MOBILEMAN

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Mobile Metropolitan Ad hoc Networks

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1. EXECUTIVE SUMMARY

As highlighted at the end of the first year of the project, even though it exists a very large literature on MANETs, ad hoc networking is not yet a consolidated field. After almost a decade of research into ad hoc networking, MANET technology has not yet affected our way of using wireless networks. As pointed out in [1], although MANET research has achieved respectable progress, there are no clear results that show how well MANETs work in reality. Simulations have not been conclusive on clearing the field of IETF MANET protocol candidates. On the other hand, realistic experiences of ad hoc networking are almost missing. There seems also to be a mismatch between what end users might find useful and what research problems are currently being addressed. Research is mainly based on simulation studies that analyze very large node scenarios (up to 1000 nodes) with CBR traffic. On the other hand, with current technology, it has been pointed out [1], that exists an *ad hoc horizon*, at two to three hops and 10 to 20 nodes, where the benefit from wireless multi-hop ad hoc networking virtually vanishes. Furthermore, legacy TPC/IP applications represent a realistic usage scenario for this type of network. Scenarios consisting of a limited number of users wanting to form an ad hoc network for information sharing is simple, but much more probable and feasible.

The above considerations have been re-enforced by our experiences during the second year of the project as documented in D8 and D10. Therefore, we believe that the project can provide a real benefit to the European research in the area by addressing in an integrated way the Implementations Integration, and Experimentation of realistic ad hoc networks *within* the current technology limits. Indeed, in the second year of the project, starting from the MobileMAN architecture and protocols developed and validated during the first year of the project, we worked towards the development, integration, and testing of MobileMAN solutions. To maximize the usefulness of project results, we limited the software development to novel mechanisms and protocols we identified during the first year of the project, while we exploited as much as possible valuable concepts/solutions (and the corresponding software implementations) already available in the literature. However, the use of these concepts/solutions was not straightforward due lack of testing, and/or lack of documentation. This required us some extra efforts to analyze the code and

[1] Per Gunningberg, Henrik Lundgren, Erik Nordstrom, Christian Tschudin, "Lessons from Experimental MANET Research," to appear in *Ad Hoc Networks Journal*, special issue on "Ad Hoc Networking for Pervasive Systems", M. Conti, E. Gregori (Editors).

test off-the-shelf SW solutions before integrating them into the MobileMAN testbed. Furthermore, the SW evolution (e.g., new releases of routing protocols to follow the evolution of Internet drafts, or to fix software bugs) required us a not negligible amount of effort, as we were obliged to several iterative integrations in order to harmonize the whole solution.

During the second year of the project emerged that performing realistic test-beds, even on a small scale, is a task that a single project partner cannot accomplish in isolation due to the limitations in number of devices and researchers that can be involved. The latter being the most critical constraint. To cope with these problems, in the MobileMAN meeting in Helsinki (7-8 June, 2004), we decided to set up a group of junior researchers that should meet on a regular basis to integrate the developed software, and set up a "reasonable" size MobileMAN to validate the developed solutions. During the second year this group has two main meetings, both meeting were hosted by CNR in Pisa. The first meeting was at the end of June (24 June - 2 July) and coincided with the MobileMAN first testing phase. Results of this testing phase are presented in Deliverable D8. The second meeting was at the end of September (29 September – 1 October) at the end of the second year of the project. Some results of this test meeting are reported in D10.

Second year technical activities were mainly focused on implementations, integration, and experimentation activities focusing, according to Annex 1, on a legacy layered-architecture. In addition, to this mainstream, we continued to further develop the idea of a MobileMAN cross-layer architecture (and related protocols). As recognized also during the first year review meeting, this is an interesting research direction that is worth investigating in parallel to the legacy approach identified in Annex 1. Furthermore, experimental results reported in Deliverable D8 provide further motivations for a cross layer approach.

As far as the legacy architecture, we focused mainly on integration (and porting) of off-the-shelf HW and SW components in a first MobileMAN testbed on which we performed extensive experimental evaluations of the mobile ad hoc paradigm. In addition, when

available solutions were not suitable for the project aims, we implemented our own HW/SW solutions (e.g., platform for the development of the 802.11 enhanced card, ad hoc routing framework, applications).

During the second year of the project relevant results have been achieved also in applying the cross-layer approach to MANETs. Specifically, we completely specify the MobileMAN cross-layer architecture that enables cross-layer interactions among protocols (to optimize performance) still guaranteeing the independence in protocols design, and hence the advantages of a modular architecture. Starting from this architecture we designed and are currently under development relevant part of it to study, in a realistic setting, the advantages of a cross-layer approach for MANET design. More precisely, we have designed and are currently under implementation (see Deliverable D10 for details):

i. a revised version of Pastry middleware (named CrossRoad) to optimize its performance by exploiting cross layer interactions;

ii. a routing protocol that joins a proactive behavior with good scalability properties; in addition, this protocol is designed to distribute in the network information required by the higher layers of the protocols stack (e.g., services' discovery protocol) to better support cross-layer interactions;

iii. a minimal set of the NeSt functionalities to guarantee cross layer interactions between the middleware (CrossRoad) and the network layer.

In addition to this, the MobileMAN cross-layer architecture is currently under implementation inside the *network simulator* framework to analyze in more general scenarios the MobileMAN cross layer potentialities.

An important element in determining the MANET success is the users acceptance. Currently, in the literature reports from the users are missing. Working towards lowering the barriers for users access to the ad hoc networking technology must be a prime objective of MANET research. However, given the current status of the MANET technology (there is virtually no deployment of multi-hop ad hoc networks that can be presented to not-expert users) it is not immediately possible to have a direct involvement of final users. Hence, indirect methods and tools need to be devised. As documented in

Deliverable D7 we investigated the users' perception of ad hoc networking potentials and limits. Measuring the users' satisfaction about the ad hoc networking paradigm does this. The problems identified and the actions taken to solve them are presented in Deliverable D8.

Finally, the economic value of the ad hoc paradigm represents the other element that may contribute to attribute a role to the ad hoc networking paradigm among the wireless networks technologies. In Deliverable D10 scenarios are investigated where ad hoc networks may have an economic value by promoting novel business processes. As a tight relationship exists between social acceptance of the MobileMAN technology and its economic value, we established a direct link between economic and social activities. The economic scenarios we developed were used to present the mobile ad hoc networking technology to the users in order to evaluate/stimulate their acceptance/interest for this technology.

The project partners performed an extensive dissemination activity during the second year of the project in different international forum (see Section 5). In fact, the innovative approach of MobileMAN to architectural analysis and design produced original and relevant results, and thus accepted for publication in several conferences and journals, invited talks and tutorials in international workshops/conferences. Project partners have been also highly involved in program committees and editorial boards of main scientific events in this field. In this way team members played a role in setting the agenda (e.g. defining special conference sessions, panels) and defining key areas of interest for the research community. Furthermore, co-operation with other national and EU projects in the field have been investigated. The MobileMAN project was presented at the workshop in Brussels (on the 10th December, 2003) organized by EC-funded ROMANTIK project (jointly with the European Commission) devoted to presenting and discussing EU projects focusing on ad hoc and multihop technologies, see http://www.ist-romantik.org/mhah-workshop/index.html. In addition, the possibility to have the exploitation of MobileMAN results in a 6th framework project is under discussion. More precisely, in a meeting held in Pisa on July 26, 2004, between the MobileMAN project (Marco Conti) and the coordinator of the IST PALCOM project (Morten Kyng) http://www.palcom.dk/ was discussed the possibility that the MobileMAN ad hoc

framework will be exploited in the PALCOM testbed (see Section 3.2 for more details). A second meeting is scheduled on mid-2005 to investigate in depth this possibility. Last, some preliminary contacts have been set up with industries that showed interest for our preliminary results. For example, after the Invited Talk given at 16th ITC Seminar** CISCO researchers expressed interest for our solutions to enhance the 802.11 cards. Furthermore, ST Microelectronics and SUPSI are already in contact for possible exploitation of results related to 802.11 enhanced cards.

** M. Conti, "Performance Modeling and Optimization of WiFi Networks", Invited talk at the 16th ITC specialist seminar "Performance Evaluation of Wireless and Mobile Systems", Antwerp, Belgium, August 31 - September 02, 2004. http://www.itcss16.ua.ac.be

2. WORK PROGRESS OVERVIEW

This project investigates the potentialities of the Mobile Ad hoc NETworks (MANET's) paradigm. Specifically, the project aims to define and develop a metropolitan area, self-organizing, and totally wireless network that we call *Mobile Metropolitan Ad hoc Network* (MobileMAN). The main technical outputs of this proposal can be summarized as follows. i) Development, validation, implementation and testing of the architecture, and related protocols, for configuring and managing a MobileMAN. ii) Physical implementation of this architecture for lowers layers (i.e., wireless technologies). iii) Integration of applications on top of our self-organized network. iv) Validation of the self-organizing paradigm from the social and economic standpoint.

During this second year, we mainly worked for the development, validation, implementation, and testing of the architecture, and related protocols, for configuring and managing a MobileMAN, and on the validation of the self-organizing paradigm from the social standpoint. The creation of an environment for promoting new business activities and processes (economic standpoint) is expected to enter next year in the project's activities. In the second year, we started to achieve some of the main expected final results of the project:

- The design, implementation (and in some cases measurements on testbeds) of effective solutions for the relevant technical issues of self-organizing networks: routing and forwarding, medium access control protocol, services, and cooperation.
- The realization of a first trial.
- The realization of a social methodology for analyzing the impact of MobileMAN.
- Identifications and analysis of scenarios were the MANET paradigm might have an economic value.
- Before giving a detailed presentation of the results achieved during the reporting period, we present the specific objectives that were identified in Deliverable D4 for the second year. This section also presents the difficulties we encountered and our actions to manage them (this information are also reported in Deliverable D9).

2.1 Specifics Objectives for the Reporting Period

The objectives reported below constitute the criteria for evaluating the success of the second year of the project identified in Deliverable D4. As shown in Section

MobileMAN architecture implementation

- Implementation and validation of the MobileMAN architecture as defined during the second year (see D5) considering both the original and the new reference model.

New applications and services

- Include the cross-layering view at application layer.
- Adaptation of existing applications (or classes of applications) identified, during the second year, as ones that can become a customer advantage, when run on top of MobileMAN, compared to traditional technologies.

Middleware

- Adaptation of Pastry middleware for the MobileMAN environment to exploit cross layering.
- Development of new solutions for P2P information delivery based on Pastry.

Co-operation Model

- Implementation and validation of the cooperation models and mechanisms defined during the second year.

Networking services

- Include the cross-layering view at network/transport layer
- Design of packet forwarding schemes suitable for MobileMAN.
- Implementation and validation of location scheme defined during the second year.
- Development and testing of a complete ad hoc network

Wireless Technologies

- Include the cross-layering view at datalink layer.
- Design and implement a full datalink layer that includes the enhanced MAC protocol for ad hoc networks as designed during the second year.

Socio-economic Model

- Apply the developed methodology for evaluating social, anthropological, and economic potential of MobileMAN, and provide the results for improving the technical parts.

2.2 Reviewers Concerns and Recommendations and Refined Success Criteria

The above success criteria, which were defined by the project partners as a result of the project self-assessment procedure, were refined and integrated to address the reviewers' concerns and recommendations listed below.

Comment1: "The potential impact of the expected project results is high. Of the results already obtained, there is a risk that the proposed modifications to the IEEE 802.11 DCF MAC may not have significant impact because the co-existence with legacy equipment is (slightly) unfavorable for the new MAC, if no additional measures are taken. A study of this point with the goal of determining potential regulatory countermeasures or economic incentives mechanisms would improve the chances of positive impact."

Our Action: We extended the success criteria for the activities related to the *Wireless Technologies* line. Specifically, in the framework of T2.9 *Domain model refinement and risk reduction,* we planned a set of activities to design and validate mechanisms to guarantee that the enhanced card operates in an efficient way also in an heterogeneous environment where enhanced and legacy equipment co-operate.

Comment2: "user satisfaction is very important and thus is the choice of a relevant application that is attractive to users."

Our Action: As in the current phase of MobileMAN it is not possible to have a direct users' access to the MobileMAN technology (the test beds we set up are suitable only for software testing), we planned a set of methods to facilitate the interaction of users with the MobileMAN world. To this end, some actions were identified (see Deliverable D8 for details):

- Tools for users' interaction. Specifically, we designed and implemented a Website to enhance the dialogue with users. Its objective is to gain the collaboration of the visitors, who can find information about the MobileMAN technology, as well as the project, and then help us to design some scenarios and applications for the use of MobileMAN through a collaborative writing tool called Wiki[2]. This form of participatory design aims at involving some end-users in the project itself and gaining views and opinions towards the technology being developed.

- Direct interactions with users (seminars, lectures, etc.) and dissemination material. While SUPSI (mainly) addressed not expert users, CNR focused its dissemination activities towards "expert users" with technical background to have preliminary and quick feedbacks on users' expectations. From preliminary interactions with the class of users represented by university students it emerged that collaborative applications, and document-sharing applications are among the most interesting applications these users can envisage for the MobileMAN technology. Hence, in this phase we developed applications belonging to this class and we mainly focussed on developing a protocol (UDDI4m) for accessing any service that integrates with our architecture and simplifies users access to applications and services implemented on top of MobileMAN.

[2] This tool allows users to modify a webpage from any browser and therefore allows the collective editing of the page content.

Comment3: "even though the study of the collaborative aspects is performed by a partner with a high technical expertise in that specific area, it is recommended that a broader view is considered, where possible. For instance, the estimation of the reputation of a node (for not forwarding packets) must take into account that the node may be hindered, either at network, MAC or physical levels. Also, there is the potential for significant results to be obtained through strengthened interaction between the "economic incentives for cooperation" related work and the work on "the cooperation enforcement mechanism (CORE)"

Our Action: Several activities were added to the second year work-plan with the involvement of 4 project partners (CNR, Cambridge, Eurecom, and SUPSI)

- Analysis of the cooperation issues in p2p systems, as suggested by the reviewers during the first year review meeting. From this analysis we generalized our selfishness model.
- Use of game theoretic studies to investigate the robustness of the planned approach (CORE).
- Extension of the mechanisms for the estimation of a node reputation by exploiting the Reliable Forwarding mechanisms.
- Analysis of the cooperation issues also from the economic and social perspective.

Comment4: "Management should enforce a closer relationship between partners working in different expertise areas, such as economics and security, or economics and technical aspects."

Our Action: We identified stronger cooperations among partners (with complementary expertises) in the following areas:

- Analysis and definition of co-operation mechanisms. Four project partners have been involved to cover technical, economic and social perspectives of the problem.
- Partners working in the economic (Cambridge) and social (SUPSI-DSAS) areas established cooperative activities to define usage scenarios to be presented to the users. More specifically, Cambridge defined some usage scenarios that have been included in the users' web site to gain views and opinions towards the technology being developed.
- We set up a testbed activity group where all partners involved (at different layers) in the prototype development participated with useful exchange and collaboration.

2.3 Overview of the Progress during the Reporting Period

During the second year, as planned, we started the activities of WP4 (Integration, Evaluation and Social Analysis) and WP5 (Dissemination and Exploitation), too. Hence all workpackages were active during the second year. They produced results according to Annex 1 and the success criteria identified at the end of the first year of the project. In particular, five deliverables were produced in the project first year; see the Deliverables'

Table below. All of them are made publicly available at the web site of the project (http://cnd.iit.cnr.it/mobileMAN). The second year activities were performed according to the Milestones defined in Annex 1. However, some schedule deviation were necessary to recover problems and difficulties that emerged during this year, see Deliverable D9. As shown in Deliverable D9 the corrective actions we planned were able to fix the problems, and at the end of this reporting period the project is well aligned with the project goals and schedule. Hereafter the second year milestones are briefly discussed.

