Semi-automatic e-chartering through multi-agent systems and satellite IP networks

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Abstract: This paper proposes a semi-automatic e-chartering in maritime markets though distributed multi-agent infrastructure over satellite IP networks. Using a distributed Multi-Agent system for Internet Virtual Chartering Markets (MAVCM) in each maritime port and the satellite information from participating vessels, we propose a mechanism for semi-automatic control and creation of e-chartering contracts services. The MAVCM system applies for business-to-business transactions in maritime markets, and provides mechanisms for Internet-based chartering informational and transactional services. The proposed system is based on Shipowners and shippers maritime contracts through the MAVCM infrastructure, services and satellite monitoring of the vessels.

Keywords: maritime e-chartering; multi-agent systems; satellite IP networks.

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1 Introduction: overview

With the advent of internet-based Business-to-Business (B2B) electronic markets, real opportunities for online transactions have opened up (Zwass et al., 1996). The maritime industry has started to acknowledge the importance of internet and of the electronic markets, as lower costs and less response time are some of the benefits when compared with the traditional procedures operated by humans. However, the most promising internet-based electronic markets (INTTRA; E4Cargo; CargoSphere) in maritime are found in the B2B environment where they act as intermediaries (middlemen) between vessels and cargoes (Baltic Exchange; Open Shipping Market; ShipBroker; Levelseas; Batrinca et al., 2007).

Currently, marketplaces may exist in the form of stand-alone web sites (INTTRA; Levelseas; SKAARUP) where specific communities of users interested in specific classes of cargo can meet and arrange their commercial transactions in an interactive way and without the constraint of physical co-location. Still, the need of some form of interaction limits the capability and widespread acceptance of such web sites due to the amount of time that may be required for searching and contracting the provision of goods.

Several challenges regarding transport, messaging and security constraints must be handled for business collaboration. As business collaborations are becoming increasingly complex and most systems will be dealing with multiple collaborations at the same time, automating business transactions using ontologies and agents is an appealing approach. These technologies provide new ways of analysing, designing and implementing electronic marketplaces (Ghenniwa et al., 2003; He and Leung, 2002). The use of software agents has mostly been directed towards applications that support Business-to-Consumer (B2C) transactions. However, another important domain is the automation of business transactions that occur in B2B electronic markets (Blake, 2002).

Despite of the growing number of electronic markets, the conduct of electronic transactions and e-chartering is still not trivial (Louis Yip, 2003; Maritime e-Commerce Association). According to the literature, it is accepted that agent technology has the ability to overcome some of these obstacles (Maamar, 2002).

On the other hand, until a few years ago, most researchers and managers considered satellite communications as effectively a last choice, which could be considered only when other connectivity options were unfeasible. However, nowadays, the same managers and researchers are increasingly relying on satellite services over the Internet Protocol (IP) to integrate seamlessly with terrestrial links, creating hybrid networking solutions that deliver the high levels of performance and reliability.

This kind of networks stands as an excellent candidate for providing broadband integrated internet services to globally scattered users/enterprises because of the high mobility support, the inherent broadband capability and the diversity of connectivity such as point-to-multipoint, multipoint-to-multipoint communication, etc. (Hu and Li, 2001).

Satellite network systems can be optimised to meet new service demands such as mobile business-to-business transactions and applications, for instance the one addressed in this paper (Harig, 2006). There is no doubt that in rich internet applications where real-time data are transmitted (voice or video flows) some specific techniques have to be applied to sufficiently overcome the barrier of latency, which will be always present due to the fact that electromagnetic waves travel in vacuum at the speed of light, thus a signal needs at least 500 ms to reach the satellite and then bounce back to the terrestrial system.

In this paper, we propose a multi-agent semi-automatic e-chartering scheme through satellite IP networks since this kind of communication technology is universal and versatile. This means that satellite IP systems support nearly all communication needs especially those needed in asynchronous transactional applications, bringing broadband facilities to the last mile of chartering enterprises. They also deliver a communication platform to areas where terrestrial alternatives are often unavailable and unreliable. Lastly, in such kind of applications where information is gathered and exchanged in a global basis, satellite IP network systems are highly reliable, since they are particularly predictable allowing constant and unvarying Quality of Service (QoS), irrespective of geography and topography parameters, while most of the heterogeneous terrestrial internet-based networks present different QoS characteristics.

Using a Multi-Agent system for internet Virtual Chartering Markets (MAVCM) (Sardis and Lambrou, 2007) and the vessel information through the satellite IP networks, for the vessels' position and estimated arrival time to the next maritime port, we provide an intelligent multi-agent and Electronic Institutions (eIs) infrastructure, that semi-automatic controls and creates e-chartering contracts services. The MAVCM infrastructure is an internet e-commerce system for B2B transactions in maritime chartering markets that provides mechanisms for internet-based chartering of a vessel for cargo transportation, after an e-investigation and an e-negotiation procedure carried out by agents and web-based technologies.

In the proposed system, the vessel that participates in MAVCM and controlled by an agent informs the MAVCM in scheduled time slots for its current position through satellite IP network technology. This info is an input that adapts the e-chartering procedures and the responsible Shipowner agent from one side and the destination maritime port agents from the other side. The latter prepare new e-chartering scenarios for the vessel and in cooperation (semi-automatic) with the shipowner agents arrange the next cargo transfer for that specific vessel.

The design of a multi-agent system for e-chartering, based on the MAVCM infrastructure and its extension with satellite services infrastructure, which controls the satellite communication with the vessel, constitutes the main subject of this study. The proposed infrastructure could also be adapted in other real-life problems where agents and humans could cooperate through internet networks. However, designing multi-agent based systems is a complex and demanding task. By using the standardised design methodology of Gaia (Zambonelli et al., 2003; Caire et al., 2001; Bellifemine et al., 2001), we regarded all this system architecture as an organised society of individual agents with their roles and different kinds of interactions among them according to specific protocols that were related to the roles of the interacting agents. The proposed infrastructure uses eIs (Sardis and Lambrou, 2007) for the modification of human e-chartering rules to electronic rules between agents.

Satellites communications have accomplished a remarkable worldwide utilisation in the recent years due to the override of land networks and benefit of services in regions where land networks are not available (boats, planes, etc.) or in cases of the land networks collapse (wars, calamities, etc.). But various disadvantages still exist; most of them are reflected in terms of transmission delays and overall cost of communication. The communication of the MAVCM infrastructure using extra services with the satellite IP networks to transmit vessel info into the MAVCM infrastructure extends the business of the human chartering in a more wide business area, where semi-automated procedures are able to be initialised and work. The satellite part of our architecture creates additional issues that have to be resolved, such as the requirements for synchronous info from vessel lost at times, as well as uncontrollable conditions that should by default be surpassed, without disturbing the whole human maritime chartering transactions. However, the implementation of such a system is not the main scope of this study, but the prospective interworking between the MAVCM system and the utilisation of the satellite communications.

