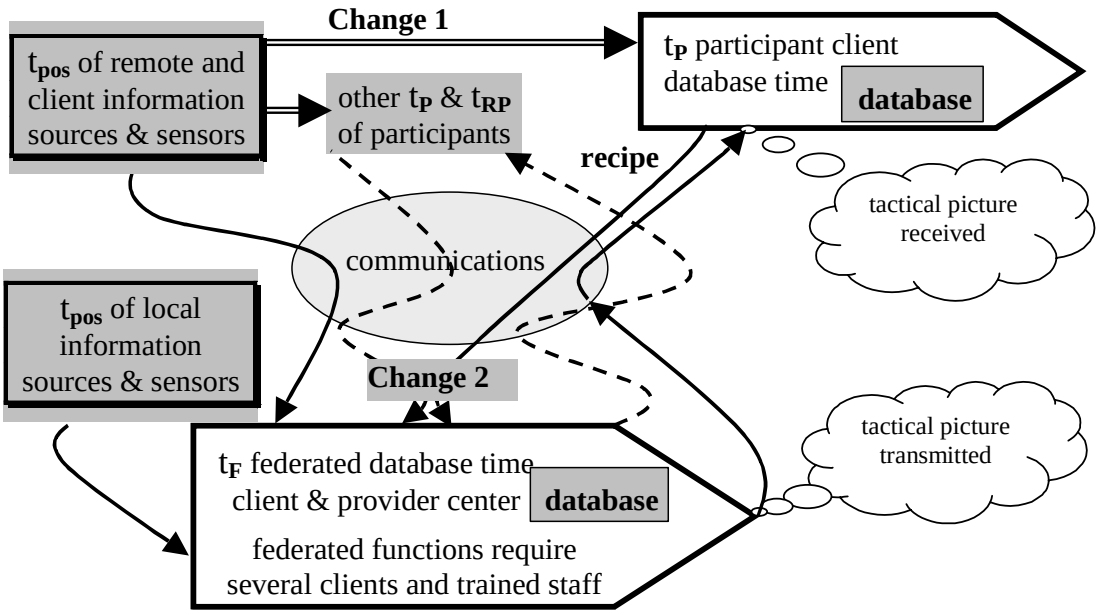

Fig. 6. Modified information flow of the systems studied where each participant uses its own sensor information locally for improving the received federated information. Each participant sensor datum is still sent to the central node of the federation. Change 1 and Change 2.

4.2 Baseline Architecture with Change 1Fig. 6

The baseline architecture implies that the federated database is generated at a central node that combines and fuses remote and local information. The central node broadcasts at prescribed time intervals the content of its database to participants. In the baseline architecture, participants are not allowed to use their local data. Change 1 allows participants to fuse their local information to the federated database received from the central node. This is one of the objectives of a technology demonstrator for the Canadian Navy: Command Decision Aid Technology I (COMDAT I) [11].

4.2.1 Change 1 assessment

During one of the exercises described in [10] we have observed that the federated database had more stable and accurate identity of contacts than each participant for the two segments of exercise analyzed for that purpose. This is one of the advantages of using all the information available from all sources. We observed for these two segments a 14% advantage over local data for the identity attribute of hostile surface ships. However local data were more timely and consequently, though not having the area coverage and identity accuracy of the federated database, they offered for local contacts potential engagement success rate increases of 14% and 19% for the two participants assessed in [9].

4.3 Baseline Architecture with Change 2 Fig. 6

This is the baseline architecture with Change 1 but with the ability to locally evaluate the value of combining genuine local information from own sources to the received federated database. For every such combination that improves locally the perceived value of the information provided to the decision-maker, an information management agent proposes the following actions. Display the improved result (e.g., more up-to-date contact location) locally in addition to the federated data. Send to the central node the instructions (a recipe) on how to obtain the results that improves locally the value of the federated data only if the improvement is above a prescribed

threshold. The recipe is sent along with the genuine data from own participant sources. This participant holds the responsibility for updating this source data and the recipe at prescribed time intervals. Specific pieces of information from the federated database received from the central node are not sent but only identified to avoid data incest. After n confirmations from other participants observing better results using the recipe rather than the centralized data only, the reporting responsibility is transferred to the participant with the highest information value for that recipe.

4.3.1 Change 2 assessment

The operational systems and infrastructures tested did not offer the capabilities required for Change 2. Performance improvements of this change can be estimated by assuming the followings: participant local sensor information is more timely; all participant local sensor information represents a large part of the federated database area covered; non-participant sources like remote sensing by satellite complete the coverage of the federated database beyond all participant genuine information, and this information is broadcast at prescribed time intervals only by the central node of the federation. Consequently, on average participants will observe the same improvements as in Change 1 plus the potential gain from the recipes sent by other participants via the central node, i.e., 14% plus an unknown percentage due to the contribution of other participants in generating situation assessment information. The maximum utopian potential increase due to Change 2 is 41% [10] assuming that 22% out of the maximum 63% is due to the mean age of the information broadcasted (the central node broadcasts only at prescribed time intervals the content of the federated database).

4.4 Distributed Baseline Architecture with Change 3 Fig. 7

This is the baseline architecture with Change 1 and Change 2 but with participants sharing the generation of the federated database. We assume that nodes contribute proportionally to the value of the information they have and their available resources (people and systems). Each participant sends only source data and recipes that fulfill value-based criteria and negotiates reporting responsibilities with others. This is a distributed version of the baseline architecture: e-worksharing. It is worth noting that such an architecture offers a unified structure that impacts positively on coalition infrastructures. Such an approach trims large infrastructures by reducing the stovepipe proliferation and anarchy. Furthermore, experimental results show that the resulting virtually federated database offers better information value to users and increases mission success rate significantly.

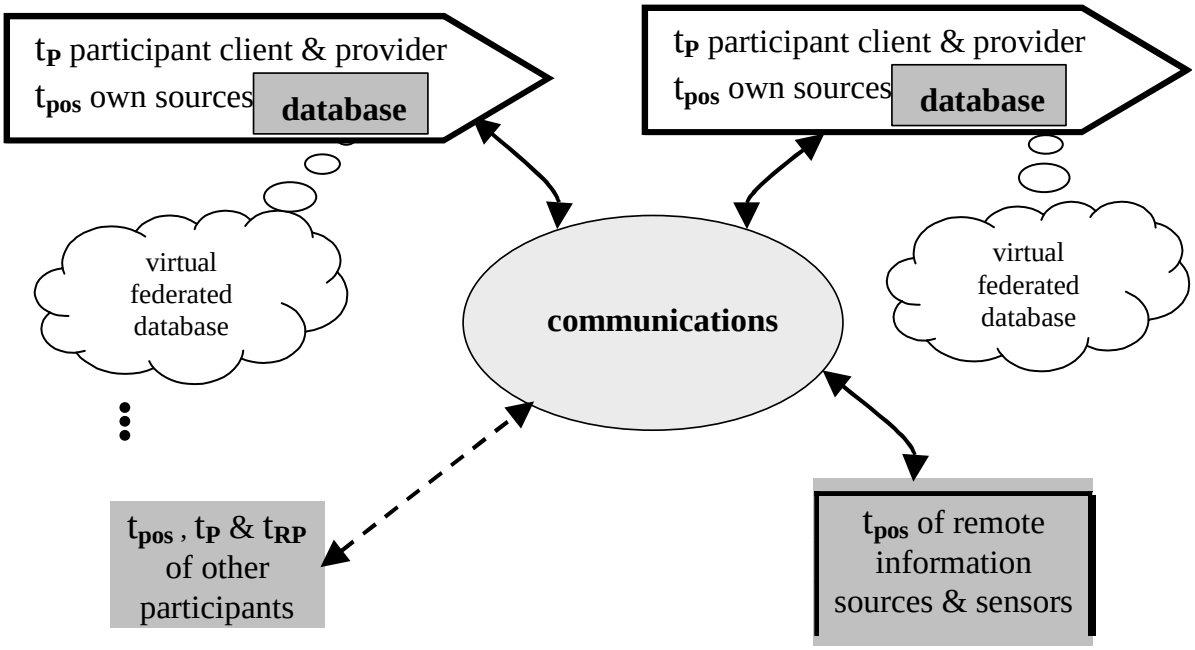

Fig. 7. Streamlined information flow of the systems studied. Each participant uses its own sensor information locally for improving the received federated information. Each participant sensor datum is evaluated before being displayed and shared as a piece of a virtual federated database. Change 3.

