Design of an intelligent waterway ambient infrastructure based on Multiagent Systems and Wireless Sensor Networks

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***Abstract*—*Lately Maritime research areas have moved their interests from traditional ship studies and traffic systems to new areas that confer a more general character to them as, for example, environmental monitoring. BOYAS project is proposed including these new perspectives as well as more classical ones. Trying to get this integral character for the waterway ambient and its activities management, the confluence between two recent research areas is studied. The convergence of Multiagent Systems and Wireless Sensor Networks constitutes a good framework and scenario in which this new research activities may be studied and develop.*

***Keywords*—*Wireless Sensor Networks, Multiagent Systems, Buoys, Inland waterway*

I. Introduction

IN recent years, maritime research has broadened its views to themes like environmental protection, use of information technologies, traffic management, safety and security.

In this evolution intelligent techniques play a fundamental role. The application of Neural Networks, Expert Systems or Automatic Learning is quite common in transport systems but most of these applications are focused on road traffic management while maritime environments receive less attention [6]. Indeed, these intelligent techniques are mostly applied to tools related to ship design aspects, like the one presented in [18], and for the development of simulation tools for logistic studies of the port areas [10].

Designing maritime systems that meet the objectives posed by previous mentioned new perspectives is a difficult task. But these difficulties can be alleviated by introducing appropriate technologies. BOYAS project focuses on all such aspects. Knowing the characteristics of the environment and the goals that the system has to reach, two research areas converge on the solution: Multiagent Systems and Wireless Sensor Networks.

There are some studies about the application and deployment of sensor networks for maritime environment monitoring [22]. But Wireless Sensor Networks have introduced a novel paradigm for reliable monitoring activities. They can be deployed in almost any environment and ease the transmission and information collection activities.

On the other hand, Multiagent Systems capabilities help with the information management and the system organization, being the perfect complement to the Wireless Sensor Network. At this confluence is found the BOYAS project.

The remainder of the paper is organized as follows. In Section 2, Multiagent System research area is revised. Section 3 presents the numerous Multiagent Systems application areas and so motivates its use in the BOYAS project. In Section 4 basic characteristics of Wireless Sensor Networks are revised. Section 5 presents the core of BOYAS project, focusing on its structure, main characteristics and challenging issues. Finally, in Section 6 some conclusions about the presented work are drawn.

II. Distributed Artificial Intelligence And Multiagent Systems

DISTRIBUTED Artificial Intelligence (DAI) appeared around the eighties as a consequence of the evolution from centralized architectures to distributed systems. It arose from multiple disciplines so different as Sociology, Operational Research, Artificial Intelligence or Philosophy, fact that confers to DAI a very general character.

DAI can be defined as the study, construction and application of so called Multiagent Systems (MAS). A Multiagent System is a system in which several interacting intelligent agents pursue some set of goals or perform some set of tasks [13].

This research area appeared to help in the resolution of big problems whose data could be distributed, heterogeneous or even incomplete. This kind of situations requires too distributed activities and intelligence. Other appropriate areas for MAS application are those situations that just need a distributed point of view for being studied.

Solving complex problems using MAS consists basically of dividing these problems into smaller ones. The integration in the resolution process of different perspectives of analysis together with fault-tolerance mechanisms reduces the uncertainty of the final solutions. Global efficiency of the

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process improves considerably due to the concurrence and cooperation of intelligent agents taking part in the resolution.

MAS are specially suited to representing problems that have multiple problem solving methods, multiple perspectives and/or multiple problem solving entities. Such systems have the traditional advantages of distributed and concurrent problem solving, but have the additional advantage of sophisticated interaction patterns (coordination, cooperation, negotiation, etc.)

III. Areas of Application

MAS are widely used in different areas of research and industry. Its flexibility and versatility make them appropriate for many types of problems. So, there exist applications on robotics [14], social systems simulation [8], Semantic Web [25], medicine [28], etc.

There are numerous possibilities for classifying these different MAS applications. The different criterions depend on the authors' point of view. So, Ferber [9] divides the applications attending to the research area to which these applications belong, Jennings et al. [13] base their classification on the industrial or professional area of the application and finally, Oliveira et al. [19] uses as a criterion for his classification the SW/HW nature of the agent.

Anyway, MAS application domains are all characterized by some typical features, such as being distributed, complex, capable of flexible interaction, dynamic and ill-structure [20].