M3 – Second year analysis of the project status;

The results of this analysis are reported in Deliverable D9.

M6 - Preliminary definition of the overall MobileMAN domain model to be used as input for WP 3 and WP 4. Meeting with the Industrial Advisory Board to present and discuss the MobileMAN domain model.

The MobileMAN domain model was subdivided in two parts: legacy model and cross-layer model. The legacy model was completely defined at the end of the first year and was approved by the project partners during the Pisa meeting on December 2003. During the second year, in the framework of Task 2.9 "Domain Model Refinement", the extension of the MobileMAN architecture and protocols to include cross-layer interactions and optimizations was carried out. The resulting architecture was presented at the meeting with IAB in Helsinki (June, 2004).

M8 –Preliminary version of the basic set of MobileMAN functionalities. First Check on the status of the implementation of all MobileMAN components;
M10 –Preliminary version of a small scale MobileMAN.

M8 and M10 have been addressed in the period June-July 2004 by an extensive experimental phase on a preliminary small scale MobileMAN. During this phase we integrated and tested the solutions for a MobileMAN defined according to the legacy architecture.

M12 – Analysis of the MobileMAN dissemination activities;

As clearly appear in Section 5, the project partners were very active and successful in disseminating MobileMAN ideas, and results. Below we briefly summarize some of the main activities performed during the second year.

To make available the MobileMAN methods and tools some thematic web site have been created:

- Social : http://mobileman.projects.supsi.ch

  This website is aimed to facilitate the interaction with users. The website structure was divided into two parts: Static part, and interactive WIKI section. The first part has the objective to inform about the technology and the project. The WIKI part is a collection of prepared pages (minimal structure) editable by any user with the goal of gaining information by them. Users had also the possibility to add pages wherever they wanted. The software used was phpWiki.

- Software: http://keskus.hut.fi/tutkimus/MobileMan/

  This web site created and maintained by HUT is mainly devoted to maintain updated releases of the software developed by HUT: ad hoc routing framework, service discovery, etc.

The project partners performed an extensive dissemination activity during the second year of the project in different international forum. These include several publications/presentations in conferences, journals and books, invited talks and tutorials in international workshops/conference. In particular, as announced at the end of the first year of the project, on July 2004 it has been jointly published by IEEE and Wiley the book “Mobile Ad Hoc Networking” co-edited (together with USA and Canada colleagues) by CNR (Marco Conti) and SUPSI (Silvia Giordano) coordinators. This book represents a milestone for the literature on MANET by presenting contributions, among the others, by Joe Maker and Scott Corson, (i.e., the co-chairs of the IETF MANET working group), and Imrich Chlamtac (i.e., Editor in chief of ACM/Kluwer MONET and WINET Journals, and the promoter of the *Mobile Computing and Communication* research inside ACM). This book constitutes an excellent vehicle for the dissemination of MobileMAN results as three chapters of this book have been written by MobileMAN

partners and present some of the project achievements in the areas of wireless technologies, security and cooperation. In addition, the publication in the *IEEE Computer* special issue on "Ad Hoc Networks" (February 2004) of an article presenting the MobileMAN approach to cross-layering provided a world-wide visibility and interest for the project given the widespread diffusion of this journal inside the IEEE Computer Society. Last, in the framework of the 1st IEEE Conference on Mobile Ad hoc and Sensor Systems (MASS) 2004[3], Marco Conti organized a panel entitled "*Is Mobile Ad Hoc Technology Ready for the Wireless Networking World*?". This panel is an outstanding vehicle to disseminate MobileMAN by presenting and discussing the MobileMAN project results with worldwide leaders in the field, such as:

Ian F. Akyldiz (Georgia Institute of Technology, USA) Editor in Chief of Ad Hoc Networks Journals, and Computer Networks Journal.

Ed Callaway (Motorola Labs, USA) member of 802.15.4 standardization committee

Mario Gerla (UCLA, USA) - project leader for several DARPA and NSF projects on Mobile Ad Hoc Networking.

Vann Hasty (MeshNetworks, USA) - Mesh Networks is an industrial leader in the mobile ad hoc networks market

Joe Macker (Naval Research Laboratory, USA) co-chair MANET IETF working group

[3] http://www.ececs.uc.edu/~cdmc/mass/

DELIVERABLES TABLE

Project Number: IST-2001-38113

Project Acronym: MOBILEMAN

Title: Mobile Metropolitan Ad hoc Networks

Del. No.	Revision	Title	Type[1]	Classification[2]	Due Date	Issue Date
D6		MobileMAN functionalities – a minimal set	**S**	Pub	October 2003	November 2003
D7		Socio-economic research methodology	**R**	Pub	March 2004	7 April 2004
D8		MobileMAN first phase	**R**	Pub	July 2004	7 August 2004
D9		MobileMAN intermediate evaluation report	**R**	Pub	September 2004	14 October 2004
D10		MobileMAN architecture, protocols, and services intermediate report	**R**	Pub	September 2004	14 October 2004

1 *R: Report; D: Demonstrator; S: Software; W: Workshop; O: Other – Specify in footnote*

2 *Int.: Internal circulation within project (and Commission Project Officer + reviewers if requested)*
Rest.: Restricted circulation list (specify in footnote) and Commission SO + reviewers only
IST: Circulation within IST Programme participants
FP5: Circulation within Framework Programme participants
Pub.: Public document

2.3.1 Deliverables Short Description

In this subsection, we briefly introduce the contents of the deliverables produced in the reporting period.

D6 *MobileMAN functionalities – a minimal set*

The aim of this deliverable was to provide a preliminary version of the software implementing, on the Linux operating system, the basic functions required to set up a MANET. The work concentrated on the implementation and analysis of routing and forwarding protocols emerging in the MANET framework. As clearly stated, in Annex 1, our approach is to use whenever possible existing software, if suitable for the project aims, and to concentrate our efforts on software integration or developing the software required to implement and test novel solutions developed inside the project. For this reason, we developed an extensible platform able to integrate both existing and novel solutions developed in the project. In addition, in the first phase we worked to integrate in the platform some of the existing MANET routing protocols. IETF MANET WG identified four major candidates routing protocols (AODV and DSR, OLSR and TBRPF). Among these, only AODV and OLSR had updated and well maintained implementations. Hence, the delivered routing framework included the AODV, OSLR routing protocols.

The software version delivered at month 13 was extensively updated during the second year as a result of several testing phases (see for example Deliverable D8) and to integrate in our ad hoc platform the updated releases of OLSR and AODV protocols. In order to make available updated versions of the software a web site dedicated to the Ad hoc Routing framework has been set up by HUT (http://keskus.hut.fi/tutkimus/MobileMan/).

The activity of this Deliverable was performed by HUT (total effort: 27 mm, including the activities of two Master students). CNR contributed with 0.5 mm. Most of these activities were performed during the first year of the project.

D7 *Socio-economic research methodology*

The aim of this deliverable is to document the activities undertaken by the social unit of the MobileMAN project to evaluate the technology from the social standpoint. We started from the assumption that there is a significant socio-cultural distance between user communities and ICT designers that may impede to anticipate users' needs and concerns. To reduce this separation, we adopted an action research approach known as 'participatory design'. This methodology was developed in Scandinavia in the late seventies and is currently used in academic, public, and private research institutes (e.g. MIT, UCLA, Microsoft, Intel, Xerox) as a strategy to anticipate and keep into account users' needs and concerns in ICT product development. During the first year, it was considered to use the methodological approach of participatory design and therefore actively involve potential end-users in the definition of the technological system.

A prerequisite to the adoption of this methodology is the development of 'user friendly' information and communication material. To this end, we produced such material to be presented (during the project second year) to various categories of stakeholders by means of focus groups to be held. We carried out a pilot test to verify the viability of this approach and concluded that other approaches to anticipate social responses to MobileMAN were more appropriate. The deliverable documents the set of interlinked activities and case studies we identified to achieve our goal. Through a user-oriented website we plan to interact with a community of potential end-users and initiate a dialogue with them that will help us in designing new applications and scenarios of use for MobileMAN. A second activity is to study similar technologies and on the basis of the gathered data anticipate the social response toward MobileMAN. We aim at understanding how users experience new information and communication technologies such as the mobile phone and wireless LAN in terms of functions, applications, ease of use and encountered difficulties. The gathered information will serve us in order to be able to provide a technology (MobileMAN) that is near to the users needs and accessibility. A third activity will focus on the categories of elderly and disabled: we intend to do a study on their relationship with information and communication technologies in order to understand in what way MobileMAN would benefit them. The test of the MobileMAN prototype and a study of the concept of cooperation with a special regard to its application in information

technologies will conclude this series of activities about the social aspects of MobileMAN. Preliminary results of these activities are presented in Deliverable D8.

The activity of this Deliverable was performed by SUPSI (total effort: 9 mm, subdivided by the first and second year of the project).

D8 *MobileMAN first phase*

The aim of this deliverable is to document the first-phase evaluation of the MobileMAN paradigm. This evaluation addressed both technical and social issues. Specifically,

- from the *technical standpoint* it presents the results obtained from a small area MobileMAN solution obtained by integrating part of the software we developed with existing software. This enabled us, by verifying that the system operates correctly, to: i) fix software problems/errors, ii) identify integration errors, iii) obtained preliminary estimates of the MobileMAN performance, and iv) to compare and contrast alternative solutions;
- from the *social standpoint* it presents the methods and tools to introduce the MobileMAN solutions to the users and to collect preliminary users' feedbacks about expectations and acceptance of this new networking paradigm.

The aim of technical activities is to perform a preliminary test of the MobileMAN solutions. In the deliverable we discuss lessons learned from our experimental work. Specifically, we present results from our prototype integrating a p2p middleware (*FreePastry*) on top of a multi-hop ad hoc network based on 802.11b technology. Recently, for this technology, it has pointed out the existence of an *ad hoc horizon* (2-3 hops and 10-20 nodes) after which the benefit of multi-hop ad hoc networking vanishes. All the experiments we performed were inside this ad hoc horizon. The aim is to compare and contrast solutions for this realistic setting, and to quantify the Quality of Service (QoS) the system is able to provide to the users. Our measurements (in addition to software problems that have been fixed) pointed out that also in this limited setting, several problems still exist to construct efficient multi-hop ad hoc

networks. Cross layering seems to be an effective approach to fix some of the problems identified in our analysis.

At this stage of the project, as direct testing with the users of the MobileMAN technology is not possible (the MobileMAN technology is not yet mature enough to be fruitful by users), for the social evaluation of the MobileMAN paradigm we identified a set of tools and methods to involve users and to collect their feedbacks. These include: an interactive users web site, users mailing list, direct presentations to the users, etc. All these "social" activities are presented in this deliverable together with very preliminary results of our interactions with potential MobileMAN users. One main lesson emerged from all the activities that involved the users: voluntary collaboration should not be taken for granted, but is a complex concept that we are currently studying in more details.

The activity of this Deliverable was performed by CNR (9.5 mm), HUT (0.5), Cambridge (0.25 mm), Eurecom (0.25 mm) and SUPSI-DSAS (1 mm). The total effort is 11.5 mm.

D9 *MobileMAN intermediate evaluation report*

The aim of this deliverable is to evaluate the activities performed during the second year of the MOBILEMAN project. During this period, the partners successfully fulfilled to the major promised project goals. Furthermore we present and discuss the lessons learned during this reporting period and the actions we performed to tackle emerging risks. By exploiting the second year experiences, this deliverable introduces the evaluation criteria for the third year, as enhancement of the project goals (as defined in the deliverable D2 "*Project Plans*") and the first- and second-year results.

It is worth noting that during the second year the self-assessment task (T1.5) was always active to continuously monitor the project activities to anticipate the risks that are intrinsic to the high degree of innovation contained in the MobileMAN project. Both social and technical potential risks emerged during the second year and the project partners activated appropriate actions to cope with them.

As expected, technical risks emerged in the first phases of the WP 4 activities. This WP has potentially associated several risks. Risks are associated both to the

integration, and to the testing phase. Integration risks are associated to the integration of components separately developed by the project partners. Software testing, integration and validation are strongly based on constructing (small) testbeds to experiment and validate the developed solutions. During the second year of the project, each project partner has the requirements to test either existing software before integrating it in the MobileMAN framework, or the software developed inside the project to implement new solutions. Each partner was able to involve in the testbed construction only a limited number of hardware resources (laptops/PDAs) and few researchers. The latter being the most critical constraint. As a consequence of these resources' limitations only very small testbeds (i.e., 3-4 nodes) can be set up, in which only a limited set of software functionalities can be investigated. In addition, also software integration and experimentation cannot be done in an efficient way having each partner working in isolation. To cope with these problems, in the MobileMAN meeting in Helsinki (7-8 June, 2004), we decided to set up a group of junior researchers that should meet on a regular basis to integrate the developed software, and set up a "reasonable" size MobileMAN to validate the developed solutions.

These experimental phases together with testing activities performed by each partner provided valuable inputs for the self-assessment phase performed at the end of the second year of the project. Specifically the following lessons derived from the second year activities:

i. Results indicate that cross layering should be included as much as possible in the prototype hence from we also activate T3.6 (*System development refinement and risk reduction*) that should coordinate the extension of the system development to include cross layer solutions. In this way the effects of the domain model changes propagate to the system implementation, integration, and testing phases.

ii. To maximize the usefulness of project results we wish to exploit as much as possible concepts/solutions (and the corresponding software implementations) already available in the literature. The use of these concepts/solutions is not straightforward due lack of testing, and/or lack of documentation. Extra efforts are required to be to analyze the code and test

off-the-shelf SW solutions before integrating them into the MobileMAN testbed.

iii. HW Platforms are not very robust/flexible. PDAs introduce not expected problems in software developing and testing. For this reason we decided to use as much as possible laptops for developing and testing. Wireless card technology when operating in ad hoc mode was in some operating scenarios not robust. Furthermore, a reliable LINUX support is not guaranteed when an upgrade of the chipset is introduced.

Social risks were pointed out with reference to the social activities to be carried out in the framework of WP 4. Specifically, during the activities carried out (mainly by SUPSI-DSAS) to validate the MobileMAN paradigm potential end-users it emerged the difficulties to stimulate the users participation without direct incentives for the users. To cope with this problem we decided to focus these activities on groups of students at HUT during the academic year starting in this September-October 2004. This would mean that the activity would be carried out later than first planned. However, it seemed a good solution to gain collaboration from a community of students by formally place the activity into a curriculum course and reward the students for their collaboration in credits or similar ways. Indeed, rewards mechanisms seem to the necessary to guarantee the users participation in MobileMAN social testing activities in a not sporadic way.

The activity of this Deliverable was performed mainly by CNR (0.75 mm), and SUPSI-DSAS (0.5 mm). The other partners contributed with (0.2 mm) each. The total effort is about 2 mm.

D10 *MobileMAN architecture, protocols, and services intermediate report*

This deliverable offers a consolidated vision of the design and implementation choices that have been made in the previous Deliverable D5 with an emphasis on the common effort towards the definition and deployment of a project-wide test-bed platform.

D10 provides an updated vision of the architecture, protocols and services designed for the MobileMAN paradigm as emerging at the end of the second year of the project. First, we present the complete architecture with the communication flows among different functions; then we discuss protocols belonging to the MobileMAN protocols' stack. Protocols are presented by following a bottom up approach from wireless technologies up to the applications. When appropriate, social and economic perspectives are introduced.

D10 addresses the domain modeling issues emerging at the end of the first-year of the project, and/or pointed out by the reviewers during the first-year review meeting: i) adapting the MobileMAN architecture to support the cross-layer interactions; ii) integration of the enhanced MAC card in an heterogeneous environment with legacy 802.11 cards; iii) a closer relationship between partners working at different layers of the architecture and/or in different expertise areas.