4.4.1 Change 3 assessment

This change requires more detailed system decomposition. Suitability of various agent-based architectures (for recipe determination and distribution) for a coalition must be assessed with appropriate simulation scenarios that account for all the messages exchanged for accomplishing some tasks. To link these assessments to the results presented in this section we propose the following MBM reference. If we assume optimality for all participants 1- to send only source data and recipes that fulfill value-based criteria, and 2- to efficiently negotiate reporting responsibilities with others; then, besides the 9% than can be attributed to sensors [9], a utopian maximum improvement of 54% of the total 63% is available. This 54% increase imposes a Change 3 that includes instantaneous situation assessment using all available information, perfect synchronization and negotiation among participants, and that information exchange delays and losses are null.

It is worth noting that the sensors and their deployment for surveillance and reconnaissance are out of this equation since the MBMs we used only consider what is available to decision makers. As pointed out in [9] other MBMs can be defined to study the effect of the decision-maker database completeness on mission effectiveness, in which case, sensors and their deployment will have a dominant role. The MBMs used here focus like a magnifying glass on assessing information management, procedures, systems and infrastructures to better employ only all participant available information, not the impact of sensor information that could have been generated if some sensors had been (better) deployed.

4.5 Sharing Recipes Instead of Fusion Results

From various studies across NATO and TTCP R&D groups, and AUS-CAN-NZ-UK-US C3 driven activities, several recommendations were made for improving the value of information to

be shared by operations participants under either joint or combined command such as in [12]. It was found to be extremely difficult to obtain measurements that supported recommendations without any doubt. Even with MBMs and sets of cybernetic models these objectives are difficult to obtain with certitude. However, the large set of results obtained offers the possibility to project with reasonable confidence some tendencies based on MBM parameter characterization for OTH-T. Fig. 8 shows the framework for this line of thought.

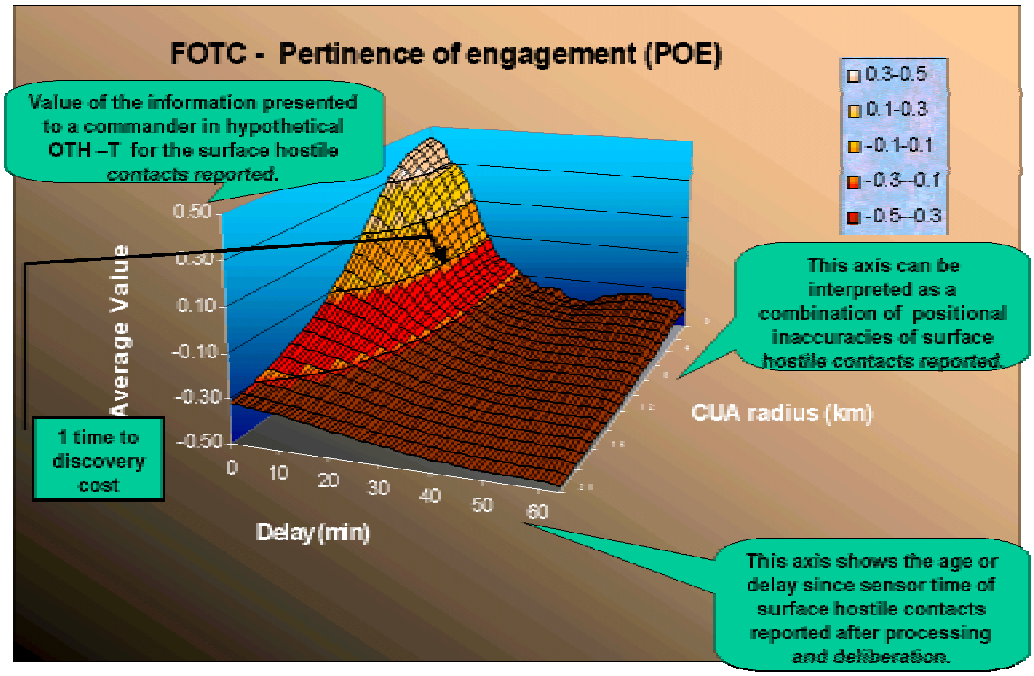

Fig. 8 Possible interpretation of MBM parameter dependencies showing the effect on OTH-T success rates of time to discover, deliberate and fuse

If we assume that the circular uncertainty area (CUA) is related to positional accuracy and delay is related to the age of positional information from a sensor, then the CUA axis can be labeled as accuracy and the delay axis as the information age. In such a case we have lines of constant value of accuracy and age for which we observe success rates that reach a maximum for the highest accuracy and smallest age. Then any process that uses some time for delivering an output will force the information to age, causing a reduction in OTH-T success rates. A first step is to try to make sense of the available tactical data to discover some pattern or a possible threat. This may require some deliberation and data fusion. This is illustrated by item 1 of Fig. 8 where the search for discovering some pattern in the dynamic data received ended up consuming time and using aged information. If more time is used for discovery the value of the information is lessen if it is not refreshed by some updates. Consequently, before the next update, the impact of using time to discover (make sense of the available data) is a decrease in information value for the task; which in turn causes a decrease in success rates.

However, if the discovery allows one to find a combination of source data and other information that improves accuracy, as expected of constructive data fusion, then success rates will increase as illustrated by item 2 of Fig. 9. We identify this discovery and record the all the facts (track numbers and other information used either encyclopedic or dynamic) that lead to it, a “recipe”. Other steps include the exploitation of updates for any of the dynamic data used. Such updates generate most of the time large improvements in information value and success rates (item 3 of Fig. 9).

In joint and combined operations, participants need to use information that is as much as possible identical at any given time for the portions requiring synchronized actions. The sharing process is accomplished through appropriate information exchange over networks, mainly over satellite or radio networks with small channel capacities since most participants are mobile. Item 4 of Fig. 9 illustrates the cost of sharing resulting information based on the delay imposed by communications networks and computers.

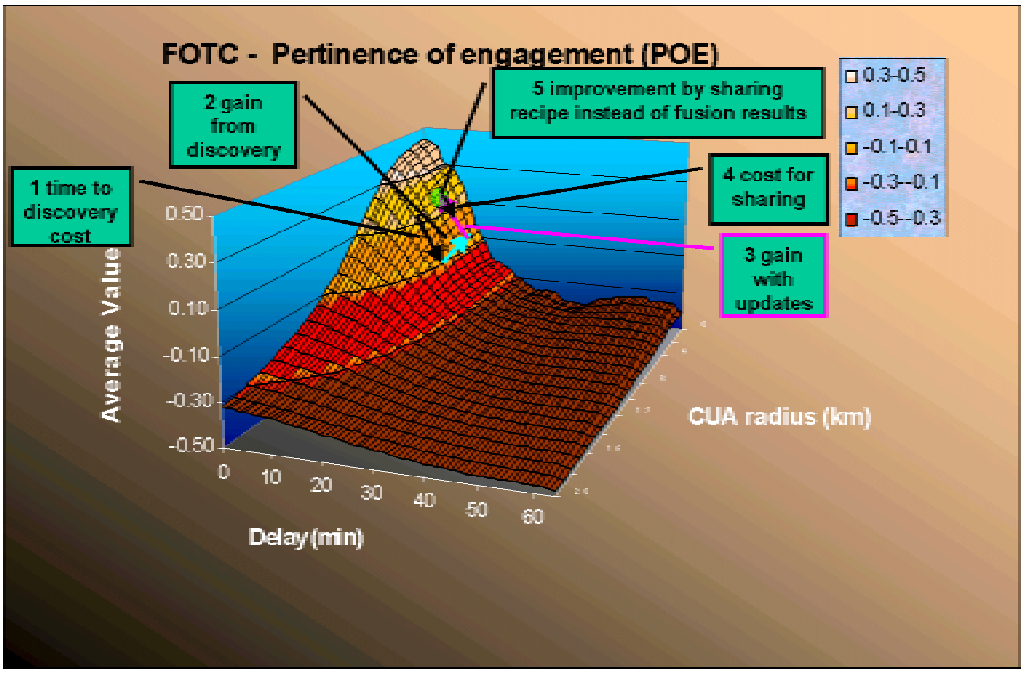

Fig. 9 Other steps up to sharing recipes for preserving information gain and system capacity

An examination of these processes reveals that it may be advantageous to share the recipes instead of the fusion results, as illustrated by item 5 (although difficult to visualize in Fig. 9, item 5 recoups some of the "cost for sharing" from item 4) of Fig. 9, for several reasons:

1- Once the recipe is available at a participant fusion center, most updates of dynamic data will be reflected in increases of success rates. After the one-time-cost of sharing the recipe, there will be a lower cost for sharing dynamic data updates compared to sharing fusion results.