In a general sense, MAS can be considered as a solving problem tool. As it has already been said, a MAS is made up of autonomous, cooperative solving problem entities able to interact to solve a problem or to reach some objectives. This is why and how they have been introduced in so different areas of research and industry. In the last decade, this research area has grown spectacularly and it attracts more and more the interest of researchers, all due to its important application possibilities.

One of the fields of intense MAS application since its origins is Decision Support Systems (DSS). DSS increase performance and efficiency of the activities or environments to which they are applied. Adding intelligence to this kind of systems causes the proliferation of MAS application in areas such as transport logistics, industrial and productive systems as well as traffic management and control [31].

The adoption of MAS paradigm for production planning and control systems can be revised in [3]. The special characteristics of current markets pose growing demands to the companies and production centers. Demands referred to lower production times, lower prices, etc. and that require new techniques for making the systems reactive, flexible and adaptable to continuous changes. Among the numerous MAS approaches developed for this situation, [26], [16] and [17] can be mentioned, as each of them addresses different aspects of the same problem to get the desired characteristics. This same situation previously presented extends to the whole Supply Chain, where MAS have been applied too to help in the coordination process [24]. More recent MAS applications trying to optimize the Supply Chain functioning are [4] and [15]. MAS application to transport systems has a more managerial character. Although they have been applied to almost every mean of transport, most approaches try to help in controlling and managing tasks, for example, [5] proposes a MAS to manage road traffic in complicated areas of Madrid or [2] uses a MAS to help in the generation of train coupling schedules. So, from this perspective, MAS are more used as an enriched DSS.

IV. Wireless Sensor Networks

So called Wireless Sensor Networks (WSN) are used to improve the performance of systems in the same areas as mentioned before. Among its most typical application areas environmental, security monitoring tasks or traffic control tasks can be mentioned.

As its own name says WSN are composed of a generally large set of sensors able to communicate using wireless technology in order to monitor and extract information from the environment in which they are deployed.

WSN appeared recently thanks to the advance in electronics and wireless communication basically. These advances allowed the development of small low-cost and low-energy consuming sensors able to communicate via wireless technology. These and other characteristics make possible to use them to monitor different kinds of environments in which they get immersed.

So, WSN applications ranges from productive process monitoring or traffic activities to environmental applications (earthquake monitoring, flooding detection, etc.), military applications and applications in dangerous or non-accessible environments as well as in vast extensions where classic techniques may be useless.

A. Characteristics of a WSN

Generic and defining characteristics of a WSN are their strong limitations of communication bandwidth, process capacity and nodes available energy. These restrictions demand the use of a high number of nodes in order to be able to cover the vast regions of applications, as well as to alleviate the effect of those restrictions. This is achieved thanks to the conjunction of individual characteristics of the nodes in the network [27].

A dense network can provide a higher level of accuracy of the collected data adding properties to the system such as redundancy, reliability or fault-tolerance. It also allows increasing the available energy for the system as a whole.

This high number of components also increases the complexity of the system making the probability of collisions in the network higher. As a consequence of these collisions, communication latency increases at the same time that the energy consumption efficiency decreases. This is basically due to two main reasons: transmission collisions and energy wasting in redundant measurements that contributes with no information to the system.

To save energy as well as communication and processing resources, WSN typically use data aggregation and common processing techniques for the information collected by the nodes. Recently, a possible strategy to fuse this data using the Kalman filter is presented in [30]. Once again, resource constraints determine which routing protocols can be used and which communication techniques (usually multihop communication).

WSN application environments are usually dynamic, and even they are sometimes hostile environments. These characteristics and the specific WSN aspects, produces frequent changes on the network topology. These changes entail re-structuring and reorganizing every node tasks, as well as solving connectivity, recognition and communication problems that may arise among them.

So, creating a WSN demands conscientious studies to design its hardware components, communication and routing protocols, as well as data treatment strategies. All these aspects area carried out to construct robust scalable systems capable of responding adequately to changes in the environment and, of course capable of providing efficient and reliable information about the events happening in its surrounding.

So deploying a WSN is a challenging work for which the use of MAS seems to suite in a quite natural way, just by identifying nodes of the network and agents in the MAS. This makes possible the use of techniques and tools developed for MAS in the creation of a WSN. This fact also facilitates getting desired characteristics for the network such as adaptability or resource management efficiency.