The remainder of the paper is organised as follows; Section 2 analyses the business process of the maritime chartering through the MAVCM infrastructures, the participating actors and their roles. Also, the business transactions that occur along with their constraints and requirements are presented. In Section 3, the information technology solutions for the satellite communications between the vessels and the proposed MAVCM infrastructure are described. The architecture of the whole infrastructure is presented and analysed in Section 4. Section 5 describes the design of the satellite services based on our evaluation of the proposed technologies that can be implemented and support the semi-automated e-chartering. Section 6 evaluates the aforementioned results of the MAVCM infrastructure and services and finally, Section 7 concludes the paper.

2 Vessel chartering

According to the international bibliography (Maritime e-Commerce Association) pertaining to the subject as well as to the shipping practice, the charter market is divided into categories based on the following criteria:

- type and nature of the bulk to be carried
- type of vessel
- geographical distribution of maritime commercial transportation
- sea areas where vessels are certified to operate
- duration of the charter period
- type of charter

Our case study was created based on 'bulk cargo' types of vessel cargo. The term 'bulk cargo' describes any cargo lot, which can fill the ship or the ship's holds to their full capacity, whereas the term 'general' or 'mixed cargo' covers any consignment which is not that voluminous, to the effect that it must be transported combined with other consignments for them to jointly fill the ship. The present study takes into consideration the use of a vessel 'bulk carrier', which can only load/unload one bulk dry cargo each time from a port. This market type can be applied to electronic transactions because the cargo type is easier to be simulated and tested through electronic transactions for vessel loading and chartering procedures (Ewart, 1984).

The parties involved in the e-chartering procedures (Sardis and Lambrou, 2007; Sardis and Vouros, 2007) are only the shipowners and the shippers.

- Shipowner is a person or a firm owning one or more ships (Sullivan, 1998).
- Shipper is the owner of the cargo to be transported. It has been mentioned earlier that often the shipper is identified with the chartered. The shipper is in charge of the goods' loading and transportation (Caire et al., 2001).

The other parties of the human maritime chartering procedures like the shipbroker, chartering broker and the shipping agent (Sardis and Lambrou, 2007), have a supporting role in the e-chartering procedures, although at times their role is substituted by the proposed MAVCM system.

Another factor significant for the success of the proposed system is the time constraint. The information and communication network of chartering, particularly in the e-chartering, is based on at 'time' parameter that is reliably important. This chartering information is more important to a shipping company than to any other type of land-based one, since shipping companies have ships travelling all around the world. The company's income is generated in international currency. Global events (financial, political, social, etc.) influence the freight rates as well as the position occupied by the company in the field of competition in shipping. Information is exchanged between the e-chartering actors concerning matters such as ships' and cargo's demand and supply, ships' operating costs, port taxes, loading, unloading and cargo handling services, canal fees, fuel prices, berths' depth, level of traffic congestion in certain berths, the situation in certain canals and other crossings, international rules of safety and navigation, weather conditions, etc. The quality and quantity of the exchanged information largely depends on the involved actors' communication and the according to the costs/fees they pay for accessing that info. This communication is separated into two main categories:

- Shipowner office to information centres communication
- Shipowner office to vessel communication

The first category uses land IP networks. In the second category, the satellite communications are the only available communication channel, especially during the vessel ocean sailing. Consequently, the proposed e-chartering system uses the satellite infrastructures and evaluates their characteristics to feather in MAVCM infrastructure.

3 Satellite communications

Satellite IP networks are becoming more and more significant for worldwide communication purposes. They not only provide global coverage through a common and well-known protocol, but they can also achieve high bandwidth levels. The rapid growth of internet-based applications pushes satellite IP networks to disseminate traffic beyond earth bounds. IP is a connectionless protocol that makes possible the data transportation across heterogeneous networks. By using the IP over satellite links, network designers are allowed to seamlessly interconnect remote users/networks to each other as well as to the internet infrastructure. Satellite IP networks can be viewed also as a set of separate Autonomous Systems (ASs) within internet space, which is an ideal backup solution in case of link failures and congestion in terrestrial networks (Ekici et al., 2001). In addition, as the internet itself becomes very popular among millions of users and enterprises, the initiatives regarding Internet 2.0 or Next Generation Internet (NGI) show that satellite IP networks are on the edge of this technology evolution (Ekici et al., 2004).

Satellite-based systems are preferable to cellular for coverage footprints and potential global applicability. Cellular-based systems are generally less expensive and possibly more suitable for some domestic applications. The Global Positioning System (GPS) is the most common source of geo-location data, but other sources are available as well (Elbert, 2004).

The ability to track the progress of a bulk carrier vessel in real time as well as determine whether it has been tampered with, offers considerable possibilities for improving the safety and security of the multimodal freight transfer system. Various companies offer equipment that allows customers to track a shipment throughout the transfer chain.

Classic computer networking theory neglects the transmission time of data packets, since that is insignificant compared with the processing time or the packet lengths. However, the large distances between nodes in a satellite constellation network have propagation delays, which are very important considering the overall delay of a packet being passed through a network as part of a real-time two-way connection with a delay budget.

More importantly, as can be seen from the physical geometry, link distances and positions between the earth and the satellite vary. This issue is significant and means that propagation delay should be one of the first 'realistic' factors to be introduced into the basic simulation, to see if delay budgets are met and to consider how different routes can be favoured as the propagation delays become shorter.

At a more realistic level, variations in propagation delay will lead to difficulties in synchronisation and timing between satellites, if it is desired to implement some form of SDH or ATM network. The propagation delay can also be used as a queue for short packets, which has interesting implications for a deflection-routing-based network. The following advantages and disadvantages of the satellite communications are categorised for the potential use of agent-based solutions:

Advantages

- possibility of wide broadcast systems
- bypass of land networks
- possibility of new circuits' installation
- possibility of network control from the user
- benefit of services in regions where land networks are disabled (boats, planes, etc.)
- benefit of services in parts where land networks do not exist
- benefit of worldwide coverage
- additional benefit of mobile services related to the land networks
- benefit of services in cases of collapse of the land networks (wars, calamities, etc.).

Disadvantages

- big initial cost of manufacture and placement
- distribution and interjections in the transmission signal
- congestion of frequencies
- congestion in the orbital levels, especially in the equatorial orbit
- vast cost of launches and satellite manufacturing and requirement of long-lasting operation
- unfavourable conditions of operation in space
- long signal delays due to the large distance between the satellite and the ground
- enormous losses of the signal level

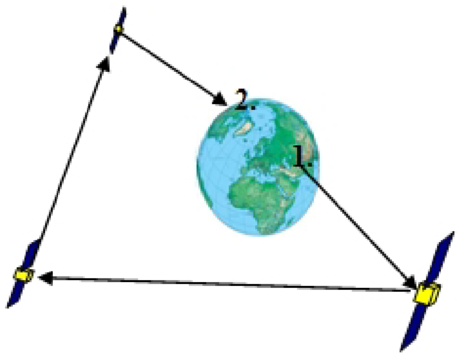
- maximisation of the available capacity that constitutes the unique source of income, which results in expensive bandwidth allocation
- modifications of the existing protocols of transmission or development of new ones.

