MOBILEMAN

IST-2001-38113

Mobile Metropolitan Ad hoc Networks

Periodic Progress Report N°:3

Covering period 1.10.2004-30.09.2005

Report Delivery Date: November 2005

Actual Date of Delivery: December 2005

Estimated Person Months: 1

Number of pages: 87

Classification: Internal circulation within project

Project Coordinator: Consiglio Nazionale delle Ricerche (Italy)

Contributing Partners: University of Cambridge (UK), Institut Eurecom (France), Helsinki University of Technology (Finland), NETikos (Italy), Scuola Universitaria Professionale della Svizzera Italiana (Switzerland)

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Project funded by the European Community under the "Information Society Technologies" Programme (1998-2002)

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1. EXECUTIVE SUMMARY

The MobileMAN project, according to the refinement of its objectives during the first and second year of the project, focuses on the Implementations Integration, and Experimentation of realistic ad hoc networks *within* the current technology limits. The aim is to define a full protocol stack, tuned on the unique features of mobile ad hoc networks, to evaluate current limits and potentialities of this emerging networking paradigm.

While the first year activities concentrated on MobileMAN architecture and protocols development and validation via simulation and analysis, and the second year activities were mainly targeted to development of the designed solutions, the emphasis in the third year activities has been on the integration and testing of MobileMAN solutions. Specifically, in addition to build up and test a complete solution based on a legacy layered architecture (according to Annex 1 plans), we have been able to achieve also the extra goals identified at the end of the second year of the project. More precisely, we have been able to show through proof-of-concept prototypes, and via simulation, the benefits of applying our cross layer approach in mobile ad hoc networks' design. Indeed, by integrating the software modules we developed (during the second year, and in the first months of the third year) with existing code, we obtained a set of software architectures that enable us to test MobileMAN concepts and ideas. Specifically, we have implemented and tested: i) a legacy (layered) TCP/IP architecture on which we run a VoIP application; ii) a legacy (layered) p2p architecture on which we run Whiteboard and UDDI4m applications, and iii) a p2p cross-layer architecture on which we run both Whiteboard and UDDI4m applications.

From a technical standpoint testing activities have been the main focus of the third year of the project. As pointed out during the second year of the project, implementing and running 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. For this reason, during the third year we planned several project meetings devoted to software integration and testing. During these meetings, junior researchers from different partners, met in the CNR campus in Pisa to perform extensive testing. In addition, to test the limits of current software and solutions, CNR set up a 23-node MobileMAN testbed. To this end, after a dissemination phase

through which the basic ideas of MobileMAN were presented to the students of Computer Engineering of University of Pisa, we opened a call for participation to the MobileMAN testing phase. Since we received many requests to participate in this experimentation, a selection between candidates based on technical skills was necessary. In particular, we were interested in selecting students with a basic knowledge of Linux operating system and the ability to configure wireless cards in ad hoc mode. Moreover, we chose students that were willing to use their own laptops during the experimentation in order to obtain a heterogeneous configuration of the network. A group of 20 students were selected among Bachelor's degree candidates and Master's degree candidates and, with their help, during summer 2005 an extensive experimentation of MobileMAN solutions on a medium size (up to 23 nodes with paths made of up top 8 hops) ad hoc network was carried out at CNR.

Involving young university students in the MobileMAN activities had the effect to increase the dissemination of MobileMAN solutions and, at the same time to increase the number of undergraduates and graduates trained in the field thus contributing to create European specialists in this relevant area. This is aligned with the IST priorities identified by the IST Advisory Group (ISTAG) that is recommending building knowledge and research skills related to the Key Enabling Technologies like mobile and wireless Internet.

It is worth pointing out that a 23-node ad hoc network is one of the largest mobile ad hoc networks tested in worldwide research projects. These experiments have been very useful to point out:

- limitations of current technologies. Routing protocols so far developed needs a careful re-tuning and enhancements to correctly operate on multi-hop networks;
- cross layering is one of the most promising techniques for improving the efficiency of mobile ad hoc networks;
- ad hoc networking technology is promising but it is quite far from being a stable technology for building 4G networks. Further (basic) research efforts are still needed to overcome current limitations of this technology and to establish ad hoc networks as a building block of future networks.

It is interesting to note that similar directions emerged, in the same period, in USA and that ideas and concepts produced by MobileMAN project are considered as reference

points also from USA researchers. Indeed, during 2005, the Defense Advanced Research Projects Agency's (DARPA) -- Advanced Technology Office (ATO) -- lunched the *Control-Based Mobile Ad-Hoc Networking* (CBMANET) Program http://www.darpa.mil/ato/solicit/cbmanet/index.htm. This program starts from the observation that the spectrum is a scarce resource, current protocols do not operate efficiently in ad hoc networks, and hence ad hoc networks do not use spectrum efficiently. Viability of TCP/IP based approaches to MANET are increasingly questioned. To cope with these inefficiencies there is a need for re-thinking of protocols for ad hoc networks by exploiting emerging hot topics like cross-layering, distributed resource allocation, and network coding. As a consequence of this call, the MobileMAN project coordinator has been contacted during September 2005 by David Zish (Senior Director Business Development Sarnoff Corporation, Princeton, New Jersey) and Jim Kaba (Sarnoff Technical Staff Responsible for the CBMANET program) to investigate the possibility to participate to the Sarnoff Corporation consortium to prepare a project proposal for the CBMANET program. Specifically, Sarnoff was highly interested to our expertise (as documented by papers appeared in these years in the scientific literature) in applying cross-layer techniques in optimizing mobile ad hoc networks. After a long phone meeting we concluded that, while from a technical standpoint there were opportunities for an interesting collaboration, the nature of the program prevented to implement a collaboration for that program.

In addition to the technical limits and potentialities, social acceptance and the possibility to build market business cases constitute the two other dimensions that have to be investigated to evaluate the success of this networking paradigm.

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. These activities will be summarized in Deliverable D17 presenting the activities undertaken at SUPSI DSAS to evaluate the social dimensions of ad hoc networks and MobileMAN. The results of these studies indicate that social acceptance is strongly related to the

understanding of the technology. University students involved in the MobileMAN tests have been the most enthusiastic toward this technology; at the other extreme we have elderly that live isolated with almost no contact with the technology. To summarize, social acceptance is much more related to knowledge and use than to the technology in itself.

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. Economic potentialities of the of Mobile Metropolitan Ad hoc Networks have been explored by analyzing several scenarios in which the use of MANET technologies is the basis for the development of services valuable for end users, and a cost-effective solution for the service providers. The approach taken by MobileMAN in this analysis is original. The main research approach used by the MANET research community has been a bottom-up one. Lots of protocols and networking solutions have been proposed to deal with the challenging networking environment in order to support legacy applications also in MANETs. In this view, MANETs are not seen as an opportunity for applications, but as quite hostile environment for legacy applications to operate in. On the contrary, we envision novel application scenarios that leverage the key MANET features in order to provide value to the end user. The research community has often neglected such a top-down approach, while we believe that it represents a key avenue to successfully bring MANET technologies into the market. The results of the economic analysis are reported in Deliverable D18.

The project partners performed an extensive dissemination activity during the third year of the project in different international fora (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 papers and talks 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. A complete report of extensive dissemination activities during the third year of the project is presented in Section 5. Here, it is work remembering that to

disseminate the MobileMAN activities inside the scientific and industrial community we organized the First IEEE Workshop on *Multi-hop Ad hoc Networks: from theory to reality* (REALMAN 2005), http://www.cl.cam.ac.uk/Research/SRG/netos/realman/05/. This workshop had a special role in our dissemination strategy; indeed we organized it with papers' presentations, demos and posters submitted to the workshop open call. All submissions (from both MobileMAN partners and world-wide colleagues) were reviewed by the international program committee involving experts in the field. This guaranteed that MobileMAN results were presented in a high-quality scientific environment able to provide a high visibility to the project results. Indeed the event attracted about 40 worldwide attendees (from China to USA) both from academia and industry. Building up on the success of REALMAN 2005, we are now organising the second edition of the workshop, which will be the satellite workshop of ACM MobiHoc, i.e., the most prestigious event for ad hoc networking. In addition, the maturity of the results produced by the project during the third year is witnessed by the two MobileMAN papers accepted in the ACM MobiHoc 2005 symposium (14% acceptance rate). It is also worth noting that, according to the analysis done by Prof. Martin Mauve (*Duesseldorf University*) on papers accepted in all MobiHoc editions, the two MobileMAN papers are the only two papers dealing with applications accepted for presentation at MobiHoc.[1]

The high visibility of the research carried out in the MobileMAN project is also confirmed by the more and more important roles of the researchers of this project in the mobile ad hoc networking scientific community, see for example Section 5.2 presenting the participation in "Journal Editorial Boards and Conference Committees". Among these activities, it is worth pointing out that IIT-CNR will have the scientific and organization responsibility of the main conference on pervasive systems by hosting in the CNR campus the 4th IEEE International Conference on Pervasive Computing and Communications (PerCom 2006),[2, 3] and the MobileMAN project coordinator is the Program Co-Chair of the 7th ACM Symposium on Mobile Ad Hoc Networking and Computing, MobiHoc 2006, Florence May 22-25, 2006.[4]

[1] See Martin Mauve slides presented at REALMAN 2005 panel.
[2] Marco Conti is the Program chair and Enrico Gregori is the General chair of PerCom 2006.
[3] PerCom 2006, is the first edition of this conference that will be organized outside USA.
[4] http://www.sigmobile.org/mobihoc/2006

During the third year, MobileMAN dissemination activities were not only directed to the scientific community but we also extensively disseminated our results on newspapers and other media (see Section 5.1.2.8 Other Dissemination Activities).

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). As indicated in Annex 1, the main expected outputs of this project are: 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.

No major modifications have been made to these targets during the first two years of the project except abandoning the target of a metropolitan-size, and concentrating the focus on a more realistic scenario (for the current technology) of a small- medium-scale network where routes have a relatively small number of wireless hops. In addition, 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, in Deliverable D9, we subdivided the success criteria for the third year 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).

To cover all these extra activities, and to better disseminate the project, we requested a three-month extension of the project duration. More precisely, as the project started on October 1st 2002, and according to the contract its duration is 36 months, we requested to postpone the end of the project up to December 31, 2005. The three-month extension is necessary to complete the development and testing activities related to the cross layer optimization of the MobileMAN architecture. European Commission has approved the project extension. As a consequence of this, we re-scheduled the deliverables to better cover also the three additional months. The new schedule is reported in Table 1. As a consequence this project report mainly focuses on the activities related to Deliverables D11 – D15.

Table 1: Deliverables Table: Updated delivery dates

Project Number:	IST-2001-38113
Project Acronym:	MOBILEMAN
Title:	Mobile Metropolitan Ad hoc Networks

Del. no.	Deliverable name	WP no.	Lead participant	Estimated person-months	Del. type*	Security**	Delivery (project month)	Updated Delivery date (project month)
D13	MobileMAN domain modelling	2	EURECOM	10	Report	Pub.	30	33
D14	MobileMAN functionalities – final set	3	HUT	14	Prototype	Pub.	32	35
D15	MobileMAN Presentation	5	UCAM-CLAB	8	Workshop	Pub.	32	34
D16	MobileMAN technical evaluation	4	EURECOM	49	Report	Pub.	34	37
D17	Socio-economic evaluation	4	SUPSI-DLS	11.4	Report	Pub.	34	37
D18	Economic value of self-organisation paradigm and market access	5	UCAM-CLAB	14	Report	Pub.	35	37
D19	Exploitation Plan	5	NETikos	5.3	Report	Pub.	35	38
D20	Project final Report	1	CNR	7	Report	Pub.	36	39

Before giving a detailed presentation of the results achieved during the reporting period, we present the specific objectives that were identified in Deliverable D9 for the third year. According to the original plans the project should end at month 36, given the three months extension of the project length, the end of the third year does not represent the end of the project but we still have three months to refine the achieved results. Indeed as shown hereafter all the main project technical results have already been achieved. The three-month extension is useful to complete the testing phase and to disseminate the project results.

2.1 Specifics Objectives for the Reporting Period

The objectives reported below constitute the criteria for evaluating the success of the third year of the project identified in Deliverable D9. With the goals defined in D2 in mind, and the refinement of the project objectives that were performed to take into account the experiences and lessons of the first and second year of the project, below we report 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 (Extra goals).

2.1.1 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 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.

2.1.2 Extra goals

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

- 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; and
- 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.

2.2 Reviewers Comments 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' comments and recommendations listed below.

Comment1: "*The proposed cross-layer architecture has been defined in detail during this period…… The reviewers consider this proposal interesting and believe that its implementation will be of high value*".

Our Action: We work hard to implement a full proof-of-concept prototype (including realistic applications) of a cross-layer architecture; an extensive experimentation phase has been performed to compare and contrast the performance of this architecture with those of a legacy layered architecture.

Comment2: "*The review panel considers that the consortium must work hard to be able to use the new hardware that is being developed within the project to perform extensive experiments during the next project year*".

Our Action: SUPSI-DTI (i.e., the partner in charge of developing the new hardware platform) concentrated all the efforts to developing and experimenting the new platform. The main activity of SUPSI-DTI during the last 12 months has been the completion of the modified 802.11 experimentation platform and implementation and test of different MAC mechanisms designed by CNR. Firstly, the AOB mechanism (see L. Bononi, M. Conti, E. Gregori. Run-Time Optimization of IEEE 802.11 Wireless LANs performance. IEEE Trans.

Parallel Distrib. Syst., 15(1):66-80, January 2004) has been implemented and tested in different configurations. The results of these tests have been presented at REALMAN 2005 workshop. Then, the firmware of the 802.11 experimentation platform has been extended and completed with an optional MAC variant, namely a credit base AOB variant (see [12] R. Bruno, M. Conti E. Gregori. Distributed Contention Control in Heterogeneous 802.11b WLANs, in Proc. of WONS 2005, Jan. 2005). Given the limited numbers of cards (four) we can rely upon within the project budget constraints, we have also developed a simulation framework that was used to extend the results for larger (than 4 nodes) networks. The simulator was extensively validated and tuned by comparing its outputs with those of the experimental testbed. These comparisons showed a good agreement between simulation and experimental results.

Comment3: "*The reviewers consider the potential results of MobileMAN to be of very high value, particularly given the relatively limited experimental research on multihop wireless networks. Therefore, the consortium is encouraged to intensify its efforts to obtain measurement-based results in realistic settings and to bring up its proposals to standardization bodies, as well as, to search for new exploitation initiatives* ".