The organization of the deliverable is based on the following guidelines: all layers of the MobileMAN architecture are presented and discussed by providing an overview of relevant issues and the research directions that have been undertaken to solve them taking into account the different perspectives of the problem offered by the collaboration of partners with different domain of expertise. When appropriate, the social and economic perspectives are also used to compare and contrast technical solutions. Moreover, when relevant, the progress status of each part of the network stack and the design and implementation details of original components are provided.

All partners contributed to this deliverable. The activity of this Deliverable was performed mainly by CNR (9 mm), Cambridge (5.6 mm) Eurecom (4.8). Additional contributions from SUPSI (2 mm), HUT (0.5 mm) and Netikos (0.5 mm). The total effort was about 22.5 mm.

2.4 Evaluation of Work Accomplished during the Reporting Period

During the second year, we tried to achieve the promised objectives, keeping in mind the message received from reviewers at the end of the first year: the cross layering reference model is appealing, but it is important to return first the results depicted in the project proposal, which refers to the legacy architecture. For this reason, we first tried to fulfil to these objectives, and then, if compatible with the project resources, to realize the cross layering architecture. As depicted in Figure 1, we came up with an architecture that integrates both the legacy and the cross layering reference models.

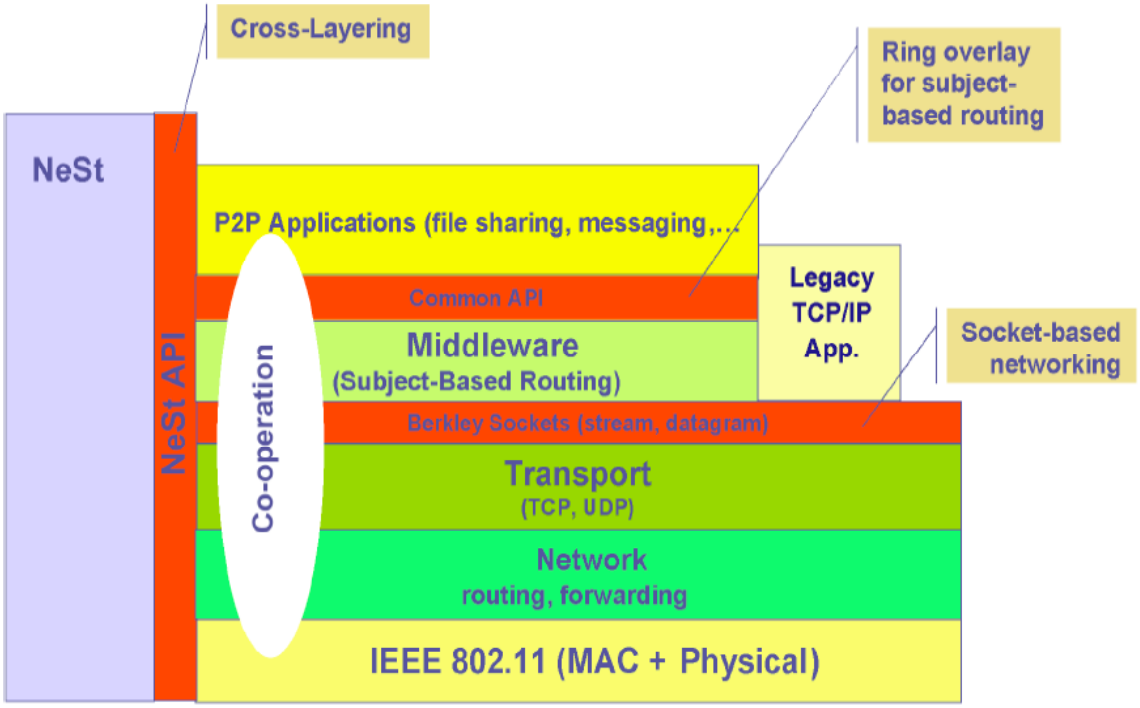

Figure 1: MobileMAN Integrated architecture

Specifically, we have a basic architecture that follows the original reference architecture defined in Annex 1. This architecture can be enhanced with cross-layer interactions if the *NeSt* is implemented and protocols implement the interfaces to interact with it.

As a consequence, the objectives for the second year (as defined in Deliverable D4 and refined after the review meeting) can be subdivided in two main classes:

- goals defined in the original project plans, as defined in Annex 1 and Deliverable D2 (Original goals), which make reference to definition, implementation and testing of the legacy architecture;

- Project goals related to the extensions of the basic architecture to exploit cross-layer interactions among different layers. These goals represent an extra-effort respect to plans contained in Annex 1 (Extra goals).

The difficulties/risks encountered in achieving the planned results, and correcting actions we performed to mitigate them, are discussed in depth in D9 *MobileMAN intermediate evaluation report* and hence it is not worth presenting again this discussion here. A summary of these difficulties and our actions is presented in the previous section where we provide a brief description of Deliverable D9.

2.4.1 Second Year Achieved Objectives

The project workplan has been fulfilled and a great majority of the project objectives (see Section 2.1) have been achieved. As explained below, some deviations from the original plans have been introduced to cope with the problems we encountered. The analysis of the second-year results is the output of Task *T1.5- Self-assessment procedure and risks mitigation* and hence documented in Deliverable D9. The material reported below, extracted from D9, is reported hereafter for completeness.

MobileMAN architecture implementation

- We achieved the implementation and the validation of the legacy part, and there is ongoing work in completing and integrating some building blocks for the cross layering part: middleware, routing, and NEST.

- We integrated and started to experiment MobileMAN solutions in trials with up to 12 nodes, with simple P2P applications (see Deliverable D8).

New applications and services

Taking into consideration preliminary users indications (see Deliverable D8) that expressed their interest for exploiting the MobileMAN technology for both cooperative activities (group communications, file sharing, etc.) and for direct communications, we identified two types of applications: i) co-operative tools for content/document sharing based on a P2P architecture; ii) Voice over IP applications exploiting the legacy TCP/IP protocol stack.

- The main work done at this layer focussed on the service aspects, where a solution for ad hoc networks was developed (UDDI4m), and there is ongoing work to integrate it with Pastry and CrossRoad.

- HUT focused on testing various SIP stacks available (e.g. Vovida, GNU oSIP, 8x8 SIP, IBM SIP Toolkit JAVA, Columbia SIP, etc.) in order to demonstrate VoIP sessions on Ad Hoc networks. After selecting the most suitable stack (i.e. Vovida stack is written on C and includes all necessary modules so can be integrated in the iPAQ), the stack was integrated and tested during the September test meeting in Pisa.

- A p2p collaborative application was developed by Cambridge to run on top of Bamboo platform. As this platform use the same Common API of Pastry, the integration of this application in the MobileMAN testbed is now undergoing.

- We also introduced some testing p2p applications (e.g., distributed mail boxes, see Deliverable D8) that were used in our experimentations.

Middleware

- We tested and integrated, in the MobileMAN architecture, a free implementation of Pastry (FreePastry).

- A new middleware (CrossRoad) for ad hoc networks was designed and developed. It optimizes the Pastry platform by exploiting cross layer interactions with the network layer.

Co-operation Model

- We generalized the cooperation model by integrating in a single local policy the CORE and Reliable Forwarding mechanisms.

- By exploiting a non-cooperative game model we showed the effectiveness of the CORE mechanisms with respect to other policies proposed in the literature.

- We partially completed the implementation and validation of the CORE and mechanisms. The final part (punishment) is still ongoing due to the difficulties we encountered with the existing SW and HW.

- We performed a social analysis of cooperation (see Socio-economic aspects below)

- We presented a critical analysis of cooperation enforcing from an economic perspective.

Networking services

- We extended a proactive routing protocol (HSLS) to support the cross-layer view at network layer. The software architecture of the protocol has been fully defined, and its implementation is currently ongoing.

- We designed and evaluated a packet-forwarding scheme (REEF) suitable for MobileMAN.

- We designed and implemented a network-layer support for the generalized Service Discovery Module (SDM). SDM provides the basic functionalities to implement (in an efficient way by exploiting cross layering) at the middleware layer the discovery of any service.

- We did not specifically covered the issue of a location scheme as (1) this can be considered as a one specific service realizable by SDM, and (2) as it emerged both from our experimental results and the literature with the current technology only small- medium-

scale ad hoc network are realistic. For this type of networks, the location issue is no more a key aspect.

Wireless Technologies

- We have an ongoing design study that includes the cross-layering view at data-link layer.

- We refined the AOB mechanism to effectively operate in a heterogeneous environment where enhanced and legacy cards co-exist. We also showed that our solution based on a credit mechanism is useful also to fix some problems occurring in the multi-hop environment.

- We designed, and implemented the platform for the enhanced card. As planned, this required to fully re-writing the MAC protocol on the selected HW platform. At this stage we have already implemented and validated a standard 802.11 data-link layer in point-to-point and multiple stations configurations. We also designed how to include the enhanced MAC protocol in the HW platform, and this implementation is ongoing.

Socio-Economic Model

- We applied the participatory design methodology, and discovered that was not really useful for the MobileMAN scenario. For that reason, we developed a more ad hoc solution, which gave us better results.

- As previously anticipated, we also discovered that it is very difficult to involve users in the experiments: without any incentive, they are no willing to collaborate. For that reason, we included the participation to MobileMAN test in the program of courses at HUT: the reward given by the final evaluation is supposed to be a good incentive to be co-operative.

2.5 Activities

According to the different perspectives of the MANET-paradigm investigation, the project activities, as explained in Deliverable D2, were naturally subdivided into three main areas (technical, social, and economic). The Figure 2 below points out the relationships existing between these areas, and the participants to each project area.

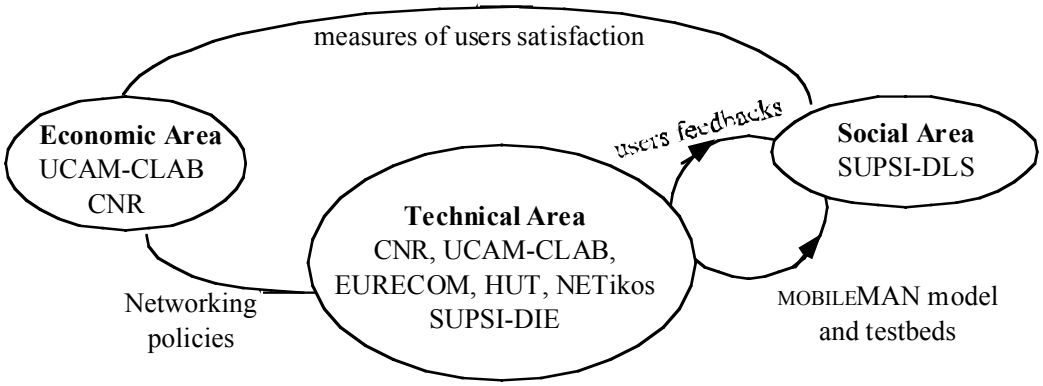

Figure 2: Relationships among the project activities

The economic and social activities were mainly under the responsibility of a single partner: Cambridge and SUPSI-DLS (now named SUPSI- DSAS), respectively. On the other hand, almost all partners contributed to the activities of the Technical Area.

During the second year of the project, the cooperation among partners was consolidated and synergies strengthen; thus partners with different expertise contributed to achieve a given objective by providing different perspectives to a problem solution. This modified the relationships among the project activities as shown in Figure 3 that presents the refinement of relationships identified at the beginning of the project and shown in Figure 2. In particular the task related to co-operation was addressed not only from the Technical perspective, but also economic and social perspectives were introduced in tackling this issue that is now a joint effort of all areas.

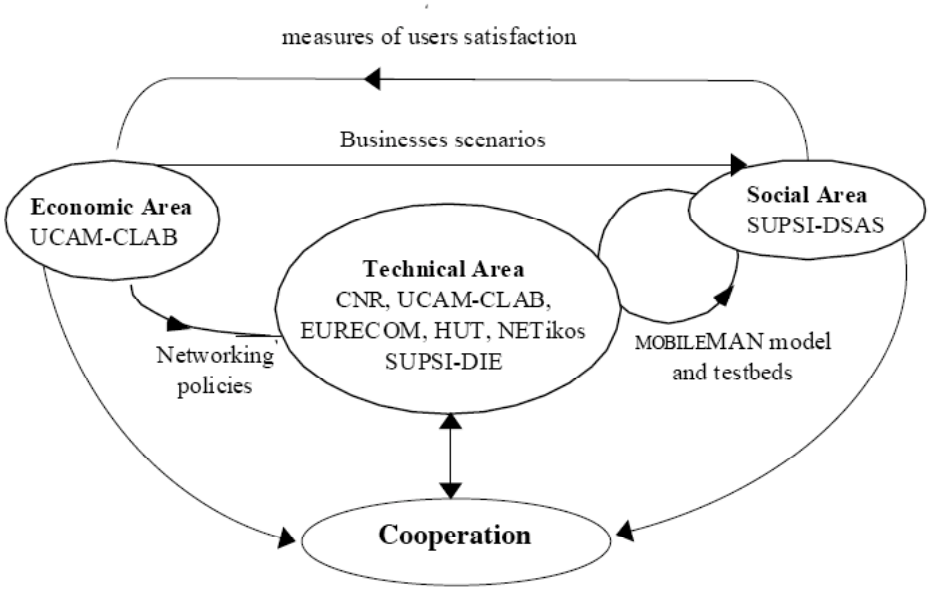

Figure 3: Refined Relationships among the project activities

The greater integration among different partners is well reflected by the activities performed during the second year (as detailed hereafter), and their contribution to deliverables. Indeed, the first two deliverables of the second year D6 (*MobileMAN functionalities – a minimal set*) and D7 (D7 *Socio-economic research methodology*), which document activities mainly performed during the first year, still present a separation between the Technical, Economic and Social Areas (D6 and D7 were produced by the

Technical and Social Areas, respectively). On the other hand, deliverables D8, D9, and D10 had contributions from all project partners.

As defined in Annex 1, during the second year all work-packages are active.

WP0 and WP1 are aimed, respectively, to manage the project and to establishing a common baseline for the project activities to be accomplished during its lifetime. In addition, in the framework of WP1 we performed, at the end of the second year, the self-assessment task to evaluate the work accomplished during the second year as reported in Deliverable D9.

WP0 was devoted to project management and included all the activities performed during the second year to guarantee the successful completion of the project within agreed time, cost and quality, compliance with the EC standard and procedures for the project management and tracking, an effective communication channel among the consortium partners. This included the organization of regular technical and management project meetings.

The WP1 activities concentrated in the Task *T1.5- Self-assessment procedure and risks mitigation* to verify the alignment with the project goals, control the quality of what has been produced, and identify and manage the project risks. This task produced Deliverable D9 as its output.

The second year technical activities spread through WP2, WP3 and WP4. Results achieved during the project were disseminated according to the actions identified in WP5 (mainly *T5.1 Dissemination*). Hereafter, we detail the activities performed in WP2, WP3, WP4 and WP5.

2.5.1 WP 2 Activities

The aim of WP 2 is to define the MobileMAN architecture and protocols. In addition, the WP provides models and methods for investigating the socio and economic value of the ad hoc networking paradigm. During the second year, the activities concentrated on the following three tasks:

- T2.7 *Socio-economic modelling*
- T2.8 *Economic driven modelling*
- T2.9 *Domain model refinement and risk reduction*

2.5.1.1 T2.7 Socio-economic modelling

The aim of the task is to develop a methodology for evaluating social, anthropological and economic potential of MobileMAN. The main activity in this framework was undertaken by the social unit (SUPSI-DSAS) by exploiting during the second half of the year some collaborations with University of Cambridge to better investigate the economic part of the MobileMAN paradigm. CNR provided a minor contribution by interacting with a class of users, university students, to have their feedbacks on interesting applicative scenarios for the MobileMAN technology.

