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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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Referência do projecto
Project reference
PTDC/EIA-EIA/115375/2009 **(Lacrado a 16-12-2009 às 14:56)**

1. Identificação do projecto
1. Project description

Área científica principal
Main Area
Engenharia Informática - Engenharia Informática

Área científica Secundária
Secondary area
Engenharia Electrotécnica - Controlo e Robótica

Título do projecto (em português)
Project title (in portuguese)
MASTER – Comunicação ad-hoc móvel e serviços de middleware para equipas de robôs

Título do projecto (em inglês)
Project title (in english)
MASTER – Mobile Ad-hoc communication and middleware Services for TEams of Robots

Financiamento solicitado
Requested funding
152.856,00€

Palavra-chave 1
Redes Móveis Ad-hoc

Keyword 1
Mobile Ad-hoc Networks

Palavra-chave 2
Comunicação sem fios

Keyword 2
Wireless communication

Palavra-chave 3
Confiabilidade

Keyword 3
Dependability

Palavra-chave 4
Seguimento de topologia

Keyword 4
Topology tracking

Data de início do projecto
Starting date
01-01-2011

Duração do projecto em meses
Duration in months
24

2. Instituições envolvidas
2. Institutions and their roles

Instituição Proponente
Principal Contractor
Fundação da Faculdade de Ciências (FFC/FC/UL)
Campo Grande - Edificio C7 -1º Piso
1749-016Lisboa

Instituição Participante
Participating Institution
Faculdade de Engenharia da Universidade do Porto (FE/UP)
Rua Dr. Roberto Frias
4200-465Porto
Universidade de Aveiro (UA)
Campus Universitário de Santiago
3810-193Aveiro

Unidade de Investigação
Research Unit
Laboratório de Sistemas Informáticos de Grande Escala (LASIGE/FC/UL)
Bloco C5, Piso 1, Campo Grande
1749-016Lisboa

Unidade de Investigação Adicional
Additional Research Unit
(Vazio)
(Void)

Instituição de Acolhimento
Host Institution
Faculdade de Ciências da Universidade de Lisboa (FC/UL)
Rua Ernesto de Vasconcelos - Edifício C5 - Campo Grande
1749-016Lisboa

3. Componente Científica
3. Scientific Component

-

3.1. Sumário
3.1 Abstract

3.1.a Em português
3.1.a In Portuguese

Existem muitas áreas em que equipas de robôs móveis se mostram úteis, tais como em aplicações de limpeza e vigilância de grande espaços físicos, em operações de busca e salvamento, em desminagem, etc... [SAPL09]. Em todos estes cenários, os robôs têm de comunicar para se coordenarem de modo a potenciar a eficiência da sua actuação conjunta. As distâncias entre robôs poderão variar entre 1 e 20m (aproximadamente) e os ambientes poderão ser quer de interior quer de exterior, mas em ambos os casos, com obstáculos que interromperão a linha de vista entre robôs.
Como estudo de caso vamos utilizar uma aplicação de limpeza e vigilância de grandes superfícies interiores, e.g., centros comerciais.
O objectivo deste projecto é criar uma infra-estrutura de middleware e comunicação de suporte à constituição e coordenação da equipa que:
• Seja ad-hoc no sentido de que se deve formar à medida que os robôs entram em contacto entre si e vão solicitando serviços de partilha de dados;
• Utilize um mínimo de informação apriorística, em particular, informação de configuração;
• Seja completamente distribuída (nenhum nodo seja diferente dos restantes, do ponto de vista da infra-estrutura);
• Seja capaz de proporcionar um nível de Qualidade de Serviço adequado ao suporte de malhas de controlo realimentado para apoio à navegação.
Estas características tornarão a infra-estrutura de comunicação única e permitirão fornecer o apoio necessário para a utilização efectiva e simples de equipas de robôs.
Os objectivos específicos da infra-estrutura de middleware e comunicação são:
• Fornecer um serviço de localização relativa baseado em RF e RSSI. A maior parte do trabalho disponível sobre localização confia num conhecimento preciso da posição de certos nodos fixos. No nosso caso, não existe um tal conhecimento o que torna o problema mais complexo. Para além disso, faz parte da natureza da propagação de sinal em RF gerar muitos erros e incertezas.
• Capacidade de fornecer informação sobre o nível de conectividade de cada robô, i.e. o número e qualidade das ligações existentes, juntamente com pontos de orientação na direcção que assegura um número desejado de ligações activas.
• Definição de mecanismos de diferenciação no modo de acesso às redes, de modo a suportar a criação de canais de controlo e definição de protocolos para obtenção de QoS nesses canais.
• Realizar a sincronização entre robôs num modo completamente ad-hoc através de redes sem fios IEEE 802.11/WiFi. A IEEE 802.15.4/ZigBee será também considerada como uma solução de recurso para situações de paragem ou interferência.
• Suporte para comunicação em grupo, detecção de partições e sincronia de vistas.
• Definição de interfaces para a aplicação de controlo do robô oferecendo informação mais rica da equipa que permita optimizá-la.
A infra-estrutura de middleware e comunicação é apresentada na figura em anexo. Esta mostra uma arquitectura por camadas que inclui os seguintes blocos:

• 802.X – Interface de comunicação ad-hoc 802.11/802.15.4.
• Comunicação assíncrona – Comunicação não tempo-real.
• Comunicação síncrona – Comunicação tempo-real sobre um modo de acesso múltiplo através de divisão temporal.
• Canal de tempo-real alternativo – Comunicação crítica através de um canal especial.
• Localização relativa – Posicionamento relativo através de RF e RSSI.
• Seguimento de topologia – Controlo da conectividade com outros robôs.
• Filiação – Serviços de filiação em grupo, detecção de partições e sincronia de vistas.
• Encaminhamento – Reencaminhamento das mensagens quando necessário.
• Partilha de informação – Serviço de partilha de informação.
• Gestão da equipa – Supervisão e controlo de formação/topologia.
• Aplicação – Coordenação dos comportamentos autónomos e globais e definição de quais deverão ser privilegiados em cada momento. Este projecto não está focado neste componente e vai fazer uso de soluções existentes.
Temos avançado na criação de protocolos que sejam ad-hoc e distribuídos, que nos dêem garantias de QdS e que sejam dinamicamente reconfiguráveis, e também em camadas de middleware que cumpram estes mesmo requisitos, mas ainda não foi possível chegar a soluções que juntem todas estas características numa infra-estrutura consistente. Dados os avanços recentes na construção de robôs móveis eficientes e de custo mais baixo e o potencial que têm para um número muito elevado de aplicações, o aparecimento de uma infra-estrutura deste tipo é essencial. Dado o nosso envolvimento no desenvolvimento de algumas das técnicas parcelares referidas atrás, estamos convencidos de que detemos as capacidades suficientes para concretizar o objectivo do projecto.