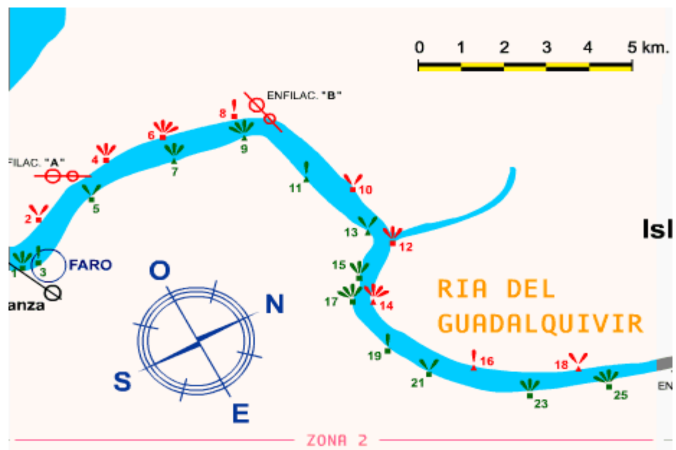
V. BOYAS PROJECT

THE overlapping among different research areas is a more and more common phenomenon these days. As it has been said, the concurrence between the two previously presented areas and their application fields is happening currently.

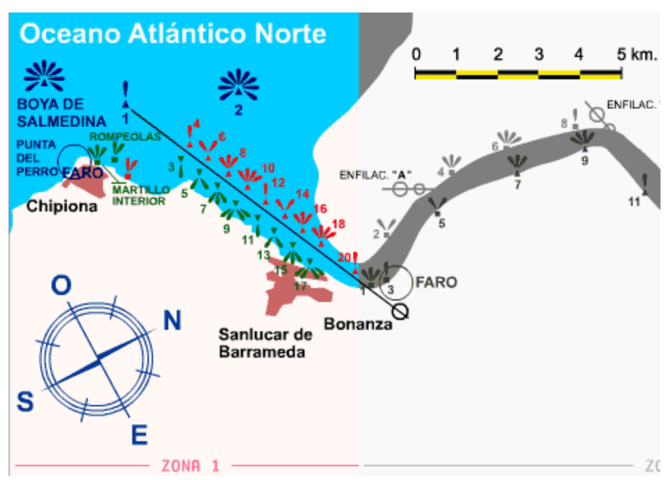
Fig. 1: Geographical area considered in the BOYAS project.

The integration between WSN and DAI takes place by AI techniques adoption to process and manage the information collected by the different elements in the network. This is the frame in which BOYAS project is developing.

Most research projects developed within this merging framework have considered networks with a small number of elements and centralized data structures. Individual sensors in this kind of networks have low autonomy and are only able to develop perception and transmission tasks. These transmission tasks just send the collected data to a central node where it is fused and processed. BOYAS project, following the most recent trends, goes one step ahead and by the identification of nodes and agents endow the first ones with autonomy and intelligence. Besides, the developed technology will be generic as it will rely on open source software and it will not depend on any specific hardware platform.



(a)



(b)

Fig. 2: Elements in the (a) mouth and (b) course of the Guadalquivir River.

The aim of this project is to create an embedded intelligent infrastructure in the buoys of the river Guadalquivir covering the area shown in Fig. 1.

Elements in the infrastructure are the buoys, the lock, the Head Platform of the Seville Port Authority and even the vessels navigating along the river (Fig. 2).

Creating this infrastructure entails the enrichment of the whole system and the improvement of its functionalities as far as capacity, security and quality of service are concerned.

The applications will cover ambitious tasks not only related to information handling as, by using the perception layer provided by the platform, intelligent multiagent algorithms will be applied to control a specific system.

The new infrastructure favors the integration of signaling, monitor and traffic control systems under efficiency and security conditions. The new infrastructure also provides additional improvements related to waterway ambient, such as agriculture in surrounding areas and the sustainable transport development taking place at the Seville Port installations. The general function scheme of the BOYAS project can be observed in Fig. 3.