2- Each participant may provide improvements by adding to the original discovery and consequently improve the recipe that in turn may result in success rate increases.

3- If each participant is provided with the ability of evaluating the value of local discovery or fusion, then participant would be able to better contribute in collaboratively improving the global picture without taxing the networks used for sharing information.

4- In such cases, when a discovery or fusion improves own picture above the received picture by a given threshold, the participating system will do the following: a- display this result locally, b- send recipe with list of ingredients (track# used), c- send own data used in recipe, and d- maintain responsibility for sending own data for this recipe until found inadequate locally or remotely.

The basic principles for this strategy were developed during a series of experiments used in identifying recommendations for the procurement of future information systems, [12], and their

Canadianization, [13]. These results are expanded and summarized by the strategy illustrated below, Fig. 10.

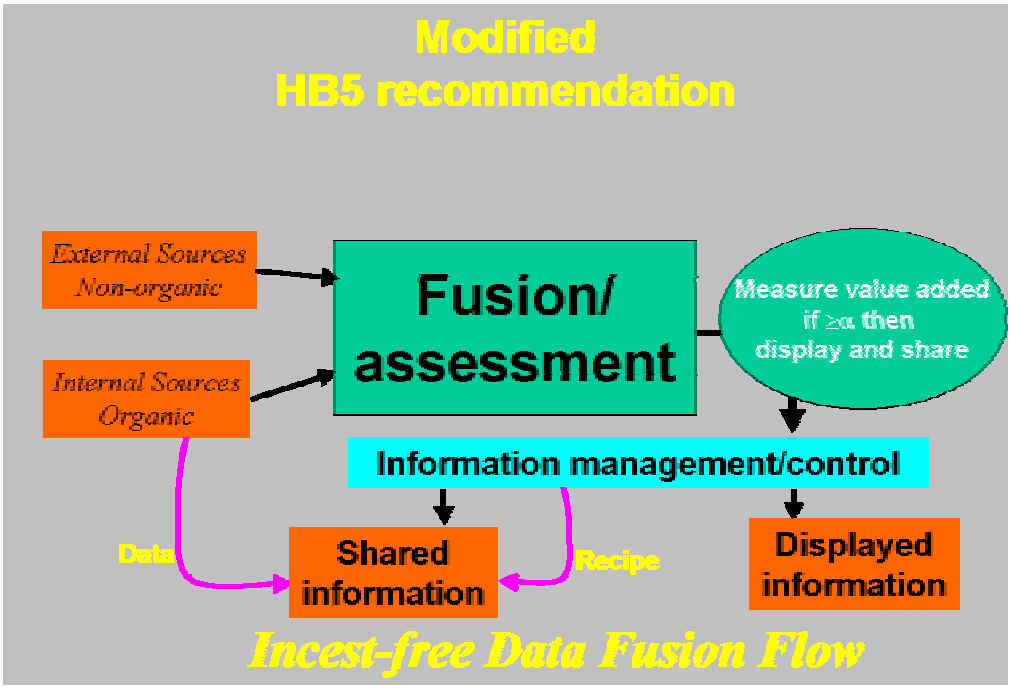

Fig. 10..Proposed information fusion strategy for improved synchronized operations

Only experimentation with such strategies will unveil their strengths and weaknesses. Nevertheless, we believe that such strategies once implemented across all participant systems with appropriate standards and agreements will eliminate data incest and do not require the sharing of source identity (to avoid loss of information required for appropriate MSDF) but provide an improved confidence in shared information. These strategies will provide "track pedigree", and provide the first steps in developing agreed information quality schemes as described in the next section. We expect that increasing the mandatory capabilities for appropriate information sharing would generate important unit and force effectiveness gain for various missions. Such experimentation would support the development of systems that would eventually allow developing the information grid [14] required for truly attaining the benefits of network centric warfare [15].

5 Assigning Priorities and Quality of Services

Information flow and management across diverse networks require the capability of measuring the degree of importance, error tolerance and promptitude of any given piece of information [16]. In evaluating the value of information, one has to consider the context in which it will be used. For a user responsible for over-the-horizon targeting, information changes in hostile tracks within its area-of-interest (AOI) are critical, while changes in other tracks or in those outside its AOI may have less immediate impact on mission effectiveness.

The proposed assessment of priority based on the value of information for a task uses the following parameters [13]:

1- Importance, I: significance of a context relative to all other contexts.

2- Potential, P: relevance of information in context.

3- Quality, Q: goodness of information, e.g., accuracy.

4- Currency, C: freshness of information.

Assuming constant I, P, Q and C parameters based on the message information content or attributes and a particular context, the generic utility function proposed for assigning priority to information in an operational context is:

$$\text{Priority}(i, \alpha) = w\, I_{\alpha} \cdot (w_P\, P_{i_\alpha} + w_Q\, Q_{i_\alpha} + w_C\, C_{i_\alpha} + X) \quad (2)$$

where:

w = priority weight, w_P = potential weight,
w_Q = quality weight, w_C = currency weight,
I_α = importance of context α,
P_{i_α} = potential information item i in context α,
Q_{i_α} = quality of information item i in context α,
C_{i_α} = information item i currency in context α, and
X = additional factors yet to be determined that can include dynamic properties of the parameters, including time dependence.

Priority is not sufficient for establishing the QoS required by a piece of information according to application, task, user and organization criteria. Another important QoS attribute is the application acceptable error rate and information loss. Consequently, smart applications will offer messaging traffic that can be optimally routed at minimal cost for required QoSs.

Hierarchical relations among information items in context are essential to efficiently develop and share tactical information. Although exercising this priority scheme is beyond the scope of this paper, we presented a much simpler approach that could be easily implemented in current hardware and software in [17]. It shows the value of information management heuristic (IMHs), which may prove essential to effective network centric warfare and for sustaining information superiority.

Infrastructures with embedded adaptive and sustainable capabilities require dynamic information attributes to control and allocate priority to information generation, authentication, processing and sharing. The exploitation of these attributes by intermediate and end users can significantly impact the global performance of man-in-the-loop systems. These attributes can also be used in computing dynamic priorities or the Quality of Service (QoS) of processes and functions required in distributed collaborative systems. At design time they depend on user functions, on systems and on the information exchange required for tasks. At operation time they depend dynamically on the structure of assets (including people) at play, i.e., the spatial distribution and mobility (asset/people-mobility), and the timeliness needed for decisions and actions if tasks and missions are to be accomplished successfully. Consequently, these attributes impact on the quality of shared information by collaborating entities, they provide the means for common knowledge and intent, and in the end they help to coordinate and synchronize the actions of an organization.

The naïve IMH proposed in [17] imposes a 1-min short broadcast period, or a mean delay of 0.5 min. Based on the estimated data aging imposed by a 15-min broadcast procedure of 7.5 min, the gain in promptness of this IMH should be approximately 7 min. Although the effect of data aging on MBM is not linear, a first approximation illustrated by Fig. 4 is to assume linearity, so one can estimate the expected IMH effectiveness gain to be (7/20)•63%, or 22%. This 22% improvement is for the impact on mission effectiveness based on the experimental data analyzed. Such a potential improvement helps to justify plans for improving information management and

cooperative engagement capabilities. This result encompasses an emerging unified joint and coalition philosophy that builds on the best practices in the field from Canada and its allies.