3.1.b Em inglês

3.1.b In English

There are many areas in which mobile robot teams can be useful, such as cleaning and surveillance applications in large spaces, search and rescue missions, demining, etc... [SAPL09]. In all these scenarios, in order to improve the efficiency of the team, the robots need to communicate and coordinate. The distances between the robots can be from 1 to 20m (approximately) and the application environments can be indoors or outdoors, in both cases, with obstacles that can obstruct the line of sight.
As case study we will focus on a cleaning and surveillance application in large indoor spaces, e.g., shopping centers.
The goal of this project is to create a middleware and communication infrastructure to support the team creation and coordination that:
• Is ad-hoc in the sense that the team is formed as the robots contact each other and request shared data services;
• Uses a minimum of beforehand information, in particular, configuration information;
• Is completely distributed (from the point of view of the infrastructure all nodes are equal);
• Is able to provide an adequate level of QoS to support the closed-loop control for navigation.
These characteristics will make the communication infrastructure unique and offer the necessary support for an effective and simple utilization of robot teams.
The specific goals of the middleware and communication infrastructure are:
• To offer a relative localization service based on RF and RSSI. Most of the available work about localization relies upon a precise knowledge of certain fixed nodes. In our case, there is no such knowledge and this makes the problem harder. Also, the nature of the signal propagation in RF is prone to give rise to many errors and uncertainty.
• Ability to supply information about the connectivity level of each robot, i.e. the number and quality of the existing connections, together with way points that assure a certain number of active connections.
• Definition of differentiation mechanisms in the mode of access to the networks, in order to support the creation of control channels and the definition of protocols for enforcing QoS on those channels.
• Accomplish a completely ad-hoc synchronization between robots by using wireless networks IEEE 802.11/WiFi. The IEEE 802.15.4/ZigBee will also be considered as a backup for situations without communication or with interference.
• Support for group communication, partition detection and view synchrony.
• Definition of the interface to the control application of the robot, so that the richer information from the team can be used to optimize it.
The middleware and communication infrastructure is presented in an attached pdf file. The figure shows a layered architecture that includes the following components:
• 802.X - Ad-hoc communication interface 802.11/802.15.4.
• Asynchronous communication - Non real-time communication.
• Synchronous communication - Real-time communication using Time Division Multiple Access.
• Alternative real-time channel - Critical communication using a special channel.
• Relative localization - Relative positioning through RF and RSSI.
• Topology tracking - Connectivity control with other robots.
• Membership - Group membership services, partition detection and view synchrony.
• Routing - Message forwarding when necessary.
• Blackboard – Information sharing service.
• Team management - Supervision and control of the formation/topology.
• Application - Coordination of the autonomous and global behaviors, and decision of which to adopt on every instant. This project is not focused in this component and will make use of existing solutions.
We have been progressing in the creation of ad-hoc and distributed protocols, with QoS guarantees and dynamically reconfigurable, and also in middleware layers that fulfill these requirements, but it was not yet possible to develop solutions that gather all these characteristics in a consistent infrastructure. Considering the recent advances in building efficient and inexpensive robots, and their potential for many applications, the development of such an infrastructure is mandatory. Considering our involvement in the development of some of the partial techniques previously mentioned, we are certain to possess the required expertise to accomplish the project goal.

3.2. Descrição Técnica

3.2 Technical Description

3.2.1. Revisão da Literatura

3.2.1. Literature Review

•Support for coordination in mobile teams

One of the problems in distributed RTE systems is the need to ensure consistency, both in the value and in the time domain. Kopetz and Kim investigated the fundamental temporal properties of a system in terms of real-time entities and real-time images [KK90]. In this context, the notions of temporal accuracy, temporal validity and temporal consistency form a powerful framework to describe temporal constraints, as needed to ensure consistency. The time-triggered paradigm [KB88] uses these notions to derive operational parameters. Mock [Mock04] extended the notion of temporal accuracy to the concept of precision distance to be suitable for a cooperative robotic scenario with safe behaviors. The project HIDENETS [Hide06][Brui07][Arla07] addressed the case of platooning and considered the distributed system having different sets of properties and relying on different sets of assumptions in different parts [MCC09][CRM+09], which matches well the diversity inherent to a multi-robot application [Veri06].

These paradigms, proved useful in closed contexts, need to be extended to take into account the dynamic nature and the openness of the considered environments. However, we will not address such issue and we will focus on the information sharing infrastructure behind.

•Wireless communication

Given the tremendous growth in using wireless communication, there is also a trend towards using it for real-time applications [SAL+09].

However, providing the required level of QoS is, in this case, more difficult than with traditional wired networks, given the open nature of the medium and its higher bit error rate, making it a challenge [WMW05].

Probably the most popular wireless communication protocol is IEEE802.11 and because of that, several studies analyzed its capability to support real-time traffic and how such capability could be improved introducing changes either on an upper software layer [SAL08] or in its own MAC layer [MVPF07]. Recently, a QoS profile was proposed IEEE802.11e, which aims at supporting different traffic classes with different levels of QoS. However, such profile still presents several limitations in what concerns the support for real-time traffic [MPVF08] and [MVPF06], and given the higher cost and its currently lower availability, this project will dedicate its main attention to the common profile with distributed arbitration, typically referred to as DCF. One problem of the protocols that operate in the ISM free band, such as IEEE802.11b/g is the interference caused by the coexistence among themselves. A report on this issue is shown in [MUVW07].

One interesting issue treated in [Svin08] is the simultaneous use of several channels available in the protocol band, in a frequency multiplexing fashion. This grants an opportunity to increase the overall network performance by distributing the load and reducing the interference.

Another possibility that highly increases these benefits and allows for the design of more robust systems is using multiple radio interfaces per node. This can also be beneficial for the dependability of the network, e.g. by decreasing the risk of congestion, or by using a different protocol/interface/channel as a backup when the main link fails. In this project we will use a low-rate wireless personal area network (LR-WPAN),namely IEEE 802.15.4. There is currently a great interest in this protocol, mainly because it is a strong candidate for use in sensor networks. An early example of its application for home networking is described in [Call02] while [FF07] describes how a synchronous layer can be deployed on top of it using a time-triggered approach.

Real-time communication specifically for mobile units is studied in [MN99] and [FBA05], but not using a specific protocol, while [FB04] describes an integrated communication framework suitable for ad-hoc networks of mobile units.

•Relative localization

Localization is fundamental to support a myriad of robotic applications. In our particular case, it is fundamental for the movement arbitration during the interactions phase, for establishing spontaneous clusters and define which robots are within a given interaction so that their communications become synchronized, for routing the information in the most efficient way in a multi-hop fashion (e.g., geographical routing), etc.

Generally, providing indoor localization services with Wireless Local Area Networks (WLANs) has been addressed both in the academia [RK07][INS08] and industry [Ekahau][AeroScout]. The main advantage of this approach is the cost-effectiveness provided by the reuse/sharing of a communication infrastructure. However, it is well known that localization systems employing distance estimation (ranging) based on Receiver Signal Strength (RSS) are affected by parameter estimation errors, over-simplified (environment) propagation assumptions, multipath effects and non-line-of-sight conditions, which have a negative impact on the localization accuracy [MNR+07]. Also, the accuracy of RSS-based systems has been found to improve marginally by employing different localization algorithms [EXM04][LAS09] and antenna diversity [LAC+09]. Nevertheless, the reported accuracy of around 3m and 9m seems adequate for the localization of mobile robots in indoor environments.

Moreover, we believe that the absolute position is not needed but rather a relative position of those that are involved in an interaction. Nevertheless, the absolute position can always be acquired if one node has a global positioning capability, such as a GPS. Under these circumstances, it has been shown that RSS-based localization estimation still works and provides sufficient information for a coarse navigation [LAW+07][LAC+08].

One interesting approach that appeared recently and which will be explored in the project is RF-ranging, i.e., the measurement of distances by measuring the round-trip signal propagation delay [nanotron].

3.2.2. Plano e Métodos

3.2.2. Plan and Methods

** Problem statement, research challenges and proposed approach

The main problem addressed in this project is to provide an information sharing infrastructure for teams of mobile robots that is scalable and configuration free and that supports spontaneous interactions among robots that come into the vicinity of each other. This infrastructure is composed of an adequate wireless communication protocol, a relative localization system and a resilient middleware that will provide the needed services to the robots control applications and will enforce an efficient cooperation, not only providing information on connectivity but also arbitrating the access to shared spaces or intersections.