3.1 InterSatellite Links

The InterSatellite Link (ISL) approach, where satellites communicate directly with each other by line of sight, supports mobile-to-mobile calls between different satellite footprints, within the constraints of a tight interactivity delay budget, far easier than the GEO approach (despite introducing additional complexities, such as handover between satellites) and removes traffic from the ground infrastructure (Werner et al., 2001).

Adding ISLs also introduces flexibility in routing, builds inherent redundancy into the network and avoids the need for visibility of both user and gateway by each satellite in the constellation. The extension of regional satellite system coverage into adjacent or very distant areas is also possible through ISLs. An example of a configuration by an ISL is depicted in Figure 1.

Figure 1 Crosslink satellite system configuration (see online version for colours)

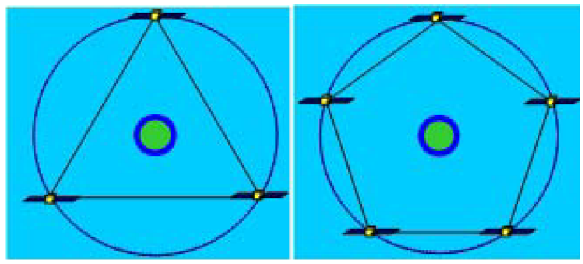


ISLs are likely to perform multiple functions:

- by providing the shortest route connection between originator and destination
- by selecting the lowest cost of terrestrial routing
- by-passing of local and international carriers
- by-passing busy satellites and terrestrial gateways (packet switching)
- by improving spare transponder capacity utilisation
- by allowing use of less-than optimum GEO slots.

For the case of GEO–GEO ISL, the distance ranges from 42,000 km (five satellites) to 73,000 km (three satellites) (Figure 2).

Figure 2 Crosslink satellite system configuration using: (a) 3 and (b) 5 satellites (see online version for colours)



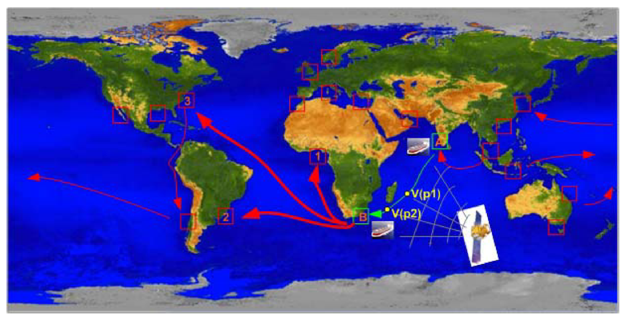
(a) (b)

4 MAs based MAVCM services

Agents may be conceived as stand-alone entities that accomplish particular tasks on behalf of a user. However, in most cases, the environments where agents complete their tasks are populated with other agents. In these MAS, the global behaviour of the system derives from the interaction (cooperation, coordination, negotiation, etc.) among the existing agents. The proposed MAVCM system supports the three phase e-chartering procedures; the *investigation stage* (where shippers and shipowners are searching for cargo and available vessels), the *negotiation stage* and the *follow-up stage* (where they conclude their contracts).

Critical aspects in open MAS applications are the organisational structure (if any) and especially the organisational rules that control the behaviour of self-interested agents (Rodriguez and Favela, 2002). The web-based infrastructure has been designed based on MAS and eIs design aspects (Sardis and Lambrou, 2007). The involved parties by using the web GUI for the first time are able to e-charter through the MAVCM marketplace. The result will be a contract for the shipowner, concerning a specific cargo to be transferred from port A to port B (Figure 3). First, the design in this market place needs the humans input of vessel availability and cargoes availability before the MAS investigation stage finds and suggests possible transfer scenarios to the involved parties.

Figure 3 AVCM semi-automatic e-chartering service through satellite networks (see online version for colours)



The new services that are proposed in this study are the following. After the first data input, the system already knows the criteria for a specific vessel's position. These are:

- description of the vessel
- the period within which the vessel is available
- type of chartering (voyage, consecutive voyages, time, bareboat, coa).

and the constraints that should be satisfied from a cargo *order*. These are:

- cargo quantity and description of the commodity
- loading and discharging ports
- the period within which the vessel is to be presented for loading (lay/can).

Then the new MAVCM Services are the semi-automatic preparation and the submission of a proposal to the shipowner concerning the next available ports and corresponding cargoes for that vessel. Figure 3 represents the e-chartering procedures that the proposed system resolves. When the MAVCM system has created a contract for a specific vessel to transfer a cargo from maritime port A to maritime port B, the vessel position through the satellite communications is triggering the semi-automatic e-chartering service of the MAVCM. For example, the values of vessel position $V(p1)$ and $V(p2)$ in different time slots are a reference point in the algorithm, which calculates the remaining days before the arrival of the vessel in port B.

Before the vessel's arrival in maritime port B, the system informs the shipowner for the possibility for the next transfer of the cargo based in maritime ports 1 (Africa), 2 (Latin America) and 3 (Canada), as depicted in Figure 3. The aim of this study is to demonstrate the benefits of the MAVCM system in maritime contracts. Our proposed system goes one step further from the conventional search-and-create contract systems (like the ERP functionality) from two aspects:

- by using advanced multi-agent systems instead of humans
- by using network technologies through satellites to have data online from vessel agents in our system.

The human factor as a 'last word' factor in the whole procedure will decide based on business rules and constraints and through the GUI of the MAVCM infrastructure for the appropriate cargo and will finalise the whole maritime e-chartering procedure.

The main technologies that are cooperating for this B2B scenario in e-chartering procedures are analysed in the following paragraphs.

4.1 Design of MAVCM and MAVCM Services

The proposed MAS system was modelled based on Gaia (Zambonelli, 2003) methodology, following the three major phases of analysis, architectural design and detailed design. Using the Agent UML (AUML) (http://www.auml.org; Huget, 2004) for the software engineering we were able to represent the core protocol functionality of the Agents Interaction Protocol (AIP) (FIPA specs) that constitutes a central aspect for MAS, specified by means of protocol diagrams.

The specification of agents with their roles and the interactions among them and with the environment, do not suffice to capture the complex and emergent behaviour deriving from many self-interested agents' applications. The complexity of the MAVCM system infrastructure, as stated in Section 2, needs additional effort for modelling the organisational structure as well as the organisational rules. This is accomplished by the eIs. EIs allow the description of the roles and interactions of both human and software agents in a specific setting (the institution) by using a comprehensive framework.

By using the ISLANDER (Blake, 2002) eIs editor, we have designed the eI details that control the MAVCM agents' behaviour.