5.1 QoS and Resource Management Internet Requirements

These strategies could also be applied to other domains where time and location dependent data are used for creating federated situation pictures used to plan future actions. For example, Internet Infrastructures that support better resource management capabilities would certainly fall into network categories that can cost-effectively support a larger variety of media and services as reported in [16]. Resource reservation (RSVP) needs improvements to avoid underutilization although some routers have poor QoS management capabilities. An alternative, the differentiated service (DiffServ) would certainly benefit from the proposed application priority scheme. Unfortunately, mechanisms for assigning and managing network priority levels, translating application priority levels to router ones, and studies of the impact of using such mechanisms with appropriately defined priority classes are not mature enough for operational networks yet [18]. However planning for future Internet infrastructures should consider including such capabilities since they would offer better resource utilization and would increase organization and user satisfaction and support. With world-wide increases of e-activities, such resource utilization improvements might be worth billions of dollars to the Internet community at large during the next decade.

6 Comparing Architectures for Collaborative Planning

It has been shown that sharing data fusion recipes can improve local situation awareness and improve operational success in a naval warfare context. This section discusses implementation issues of knowledge sharing via software agents within multi-agent systems for air operations planned by two command centers and supported by three ground bases. The idea is to expand conclusions from naval warfare context to a coalition context by using specific simulation of messages exchanged that allow coordination and synchronization of actions of air operations.

6.1 Background

Experts in Distributed Artificial Intelligence (DAI) have identified a broad range of issues related to the distribution and coordination of knowledge, and to actions in environments involving multiple agents. These agents can be thought of collectively as forming a society. Agents can take different forms, depending on the nature of the environment in which they evolve. Software Agents (SAs) can be gathered into MultiAgent Systems (MASs). This particular type of agent, the SA, has recently attracted much attention [19]. SAs are autonomous entities with the ability to assist users in performing tasks, to collaborate with each other to solve specific problems jointly, and to answer user queries.

Information technologies and communication capabilities evolve, and a single “mono-agent” approach cannot deal with the complexities of many separate agents (collaborative or competitive) evolving in the same environment and needing to interact in order to achieve a global goal - this is why agents are gathered into MASs. In such an environment, each agent's activities must consider the activities of the others, and research in MASs is concerned with understanding and modeling action and knowledge in a collaborative environment. The management of a distributed environment must coordinate behavior among agents and must detail how agents coordinate their knowledge, goals, skills, and plans to make decisions for solving problems.

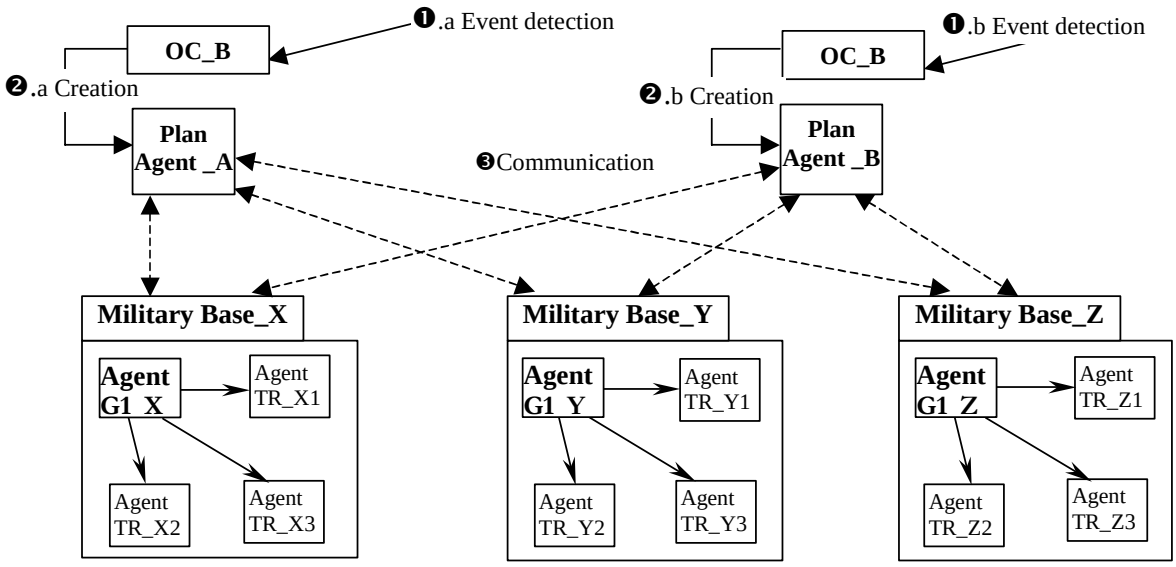

Fig. 11. Assumed connectivity amongst OCs and airbases.

In the previous section the level of abstraction of infrastructures and systems used were appropriate for assessing technologies insertion value in terms of mission effectiveness for large exercises with 40,000 people, 50 warships including aircraft carriers, and hundreds of aircraft. However in order to compare architectures for collaborative planning that fulfill the requirements of proposed Change 3 of Fig. 7 to the baseline architecture of Fig. 1, appropriate scenarios and simulations were devised to better identify their properties and usefulness for typical tasks [20]. Agent-based architectures implemented with sufficient details were stressed by identical tasks. The message exchanges required by each architecture for accomplishing the selected tasks were carefully prepared. In these scenarios, participants are Air-forces Operations Centers (OCs) instead of ships. Such tailored simulations provided key performance results allowing architects to select agent-based architectures suitable to the services of target systems.

In our scenarios, an OC monitors airspace and must react rapidly and efficiently when unexpected events occur such as the detection of an unidentified plane: the event detection of Fig. 11 that triggers the scenario. In order to react to such events, an OC uses various resources including interception airplanes from various military airbases geographically distributed across large distances. We assume that military airbases are service providers to OCs. When several OCs need the same resources for different missions that need to be conducted concurrently, there is a conflict and contention for similar resources that must be resolved. In such circumstances, contentious OCs must interact with the nearest airbases that can help managing the resource allocation problems encountered, and contribute in developing appropriate flight itineraries. Our scenarios use two OCs and three military airbases. We assume that OCs are similar in organizational structure, functionalities, and procedures. Three types of agents are used to support the operations of the OCs and the airbases. They can be classified and described as follows:

1- PlanAgent, which represents an OC and plays the role of a service consumer;

2- Agent G1, which represents an airbase and plays the role of a service supplier; and

3- AgentTR, which represents a type of resource supplied by an airbase.

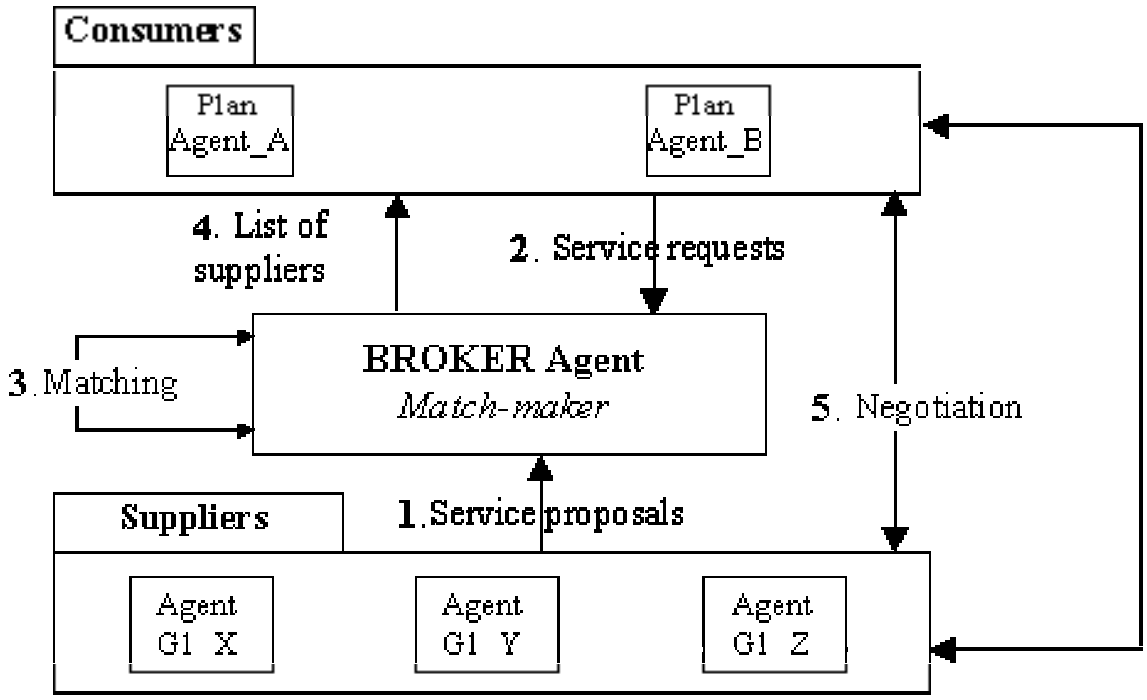

Fig. 12. Architecture based on a Broker Agent Match-maker

Next we describe three of the studied agent-based architectures and present some of the assessment results.