The project team already has expertise in the needed areas and has developed recent work that will serve as start point for the work to develop here. We consider the following to be the main scientific challenges:

• Carry out the synchronization among the robots in a fully ad-hoc mode. Preliminary work in [SAL08] was carried out in infrastructured
mode, establishing a reconfigurable and adaptive TDMA framework on top of the ordinary IEEE802.11. Nevertheless, moving to ad-hoc mode will require the definition of neighborhoods and clusters in a dynamic environment with moving robots. On the other hand, the proposal in [MPVF07] grants real-time behavior to a class of stations but it also needs to be

re-analyzed in what concerns the applicability to such dynamic scenario.
• Provide an RF-based relative localization service. Most of the work available in localization relies on the accurate knowledge of the position of certain fixed nodes. In our case, no such knowledge exists making the problem more complex. Moreover, the nature of the RF signal propagation generates many errors and uncertainties. Preliminary work, though, has shown the viability of using the received signal strength to achieve some coarse localization information [LAW+07][LAC+08]. Adapting them to cope with the dynamics of the envisaged scenarios, or developing new more expedite and possibly more accurate methods is a challenging task. One new method that will be researched is the use of new wireless interfaces that carry out RF-ranging, with relatively accurate distance measurements. Relative distances will then be fed to a Multi-Dimensional Scaling (MDS) algorithm such as in [LAW+07] that will provide the relative localization.
• Provide a middleware that supports robots safe behaviors. In such dynamic environments this is also challenging given the real-time nature of the robots interactions and the associated time constraints, and the need to assure consistency. The fact that we are aiming at a full ad-hoc communication mode further complicates achieving these properties. In this case, the European project HIDENETS [Hide06] in which several project team members participate will be a good start point, as well as the wormhole abstraction to achieve timeliness and safety in asynchronous systems [Veri06][MCC09][CRM+09]. The middleware is also crucial to improve the overall efficiency of the team, providing augmented sensing capabilities as well as the means for fast message routing and topology-oriented navigation.
** Why is the research challenge important and interesting?
Overcoming these research challenges will allow building efficient cooperative robotic applications that can be useful in a myriad of situations, from surveillance to search and rescue, cleaning, etc. Probably the most important detail is that the robotic team can be deployed without pre-configuration and without the need for a pre-existing fixed infrastructure. The cooperation will be supported by spontaneous interactions when robots come into the vicinity of each other. This increases substantially the easiness of deploying such robotic team applications, making them scalable, adaptable and portable.
** Which is our viewpoint and which methodologies are we planning to adopt?
The MASTER project looks at the issue of cooperating robotic applications from the viewpoint of the information sharing infrastructure. The actual robots coordination is left out of the project but the approaches used for that purpose can be deployed on top of the planned infrastructure. Moreover, it is our view that such infrastructure must be scalable, configuration free, or near, and it must not rely on a fixed infrastructure so that it can be used anywhere, with any number of robots. The robots should automatically detect other robots and synchronize to share information and coordinate actions. This will rely on ad-hoc wireless communication with spontaneous clusters to support interactions among neighboring robots, on relative localization and on a middleware that supports safe behaviors. Each of these issues will be addressed in a specific task. Another task at the end, integrates these components into a real case study that will be a proof of concept.
** How will this project contribute to the state of the art and which are the fundamental ideas to accomplish that?
We believe that the project will bring a main contribution to the state of the art in the field of middleware for the cooperation of autonomous mobile robots, with its properties of scalability, adaptability, robustness, safety and absence of configuration and fixed infrastructure. However, we also believe that the work in the communication protocol will bring a contribution to the state of the art in mobile ad-hoc networks, in what concerns the on-line spontaneous creation of clusters for the synchronization of transmissions and actual sharing of information. The clustering algorithms existing today are not meant for such dynamic situations thus the novelty of the proposed work. Finally, there is few work in anchor-free relative localization and thus, we also expect to bring along contributions in this domain.
** What are the main research ideas?
The main research ideas have already been referred before. In fact, they can be set as:
• Define clusters on-line accordingly to the current topology and synchronize transmissions within such clusters. This needs to be done consistently in all robots that are currently connected and in a prompt way;
• Improve existing RF-based relative localization schemes and particularly using RF-ranging capabilities;
• Create a middleware to support safe behaviors by means of sensing augmentation, arbitration of movements, support to connectivity aware navigation and geographic message routing.
Particular emphasis will be put on embedding those solutions in prototypes in a real scenario.
** What are the expectable results?
The expected results are:
• An architecture & middleware for safe interaction among robots;
• A relative localization system;
• A wireless communication protocol that synchronizes the transmissions of the involved robots (at the intra and inter cluster level) and which is resilient to interference and omissions.
** How will the partners collaborate and what is the role of each one?
The three partners have complementary expertise, despite some level of overlapping, which is expected to facilitate cooperation. Basically, all partners will be engaged in the use cases and requirements definition. Then each partner will be in charge of the task in which it has stronger expertise. UA will lead the task on wireless communication, FEUP will lead the one on relative localization and FCUL will lead the task on the architecture and middleware. Nevertheless, there will always be two partners involved in each of these three tasks to promote an enlarged debate on the technical options, benefiting from the expertise existing in all groups. Finally, after these three main tasks, all teams will be involved in the development of the case study. The involvement of all teams allows cross-fertilization of the acquired competence and expertise and it also allows design diversity, which is known to be a robust design approach. The global coordination will be done by FCUL but with the accompaniment of the other two teams.

3.2.3. Tarefas
3.2.3. Tasks

Lista de tarefas (6)
Task list (6)

Designação da tarefa Task denomination	**Data de início** Start date	**Data de fim** End date	**Duração** Duration	**Pessoas * mês** Person * months
Definition of the use case and requir...	01-01-2011	30-06-2011	6	23

Descrição da tarefa e Resultados Esperados
Task description and Expected results
Expected results
- Definition of the use case and hazardous environment
- List of requirements for the robot team, the individual robots and the information sharing infrastructure
This task focuses on the definition of the use case scenario and extraction of the system requirements. The use case scenario comprehends the definition of a situation in which a robotic team is deployed in a given area with a common global goal. This use case is based on a cleaning and surveillance scenario in large indoor spaces. From
such use case, this task will derive the requirements for the robots, in terms of sensory equipment and navigation capabilities, as well as in terms of their interactions, namely the set of safe behaviors that they must exhibit. In turn, these behaviors will lead to the definition of requirements for the middleware layer, namely the definition of its services that will be provided to the robot control layer.
Upon the definition of the middleware, this task will also provide the requirements for the communication and localization systems, completing the whole set of system requirements, i.e., local sensing, local navigation, interacting behaviors, middleware services, communication and localization.
This task will be coordinated by José Rufino
Membros da equipa de investigação nesta tarefa
Members of the research team in this task
(BI) Bolseiro de Investigação (Mestre) 1; (BI) Bolseiro de Investigação (Mestre) 2; (BI) Bolseiro de Investigação (Mestre) 3; António Casimiro Ferreira da Costa; António Paulo Gomes Mendes Moreira; Jeferson Luiz Rodrigues Souza; José Alberto Gouveia Fonseca; José Manuel de Sousa de Matos Rufino; Luis Miguel Pinho de Almeida; Mário João Barata Calha; Mônica Lopes Muniz Corrêa Dixit; Paulo Jorge de Campos Bartolomeu; Paulo José Lopes Machado Portugal; Valter Filipe Miranda Castelão da Silva;

Designação da tarefa	**Data de início**	**Data de fim**	**Duração**	**Pessoas * mês**
Task denomination	Start date	End date	Duration	Person * months
Management	01-01-2011	31-12-2012	24	4