Our Action: During the third year, the consortium concentrated its efforts to obtain measurement-based results (see Section 2.5.3.3 and D16). Indeed, we mainly exploited the travel budget for organizing technical meetings devoted to experimentation activities. Young researchers met several time in the CNR campus in Pisa to perform extensive tests. In addition, given the limited resources in terms of travel budget and man-months, we evaluated that direct participation to standardization bodies was not possible but we promoted several initiatives to disseminate our results to have as large as possible impact. Among these initiatives it is worth remembering:

- The collaboration with Dr. Adrian Bukalov chairman of the Technical Specification Group – Systems (TSG SYS) of the MESA (Mobility for Emergency and Safety Applications) project http://www.projectmesa.org. The Mesa project is an international partnership between the European Telecommunications Standards Institute (**ETSI**), and the Telecommunications Industry Association (**TIA**) aimed producing globally applicable technical specifications for digital mobile broadband technology, aimed initially at the sectors of public safety and disaster response (see Section 3.1).
- Organization of international scientific events with large impact. As part of MobileMAN, the workshop planned for the dissemination of the project results (REALMAN 2005) was organized as part of an IEEE conference. This guaranteed a worldwide visibility to the

project activities. In addition, we are very active to organize session and workshops on MobileMAN related themes in the most prestigious conferences of the field.

- Participation to journal editorial boards and organization of journal special issues are other important tools for "marketing" of MobileMAN results.
- A special role in the dissemination of MobileMAN results is taken by two books:
    - "Mobile Ad Hoc Networks: from Theory to Reality", edited by Marco Conti, Jon Crowcroft and Andrea Passarella, and published by Nova Science Publishers (USA) in 2006. This book is closely related with REALMAN workshops series. Indeed, the aim of the book is to providing an overview of experimental research activities related to ad hoc networking. The book, in addition to several chapters devoted to the presentation of MobileMAN results, will contain chapters from world-wide leaders such as Nitin Vaidya (Editor in chief of IEEE Transactions on Mobile Computing), and Robert Morris (MIT, Roofnet project).
    - "Mobile Multi-hop Ad hoc Networks (MobileMAN)" edited by Marco Conti and published by Springer. The aim of this book is to provide an in depth analysis of mobile ad hoc networks and to present MobileMAN architecture and protocols as an integrated solution for mobile ad hoc networks design.

The effectiveness of these policies is witnessed by the worldwide interest for our results both from academia and industry; specifically, cross-layer activities produced the interest of USA industry (Sarnoff Corporation) to prepare an ambitious research proposal to reduce to 1/10 the bandwidth consumption of ad hoc networks with respect to legacy TCP/IP based architectures. At EU level, the project partners (given the expertise and knowledge developed in MobielMAN) were invited to be part of several consortia addressing the challenging of future.

As far as the exploitation initiatives, we continued the investigation of the business models with a special attention to the "City Cabs" usage scenario, which was considered interesting and valuable by the review panel. This analysis has produced a paper[5] presented at the most prestigious conference for mobile ad hoc networks: ACM MobiHoc. In addition, we investigated other directions for the exploitation of ad hoc networks. Specifically, we analyzed two directions of ad hoc networks evolution: mesh networks and opportunistic networks. In the case of the mesh networks several exploitation scenarios have been pointed out.[6] This also generated project proposals at EU level for

[5] E. Huang, W. Hu, J. Crowcroft, I. Wassell, "Towards Commercial MobileAd Hoc Network Applications: A radio Dispatch System" Proc. ACM MobiHoc Symposium, Urbana-Champain, May 2005, pp. 355-365.
[6] R. Bruno, M. Conti, E. Gregori, "Mesh Networks: Commodity Multi-hop Ad Hoc Networks", *IEEE Communications Magazine*, March 2005, pp.123-131.

exploiting mesh-based ad hoc networks for different applicative scenarios: public safety (MEHEN), and wireless Internet service providers (WISEMAN). These project proposals were well evaluated from the technical standpoint but not funded due to the limited amount of funding available.

Comment4: "*The review panel recommends a closer alignment of social and technical activities to ensure that the social studies consider the specific characteristics of ad hoc networks and not mobile communications in general".*

Our Action: SUPSI-DSAS, the partner in charge for social studies, implemented several initiatives, based on the use of the participatory design approach, to perform the social evaluation of mobile ad hoc networks. To stimulate cooperation and to reduce language problems, we used as MobileMAN users university students with a high technical background in ICT. Specifically, at the beginning of the third year we performed a participatory design experiment with a group of students at HUT. Some results have been obtained (as reported in Deliverable D17) but problems still emerged due to a lack of real experiences of these students with ad hoc networking technologies. To overcome this difficulty, we involved as users the Pisa University students that participated to the large-scale MobileMAN testbed. Specifically, CNR promoted in collaboration with the Social Communications department of the University of Siena a thesis (by Patrizia Andronico which is a member of CNR team) for social evaluation of MobileMAN technologies with the involvement of University of Pisa students. The experimental phase of this thesis (including results analysis) will be completed by mid-December. In addition to university students with technical ICT background, SUPSI-DSAS performed social analyses involving other categories of users, from elderly to businesses people. In all cases it emerged that real experiences in everyday life with a new technology is necessary to real evaluate it. For this reason, we also introduced comparative studies of: i) mobile phones and ad hoc networks' devices, and ii) public WLANs and ad hoc networks.

2.3 Overview of the Progress during the Reporting Period

During the third year all work-packages have been active. They produced results according to Annex 1 and the refined success criteria (see Section 2.2). In particular, five deliverables were produced; 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

third year activities were performed according to the Milestones defined in Annex 1. Hereafter the third year milestones are briefly discussed.

M7 Month 28: Refinement of the MobileMAN domain model to be used as input for WP3 and the second phase of WP 4

M9 – Month 28: Delivery of a preliminary version of all the components of a MobileMAN. Check on the status and quality of what has been produced.

At the end of Month 28 we had a project meeting, via video-conference, to discuss the refined MobileMAN domain model and to plan the production of Deliverable D13 whose delivery was postponed by three months (the Project Officer approved the new schedule) according to the revised project schedule. In the same meeting we analyzed the status of hardware/software modules' implementations.

M11 – Month 30: Preliminary version of a large scale MobileMAN

As said before, during June-July 2005 (i.e., months 32 and 33) an extensive experimentation of MobileMAN solutions on a medium size ad hoc network (up to 23 nodes with paths made of up top 8 hops) was carried out at CNR.

M13 – Month 30: Meeting with the IAB to evaluate the MobileMAN economic value

At Month 33 we organized the First IEEE Workshop on *Multi-hop Ad hoc Networks: from theory to reality*, (REALMAN 2005), (http://www.cl.cam.ac.uk/realman) to present the MobileMAN results and we invited the IAB members. Unfortunately, budget problems, or not deferrable businesses meetings, prevented the participation of IAB members. Michael Bahr (Siemens) asked for the workshop proceedings that we sent him just after the workshop. We have now made them available all the documentation produced in the project soliciting for their comments and contributions. Even though we had no IAB members participating to the workshop, we received several positive feedbacks from the academic and industrial participants to the workshop. For example, as a consequence of Telecom Italia interest for the developed solutions, CNR established collaboration with Telecom Italia that in September 2005 produced a project proposal (in

the framework of the Italian three-year plan for research promoted by Ministry for Research) aimed at applying ad hoc networking technologies for emergency situations.

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
D11		MobileMAN functionalities – Enhanced Set	**S**	Pub	31 October 2004	16 November 2004
D12		MobileMAN Wireless Network Interface	**O** (**)	Pub	31 January 2005	23 February 2005
D13		MobileMAN domain modelling	**R**	Pub	30 June 2005 (*)	10 June 2005
D14		MobileMAN functionalities – final set	**S**	Pub	31 August 2005 (*)	1 September 2005
D15		MobileMAN Presentation	**W**	Pub	31 July 2005 (*)	29 July 2005

[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

(*) new schedule approved by the Project Officer after the three-month extension of the project length

(**) prototype of a complex electronic system composed of 5 parts (modem, voltage adaptor, DSP board, host PC, power supply). The system is an experimental and demonstration bench for research and verification of novel wireless communications, like the enhanced 802.11 PHY (optimized MAC) as specified in the MobileMAN project.

2.3.1 Deliverables Short Description

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

D11 MobileMAN functionalities – Enhanced Set

The aim of this deliverable is to provide the software that implements, on the Linux operating system, the basic functions required to set up a relatively small campus-wide MobileMAN to be used during the MobileMAN preliminary testing phases (see Deliverables D8 and D10). To this end we mainly concentrated on the implementation and testing of the network and middleware layer functionalities. Specifically, the software we are delivering includes: i) the revised ad hoc routing framework that enables us to construct a multi-hop ad hoc network, ii) a p2p middleware platform based on Pastry (*FreePastry*) that enables us to run simple p2p testing applications on top of the multi-hop ad hoc network. After, the extensive tests performed during the MobileMAN First Phase testing the software was updated to fix software problems/errors, and integration problems/errors. In addition, we also deliver the additional functionalities that have been completed at the end of the second year for which preliminary tests have been reported in Deliverable D10. Specifically, these include a whiteboard and VoIP application for the multi-hop ad hoc network, and a watchdog mechanism required to implement the cooperation enforcing mechanism. In this document, we briefly present the main characteristics of software functionalities we are delivering. More details can be found in Deliverables D5 and D10. The software we are delivering is contained in the CD ROM associated with this deliverable and which is also made available in the Software web site http://keskus.hut.fi/tutkimus/MobileMan (maintained by HUT).

D12 MobileMAN Wireless Network Interface

This report describes the system composed of 5 parts (modem, voltage adaptor, DSP board, host PC, power supply) that constitutes an experimental and demonstration bench for research and verification of novel wireless communications. Particularly, the system allows experimental verification and performance measurements of the enhanced 802.11 PHY (optimized MAC) as specified in the MobileMAN project. A detailed presentation of

the code we developed and the hardware schemes can be found in a technical report published on the project web site http://cnd.iit.cnr.it/mobileMAN/pub-deliv.html

The Wireless Network Interface systems (4 of them have been until now manufactured) are physically located at the SUPSI campus, in Manno, (Switzerland) where they are available for demonstrations.

D13 *MobileMAN domain modelling*

This document presents the consolidated MobileMAN architecture and protocols (from the medium access control to the application layer). The presentation follows a bottom up approach from wireless technologies up to application and economic issues. When appropriate, the social and economic perspectives are also used to compare and contrast technical solutions.

Deliverable D13 is the third document in a series (D5, D10 and D13) devoted to present the MobileMAN architecture and protocols. To make reading easier, we decided to include in D13 all the material relevant to understanding the MobileMAN architecture. Thus, part of the material presented in D5 and D10 is replicated here. This makes D13 a self-contained presentation of MobileMAN architecture and protocols.

The MobileMAN architecture supporting cross-layer interactions is presented in Section 1. In this section we focus on the specification of the Network Status (NeSt) which is a node local memory where information gathered at different layers of the network stack is shared among different protocols and used to adapt the behavior of the node depending on the particular circumstance (e.g., traffic type, channel perturbations, network status, node selfishness and/or maliciousness, among the others) the node operates in. With respect to D10, a new section (Section 1.5) has been added to D13 to provide a description of our software architecture implementing the NeSt. Specifically, in Section 1.5, we present the software architecture of a NeSt prototype supporting cross-layer interactions between a proactive routing protocol and the middleware platform, CrossROAD, which has been developed during the project.

Section 2 discusses the problems when using 802.11 cards in multi-hop ad hoc networks and the enhanced card we designed and implemented to solve these problems.

No new contributions are presented in this section. The description of the enhanced card has been presented in Deliverable D12.

Section 3 is devoted to presenting MobileMAN networking protocols that use the one-hop transmission services provided by the network interface card to construct end-to-end (reliable) delivery services. The basic functionalities implemented by these protocols include routing and forwarding algorithms to deliver the information through the MANET. In addition the low reliability of communications (due to wireless communications, users' mobility, etc.), and the possibility of network congestion require a transport protocol tuned for the MANET environment. Last, to efficiently support cross-layer interactions the routing algorithms have to be extended to support a *location service* to discover the nodes in the network that are offering a specified service. All these functionalities and protocols were already specified in D5 and D10. The new material presented in this section is related to the validation of the transport protocol mechanisms we developed (see the TPA protocol in Deliverable D5). This validation, performed via simulation, shows that TPA outperforms legacy TCP protocol in all operating conditions we investigated.

Section 4 addresses the enforcement of cooperation within a MANET. The deliverable proposes an approach that analyzes the implications of the lack of cooperation in a peer-to-peer network together with a sociological study of cooperation models. Sections 4.6 and 4.7 present the new contributions. Section 4.6 completes the theoretical study of cooperation models developed in deliverable D10, while Section 4.7 contains the application of such concepts to existing peer-to-peer groups - that is, users of file-sharing applications over the internet. Analogies between these groups and a MobileMAN users group are underlined and some conclusions that can apply to the case of MobileMAN are drawn.

Section 5 deals with the MobileMAN middleware platforms. Firstly, we present the Pastry platform that was identified in Deliverable D5 as the most interesting middleware platform (among existing p2p platforms) for a MobileMAN network. Then, we introduce and describe *CrossROAD*: *CROSS-layer Ring Overlay for AD hoc networks*. CrossROAD is our proposal to enhance Pastry by exploiting cross-layer interactions. The new material we present in D13 is the detailed description of the CrossROAD software architecture.

In Section 6 we present the three applications we selected to test the MobileMAN architecture: UDDI, a whiteboard application (WB) and a VoIP session. The three

applications were already presented in Deliverable D10. The new material presented in D13 is related to UDDI and WB. Both applications were integrated in the MobileMAN architecture by exploiting the services offered by Pastry (see D10). During the third year of the project we investigated the integration of UDDI and WB with CrossROAD in order to exploit the better quality of service possible by cross-layer optimizations.

D14 *MobileMAN functionalities – final set*

The aim of this deliverable is to provide the software modules that implements, on the Linux operating system, the functions required to set up a campus-wide MobileMAN, as identified in D5, D10 and D13. Indeed, by integrating the software modules we developed with existing code, we obtained a set of software architectures that enable us to test MobileMAN concepts and ideas. Specifically, we have: i) a legacy (layered) TCP/IP architecture on which we run a VoIP application; ii) a legacy (layered) p2p architecture on which we run Whiteboard and UDDI4m applications, and iii) a p2p cross-layer architecture on which we run both Whiteboard and UDDI4m applications. In this document we describe the main characteristics of the software modules we deliver. More details on our solutions can be found in Deliverables D5, D10 and D13. The software we are delivering is contained in the CD ROM associated with this deliverable and which is also made available in the Software web site http://keskus.hut.fi/tutkimus/MobileMan.

In addition, in this deliverable, we also present our solution to interconnect MobileMAN ad hoc islands among themselves and with the Internet. To this end, we implemented an *Ad Hoc Proxy ARP daemon* (*AHPAd*).

D15 *MobileMAN Presentation*

The aim of this deliverable is to report on the international workshop we organized to disseminate the MobileMAN activities inside the scientific and industrial community. To this end, in the framework of the *IEEE International Conference on Pervasive Services 2005 (ICPS'05)* we organized the First IEEE ICPS Workshop on *Multi-hop Ad hoc Networks: from theory to reality*, REALMAN 2005 (http://www.cl.cam.ac.uk/realman).