On the basis of GAIA analysis, the MAVCM services have been divided into different MAS organisations that are controlled by different eIs. The *MAVCM infrastructure* is based on eIs e-chartering constraints and rules and the *MAVCM Services* are based on communication and event driven rules that apply using different eI dialogical framework, performative structure and normative rules.

Figure 4 presents different maritime ports A and B, where different eIs operate for the direction and the coordination of the port specific e-chartering procedures that humans and agents have to comply with. The main parts of the infrastructure are separated in port infrastructure represented as *MAVCM infrastructure* (Sardis and Lambrou, 2007) and *MAVCM Services* infrastructure. The *MAVCM infrastructure* in each Maritime port (A, B, …, N) is composed of:

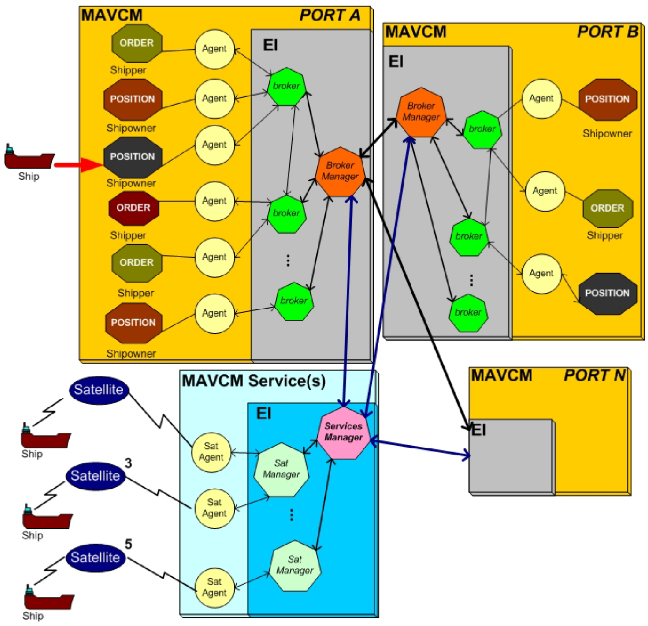
- *An Agent*, who acts instead of the shipowners (*position* vessel info) and the shippers (*order* cargo info) in each port and interacts with the MAVCM services through GUI.
- *A Broker*, the eI structure containing the rules and norms for each actor.
- *A Broker Manager*, the port coordinator and also the agent interface for the communication between different ports. It is the core module of the system which involves procedures and services for eIs interactions and is vital for the implementation of the eI performative structure (Rodriquez-Aguilar et al., 2006; Vazquez-Salceda et al., 2004).
- *An EI*, which enables agents to exchange knowledge with other agents through its dialogical framework.

The main parts of the *MAVCM Services* are:

- *A Sat Agent*, who is responsible for the satellite information from the vessel to the *MAVCM infrastructure*, through synchronous data transfers of the satellite IP networks. This agent knows the current vessel's position in specific time slots. Satellite data are transformed into useful semantic keywords for *Sat Manager* management.

- *A Sat Manager,* which it is an agent that controls more than one *Sat Agents.* The criteria in our case study were the traffic load and the hypothesis that more than one vessel are transferring data through the same satellite (or the same geographical area) that the *Sat Manager* controls. The role of the *Sat Manager* is based on the normative rules of the eI of the *MAVCM Services* infrastructure. This eI has been designed as a pool of MAVCM services, where in our case study hosts the satellite services. Services extensions of this infrastructure are under future research.
- *A Services Manager*, which is based on the eI constraints and has a dual role. On one hand, to facilitate the necessary protocol communications between different *MAVCM infrastructures* and the *MAVCM Services* infrastructure. On the other hand, to coordinate the *Sat Managers* info and to send the right vessel data to the *MAVCM infrastructure* on time. The data will trigger the e-chartering algorithms representing new e-chartering scenarios for the vessel.

Figure 4 MAVCM infrastructure and MAVCM Services involved agents (see online version for colours)



4.2 Satellite communication with MAVCM Services

The communication between the *MAVCM infrastructure* and the *MAVCM Services* infrastructure is based on the synchronous satellite transactions that depend on latency values, bandwidth availability and message ordering (Carzaniga, 1998; Eugster et al., 2003).

Latency, also known as *time* of *delivery,* is defined as the period of time between the publication of an event by the publisher and the reception of the relevant notification by the subscriber. The overlay network must effectively reduce the overall latency of event notifications in the *MAVCM Services* infrastructure. If T_d represents transmission delay, P_d represents propagation delay (which is constant for a network), Q_d represents buffering/queuing delay, e represents an event of type τ and b is the total number of nodes occurring in the path between a publisher and a subscriber, then the latency L for a single notification of an event is as follows:

$$L(e_\tau) = b(P_d) + \sum_{i=1}^{b}(T_d[i] + Q_d[i]). \tag{1}$$

Latency calculation is the summation of the delay in propagation at all MAVCM modules and the transmission and queuing delay at each module's buffer.

The available *satellite bandwidth* capacity depends on the satellite services that each vessel has been subscribed to the satellite provider.

Message ordering can follow the First In/First Out (FIFO) or Last In/First Out (LIFO) operation. Using a timestamp Θ the FIFO operation is expressed as:

$$\Theta[e(\tau_i)] \prec \Theta[e(\tau_j)] \Rightarrow n[e(\tau_i)] \rightarrow n[e(\tau_j)] \tag{2}$$

where e are the events of type τ_i, τ_j in the system and n is a notification message, whereas the LIFO ordering is expressed as:

$$\Theta[e(\tau_i]) \prec \Theta[e(\tau_j)] \Rightarrow \neg(n[e(\tau_i)] \rightarrow n[e(\tau_j)]). \tag{3}$$

The data from the vessel, which through the *MAVCM Services* infrastructure triggers the *MAVCM infrastructure* to execute a series of actions, have been classified into three categories of adaptive trigger events:

- vessel-related (vessel mobility)
- event-model-based (notification of an urgent event)
- resource-based (agent or satellite channel failure).

A real-time operating environment is needed in the implementation of the *MAVCM infrastructures* and *MAVCM Services* to handle the timings of the above events in the communications among these nodes. The success of the proposed system relies on the effective satellite IP communication network between the vessel and the *MAVCM infrastructure*.

4.3 MAVCM Services infrastructure

When a shipper and a shipowner conclude on a contract through the *MAVCM infrastructure*, an event triggers the MAVCM *Services* to start receiving vessel data (e.g., vessel position). During these experiments, various information of the vessel is used, such as Geographical Positioning Data (GPS), weather and vessel conditions, etc., due to their small file size and low bandwidth requirements. Delays and data-packet losses of the network create empty slots and zero values of the variables into the *Sat Manager.* The solution of buffering data functions only between specific e-chartering time constraints. For example, for a vessel sailing for ten days the time constraints could not exceed a 'one day' period, whereas, for a vessel sailing for two days the previous time constraint is not in effect. Such cases are resolved, based on chartering and maritime rules and are transformed into software constraints through the eI norms of the *MAVCM Services* infrastructure.