Descrição da tarefa e Resultados Esperados
Task description and Expected results
Expected results
- Successful execution of the project
- All the necessary progress and final reports
- Coordination of project activities and interaction between team members.
- A website to serve as repository of the information related to the project.
- Publicity materials, contributions to the website, organization of seminars and special sessions in related events.
Task description
This task addresses all the project management issues, including the organization of global events (e.g. kickoff, dissemination), task monitoring to permanently assess the progression of the respective work, and promotion of task interactions, to facilitate the transfer of intermediate results. A project website will be setup in the beginning that will serve as repository of information for dissemination among the team members and also for the general public.
The management strategy will include regular meetings between the PI and the other team members to facilitate early detection of any unforeseen difficulties and react appropriately. There will be two types of meetings, between the PI and the team members involved in each task, which will take place on a monthly basis, and general meetings / internal workshops, which will take place once a year.
This task also deals with the promotion and dissemination of the project results. Several publicity materials will be made available on the project website. The technical and scientific publications in related conferences and journals will also serve as dissemination for the project.
Particularly, this task will consider the organization of special sessions and seminars both in scientific-oriented and in industryoriented
events.
The task also includes the preparation of a demonstrator to be used in public exhibitions.
In each task there will be a particular person in charge of its coordination. In the case of the Management task T1, such person is the project PI.
Membros da equipa de investigação nesta tarefa
Members of the research team in this task
(BI) Bolseiro de Investigação (Mestre) 1; José Alberto Gouveia Fonseca; Luis Miguel Pinho de Almeida; Mário João Barata Calha;

Designação da tarefa	**Data de início**	**Data de fim**	**Duração**	**Pessoas * mês**
Task denomination	Start date	End date	Duration	Person * months
Wireless communication	01-04-2011	31-12-2011	9	17

Descrição da tarefa e Resultados Esperados
Task description and Expected results
Expected results
- Fully operational wireless ad-hoc communication system
This task deals with the full specification and implementation of the wireless communication system. This system will follow the communication requirements defined in task T1, as a consequence of the desired interactions and middleware services. It will be fully ad-hoc to avoid the need for a fixed infrastructure, grant scalability, be based on the notion of spontaneous clusters and provide synchronized communication for the robots in a cluster, and include a minimal or no configuration parameters to facilitate deployment anywhere, with any number of robots. The communication protocol must also support a multi mode approach, with a simple asynchronous transmission mode when there are no interactions or they are light in the sense that the robots are sufficiently far apart and the level of connectivity is low.
In terms of technologies, two will be used, to grant some level of redundancy. The main technology will be IEEE 802.11 in the usual DCF mode and the secondary technology will be IEEE 802.15.4. The way these two technologies will be used will be defined in task T1 and revised early in task T2. Most likely, the secondary technology will be used for backup purposes, when the communication through the main one is considered blocked. Nevertheless, because of possible inconsistency during such changes, the robots will continue issuing signaling packets and monitoring the channel in both networks.

The choice of technologies and their use will be provided as input to task T3 that will develop the localization system.
This task will benefit from the expertise in real-time communications of the UA and FEUP teams, with a strong track record in the development of similar system (see for example the work in the CAMBADA robotic soccer team) and it will be coordinated by the UA team, in particular by José Alberto Fonseca.

Membros da equipa de investigação nesta tarefa
Members of the research team in this task
(BI) Bolseiro de Investigação (Mestre) 2; (BI) Bolseiro de Investigação (Mestre) 3; António Casimiro Ferreira da Costa; Jeferson Luiz Rodrigues Souza; José Alberto Gouveia Fonseca; Luis Miguel Pinho de Almeida; Mário João Barata Calha; Paulo Jorge de Campos Bartolomeu; Paulo José Lopes Machado Portugal; Valter Filipe Miranda Castelão da Silva;

Designação da tarefa Task denomination	**Data de início** Start date	**Data de fim** End date	**Duração** Duration	**Pessoas * mês** Person * months
Topology discovery and tracking	01-07-2011	31-03-2012	9	16

Descrição da tarefa e Resultados Esperados
Task description and Expected results
Expected results
- Fully operational relative localization system
- Topology tracking system

This task deals with the full specification and implementation of the relative localization system. This system will follow the localization requirements defined in task T1, as a consequence of the desired interactions and middleware services. It will be mainly based on RF communications and two main approaches will be considered, one using the receive signal strength (RSS) for a course notion of localization, such as indications of azimuth in octants and just three or four distance levels classification, and another one more accurate and precise, based on a novel RF-ranging technique. While the latter provides a better performance, it is based on specific and currently expensive interfaces, exactly opposite characteristics when compared with the former method.
The vision-based localization, which might be a capability of just a few robots, will be used as a complementary system that can help calibrating and compensating the faults of the RF-based methods. The relative positions generated by this method can also be shared with the remaining robots through interactions over the middleware system.
Finally, an alternative RF-based method based on a set of fixed wireless access points will be considered for the case in which the other methods fail in providing adequate performance. This will only be used in case of need, since it conflicts with the global target of using no fixed infrastructure.
The relative localization is essential for the management of the topology. For instance, it can be used to minimize the possibility for the robots to lose connection to the network.
This task will benefit from the expertise in relative localization developed by the teams at FEUP and UA, covering from vision-based to RSS-based localization, tracking and navigation. It will be coordinated by the FEUP team, in particular by Luís Almeida.

Membros da equipa de investigação nesta tarefa
Members of the research team in this task
(BI) Bolseiro de Investigação (Mestre) 2; (BI) Bolseiro de Investigação (Mestre) 3; António Paulo Gomes Mendes Moreira; José Alberto Gouveia Fonseca; Luis Miguel Pinho de Almeida; Mário João Barata Calha; Paulo Jorge de Campos Bartolomeu; Valter Filipe Miranda Castelão da Silva;

Designação da tarefa Task denomination	**Data de início** Start date	**Data de fim** End date	**Duração** Duration	**Pessoas * mês** Person * months
Resilient architecture & middleware	01-07-2011	31-03-2012	9	17

Descrição da tarefa e Resultados Esperados
Task description and Expected results
Expected results
- Resilient architecture & middleware
- Definition of the information sharing service
- Definition of the communication modes

This task focuses on the design of the system according to the use case defined in task T1. The output comprises two aspects, namely: the architecture of the system and the middleware solution. This task covers the implementation and evaluation of the resilient architecture & middleware. This implies the detailed definition of the software and the integration with the various hardware modules (localization and network).
The idea is to deal with the different operational situations, adapting the system accordingly in order to achieve the best possible trade-off between safety and efficiency. Each robot always makes use of all gathered information and contributes to the team strategy. This information is stored in a database that is shared among the team members. On one extreme a robot may
have timely (fresh) information from the other robots and local sensors. On the other extreme the
communication may be partitioned and the robot will have to rely mainly on data acquired locally, and maybe on stored information (previously obtained from external sources and possibly not fresh). Naturally, each
robot has a limited data acquisition and processing capability when compared with the conjoined capabilities of the team. When all robots are able to cooperate tightly, each robot can rely on processed data in order to take better decisions.
This task also addresses error detection and confinement issues. In terms of timing errors, a resilient architecture must be able to focus on the safety of the robot.
This task will be coordinated by António Casimiro.