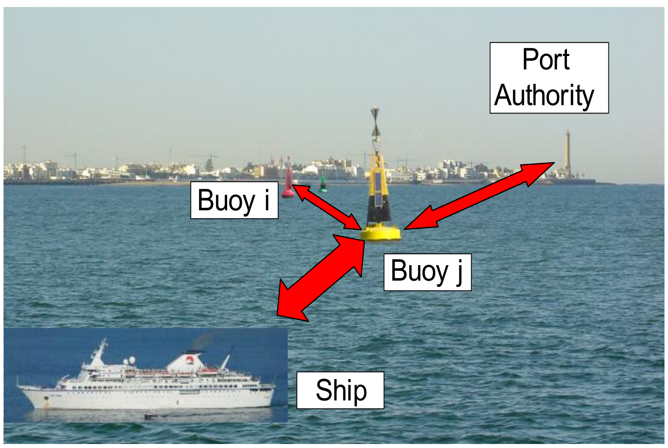


Fig. 3: Functioning scheme of the BOYAS project.

BOYAS project goes beyond the simple addition of DSS, MAS and WSN concepts. Its objective exceeds the prospects of each of these individual approaches. As we are not trying to solve a concrete signaling or traffic control problem nor monitoring the environment but improving a currently working system to provide it with the most modern advances and techniques.

A general view of the characteristics of the WSN being developed is shown in the Table 1. These characteristics are presented following the taxonomy proposed in [29]. This classification allows distinguishing different kinds of WSN depending on the characteristics of its elements. According to the chosen taxonomy, WSN are classified depending on the properties of the sensing nodes, the network, the environment and the designer's goals.

Most of the sensing nodes in the network are battery-powered and only some of them, when possible and depending on the situation of the nodes are electric-powered. Nodes can be configured by the network as this can act over them setting their properties. Nodes are also active and able to cause changes in the environment. At the same time, they are dynamic (being affected by external processes or events in the environment in which they are situated). Last, they are fully self-aware as the network can know their state and circumstances at every moment.

As far as the network is concerned, it has a heterogeneous nature as not all the nodes have the same sensors and capacities. Communication among nodes is constrained by energy limitations of the own nodes and the available communication bandwidth. The network is deployed in a deterministic way as the node positions are given by the buoys and other elements' situation along the river. The number of nodes in the network is small and limited to the number of these elements in the area to monitor. As a consequence of the dynamic nature of the sensor and the environment, the network itself is dynamic too. Finally, the network belongs to a single owner, Seville Port Authority.

Table I: BOYAS project WSN characteristics.

Sensors	Power supply	Electric-powered ✓ Battery-powered ✓
	Self-awareness	Full ✓ Partial
	Dynamics	Dynamic ✓ Static
	Configurability	Non-configurable Configurable ✓
	Activity	Passive Active ✓
Network	Composition	Homogeneous Heterogeneous ✓
	Deployment	Deterministic ✓ Ad-hoc
	Communication	Restricted ✓ Non-restricted
	Dynamics	Dynamic ✓ Static
	Ownership	Single-owner ✓ Multiple-owner
	Number of nodes	Large Small ✓
Environment	Dynamics	High ✓ Low
	Nature	Deterministic Non-deterministic ✓
	Observability	Full Partial ✓
Goals	Actions	Individual ✓ Collective ✓
	Environment dependency	None Local Non local ✓
	Actions effects	Short-term ✓ Long-term ✓

The network environment is dynamic, non-deterministic and partially observable. These last two characteristics imply some kind of uncertainty on the results of the actions taking place in the environment and the own environment state.

Last, network goals determined by the designer are given by the nature of nodes' actions (individual or collective), the effects of these actions in the environment and the relation established with the environment. Sensors' actions are both directed towards group and individual targets. And in general, nodes' actions have long and short term effects.

So, this brief presentation shows the hard and clear influence that the environment has on the network definition.

The system structure is divided into three levels corresponding to the hardware (HW), middleware (MW) and software (SW) layers. For each of these layers different strategies are defined taking care of the most difficult aspects for the development of the network.

A. Hardware layer

Nature conditions of the environment are specially taken into account in the HW platform design. First, nodes have small consumption as most of them are battery-powered. They have to be very strong to stand the circumstances of a very aggressive and corrosive environment with strong swell, humidity, etc.

The information to be collected is vast and heterogeneous. So, different kinds of sensors are needed too to get these data in an efficient way. Among these sensors are visibility sensors, pressure sensors, magnetic sensors, anemometers, etc. (Fig. 4).