The REALMAN workshop idea steams from the lessons we learnt in the

framework of the MobileMAN project. The results obtained in the MobileMAN project and the emerging world-wide literature indicated that to consolidate the ad hoc networking field we need to complement theoretical research activities with the realization and testing of realistic small/medium scale testbed. Indeed, after almost a decade of research into ad hoc networking, MANET technology has not yet affected our way of using wireless networks and there are no clear results showing how well MANETs work in reality as the research in this area has been based on theoretical analyses and simulation results only. Simulation models often introduce simplifications and assumptions that mask (in simulation experiments) important characteristics of the real protocols behavior. To make mobile multi-hop ad hoc networks (MANETs) a reality, simulation modeling and theoretical analyses have to be complemented by real experiences (e.g., measurements on real prototypes) which provide both a direct evaluation of ad hoc networks and, at the same time, precious information for a realistic tuning of simulation models. 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. This is fundamental to reduce the gap 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.

The need for more experimental activities has stimulated the emerging of a new community of researchers combining theoretical research on ad hoc networking with experiences/measurements obtained by implementing ad hoc network prototypes. The aim of REALMAN was to bring together this community and to disseminate the MobileMAN results to the scientific community. The workshop constituted a unique forum for presenting and discussing experiences/results from real ad hoc networks test-beds and prototypes.

The answer to the open call for papers was very encouraging. We received 39 submissions out of which we selected 13 papers for presentation in the workshop sessions. In addition, in response to a separate call we received several interesting demo proposals. The final program also included 8 demos (5 from MobileMAN partners) and 4 posters. 36 worldwide researchers participated to the workshop. These numbers show that REALMAN is already a reference forum for the growing community of researchers

working in this field.

The workshop also included a panel "How to make MANETs scale and provide coverage *for real*" to discuss/identify research directions for making mobile ad hoc networks a reality. The panel, organized and chaired by Jon Crowcroft, had a set of panelists -- Matthias Grossglauser (*EPFL*), Edward Knightly (*RICE University*), Martin Mauve *(Duesseldorf University),* Joerg Ott *(Helsinki University of Technology*), Christian Tschudin (*Basel University*) -- that addressed the discussion from two different perspectives. Specifically, Matthias Grossglauser started by observing that applications are hard to predict (and hence scale is easy to underestimate); he pointed out the value of model-based research, especially for architectural decisions. On the opposite, the other speakers emphasized the key role of applications and real implementations.

Martin Mauve took the opposing view to Matthias Grossglauser; his claim was: *application led research is better!* Martin gave many examples from a large vehicle/car-to-car network they built, telling how the wireless network design worked much better when the architecture was application centered.

Edward Knightly and Joerg Ott discussed two directions for the evolution of ad hoc networks: mesh networks and opportunistic networking. Edward Knightly discussed research challenges in implementing a real and scalable mesh network by exploiting his experience with the RICE TAP project; Joerg Ott talked about opportunistic networking and pointed out very nice real examples to show that opportunistic networking (i.e., delay tolerant networks, DTN) can immediately provide useful applications for ad hoc networking. In Joerg view DTN precedes MANET.

Christian Tschudin summarized the discussion pointing out the need for a pragmatic approach in the mobile ad hoc research: use an application driven approach, and integrate/consolidate existing algorithms and software. Specifically, he stated: *While in theory it might be feasible to have 100 hop paths, I don't think that this will happen in real MANETs. The limit lies somewhere below and is determined more by pragmatic property bundles like routing stability or TCP fairness rather than single functions (finding a route) or optimizations (battery life time). What can theory, what can systems work contributes to bracket this ad hoc horizon? Agreeing on the "real objectives" would be a first step.*

The slides of the panel presentations and other workshop material can be found at: http://www.cl.cam.ac.uk/realman. All partners contributed to this deliverable.

2.4 Evaluation of Work Accomplished during the Reporting Period

From a technical standpoint the main objective of third-year activities has been the validation of the solutions devised during the first and second year of the project for constructing a MobileMAN based on a legacy layered architecture. In addition we developed a proof-of-concept MobileMAN prototype based on our cross-layer architecture. Figure 1, represent our reference architecture, integrating both the legacy and the cross layering reference models, see D13 for details.

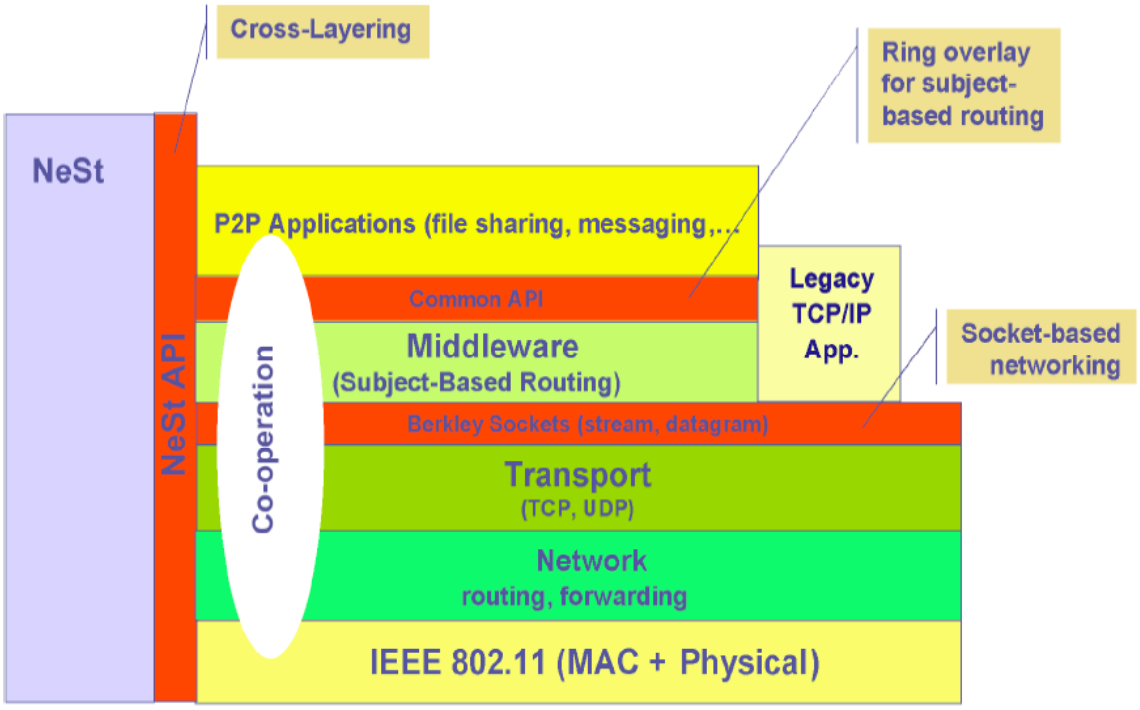

Figure 1: MobileMAN Integrated architecture

By exploiting the software we developed, and integrating it with existing software modules, we obtained three (software) architectures to be used for testing MobileMAN ideas. Specifically, we have:

1) a legacy TCP/IP architecture on which we run VoIP applications;
2) a legacy p2p architecture on which we run both Whiteboard and UDDI4m applications
3) a p2p cross-layer architecture on which we run both Whiteboard and UDDI4m applications

Scenario 1: VoIP on legacy TCP/IP architecture

The Voice over IP (VoIP) is a real time application that is highly demanding for ad hoc networks. The VoIP application contains two main modules; signalling module and data transport module. In the current implementation, the SIP signalling protocol uses UDP as the only transport protocol. The data transport module implements a RTP client for exchanging the voice packets.

Figure 2 summarizes the software modules used in this scenario.

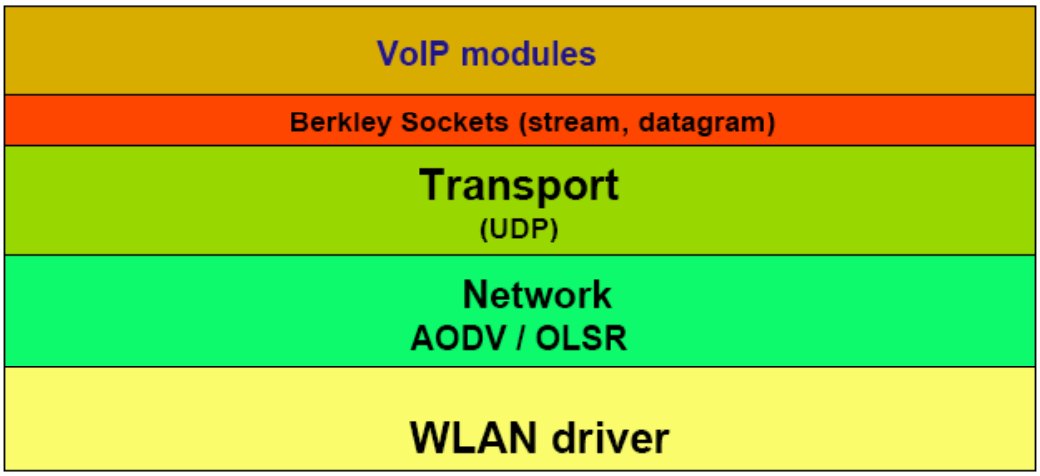

Figure 2: Scenario 1 software architecture

Scenario 2: Whiteboard and UDDI4m on legacy p2p architecture

In this scenario we investigate the behavior of content/document sharing applications based on legacy p2p middleware architecture. Specifically, we considered a whiteboard multicast application, and a service discovery protocol and delivery mechanism, named UDDI4m, which is based on the traditional UDDI protocol. UDDI4m introduces a level between the transport and application level. An overlay network composes the additional level of UDDI4m, where each node may have (at the same time) the role of client and server. Service discovery is realized through the communication with the other servers on the overlay network. In this scenario the overlay network is built using the Pastry platform. Both Whiteboard and UDDI4m exploit Pastry services through the Common API.

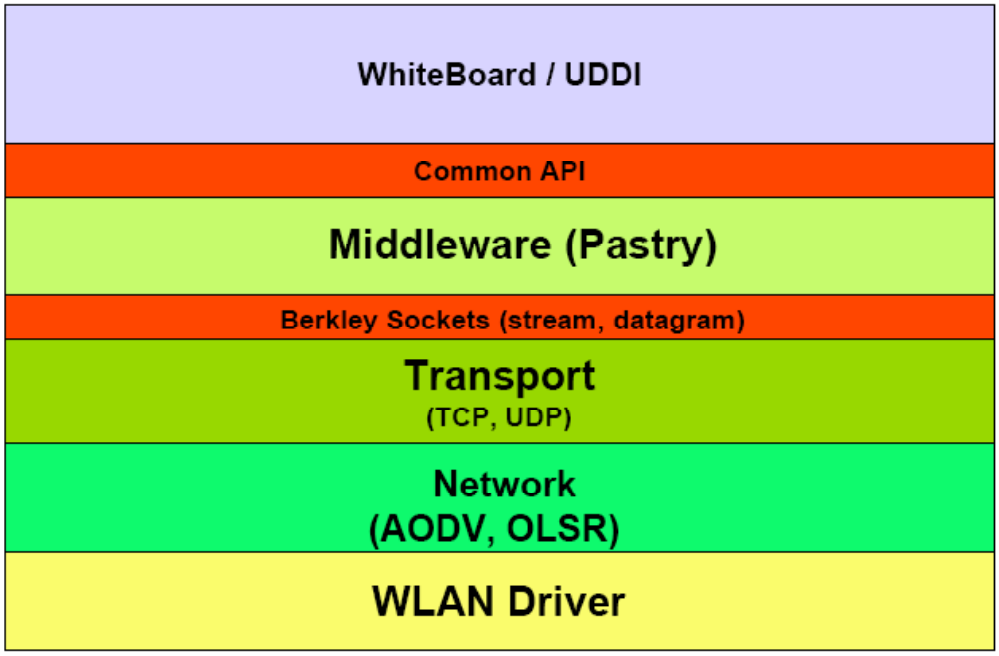

Figure 3: Scenario 2 software architecture

Scenario 3: Whiteboard and UDDI4m on cross-layer p2p architecture

In this scenario we can investigate the impact of cross-layer optimizations on Whiteboard and UDDI4m. To this end we implemented CrossROAD, i.e., our cross-layer version of Pastry, and the subset of the NeSt (XL-plugin) required to support cross-layer interactions between middleware and routing.

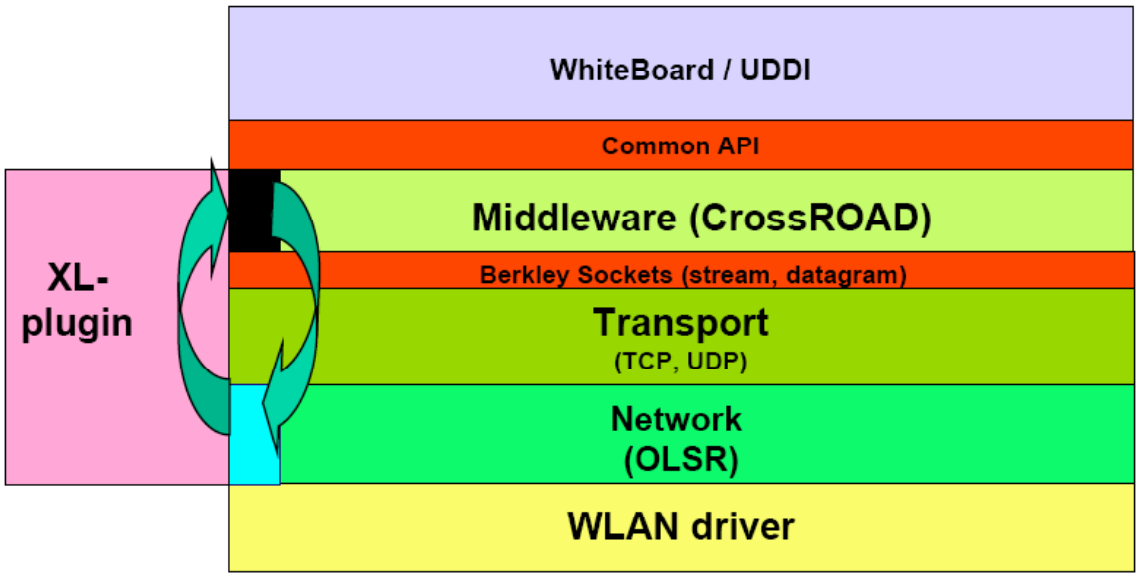

Figure 4: Scenario 3 software architecture

2.4.1 Third Year Achieved Objectives

The project workplan has been fulfilled and a great majority of the project objectives (see Section 2.1) have been achieved. It is worth remembering that the project length was extended of three months and that some of the project objectives originally planned for the third year have now been moved in the three extra months. More specifically, the three extra months have been used to refine our solutions and complete the testing phase of MobileMAN from the technical, economical, and social perspectives. In particular, the deliverables related to technical, economical, and social evaluations have been postponed to the last three months of the project. Starting from this note, hereafter we first discuss the objectives achieved during the third year; then we report about the status of the ongoing activities needed to achieve all the pending project objectives.