6.2 Broker Agent Systems

A Broker Agent is a system that mediates interactions between suppliers and consumers of services. It receives proposals from suppliers and requests from customers. Then, it matches proposals with requests. Finally, it provides customers with a list of suppliers offering the requested services. We call such an agent a Matchmaker. After receiving the list of suppliers the consumer negotiates with them and choose one that provides the most appropriate services. Fig. 12 shows how this approach applies to our application domain. We have two consumers (OCs) and three suppliers (airbases). In Fig. 12 we represent the various types of interactions and the chronology of operations taking place in this environment. In this environment all messages are exchanged remotely.

6.3 Contract-net Protocol Systems

Contracting processes in businesses inspired the Contract-net protocol (CNP). Agents coordinate their activities through contracts to accomplish specific goals. An agent, acting as a manager, decomposes its contract (a task or a problem) into sub-contracts to be accomplished by other potential contractor agents. For each sub-contract the manager advertises a task to a network of agents. Agents receive and evaluate the task. Agents with appropriate resources, expertise, and information reply to the manager with bids that indicate their ability to achieve the advertised task. The manager evaluates the received bids and awards the task (sub-contract) to the most suitable agent, called the contractor. Finally, manager and contractor exchange information during the accomplishment of the task.

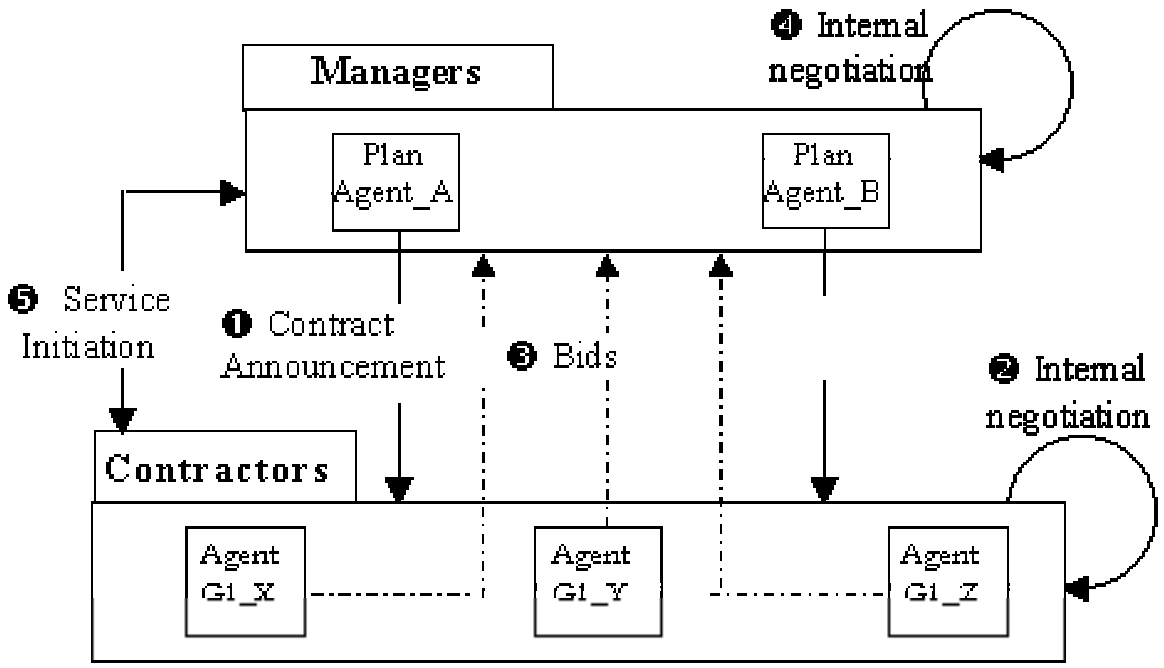

Fig. 13. Architecture based on the Contract-net protocol.

Fig. 13 shows how the CNP approach applies to our domain. PlanAgents (representing the OCs) play the role of managers and AgentG1s (representing the military airbases) are potential contractors. In our case it is not necessary to decompose tasks since each contract corresponds to a request for resources. In Fig. 13 the dashed arrows correspond to managers' announcements and plain arrows represent contractors' bids. All the messages are exchanged remotely. The managers announce potential contracts (step 1). The circling arrow (step 2) corresponds to an "internal negotiation" which takes place in each military base in order to choose which sub-contract to bid for. The contractors, then, send their bids (step 3). The circling arrow (step 4) corresponds to an "internal negotiation" which takes place in each OC in order to decide which bid to select. Finally, a request for initiating the requested service is sent by each PlanAgent to the selected AgentG1 (step 5). Using the Contract-Net protocol permits to solve the problem of bottleneck that arises when using broker agents. Agents are free to negotiate as they wish, i.e. no third party is involved.

However, such an approach requires that several messages be remotely exchanged. This might be a problem in environments with small wireless-channel capacity and in which security is a concern. In order to deal with this problem, we consider a third environment. It is based on a meeting infrastructure in which agents will be able to move and to negotiate locally using the CNP.

6.4 Meeting Infrastructure Systems

The meeting infrastructure is a workspace in which suppliers and consumers can meet in order to negotiate. All messages are locally exchanged. It is clear that a meeting infrastructure can be used if negotiating agents are mobile. However, a new service must be supplied which enables the suppliers and consumers to send delegate agents to the meeting infrastructure.

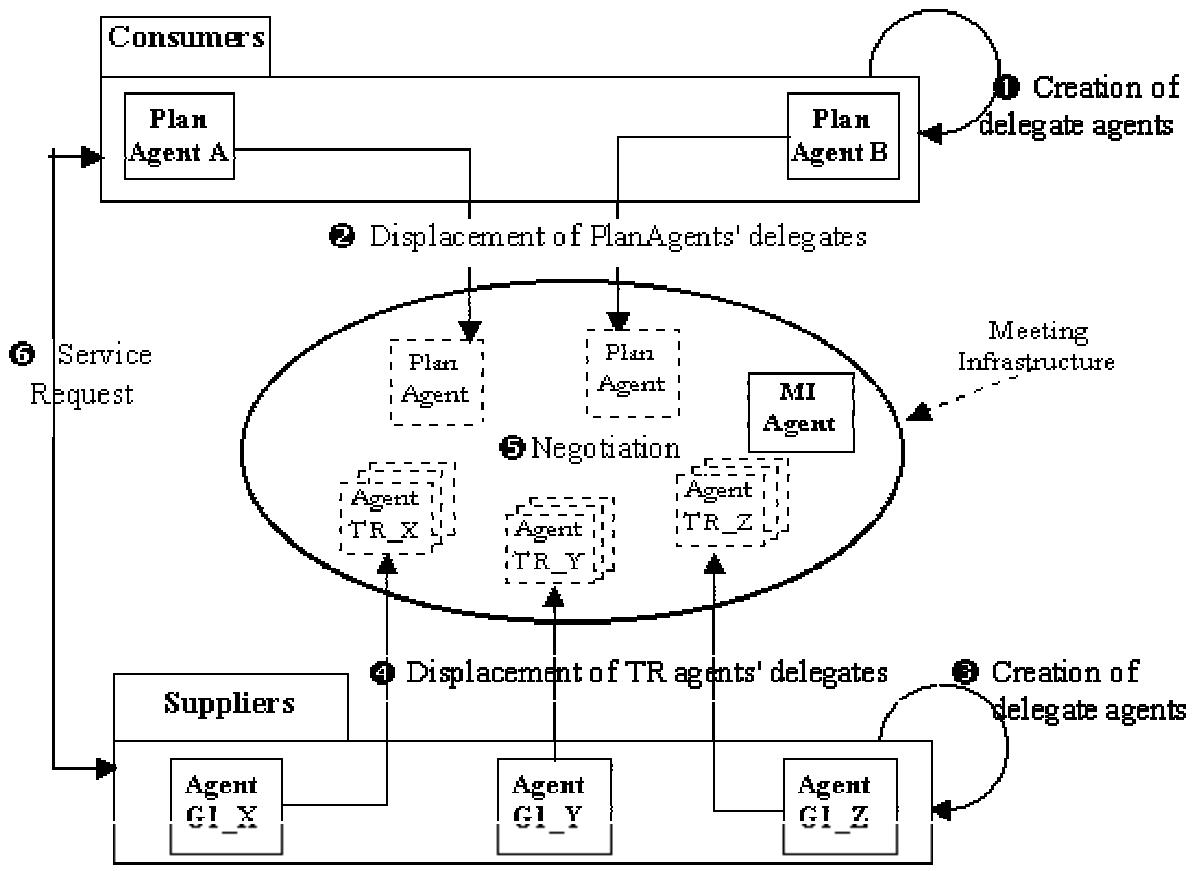

Fig. 14. Architecture based on a Meeting Infrastructure.