Membros da equipa de investigação nesta tarefa
Members of the research team in this task
(BI) Bolseiro de Investigação (Mestre) 1; António Casimiro Ferreira da Costa; Jeferson Luiz Rodrigues Souza; José Manuel de Sousa de Matos Rufino; Luis Miguel Pinho de Almeida; Mário João Barata Calha; Mônica Lopes Muniz Corrêa Dixit;

Designação da tarefa Task denomination	**Data de início** Start date	**Data de fim** End date	**Duração** Duration	**Pessoas * mês** Person * months
Proof of concept prototyping & evalua...	01-04-2012	31-12-2012	9	44

Descrição da tarefa e Resultados Esperados
Task description and Expected results

Expected results
- Prototypes of the robots.
- Evaluation of the prototypes and use case including scenarios with good and poor connectivity.
This task aims at the validation, verification and evaluation of the complete system. This will be
carried out by developing a case study based on real robots that will incorporate the results of the previous tasks, namely T2, T3 and T4. Several real application scenarios will be created to test the prototype in very different operating conditions, mainly in what concerns network connectivity. This will allow evaluating the performance of the infrastructure with many interactions in fully connected situations (but not fully linked meaning that it is a multi-hop topology), in which the robots will create clusters and synchronize with each other for proper handling of transmissions and efficient information sharing, and other cases with poor connectivity, when only a few robots are linked, as well as the transitions from one phase to the other.
This task will be coordinated by the PI.

Membros da equipa de investigação nesta tarefa

Members of the research team in this task

(BI) Bolseiro de Investigação (Mestre) 1; (BI) Bolseiro de Investigação (Mestre) 2; (BI) Bolseiro de Investigação (Mestre) 3; António Casimiro Ferreira da Costa; António Paulo Gomes Mendes Moreira; Jeferson Luiz Rodrigues Souza; José Alberto Gouveia Fonseca; José Manuel de Sousa de Matos Rufino; Luis Miguel Pinho de Almeida; Mário João Barata Calha; Mônica Lopes Muniz Corrêa Dixit; Paulo Jorge de Campos Bartolomeu; Paulo José Lopes Machado Portugal; Valter Filipe Miranda Castelão da Silva;

3.2.4. Calendarização e Gestão do Projecto

3.2.4. Project Timeline and Management

3.2.4.a Descrição da Estrutura de Gestão

3.2.4.a Description of the Management Structure

The management of the MASTER Project will be performed by a Management Board (MB) that includes the PI and two more key
persons, one from each research team, that is, FCUL, FEUP and UA. The MB will meet physically at least 6 times a year and by conference call other 6 times, leading to an average of one meeting per month. The members of the MB will act as local coordinators and will make the connection with the local teams. The SMB meetings will include other team members when required. There will be minutes of each meeting.
The PI will be responsible for the communication with FCT and the required project reporting and will also have the casting vote inside the MB.
Each task also has a coordinator that is responsible for reporting to the MB on the task status and leading the production of deliverables, in timely way.
An international consultant will participate in two project meetings, one during the use case and requirements definition and another closer to the end of Year one (mid project - Milestone M1), to provide input to the project, help evaluate its development and define corrective measures, if needed.
The MASTER project web page will be used either for external dissemination purposes but also to disseminate documentation and
information by the overall team members, using a restricted access page. A wiki will also be considered for repository of internal information.
At least once a year (twice in the 2nd year if results justify) there will be a project workshop that will be open to external observers upon invitation. The PI and the task coordinators will present the status of the project and of the tasks. Other team members will present more specific work-in-progress or the results already obtained.
The MB will also perform a budgetary evaluation of the project execution each six months to check the compliance with the plan. This will be supported by the accountancy team of the Fundação da Faculdade de Ciências da Universidade de Lisboa. It will be mandatory for all the partners to supply the adequate information to the MB one month prior to this meeting. It is planned that these meetings will be held in the 8th, 16th, 24th and two months after the end of the project.

3.2.4.b Lista de Milestones

3.2.4.b Milestone List

Data Date	**Designação da milestone** Milestone denomination
31-12-2011	Wireless communication

Descrição

Description

Wireless communication protocol fully specified and implemented, ready for use. A progress report will be issued, including the state of all tasks. Any delay will lead to reconsider the respective task and, if needed, opt for a simpler but working solution not to jeopardize the overall aim.

Data Date	**Designação da milestone** Milestone denomination
31-03-2012	Relative localization, resilient architecture & middleware

Descrição

Description

Relative localization system plus Resilient architecture and middleware fully specified and implemented, ready to be used. Any delay in these tasks will lead to reconsider the techniques used and, if needed, opt for simpler but working solutions not to jeopardize the overall aim.

3.2.4.c Cronograma

3.2.4.c Timeline

Ficheiro com a designação "timeline.pdf", no 9. Ficheiros Anexos, desta Visão Global (caso exista).

File with the name "timeline.pdf" at 9. Attachments (if exists).

3.3. Referências Bibliográficas
3.3. Bibliographic References

Referência Reference	Ano Year	Publicação Publication
[Brui07]	2007	I. Bruin et al, Report on Specification HIDENETS laboratory set-up scenario and components, EU FP6 IST project HIDENETS, Deliverable D6.2, Oct. 2007.
[Arla07]	2007	J. Arlat et al, Report on HIDENETS Reference Model, EU FP6 IST project HIDENETS, Deliverable D1.2, Jun. 2007.
[Hide06]	2006	HIDENETS project, IST-FP6-STREP-26979.
[Veri06]	2006	P. Verissimo. Travelling through wormholes: a new look at distributed systems models. SIGACT News, 37(1):66–81, 2006.
[MCC09]	2009	L. Marques, A. Casimiro, and M. Calha, "Design and development of a proof-of-concept platooning application using the hidenets architecture," in DSN '09: Proceedings of the International Conference on Dependable Systems and Networks, 2009, pp. 223–228.
[CRM+09]	2009	A. Casimiro, J. Rufino, L. Marques, M. Calha, and P. Veríssimo, "Applying architectural hybridization in networked embedded systems," in The Seventh IFIP Workshop on Software Technologies for Future Embedded and Ubiquitous Systems, Newport Beach, USA, Nov. 2009.
[MPVF08]	2008	Moraes, R. Portugal, P. Vasques, F. Fonseca, J.A. . "Limitations of the IEEE 802.11e EDCA protocol when supporting real-time communication". WFCS'2008, 7th IEEE Workshop on Factory Communication Systems, Dresden, Germany, May 20-23, 2008.
[WMW05]	2005	A. Willig, K. Matheus, and A. Wolisz, "Wireless technology in industrial networks", Proceedings of the IEEE, vol. 93, no. 6, pp. 1130 – 1151, 2005.
[MUVW07]	2007	D. Miorandi, E. Uhlemann, S. Vitturi, and A. Willig, "Guest Editorial: Special Section on Wireless Technologies in Factory and Industrial Automation, Part I", IEEE Transactions on Industrial Informatics, vol. 3, no. 2, pp. 95–98, 2007.
[MVPF06]	2006	MOARES, R. ; VASQUES, F. ; PORTUGAL, P. ; FONSECA, J. A. – A new Traffic Separation Mechanism (TSm) in Wireless 802.11e Networks : A simulation study . In ROCOM '06 : 6th WSEAS International Conference on Robotics, Control and Manufacturing Technology . Hangzhou, CN, Abr. 2006 . p. 107 – 112.
[FF07]	2007	N. Ferreira, J.A. Fonseca, "Using Time-Triggered Communications over IEEE 802.15.4", WIP, Proceedings 12th IEEE Conference on Emerging Technologies and Factory Automation, Patras – Greece, September 25-28, 2007.
[Call02]	2002	E. Callaway, et al., "Home Networking with IEEE 802.15.4: A Developing Standard for Low-Rate Wireless Personal Area Networks", IEEE Communications Magazine, August 2002.
[RK07]	2007	Christof Röhrig and Frank Künemund. "Estimation of Position and Orientation of Mobile Systems in a Wireless LAN". Proceedings of the 46th IEEE Conference on Decision and Control, New Orleans, Lousiana, USA, December 12-14, 2007.
[INS08]	2008	Ivanov, S. Nett, E. Schemmer, S. – "Automatic WLAN localization for industrial automation". WFCS'2008, 7th IEEE Workshop on Factory Communication Systems, Dresden, Germany, May 20-23, 2008.
[FBA05]	2005	Tullio Facchinetti, Giorgio Buttazzo, and Luis Almeida. "Dynamic Resource Reservation and Connectivity Tracking to Support Real-Time Communication among Mobile Units". EURASIP Journal on Wireless Communications and Networking 2005:5, 712–730.
[FB04]	2004	Tullio Facchinetti, Giorgio Buttazzo. "Integrated Wireless Communication Protocol for Ad-Hoc Mobile Networks". 3rd Int. Workshop on Real-Time Networks (RTN). 2004.
[Svin08]	2008	I.-E. Svinnset et al, Report on resilient topologies and routing, EU FP6 IST project HIDENETS, Deliverable D3.1.2, Jul. 2008.
[MN99]	1999	Mock, M., Nett, E., "Real-Time Communication in Autonomous Robot Systems", Proc. 4th Int. Symp. On Autonomous Decentralized Systems, 1999, Integration of Heterogeneous Systems, 21-23 March 1999, pp. 34-41.
[LAW+07]	2007	Hongbin Li, Luis Almeida, Zhi Wang, Youxian Sun. Relative Positions within Small Teams of Mobile Units. MSN 2007, 3rd Int. Conf. on Mobile Ad-hoc and Sensor Networks. Beijing, China. Dec 2007.
[Mock04]	2004	M. Mock. On the Real-Time Cooperation of Autonomous Systems, published in the Fraunhofer Series in Information and Communication Technology as issue 2004/6 by Shaker Verlag, Aachen, Germany, 2004.
[SAL+09]	2009	Frederico Santos, Luıs Almeida, Luıs S. Lopes, Jose L. Azevedo, M. Bernardo Cunha. Communicating among robots in the RoboCup Middle-Size League. RoboCup Symposium 2009, Graz, Austria. June 29-July 5, 2009.