The first phase of this activity (mainly carried out during the first year of the project) was aimed to analyze the methodological approach of participatory design, and therefore actively involve potential end-users in the definition of the technological system. We carried out a pilot test to verify the viability of this approach and concluded that other approaches to anticipate social responses to MobileMAN were more appropriate (see Deliverable D7). These include:

a) enhance a dialogue between system developers and potential MobileMAN customers through an end-users project website;
b) study the social dimension of wireless technologies in use as a strategy to anticipate responses to MobileMAN;
c) review the needs and concerns of the communities of elderly and disabled people in relation to wireless ICTs;
d) test the MobileMAN fully functional prototype with a community of students;

The first step we performed was the Design and Implementation of a Website to enhance the dialogue with users. The website oriented to MobileMAN potential end-users was

designed, implemented and was ready by the month of June 2004[4]. The web-site development was done by SUPSI with the support of University of Cambridge to identify suitable scenarios to be presented to the users.

Its objective is to gain the collaboration of the visitors, who can find information about the MobileMAN technology, as well as the project, and then help us to design some scenarios and applications for the use of MobileMAN through a collaborative writing tool called Wiki[5]. This form of participatory design aims at involving some end-users in the project itself and gaining views and opinions towards the technology being developed.

This activity was subdivided in two phases: a **first** test phase with students to check whether collaboration was to be expected. After that, a **second** phase was planned: this would consist of the involvement of web users who are interested in new technologies and technological development. In fact, these people are the most likely "innovators" – that is, the first adopters of a new technology being marketed[6]. However, the first test phase with a community of students gave us some results that showed the necessity to revise this activity and to postpone it to the third project year. The main result of this phase was about the issue of collaboration. It was demonstrated that for the students, the cost (in generic terms of time and effort) of the collaboration was too high in relation to the benefit they would gain back and, therefore, levels of collaboration were low. The new strategy, to be put in action during the coming months, will consist of creating a way to incentive the students to participate. For this reason, the activity will be framed within academic courses, with rewarded participation by the students. The activity will consist of groups of 3 or 4 students elaborating scenarios in which the employment of MobileMAN will give to the users interesting benefits. After that, students will be requested to choose three scenarios among all the elaborated ones and provide some comments on them or complete them. The activity will conclude with a questionnaire to fill in that will have the objective to find out the attitudes and opinions towards both technologies in use and MobileMAN itself. Students will be rewarded for participation in modalities that will be discussed with

[4] Website URL: http://mobileman.projects.supsi.ch

[5] The version of Wiki used for the website was phpWiki. This tool allows users to modify a webpage from any browser and therefore allows the collective editing of the page content.

[6] According to Norman, 1998 (The Invisible Computer), adopters of technology are divided in groups (innovators, early adopters, early majority, late majority and skeptics). Innovators are the first to accept and adopt a technology. Eventually, a successful technology will go through the phases of adoption until the late majority (mass) has also decided to adopt it. Unsuccessful products do not reach this phase.

responsible persons of the involved courses. The second phase will be also an occasion for the dissemination of the technology and the project results.

2.5.1.2 T2.8 Economic driven modelling

Research work at Cambridge SRG continued on examining the economic aspects of MobileMAN. The work looked at higher-level questions of business models that need to accompany good technical MobileMAN solutions so that the probability of overall success can be raised. These models determine the relationships that exist between players and how these players can influence outcomes for the network. To get a concrete understanding of the issues involved, usage scenarios can be envisaged revealing some of the situations that will be faced during the operation of the network. Firstly, we introduced a framework, which allowed us to classify typical business players that are required to deploy and operate general networks. Then we identified core strengths and weaknesses of the MobileMAN paradigm in order to come up with scenarios and applications best suited to it and identify the user segments most likely to benefit. At this point we were ready to come up with scenarios and applications best suited to it and identify the user segments most likely to benefit. Following on, we designed three scenarios (Taxi Dispatch, mobile games, and Shopping Mall) to illustrate the wide variety of possible uses of ad hoc networks. These scenarios show that applications for ad hoc networks need to be tailored to take into account the unique strengths and weaknesses of the technology as well as the fact that unique business models need to be used to make the networks financially viable. They also highlight the problems that are likely to be faced when implementing such systems. Through the analysis of these scenarios, we can draw a number of conclusions about where and how MANET's should be used in order to achieve financially viable networks. It can be seen through the very different scenarios presented that revenue is not generated from the provision of the service itself, but rather through the enhanced value that it brings to the application it is used for. Another key challenge for ad hoc technology in any business application is to encourage a large enough number of early adopters to use the technology in order to build up critical mass.

As MANET are based on users collaboration, we analyzed the cooperation issues in ad hoc network by taking into consideration the economic value for users to not cooperate. We argued that there might not be a need for incentive systems at all, especially in the early

stages of adoption, where excessive complexity can only hurt the technology's deployment. We looked at the needs of different customers segments for each stage within the projected technology adoption cycle and proposed that incentive systems not be used until ad hoc networks enter mainstream markets. Even then, incentive systems should be tailored to the needs of each individual application rather than a general cookie cutter solution that may be too flawed or technically demanding to be implemented in reality. Punishments/incentives other than the denial of service to misbehaving nodes might be considered as an alternative. For example, within a file sharing application, users might be punished by limiting their query returns, rather than ostracising them from the network completely.

2.5.1.3 T2.9 Domain model refinement and risk reduction

One of the main first-year lessons was related to the potentialities of "cross-layering" in MANET design that it is worth to exploit in the MobileMAN project. This was also confirmed during the first-year review meeting. To achieve this, it was decided to extend the reference model of MobileMAN as defined in Annex 1. A new reference architecture, where parameters and information are exchanged among services and protocols by means of a widely accessible component was introduced (in line with current evolution of wireless research) to achieve better performance in the MobileMAN network (see Deliverable D5). To exploit the potentialities of the new architecture the MobileMAN we decided to activate the task T2.9 *Domain model refinement and risk reduction*. The main objective of task T2.9 is the refinement of the domain model to take into account the impact of cross layering on the MobileMAN architecture and protocols. Furthermore, to reduce the risks, we decided to continue also the development of the original reference architecture as defined in Annex 1. Therefore, Task T2.9 also includes activities devoted to refining the original MobileMAN architecture and its protocols.

The resulting MobileMAN architecture is shown in Figure 1. As explained in D5 and D10, the Network Status (NeSt) is the element that guarantees indirect cross-layer interactions among the protocol layers. If cross layer interactions are not supported the architecture reduced to the original MobileMAN reference architecture as defined in Annex 1.

The activities performed in Task T2.9 focused on definition e/o refinement of all the layers of the architecture including the NeSt.

2.5.1.3.1 NeSt

The *Network Status*[7] (NeSt) is the basic element we have designed to introduce cross-layering interactions in the MobileMAN architecture still maintaining the layer separation principle. To this end the NeSt stands vertically beside the network stack handling eventual cross-layer interactions among protocols. The idea is to have the NeSt exporting an interface toward protocols, so as to allow sharing of information and reaction to particular events. The work described in Deliverable D5 introduces this idea as it emerged at the end of the project first-year. The work performed during the second year completes the NeSt specification by defining interaction models, and presenting the exported interface. A detailed presentation of the NeSt interaction models, and exported interface is reported in deliverable D10.

2.5.1.3.2 Applications and New Services

Taking into consideration preliminary users indications (see Deliverable D8) that expressed their interest for exploiting the MobileMAN technology for both cooperative activities (group communications, file sharing, etc.) and for direct communications, we identified two types of applications:

- co-operative services for content/document sharing based on a P2P architecture that points out the co-operative nature of Mobile ad Hoc networks.
- Voice over IP applications exploiting the legacy TCP/IP protocol stack.

Applications providing content/document sharing require the support of service discovery and delivery protocols. In the literature there are many discovery service protocols for the wireless networks, but these protocols rely on an infrastructure such as Access Points, or Home/Foreign Agent. In an ad hoc network each node is at the same level so there aren't dedicated nodes. In the framework of the MobileMAN project, Netikos explored the idea to introduce a supplemental level between the transport and the application layer that provides a service location distributed among all present nodes in the network. In particular, the objective has been to extend the Universal Description, Discovery and Integration specifications (that define a way to publish and discover information about Web services) to obtain a UDDI service distributed among all the devices of the network.

[7] This name indicates the collection of network information which a node gathers at all layers. It should not be confused with a concept of globally shared network context.

As shown in Section 6 of Deliverable D10, during the second year of the project the classic UDDI scheme has been modified and fitted in Mobile Ad Hoc environment (UDDI4m).

As an example of a collaborative application for content/document sharing we selected a scalable and flexible whiteboard multicast application for peer-to-peer systems based on the Common API used by several middleware platforms such as Pastry, Bamboo, etc. This application provides the basic functionality like subscribing to an arbitrary topic and publishing changes on the canvas to the multicast group associated to the topic. The multicast group in this context could be dynamic, in which the members join and leave at anytime. A multicast protocol layer was created for Bamboo substrate. Besides the multicast function, it also provides a communication interface for the application to use its services.

HUT has focused on testing various SIP stacks available (e.g. Vovida, GNU oSIP, 8x8 SIP, IBM SIP Toolkit JAVA, Columbia SIP, etc.) in order to demonstrate VoIP sessions on Ad Hoc networks. After selecting the most suitable stack (i.e. Vovida stack is written on C and includes all necessary modules so can be integrated in the iPAQ), the stack was integrated and tested. The result was that SIP stacks that perform well in nodes with enough resources (e.g. laptops) do not work properly on nodes with limited resources (i.e. iPAQ). The voice quality was poor and hence we developed a lightweight implementation. The new SIP stack requires less resources and the end-to-end delay is minimized because the processing delay has been reduced.

2.5.1.3.3 Bursty-responsive MAC

During the first year of the project we developed an algorithm to enhance the 802.11 back off algorithm that utilizes a very simple estimate of the channel conditions, which can be measured by all stations inside the physical carrier sensing range of the transmitting one. Specifically, our mechanism, named Asymptotically Optimal Backoff (AOB), dynamically adapts the backoff window size to the current network contention level, and guarantees that an IEEE 802.11 WLAN asymptotically achieves its optimal channel utilization. As pointed out during the first review meeting this mechanism may suffer when operating in a

heterogeneous environment "the co-existence with legacy equipment is (slightly) unfavorable for the new MAC, if no additional measures are taken."

During the second year of the project, we carefully investigated this aspect and we extended the AOB protocol with a credit-based mechanism (see Deliverable D10) to enforce fairness in heterogeneous networks. Specifically, a station using the enhanced AOB card, is remunerated with credits each time it postpones a transmission attempt, credits that the station will spend to be rewarded with new transmission opportunities (multiple consecutive transmissions). The proposed credit-based mechanism guarantees that: i) stations using the AOB scheme are not penalized with respect to legacy 802.11 Wireless cards, ii) that in a network of enhanced cards only, implementing the credit mechanism, the maximum achievable throughput increases. Simulation studies show the effectiveness of the proposed mechanism in all the network scenarios investigated.

It is worth pointing out that multiple consecutive transmissions is a mechanism under consideration under the task group 802.11*n* to achieve higher throughput in 802.11 MAC. However no rule is identified in the task group 802.11*n* to define the number of multiple transmissions; on the other hand, our credit mechanisms introduce multiple transmissions by guaranteeing both fairness and optimal behavior.

2.5.1.3.4 T2.4 networking services refinement

The activities at this level focused on enhancing the Network layer functionalities to exploit/support the cross layer interactions. Three activities were performed: i) extension of the ad hoc routing framework to include a scalable, pro-active routing protocol; ii) extension of link state packets to support service discovery; and iii) definition and evaluation of a reliable forwarding scheme.

As far as point i), we investigated the family of *Link State* routing protocol based on *Limited Dissemination* policies and we selected for our routing framework the **Hazy Sighted Link State (HSLS)** in which routing updates are flooded in the network with a binary exponential sequence. The reliability mechanism was then added to guarantee

reliable information dissemination. Last, we extended the software architecture of the ad hoc routing framework to include HSLS.

In the area of service discovery a design for including service information within link information was completed (and is under testing). This task considers including service information in the link state messages. This approach allows exchanging service information within the routing packets. The nodes can obtain the service information directly from the routing layer or they can issue a service discovery request to find services in the Ad Hoc network. The service discovery module includes extensions to reactive routing protocol (i.e. AODV) to search services in other nodes.

Last, the reliable forwarding scheme already presented in Deliverable D5 has been refined and evaluated. This activity produced a lightweight mechanism named REEF (Reliable and Efficient Forwarding (REEF)) which mitigates the effects of adverse situations caused by cooperation misbehavior or network fault conditions. It exploits nodes' local knowledge to estimate route reliability and multi-path routing to forward packets on the most reliable route. REEF can also be part of the MobileMAN cooperation enforcing mechanism (see next section).

2.5.1.3.5 Security and Co-operation Model and Mechanisms

During the first year of the project we defined a cooperation enforcement mechanism "CORE" that encourages users to behave as "good citizens" and we provided a formal assessment of the properties of the CORE mechanism using cooperative game theory.

During the second year the Game theoretical validation of Core was extended to provide a more realistic representation of communication errors that affect the monitoring mechanism used by CORE, and other similar cooperation mechanisms.

The new game theoretical approach has been shown to be particularly adapted for the definition of an advanced simulation methodology called evolutionary simulation. In this setting, population of nodes compete for survival by adopting a given cooperation strategy: if the cooperation policy used by members of a population is more efficient than another policy used by a competing population, the winning population size increases until a stable point (if exists) while the population that used the loosing strategy gradually disappears. Numerical results based on the new simulation approach have shown that the CORE

mechanism is superior to other similar approaches available in the literature and that it is evolutionary stable.

During the review meeting it was recommended that a broader view be considered, where possible. To address this issue, several activities were added to the second year work-plan with the involvement of 4 project partners (CNR, Cambridge, Eurecom, and SUPSI) in order to tackle the cooperation problem from different perspectives: technical, social, and economic.

First of all, the analyzed how cooperation issues were addressed in p2p systems, as suggested by the reviewers during the first year review meeting. From this analysis we generalized our selfishness model. It clearly resulted that selfishness is highly dependent on human behavior and hence we also investigated the problem from a social science perspective to understand under what conditions does an individual voluntarily cooperate to pursue a common goal.

We also showed that cooperation-enforcing mechanisms based on "economic incentives" have a number of inherent flaws that make them difficult and undesirable to implement in practice. If badly implemented, some of them even have the potential to backfire by offering an incentive to cheat the incentives system in order to gain further benefits.

These problems do not affect our cooperation-enforcing model as it is based on a local policy, i.e., a node takes its decisions by exploiting its own knowledge of the system:

i) a node by observing the network collects information about the behavior of other nodes; this information is used to construct estimates of the other nodes reputations (i.e., a measure of their wiliness to cooperate).
ii) By exploiting the reputation indexes, a cooperation enforcing policy is then applied when the node should provide a service to the other nodes (e.g., traffic forwarding).

During the second year the two steps of our cooperation-enforcing model were refined to take into consideration the generalized selfish model resulting from the studies of cooperation in other systems. Specifically, as far as point i) we can use in addition to the watchdog mechanism, the reliability estimates provided by REEF; while to enforce the cooperation we introduce a priority policy to control traffic forwarding. Indeed as pointed out in the economic analysis presented in Section 7 of Deliverable D10: "*…Punishments/incentives other than the denial of service to misbehaving nodes might be considered as an alternative. For example, within a file sharing application, users might*

be punished by limiting their query returns, rather than ostracising them from the network completely."