Fig. 4: Some of the sensors of the environment: accelerometer, magnetic sensor, high sensibility compass.

The data generated by the sensors have to be processed by embedded software that transmits the information to the Head Platform. To make this possible a wireless communication network among all nodes in the system is needed.

Each node in the network has different sensors and capacities. These differences are due to the physic nature of the system and its structure. So the characteristics of a node depend basically on its geographical position. Besides, the Head Platform of the Port Authority represents the higher level element in the system. It is the one who is able to store the historic information of the set of nodes and that also has a global perspective and power over the actions taken by the system.

Once again, the special character of the environment determines the design of the communication network too. Geographic characteristics of the environment are different along the river course and at its mouth and so demand a mixed communication network that allows local and global communication for every node in the net.

Communication security is a very important aspect in a system like the one being developed. To guarantee the security of the project, two communication channels coexist to transmit information: one based on GPRS technology and a second one using ZigBee. The use of one or the other depends on the data criticism.

GPRS is a digital technology that provides high data transfer rates. It is specially suited for Internet connections. In BOYAS project, GPRS is used as a back network and to support the ZigBee net.

GPRS is used to send critic data that may affect decisions related to node, system or environment security (data related to illegal traffic or environmental disasters.

Regular data transmission uses 802.15.4 technology (ZigBee). This communication channel is appropriate for transmitting normal data generated by the sensing nodes like environmental measurements or node state measurements, for example.

Transmitting all the data collected by the sensor nodes using the GPRS channel would imply a very high cost so, regular transmission of collected data use the ZigBee channel as it has already been said.

ZigBee is a low power consumption technology, which plays a fundamental role in the project. The number of devices that can connect to this communication channel is large enough for the applications under development. The transmission range varies from 10 to 100m approximately, which is appropriate for most of the areas covered by the system.

GPRS communication takes place between a node and the Head Platform directly. ZigBee communications take place among elements that are quite close, fact that implies smaller costs for the system and that favors the communication among agents to share information.

As we said at the beginning of the section, extreme environmental conditions require good isolation for all the devices used in the system. To get this, Fig. 5 shows how cabinets should be used.

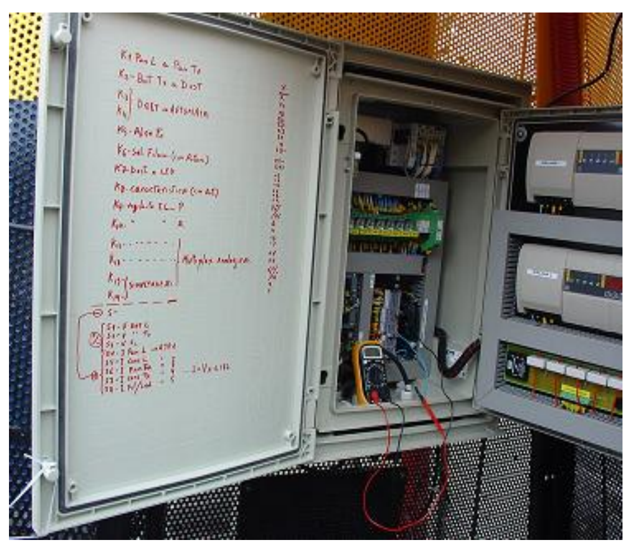


Fig. 5: Devices inside the buoy.

B. *Middelware layer*

The main aim of the middleware layer is to hide the complexity and distribution of the underlying HW layer. So that it is possible to develop intelligent applications over it.

Middleware for distributed systems is an active work area, not only in the area of traditional computer systems and networks, but also for more resource-constrained systems found in ubiquitous computing and in sensor networks. The task of a middleware is to abstract low-level functionality of the hardware, the operating system and especially the distribution aspects of a networked infrastructure. It provides a high-level programming interface which is then used by application developers to implement various types of distributed applications on top of the middleware.

Traditional middleware systems are based on assumptions that do not necessarily hold in mobile and ubiquitous computing scenarios. The mobility and the resource constraints of the participating nodes as well as the highly dynamic environment the system usually operate in necessitate novel solutions.