[MVPF07]	2007	**R. Moraes, F. Vasques, P. Portugal, J.A. Fonseca, "VTP-CSMA: A Virtual Token Passing Approach for Real-Time Communication in IEEE 802.11 Wireless Networks", IEEE Transactions on Industrial Informatics,Vol. 3, No. 3, August 2007.**
[MNR+07]	2007	**Morelli, C.; Nicoli, M.; Rampa, V.; Spagnolini, U., "Hidden Markov Models for Radio Localization in Mixed LOS/NLOS Conditions," Signal Processing, IEEE Transactions on , vol.55, no.4, pp.1525-1542, April 2007.**
[EXM04]	2004	**Elnahrawy, E.; Xiaoyan Li; Martin, R.P., "The limits of localization using signal strength: a comparative study", Sensor and Ad Hoc Communications and Networks, SECON'2004., pp. 406-414, 4-7 Oct, 2004.**
[KB88]	1988	**H. Kopetz and G. Bauer, The time-triggered architecture, Proceedings of the IEEE, vol. 91, no. 1, pages 112-126, 1988.**
[KK90]	1990	**H. Kopetz and K. H. Kim. Temporal Uncertainties in Interactions among Real-Time Objects, 9th IEEE Symposium on Reliable Distributed Systems, IEEE CS, Huntsville, AL, USA, pp. 165-174,1990.**
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[LAC+09]	2009	**Hongbin Li, Luis Almeida, Fausto Carramate, Zhi Wang, Youxian Sun. Using Low-Power Radios for Mobile Robots Navigation. FET 2009 – 8th IFAC Conference on Fieldbuses and Networks in industrial and embedded systems. Ansan, Korea. May 20-22, 2009.**
[LAS09]	2009	**Hongbin Li, Luis Almeida, Youxian Sun. Dynamic Target Tracking with Integration of Communication and Coverage using Mobile Sensors. IECON 2009, 35th Annual Conf of the IEEE Industrial Electronics Society, Porto, Portugal, 3-5 Nov 2009.**

3.4. Publicações Anteriores
3.4. Past Publications

Referência Reference	**Ano** Year	**Publicação** Publication
[SAPL09]	2009	**Frederico Santos, Luis Almeida, Paulo Pedreiras, Luis Seabra Lopes. A real-time distributed software infrastructure for cooperating mobile autonomous robots. ICAR 2009 – 14th Int. Conf. on Advanced Robotics. Munich, Germany. June 22-26, 2009.**
[MSCV05]	2005	**Pedro Martins, Paulo Sousa, António Casimiro and Paulo Veríssimo, "A New Programming Model for Dependable Adaptive Real-Time Applications", IEEE Distributed Systems Online, May 2005 (vol. 6 no. 5), 2005.**
[SAL08]	2008	**F. Santos, L. Almeida, L. S. Lopes. Self-configuration of an Adaptive TDMA wireless communication protocol for teams of mobile robots. ETFA 2008, 13th IEEE Conference on Emerging Technologies and Factory Automation. Hamburg, Germany, 15-18 September 2008.**
[LAC+08]	2008	**Hongbin Li, Luis Almeida, Fausto Carramate, Zhi Wang, Youxian Sun. Connectivity-Aware Motion Control among Autonomous Mobile Units. SIES 2008, 3rd IEEE Symposium on Industrial Embedded Systems. Montpellier, France, 11-13 June, 2008.**
[OBFC08]	2008	**J. Oliveira, P. Bartolomeu, J.A. Fonseca, L. Costa, "Evaluating Severe Noise Interference in IEEE 802.15.4 based Location Systems", ETFA'2008, 13th IEEE International Conference on Emerging Technologies and Factory Automation, Hamburg, Germany, September 15-18, 2008.**

4. Equipa de investigação
4. Research team

-

4.1 Lista de membros
4.1. Members list

Nome Name	**Função** Role	**Grau académico** Academic degree	**%tempo** %time	**CV nuclear** Core CV
Mário João Barata Calha	Inv. Responsável	DOUTORAMENTO	30	✓
António Casimiro Ferreira da Costa	Investigador	DOUTORAMENTO	20	✓
António Paulo Gomes Mendes Moreira	Investigador	DOUTORAMENTO	15	X
José Alberto Gouveia Fonseca	Investigador	DOUTORAMENTO	15	✓
José Manuel de Sousa de Matos Rufino	Investigador	DOUTORAMENTO	15	X
Luis Miguel Pinho de Almeida	Investigador	DOUTORAMENTO	15	✓
Paulo Jorge de Campos Bartolomeu	Investigador	MESTRADO	15	X
Paulo José Lopes Machado Portugal	Investigador	DOUTORAMENTO	15	X
Valter Filipe Miranda Castelão da Sil...	Investigador	MESTRADO	15	X
JEFERSON LUIZ RODRIGUES SOUZA	Bolseiro	MESTRADO	20	X
Mônica Lopes Muniz Corrêa Dixit	Bolseiro	MESTRADO	30	X

(O curriculum vitae de cada membro da equipa está disponível clicando no nome correspondente)
(Curriculum vitae for each research team member is available by clicking on the corresponding name)
Total: 11

4.2. Lista de membros a contratar durante a execução do projecto
4.2. Members list to hire during project"s execution

Membro da equipa Team member	Função Role	Duração Duration	%tempo %time
(BI) Bolseiro de Investigação (Mestre) 1	Bolseiro	24	100
(BI) Bolseiro de Investigação (Mestre) 2	Bolseiro	24	100
(BI) Bolseiro de Investigação (Mestre) 3	Bolseiro	24	100