2.5.1.3.6 P2P information delivery

A new middleware (CrossRoad) for ad hoc networks was designed and developed. It optimizes the Pastry platform by exploiting cross layer interactions with the network layer. Applying Pastry through classical legacy architecture to ad hoc networks is not the real solution to realize an optimized middleware platform for this kind of scenario. In fact Pastry is designed for wired network where thousands of nodes take part to the same service in order to share and exchange information. In this case, nodes have generally fixed positions and they have not power constraints or connection problems, while in ad hoc networks mobile nodes cause frequent topology updates due to their movements and also to possible coverage problems. In addition, they also have to save energy. The performance problems in using Pastry over an ad hoc network have been pointed out in Deliverable D8 were we report the results we got in a small scale ad hoc network in which Pastry was implemented on top of an 802.11 ad hoc network. Particularly, join operations and monitoring overlay status require a lot of remote connections, not only to physical neighbors, producing a big overhead for ad hoc networks. In addition the distribution and recovery of information, forcing the message forwarding to use additional path due to the subject-based policy, can introduce a further overhead.
Applying the cross-layer architecture in order to share information between the network layer and the middleware layer, we have planned a new solution that has been named *CrossRoad*: *CROSS-layer Ring Overlay for AD hoc networks*. A presentation of CrossRoad is given in Deliverable D10.

2.5.2 WP3 Activities

During the second year, we continued the WP3 activities started during the first year (on T3.1 *Bursty-responsive MAC* and T3.3 *Routing and forwarding*) and activated the activities of all the other tasks of this WP.

2.5.2.1 T3.1 Bursty-responsive MAC

The work done in the last 12 month was basically split in two parallel activities:

- the first activity focused on the hardware development. The developed hardware is based on a modified commercial 802.11 system, and it includes the firmware for both the standard 802.11 MAC and the modified MAC, which is much better adapted for mobile ad-hoc networks.
- the second activity focused on the software for packet- and other data management within the access hardware. Starting from the analysis of the standard 802.11, and considering the desirable requirements of a mobile ad-hoc network, an optimized software architecture is being developed. The software architecture cornerstone, and the first item that will be developed is the data structure.

Access technology (hardware and firmware)

During the second project year, the following work has been completed on the Medium Access Control platform.

- Deep analysis of the 802.11 standard
- Flowcharts and procedures definition the Tx/Rx
- Implementation of the monitor loop
- Implementation of the 802.11 MAC CRC on the embedded FPGA (this is an Intellectual Property block with source written in VHDL)
- Implementation of Tx routines (MAC to BB/RF modem)
- Implementation of Rx routines (BB/RF modem to MAC)
- Implementation of the channel sensing mechanism (signals from RF part)
- Implementation of the standard 802.11 backoff mechanism
- Implementation of the regular 802.11 frame generation
- Implementation of the fragmented frame generation
- Implementation of the RTS/CTS/DATA/AK handshake
- Implementation of the MAC Address recognition
- Implementation of the channel contention mechanism

The realized firmware gave the possibility to perform a first series of tests on the actual systems: the correct firmware functionality has been successfully verified with the help of following tests (2 platforms where connected through a *coaxial cable* in a "laboratory set-up"):

- Stress test of Tx between 2 systems
- Stress test of Rx between 2 systems
- Stress test of alternating Tx/Rx between 2 systems

Moreover, tests have been performed in wireless mode also, with the 2 systems connected through off-the-shelf WLAN antennas; following functionalities have been successfully verified:

- Alternating Tx/Rx between 2 systems
- Tx/Rx with standard backoff mechanism activated (collisions were artificially forced)
- Fragmented Tx/Rx transmissions
- Handshake mechanism in RTS/CTS/DATA/AK transmissions

Data structure for packet- and other data management within the access hardware

The present stage has passed trough the analysis and design and now is going on in to the implementation phase.

The analysis pointed out all the aspects that must be taken into consideration designing of such a software, in particular: the memory management, a descriptor mechanism, different descriptors queues for managing data transfers, an implementation of priority mechanisms for each queue and the control flags.

In the design phase all the most critical aspects of the data structure has been defined, in which there are: the packet management mechanism, the data area structure, the data storage procedure, the transmission and reception descriptor areas and the descriptor structure.

2.5.2.2 T3.2 Implementation of Location Protocols

As explained in Deliverable D9, instead of concentrating our efforts on the development of a specific node location scheme (that given the size of a realistic ad hoc network is of limited usefulness) we focused our effort on the implementation of the Service Discovery Module that provides the support for implementing the service required by any discovery/location service. Specifically, we designed and implemented a network-layer support for the generalized Service Discovery Module (SDM). SDM provides the basic functionalities to implement (in an efficient way by exploiting cross layering) at the middleware layer the discovery of any service. To this aim we included service information in the link state messages of OLSR protocol. This approach allows exchanging service information within the OLSR packets. The nodes can obtain the service information directly from the routing layer or they can issue a service discovery request to find services in the Ad Hoc network. The service discovery module includes extensions to reactive routing protocol (i.e. AODV) to search services in other nodes.

In addition to this, Netikos focused on the adaptation to mobile ad hoc architecture of an application for location services and service information retrieving. Specifically, we developed an application for Service Discovery based on UDDI approach that will be integrated within the ad hoc environment via the selected Pastry Middleware.

2.5.2.3 T3.3 Routing and forwarding

The implementation activities related to routing and forwarding must be subdivided in two parts. With reference to the legacy architecture the main effort was related to the maintenance of the ad hoc routing framework (mainly) developed during the first year. Specifically, in addition to software development activities required to fix the bugs emerging during software integration and testing, a significant effort was required to update the framework to integrate the new releases of the OLSR and AODV protocols.
Furthermore, in order to implement a proof-of-concept prototype for the cross-layer architecture:

- We extended a proactive routing protocol (HSLS) to support the cross-layer view at network layer. The software architecture of the protocol has been fully defined, and its implementation is currently ongoing.

- We designed and implemented a network-layer support for the generalized Service Discovery Module (SDM).

2.5.2.4 T3.4 Security and Co-operation Model

The activities of this task focused on the implementation of the CORE mechanism for the Linux operating system. In order to set up a real life test bed the first activity carried out was a survey of the hardware available on the market. Results of this study have been shared across the whole MobileMAN community in order to define a kind of common development platform and as a result the proposed hardware has been partly adopted by the CNR and HUT research teams. We chose to use Compaq iPaq 3950 as nodes of the test-bed mobile ad-hoc network, as the personal assistants better incarnate the features of a node of such a network in terms of mobility and energy constraints. Unfortunately as explained in D9, this platform is not very robust and flexible for software development and this caused some not expected problems which result in some delays on the planned schedule.
For our research purposes, we need WLAN adapters that support the promiscuous mode. We selected the Dell Truemobile 1150 WLAN adapters. We chose as an operating system Familiar Linux distribution. In order to set up a multi-hop test-bed, we evaluated several existing routing protocol for ad-hoc network implementations. We decided to use Unik

OLSR. This implementation turned out to be the best available because it is well-maintained, well-documented and really stable.

After those preliminary steps we started the design of the software module that realizes the functions of the CORE cooperation enforcement mechanism. The CORE module defined during the first year was refined to make it completely independent of the routing protocol implementation. This means that the CORE module does not exchange any information with the routing protocol and that CORE module can be operated beside any routing protocol implementation. CORE has been then implemented as a Linux daemon.

CORE software architecture can be decomposed in three building blocks:

- A MAC layer sniffer that monitors the packets that pass across layer 2 of the TCP/IP stack of a node and deduces whether neighbors are participating or not to basic networking functions. Monitoring of neighbors behavior is achieved by setting the WLAN card in promiscuous mode.
- A reputation function that according to the output of the MAC layer sniffer, calculates a reputation value for each neighboring node and marks neighbors as selfish when their reputation falls below a given threshold.
- A punishment mechanism that punishes neighbors marked as selfish. According to a simple punishment model, a node punishes a selfish neighbor by refusing the forwarding of the selfish neighbor packets. A selfish node can be reintegrated in the MANET if it restarts performing packet forwarding function.

Currently, the first two modules have been completed while we have a small delay, due to the HW platform problems, in completing the third module that however will be completed during the first 2-3 months of the third year of the project. The testing and debugging phase is ongoing and it is affected by delays due to the instability of the iPaq hardware when combined with the Familiar Linux distribution. Some bugs mainly related to the integration of Hash tables library were found and corrected. Some other bugs emerged related to the layer 2-sniffer code.

When designing CORE software architecture, special attention was put on designing a power aware mechanism. This has been achieved minimizing the processing of packets in the CORE module.

2.5.2.5 T3.5 P2P delivery mechanisms

Two types of activities were performed:

i) integration of the Pastry in the MobileMAN small scale testbed. To this aim a free implementation named FreePastry provided by Rice University, has been integrated in the MobileMAN testbed used for a first field trial (see D8).

ii) Implementation of the CrossRoad. Currently CrossRoad software architecture is completely defined and the implementation is under development. As soon as it will be ready, an experimental phase will be planned to compare the legacy and the cross-layer architectures. In the meantime, the experimentation with a legacy ad hoc network has been started in order to evaluate the real behavior of Pastry and quantify the overhead introduced.

2.5.2.6 T3.6 Risk reduction in the system development

This task was activated during the second year to identify suitable actions to fix the problems emerging in the HW (PDA, wireless cards) and SW platform (off-the-shelf components not reliable/documented). An in depth discussion of these problems is reported in Deliverable D9.

2.5.3 **WP4 Activities**

During the second year, WP4 activities concentrated as planned on T4.1, T4.2 and T4.3. Task 4.1 activities were successfully completed, according to the planned schedule, as well as Task 4.2 technical activities (see D8). On the other hand, as explained in Deliverables D8 and D9, a temporal shift occurred in the validation of the MobileMAN paradigm from the social standpoint. Indeed methods and tools for the social validation have been designed and implemented as planned, but we experienced problems in the users involvement.

2.5.3.1 T4.1 Small Area Scale Integration:

We integrated HW/SW components either developed by project partners (reduced networking and services capabilities) or using off-the-shelf components to construct a small scale MobileMAN testbed. Specifically, by exploiting a multi-hop ad hoc network based on 802.11b technology, we integrated a peer-to-peer middleware (Pastry) on top of a multi-hop ad hoc network based on AODV and OLSR routing solutions. In addition, simple test applications have been used on top of Pastry to measure the application-level

quality of service.[8] In this way we were able to identify HW/SW problems. Fix problems/errors found in the software and verifying that the system operates correctly. A detailed description of these activities can be found in Deliverable D8.

2.5.3.2 T4.2 Small Area Scale Validation and Analysis:

The aim of these activities was to validate the small scale MobileMAN from a technical (i.e., the technical constraints and limitations of the system), and social standpoint. The technical objectives were fully achieved by setting up a prototype of a multi-hop ad hoc network, and testing its performance on a small-scale ad hoc network (up to 12 nodes).
Our measurements pointed out that also in this limited setting, several problems still exist to construct efficient multi-hop ad hoc networks. Cross layering seems to be an effective approach to fix some of the problems identified in our analysis.

At this stage of the project, direct testing with the users of the MobileMAN technology was not possible (the MobileMAN technology is not yet mature enough to be fruitful by users), for the social evaluation of the MobileMAN paradigm we identified a set of tools and methods to involve users and to collect their feedbacks. These include: an interactive users web site, users mailing list, direct presentations to the users, etc. While these tools were developed on time according the schedule some problems emerged when using them to interact with the community of users we selected, university students. Specifically, we learned that for the students, the cost (in generic terms of time and effort) of the collaboration was too high in relation to the benefit they would gain back and, therefore, levels of collaboration were low. To overcome this problem a new strategy, to be put in action during the coming months, will consist of creating a way to incentive the students to participate. For this reason, the activity will be framed within HUT academic courses, with rewarded participation by the students. This caused a temporal shift of the social validation from summer to fall 2004.

[8] In the tests performed at the end of September 2004, we also integrated in our environment a lightweight VoIP application.

2.5.3.3 T4.3 Evaluation of MobileMAN Networking:

The aim of this task is to develop a simulative study of the MobileMAN Networking components with other relevant elements as the connection to Internet, as well as congestion control and error recovery mechanisms to optimise the utilization of the resources. As explained in Deliverable D9, we are currently developing in the ns framework the full MobileMAN cross layer architecture to study, cross layer interactions between: middleware, transport and network layer. The simulation model will also enable the study of the cross layer architecture on a larger scale with respect to testbed experiments. Currently, we have already completed the implementation of all mechanisms at the network layer to support cross layer interactions: multi-path extension of the OLSR routing protocol, support for the Service Discovery Module. In addition we have completed the implementation of the REEF mechanism. The development of several legacy and cross-layer enhanced middleware layers is currently ongoing (e.g., Gnutella, Pastry and their cross-layer optimized versions).

2.5.3.4 T4.6 Risk reduction in the system testing

As planned this task was activated during the MobileMAN testing phase to control the technical problems that emerged in these phases. One of the output of this task was the creation of the group of junior researchers that is in charge of the testing meetings.
In addition, as explained before, this task was in charge to identify a solution to the non cooperative attitude of the users as pointed out in Task T4.2.

2.5.4 **WP5 Activities**

During the second year, as planned, we started the activities of Tasks T5.1 and T5.2. Both tasks are ongoing, however Task 5.1 have already produced measurable results as shown in Section 5, while Task 5.2 results will be available during the third year.

2.5.5 **Effort used and Planned for the Reporting Period**

Table 1 compares the planned and the real effort (planned plus additional effort) for the second year of the project. As pointed out by the figure there have been a major deviation from original planning of Annex 1: CNR (6 extra person months). This extra effort was

necessary to cover new activities that emerged: i) during the first year of the project (cross-layering); ii) during the review meeting; and iii) during the second year of the project to cope with risks and problems. Indeed, CNR extra man-months (for which we will not request extra funding, but will be managed with a reduction in the expenses of other cost categories, e.g., consumables) have been used:

- to design the protocols of the innovative cross-layered architecture (NeSt, CrossRoad, Service Discovery Module, HSLS);
- to address the reviewers' concern about integration of the enhanced card with legacy cards.
- to set up the testbeds for the MobileMAN experimental phase and to perform extensive measurements on these testbeds (both indoor and outdoor).

The workplan modifications caused also a manpower re-allocation in Eurecom budget: some man months for the extra WP2 activities were taken from WP3 budget. This caused a slight delay in some implementation activities. More precisley, according to the recommendations emerged during the first year review meeting, Eurecom dedicated some additional effort to better analyze (via game theory) the characteristics of the CORE mechanism. This was obtained by removing part of the manpower from the CORE implementation activities.

Table 1. Effort for the reporting period per WPs/Tasks (person months)												
	CNR		Cambridge		Eurecom		HUT		Netikos		SUPSI	
WP/Task	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act
WP0	1.0	1.0	0.5	0.5	0.8	0.8	0.5	0.5	0.4	0.4	1.2	1.2
WP1	2.5	2.5	0.5	0.5	1.2	1.0	0.7	0.7	0.4	0.4	1.5	1.5
WP2	1.0*	1.0*			1.0	1.0						
Task 2.7											7.5	7.5
Task 2.8			3.5	3.5								
Task 2.9	3.5	7.5	1.0	1.0	3.0	4.3	0.5	0.5			1.2	1.2
WP 3	0.5*	0.5*							4+	4+		
Task 3.1											16	16
Task 3.2	2.0						2.5	2.5				
Task 3.3	3.0	3.0					2.5	2.5				
Task 3.4					8.7	7.6						
Task 3.5		2.0	3.5	3.5								
Task 3.6	0.5	0.5										
WP 4	0.5*	0.5*										
Task 4.1	1.0	1.0	0.6	0.6	1.0	1.0	2.0	2.0	5.6	5.6		
Task 4.2	2.5	4.5	0.5	0.5	1.0	1.0	3.0	3.0	1.0	1.0	1.0	1.0
Task 4.3	3.0	3.0										
Task 4.6		0.1										
WP 5 *												
Task 5.1	1.5	1.5	1.0	1.0	1.5	1.5	1.0	1.0	0.2	0.2	1.5	1.5
Task 5.2	0.5	0.5	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TOTAL	23	29.1	12.1	12.1	18.7	18.7	13.2	13.2	12.1	12.1	30.4	30.4

* WP coordination and deliverables management.
+ Application level software development.