With reference to the success criteria defined in Section 2.2, during the third year all the following objectives have been fully met. Hereafter, we first report the success criteria and then what we have really achieved to meet it.

- *Success Criteria:* 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.

Our Achievements:

The description of the devised solutions is reported in Deliverable D13 (which complements the presentations of MobileMAN solutions given in D5 and D10). In this deliverable we present our solutions following a bottom up approach from wireless technologies up to the applications (see description of D13 at page 19). In addition, the deliverable contains a detailed presentation of our cross-layer architecture and protocols for a proof-of-concept prototype of cross-layering concepts.

- *Success Criteria:* The hardware/software implementation of the above solutions.

Our Achievements:

Deliverables D11 and D14 report the software modules that implement, on the Linux operating system, the functions required to set up a campus-wide MobileMAN, as

identified in D5, D10 and D13. In addition Deliverable D12 reports the complex electronic system composed of 5 parts (modem, voltage adaptor, DSP board, host PC, power supply) that implements an experimental and demonstration bench for research and verification of novel wireless communications. Particularly, the system allows experimental verification and performance measurements of the enhanced 802.11 PHY (optimized MAC) as specified in the MobileMAN project.

• *Success Criteria:* 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.

Our Achievements:

As explained in Deliverbale D15, by integrating the software modules we developed with existing code, we obtained a set of software architectures that enable us to test MobileMAN concepts and ideas. Specifically, in addition to a full-layered protocol stack, we devised and implemented the software modules needed to build a proof-of-concept prototype of a MobileMAN cross-layer architecture. Specifically, we have: i) a legacy (layered) TCP/IP architecture on which we run a VoIP application; ii) a legacy (layered) p2p architecture on which we run Whiteboard and UDDI4m applications, and iii) a p2p cross-layer architecture on which we run both Whiteboard and UDDI4m applications.

Hereafter, we discuss the success criteria not completely achieved at the end of the third year of the project and we present the ongoing activities to achieve them in the last three months of the project.

• *Success Criteria*: A realistic (with respect to the current technology) “large-scale” testbed with a community of student as users.

Our Achievements:

This activity has been almost completed within the third year by implementing in the CNR campus in Pisa a 23-node MobileMAN testbed in which we involved, as users, students of Computer Engineering of University of Pisa. Specifically after a dissemination phase, we opened a call for participation to the MobileMAN testing phase. Since we have received many requests to participate in this experimentation, a selection between candidates based on technical skills was necessary. A group of 20 students were selected among Bachelor's degree candidates and Master's degree candidates and, with their help, during summer 2005 an extensive experimentation of MobileMAN solutions on a medium size (up to 23 nodes with paths made up of up top 8 hops) ad hoc network was carried out at CNR.

The report of these activities is contained in Deliverable D16 to be delivered at month 37.

• *Success Criteria:* 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.

Our Achievements:

During the third year of the project we have developed a simulation framework, which extends the Network Simulator NS-2 (v. 2.27) with a cross-layer interface (XL-interface) that standardizes vertical interactions among protocols according to the MobileMAN cross-layer architecture. This simulation framework has been successfully presented at Fourth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2005); see the list of publication in Section 5. Indeed the paper was selected for the special issue devoted to Med-Hoc-Net 2005 to appear on *Ad Hoc & Sensor Wireless Networks: An International Journal* (Old City Publishing). This simulation framework, together with results obtained by applying it for analyzing our cross-layer solutions (e.g., see *Reliable Forwarding* and cross-layer optimization of the *Gnutella protocol*), is described in Deliverable D16.

- *Success Criteria:* Measures (whenever possible on the real testbed) of the users' satisfaction of the ad hoc networking paradigm.

Our Achievements:

Interaction with users generated several problems that we cannot anticipate. Indeed we experienced problems related to the level of users cooperation, language difficulties (moving from a technical language to everyday language) and the difficulty to make users aware of a technology that they cannot yet directly experiment in everyday life. To cope with these problems different research strategies were applied. To stimulate cooperation and to reduce language problems, we used as MobileMAN users university students with a high technical background in ICT. Specifically, at the beginning of the third year we performed a participatory design experiment with a group of students at HUT. Some results have been obtained (as reported in Deliverable D17) but problems still emerged due to a lack of real experiences of these students with ad hoc networking technologies. To overcome also this difficulty, we involved as users the Pisa University students that participated to the large-scale MobileMAN testbed. Specifically, CNR promoted in collaboration with the Social Communications department of the University of Siena a thesis (by Patrizia Andronico which is a member of CNR team) for social evaluation of MobileMAN technologies with the involvement of University of Pisa students. The experimental phase of this thesis (including results analysis) will be completed by mid-December.

- Success Criteria: Exploitation of the MobileMAN solutions for: i) the creation of start-ups, and ii) novel business processes.

Our Achievements:

Our main approach to study the potentialities of MobileMAN from an economic point of view, and hence promote novel businesses, is based on the definition and analysis of scenarios in which the use of ad hoc networking technologies is the basis for the development of services valuable for end users, and a cost-effective solution

for the service providers. As reported in Deliverable D18, we provide examples of how re-engineering existing applications based on the MANET paradigm allows to i) reduce the maintenance costs for the service providers, ii) reduce the entry barriers for new competitors, and thus iii) reduce the costs for end users. Moreover, we present scenarios in which MANETs allow to develop brand-new applications and services. The economical benefits of these scenarios provide the basis for start-ups creation. In addition, by investigating the extension of MANET paradigm towards *mesh networks* we highlighted the big economic potentialities of ad hoc networking protocols when used in a hybrid architectures to provide "low cost" broadband wireless access to Internet.

2.5 Activities

As defined in Annex 1, during the third 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 third year, the self-assessment task to evaluate the work accomplished during the third year and to define the actions for the last three months of the project to meet all the project objectives.

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. It is worth noting that, to optimize the project budget during the third years several project management meetings were performed by videoconference. Indeed, CNR made available to the consortium a very effective video-conferencing tool (Marratech E-Meeting Portal) that enables very effective VoIP communications, working on shared documents and video interactions. This enabled us to save part of the traveling budget that was used for technical meeting devoted to software integration and testing.

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. From this analysis it emerged that the project was very well aligned with project goals. Indeed we verified that we are not only able to achieve all the main project objectives as defined in Annex 1 but we are able to show (both via simulation and real testbeds) the effectiveness of the cross-layer approach. As explained before to cope with difficulties emerging in the social evaluation activities, CNR complemented SUPSI-DSAS activities, with a thesis in cooperation with Social Communications department of University of Siena.

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. 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 third 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 participatory design approach has been selected for the social evaluation of MobileMAN. Participatory design seemed the best approach, since it makes use of several techniques to involve potential end-users in the design and development phases of a system. By involving potential end users in the design of

MobileMAN, we would have the opportunity to know from near how the user perceives the MobileMAN technology and how they might integrate it into their life. By taking into account the difficulties encountered in involving end-users, at the beginning of the third year we refined and modified our initial methodology for users involvement (see Deliverable D17). In addition to direct analysis of people experimenting MobileMAN technology, interviews and questionnaires have been used to perform a social evaluation of MobileMAN with different categories of citizens. Specifically, we interviewed several elderly to investigate their relationship with technology, in particular with communication technology. We investigated their use of technology, their opinions and ideas towards it. We tried to find out what types of needs the elderly have that MobileMAN could address, to enhance the quality of life of the elderly. In addition to elderly, other citizens belonging to several different categories have been involved (students, professionals, businessmen, etc.). In order to cope with the users difficulty in seeing the aspects that are specific features of ad hoc networks, as they have not a direct experience of what ad hoc networks are, comparative studies with well-known technologies have also been introduced during the interactions with the users. Specifically, we performed comparative study of mobile phones and ad hoc networks' devices, and a second comparative study of public WLANs and ad hoc networks.

2.5.1.2 T2.8 Economic driven modelling

Research work at Cambridge 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

As explained in the previous Progress Report (N. 2), the main objective of task T2.9 has been the refinement of the domain model to take into account the impact of cross layering on the MobileMAN architecture and protocols. This activity ended with the production of Deliverable D13 that presents the consolidated architecture, protocols and services designed for the MobileMAN project. During the third year cross-layer activities

concentrated on solutions necessary to define a proof-of-concept prototype of our cross layer architecture to compare it with the legacy layered MobileMAN architecture as planned in Annex 1.

2.5.2 **WP3 Activities**

During the third year, we completed the WP3 activities already active at the end of the second year.

2.5.2.1 T3.1 Bursty-responsive MAC

The main activity of SUPSI-DTI during the last 12 months has been the completion of the modified 802.11 experimentation platform and implementation and test of different MAC mechanisms (proposed by CNR-IIT).

During the third year we completed the implementation of the experimental and demonstration bench Wireless Network Interface systems that allows experimental verification and performance measurements of the enhanced 802.11 PHY (optimized MAC) as specified in the MobileMAN project. Specifically, we developed a complex electronic system composed of 5 parts (modem, voltage adaptor, DSP board, host PC, power supply. The Wireless Network Interface systems (4 of them have been until now manufactured) are physically located at the SUPSI campus, in Manno, Switzerland where are available for demonstrations.

First, a slight variation of the AOB mechanism (see L. Bononi, M. Conti, E. Gregori. Run-Time Optimization of IEEE 802.11 Wireless LANs performance. IEEE Trans. Parallel Distrib. Syst., 15(1):66-80, January 2004) has been implemented and tested in different configurations.

Furthermore, the firmware of the 802.11 experimentation platform has been extended and completed with an optional MAC variant, namely a credit base AOB variant (see R. Bruno, M. Conti E. Gregori. Distributed Contention Control in Heterogeneous 802.11b WLANs, in Proc. of WONS 2005, Jan. 2005).

The specification of the structure for packet- and other data management within the access hardware has been completed. 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 proposed. Particular attention has been deserved to cross-layering future extension.

A last activity on the 802.11 experimentation platform has been the implementation of the connection between platform and host computer. IEEE1394a (FireWire) has been chosen since it was available on the used DSP board. The connection allows to perform test with real traffic, and even to integrate the upper protocol layers (i.e. IP) in the system in order to use the platforms in real applications scenarios.

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 (see next section).

2.5.2.3 T3.3 Routing and forwarding

The third implementation activities related to routing and forwarding concentrated on designing and implementing a network-layer support for the generalized Service Discovery Module (SDM). 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. Specifically, a plugin, called XL-plugin, has been defined in order to encapsulate additional information in routing packets. This information is represented by services identifiers, used to associate to each node the list of services locally provided. When OLSR receives a routing message containing this additional information, it passes the contents to XL-plugin that provides to store services identifiers of other nodes in its local data structures.

2.5.2.4 T3.4 Security and Co-operation Model

The activities of this task focused on the implementation of our cooperation enforcing mechanism, CORE, for the Linux operating system. CORE has been implemented as a Linux daemon. CORE software architecture includes 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.

2.5.2.5 T3.5 P2P delivery mechanisms

As explained in the previous report, during the second year, we revised the Pastry platform to optimize its performance by exploiting cross-layer interactions. The result of this was the definition of a middleware platform supporting the same API as Pastry but optimized for operating in the ad hoc environment. This platform has been named *CrossROAD*: *CROSS-layer Ring Overlay for AD hoc networks* (see D13). During the third year we completed the implementation of CrossRoad. Specifically, to develop a MobileMAN proof-of-concept prototype, we choose to limit the implementation of the cross-layer architecture by exploiting an open source implementation of the proactive routing protocol OLSR which allows the development of dynamic libraries (plugins) for the definition of additional information to be sent on the network through routing packets. In case of CrossROAD, this library has been called *XL-plugin*, because it implements cross-layer interactions between middleware and routing protocols.

In addition, we have extended the P2P approach beyond the implementation of a DHT system. Specifically, on top of the DHT we have used a P2P multicast protocol (Scribe), and we have developed a P2P Group-Communication application (the Whiteboard). From a design standpoint, Scribe nicely integrates with CommonAPI DHTs (such as Pastry, Bamboo and CrossROAD), and builds a multicast tree on top of the logical network provided by the DHT system. During the third year Cambridge refined the original Scribe module in order to make it fully compliant with a CommonAPI interface. This allowed us

to port the Scribe module to CrossROAD (please note that the original Scribe module was developed on top of Pastry, and then was ported to Bamboo in the first stages of the Project). The Scribe module is the multicast engine for the Group Communication applications targeted by Cambridge in the Project. Specifically, in the third year we completed the development of Whiteboard, which is a simple application out of this class. Every user running the Whiteboard module can draw strokes on a canvas. Strokes drawn by a user are disseminated in the network and reach the other users running the same application. There they are rendered on the local canvas. This way, Whiteboard implements a distributed whiteboard, which users can use to lively exchange short messages or drawings. Together with the DHTs used in the Project (i.e., Pastry and CrossROAD), Scribe and Whiteboard constitute a complete P2P stack for Group Communication Application, that has been implemented in the network test-beds deployed during the project (see Deliverables D11 and D14).

2.5.2.6 T3.6 Risk reduction in the system development

The main software and hardware problems for the implementation of our solutions were tackled during the second year. During the third year we did not experience any major new problem. In Deliverable D9 we announced the set-up of a junior researchers group to cope with issues generated by the integration of different software components developed by the Project partners. This group has been actively operating in the third year to carry out integration tests. In particular, the link established between the Cambridge and CNR researchers within the group have been very active throughout the whole third year in order to achieve a high-performance integration of the respective software components.

2.5.3 **WP4 Activities**

During the third year, WP4 activities concentrated as planned on T4.3, T4.4 and T4.5. Task 4.1 activities were successfully completed, during the second year, as well as Task 4.2 technical activities (see D8). On the other hand, as explained in Deliverable 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. Hence some activities of T4.2 were completed at the beginning of the third year.

2.5.3.1 T4.2 Small Area Scale Validation and Analysis:

The aim of these activities is to validate the small scale MobileMAN from a technical (i.e., the technical constraints and limitations of the system), and social standpoint. According to Annex 1 these activities have to be completed during the second year of the project. However, as explained in previous Progress Report (N. 2), while the technical objectives were fully achieved during the second year, we had some delays in completing the social evaluation part due to users collaboration problems. This caused a temporal shift of the social validation from summer to fall 2004. Specifically, to overcome collaboration problem we defined a social evaluation strategy within HUT academic courses, with rewarded participation by the students. For this reason we have to wait the first months of the third year to implement it. Our evaluation strategy implemented a participatory design experiment with a group of students at HUT that developed (by working in groups either through a *wiki* website that we set up for this activity, or through traditional paper) scenarios and applications for ad hoc networking technology. The activity of the collective creative scenarios and applications building through the wiki website that we realized for this purpose had three objectives:

a) to initiate a dialogue with individuals that would provide information, opinions and ideas for new applications and use scenarios for MobileMAN, as well as initiate dissemination activities among non-academic individuals;

b) to test "collaboration in use" by the students and "collaborative interaction" among users;

c) to test the wiki as participatory design instrument for this kind of activities (tool for collective brainstorming, independently from time and location of the single participants activity).