To cope with dynamic environments, traditional middleware approaches have been extended to allow for dynamic reconfiguration at runtime. However, these extended middleware systems are not tailored for infrastructure-less networking and the operation on resource-poor devices, so that ubiquitous computing still is not very well supported. The specific properties of wireless sensor networks necessitate separate middleware solutions that, besides supporting the application developer, address the challenges of running software in this domain. The main points to consider are the inherent resource constraints of wireless sensor nodes, the unreliability of the sensor nodes and the need for intensive cooperation among the sensing nodes.

The middleware should support the underlying infrastructure in attaining the following properties:

- Sentience: infrastructure is context-aware, i.e. has the ability to perceive the state of the surrounding environment, through the fusion and interpretation of information.
- Autonomy: Components of the infrastructure will be capable of acting in a decentralized fashion, based solely on the acquisition of information from the environment and on their own knowledge.
- Decentralization: There is no single central server that does intensive computation. Components are typically scattered across geographical regions.
- Proactivity: The infrastructure is able to act in anticipation of future goals or problems without direct human intervention. They should have a certain degree of intelligence, and be able to decide what action to take from gathered sensor data.
- Adaptivity: The infrastructure will have to cope with changing conditions during their lifetime. Not only must be designed to evolve, but their underlying support must be adaptable as well.
- Time and safety criticality: The infrastructure interacts with physical environments and is required to provide real-time services to human users. It is important to provide real-time guarantees and dependability assurance through some system or middleware modules, e.g. resource management and configuration, timing failure detection and Quality of Service (QoS) management.

MW layer makes use of **DAI and MAS techniques**. When a node is identified as an agent, it is considered as an intelligent, autonomous, proactive entity able to interact with other agents and its surrounding environment. So, these entities can show now behavior patterns and adaptable strategies to every condition.

One important task for the creation of the MW layer is the development of a general and consistent interface for accessing sensor values recorded on the different sensor nodes. The interface should hide the peculiarities of the specific sensor and network hardware and should be extensible for being able to integrate new hardware at any time.

Communication plays a fundamental role in interaction and coordination. [11] represents a recent MW design that supports a common abstraction for the exchange of information between different types of network nodes that use different radio frequency.

Considering the sensing nodes as agents helps in the comprehension and favors the use of DAI strategies. To share these data with minimum power consumption, the process coordination is based on the data-centric abstraction [21]. This concept considers data as the key element of communications, as changes in the values of the data are what trigger the communication processes. Data-centric abstraction simplifies in a notable manner the development of applications based on data collected by a sensor network.

Network centric computing paradigms are taken into account to create proactive intelligence based in cooperation between the nodes of the network of embedded systems. Data network paradigm is applied as the data obtained from the perception layer of each node must be available to many other nodes of the system and this way, each node do not necessarily need to ask for the retrieval of the data from an specific node. Using intelligent multiagent algorithms, the system is able to react to the physical world.

This is the most complicated point in the system design as defining data aggregation techniques, transmission and routing strategies determine the efficiency level of resource management. According to [1] the networking strategies of sensor networks are usually designed attending to the following principles, some of them have already been mentioned.

- Power efficiency, which is a factor that has to be considered always.
- Sensor networks are mostly data-centric.
- Data aggregation is useful only when it does not hinder the collaborative effort of the sensor nodes.

- An ideal sensor network has attribute-based addressing and location awareness.

All these perspectives and characteristics are taken into account in the design and proposal of the MW strategies.

Trying to make an efficient use of the available resources and to save energy, information collected from the environment is preprocessed by the nodes in a local and group manner.

The individual preprocessing is based on an algorithm that adapts nodes sample rate to the frequency of changes in the environment (subject to logical and feasible values). So the sample rate increases when numerous or frequent changes appear in the surroundings of a node, allowing then this node to follow the phenomena taking place. In case that the environment remains quiet for a certain period of time, the node can decrease the frequency of sample for some of its sensors in order to save energy.

On the other side, group processing relies on dynamic group formation. According to the distance among nodes and the similarity of their measurements, different groups appear in the network at each moment. Neighbor nodes fulfilling previous requirements sense the environment and preprocess the information in a common way. Stability and group life-length depends on the coherency of the data collected by its members. So when the measurements of one of the nodes that belongs to a group differ from the mean measure accepted by the other group components, this node can decide to leave the group and restart the process of group formation among its neighbors.