2.6 World-wide state-of-the-art Update

In the last ten years there has been a large volume of research activities devoted to mobile ad hoc networking (see [CCL03], and [BCGS04]). However, After almost a decade of research into ad hoc networking, MANET technology has not yet affected our way of using wireless networks. There are no clear results that show how well MANETs will work in reality. A very large number of simulation models have been developed to study ad hoc network architectures and protocols under many network scenarios, number of nodes, mobility rates, etc., see [BB04]. Simulation studies have been extensively applied for instance to compare and contrast large number of routing protocols developed for MANETs, see e.g., [JLHM99] [DCY00] [DPR00] [BMJHJ98].

As pointed out in [GLNT04], simulations have not been conclusive for selecting MANET protocols among the several available solutions. Furthermore, simulation models often introduce simplifications and assumptions that mask (in simulation experiments) important characteristics of the real protocols behavior [ABCG04, LNT02]. To avoid these modeling approximations, simulations have to be complemented by experiments on real prototypes.

In addition, the availability of prototypes will also make possible to start creating communities of MANET users that, by experimenting with this technology, will provide feedbacks on its usefulness and stimulate the development of applications tailored for the ad hoc environment. At the end, users' interaction can drive to identify possible ad-hoc-network killer applications making MANETs a success beyond the academic world. Although MANET research has been ongoing for some time, there are relatively few experiences with real ad hoc networks. Instead, a large portion of protocol development is done in (often unrealistic) simulation settings only. Among the most relevant results for the MobileMAN project are those obtained in the Uppsala University APE testbed [APE] and Dartmouth College Experimental testbed [GKND04, KNGL04]. The results from these testbeds are very important for the MobileMAN project and point out that to consolidate the ad hoc networking research field a pragmatic approach focused on **realization and testing of realistic small scale and complete solutions is mandatory** to reduce the gap between between what end users might find useful and what research is

currently addressing, making the cost of using ad hoc networking lower than the potential benefit.

2.6.1 The Uppsala University APE testbed

The Ad hoc Protocol Evaluation testbed (APE), is one of the largest test-bed for MANETs, having run tests with up to 37 nodes to evaluate the performance of AODV and OLSR with nodes moving along indoor hallways. The main outcome of this experimental activity is that MANET research should focus on the realization on **realistic small scale and complete solutions**.

Realistic means focusing of case studies relevant for the users. A scenario consisting of a few people wanting to form an ad hoc network and sharing access to the Internet is simple, but much more probable and feasible.

Small scale is dependent on the current technology that has an ad hoc horizon at two to three hops and 10 to 20 nodes where the benefit from wireless multihop ad hoc networking virtually vanishes. The focus should therefore be to get the most out of ad hoc networking *within* these limits. However, this is not the prominent model that is valued in the competition among routing protocols. Instead, proposals how to change the MAC scheme (and thus to invalidate the deployed hardware) and 1000 node scenarios with CBR traffic are prevalent.

2.6.2 Dartmouth College Experimental testbed

The experimental work recently performed at Dartmouth complements the Uppsala results by focusing on the performance of ad hoc routing algorithms under outdoor conditions with a significant number of moving nodes. The 33 nodes testbed probably represents the largest outdoor and mobile routing experiment for which results are publicly available. By comparing the outdoor results with indoor and simulation results two main results were obtained:

- Critical assumption in simulation modeling [KNGL04]
- Difference between outdoor results with indoor results. [GKND04]

1. Critical assumption in simulation modeling and in protocol design

By using an extensive set of measurements from the outdoor routing experiment, the authors demonstrated the weakness of the assumptions (like symmetric links, independence from the ground heights, constant and "sharp" radio links, etc.) used in simulative radio model. These assumptions cause simulation results that highly differ from experimental ones.

Unfortunately, real radios are much more complex than the simple models used by most MANET simulations, and these complexities have a significant impact on the behavior of MANET protocols and algorithms. For this reason in designing MANET protocols it is important:

i. Carefully consider the assumptions of lower layers.
ii. Develop protocols that adapt to environmental conditions.

2. Difference between outdoor results with indoor results

This comparison showed very interesting results: a protocol performance may change significantly from outdoor to indoor scenarios due to the different levels of contention. This indicates that indoor experiments on real hardware cannot predict the outdoor performance of common routing algorithms. Furthermore, results indicate that the level of clustering of the nodes (which determines the contention level) may play a large role in outdoors experiments. For this reason, the authors pointed the importance to set up outdoor testbed with a sufficiently large number of nodes to study the contention effect.

2.6.3 Experimental results in MobileMAN

The results from these test-beds are very important as they point out research directions to consolidate the ad hoc networking research field. The MobileMAN project is aligned with the direction identified in the previous sections:

1. we try to offer on top of the MobileMAN simple applications that are close to the users interests;
2. we are working toward complete small scale solutions;
3. our solutions are as soon as possible validated through experiments on real testbeds, or by using simulative models with realistic radio characterizations.

As far as point 3, our experimental results are complementary to those derived in the APE and Dartmouth testbeds as:

iii. we focus on design, implementation and testing of a full protocol stack instead of concentrating the attention on routing protocols only;

iv. we directly investigated the characteristics of the 802.11 radio model by focusing on physical and MAC layers, instead of measuring the routing protocol performance; in this way we were able to isolate the basic elements that characterize a realistic channel model. It is also worth noting that the basic characteristics of the radio model that have been isolated by observing a WiFi LAN have been recently observed also in the radio of Berkeley Motes [ACFGP04].

2.6.4 References

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2.7 Planned Work for the Next Reporting Period

No major modifications have been made with respect to the plans (see Deliverable D2 and D4). Indeed, we extended the scope of the project by adding the new concept of "cross layering" in the MobileMAN architecture and protocols. Thus, taking into account the experiences and lessons of the first two years of the project, below we define the criteria for evaluating the success of the third year of the project. Specifically, we subdivided the success criteria in two main classes:

- goals defined in the original project plans as defined in Annex 1 and Deliverable D2 (Original goals);

- additional goals that emerged during the project execution to exploit the cross-layer approach (Extra goals).

2.7.1 **Original goals**

- The development, and validation of effective solutions for the relevant technical issues of self-organizing networks: routing and forwarding, service location, medium access control protocols, security and cooperation.

- The hardware/software implementation of the above solutions.

- The integration of the developed solutions in a fully functioning testbed.
- A realistic (with respect to the current technology) "large-scale" testbed with (whenever possible) a community of student as users.
- Measures (whenever possible on the real testbed) of the users' satisfaction of the ad hoc networking paradigm.
- Exploitation of the MobileMAN solutions for: i) the creation of start-ups, and ii) novel business processes.

2.7.2 Extra goals

These objectives are related to show through a proof-of-concept prototype, and via simulation, the benefits of the cross layer approach. More precisely,

- we plan to develop and integrate in a testbed a cross layer solution for the middleware layer (CrossRoad) that exploits cross layer interactions with the network layer (topology information enhanced with services information). The software module supporting these interactions will be also developed.
- We plan to develop in the ns framework the model of the cross layer architecture to study, cross layer interactions between: middleware, transport and network layer. The simulation model will also enable the study of the cross layer architecture on a larger scale with respect to testbed experiments.

2.8 Assessment of Project Results and Achievements

SCIENTIFIC AND TECHNOLOGICAL ACHIEVEMENTS OF THE PROJECT. The project has proposed a system architecture that introduces cross-layer optimization and, at the same time, permits the use of legacy protocols without changes. The design and implementation of a cross-layer architecture and protocols for ad hoc networks is novel and very relevant for future research in the area. In addition, measurements, simulation and analysis have

been used to characterize the ad hoc networks environment and to design the MobileMAN protocols.

Impact on Science and Technology: Scientific Publications and Participation to Conferences/Symposium/Workshops or other dissemination events. During the second year the project partners were heavily involved in dissemination activities by organizing and participating to international conferences/workshops (also as invited speakers and tutorial speakers), participation to the journals editorial boards, and the organization of journals special issues, and producing a large number of technical documents (Journal papers, Conferences presentations, books, books chapters, theses, etc.). A detailed presentation of these activities can be found in Section 5. In addition, to broadly disseminate MobileMAN methods and tools, in addition to the project web site, we implemented thematic web sites to better disseminate the MobileMAN ideas, methods, and tools. In particular

- The "Social studies" web site designed and maintained by SUPSI is devoted to facilitate the interaction with users. The website has an interactive section which enable users to collaborate with us in creative scenarios building activities.
- The Software web site maintained by HUT, was implemented with the aim to make available the updated versions of the HUT developed software. This web site has two parts: a public and private ones. The latter contains the software that is still under testing and available for project internal use only. Currently, all the software is still in the private area as software is updated and testing phases are ongoing.

TRAINING. The technological challenges of the MobileMAN project attracted several good students and this contributes to increase the number of European specialists in mobile and wireless technologies. ISTAG has identified this area as one of the key technologies where Europe needs to build knowledge and research skills. Currently, within the consortium, there are 7 PhD students working on MobileMAN issues. Furthermore, a large number of Master-level students completed (and others are currently working to complete) their theses in the framework of the project. Specifically, during the second year the following PhD and Master theses have been completed in the framework of the MobileMAN project:

CNR

CNR researchers give a set of lectures in Master course on Internet Technology "Master .it" (jointly organized by IIT-CNR and Department of Information Engineering of the University of Pisa); in this framework by presenting in some lectures the MobileMAN research activities CNR had the possibility to attract a set of Master students that, during Summer 2004, performed their Master theses by working on the MobileMAN project. Specifically,

- Nicola Scalabrino and Ivan Velasco worked on outdoor MobileMAN testbed;
- Carlo Spagoni tested the available DSR implementations;
- Giuseppe Valente worked on the indoor MobileMAN testbed.

CAMBRIDGE

Marcel Dischinger "A Flexible peer-to-peer scalable multicast appalication using Bamboo", Master thesis University of Cambridge & University of Karlsruhe

Eurecom

- Pietro Michiardi PhD Thesis "*Cooperation enforcement and network security mechanisms for mobile ad hoc networks*"

HUT

- "Design and Implementation of an optimized architecture for Service Discovery in Ad Hoc networks", Olmo Leon Cadahia.
- "Study of VoIP over wireless Local area networks", Javier Garcia Sanchez

IMPACT ON INNOVATION AND MICRO-ECONOMY. The area of ad hoc networking is of long-term nature. Furthermore, the project is still in the phase in which solutions are developed and tested. However, preliminary results show good potentialities from the innovation and economic standpoint. Specifically,

i. the pragmatic approach of the project to develop, and implement innovative solutions for MANETs in realistic scenarios (small scale networks with legacy applications) is working towards lowering the barriers for ad hoc networking; we believe that this has to become a prime objective of MANET research to make it successful in everyday life.

ii. The extensive experimental activities performed in the framework of the project contribute to remove a set of simplifying assumptions commonly used in simulative studies that caused a lack of credibility in most of the results so far obtained. In addition, experimental activities pointed out problems that have no been previously identified.

iii. The implementation of a proof-of-concept prototype for a cross layer MANET architecture will provide a preliminary understanding of the benefits of this new approach in MANET design.

iv. The algorithm designed and evaluated for the enhanced 802.11 card is very promising both from a scientific and economic standpoint.

- it provides a formal basis to the activities of TG 802.11n that is working toward higher throughput for 802.11 networks. Indeed, AOB extended with the credit mechanism provides an optimized and efficient solution to the multiple transmissions approach currently under study in TGn.
- It provides an efficient solution to fix 802.11 unfairness in multi-hop scenarios
- The widespread usage of the 802.11 technology, and its economic value in the wireless market, open to our solution (which is compatible with existing standards) extremely interesting opportunities for creating business opportunities. However, it must be pointed out that the development of the new card implementing the enhanced algorithm is still ongoing and hence, economic exploitation of this output of the project will be better evaluated after field tests of the new card.

3. PROJECT MANAGEMENT AND CO-ORDINATION

The activities of the second year of the project were planned and monitored by continuous communications among partners, and in the three official Executive Board meetings. We had these Executive Board meetings during the three plenary workshops we organized during the second year of the project: Pisa (December 2003), Cambridge (March 2004), and Helsinki (June 2004). In addition, a brief Executive Board meeting was held in Brussels, as a follow up of the first year review meeting.

During these workshops, after a review of the activities performed, we defined the plans for progressing work packages with particular attention given to deliverables in the second year. In addition, whenever risks and problems emerged, we devised the appropriate corrective actions to cope with them in order to guarantee that the project can achieve the expected results. In addition, to project meeting discussions, continuous communications (primarily through the project mailing list) occurred among the project partners to coordinate on a shorter time scale the project activities.

3.1 Project Management Details

The second year of the MobileMAN project started with a follow-up meeting just after the first year review meeting with the aim of discussing the reviewers recommendations and concerns in order to start thinking to the appropriate actions that were discussed and approved in the Executive Board meetings held in Pisa (4 December 2003). The Pisa meeting was indeed primarily dedicated to redefine the plans of our activities for the second year (as defined in Deliverable D4 and Annex 1) to integrate the appropriate actions we devised to properly address the reviewers recommendations (see Section 2.2 for details). According to the revised plans, the activities of the second year of the project were subdivided into two main phases corresponding to

- Design and implementation (months 1-8), i.e., mainly WP2 and WP3 activities
- Integration and testing (months 9-12), i.e., mainly WP4 activities

During the first phase two projects meeting were organized to coordinate these activities. The first brought together all the partners at the 4th Project Closed Workshop hosted by Netikos (Pisa, Italy, 4 December 2003).

The second meeting was at Cambridge (UK), 22 March 2004. At the Cambridge meeting participated also Prof. A.T. Campbell (Columbia University) that was on sabbatical leave at Cambridge University. Prof. Campbell is a well know USA researcher in the field (among other he was Technical program co-chair for ACM MobiCom 2002, and will be the Technical program co-chair for ACM MobiHoc 2005). We had the opportunity to have fruitful discussions with him i) about the role of cross layering in ad hoc networking; and ii) the relevance of experimental activities on real testbeds. Specifically, he agreed with us on the effectiveness of our approach that combines the flexibility of a layered approach with relevant performance optimization. After the Cambridge meeting researchers from Cambridge, CNR and Eurecom participated to the 2nd WiOpt'04 workshop that was jointly organized by Cambridge University and IIT-CNR. Technical discussions on MobileMAN related issues continued all the week with worldwide colleagues.

The meeting in Helsinki represented the border between the two phases of the project. Indeed, after Helsinki meeting the project partners concentrated on integration and testing as reported in Deliverable D8 (and partially) in Deliverable D10.

As at this stage of the project the refinement of the MobileMAN architecture and protocols was (mostly) completed, we identified the Helsinki meeting as the checkpoint to present and discuss the status of the MobileMAN project with IAB members.

To this end, the Helsinki had a first day devoted to the meeting with MobileMAN IAB members, and a second day to an internal meeting among MobileMAN partners. In this way during the internal meeting the project partners had the opportunity to discuss the IAB comments/suggestions and to integrate in the future project plans appropriate actions.