For our scenarios, Fig. 14 illustrates how we have mapped the OCs and airbases onto the meeting infrastructure. An agent called MIAgent manages the meeting infrastructure. This agent controls the access to the workspace and monitors the agents' behavior, which are located within it. Fig. 14 shows the chronology of operations that enables a consumer to select the best supplier for a given required resource. A PlanAgent located in an OC that needs some resources creates a delegate PlanAgent (circling arrow of step 1). Then, this delegate agent migrates to the meeting infrastructure (step 2). In the same way each TRAgent of each military base creates a delegate agent (step 3) that migrates to the meeting infrastructure (step 4). Delegate agents of Plan Agents and of TRAgents can then negotiate using the contract net protocol (step 5). Consequently, all the negotiation messages are exchanged locally. When a negotiation between a PlanAgent and a TRAgent is completed successfully, the agents must send messages to their respective parents in order to inform them (this step is not included in Fig. 14). When such an agreement is reached, the PlanAgent (on the OC) interacts with the Agent G1 of the contracted military base in order to get the proposed service (the corresponding messages are exchanged remotely). Introducing a meeting infrastructure is a means to reduce the number of messages exchanged remotely, while providing the flexibility offered by the use of a negotiation protocol such as the contract net. Moreover, in such an environment it is easier to ensure a good level of security for the exchanges. Replication is necessary to eliminate a single point of failure.

6.5 Comparison Method

In this section, we present an approach, which aims at comparing different architectures for interoperable environments. Our application domain consists of several C2 centers which require resources offered by different resource-providing sites in order to carry out different tasks. Conflicts might arise in the reservation of resources. In order to compare various ways of making these C2 centers and sites interoperate, we examine three interoperability environments which are based on different architectures, namely Broker-Agent [21], Contract-Net protocol [22] and Meeting Infrastructure [23]. The broker-agent architecture and the contract-net architecture involve exchanges of remote messages between the C2 centers and the different resource-providing sites, while the meeting infrastructure architecture involves the use of mobile agents. We developed a system that enables us to simulate the activities of these different architectures and to track the number and types of the exchanged messages.

6.5.1 Evaluation function

We identified the different kinds of messages that the agents could exchange during their interactions in our application domain:

- **Proposal** to use a resource
- **Counter-proposal** relative to a proposal.
- **Acceptation** of either a proposal or a counter-proposal.
- **Definitive refusal** of either a proposal or a counter-proposal.
- **Weak refusal** of a proposal.
- **Modification** of a proposal.
- **Announcement** of a service by a supplier.
- Sending the list of **suppliers** (for a *broker agent*).
- Sending the **results of a negotiation** (for a *broker agent*).
- **Identification** of an agent (in the meeting infrastructure architecture).

The three proposed architectures are compared on the basis of the number of exchanged messages and the types of messages that are exchanged. Indeed, on the provider's side resources allocation (scenarios, algorithms) is dealt with in the same way by the three architectures and does not influence the comparison. However, agent negotiation is different within each architecture. Hence, it is relevant to compare the number and types of messages exchanged during the negotiation. Formula 1 expresses the evaluation function that we used.

In function *f*, the number of sent messages is associated with a weight a_i. Each message type has a corresponding weight that depends on the following factors:

- Message transfer: local or remote.
- Message size.
- Risk associated to sending a message (possible interception, confidentiality of message content)

$$f(arch) = \sum_i [a_i \times nbmsg_i]$$

f : Evaluation function.
arch : architecture to be evaluated.
i : Message type .
a_i : Fixed coefficient characteristic of message type i.
$nbmsg_i$: number of exchanged messages of type i.

Formula 1: evaluation function of an architecture

Let us mention that we will not take into account in the comparison of the architectures the phase which aims at initiating the requested service after the negotiation phase. Because the service initiation phase is carried out in the same way for all the architectures (the same number of remote messages is exchanged between consumers and suppliers), it has no influence on the comparison.

Obviously, local messages are preferred to remote messages because a large number of remote messages might reduce an architecture's efficiency. However, other factors should be taken into account. Message size must be considered in the comparison because large messages might have an effect on an agent's processing and might induce delays for information transfer. The message size is related to the number of parameters of the message. The risk factor is related to the confidentiality of the information contained in the message and is of interest especially in military applications. For example, a proposal to use certain planes has a greater importance than a simple acceptation message. In other words, the risk of having a proposal intercepted is higher than the risk of having a sequence number for acceptation intercepted.

We assume that each of the three factors (message type, message size and risk) can be computed independently of the other factors. We also consider that the message type is more important than the other two factors because it greatly influences the time required to deliver the message. The importance of the two other factors depends on certain weighting coefficients used to compute the weight a_i that will be presented later. Let us denote the three factors in the following way (*i* represents the message type):

Local/remote message : L_i ; Message size: T_i ; Risk: R_i.

For which choose the following values :

L_i = 1 if message i is local; L_i = 4 if message i is remote.

The number of parameters[1] of a message of type i is denoted N_i.

$$T_i = \frac{N_i}{4}$$

R_i takes its value in [1,2,3,4] depending on the importance of message content

We chose to keep the value of the three factors between 1 and 4. N_i can take a maximum value of 16 (in the case of a proposal there are 16 parameters). Hence, T_i can take a maximum value of 4. R_i takes a value among [1,2,3,4]. For each message, the value of R_i depends on the importance and confidentiality of the message content (risk of being intercepted). For example, R_i=4 for proposal and identification messages, R_i=1 for acceptation and refusal messages. Formula 2 is the function used to compute the weight a_i.

$a_i = C1 \cdot L_i \, (C2 \cdot T_i + C3 \cdot R_i)$ *with* **C1, C2, C3** *positive constants.*
Formula 2: computation of weight a_i

As we mentioned earlier, L_i has a greater importance than the other two factors, namely T_i and R_i. This is the reason why it is multiplied by the weighted sum of the two other factors. Each of the three factors is weighted by a positive constant C_i. This will enable the user to adjust the relative

[1] At the beginning of this section we listed the different message types that our agents can exchange. Due to space limitation, we cannot present the detailed structure of each message type in this paper. However, we can mention that the message types have different numbers of parameters.