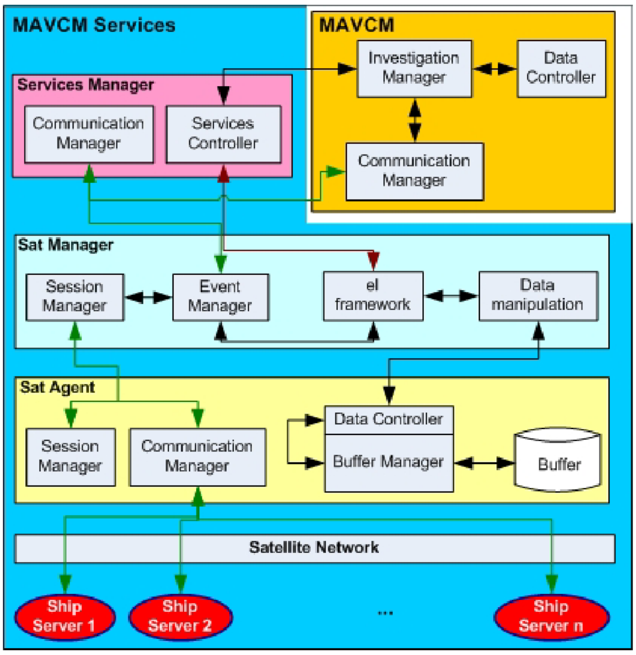
The *MAVCM Services* infrastructure is analysed in more detail in Figure 5. The vessel route depends on different parameters such as weather conditions, human interaction or vessel geometry, etc.

Sat Agent main modules can be classified in two main categories:

- The communication and session controlling modules; the *Communication Manager* and the *Session Manager* modules belong to this category. Through these modules the agent communicates with the correct vessel through satellite and with the *Sat Manager* agent. These modules replicate state changes to maintain consistent views and data across the infrastructures and are responsible for the replication of the signalling messages to handle special situations or exchange control information. *Session Manager* modules are representing a period of synchronous interaction between the modules where they form a *session*. On the basis of the above remarks, the *MAVCM infrastructure* through its *Communication Manager* module interacts with the *MAVCM Services.*

- This category of modules is cooperating for the generation and exchange of data between the vessel and the *MAVCM infrastructure* through the *MAVCM Services*. The *MAVCM infrastructure* generates events based on the e-chartering contracts. These events are forwarded from the *Services Manager* agent, through the *services Controller* in the *Sat Manager* agent and in a module named *Event Manager*. This module includes a mechanism for intercepting events that are generated according to the implemented *MAVCM infrastructure* contracts between shipowners and shippers. The *Event Manager* uses an event handler listener, that is triggered whenever a new event (new vessel) should be monitored by the *MAVCM Services* infrastructure. Also converts the events into messages with a predefined format and then passes them to the *Session Manager*. The *Event Manager* also extracts events from received messages and passes them to the *Services Manager* through its *Communication Manager* module. The *Sat Manager* creates *Sat agent(s)* based on the number of vessels to be monitored. The *Data manipulation* module uses the rules of the *eI framework* module for storing or retrieving the data through the *Data Controller* and *Buffer Manager*.

Figure 5 MAVCM Services internal modules (see online version for colours)



Buffering conditions help to keep the previous vessel data, when no satellite communication exists until the next requesting time slot. The events are functioning in synchronous mode and any delay in the data exchange could negatively affect the proposed infrastructure. We have assumed that the agents of the same maritime port are working in the same IP network infrastructure and only the satellite network could import delay and latency. For this reason, the analysis of the satellite network latency and the whole delay of the vessel data according to the involved number of the satellites during a communication line (vessel to office station) are the evaluation criteria for the success or failure of the *MAVCM Services* infrastructure.

The sequence diagram in Figure 6 is presenting the communication sequence of the different agents' modules, when the *MAVCM infrastructure* requests a vessel communication based on FIPA-Foundation (FIPA-Foundation). The *MAVCM Services* systems' initialisation is depicted in the diagram. The data exchanging through the involved modules of the *MAVCM Services* is shown in Figure 7. Both sequence diagrams are presenting the sensitive point of the whole infrastructure that is the satellite communication and the modules that support that communication to be seen as synchronous when any problem occurs. On the basis of Figure 7 and steps 11–20, it is defined that the *SA_Buffer Manager* will inform the *MAVCM infrastructure* about the last GPS value of the vessel or the direct online value of the vessel in case of live satellite communication.