The activity consisted of groups of 3 or 4 students elaborating scenarios in which the employment of MobileMAN has to provide interesting benefits to the users. The students produced and discussed possible scenarios for exploitation of ad hoc networking but many of the created scenarios do not really exploit the nature of MobileMAN as ad hoc network. Indeed a main difficulty (and perhaps the most important aspect for us) emerged due to the perceived abstract nature of ad hoc networks: individuals have huge difficulties in seeing the aspects that are specific features of ad hoc networks.

2.5.3.2 T4.3 Evaluation of MobileMAN Networking:

The aim of this task is to develop a simulative study of the MobileMAN networking components (e.g., connection to Internet, as well as congestion control and error recovery mechanisms). To perform this study we have to extend the NS-2 tool with MobileMAN mechanisms and protocols (e.g., enhanced MAC card, cross-layer architecture, Pastry, Gnutella and CrossROAD). Simulation studies have been used to investigate the effectiveness of several aspects of the MobileMAN protocol stack. Specifically, we analyzed and compared the performance (in multi-hop ad hoc networks) of 802.11 card with those of the enhanced card we designed and implemented. These studies enabled us to analyze the performance of the enhanced card in scenarios which are more complex with respect to those achievable in experimental 4-node testbeds. Simulation studies have also been used to analyze the performance of MobileMAN mechanism for cooperation enforcing, CORE, and to study the TCP congestion control mechanisms when used in ad hoc environment and compare it with TPA (a Transport Protocol for Ad hoc networks).

A special attention was devoted to study the performance of our cross-layer architecture. To this end we extended the Network Simulator NS-2 (v. 2.27) with a cross-layer interface (XL-interface) that standardizes vertical interactions among protocols according to the MobileMAN cross-layer architecture. This simulation framework has been then used to validate our cross-layer solutions (e.g., see *Reliable Forwarding* and cross-layer optimization of the *Gnutella protocol*). These results reported in Deliverable D16 include the performance analysis of our mechanism for reliable forwarding which exploits cross layer interactions (REEF) and the performance of Gnutella protocol vs. XL-Gnutella (i.e., Gnutella optimized with cross-layer interactions).

2.5.3.3 T4 .4 Final Integration and Testing:

The aim of this task is the integration and testing of MobileMAN solutions on a medium scale ad hoc network. According to the plans this task provides its input to Deliverable D16 to be delivered at month 37 according to the new schedule. However, most of this task's activities have been performed during the third year and had as a main result the experimental phase performed at CNR during June-July 2005 during which MobileMAN solutions were tested on a 23-node ad hoc network.

2.5.3.4 T4 .5 Large Area Scale Validation:

The aim of this task is to evaluate the ad hoc networking technology with users. This task constitutes one of the main inputs for Deliverable D17 (month 37). The main activity in this framework was undertaken by the social unit (SUPSI-DSAS) by exploiting the collaboration with CNR that provided support by organizing groups of university students with technical background to investigate applicative scenarios for the MobileMAN technology. Indeed to cope with the difficulties emerged in the previous evaluation phase (due to the perceived abstract nature of ad hoc networks: individuals have huge difficulties in seeing the aspects that are specific features of ad hoc networks), in the second half of the third year we involved in the social evaluation of MobileMAN the group of students that were also performing the experimental test on the small-medium size (23 nodes) ad hoc networks (see T4.4). Although the test session was about technical solutions, we were able to initiate an interesting dialogue with a group of potential end-users that are technology skilled and aware of what a MobileMAN is. This activity was extended with a Laurea thesis (supervised by CNR and University of Siena – Social Communications department) analyzing the expectations (with respect to ad hoc networking) of the group of students after completing the testing phase of the medium size MobileMAN network.

2.5.3.5 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. In addition to the creation of the group of junior researchers in charge of the testing meetings, during the third year in order to tackle the big challenge of experimenting MobileMAN technologies on a medium-scale network, CNR carefully identified a group of university students to be involved in the testing phase. To reduce the risks, the students were selected from students of Computer Engineering of University of Pisa. Since we have received many requests to participate in this experimentation, a selection between candidates based on technical skills was necessary. In particular, we identified students with a basic knowledge of Linux operating system and the ability to configure wireless cards in ad hoc mode. Moreover, we chose students that were willing to use their own laptops during the experimentation in order to obtain a heterogeneous configuration of the network. As participation to the testing phase was time-consuming for the students (during a period of the year in which they have university

exams), to guarantee a reliable participation of the students to the testing CNR provided them a contract as "occasional collaborators".

2.5.4 **WP5 Activities**

During the third year, as planned, we started the activities of Tasks T5.3, too. Hence all workpackage tasks were active during the third year.

2.5.4.1 T5.1 Dissemination

The project performed extensive dissemination activities during the third year which produced measurable results as shown in Section 5. Hereafter, we only wish to remember that to disseminate the MobileMAN activities inside the scientific and industrial community we organized the First IEEE Workshop on *Multi-hop Ad hoc Networks: from theory to reality*, (REALMAN 2005), (http://www.cl.cam.ac.uk/realman). This workshop had a special role in our dissemination strategy attracting 36 worldwide researchers from academia and industry. The workshop program in addition to 13 technical presentations included 8 demos (5 from MobileMAN partners) and 4 posters and a panel "How to make MANETs scale and provide coverage *for real*" to discuss/identify research directions for making mobile ad hoc networks a reality.

Building up on the success of REALMAN 2005, the second edition of the workshop will be the satellite workshop of ACM MobiHoc, i.e., the most prestigious event for ad hoc networking.

2.5.4.2 T5.2 Exploitation Plan Definition

We envision several exploitations for the results achieved in the Project, either in the industrial, and in the research field. The exploitation plan is currently under definition. This task constitutes the main input to Deliverable D19 (month 38). Among the activities for the exploitation of MobileMAN it is worth remembering:

- Workshop for Nokia Networks representatives to show the usage of VoIP on top of Ad Hoc networks. Their intent is to launch a Nokia project on this topic.
- Two meetings with the "new innovation integration" center located in the Helsinki University of Technology campus to present MobileMAN project and announce it for interested start-ups.

2.5.4.3 T5.3 Market Access:

We have complemented and completed the technical and economical evaluation of possible applications, started in Deliverable D5 (see Deliverable D18 for the complete analysis). Specifically, we have identified new applications that can leverage the ad hoc technology to provide valuable services to the user. We have analysed in depth the city cab scenario, i.e., the use of 802.11 ad hoc networks to replace the currently used taxi radio dispatch systems. We have found that such a system is viable both economically and technically. From a technical standpoint, such a system will present outage times, i.e., time intervals during which some taxi is isolated from the rest of the network, and thus not reachable. The length of outage times depends on a bunch of parameters, including the traffic congestion, the number of taxies using the ad hoc system, etc. However, average outage times are in the order of few tens of seconds, and they are never longer than a few minutes. These figures are completely compatible with the performance required by the radio dispatch application. From an economical standpoint, the system is able to cut both the one-time and recurrent costs associated to proprietary radio-dispatch systems. Thus, it allows reducing the entry barriers for new operators. The need for a fairly high number of taxies adopting the system calls for the integration of the radio-dispatch systems of different cab companies. This opens very interesting and profitable market models and opportunities for an open radio dispatch system based on 802.11 ad hoc networks.

We have also investigated possible future directions for the use of ad hoc technologies in the real world. Specifically, we have started exploring the mesh network and opportunistic networking. It should be noted that the latter constitutes a strong link between the MobileMAN Project and the starting EC Haggle Project (see Deliverable D18).

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 only a major deviation from original planning of Annex 1, CNR which has 4 + 7.8 extra person months. 4 months correspond to CNR personnel extra effort necessary for the implementation and testing of the innovative cross-layered architecture (NeSt, CrossRoad, Service Discovery Module, XL-plugin, etc.). The other 7.8 person months correspond to the efforts of the 20

students that have been involved in the MobileMAN medium-size testbed. As explained before, to guarantee a reliable participation of the students to the testing, CNR provided them contracts as “occasional collaborators”. This required a re-allocation of the budget. Specifically, we re-allocated to “occasional collaborators” contracts the budged originally planned for a subcontract with University of Pisa and the budget for rental the hardware required for the testing phase. It is worth noting that the re-allocated budget was in any case related to the experimentation phase.

Table 1-I. Effort for the reporting period per WPs/Tasks (person months)

	CNR				Cambridge				Eurecom			
	Period		Total		Period		Total		Period		Total	
WP/Task	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act
WP0	1.0	1.0	5.5	5.5	0.5	0.5	1.5	1.5	0.5	0.5	2.1	2.1
WP1	0.5	0.5	4.5	4.5	0.5	0.5	1.5	1.5	0.5	0.5	2.7	2.5
WP2	0.5*	0.5*	2.5	2.5					1.0	1.0	6.0	6.0
Task 2.1							0.5	0.5				
Task 2.2			1.0	4.0			0.6	0.6			0.5	0.5
Task 2.3			7.0	15.0								
Task 2.4			5.0	2.5							1.0	1.0
Task 2.5											9.3	9.3
Task 2.6			1.0	1.0			4.5	4.5				
Task 2.7												
Task 2.8					1.0	1.5	9.0	8.5				
Task 2.9	1.0	1.0	4.5	8.5			1.0	1.0	1.0	1.0	4.0	5.3
WP 3	1.0*	1.0*	2.5	2.5								
Task 3.1												
Task 3.2	1.0	1.0	3.5	1.0								
Task 3.3	1.0	1.0	4.5	4.5								
Task 3.4									8.0	8.0	18.7	17.6
Task 3.5	0.0	1.0		3.0	3.0	4.0	7.5	7.5				
Task 3.6	0.5	0.5	1.0	1.0	0.5	0.5	0.5	0.5				
WP 4	0.5*	0.0	1.0	0.5								
Task 4.1			1.0	1.0			0.6	0.6			1.0	1.0
Task 4.2			2.5	4.5			0.5	0.5			1.0	1.0
Task 4.3	5.0	7.5	8.0	10.5	1.0		1.0		2.0	2.0	2.0	2.0
Task 4.4	8.0	9.0 (+7.8)	8.0	9.0 (+7.8)	2.0	3.2	2.0	3.2	3.0	3.0	3.0	3.0
Task 4.5	0.0	0.0	0.0	0.0								
Task 4.6	0.5		0.5	0.1	0.5	0.1	0.5	0.1				
WP 5 *	0.5	0.5	0.5	0.5								
Task 5.1	1.0	1.5	2.5	3.0	2.0	2.5	3.0	3.5	1.5	1.5	3.0	3.0
Task 5.2	0.5	0.5	1.0	1.0	0.3	0.3	1.3	1.3	1.0	1.0	1.5	1.4
Task 5.3	0.5	0.5	0.5	0.5	1.0	1.5	1.0	1.5	0.5		0.5	0.0
TOTAL	23.0	27.0 (+ 7.8)	68.0	86.1 (+ 7.8)	12.3	14.6	36.5	36.8	19.0	18.5	56.3	55.7

* WP coordination and deliverables management.

+ Application level software development.

Table 1-II. Effort for the reporting period per WPs/Tasks (person months)

	HUT				Netikos				SUPSI			
	Period		Total		Period		Total		Period		Total	
WP/Task	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act
WP0	0.5	0.5	1.5	1.5	0.5	0.5	1.1	1.2	1.0	1.0	3.4	3.5
WP1	0.5	0.5	1.7	1.7	0.5	0.5	1.1	1.2	0.5	0.5	3.5	3.5
WP2									1.0	1.0	1.0	1.0
Task 2.1							2.5	2.5			0.5	0.5
Task 2.2			0.5	0.5			0.2	0.2			0.5	0.5
Task 2.3											3	3
Task 2.4			1.0	1.5								
Task 2.5												
Task 2.6												
Task 2.7									1.0	1.0	11.9	12.4
Task 2.8												
Task 2.9	0.5	0.5	1.0	1.0					0.5	0.5	1.7	1.7
WP 3	1.0	4.0	1.0	4.0	2[+]	2.5[+]	6	7.5				
Task 3.1									10.0	11.0	36.7	38.5
Task 3.2	2.5	2.5	5.0	6.0								
Task 3.3	4.0		17.2	12.5 (+ 15)***								
Task 3.4												
Task 3.5												
Task 3.6												
WP 4									3.0	3.0	3.0	3.0
Task 4.1			2.0	2.0			5.6	6.0				
Task 4.2	0.0	1.0	3.0	3.0			1.0	2.0	0.0	1.0	1.0	2.0
Task 4.3												
Task 4.4	3.0	4.0	3.0	4.0	2.0	2.5	2.0	2.5				
Task 4.5												
Task 4.6									3.0	3.0	3.0	3.0
WP 5 [*]												
Task 5.1	1.0	1.0	2.0	2.0	0.5	0.5	0.7	0.7	1.0	1.0	2.5	2.5
Task 5.2	0.5	0.5	1.0	1.0	2.0	2.0	2.5	2.5	0.5	0.5	1.0	1.0
Task 5.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TOTAL	14.0	15.0	40.4	41.2 (+ 15)[***]	8.0	9.0	23.2	26.8	22.0	24.0	73.2	76.6

[*] WP coordination and deliverables management.

[+] Application level software development.

[***] The 15 man months are related to master students and are not charged on the project costs

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

In spite of the massive efforts in researching and developing mobile ad hoc networks the current state of the art (and also MobileMAN results) indicates that:

i) this technology is not yet mature, and

ii) its suitability for mass-market adoption is still questionable.

Hereafter we will discuss these two points with special reference to the current worldwide state-of-the-art.

2.6.1 Mobile Ad Hoc Networks Research

Currently, the USA research community is promoting a second-phase in the mobile ad hoc networks research. This second phase is driven by the DARPA *Control-Based Mobile Ad-Hoc Networking* (CBMANET) program.[7] This program starts from the observation that the spectrum is a scarce resource, current protocols do not operate efficiently in ad hoc networks, and hence ad hoc networks do not use spectrum efficiently. Viability of TCP/IP based approaches to MANET are increasingly questioned. The objective of the *Control-Based Mobile Ad-Hoc Networking* program is to research, design, develop and evaluate a revolutionary Mobile Ad-hoc NETwork (MANET) prototype that improves effective performance from network stakeholder (user and operator) perspectives by an order of magnitude or more relative to the state of the art. The re-design of protocols for ad hoc networks should be performed by exploiting emerging hot topics like cross-layering, distributed resource allocation, and network coding.