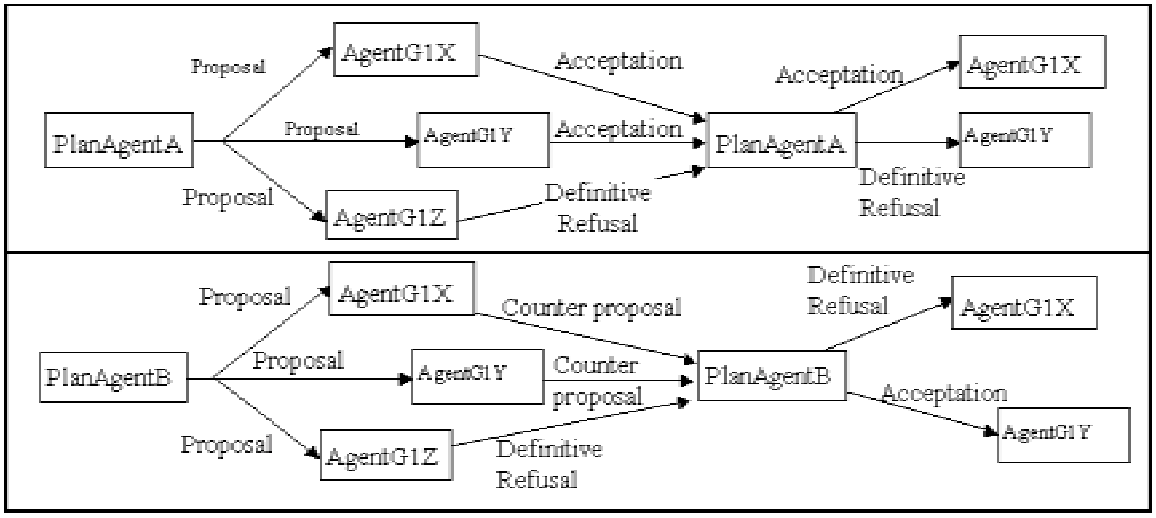

Fig. 15. A scenario for message exchange

importance of the factors as he wishes. Finally, let us mention that there are different ways of comparing the three architectures. We propose to use Formula 1 in order to get a global evaluation of each architecture and to compare them accordingly. However, a user might be interested in a more detailed comparison such as comparing the number of exchanged messages for each message type. Our system allows such a detailed comparison.

6.5.2 Comparison approach

In order to compare the architectures we considered several scenarios corresponding to different possibilities of message exchanges between the providers and consumers of services with regard to the resource allocation problem. Fig. 15 presents such a scenario. In this figure rectangles represent agents and arrows represent the exchanged messages. The upper part of Fig. 15 shows the messages resulting from a proposal generated by PlanAgent A and the lower part presents the messages resulting from a proposal generated by PlanAgent B. PlanAgents (A and B) represent C2 centers while AgentG1s (X, Y and Z) represent resource-providing sites.

In fact, a given architecture may be more appropriate for certain scenarios and less efficient for others. For this reason the comparison approach is composed of two steps. In the first step, a number of resource allocation scenarios are randomly chosen. Each scenario is executed with each architecture and evaluated according to Formula 1. These results provide a global measure of the performance of each architecture. In the second step the three architectures are evaluated for specific scenarios and the comparison provides the relative performance of the architectures for each one of these scenarios.

6.6 Experimental results

For the resource allocation problems of two OCs and three airbases, simulation results of [20] reveal that the Meeting Infrastructure outperforms the Broker Match-maker by 63% and the Contract-net Protocol by 30% in terms of a utility functions that factors in higher cost of using wide-area networks compare to local-area networks, information risk/security and message size. Details on the message exchange used and the utility function developed are available at [20]. It is worth noting that the number of messages exchanged is similar for the three architectures but the only one (the Meeting Infrastructure), to use mobile agents (software that migrates to a common location for negotiation) negotiates by almost only using local messages. Consequently the Meeting Infrastructure offers important advantages when distance, delay and security issues are

factored in the evaluation of architectures for a variety of activities that require some degree of negotiation or global optimization.

In e-activities such as air interdiction, infrastructures must provide the highest promptitude, reliability, and security achievable cost effectively. The Meeting Infrastructure is a good basis that can be improved by having replicas at each airbase and using a timed-colored token (time is used for non-compliance and color for resolution status) passed amongst them for coherent synchronization of resulting plans. The fact that delegates can reside permanently in the distributed Meeting Infrastructure increases promptitude and robustness against various impairments and malevolent actions.

For diverse activities, sharing awareness effectively may require adapting agent infrastructures to account for optimal distances for efficient interaction amongst users [24] or providing geographical and positional information by integrating appropriate technologies in mobile transceiver units as in [25].

7 Wirelessly Enabled Mobile E-activities

Wireless and non-wireless e-activities of nomadic (frequent location changes or on the move) participants (service clients or providers) on the Internet offer substantial market opportunities and technology challenges. This growing community of users would appreciate better support from portable information systems for managing changes in location, file retrieval, secure and robust re-routing of information exchange, monitoring of e-activities when sporadically connected, etc.

As indicated above in nomadic activities, clients and servers can be either mobile or stationary, and used either wireless links for both mobile and fixed applications or non-wireless connections when stationary [5]. In such context agents are either software or people. Software agents, SAs, in nomadic activities require the following attributes:

1- Autonomous: An agent is able to take initiatives and exercise a non-trivial degree of control over its own actions.

2- Collaborative: An agent does not blindly obey commands, but has the ability to modify requests, ask clarifications, or even refuse to satisfy certain requests.

3- Flexible: The agent's actions are not scripted; it is able to dynamically choose which actions to invoke, and in what sequence, in response to the state of its external environment.

4- Mobile: An agent is able to transport itself from one machine to another across different computing platforms.

Nomadic computing activities require more anticipation than fixed facility computing due to frequent loss of connections and changes in network addresses. When mobility, transaction and negotiation between consumers and providers are combined we obtain the following requirements:

1- Time, date, and duration: A client suggests the start time and date (when), and duration (how long) for which it needs a service. These can be adapted to the existing commitments of the providers of services.

2- Quality of service: Client's requirements for the parameters of the offered service where in most cases a higher quality of service incurs a higher cost.

3- Security: The method and level of encryption that are used for securing the data being transferred during service invocation. Service providers may offer different methods or levels of encryption.

4- Cost: The expenses that a client incurs for the service it desires from a provider. This cost mainly depends on the above-cited requirements.

5- Response time: The client expected deadline for a response from providers and beyond that deadline the client may ignore the offers, and either renew its requests or look for alternate providers. It is reasonable to assume that the larger a client expected response time is, the more likely suitable services would be identified by providers.

6- Adaptive addressing: A nomadic client has alternate locations for receiving responses or services, directly or via delegate agents. A client uses different computers, public services or several IP addresses at fixed and mobile locations.

7- Soft-mobility: Client SAs migrate onto fixed computing asset or networks and reports to client hardware thus offering asset-mobility for nomadic activities. Delegated client SAs provide services and act on the client's behalf according to specified mandates while the client is not reachable.

Internet infrastructure adaptations for nomadic applications would be designed to consider at least the following factors when clients use mobile wireless devices:

1- reduced channel capacity,

2- limited input device (small pad or keyboard),

3- small viewing area,

4- smaller data storage capacity, and

5- computation power limited by power source restriction.

To alleviate some of these problems, a client can use a repository of services via delegate agents that seek and monitor brokerage activities independently of client connectivity. Clients can register and de-register to repository services and adjust the level of details, volume and frequency of notifications.

However, it can be argued that running a SA on a handheld wireless device, like internet-ready cellular phones, is not current technology. A solution to this problem is to define reception platforms at fixed locations as part of the Internet infrastructure interfaces to wireless users. This is exemplified by the work done by [26] known as AGORA multi-agent. AGORA is an architecture that supports modeling cooperative work in a distributed setting. The rationale of AGORA in the nomadic applications is to illustrate the cooperative interactions that occur between user-agents and Internet services in the reception platform.

According to [5], personalization is among the keys to success of wireless applications. Wireless devices are different and need matched arrangements to deal with their specific characteristics. From a research perspective in nomadic environment, device-agents may reside on users' wireless devices. Device-agents will be in charge of displaying results obtained from the provider-agents, transferring users' needs to the supervisor-agent, monitoring the state of the battery, beeping the supervisor-agent in case there is a delay in returning the user's response, and so on. Another research perspective consists of providing location-based answers to users' requests. As user-agents operate on users' requests, it may be helpful to know the users' direction and spatial location at any given instant of time. Combining these research perspectives, namely personalized services and location-based responses, should contribute to paving the way to wireless applications success. Mobile cinema ticketing is a service that would definitely benefit

from these perspectives [27]. First, a positioning system, e.g. GPS, would determine the user's geographical location. Then, the service would access a cinema database to generate a list of nearby movie theatres and a user profile database to determine what kind of movies the user prefers. Based on both criteria, the service would offer the user a selection of available movies and show times. The user would then have the option, if he wishes, of previewing the different suggestions, before deciding or committing to any. Finally, the service initiates a payment system to complete all the transactions.