To verify data consistency, nodes check their measurements along two dimensions: internally (temporal consistency) and at the group level (spatial consistency). Due to the aggressive conditions that the sensing nodes have to stand in this particular environment, it is possible that some of the node modules break down sometimes. To avoid that erroneous measurements condition the right behavior of the system, each node checks its own measurements with the ones collected in a previous period. Different approaches have been propose to deal, not only with erroneous measurements in breakdown situations, but to deal with the general imprecision or inequality of environmental data in order to decrease the risk of mistake [12].

The two consistency processes previously presented help not only in the preservation of the system behavior, but it also contributes in a clear way to the monitoring applications, as it allows an individual node and/or a group of nodes to track the evolution of different phenomena happening in the immediate environment of a node and in the surrounding area. Another aspect that needs to be taken into account refers to

One of the most challenging aspects of the WSN design refers to the routing strategies. Typical algorithms for information dissemination over the network are gossiping or flooding techniques. Point to point routing techniques distinguishes between strategies using routing tables and the ones that calculate the route depending on the demand of the source node [23]. Anyway, these classic techniques cannot be directly applied to the WSN being developed due to its special characteristics. So, new routing algorithms that take into account node limitations are being studied. Among one of the newest proposals for routing information in Mobile Ad Hoc Networks (MANET) is the AntHocNet routing algorithm described in [7].

C. *Software and application layer*

The design of the system is based on open source software, which favors system extensibility and adaptation as it evolves. Besides, not requiring licenses implies lower development costs.

Over the software layer, and interacting with the two last ones, appears the application level. The applications cover ambitious tasks not only related to information handling as, by using the perception layer provided by the platform, intelligent multiagent algorithms are applied to control and manage the whole system and its environment.

To obtain a proactive collaborative intelligent environment, the system allows evaluating the current situation (what is happening?) as well as its short term evolution (what may happen if…?) within different scenarios, and elaborate potential action plan to apply (what to do?), so that an adequate real-time intelligent agenda is performed.

All the nodes provide a vast amount of data networked that must be interpreted and managed in a key direction. But decisions have to be taken individually and in a cooperating way. DAI models and architectures are an adequate approach to deal with such problem. DAI system acts accordingly with the following model:

- What is happening?

The system needs to analyze a situation and understand it by identifying advantageous and problematic aspects. In order to do so, the sensing nodes capture information from the environment state.

- What may happen if…?

The system of embedded systems by using a network centric approach reasons about of this question if no intervention takes place. The main objective of this question is to foresee the decay of the present circumstances into an undesirable future situation, in order to be given the possibility to undertake appropriate counteractions. Several scenarios must be considered.

- What to do?

The system reacts to the physical world and it selects the most convenient actions to improve the results of system operation, for example by means of actuators.

DAI models for networked embedded systems are mainly governed by multiagent decision support systems. Agents are well suited to modular problems because they are objects. Also, they are well suited to decentralized problems because they are proactive objects. These two characteristics combine to make them especially valuable for the applications to be developed in an environment which is likely to change frequently, as the one in the BOYAS project.

Fig.6 shows the agent architecture to be implemented in the nodes following the DAI principles.

The architecture is built around three major components:

- Perception subsystem.

It allows the agent to be situated by data acquisition (using the sensing capacities) and in the society by perceiving agent messages.

- Intelligent subsystem.

The intelligent subsystem manages the different aspects of information processing as well as individual and social problem-solving.

- Action subsystem.

The action subsystem enacts the plans produced by the intelligence subsystems displaying messages to the Head Platform, sending messages to other agents or activating specific actuators.

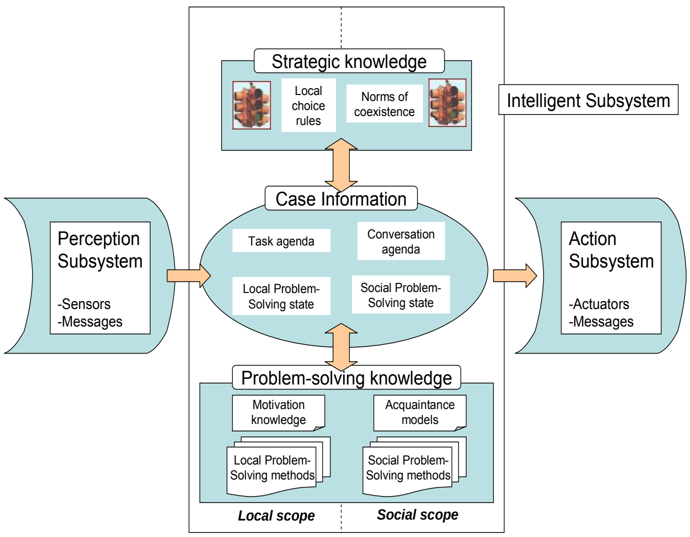


Fig. 6: Agent architecture [31].