Figure 6 Communication modelling of MAVCM and MAVCM services modules

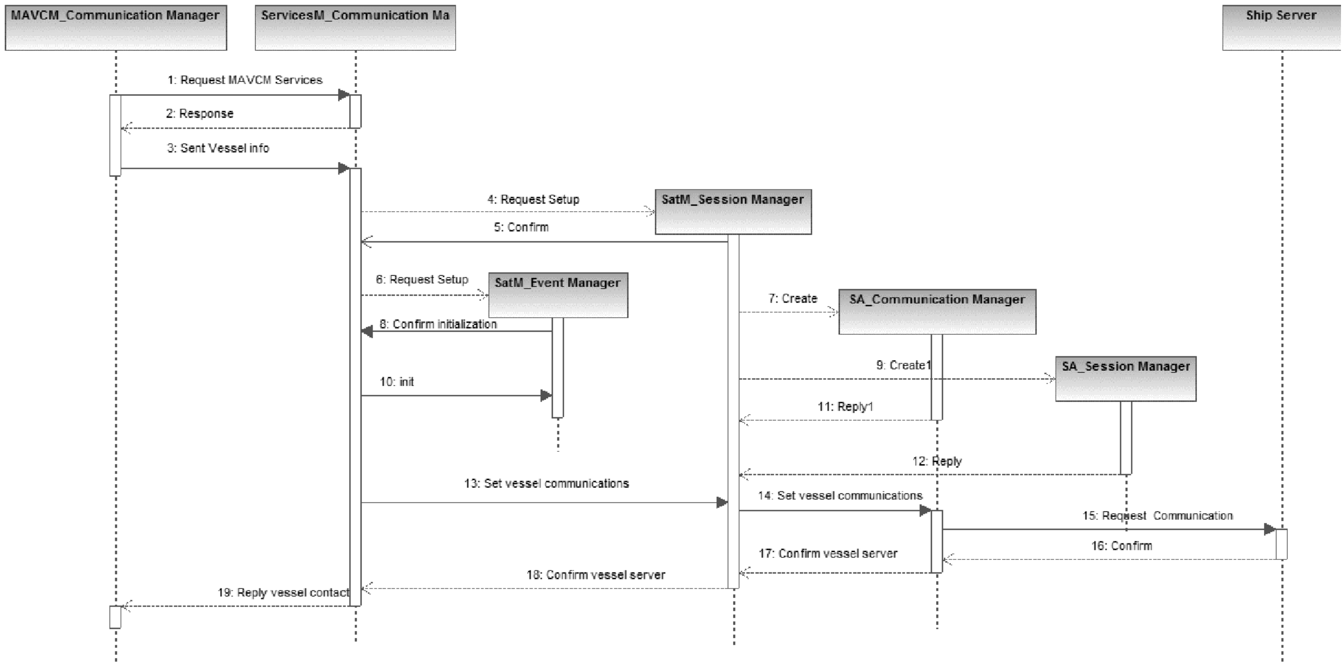
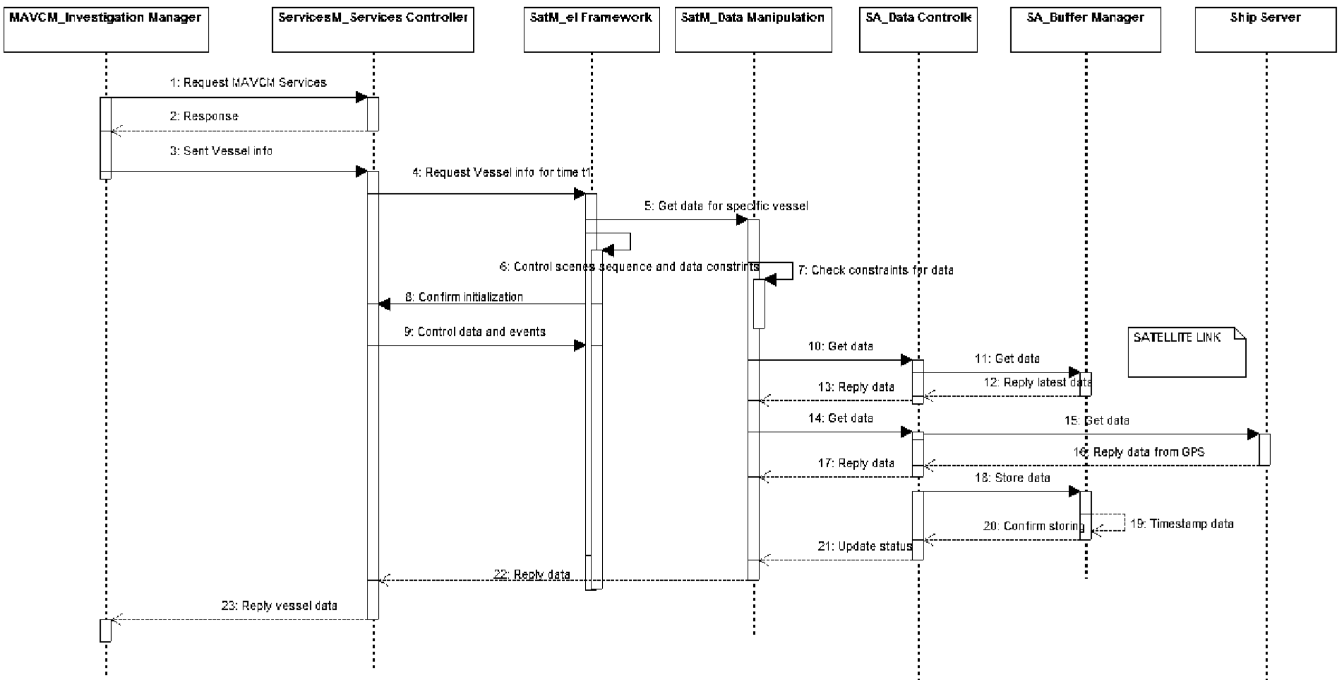


Figure 7 Data exchange between MAVCM modules, MAVCM Services modules and Ship Server



Time constraints based on vessel sailing speed, may trigger the algorithm to request more often data values from the vessel through the satellite to have a more synchronous response. This response from the *MAVCM Services* is critical, as the transferred values will trigger the *MAVCM infrastructure* algorithms for searching and proposing e-chartering scenarios.

The following section analyses the satellite networks' problems and network communication limits that the design of the *MAVCM Services* infrastructure has to resolve and evaluates the proposed solutions.

5 Satellite communications experiments and performance evaluation

Hereafter, we describe and analyse the experimental procedure for calculating and evaluating the performance of several satellite scenarios, regarding the propagation time delay of the transmitted and received data, between the vessel and the shipowner, respectively and the delay of the satellite IP network.

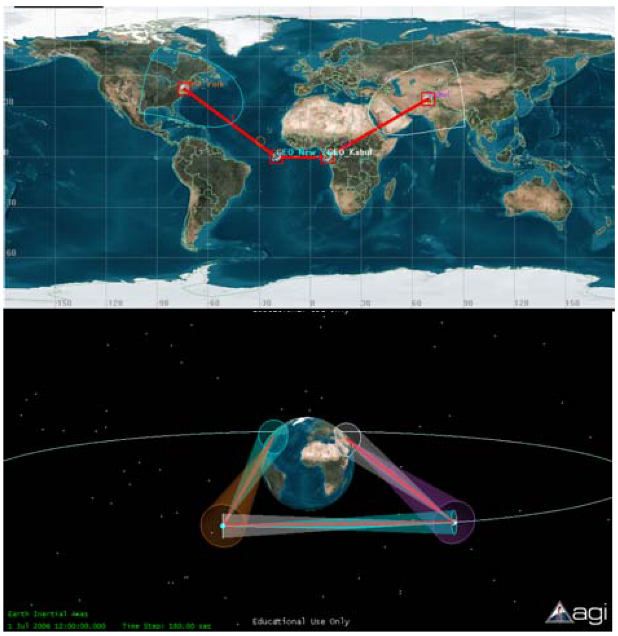
5.1 Simulation experiments for propagation delay

Propagation delay has large effect on source-sink communication time. It can be introduced as link weighting, where each link is assigned a length or delay value determined by the physical orbital spacing. This will result in some minimum paths being favoured over others because they are shorter and this must be accounted for with some sort of strategy. The resulting delays can be compared with the GEO case and the delay that the agent system can tolerate for synchronous data transmission and processing.

Simulation runs were taken into consideration accomplishing a broad area of satellite communications links. One of the several scenarios is depicted in Figure 8, where a link between New York and Kabul incorporating ISL between two GEO satellites is presented. This is an example of an ISL, simulated using AGI's Satellite ToolKit.

The average total transmission time for this scenario (one-hop) is 338.11 ms. The expression 'one-hop' indicates the uplink transmission between the vessel and the satellite or the downlink transmission between the satellite and the shipowner. The expression 'two-hops' indicates the uplink and downlink transmission between the vessel and the shipowner.