8 Conclusions and Discussions

This paper demonstrates that updating the local tactical picture by fusing local sensor data with identification information from the federated database holds great promise for improving coalition force MOEs. In addition, further increases in performance may be obtained by letting the platform having the best sensor coverage of a given contact share its data fusion recipe with nearby platforms and taking over position data updates. The sharing of this knowledge (recipes) on a distributed architecture may be implemented via mobile software agents.

This paper builds from the experience and knowledge acquired from research in information management, system architecting, agent-based architectures, user-oriented requirement capture and telecommunications. In summary, our few critical emergent properties that impact on dedicated network, intranet and Internet Infrastructures for e-activities are:

1- Negotiation, collaboration, and synchronization should use a meeting infrastructure.

2- Mobile agents should be used when agents can reside or a-priori moved where needed for promptness and security.

3- Value of information to end-users should be translated in terms of network priorities and QoSs as function of evolving operations. This mapping would be highly dynamic.

4- All network routers should use a complete set of QoS with appropriate hardware and software capabilities for resource management functions. This is especially critical when software mobility and asset mobility are both required.

5- Mechanisms for users' QoS dynamic requirement computation and negotiation across network resources for all routes. This implies appropriate matching of users' QoS onto routers' QoS for better use of Internet resources, e.g., video may accept some level of errors but e-credit should use secure and robust techniques.

6- Authentication on the networks should be revisited.

7- Only compliant routers should be allowed so that tracking malevolent users or activities would be easier and cheaper without breaching user privacy.

8- Addressing (georouting) should include a more precise notion of geo-location (geocoding), especially if we consider mobile users with global positioning (GPS) capabilities.

The QoS requirements described in this paper would be difficult to meet by several of the current routers on current dedicated network, intranet and Internet. Nevertheless, the main idea here is to raise the mandatory requirements of recognized network citizenship for software agents, routers and other components of these network infrastructures. Only good citizens, network components or agents, that fulfill these mandatory requirements should pervade while non-compliant citizen would have only limited interactions and/or over time disappear.

9 References

[1] S. Nakamura. Defense Infrastructure of Communication. , 2001, Defense Research Center, Tokyo.

[2] W. Zachary, P. Holt and A. D. Katz. Defense Infrastructure. CS99 Pre-Y2K Report, Dartmouth College Computer Science, Hanover, NH, 15 March.

[3] B. Huffaker, M. Fomenkov, D. Moore and K. Claffy. Macroscopic Analuses of the Infrastructure: Measure and Visualization of Internet Connectivity and Performance. *In Proceedings of the PAM2001 - A Workshop on Passive and Active Measurements*, 2001, Amsterdam, Netherlands, RIPE NCC, http://www.caida.org/outreach/papers/.

[4] V. G. Cerf. Computer Networking: Global Infrastructure for the 21st Century. , 1997, Computer Communication Networks.

[5] Z. Maamar, H. Yahyaoui and W. Mansoor. E-Commerce through Wireless Devices. *In Proceedings of the Engineering of e-Business Applications Workshop held in conjunction with IEEE Tenth International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises~(WETICE'2001)*, 2001, Cambridge, USA, MIT.

[6] S. McGrath, D. Chacón and K. Whitebread. Intelligent Mobile Agents in Military Command and Control. *In Proceedings of the Agents in Industry Workshop at the The Fourth International Conference on Autonomous Agents*, 2000, Barcelona, Spain.

[7] NATO. Code of Best Practice (COBP) on the Assessment of C2 (Command and Control). RTO-TR-009, NATO, Neuilly-sur-Seine, March 1999.

[8] P. Labbé. Analysis Methods for the Management of Tactical Information in a Maritime Environment. DREV R-9614, Defence Research Establishment Valcartier, Val-Bélair, Québec, January 1997.

[9] P. Labbé and R. Proulx*. Model-based Measures for the Assessment of Engagement Opportunities: Implementation and Test Results. DREV R-9807, Defence Research Establishment Valcartier, *APG Solutions & Technologies Inc., Val-Bélair, Québec, November 1998.

[10] P. Labbé and R. Proulx. Impact of Systems and Information Quality on Mission Effectiveness. *In Proceedings of the 5th International Command and Control Research and Technology Symposium, 5th ICCRTS*, 2000, Canberra, ACT, Australia, DoD Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Cooperative Research Program (CCRP), http://www.dodccrp.org/2000ICCRTS/index.htm.

[11] E. Shahbazian, D. E. Blodgett and P. Labbé. The Extended OODA Model for Data Fusion Systems. *In Proceedings of the 4th International Conference on Information Fusion, Fusion' 2001*, 2001, Montréal, Canada, ISIF, http://www.inforfusion.org/.

[12] AUS-CAN-NZ-UK-US Organization's MONIME Ad-hoc Working Group (Co-author). Handbook 5: Guidelines for Maritime Information Management, The Management of Organic and Non-organic Information in the Maritime Environment (MONIME) Ad-hoc Working Group (Command, Control and Communications Committee), 19 April 1997.

[13] A. Flores, D. Blogett and V. Auns. Canadianization of Handbook 5, CSIS Task 109. LMC 500000109 Rev. 1, Lockheed Martin Canada Inc., Montréal, Canada, January 1999.

[14] JROCM. GLOBAL INFORMATION GRID (GIG). JROCM 134-01, U.S. Joint Forces Command, 30 August 2001.

[15] D. S. Alberts, J. J. Garstka and F. P. Stein. Network Centric Warfare; Developing and Leveraging Information Superiority. 2nd ed. 2000, Washington, D.C., CCRP.

[16] Q. Zhang, W. Zhu and Y.-Q. Zhang. Resource Allocation for Multimedia Streaming Over the Internet. *IEEE Trans. on Multimedia*, 2001, **3**(3), p. 339-355.

[17] P. Labbé. Information-management Heuristics for Improved Coalition-operations Effectiveness. *In Proceedings of the 1999 IEEE Military Communications Conference (MILCOM '99); Into the Next Millennium-Evolution of Data Into Knowledge*, 1999, Fort Monmouth & Atlantic City, NJ, IEEE.

[18] J. Shin, J. W. Kim and C.-C. J. Kuo. Content-based Packet Video Forwarding Mechanism in Differentiated Service Networks. *In Proceedings of the 10th Int. Workshop on Packet Video*, 2000, Sadinia, Italy.

[19] N. Jennings, K. Sycara and M. Wooldridge. A Roadmap of Agent Research and Development. *Autonomous Agents and Multi-agent Systems*, 1998, **1**(1), p. 7-38.
[20] A. Elkadhi, B. Moulin and Z. Maamar. Towards a Comparison Approach of Architectures for Interoperable Environments. *In Proceedings of the NATO IST Symposium on Information Management Challenges in Achieving Coalition Interoperability*, 2001, Québec City, NATO.
[21] M. R. Genesereth and A. P. Ketchpel. Software Agents. *Communication of the ACM*, 1994, **37**(7), p. pp. 48-53.
[22] R. Davis and R. G. Smith. Negotiation as a Metaphor for Distributed Problem Solving. *Artificial Intelligence*, 1983, **20**, p. pp. 63-100.
[23] Z. Maamar and R. Charpentier. A Business Object-oriented Environment for CCISs Interoperability. *Journal of Information & Software Technology (Elsevier Science Editor)*, 2000, **42**(3), p. pp. 211-221.
[24] Y. Ye, S. Boies and J. K. Tsotsos. Agents-supported Adaptive Group Awareness: Smart Distance and WWWaware. *IEEE Trans. on Systems, Man, and Cybernetics-Part A: Systems and Humans*, 2001, **31**(5), p. 369-380.
[25] P. Labbé, D. Kettani and Z. Maamar. Assessing Shared Awareness of Wireless-mobile Units. *In Proceedings of the International Conference on Telecommunications*, 2001, Bucharest, Rumania.
[26] M. Matskin, M. Diviniti and S. A. Petersen. An Architecture for Multi-agent Support in a Distributed Information Technology Application. *In Workshop on Intelligent Agents in Information and Process Management*, A. Holsten, Editor, 1998, p. 47-58.
[27] L. Elsen, F. Hartung, U. Horn, M. Kampmann and L. Peters. Streaming Technology in 3G Mobile Communication Systems. *IEEE Computer*, 2001, **34**(9), p. 46-52.