2.6.2 Mobile Ad Hoc Networks Market Perspective

In spite of the massive efforts in researching and developing mobile ad hoc networks in the last decade, this type of networks has not yet witnessed a mass-market deployment. The low commercial penetration of products based on the ad hoc networking technology could be explained with the lack of *general-purpose* applications where high bandwidth and open access to Internet are consolidated and cheap commodities. One possibility to turn mobile ad hoc networks in a commodity, is moving to a more pragmatic "opportunistic ad hoc networking" in which multi-hop ad hoc networks are not isolated, self-configured networks, but rather they emerge as a flexible and "low cost" extension of wired

[7] http://www.darpa.mil/ato/solicit/cbmanet/index.htm

infrastructure networks and coexist with them. Indeed, a new class of networks is emerging from this view: the *mesh networks*. Mesh networks are built upon a mix of fixed and mobile nodes interconnected via wireless links to form a multi-hop ad hoc network. As in MANETs, the users' devices are an active part of the mesh. They dynamically join the network, acting as both users' terminals and routers for other devices, consequently further extending the network coverage. Mesh networks inherit many results from the MANET research. Furthermore, while the MANET development approach was mainly simulation-based, from the beginning, mesh networks have been associated with real test-beds. By designing/implementing "good enough" solutions it has been possible to verify the suitability of this technology for civilian applications and to stimulate the users' interest to adopt it. Even though mesh networks are a quite recent technology they have already shown big potentialities in the wireless market. An analysis of mesh networks' potentialities and a discussion of the open research issues in this area can be found in [BCG05].

[BCG05] R. Bruno, M. Conti, E. Gregori, "Mesh Networks: Commodity Multi-hop Ad Hoc Networks", *IEEE Communications Magazine*, March 2005, pp.123-131.

2.7 Planned Work for the Next Reporting Period

For the three left months of the project we have to complete the activities to fulfill the remaining success criteria.

- 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.
- To study, by exploiting out NS-2 extensions, the 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 third year the project partners were heavily involved in dissemination activities by organizing and participating to international conferences/workshops (also as invited 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. Currently, all the software is still in the private area and will moved in the public one at the end of the project.
- A blog to perform a social evaluation study on ad hoc networking potentialities. Specifically, the blog was used for interacting with a group of potential end-users that are technology skilled and aware of what a MobileMAN is. The blog was implemented as a part of the thesis jointly supervised by CNR and University of Siena (Social Communications department). http://mobilemanstorytelling.blogspot.com/

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 several 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. The details of these training activities are reported below.

CNR

During the third year of the project, Gaia Maselli completed her PhD Thesis "*Performability in mobile ad hoc networks*" (University of Pisa Computer Science Department, June 2006);

In addition, four PhD candidates worked, during third year of the project, at CNR on MobileMAN related topics:

- Emilio Ancillotti (2nd year PhD program in Computer Engineering) has been working on: i) transport protocols for ad hoc networks, and ii) mechanisms to interconnect ad hoc islands to the Internet.
- Eleonora Borgia (3rd year PhD program in Computer Engineering) has been working on routing protocols for ad hoc networks and, in the framework of MobileMAN was in charge of routing protocols experimental activities.
- Franca Delmastro (3rd year PhD program in Computer Engineering) has been working on cross layer solutions for optimizing p2p platforms on ad hoc networks. In the framework of MobileMAN was in charge of comparing Pasty and CrossROAD solutions.
- Giovanni Turi (3rd year PhD program in Computer Engineering) has been working the extension of the NS-2 simulation framework for studying cross layer solutions.

Marco Conti has also been invited as opponent of Henrik Lundgren PhD thesis defense "Implementation and Experimental Evaluation of Wireless Ad Hoc Routing Protocols", Uppsala University, March 2005.

Dr. Claude Chaudet (ENST / GET, Paris, France) was a ERCIM Fellowship at CNR (November 2004 – January 2005) working on 802.11 enhancements for ad hoc networks.

CNR researchers gave lectures to master students (master on Internet Technology "Master .it" jointly organized by IIT-CNR and Department of Information Engineering of the University of Pisa), and to bachelor students at University of Pisa; by presenting the MobileMAN research activities CNR had the possibility to attract a set of students that, during Summer-Fall 2005, performed their theses by working on the MobileMAN project. Specifically,

- Elvis Shera (master student) performed extensive analysis on a small real testbed about the impact of unidirectional links on the AODV performance;
- Antonio Alagudi (bachelor student) participated to testing Scribe over Pastry;
- Marco D'Alò (bachelor student) participated to testing Scribe over CrossROAD;.

Twenty students from University of Pisa (Computer Engineering) were selected to participate to MobileMAN medium-size testbed:

Bachelor's degree candidates:

- Gaetano Anastasi, Giovanni Bianchi, Roberto Corradi, Marco D'Alò, Danilo Levantesi, Fabrizio Lovino, Damiano Macchi, Matteo Mattei, Luca Melette, Luca Niccolini, Mario Olivari, Stefano Pallicca

Master's degree candidates:

- Annalisa Bizzarrini, Chiara Boldrini, Edoardo Canepa, Mario Di Francesco, Salvatore Gerace, Ilaria Giannetti, Iacopo Iacopini, Giacomo Santerini

CAMBRIDGE

Ph.D. thesis (advisor: Jon Crowcroft): Meng How Lim, "Landmark Guided Routing", submitted October 2005

Ph.D. theses examined elsewhere:

- Pietro Michiardi (Eurecom); topic: Trust in MANETs
- Ramin Hekmat (Delft); topic: Fundamental Properties of Wireless Ad Hoc and Sensor Networks
- Einer Vollset (Newcastle); topic: reliable and consensus protocols for MANET

Visitors:

- Carlos Jesus Bernardos-Cano (mobility/handover) from Madrid
- Xiaoming Zhou, TU Delft, and Michael Kleis, Fraunhofer Institute FOKUS (under EneXT funding) working with Eng Keong Lua on P2P systems

IMPACT ON INNOVATION AND MICRO-ECONOMY. The area of ad hoc networking is of long-term nature. However, MobileMAN 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 provides 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.

v. The usage of VoIP on top of Ad Hoc networks has interesting potentialities. After a MobileMAN presentation for Nokia Networks representatives, Nokia shows the interest to launch a project on this topic.

vi. We have identified new applications that can leverage the ad hoc technology to provide valuable services to the user. The city cab scenario (i.e., the use of 802.11 ad hoc networks to replace the currently used taxi radio dispatch systems) is the most promising one. We have found that in this scenario, an ad hoc networking system is viable both economically and technically.

vii. Mesh networks constitute a short-term direction to turn mobile ad hoc networks in a commodity by providing a flexible and "low cost" extension of wired infrastructure networks.

3. PROJECT MANAGEMENT AND CO-ORDINATION

The activities of the third year of the project were planned and monitored by continuous communications among partners, and in the three official Executive Board meetings.
It is worth noting that, to optimize the project budget during the third years whenever possible project management meetings were performed by videoconference. Indeed, CNR made available to the consortium a very effective video-conferencing tool (Marratech E-Meeting Portal) that enables very effective VoIP communications, working on shared documents and video interactions. This enabled us to save part of the traveling budget that was used for technical meeting devoted to software integrations and to experimental evaluations. In addition, virtual meetings were very effective as we were able to quickly organize a meeting whenever necessary eliminating the travels' overheads. During the meeting, after a review of the activities performed, we defined the plans for progressing work packages with particular attention given to deliverables in the third 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 the "virtual" meetings, we organized a legacy Executive Board meeting during the plenary workshop we organized at Sophie-Antipolis hosted by Eurecom on 3-4 June 2005. In addition, an Executive Board meeting was held in Santorini, as a follow up of the IEEE ICPS REALMAN workshop discussions.

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 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. Co-operations established during the first and second year of the project are reported in previous Progress Report. Hereafter, we report co-operations activated during the third year of the project.

CNR

CNR has established collaboration links with people working in the public safety and interested to apply ad hoc networking techniques in this field. Indeed public safety is one of the main areas for the exploitation of ad hoc networking potentialities. The starting point of these collaborations has been the visit at CNR of Dr. Adrian Boukalov during December 2004. Dr. Adrian Boukalov is very active in the public safety field. At the time of the meeting he was the chairman of the Technical Specification Group – Systems (TSG SYS) of the MESA (Mobility for Emergency and Safety Applications) project http://www.projectmesa.org. The Mesa project is an international partnership between the European Telecommunications Standards Institute (**ETSI**), and the Telecommunications Industry Association (**TIA**) aimed producing globally applicable technical specifications for digital mobile broadband technology, aimed initially at the sectors of public safety and disaster response. In addition Dr. Adrian Boukalov, was workpackage leader of the IST project WIreless DEployable Network System, (WIDENS) aimed 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. As a result of the meeting with Dr. Boukalov we established a Virtual Public Safety Communication Lab to integrate MobileMAN and WIDENS expertise on ad hoc networking. In the framework of this Lab, a member of WIDENS project (Luca Bergonzi) spent 2 months during 2005 at CNR working on public safety ad hoc communication networks. Starting from this collaboration, during 2005, a consortium was set up for a project proposal on the use of mesh networks to support public safety applications. The project, *Meshing European Heterogeneous Emergency Networks* (*MEHEN*) --involving in addition to CNR and HUT some main European industries (Thales (France), OTE (Italy))-- has its target in advancing PAN-European technological solutions for the meshing of European public safety networks. The project submitted to the 5th IST call was positively evaluated but not reached a sufficient mark to get funded. Even though this unsuccessful attempt, we believe that applying ad hoc networking techniques to support public safety applications is a very relevant area for exploiting MobileMAN results. Indeed CNR is continuing to work in this direction both at national and European level. At national level, IIT-CNR proposed the exploitation of ad hoc networking techniques for project ideas that have been submitted for the call of Ministry for Research for the three-year Italian national plan for research (2005-

2008). Specifically, IIT-CNR proposed the use of ad hoc networking as a relevant technique to achieve two of the program main objectives: telecommunication systems for natural disasters -- "*Sistemi di telecomunicazione innovativi a larga banda anche con impiego di satelliti per utenze differenziate in materia di sicurezza, prevenzione e intervento in caso di catastrofi naturali*" – and infomobility --"Trasporti e logistica avanzata, infomobilità di persone e merci". These project ideas are currently under evaluation. If successful they will produce R&D projects in cooperation with the main Italian industries and research institutions.

As pointed out in the previous section, mesh networks represent one of the most interesting direction for commercial exploitation of ad hoc networking techniques. For this reason, during 2005, CNR established several co-operation projects aimed at exploiting MobileMAN results for mesh networking. Specifically the following cooperation links have been established:

- A bilateral project between IIT-CNR and FORTH-ICS (Greece) "Routing Protocols in Wireless Mesh Networks based on Cross-Layer Design". On December 6th 2005, the Italian-Greek cooperation for 2006-2008 has been signed and our project was included in the cooperation agreement.
- A bilateral project between IIT-CNR and IITP Institute of Russian Academy of Science (Russia) "Wireless Multi-Hop Mesh Networks with QoS support". On August 2005, the project was selected among those eligible for funding. A negotiation is currently ongoing between Italian and Russian governments to define the funding procedures.
- A joint project between IIT-CNR and University of Pisa "QWiMAN – Progetto di rete wireless mesh con garanzie di Qualità del Servizio" that we submitted to a local funding agency ("Fondazione Cassa di Risparmio di Pisa"). The project proposal is currently under evaluation.

Opportunistic networking represents the other direction (with respect to mesh networks) for the evolution of ad hoc networks. CNR is also very active in this direction. During 2005 research collaborations have been established that produced the successful

participation to two project proposal under the IST – FET proactive call "Situated and Autonomic Communications": HAGGLE (http://www.haggleproject.org/) and BIONETS (http://www.create-net.org/create-net/bio-nets/). In the framework of these two research projects, CNR established cooperation links with several European industrial and academic organizations, see also http://www.cordis.lu/ist/fet/comms-sy.htm

Cambridge

Cambridge has been one of the promoter (together with EPFL, and Uppsala University, and Intel research) of the HAGGLE project by exploiting at least in part the expertise and contacts gained by Cambridge during the MobileMAN Project. This project proposal, that was firstly submitted to the FET open call, has been then extended to other MobileMAN partners (CNR, Eurecom and SUPSI) and Thomson (France), and successfully presented at the FET proactive call on Situated and Autonomic Communications.

Eurecom

Collaboration with the *ACI Splash project* granted from French National Funding

Participants:
EURECOM: Refik Molva, Pietro Michiardi, Claudio Lavecchia
INRIA: Pars Mutaf, Claude Castelluccia
University of California Irvine: Gene Tsudik

Presentations and discussed topics:

- Presentation of the CORE test-bed and experimental results (EURECOM)
- A new crypto-based cooperation enforcement mechanism for MANET (EURECOM/INRIA)
- Key pre-distribution mechanisms for sensor networks (UC Irvine)
- Message authentication for dynamic networks (EURECOM)

HUT

HUT has been the coordinator of a FET open proposal (involving also Cambridge, CNR and Universität Bremen) aimed at integrating ad hoc networks with infrastructure based networks by exploiting opportunistic networking concepts, too. Even though the proposal has been unsuccessful the team expressed interest to continue the collaboration on these topics.

4. COST BREAKDOWN

The costs (in Euro) incurred for the reporting period are summarized in the next table. As it appears from the table the costs are aligned with expected costs.

Costs in euro for reporting period 01/10/2004 – 30/09/2005

	CNR				UCAM-CLAB				EURECOM				Total			
	Period		Total		Period		Total		Period		Total		Period		Total	
Cost category	Est.	Act	Est.	Act	Est.	Act	Est.	Act	Est.	Act	Est.	Act	Est.	Act.	Est.	Act.
Direct costs																
1. Personnel	116.977	135.365	332.080	379.639	57.981	33.180	159.179	82.820	60.427	65.827	181.035	191.593	235.385	234.372	672.294	654.052
2. Durable equipment		6.172	25.450	17.391		803	3.400	2.323		2.783	9.700	6.072		9.758	38.550	25.785
3. Subcontracting	8.000		8.000										8.000		8.000	0
4. Travel and subsistence	12.300	13.538	35.900	41.197	1.870	6.120	5.610	11.921	8.500	7.319	25.500	18.457	22.670	26.976	67.010	71.576
5. Consumables			9.258		1.700	3.151	5.100	5.188			2.500	1.624	1.700	3.151	16.858	6.812
6. Computing																
7. Protection of knowledge																
8. Other specific costs	34.000	2.009	36.000	4.446				293	5.000	1.576	8.000	4.239	39.000	3.585	44.000	8.978
Subtotal	**171.277**	**157.084**	**446.688**	**442.673**	**61.551**	**43.255**	**173.289**	**102.545**	**73.927**	**77.504**	**226.735**	**221.985**	**306.755**	**277.842**	**846.712**	**767.203**
Indirect costs																
9. Overheads	93.582	92.932	265.665	288.351	12.310	8.651	34.658	20.509	76.752	65.827	229.944	213.476	182.644	167.410	530.267	522.337
Total	**264.859**	**250.016**	**712.353**	**731.024**	**73.861**	**51.906**	**207.947**	**123.054**	**150.679**	**143.331**	**456.679**	**435.461**	**489.399**	**445.252**	**1.376.979**	**1.289.540**

Period: Est.: estimated costs in contract for period Act.: actual costs in period
Total: Est.: estimated cumulative costs to date in contract Act.: cumulative actual costs to date

Costs in euro for reporting period 01/10/2004 – 30/09/2005

	HUT				NETIKOS				SUPSI				Total			
	Period		Total		Period		Total		Period		Total		Period		Total	
Cost category	Est.	Act	Est.	Act	Est.	Act	Est.	Act	Est.	Act	Est.	Act	Est.	Act.	Est.	Act.
Direct costs																
1. Personnel	45.360	37.618	129.600	88.518	42.724	44.546	113.724	111.671	164.926	143.957	509.028	470.110	253.010	226.122	752.352	670.299
2. Durable equipment		1.122		3.133		1.787	9.000	4.913		10.830	25.000	27.728		13.738	34.000	35.774
3. Subcontracting																
4. Travel and subsistence	5.200	5.999	15.600	15.100	10.000	4.032	24.000	8.674	6.750	3.961	19.000	14.258	21.950	13.993	58.600	38.032
5. Consumables			6.000				1.000				7.500				14.500	0
6. Computing																
7. Protection of knowledge																
8. Other specific costs				293												293
Subtotal	**50.560**	**44.740**	**151.200**	**107.044**	**52.724**	**50.365**	**147.724**	**125.259**	**171.676**	**158.748**	**560.528**	**512.096**	**274.960**	**253.853**	**859.452**	**744.399**
Indirect costs																
9. Overheads	4.677	8.948	13.987	21.409	34.179	35.637	90.979	89.337	34.335	28.791	112.105	94.021	73.191	73.376	217.071	204.767
Total	**55.237**	**53.687**	**165.187**	**128.453**	**86.903**	**86.002**	**238.703**	**214.596**	**206.011**	**187.540**	**672.633**	**606.117**	**348.151**	**327.229**	**1.076.523**	**949.166**

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 third year of the project but that were already announced (as submitted/accepted for publication) in the Periodic Progress Report N°:2. 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 Book Chapters

- 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, March 2005.