Figure 8 An example of ISL using two GEO satellites between New York and Kabul (see online version for colours)



Delay to a ground station directly below the satellite will be approximately $t = \text{Distance}/c = 35786 \times 10^3\ \text{m}/3 \times 10^8\ \text{ms}^{-1} = 0.119\ \text{s}$, ignoring the change of the speed of light in atmosphere, which is insignificant compared with the total distance. Note that for ground stations outside the satellite's nadir, the delay will be slightly larger, thus a round trip delay between two ground stations can be up to 278 ms. In case of GEO–GEO ISL with a total of 3 GEO satellites, the distance of ISL is 73,000 km and the delay is 243 ms.

For the case of a GEO–GEO ISL with a total of 5 GEO satellites, the maximum distance of ISL is $2 \times 42{,}000$ km with a delay of 280 ms and the minimum distance of ISL is 42,000 km with a delay of 140 ms. Of course, we prefer ISL GEO satellites attributing less than 90 ms delay in propagation time and thus small distance between them. But, selecting the worst case scenario for the propagation time, the total delay from the vessel anywhere in the world to a ground station anywhere in the world (one-hop) can be from 418 ms up to 558 ms.

For the case where no ISLs are necessary, the total propagation delay between the vessel and the ground station (shipowner office) is from 238 ms up to 278 ms (two-hops), using 1 GEO satellite.

5.2 Experiments and Evaluation of the Satellite IP Network Platform

Despite of the delay caused by the propagation time, the satellite IP Networks are suffering from transmission delay due to packet loss, interference situations, signalling, scheduling, etc. A typical satellite IP network consists of a classical Digital Video Broadcasting via Satellite (DVB-S) system, like a Very Small Aperture Terminal (VSAT). A more advanced system comprises of a full duplex (two-way) Digital Video Broadcasting with Return Channel via Satellite (DVB-RCS) (ETSI EN 301 790; ETSI EN 300 468). European Space Agency (ESA) (http://www.esa.org) has initiated the DVB-RCS technology enabling almost all potential locations – even the most geographically dispersed and isolated ones – to gain access to broadband services using low-cost Satellite Interactive Terminals (SITs), effectively satisfying the QoS requirements of high demanding applications.

The DVB-RCS satellite core network can gain access by any satellite provider using the expensive but necessary satellite bandwidth (satellite transponder) to provide SIT and DVB-RCS hub interconnection. The platform may consist of one or more SITs placed in several remote areas (vessels, shipowner building, broker, etc.). Every SIT can be equipped with appropriate communication devices (i.e., videoconference units, videophones, IP phones, etc.). Each SIT has access via ethernet IP connection to the MAVCM platform.

Regarding the satellite security issue, the proposed satellite system is DVB-RCS. This architecture utilises a special system for the creation of safe encrypted connections between SIT and the hub. This system uses the IP Secure (IPSec) protocol (Paterson and Yau, 2006) for advanced security and it comes in the form of a server–client mechanism with one or more servers incorporated in the hub. It has the characteristics to support standard IPsec, Layer 2 Tunnelling Protocol (L2TP), Point-to-Point Tunnelling Protocol (PPTP) and Layer 2 Forwarding (L2F) tunnelling protocol. Also, it supports the

Data Encryption Standard (DES), triple DES (3DES) and Advanced Encryption Standard (AES) and has stateful packet inspection firewall capability.

In this context, a potential maritime scenario demonstrating a vessel-to-shipowner satellite IP network may consist of such a system. A simulation campaign was performed using OPNET simulation platform, so as to evaluate the performance of the network, in terms of packet delay. The satellite IP network composed of several SITs connected to the hub, transmitting and receiving various data rates that the hub can support, resulting in a congested network.

Various data of the vessel can be transmitted within the specific throughput of 300 kbps, including GPS spot, weather conditions, vessel conditions (mechanical problem, etc.), velocity of the vessel and everything that will enable the MAVCM system to estimate the time of arrival at the port. The transmitted data rate from a SIT can be guaranteed (Constant Rate Assignment – CRA) or dynamic (Volume Based Dynamic Capacity – VBDC), depending on the available bandwidth, or combination of the above two bandwidth allocation schemes (Vouyioukas et al., 2007).

The results are depicted in Figure 9 for aggregate asynchronous data transmission of 300 kbps, for synchronous application transmission and in a congested network. We tried to facilitate the study and the usage of the MAVCM services via satellite IP networks, by exploiting the simulation of the worst case scenario, meaning that the status of the satellite network is congested with several SITs and data rates, leading to the maximum capacity the system can handle. The results showed zero delay of the packets when the CRA algorithm is adopted, while the VBDC algorithm evolves excess delay and packet loss, depending of course on the network traffic. Furthermore, the VBDC algorithm appears to be inappropriate for synchronous transmissions.

Figure 9 Comparison of data delay between CRA and VBDC algorithms for a congested network and for synchronous transmission

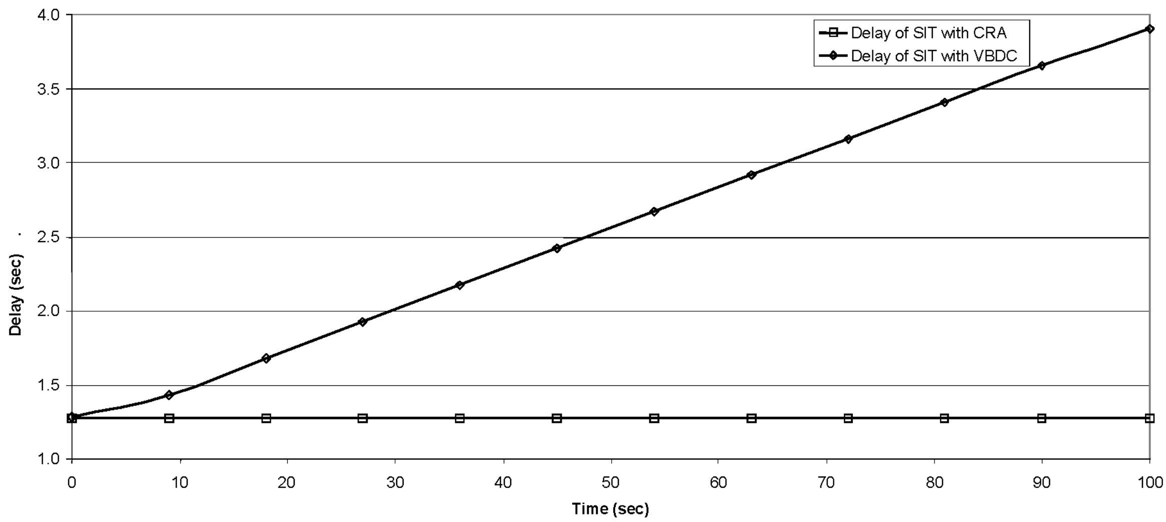
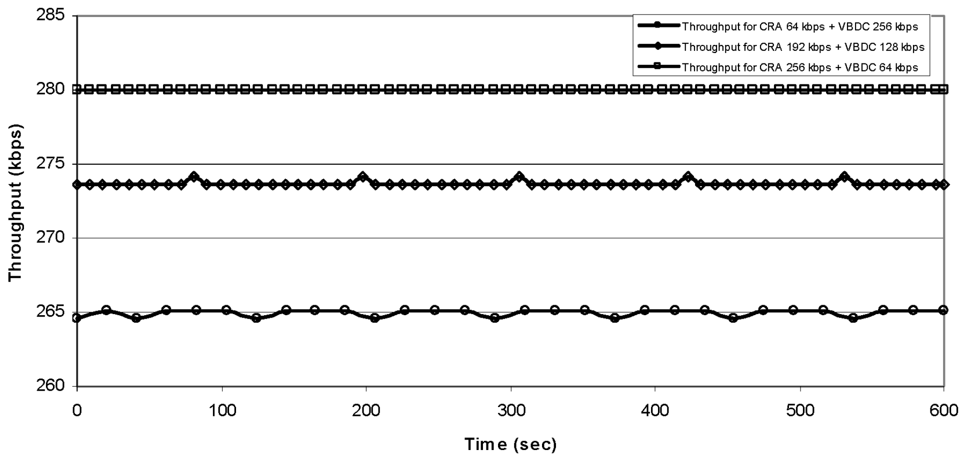