Total: 3

5. Projectos financiados
5. Funded projects

-

(Sem projectos financiados)
(No funded projects)

6. Indicadores previstos
6. Expected indicators

-

Indicadores de realização previstos para o projecto
Expected output indicators

Descrição Description	2010	2011	2012	2013	2014	Total
A - Publicações Publications						
Livros Books	0	0	0	0	0	**0**
Artigos em revistas internacionais Papers in international journals	0	0	2	0	0	**2**
Artigos em revistas nacionais Papers in national journals	0	0	0	0	0	**0**
B - Comunicações Communications						
Comunicações em encontros científicos internacionais Communications in international meetings	0	2	4	0	0	**6**
Comunicações em encontros científicos nacionais Communications in national meetings	0	1	1	0	0	**2**
C - Relatórios Reports	0	2	2	0	0	**4**
D - Organização de seminários e conferências Organization of seminars and conferences	0	1	1	0	0	**2**
E - Formação avançada Advanced training						
Teses de Doutoramento PhD theses	0	0	0	0	0	**0**
Teses de Mestrado Master theses	0	0	3	0	0	**3**
Outras Others	0	0	0	0	0	**0**
F - Modelos Models	0	0	0	0	0	**0**
G - Aplicações computacionais Software	0	0	0	0	0	**0**
H - Instalações piloto Pilot plants	0	0	0	0	0	**0**
I - Protótipos laboratoriais Prototypes	0	0	1	0	0	**1**
J - Patentes Patents	0	0	0	0	0	**0**
L - Outros Other						
	0	0	0	0	0	**0**
	0	0	0	0	0	**0**
	0	0	0	0	0	**0**

Acções de divulgação da actividade científica
Scientific activity spreading actions

The dissemination will be carried out using both a web site that will contain information on the project as well as its results as they are developed, and related paper publications in international conferences and journals. Since the members of the research team are normally involved in scientific activities and are experienced in the organization of scientific events, it is also foreseen the organization of workshops and special sessions, centered on dependable wireless communications for multi-robot teams.

7. Orçamento
7. Budget

-

Instituição Proponente
Principal Contractor

Fundação da Faculdade de Ciências

Descrição Description	2010	2011	2012	2013	2014	Total
Recursos Humanos Human resources	0,00	13.080,00	13.080,00	0,00	0,00	**26.160,00**
Missões Missions	0,00	2.500,00	3.000,00	0,00	0,00	**5.500,00**
Consultores Consultants	0,00	1.500,00	1.500,00	0,00	0,00	**3.000,00**
Aquisição de bens e serviços Service procurement and acquisitions	0,00	500,00	500,00	0,00	0,00	**1.000,00**
Registo de patentes Patent registration	0,00	0,00	0,00	0,00	0,00	**0,00**
Adaptação de edifícios e instalações Adaptation of buildings and facilities	0,00	0,00	0,00	0,00	0,00	**0,00**
Gastos gerais Overheads	0,00	5.356,00	3.616,00	0,00	0,00	**8.972,00**
TOTAL DESPESAS CORRENTES TOTAL CURRENT EXPENSES	**0,00**	**22.936,00**	**21.696,00**	**0,00**	**0,00**	**44.632,00**
Equipamento Equipment	0,00	9.200,00	0,00	0,00	0,00	**9.200,00**
Total	**0,00**	**32.136,00**	**21.696,00**	**0,00**	**0,00**	**53.832,00**

Instituições Participantes
Participating Institutions

Faculdade de Engenharia da Universidade do Porto

Descrição Description	2010	2011	2012	2013	2014	Total
Recursos Humanos Human resources	0,00	13.080,00	13.080,00	0,00	0,00	**26.160,00**
Missões Missions	0,00	2.500,00	3.000,00	0,00	0,00	**5.500,00**
Consultores Consultants	0,00	0,00	0,00	0,00	0,00	**0,00**
Aquisição de bens e serviços Service procurement and acquisitions	0,00	300,00	300,00	0,00	0,00	**600,00**
Registo de patentes Patent registration	0,00	0,00	0,00	0,00	0,00	**0,00**
Adaptação de edifícios e instalações Adaptation of buildings and facilities	0,00	0,00	0,00	0,00	0,00	**0,00**
Gastos gerais Overheads	0,00	4.776,00	3.276,00	0,00	0,00	**8.052,00**
TOTAL DESPESAS CORRENTES TOTAL CURRENT EXPENSES	**0,00**	**20.656,00**	**19.656,00**	**0,00**	**0,00**	**40.312,00**
Equipamento Equipment	0,00	8.000,00	0,00	0,00	0,00	**8.000,00**
Total	**0,00**	**28.656,00**	**19.656,00**	**0,00**	**0,00**	**48.312,00**

Universidade de Aveiro

Descrição Description	2010	2011	2012	2013	2014	Total
Recursos Humanos Human resources	0,00	13.080,00	13.080,00	0,00	0,00	**26.160,00**
Missões Missions	0,00	2.500,00	3.000,00	0,00	0,00	**5.500,00**

Consultores Consultants	0,00	0,00	0,00	0,00	0,00	**0,00**
Aquisição de bens e serviços Service procurement and acquisitions	0,00	300,00	300,00	0,00	0,00	**600,00**
Registo de patentes Patent registration	0,00	0,00	0,00	0,00	0,00	**0,00**
Adaptação de edifícios e instalações Adaptation of buildings and facilities	0,00	0,00	0,00	0,00	0,00	**0,00**
Gastos gerais Overheads	0,00	5.176,00	3.276,00	0,00	0,00	**8.452,00**
TOTAL DESPESAS CORRENTES TOTAL CURRENT EXPENSES	**0,00**	**21.056,00**	**19.656,00**	**0,00**	**0,00**	**40.712,00**
Equipamento Equipment	0,00	10.000,00	0,00	0,00	0,00	**10.000,00**
Total	**0,00**	**31.056,00**	**19.656,00**	**0,00**	**0,00**	**50.712,00**

Orçamento Global
Global budget

Descrição Description	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Recursos Humanos Human resources	0,00	39.240,00	39.240,00	0,00	0,00	**78.480,00**
Missões Missions	0,00	7.500,00	9.000,00	0,00	0,00	**16.500,00**
Consultores Consultants	0,00	1.500,00	1.500,00	0,00	0,00	**3.000,00**
Aquisição de bens e serviços Service procurement and acquisitions	0,00	1.100,00	1.100,00	0,00	0,00	**2.200,00**
Registo de patentes Patent registration	0,00	0,00	0,00	0,00	0,00	**0,00**
Adaptação de edifícios e instalações Adaptation of buildings and facilities	0,00	0,00	0,00	0,00	0,00	**0,00**
Gastos gerais Overheads	0,00	15.308,00	10.168,00	0,00	0,00	**25.476,00**
TOTAL DESPESAS CORRENTES TOTAL CURRENT EXPENSES	**0,00**	**64.648,00**	**61.008,00**	**0,00**	**0,00**	**125.656,00**
Equipamento Equipment	0,00	27.200,00	0,00	0,00	0,00	**27.200,00**
Total	**0,00**	**91.848,00**	**61.008,00**	**0,00**	**0,00**	**152.856,00**

Plano de financiamento
Finance plan

Descrição Description	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Financiamento solicitado à FCT Requested funding	0,00	91.848,00	61.008,00	0,00	0,00	**152.856,00**
Financiamento próprio Own funding	0,00	0,00	0,00	0,00	0,00	**0,00**
Outro financiamento público Other public-sector funding	0,00	0,00	0,00	0,00	0,00	**0,00**
Outro financiamento privado Other private funding	0,00	0,00	0,00	0,00	0,00	**0,00**
Total do Projecto Total of the project	**0,00**	**91.848,00**	**61.008,00**	**0,00**	**0,00**	**152.856,00**

8. Justificação do orçamento
8. Budget rationale

-

8.1. Justificação dos recursos humanos
8.1. Human resources rationale

Tipo
Type
(BI) Bolsa de Investigação (Mestre)

Nº de pessoas
No. of persons
3

Duração (em meses)
Duration (in months)

Custo envolvido (€) *(calculado)*
Total cost (€) *(estimated)*

Outros custos (€)
Other costs (€)

24	70.560,00	7.920,00

Justificação do financiamento solicitado
Rationale for requested funding

The MASTER project includes extensive work related to the development and testing of both the communication protocol and the
localization service. This kind of work requires human resources with qualification at the level of "mestrado" (master degree) with expertise in wireless networks and programming. These human resources will work under the coordination and in complement to other elements in the project team.
The other cost is related to Social Security and insurance.