There are numerous applications for the system. These applications can be divided into three main groups: maritime traffic management applications, security applications and added-value applications.

- **Traffic management applications.**

In the first group are included activities like seaway light signaling, vessel data detection or river draught monitoring.

Light signaling activity is basic and of capital importance as this is the aim for which buoys were created. So, the main function of the buoys system has to be guaranteed.

Besides, and thanks to the new infrastructure being developed, activities to get information from the environment and from the vessels and their move are possible too. So, vessels speed or length can be observed.

The infrastructure has also the ability to control and monitor the river draught and its changes due to tides, swell or other geological or artificial processes.

Agents and DAI techniques, and tools come to a first level of importance as relying on them and the cooperation among agents, the system reaches decisions about how to manage the traffic.

- **Security/Safety applications.**

The aim of security applications is to protect the ships navigating through the waterway as well as the own system infrastructure.

Among both kinds of applications are found activities like non-authorized traffic detection as well as vessels without Automatic Identification System (AIS) detection.

The infrastructure is also able of early detection of dangerous swell and can predict the formation of swell that may affect the right working regime of the system.

Difficult navigation areas, such as the dock or the lock can be extra-illuminated and acoustic signaling can be use too for special dangerous areas or bad temporal navigation situations.

Agents manage and benefit from the collected information being able to prevent or predict dangerous situations. Learning capacity of the agents allows them to identify these potential dangerous situations.

- **Environmental and added-value applications.**

Last, added-value applications give an additional character to the system. Rivers and estuaries are rich ecosystems providing support to a wide diversity of flora and fauna. The huge amount of information collected by the sensing nodes can be used too to monitor the environment state. So, for example, non-authorized dumping into the water can be detected. Specially hydrocarbon dumping. This activity may include too direct transmission to the correspondent authority.

The monitor of water quality allows determining the possibility and adequateness of its use for irrigating nearby plantations. Buoys allow a continuous monitoring of the water quality and its nutrient properties and allow connecting them in relation with farmers irrigation systems located on the river banks. The degree of salinity and the measurement of other water components allow the determination of the quality of the water for its use in the fish farms too.

The system capacity to take meteorological measurements allows the use of it as a network of weather report stations.

The increasing activity of the inland navigation for freight transporting is damaging the ecosystems, but the previous activities help in avoiding or alleviating these effects and consequences.

The development of a tourism integrated with the ecosystem is a claim for a sustainable growth. So, besides more natural activities, the new infrastructure can be used for tourist issues too favoring the sustainable integrated development of tourist activities within the environment. So the illumination system can be used for ornamental purposes at certain times and moments for illuminating specially beautiful and/or touristic places situated along the river.

The global and integrating nature of the system for this particular maritime-river environment in which artificial and natural activities coexist (freight transport and agriculture, for example) can be appreciated and motivates the work and effort to develop the project.

VI. Conclusions

BOYAS project appears from new trends in maritime research areas, trying to cover classic research aspects like security and traffic management as well as more global and integrative activities like environmental protection.

This project represents a real good frame for the study and comprehension of two growing and important research areas: MAS and WSN. Both research areas are receiving more and more interest these days. This interest is not only focused on developing both paradigms themselves but in broadening their application areas, so new experiments and projects for applying MAS and WSN to different kinds of problems in several environments has been taking place.

The brief study of previously mentioned research areas presents the multiple aspects that has to be taken into account when developing or implementing a MAS, a WSN or a combination of both, noting most challenging issues.

Besides this work presents the theoretic aspects that have led to the confluence between these two previously mentioned research areas. So it could be used as a starting point for proposing or developing new solutions to future problems.

It is worth noting once more the special character of the BOYAS project, the conjunction of traffic management systems, security/safety systems and environmental applications that it presents. Its generality represents the most notorious feature of the work being developed and its main contribution to the new trends in maritime research areas.

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