- M. Conti, J. Crowcroft, G. Maselli, T. Turi, "A Modular Cross-layer Architecture for Ad Hoc Networks" Chapter 1 in *Handbook on Theoretical and Algorithmic Aspects of Sensor, Ad Hoc Wireless, and Peer-to-Peer Networks,* Jie Wu (Editor), Auerbach Publications (Taylor & Francis Group), Boca Raton (FL), 2005, pp. 5-16.

- G. Anastasi, M. Conti, A. Passarella, in "Power Management in Mobile and Pervasive Computing Systems", Chapter 24 in *Algorithms and Protocols for Wireless and Mobile Networks*, Azzedine Boukerche (Editor), CRC-Hall Publisher, October 2005.

5.1.1.2 Journals

- 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, 2005.

- 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). Volume 3, Number 2, March 2005.

5.1.2 New Publications

This section contains the list of books, book chapters, conference/workshop papers that have been accepted for publication during the third year of the project (publication not reported in Periodic Progress Report N°:2).

5.1.2.1 Book

B.1. Marco Conti, Dipankar Raychaudhuri, Proceedings of the 6th IEEE Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM 2005), Taormina, Italy 5-8 April 2005.

B.2. Marco Conti, Ali Hurson Proceedings of the Third IEEE Conference on Pervasive Computing and Communications (PerCom) 2005 - Workshops, Kauai, Hawaii, March 8-12, 2005.

B.3. S. Giordano, I. Stojmenovic, C. Tschudin, Proceedings of the Second Wireless On demand Network Systems and Services (WONS) conference, IEEE Press, January 2005

B.4. Marco Conti, Jon Crowcroft, Andrea Passarella, Proceedings of the 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece. http://www.cl.cam.ac.uk/realman

5.1.2.2 Book Chapters

BC.1. M. Conti, F. Delmastro, T. Turi, "Peer-to-peer Computing in Mobile Ad Hoc Networks", in *Mobile Middleware,* Antonio Corradi and Paolo Bellavista (Editors), CRC press (To appear)

BC.2. Raffaele Bruno, Claude Chaudet, Marco Conti and Enrico Gregori, "Fair MAC Protocols for 802:11-based Multi-Hop Ad hoc Networks: Challenges and Solutions" in *Performance Analysis of Mobile Ad Hoc Networks*, Chita Das, Yi Pan Chansu Yu (Editors) Nova Science Publishers Inc. (to appear)

BC.3. M. Conti, Peer-to-peer Computing in Mobile Ad Hoc Networks, in *Mobile Middleware* Antonio Corradi and Paolo Bellavista (Editors), CRC Press (to appear)

BC.4. P. Michiardi, R. Molva, "Ad hoc network security"Chapter in Book: Handbook of information security IEEE Press, Wiley & Sons (to appear)

5.1.2.3 Journals

J.1. R. Bruno, M. Conti, E. Gregori, "Mesh Networks: Commodity Multi-hop Ad Hoc Networks", *IEEE Communications Magazine*, March 2005, pp.123-131.

J.2. A. Anastasi , E. Borgia, M. Conti, E. Gregori, A. Passarella, "Understanding the Real Behavior of Mote and 802.11 Ad Hoc Networks: An Experimental Approach", *Pervasive and Mobile Computing* Journal, Vol 1, N. 2, June 2005.

J.3. M. Conti, E. Gregori, and G. Maselli, "Reliable and Efficient Forwarding in Ad Hoc Networks", *Ad Hoc Networks* Journal, (to appear).

J.4. M. Conti, G. Maselli, G. Turi, "A flexible cross-layer interface for ad hoc networks: Architectural and Implementation issues", *Ad Hoc & Sensor Wireless Networks: An International Journal* (Old City Publishing), (to appear).

5.1.2.4 Conference Proceedings

C.1. M. Conti, E. Gregori, G. Turi, "A Cross Layer Optimization of Gnutella for Mobile Ad hoc Networks", Proc. ACM MobiHoc Symposium, Urbana-Champain, May 2005, pp.343-354.

C.2. E. Huang, W. Hu, J. Crowcroft, I. Wassell, "Towards Commercial MobileAd Hoc Network Applications: A radio Dispatch System" Proc. ACM MobiHoc Symposium, Urbana-Champain, May 2005, pp. 355-365.

C.3. G. Anastasi, E. Ancillotti, M. Conti, and A. Passarella, "TPA: A Transport Protocol for Ad hoc Networks", Proc. 10th IEEE Symposium on Computers and Communications, June 2005.

C.4. M. Conti, G. Maselli, and G. Turi, "Design and evaluation of a flexible cross-layer interface for ad hoc networks", Proceedings Fourth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2005), June 2005 (21-24) Ile de Porquerolles (France).

C.5. Ralf Bernasconi, Raffaele Bruno, Ivan Defilippis, Silvia Giordano, and Alessandro Puiatti, "Experiments with an enhanced MAC architecture for multi-hop wireless networks", Proc. 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece

C.6. Franca Delmastro and Andrea Passarella, "An Experimental Study of P2P Group-Communication Applications in Real-World MANETs", Proc. 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece

C.7. E. Borgia, M. Conti, F. Delmastro, E. Gregori, "Experimental comparison of routing and middleware solutions for mobile ad hoc networks: legacy vs cross-layer approach", ACM SIGCOMM Workshop on Experimental Approaches to

Wireless Network Design and Analysis (E-WIND) August 22, 2005 - Philadelphia, PA.

C.8. M. Conti, E. Gregori, G. Maselli "Improving the performability of data transfer in mobile ad hoc networks", Proc. Second IEEE International Conference on Sensor and Ad Hoc Communications and Networks (SECON), Santa Clara, CA, September 2005.

C.9. Raffaele Bruno, Claude Chaudet, M. Conti, E. Gregori, "A Novel Fair Medium Access Control for 802.11-based Multi-Hop Ad hoc Networks, Proc. 14th IEEE Workshop on Local and Metropolitan Area Networks, Chania, Greece, September, 2005.

C.10. Altman, Eitan; Kherani, Arzad; Michiardi, Pietro; Molva, Refik, "Non cooperative forwarding in ad hoc networks", Proc. IFIP Networking 2005

C.11. Altman, Eitan; Borkar, Vivek; Kherani, Arzad; Michiardi, Pietro; Molva, Refik "Some game-theoretic problems in wireless ad hoc networks" Proc. EURO-NGI 2005.

5.1.2.5 Tutorial, Invited Talks, Conference Presentations

- Andrea Passarella, "Understanding the Real Behavior of Mote and 802.11 Ad hoc Networks: an Experimental Approach", Intel Research, Cambridge, UK, 27 April 2005
- Andrea Passarella, "MobileMAN Project: building Campus-Wide MANETs through Cross-Layering", 4th Cost 290 Management Committee Meeting, Wuerzburg, Germany, 16 October 2005
- Andrea Passarella, "Ad hoc and Sensor Netowrk Desing: it's All about Cross-Layering", University of Parma, Italy, 7 November 2005
- Jon Crowcroft, "Wireless Architecture", Max Planck Institute. for Software Systems, 22 September 2005
- Jon Crowcroft, "Haggle", TU Delft , 23 September 2005

5.1.2.6 Conference Demos & Posters

To disseminate MobileMAN activities during the third year MobileMAN partners presented a set of Posters and Demos at the 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece:

P.1. Claudia Brazzola, "Social networks, novel communication applications and needs in mobile contexts", Poster presentation.

P.2. Marco Conti, Franca Delmastro, Jon Crowcroft, and and Andrea Passarella, "Cross-Layer Support for Group-Communication Applications in MANETs", Demo and Poster presentation.
P.3. Claudio Lavecchia, Pietro Michiardi, and Refik Molva, "Real Life Experience of Cooperation Enforcement Based on Reputation (CORE) for MANETs", Demo and Poster presentation.
P.4. Jose Costa-Requena, Mohammand Ayyash, Jarrod Creado, Jarkko Hakkinen, Raimo Kantola, and Nicklas Beijar, "VoIP Testbed in Ad Hoc Networks", Demo and Poster presentation.
P.5. Raffaele Bruno, Marco Conti, Enrico Gregori, Antonio Pinizzotto and Emilio Ancillotti "Experimenting a Layer 2-based Approach to Internet Connectivity for Ad Hoc Networks", Demo and Poster presentation.
P.6. Piergiorgio Cremonese and Veronica Vanni "Discovering and Accessing services on the Mobile Ad Hoc Networks", Demo and Poster presentation.

5.1.2.7 Paper Submitted and Technical Reports

R.1. Michiardi, Pietro; Molva, Refik
"Identity-based Message Authentication for Dynamic Networks"
Submitted to IFIP SEC 2006

R.2. Mutaf, Pars; Molva, Refik
"Pocket Bluffs"
Technical Report, INRIA-5664

R.3. Legout, Arnaud; Urvoy-Keller Guillaume; Michiardi, Pietro
"Understanding BitTorrent: an Experimental Perspective"
Technical Report, INRIA-00000156

R.4. P. Cremonese, V. Vanni, "Discovering and Accessing Services on the Mobile ad-hoc Network", submitted.

5.1.2.8 Other Dissemination Activities

Newspapers Interviews

During the third year of the project CNR was very active in dissemination activities through interviews on major Italian newspapers. Of special relevance are Marco Conti interviews for (see Appendix for the articles):

Almanacco della Scienza Rivista on line del Consiglio Nazionale delle Ricerche
8 Giugno, 2005
http://150.146.47.106/rivistaonline/documenti/storiadicopertina/06_8_2005.htm

La Nazione (national newspaper)– Firenze 23 May, 2005 (page 16) "Ecco il cellulare gratuito. Crea la rete da solo e può avere mille usi" - not available on line

Il **Tempo** (national newspaper)– Roma 9 August 2005 "Mobileman» la rete senza fili e infrastrutture"

http://www.iltempo.it/approfondimenti/inde x.aspx?id=746320&editionId=5&SectionId=4

In addition, the above MobileMAN articles have been re-published on:

- The web site of the Italian public TV:
  - http://www.rai.it/accessibile/news/articolonews/0,9217,107754,00.html
  - http://www.raifiction.rai.it/news/articolonews/0,9217,107754,00.html
- Adnkronos news agency web site

  http://www.adnkronos.com/Speciali/Scienza/NotizieManuali/01_2504.html
- Portals devoted to ICT technologies
  - http://www.i-dome.com/flash-news/pagina.phtml?_id_articolo=8559
  - http://www.heos.it/tecno_05/tecno_12.htm
  - http://www.weekit.it/index2.php?option=com_content&do_pdf=1&id=36334

It is also worth mentioning the article appeared on

La Repubblica – Affari e Finanza 7 November 2005

http://www.repubblica.it/2005/j/sezioni/scienza_e_tecnologia/wifi/senzaintern/senzaintern.html

that establish the relationship between MobileMAN and the HAGGLE project.

Interaction with University Students

- CNR organized presentation of MobileMAN technologies to university students with a very high skill in information technology. Specifically, on April 22, 2005 Marco Conti gave a one-hour lecture on MobileMAN in the framework of the course *Operating Systems and Networks* for the last-year bachelor students in

Computer Engineering (3-year degree) at the University of Pisa (Engineering Faculty). The aim of this lecture was to present the MobileMAN experimental activities in order to identify students to be involved in the project experimental activities.

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 *IEEE Transactions on Mobile Computing.*

- 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, and* **Area Editor** of *Ad Hoc Networks Journal* (Elsevier).

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

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

5.2.2 Journals Guest Editors

- Special Issue on "Networking Technologies, Services and Protocols", *Cluster Computing Journal* (Springer). Volume 8, Issue 1, January 2005. (**Co-guest Editors**: M. Conti and E. Gregori).

- Special issue on "Ad Hoc Networking for Pervasive Systems", *Ad Hoc Networks Journal* (Elsevier). Volume 3, Number 2, March 2005, (**Co-guest Editors**: M. Conti and E. Gregori).

- Special issue on "Ad hoc and Sensor Networks", IEEE Communication Magazine, March 2005, (**Co-guest Editors**: S. Giordano).

- Special issue on "Ad hoc and Sensor Networks", IEEE Communication Magazine, July 2005, (**Co-guest Editors**: S. Giordano).

- Special issue on "WiOpt 2004", *ACM/Kluwer Mobile Networks and Applications (MONET) Journal*. Publication scheduled for Vol. 11, No. 3 (June 2006). (**Co-guest Editor**: M. Conti).

- Special issue on "Multimedia over Broadband Wireless Networks", IEEE Network. Publication planned in 2006 (**Co-guest Editor**: M. Conti). URL: http://www.comsoc.org/pubs/net/ntwrk/cfpnetwork2006.htm

- Special issue on "Broadband Wireless Multimedia: Algorithms, Architectures and Applications", *ACM/Kluwer Wireless Networks (WINET) Journal*. Publication planned in 2006 (**Co-guest Editor**: M. Conti).

- Special section on "REALMAN 2005", *Ad Hoc & Sensor Wireless Networks: An International Journal*. Publication planned in 2006 (**Co-guest Editors**: M. Conti, Jon Crowcroft and Andrea Passarella).

- Special issue on "Wireless Mesh Neworks", *Ad Hoc Networks* (Elsevier) Journal, Publication planned in 2006 (**Co-guest Editor**: M. Conti).