8.2. Justificação de missões
8.2. Missions rationale

Tipo Type	**Nº de deslocações** No. of participations
Participação em congressos	12
Local Venue	**Custo envolvido (€)** Cost (€)
Multiple locals	16.500,00

Justificação do financiamento solicitado
Rationale for requested funding

Participation in international conferences and workshops, presenting papers or organizing special sessions, will be a privileged form of discussing the project aims, evolution and results with the related scientific community and obtain relevant feedback.

8.3. Justificação de consultores
8.3. Consultants rationale

Nome completo
Full name

Jörg Kaiser

Instituição
Institution

Faculty of Computer Science at the Otto-von-Guericke University of Magdeburg

Fase do projecto Project phase	**Custo (€)** Cost (€)
Beginning of the project and the other at the end of M2	3.000,00

Justificação do financiamento solicitado
Rationale for requested funding

Jörg Kaiser is a Full Professor in the Faculty of Computer Science at the Otto-von-Guericke University of Magdeburg where he leads the Department for Embedded Systems and Operating Systems (EOS). His research areas now have a strong emphasis on large scale distributed real-time systems supervising and controlling real-world applications like teams of robots. His experience will be of high value to the project both in the initial specification of the architecture and services as well as in M2 to analyze the project evolution and comment on the results achieved.

Página na Internet onde pode ser consultado o CV do consultor
Web page where the consultant's CV can be accessed

http://www.informatik.uni-ulm.de/rs/mitarbeiter/jk/

8.4. Justificação de aquisição de bens e serviços
8.4. Service procurement and acquisitions

Tipo Type	**Custo (€)** Cost (€)
Assembly of robot parts and other equipment	2.200,00

Justificação do financiamento solicitado
Rationale for requested funding

Due to the nature of project MASTER, it will be necessary to assemble several parts in order to get to a fully functional robot that
is able to communicate. The development of the prototypes will require various actions like soldering and other techniques in order to improve their mechanical resistance and physical robustness.

Also some office consumables (paper, printer toner, etc.) might be required in the scope of the project.

8.6. Justificação do Equipamento
8.6. Equipment rationale

8.6.1. Equipamento já disponível para a execução do projecto
8.6.1 Available equipment

Tipo de equipamento Equipment type	**Fabricante** Manufacturer	**Modelo** Model	**Ano** Year
Robot base with 4-wheels	Lynxmotion	A4WD1	2008

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Ano Year
ARM Microprocessor kit	Hectronic	H6042	2008

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Ano Year
Microcontroller development kit	Lynxmotion	Bot Board II	2008

8.6.2. Discriminação do equipamento a adquirir
8.6.2. New equipment requested

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
3 units of Robot base with 4-wheels	Lynxmotion	A4WD1	1.500,00

Justificação do financiamento solicitado
Rationale for requested funding

This is an indispensable robot part for task T5. The reason for the 3 units is that it is a major goal of MASTER to demonstrate how
the robots avoid collisions while moving quickly to their destination. Also it is important to demonstrate the cooperation between them.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
4 units of Netbook	ASUS	Eee PC	2.000,00

Justificação do financiamento solicitado
Rationale for requested funding

This is an essencial robot part for task T5 that is responsible for running the middleware.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
3 units of Microcontroller development kit	Lynxmotion	Bot Board II	300,00

Justificação do financiamento solicitado
Rationale for requested funding

This is a basic hardware that will be responsible for the movement of the robot. This makes possible to have an independent control of the robot. This is essential for task T5.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
6 units of laptop	Dell	laptop with wifi	9.000,00

Justificação do financiamento solicitado
Rationale for requested funding

The laptops constitute a main tool for the development end evaluation of the applications and protocols to be developed. These also form the core of the fixed infrastructure nodes. The laptops can support the uploading of data and programs into the robots wherever they are. Also they allow more easily to change the position of the "fixed" nodes. Bulky computers would not be adequate.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
4 sets of sensors for controlling the robot	Farnell	Ultrasonic, infrared, compass	800,00

Justificação do financiamento solicitado
Rationale for requested funding

This is a basic equipment for a robot. It should be noticed the inclusion of an extra set for the robot already at the lab. This equipment supports directly task T5.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
4 sets of Sensors for danger detection	Farnell	Temp, humidity, smoke	800,00

Justificação do financiamento solicitado
Rationale for requested funding

This is a fundamental set of sensors for a robot. This will allow it to
sense high temperatures, humidity and smoke.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)
12 External 802.11 interfaces	Linksys	WRT54GL	1.200,00

Justificação do financiamento solicitado
Rationale for requested funding

Wireless communication interface. This is an essential component so that the various team members can evaluate their designs. This equipment provides support to the tasks from T2 to T5.

Tipo de equipamento Equipment type	Fabricante Manufacturer	Modelo Model	Custo (€) Cost (€)

4 Video cameras	Farnell	basic cam	400,00

Justificação do financiamento solicitado
Rationale for requested funding
Cameras used for image processing are fundamental for the project.

Tipo de equipamento Equipment type	**Fabricante** Manufacturer	**Modelo** Model	**Custo (€)** Cost (€)
Kit Zigbee	nanotron technologies	nanoLOC development kit	5.000,00

Justificação do financiamento solicitado
Rationale for requested funding
Essential kit for zigbee communication as an alternative when the 802.11 infrastructure is not working.

Tipo de equipamento Equipment type	**Fabricante** Manufacturer	**Modelo** Model	**Custo (€)** Cost (€)
2 PDAs	Asus	P552W	800,00

Justificação do financiamento solicitado
Rationale for requested funding
Mobile terminal for localization testing.

Tipo de equipamento Equipment type	**Fabricante** Manufacturer	**Modelo** Model	**Custo (€)** Cost (€)
1 WLAN analyzer	Fluke networks	Fluke EtherScope™ Series II Network Assistant	5.000,00

Justificação do financiamento solicitado
Rationale for requested funding
Essential equipment for supporting the development of a communication protocol.

Tipo de equipamento Equipment type	**Fabricante** Manufacturer	**Modelo** Model	**Custo (€)** Cost (€)
4 kits 802.15.4 external interface	XBee	XBee 802.15.4 Starter Kit	400,00

Justificação do financiamento solicitado
Rationale for requested funding
Wireless communication interface. This is an essential component so that the various team members can evaluate their designs. This equipment provides support to the tasks from T2 to T5.

8.7. Justificação de registo de patentes
8.7. Patent registration

(Vazio)
(Void)

8.8. Justificação de adaptação de edifícios e instalações
8.8. Adaptation of buildings and facilities

(Vazio)
(Void)

9. Ficheiros Anexos
9. Attachments

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Nome Name	Tamanho Size
MASTER09_Figure.pdf	21Kb
timeline.pdf	5Kb

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