Figure 10 Comparison of data throughput between different allocations of cra and vbdc algorithms for a non-congested network and for synchronous transmission



For non-congested network, the two algorithms attribute equally with minimum delay and minimum packet losses, putting into effect priority to the VBDC, since the satellite capacity is expensive and its availability is usually limited. Optimum performance is achieved by utilising a combination of the two algorithms, thus accomplishing zero delay and packet losses for synchronous communication issues (Komnakos et al., 2007), as it can also be seen in Figure 10.

6 Evaluation of MAVCM services infrastructure and results

For the proposed architecture for marketplace in the maritime sector we used the most popular development environment JADE, although there are several environments available, including ZEUS, FIPA-OS and CoABS. This environment provides the basic skeleton agents and implementations of standard FIPA interaction protocols.

It implements FIPA's agent Management System, Directory Facilitator and Agent Communication Channel. The created agents can be deployed and executed on a variety of platforms, including PDAs, something very important for the maritime sector. For the support of the proposed distributed environment, each JADE platform has its own Java Virtual Machine, in which each agent is a single thread. Basic state-machine behaviours for the testing of the data transfer between MAVCM and vessel were used.

The security issues are fundamental to the successful adoption of agents' technologies for business applications, but have not, however, been implemented in our test cases. The main issue of our study was the prototyping of the whole system using agents infrastructure and satellite communications under an environment that could be extended in the future and support all the necessary standards like the security model FIPA-MAS (Poslad et al., 2003) for embedding security such as the authentication, authorisation and the access control aspects. JADE security model can be used to attest the identity of the agent executing in the MAVCM system (Poggi et al., 2001), while fulfilling the authentication security requirements. Using the *Secure Socket Layer* SSL as a base to protect JADE transmission is another security measure to protect the network connections and guarantee the authentication and encryption of the TCP connections. Finally, the use of certificates for implementing security delegation, under the JADE, could protect the MAVCM system from the unauthorised use of MAVCM resources and data. The above security measures are a set of extra requirements that MAVCM infrastructure should support. Their effect in the transmission delays and the related MAVCM performance is a second step in our research.

To test and evaluate our MAS infrastructures, we assumed that they consist of two networks. Firstly, the IP network of the maritime ports, where the IP network of port A sends contract detail data and cooperates with maritime port B. Secondly, the satellite IP network, where vessel data is transferred into port A and port B, as already presented in Figure 3. Both networks were connected via the internet. Our simulation results measured the data transfer from the *MAVCM infrastructure* to the *MAVCM Services* infrastructure and then to the vessel through the satellite. For the reverse order of the messages, we assumed that the data transfer takes the same time. Two criteria have been used, the round trip time (RTT) and jitter. RTT measures the time between the transmission of an event (*MAVCM infrastructure* event) to the *MAVCM Services* and the vessel the reception of the response by the sender (vessel GPS data). Jitter is the variation in transmission time. These two criteria are very relevant. When the value of the RTT is high, it indicates that the vessel data arrives late in the *MAVCM infrastructure*. On the contrary, high jitter value signifies that the expecting data, which is used as input into *MAVCM infrastructure* algorithms, should be replaced by the previous one, due to delay and failure for timely arrival.

On the basis of Figures 9 and 10, the system architecture can be implemented either as synchronous based on CRA algorithm or as asynchronous using the VBDC algorithm. Combination of these two bandwidth allocation schemes algorithms may conclude to intermediate delays. The time delay from satellite IP network in the second case is resolved using the *Buffer Manager* module in the *MAVCM Services* infrastructure. The result is a synchronous system that cooperates in both IP networks.

The contribution and evaluation of the satellite in the e-chartering procedures gives an add-on to this type of marketplaces and opens new areas of exploitation and market extensions. Moreover, the advantages of using real-time vessel data in such type of marketplaces, helps the involved parties to cooperate simultaneously in more than one e-chartering negotiations and contract investigation phases.

7 Conclusion and future work

The main contribution of this research work is the analysis of the chartering maritime market, where until now most of the procedures are been done manually by humans and the suggestion of an intelligent system based on IP networks, that offers semi-automatic chartering services to the involved human parties. The identification of the chartering procedures and necessary functions and then the design of an intelligent system based on these market requirements using multi-agent systems and eIs over the web is an add-on. The use of the MAVCM infrastructure and the extension to this by the MAVCM Services through satellite communications is a very challenging topic for B2B transactions over IP networks. The architecture in many applications, where their communication topology is based on many different IP networks and on multi-agents technologies, is under research.

During this work, the case study of network problems based on satellite IP technology and the proposed solution to overcome these limitations, for the design of the *MAVCM infrastructure*, was a challenge. The proposed system surpasses all the traditional methods of the maritime chartering and brokering procedures giving add-on for the maritime community. The design of an intelligent system that uses MAS and eIs technologies, under the umbrella of e-chartering constraints, showed that satellite IP networks could be involved and are cooperative. These results are boosting the e-chartering methodologies as vessel monitoring data can add grateful info to these virtual organisations and perform semi-automatic e-chartering scenarios to shippers and shipowners.

Our future research topics will try to extend this infrastructure and implementation of e-chartering markets taking into account additional satellite data, such as weather or vessel conditions, while increasing the number of vessels. The data management of the *MAVCM Services* infrastructure is under research by means of different scenarios preparation in conjunction with an illustrative test case, where the MAVCM system utilises the vessel information and prepares different transfer scenarios to be considered by the shipowner concerning the ports and cargoes. In addition, the implementation of the above proposed design using small distributed LANs and satellite information with the use of agents' development framework (JADE) is on process.

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Notes

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