The IAB meeting was an important checkpoint for the project as we met the IAB after one year. The organization of this meeting was quite problematic as two out four of the members (BTexact Technologies and ST Microelectronics), immediately declared that were not able to attend. Indeed, BTexact Technologies people did not have budget this year for this work (given that the meeting was outside UK), while the ST Microelectronics representative, Jeff Owen, during this period was temporarily re-located in California. Given these constraints we organized the meeting together with Michael Bahr (Siemens), and Pertti Suomela (Nokia). Unfortunately, two days before the meeting, Pertti Suomela declared its inability to participate he got an unexpected request for an important meeting inside Nokia for the same day. To summarize, at the MobileMAN IAB meeting we have

only the Siemens representative: Michael Bahr. Apart these problems, the meeting was very fruitful as Michael Bahr has an excellent expertise in the field as he is leading Siemens projects in the ad hoc networking area. The comment of Michael was that "*the project showed a good progress with respect to the first IAB meeting. Now the activities of the different partners are clearly integrated toward the same objective. In addition, the project has already produced a lots of good outputs."* In particular, Michael showed a big interest on the algorithms for the enhanced card and the development of CrossRoad. To this very positive comment on the status of the project he associated a set of recommendations:

- need to immediately start to focus on software integration and testing;
- the 802.11 activity is very relevant and worth to use our results to make input to standards;
- we should publicize more about business cases.

The internal meeting on June 8th was a good opportunity for a follow-up discussion on Michael Bahr recommendations. In addition, to the partners presentations about ongoing activities, and plans for the production of Deliverables D8, D9 and D10, the Executive Board meeting focused on the best approach toward software integration and testing. Indeed a potential risks/problems emerged in this area if partners continued to work (mostly) in isolation. To cope with these problems, we decided to set up a group of junior researchers that should meet regularly to integrate the developed software, and set up "reasonable" size MobileMAN testbeds to validate the developed solutions. As documented by Deliverable D8 and D10 this approach has been successful, as significant progresses in software integration and testing have been made in the last 4 months of the second year. Indeed the group of junior researcher coordinated by CNR research assistants, Eleonora Borgia and Franca Delmastro, organized two testing meetings which produced relevant results. The two meetings were held in the CNR campus in Pisa: i) at the end of June for a 7-day (24 June - 2 July) MobileMAN first testing phase; and ii) at the end of September (29 September – 1 October).

In these meetings, it was also possible to compare and contrast alternative solutions for the HW and SW platform to identify the best components for the MobileMAN testbed. In

addition to the two project testing meetings, other interim (technical) project meetings were organized. Specifically, in coincidence with the Helsinki meeting, there was an interim project meeting (technical) still in Helsinki (June 3-4 and June 9) between CNR and HUT junior researcher. This meeting was entirely devoted to software testing (mainly routing protocols). This meeting was very useful because researchers of the two groups for the first time worked together toward software testing and integration. This activity was very important because they identified the best way to tackle the first project-testing meeting.

Another interim project meeting was organized on September 21 (still in Pisa) between SUPSI and CNT researchers to perform a check on the implementation of the new card and to define the plans for its future extensions. By analyzing SUPSI preliminary experimental results it was verified that the new implementation correctly behaves.

The second phase of the project second year was mainly devoted to WP4 activities, i.e., integration and testing of MobileMAN solutions. This phase ended at month 12 with a self-assessment phase to compare and contrast the project results with the project success criteria defined in Deliverable D4. The results of this self-assessment phase are presented in Deliverable D9.

3.2 Cooperation with other projects

The project partners are cooperating with other national and EU-funded projects, whose results could be valuable for MobileMAN, and vice versa. Hereafter, we report these cooperations by separating the cooperations already active during the first reporting period from the new co-operations that were activated during the second year of the project.

3.2.1 Cooperation established during the project first year

In this section we report the co-operations with other projects that were active during the MobileMAN first year and continued during the second year.

CNR

Virtual Immersive Communications (VICOM) is a three years Italian project (Nov. 2002 – Nov. 2005) funded by the Italian Ministry for Research (MIUR). This project is aimed to

investigate communications technologies, including ad hoc networks, for supporting ambient intelligence.

Cambridge

EQUATOR. This is a six-year Interdisciplinary Research Collaboration (IRC) supported by The Engineering and Physical Sciences Research Council (EPSRC) of the UK Government. Equator challenges address fundamental research issues arising from the mixing of the physical and digital. Three different forms of challenge are important to Equator: Devices, Adaptive Infrastructures, and Understanding Interaction.

MMAPPS*: Market Management of Peer to Peer Services*. The MMAPPS project started on March 1st, 2002 with funding from the EU Fifth RTD Framework Programme.

The MMAPPS project is researching how to use techniques from economics and social science to tackle some of the fundamental difficulties in creating well-founded, and therefore sustainable, P2P applications.

Eurecom

CNRS / *ACI* SPlaSH *project*: *Sécurisation des ProtocoLes dans les réseAux mobileS ad Hoc.* (French National Funding). Participants: EURECOM (Refik Molva, Pietro Michiardi, Claudio Lavecchia) INRIA (Pars Mutaf) and University of California Irvine (Claude Castelluccia)

HUT

WIreless DEployable Network System, Proposal acronym: WIDENS,
The project is supported by the European Commission under the IST Framework Programme 6. The overall objective of the WIDENS project is to design, prototype and validate a high data-rate, rapidly deployable and scalable wireless ad-hoc communication system for future public safety, emergency and disaster applications.

Project AHRAS (http://www.netlab.hut.fi/tutkimus/ahras/)

concentrates on the routing and other traffic related issues in wireless ad hoc networks. The project started in 2001 and it is funded by the Finnish Defence Forces Technical Research Centre.

Project NAPS (Networking and Architecture for Proactive Systems) is a 3 year project (2003-2005) funded by the Academy of Finland. It is part of the research programme on Proactive Computing (PROACT). http://www.netlab.hut.fi/tutkimus/naps/

3.2.2 Cooperation established during the second year

In this section we report the links that MobileMAN project established during this reporting period with other projects. According to the reviewers suggestions to take into consideration the activities of the UCAN project, we activated to establish links with other EU project working in MobileMAN related areas. To this end we exploited the workshop in Brussels (on the 10th December, 2003) organized by EC-funded ROMANTIK project (jointly with the European Commission) devoted to presenting and discussing EU projects focusing on ad hoc and multihop technologies, see http://www.ist-romantik.org/mhah-workshop. During this event, relevant projects related to MobileMAN were presented in a poster session. Among others, in addition to MobileMAN: UCAN, BROADWAY, 6HOP, ROMANTIK, EYES, and WIDENS. In addition, the SUPSI representative in the MobileMAN project (Silvia Giordano) participated to the workshop panel presenting her view about "Is multi-hop and ad hoc networking going to happen?

During the second year of the project, MobileMAN partners established collaboration links with the following projects.

CNR

CNR has established a link between the MobileMAN project and the VI framework PalCom project (http://www.palcom.dk/). PalCom is an integrated project in EU's 6th Framework Programme under the proactive initiative The Disappearing Computer in Future and Emerging Technologies (FET), part of the Information Society Technologies. The duration of the project is 48 months (01.01.2004 - 31.12.2007).

A meeting between the coordinator of the MobileMAN project (Marco Conti) and the coordinator of the PALCOM project http://www.palcom.dk/ was held in Pisa on July 26, 2004.

Cambridge

Network of Excellence Emerging Network Technologies (E-NeXT)

http://www.ist-e-next.net/

In the framework of this project the University of Cambridge had three visitors (Marcel Dischinger, and Jan Hoeft, from the University of Karlsruhe, and Carlos Jesus Bernardos-Cano, from Madrid) that worked on MobileMAN related topics.

A STREP has been submitted by Cambridge, together with EPFL, and Uppsala University, and Intel research, on the area of Opportunistic Networking – this arose at least in part due to the expertise and contacts gained by Cambridge during the MobileMAN Project.

Eurecom

Mosquito STREP Project, Proposal/Contract no.: 004636 EU Founded project

MOSQUITO's vision is that mobile workers have secure, trusted and ubiquitous access to business applications. The project will provide the technical infrastructure required so that workers and their clients can perform daily business processes collaboratively and safely according to determined security policies.

HUT

Network of Excellence Emerging Network Technologies (E-NeXT)

http://www.ist-e-next.net/

4. COST BREAKDOWN

Partners are currently working to fill their own cost statements. This section will be completed as soon as cost statements will be available.

5. PROMOTION, INFORMATION AND DISSEMINATION

5.1 Publications

5.1.1 Papers Published during the Second Year

This section contains the list of book, book chapters, conference/workshop papers that have been published during the second year of the project but that were already announced (as submitted/accepted for publication) in the Periodic Progress Report N°:1. We report these publications to provide the exact and complete information about these works: publication title, authors and the reference to the conference proceedings/books/journals where the contributions appeared.

5.1.1.1 Books

- S. Basagni, M. Conti, S. Giordano, I. Stojmenovic (Editors), Mobile Ad hoc networking, IEEE Press and John Wiley and Sons, Inc., New York, 2004. ISBN 0-471-373133.
  http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471373133.html

5.1.1.2 Book Chapters

- G. Anastasi, M. Conti, E. Gregori, "IEEE 802.11 Ad Hoc Networks: Protocols, Performance and Open Issues", Chapter 3 in Mobile Ad hoc networking, S. Basagni, M. Conti, S. Giordano, I. Stojmenovic (Editors), IEEE Press and John Wiley 2004.
- P. Michiardi, R. Molva, "Ad hoc Networks Security" Chapter 12 in Mobile Ad hoc networking, S. Basagni, M. Conti, S. Giordano, I. Stojmenovic (Editors), IEEE Press and John Wiley 2004.
- S. Giordano, A. Urpi, "Self-Organized and Cooperative Ad Hoc Networking", Chapter 13 in Mobile Ad hoc networking, S. Basagni, M. Conti, S. Giordano, I. Stojmenovic (Editors), IEEE Press and John Wiley 2004.

5.1.1.3 Journals

J.1. Luciano Bononi, Marco Conti, Enrico Gregori, "Runtime Optimization of IEEE 802.11 Wireless LANs Performance", *IEEE Transactions on Parallel and Distributed Systems*, Vol. 15, N. 1, January 2004, pp. 66-80.

J.2. P. Michiardi, R. Molva, *"Ad hoc Network Security"*, ST Microelectronics Journal of System Research.
J.3. Jon Crowcroft, Richard Gibbens, Frank Kelly, Sven Östring *"Modelling Incentives for Collaboration in Mobile Ad Hoc Networks"* Performance Evaluation, 57 (2004) 427-439.
J.4. Jose Costa-Requena, Nicklas Beijar, Raimo Kantola: Replication of Routing Tables for Mobility Management in Ad Hoc Networks. Wireless Networks 10(4): 367-375 (2004)

5.1.2 **New Publications**

This section contains the list of book, book chapters, conference/workshop papers that have been accepted for publication during the second year of the project (publication not reported in Periodic Progress Report N°:1).

5.1.2.1 Book

B.1. R. Battiti, M. Conti, R. Lo Cigno, (Eds.), "Wireless On-Demand Network Systems" Proceedings of the First IFIP TC6 Working Conference, WONS 2004, Madonna di Campiglio, Italy, January 21-23, 2004, Lecture Notes in Computer Science Vol. 2928.

B.2. T. Basar, M. Conti, (Eds) Proceedings Second IEEE Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt '04), Cambridge, UK, 24-26 March, 2004.

B.3. Pierangela Samarati, Dieter Gollmann, Refik Molva: Computer Security - ESORICS 2004, 9th European Symposium on Research Computer Security, Sophia Antipolis, France, September 13-15, 2004, Proceedings Springer 2004.

5.1.2.2 Book Chapters

BC.1. M. Conti, "Wireless Communications and Pervasive Technologies", Chapter 4 of Environments: Technologies, Protocols and Applications, Diane Cook and Sajal K. Das (Editors), John Wiley and Sons, 2004, ISBN 0-471-54448-5. pp. 63-99.

BC.2. E. Baccarelli, M. Biagi, R. Bruno, M. Conti, E. Gregori, "Broadband Wireless Access Networks: a Roadmap on Emerging Trends and Standards", Chapter 14 in Broadband Services to Businesses Communities: Business models and technologies. C. Szabo, I. Chlamtac, A. Gumaste (Editors), John Wiley and Sons, Inc., New York, 2004. (to appear)

BC.3. M. Conti, J. Crowcroft, G. Maselli, T. Turi, "A Modular Cross-layer Architecture for Ad Hoc Networks" in Handbook on Theoretical and Algorithmic Aspects of Sensor, Ad Hoc Wireless, and Peer-to-Peer Networks, Jie Wu (Editor), CRC Press, New York, 2004 (to appear).

BC.4. G. Anastasi, M. Conti, A. Passarella, in "Power Management in Mobile and Pervasive Computing Systems", in Algorithms and Protocols for Wireless and Mobile Networks, Azzedine Boukerche (Editor), CRC-Hall Publisher, 2004 (to appear).

5.1.2.3 Journals

J.1. M. Conti, G. Maselli, G. Turi, S. Giordano, "Cross Layering in Mobile Ad Hoc Network Design", *IEEE Computer*, February 2004, pp. 48-51.

J.2. M. Conti, E. Gregori, and G. Maselli, "Self-Interest in Mobile Ad Hoc Networks: issues and solutions", To appear in the *International Journal on Wireless and Mobile Computing* (Inderscience), Special issue on *Wireless Ad Hoc Networking*, D. Simplot and I. Stojmenovic (Editors).

J.3. Eleonora Borgia, Marco Conti, Franca Delmastro, Luciana Pelusi "Lessons from an Ad hoc Network Test-bed: middleware and routing issues", *Wireless Ad Hoc and Sensor Networks: An International Journal*, Old City Publishing, Vol. 1, N. 1, 2004.

J.4. Pietro Michiardi, Refik Molva, "Analysis of Cooperation Strategies in Mobile Ad hoc Networks with Imperfect Monitoring" to appear in *Ad Hoc Networks Journal*, special issue on "Ad Hoc Networking for Pervasive Systems", M. Conti, E. Gregori (Editors).

5.1.2.4 Conference Proceedings

C.1. A. Anastasi , E. Borgia, M. Conti, E. Gregori, "Wi-Fi in ad hoc mode: a measurement study", Proceedings of the Second IEEE Annual Conference on Pervasive Computing and Communications (PerCom 2004), March 14-17, 2004 pp. 145- 154.

C.2. M. Conti, E. Gregori, and G. Turi, "Towards scalable P2P computing for mobile ad hoc networks", Proc. workshop on Mobile Peer-to-Peer computing (MP2P'04), IEEE PerCom 2004 Workshops proceedings, pp. 109- 113.

C.3. M. Conti, E. Gregori, and G. Maselli, "Cooperation Issues in Mobile Ad Hoc Networks", International Workshop on Wireless Ad Hoc Networking (WWAN), Proceedings of IEEE ICDCS Workshops, Tokyo, Japan, March 2004.

C.4. M. Conti, E. Gregori, and G. Maselli, "Performability in Ad hoc Networks", Proceedings of the 59th IEEE Vehicular Technology Conference, Milan, Italy, May 2004.

C.5. R. Bruno, M. Conti, E. Gregori, "Distributed Contention Control in Heterogeneous 802.11b WLANs", (to appear) Proc. The Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005.

C.6. Eitan Altman, Arzad A. Kherani, Pietro Michiardi, Refik Molva, "Non cooperative forwarding in Ad hoc Networks", Proc. 15th IEEE PIMRC Symposium, Barcelona, Spain, 5-8 September, 2004.

C.7. P.Cremonese, V.Vanni *"UDDI4m: UDDI in Mobile Ad Hoc Network",* Proc. Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005.

C.8. Silvia Giordano, Davide Lenzarini, Salvatore Vanini, Alessandro Puiatti, *"WiSwitch: Seamless Handover between Multi-Provider Networks",* Proc. Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005.

C.9. Jose Costa-Requena, Raimo Kantola and Jorge Nuevo Fonseca, "Strategies for the Formation of a Service Distribution Backbone in Ad Hoc Networks", Proc. International Conference on Communications, Internet and Information Technology (CIIT 2004), November 22 to November 24, 2004, in St. Thomas, Virgin Islands, USA.

C.10. J. Costa-Requena, J. Gutiérrez, R. Kantola, J. Creado, N. Beijar "Network architecture for scalable Ad Hoc Networks", Proc. International Conference on Telecommunications ICT2004, Agust 01-06, 2004 - Fortaleza - Ceará – Brazil, http://www.ict2004.com.br/index.shtml

C.11. Elgan Huang, Jon Crowcroft, Ian Wassell, "Rethinking incentives for mobile ad hoc networks ", Proceedings of the ACM SIGCOMM workshop on Practice and theory of incentives in networked systems 2004, Portland, Oregon, USA September 03 - 03, 2004, Pages: 191 – 196.

5.1.2.5 Tutorial, Invited Talks, Conference Presentations

- Pietro Michiardi has been **Tutorial Speaker**, *"Ad hoc Networks Security*, SEE – SIC, March 11th 2004 - ENST – Paris

- Pietro Michiardi has been **Tutorial Speaker**, *"Ad hoc Networks Security*", at the Conference on Security and Network Architectures - July 2004 - La Londe

- Marco Conti has been **Invited Speaker** "WiFi Performance Modeling and Optimization", at 16th ITC specialist seminar "Performance Evaluation of Wireless and Mobile Systems", Antwerp, Belgium, August 31 - September 02, 2004.

5.1.2.6 Conference Presentations

P.1. M. Conti, S. Giordano, G. Maselli, and G. Turi, "Mobile Metropolitan Ad hoc Networks: The Cross-layer Architecture" Poster presentation at the *Workshop on Multi-hop and Ah-Hoc Networking (MHAH 03)*, Brussels, Dec. 2003. http://www.ist-romantik.org/mhah-workshop/

P.2. Patrizia Andronico, "MobileMAN project", ACM CHI2004 Workshop: Lost in Ambient Intelligence? http://parlevink.cs.utwente.nl/chi2004-conference/chi04-abstracts.html

P.3. Patrizia Andronico, Claudia Brazzola and Jennifer Duyne "Social Dimensions of MobileMAN. Opportunities and Constraints in Adopting Participatory Approaches in ICT Projects" accepted for a poster presentation at the 13th IST Mobile and Wireless Communication Summit in Lyon (France) in May 2004. It is, available at the following
URL: http://mobileman.projects.supsi.ch/MMDocuments.html

P.4. Silvia Giordano; *Quali prospettive per il futuro? Reti Wireless e tecnologie pervasive*; Lugano Communication Forum; Lugano, Switzerland; April 8, 2004.

5.1.2.7 Paper Submitted and Technical Reports

R.1. Pietro Michiardi, Refik Molva, "*Analysis of Cooperation Strategies in Mobile Ad hoc Networks with Imperfect Monitoring*", Eurecom Research Report RR-04-099 - February 2004

R.2. Eitan Altman, Arzad A. Kherani, Pietro Michiardi, Refik Molva, "*Non cooperative forwarding in Ad hoc Networks*", INRIA Report No. RR-5116, Sophia-Antipolis, France, February 2004

R.3. Pietro Michiardi, Refik Molva, "*Analysis of Cooperation Strategies in Mobile Ad hoc Networks with Imperfect Monitoring*", Eurecom Research Report RR-04-099 - February 2004.

R.4. Eitan Altman, Arzad A. Kherani, Pietro Michiardi, Refik Molva, "*Non cooperative forwarding in Ad hoc Networks"*, [INRIA Report No. RR-5116, Sophia-Antipolis, France, February 2004.

R.5. Pietro Michiardi, Refik Molva, Chapter on "Ad hoc networks Security" Wiley & Sons, "Handbook of Information Security"- In preparation

R.6. Pietro Michiardi, Refik Molva, "*ID-based hash chains for broadcast authentication in wireless networks*", Submitted to Infocom 2005 (also available as an Internal Research Report at Eurecom Institute)

R.7. Eitan Altman, Arzad A. Kherani, Pietro Michiardi, Refik Molva, "*Some game theoretical problems in ad hoc networks*", Submitted to Infocom 2005.

5.1.2.8 Other Dissemination Activities

Radio Interview

On the 17th of February 2004, a radio interview about the project MobileMAN and the related activities that involve the University of Applied Sciences, with both the DTI and DSAS parts was conducted. The interview was broadcasted shortly afterwards during the frame of a series of transmissions about research activity in the southern part of Switzerland:

> Claudia Brazzola, Ivan Defilippis, and Silvia Giordano; *MobileMAN: da utente a nodo di rete*; radio interview in the serie *Usi e Ricerche*; RTSI–Radiotelevisione svizzera di lingua italiana; broadcasted February 28, 2004, 17^{20}–17^{35}.
> http://www.rtsi.ch/prog/Rete2/welcome.cfm?mpg=5876

Presentations in University Courses

5.1.3 Interaction with University Students

CNR organized a presentation of MobileMAN technologies to university students with a very high skill in information technology. Specifically, on May 13th, we arranged a two-hour presentation in the framework of the course *Applications for Mobile Computers* for the last-year students in Computer Engineering (5-year degree) at the University of Pisa (Engineering Faculty). To present MobileMAN we prepared a set of four presentations (now available on the project web site) in Italian language for making interactions with student easier:

- M. Conti "MobileMAN: Mobile Metropolitan Ad Hoc Network"
- E. Borgia "Routing su reti Ad Hoc"
- F. Delmastro "CROSS-ROAD: CROSS-layer Ring Overlay for Ad Hoc Networks"
- P. Andronico "Design Mobile Communicators"

5.2 Journal Editorial Boards and Conference Committees

5.2.1 Journal Boards

- M. Conti is **Associate Editor** of *Pervasive and Mobile Computing (Elsevier);* **Advisory and Regional Editor** (for Europe) of *Wireless Ad Hoc and Sensor Networks: An International Journal;* **Area Editor** of the following journals: *Ad Hoc Networks Journal* (Elsevier) and *ACM Mobile Computing and Communications Review* (MC2R)

- J. Crowcroft is on the **editorial board** of the following journals: *Computer Networks, IEEE Networks, Internet Protocol, Grid Computing, Cluster Computing, and Mobile Applications and Networks.*

- S. Giordano is on the **editorial board** of *IEEE Communications Magazine*. Editor of the Series on *Ad hoc and Sensor Networks.*

- E. Gregori is on the **editorial board** of the following journals: *Computer Networks Journal*, *Cluster Computing Journal*.

- R. Molva is on the **editorial board** of *Pervasive and Mobile Computing (Elsevier).*

5.2.2 Journals Guest Editors

- Special issue "Internet Wireless Access: 802.11 and Beyond", *ACM/Kluwer Mobile Networks and Applications (MONET) Journal*. Publication planned in 2005 (**Co-guest Editor**: M. Conti).

- Special issue on "Ad Hoc Networking for Pervasive Systems", *Ad Hoc Networks Journal* (Elsevier). Publication planned in 2005 (**Co-guest Editors**: M. Conti and E. Gregori).

- Special issue on "WiOpt 2004", *ACM/Kluwer Mobile Networks and Applications (MONET) Journal*. Publication planned in 2005 (**Co-guest Editor**: M. Conti).

5.2.3 Conference Executive Committees

- Marco Conti has been **Program Co-Chair** (with Renato Lo Cigno, University of Trento, Italy) - First IFIP TC6 Working Conference on Wireless On-demand Network Systems (WONS 2004), Madonna di Campiglio (Italy) January 21-23, 2004 URL: http://www.dit.unitn.it/wons/

- Marco Conti has been **Program Co-Chair** (with T. Basar, University of Illinois) - Second IEEE Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt '04), Cambridge, UK, 24-26 March, 2004.
- URL: http://www.cl.cam.ac.uk/Research/SRG/wiopt04/

- Marco Conti is the **Vice-Program Chair** - 1st IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS) Fort Lauderdale, Florida, October 25-27, 2004. URL: http://www.ececs.uc.edu/~cdmc/mass

- Marco Conti is the **Workshop Coordinator** (with A. Misra, IBM Research, USA) -- First International Workshop on Broadband Wireless Multimedia: Algorithms, Architectures and Applications (BroadWIM) October 29, 2004 San Jose, California, USA. URL: http://www.broadwim.org

- Silvia Giordano is the **General Chair** Second IFIP TC6 Working Conference on Wireless On-demand Network Systems (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005. http://www.wonss.org/

- Refik Molva has been the **General Chair** 9th European Symposium On Research in Computer Security (ESORICS 2004), Sophia Antipolis, French Riviera, France - September 13-15, 2004.

- Refik Molva has been the **General Chair** 7th International Symposium on Recent Advances in Intrusion Detection (RAID 2004), Sophia Antipolis, French Riviera, France - September 15-17, 2004.

5.2.4 Conference Technical Program Committees

- The 10th International Conference on High Performance Computing (HiPC'03), Hyderabad, India, 17-20 December 2003. http://www.hipc.org (TPC member: M. Conti)

- First IFIP TC6 Working Conference on Wireless On-demand Network Systems (WONS 2004), Madonna di Campiglio (Italy) January 21-23, 2004. http://dit.unitn.it/wons (TPC member: M. Conti, E. Gregori, S. Giordano)

- European Wireless 2004: the Fifth European Wireless Conference Conference, Barcelona, Spain, February 24th-27th, 2004. http://research.ac.upc.es/EW2004/ (TPC member: M.Conti)

- IASTED International Conference on Parallel and Distributed Computing and Networks (PDCN 2004), Innsbruck, Austria, February 17-19 2004. http://www.iasted.org/conferences/2004/Innsbruck/pdcn.htm (TPC member: M. Conti)

- WiOpt 2004: 2nd Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, March 24 - 26, 2004, Cambridge, UK (TPC member: J. Crowcroft, S. Giordano, M. Michiardi)

- NETWORKING 2004: The Third International IFIP-TC6 Networking Conference, Athens, Greece, May 9-14, 2004. http://www.ece.ntua.gr/networking2004/ (TPC member: M. Conti, E. Gregori, S. Giordano)

- The Second IEEE International Conference on Pervasive Computing and Communication (PerCom2004), Orlando, Florida, March 14-17, 2004, http://www.percom.org (TPC member: M. Conti)

- IEEE WWAN 2004, Int. Workshop on Wireless Ad hoc Networking in conjunction with the 24th International Conference on Distributed Computing Systems, Tokyo, Japan, March 23-26, 2004. http://www.lifl.fr/RD2P/WWAN2004/ (TPC member: M. Conti)

- IEEE MDC'04, the second workshop on Mobile Distributed Computing (MDC'04), in conjunction with the 24th International Conference on Distributed Computing Systems, Tokyo, Japan, March 23-26, 2004. http://www.comp.polyu.edu.hk/~mdc04 (TPC member: M. Conti)

- HET-NETs'04: the Second Int. Conf. Performance Modelling and Evaluation of Heterogeneous Networks, Ilkley, West Yorkshire, U.K., 26- 28th July, 2004, http://www.comp.brad.ac.uk/het-net/ (TPC member: M. Conti)

- 2004 International Workshop on Mobile and Wireless Networking (MWN'04) in conjunction with the 33rd International Conference on Parallel Processing Aug. 15-18, 2004 in Montreal, Quebec, Canada. http://www.cs.ua.edu/mwn/ (TPC member: M. Conti)

- The 16th ITC specialist seminar "Performance Evaluation of Wireless and Mobile Systems", Antwerp, Belgium, August 31 - September 02, 2004. http://www.itcss16.ua.ac.be (TPC member: M. Conti)

- Seventh ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2004), October 4-6, 2004, Venice, Italy. http://www.cs.unibo.it/mswim2004/ (TPC member: M. Conti)

- The Second ACM International Workshop on Wireless Mobile Applications and Services on WLAN Hotspots (WMASH'04), ACM Mobicom 2004 workshop. Philadelphia October 1st, 2004. http://wmash2004.intel-research.net/ (TPC member: M. Conti)

- 2nd ACM International Workshop on Mobility Management and Wireless Access Protocols (MobiWac), ACM Mobicom 2004 workshop. Philadelphia October 1st, 2004. http://ru1.cti.gr/mobiwac04/ (TPC member: M. Conti)

- IEEE Infocom 2004: March 2004. Hong-Kong. http://www.ieee-infocom.org/2004/index.html (TPC member: J. Crowcroft)

- AMOC04: 3rd Asian International Mobile Computing Conference, 26-28 May 2004, Bangkok, Thailand (TPC member: J. Crowcroft)

- GAN04: Workshop on Grids and Advanced Networks, April 19 - 22, 2004, Chicago, Illinois, USA. http://perso.ens-lyon.fr/laurent.lefevre/gan04/ (TPC member: J. Crowcroft)

- MM04: ACM Multimedia Conference, 10-16 October 2004, New York, USA (tutorial co-chair). http://www.mm2004.org/acm_mm04.htm. (TPC member: J. Crowcroft)

- CCNC04: 2004 IEEE CONSUMER COMMUNICATIONS AND NETWORKING CONFERENCE "Consumer Networking: Closing the Digital Divide", 5-8January 2004, Las Vegas, Nevada USA. (TPC member: J. Crowcroft)

- IWQoS04: The Twelfth IEEE International Workshop on Quality of Service, June 7-9, 2004, Montreal, Canada. http://iqua.ece.toronto.edu/iwqos04/index.html (TPC member: J. Crowcroft)

- NSDI04: 1st Symposium on Networked Systems Design and Implementation, 29-31 March 2004, San Francisco, California. http://www.usenix.org/events/nsdi04/ (TPC member: J. Crowcroft)

- QoFIS04: Fifth International Workshop on Quality of future Internet Services "Quality of Service in the Emerging Networking Panorama", September 29 - October 1, 2004 Barcelona, Catalunya, Spain. (TPC member: J. Crowcroft)

- ACM SIGCOMM' 04, August 30 September 3, Portland. Oregon, USA (TPC member: J. Crowcroft).

5.3 Participation at Conferences and Workshops

MobileMAN project members attended the following conferences during the second year of the project:

- First IFIP TC6 Working Conference on Wireless On-demand Network Systems (WONS 2004), Madonna di Campiglio (Italy) January 21-23, 2004. http://dit.unitn.it/wons (Participants: M. Conti, E. Gregori, S. Giordano, P. Cremonese)

- WiOpt 2004: 2nd Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, March 24 - 26, 2004, Cambridge, UK (Participants: M. Conti, J. Crowcroft, M. Michiardi)

- NETWORKING 2004: The Third International IFIP-TC6 Networking Conference, Athens, Greece, May 9-14, 2004. http://www.ece.ntua.gr/networking2004/ (Participant: E. Gregori)

- The Second IEEE International Conference on Pervasive Computing and Communication (PerCom2004), Orlando, Florida, March 14-17, 2004, http://www.percom.org (Participant: E. Gregori)

- ACM Conference on Human Factors in Computing. (Participant: Patrizia Andronico)

- 59th IEEE VTC Conference (Milan Italy 17-19 May 2004). http://www.eee.strath.ac.uk/vtc2003/vtc2004spring (Participant: Gaia Maselli)

- IEEE WWAN 2004, Int. Workshop on Wireless Ad hoc Networking in conjunction with the 24th International Conference on Distributed Computing Systems, Tokyo, Japan, March 23-26, 2004. http://www.lifl.fr/RD2P/WWAN2004/ (Participant: G. Maselli)

- The 16th ITC specialist seminar "Performance Evaluation of Wireless and Mobile Systems", Antwerp, Belgium, August 31 - September 02, 2004. http://www.itcss16.ua.ac.be (Participant: M. Conti)

- International Conference on Telecommunications ICT2004, Agust 01-06, 2004 - Fortaleza - Ceará – Brazil (Participant: J. Costa-Requena)

- ACM SIGCOMM Portland, Oregon, Aug 2004 (Participant: J. Crowcroft)