5.2.3 Conference Executive Committees

- Silvia Giordano has been the **General Chair** of the Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005. http://www.wonss.org/

- Marco Conti has been **Workshops Co-Chair** (with A. Hurson, University of Pensilvania, USA) -- Third IEEE Conference on Pervasive Computing and Communications (PerCom) 2005, Kauai, Hawaii, March 8-12, 2005.
  URL: http://www.percom.org.

- Marco Conti has been **Track Chair** (with G. Anastasi University of Pisa, Italy, and M. Kumar, University of Texas, USA) - Special track on *Energy Management in Mobile and Pervasive Computing Systems* at the 38th Annual Hawaii International Conference on System Sciences, 2005.

- **Program Co-Chair** (with D. Raychaudhuri, Rutgers University, USA) - The 6th IEEE Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM 2005), Taormina, Italy June 2005. http://cnd.iit.cnr.it/wowmom2005

- Jon Crowcroft has been **General Chair** of the 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece URL: http://www.cl.cam.ac.uk/realman

- Marco Conti has been **Program Chair** of the 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece URL: http://www.cl.cam.ac.uk/realman

- Andrea Passarella has been **Program Vice Chair** of the 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece URL: http://www.cl.cam.ac.uk/realman

- Silvia Giordano has been **Workshop Co-Organizer** of the - 1st IEEE WoWMoM Workshop on Autonomic Communications and Computing (ACC 2005), http://www.autonomic-communication.org/acc/index.html

- Silvia Giordano has been **Workshop Co-Organizer** of the - 1st IEEE PerCom Workshop on Sensor Networks and Systems for Pervasive Computing (PerSeNS 2005), http://www.ing.unipi.it/persens2005/

- Refik Molva has been **Workshop Co-Organizer** of the - 1st IEEE WoWMoM Workshop on Trust, Security and Privacy for Ubiquitous Computing (TSPUC2005) http://www.iit.cnr.it/TSPUC2005

- Jon Crowcroft has been **Program Co-chair** of Fourth Workshop on Hot Topics in Networks (HotNets-IV), November 14-15, 2005 College Park, MD USA http://www.acm.org/sigs/sigcomm/HotNets-IV

- Jon Crowcroft has been **General Co-chair** of the 1st Conference on Wireless Internet (WICON 2005), Budapest, Hungary, 10-15 July 2005

- Refik Molva has been **Program Co-Chair** of the 2nd European Workshop on Security and Privacy in Ad hoc and Sensor Networks (*ESAS 2005*), July 13-14, 2005, Visegrad, Hungary, http://www.crysys.hu/ESAS2005/cfp.html

5.2.4 Conference Technical Program Committees

- The Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005.

http://www.wonss.org/ (TPC member: M. Conti, J. Crowcroft E. Gregori, S. Giordano)

- Third IEEE Conference on Pervasive Computing and Communications (PerCom) 2005, Kauai, Hawaii, March 8-12, 2005. URL: http://www.percom.org. (TPC member: M. Conti)

- 3rd Symposium on Modeling and Optimization in Mobile, Wireless and Ad Hoc Networks (WiOpt 2005), Trento, Italy April 2-5, 2005. http://www.wiopt.org (TPC member: M. Conti, J. Crowcroft, S. Giordano)

- 6th European Wireless Conference (EW2005) Nicosia, Cyprus, April 10-13, 2005 http://grid.ucy.ac.cy/ew05/cfp.html (TPC member: M. Conti)

- NETWORKING 2005: The Fourth International IFIP-TC6 Networking Conference, Waterloo, Ontario, Canada May 2-5, 2005. http://www.cs.uwaterloo.ca/conferences/networking2005/ (TPC member: M. Conti, E. Gregori, S. Giordano)

- Sixth ACM MobiHoc 2005 Symposium, Urbana-Champaign, Illinois, May 24-28, 2005 http://www.sigmobile.org/mobihoc/2005/ (TPC member: M. Conti, J. Crowcroft)

- 5th IEEE Workshop on Algorithms for Wireless, Mobile, Ad Hoc and Sensor Networks (WMAN) to be held jointly with IPDPS 2005 http://www.site.uottawa.ca/~boukerch/ipdpswman.html (TPC member: M. Conti)

- Fourth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2005), June 2005 (21-24) on the Ile de Porquerolles (France) http://med-hoc-net2005.lri.fr/ (TPC member: M. Conti)

- 3rd Int'l workshop on Mobile Distributed Computing (MDC'05) in conjunction with 25th Int'l Conf. on Distributed Computing Systems (ICDCS'05) Columbus, Ohio, USA from June 5 to June 10, 2005. http://www4.comp.polyu.edu.hk/~mdc05 (TPC member: M. Conti)

- 2nd International Workshop on Wireless Ad Hoc Networking (WWAN 2005)" in conjunction with 25th Int'l Conf. on Distributed Computing Systems (ICDCS'05) Columbus, Ohio, USA from June 5 to June 10, 2005, http://www.lifl.fr/RD2P/WWAN2005 (TPC member: M. Conti)

- First Workshop *on Information Fusion and Dissemination in Wireless Sensor Networks* co-located with WICON 2005 Budapest Hungary 10-14 July, 2005, http://www.sensorfusion.org/ (TPC member: M. Conti)

- 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece

URL: http://www.cl.cam.ac.uk/realman (TPC member: Refik Molva, Pietro Michiardi, Raimo Kantola, Silvia Giordano, Enrico Gregori)

- 8th ACM International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM), Montreal, Canada, October 10-13, 2005. http://www.cs.unibo.it/mswim2005/ (TPC member: M. Conti)

- First IEEE WoWMoM workshop on "Autonomic Communications and Computing" (ACC 2005), Taormina, June 13, 2005, http://www.autonomic-communication.org/acc/index.html (TPC member: M. Conti)

- The 14th IEEE workshop on Local and Metropolitan Area Networks, 18-21 September 2005, Chania, Crete, Greece http://www.ieee-lanman.org/ (TPC member: M. Conti)

- The Second IEEE International Conference on Sensors and Ad Hoc Communications and Networks (SECON 2005), Santa Clara, CA September 26-29, 2005. http://www.ieee-secon.org/2005/ (TPC member: M. Conti, S. Giordano)

- AdHocNow! 2005, 4th International Conference on AD-HOC Networks & Wireless October 6 - 8 , 2005, Cancun, MexicoCancun, October 6-8
  URL: http://www.fismat.umich.mx/adhoc_now/ (TPC member: M. Conti)

- Second IEEE Conference on Mobile Ad-hoc and Sensor Systems (MASS05), Washington DC Nov 7-10, 2005, http://www.MASS05.wpi.edu (TPC member: M. Conti)

- ISPA 2005: IEEE International Symposium on Parallel and Distributed Processing and Applications, Nanjing, China, 2-5 November, 2005 (TPC member: A. Passarella)

- PE-WASUN 2005: ACM International Workshop on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks, Montreal, Canada, October 13, 2005 (TPC member: A. Passarella)

- PerCom 2006: Fourth Annual IEEE International Conference on Pervasive Computer and Communications, Pisa, Italy, 13-17 March 2006 (TPC member: A. Passarella, P. Michiardi)

- IEEE Infocom 2005: (TPC member: J. Crowcroft)

- ACM SIGCOMM' 05 (TPC member: J. Crowcroft, *shadow* TPC: Pietro Michiardi)

- 21st IFIP TC-11 International Information Security Conference "Security and Privacy in Dynamic Environments", IFIP SEC 2006, (TPC member: Refik Molva)

- IEEE SECURECOMM 2005 (TPC member: Refik Molva, Pietro Michiardi)

5.3 Participation at Conferences and Workshops

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

- The Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005 (Participants: E. Gregori, S. Giordano, P. Cremonese)

- Third IEEE Conference on Pervasive Computing and Communications (PerCom) 2005, Kauai, Hawaii, March 8-12, 2005. URL: http://www.percom.org. (Participants: M. Conti, E. Gregori)

- Sixth ACM MobiHoc 2005 Symposium, Urbana-Champaign, Illinois, May 24-28, 2005 (Participant: M. Conti)

- Fourth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2005), June 2005 (21-24) on the Ile de Porquerolles (France) http://med-hoc-net2005.lri.fr/ (Participant: G. Maselli)

- The Second IEEE International Conference on Sensors and Ad Hoc Communications and Networks (SECON 2005), Santa Clara, CA September 26-29, 2005. http://www.ieee-secon.org/2005/ (Participant: G. Maselli)

- The 6th IEEE Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM 2005), Taormina, Italy June 2005. http://cnd.iit.cnr.it/wowmom2005 (Participants: M. Conti, S. Giordano, R. Molva)

- The 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece URL: http://www.cl.cam.ac.uk/realman (Participants: M. Conti, A. Pinizzotto, A. Passarella, S. Giordano, P. Cremonese, V. Vanni, R. Bernasconi, C. Brazzola, P. Michiardi, C. Lavecchia, J. Crowcroft, M. Ayyash)

- IEEE International Conference on Pervasive Services (ICPS 2005), Santorini, Greece, 11-13 July, 2005 (Participants: M. Conti, A. Passarella, P. Michiardi)

- NETWORKING 2005: The Fourth International IFIP-TC6 Networking Conference, Waterloo, Ontario, Canada May 2-5, 2005. http://www.cs.uwaterloo.ca/conferences/networking2005/ (Participant: P. Michiardi)

6. PROJECT'S ASSESSMENT FICHE

Questions about project's outcomes	Number	Comments
1. Scientific and technological achievements of the project (and why are they so ?)		
Question 1.1. Breakthrough or "real" innovation		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, a) 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. b) We have defined and investigated scenarios in which the use of ad hoc networking solutions have a market value. The city cab scenario, i.e., the use of 802.11 ad hoc networks to replace the currently used taxi radio dispatch systems is viable both economically and technically. c) 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. d) 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. e) 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

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		new card. f) The usage of VoIP on top of Ad Hoc networks has interesting potentialities. After a MobileMAN presentation for Nokia Networks representatives, Nokia shows the interest to launch a project on this topic. g) We have identified new applications that can leverage the ad hoc technology to provide valuable services to the user. The city cab scenario (i.e., the use of 802.11 ad hoc networks to replace the currently used taxi radio dispatch systems) is the most promising one. We have found that in this scenario, an ad hoc networking system is viable both economically and technically. h) Mesh networks constitute a short-term direction to turn mobile ad hoc networks in a commodity by providing a flexible and "low cost" extension of wired infrastructure networks.
2. Impact on Science and Technology: Scientific Publications in scientific magazines		
Question 2.1. Scientific or technical publications on reviewed journals and conferences	15	Title and journals/conference and partners involved 1) R. Bruno, M. Conti, E. Gregori, "Mesh Networks: Commodity Multi-hop Ad Hoc Networks", *IEEE Communications Magazine*, March 2005, pp.123-131. (partner(s): CNR) 2) A. Anastasi , E. Borgia, M. Conti, E. Gregori, A. Passarella, "Understanding the Real Behavior of Mote and 802.11 Ad Hoc Networks: An Experimental Approach", *Pervasive and Mobile Computing* Journal, Vol 1, N. 2, June 2005. (partner(s): CNR) 3) M. Conti, E. Gregori, and G. Maselli, "Reliable and Efficient Forwarding in Ad Hoc Networks", *Ad Hoc Networks* Journal, (to appear). (partner(s): CNR) 4) M. Conti, G. Maselli, G. Turi, "A flexible cross-layer interface for ad hoc networks: Architectural and Implementation issues", *Ad Hoc & Sensor Wireless Networks: An International Journal* (Old City Publishing), (to appear). (partner(s): CNR) 5) M. Conti, E. Gregori, G. Turi, "A Cross Layer Optimization of Gnutella for Mobile Ad hoc Networks", Proc. ACM MobiHoc Symposium, Urbana-Champain, May 2005, pp.343-354. (partner(s): CNR) 6) E. Huang, W. Hu, J. Crowcroft, I. Wassell, "Towards Commercial MobileAd Hoc Network Applications: A radio Dispatch System" Proc. ACM MobiHoc Symposium, Urbana-Champain, May

2005, pp. 355-365. (partner(s): Cambridge)

7) G. Anastasi, E. Ancillotti, M. Conti, and A. Passarella, "TPA: A Transport Protocol for Ad hoc Networks", Proc. 10th IEEE Symposium on Computers and Communications, June 2005. (partner(s): CNR)
8) M. Conti, G. Maselli, and G. Turi, "Design and evaluation of a flexible cross-layer interface for ad hoc networks", Proceedings Fourth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2005), June 2005 (21-24) Ile de Porquerolles (France). (partner(s): CNR)
9) Ralf Bernasconi, Raffaele Bruno, Ivan Defilippis, Silvia Giordano, and Alessandro Puiatti, "Experiments with an enhanced MAC architecture for multi-hop wireless networks", Proc. 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece (partner(s): CNR and SUPSI)
10) Franca Delmastro and Andrea Passarella, "An Experimental Study of P2P Group-Communication Applications in Real-World MANETs", Proc. 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece (partner(s): CNR and Cambridge)
11) E. Borgia, M. Conti, F. Delmastro, E. Gregori, "Experimental comparison of routing and middleware solutions for mobile ad hoc networks: legacy vs cross-layer approach", ACM SIGCOMM Workshop on Experimental Approaches to Wireless Network Design and Analysis (E-WIND) August 22, 2005 - Philadelphia, PA. (partner(s): CNR)
12) M. Conti, E. Gregori, G. Maselli "Improving the performability of data transfer in mobile ad hoc networks", Proc. Second IEEE International Conference on Sensor and Ad Hoc Communications and Networks (SECON), Santa Clara, CA, September 2005. (partner(s): CNR)
13) Raffaele Bruno, Claude Chaudet, M. Conti, E. Gregori, "A Novel Fair Medium Access Control for 802.11-based Multi-Hop Ad hoc Networks, Proc. 14th IEEE Workshop on Local and Metropolitan Area Networks, Chania, Greece, September, 2005. (partner(s): CNR)
14) Altman, Eitan; Kherani, Arzad; Michiardi, Pietro; Molva, Refik, "Non cooperative forwarding in ad hoc networks", Proc. IFIP Networking 2005 (partner(s): Eurecom)
15) Altman, Eitan; Borkar, Vivek; Kherani, Arzad; Michiardi, Pietro; Molva, Refik "Some game-theoretic problems in wireless ad hoc networks" Proc. EURO-NGI 2005. (partner(s): Eurecom)

Question 2.2. Scientific or technical publications on non-reviewed journals and conferences	0	Title and journals/conference and partners involved
Question 2.3. Invited papers published in scientific or technical journal or conference.	4	Title and journals/conference and partners involved 1) M. Conti, F. Delmastro, T. Turi, "Peer-to-peer Computing in Mobile Ad Hoc Networks", in *Mobile Middleware,* Antonio Corradi and Paolo Bellavista (Editors), CRC press (To appear) . (partner(s): CNR) 2) Raffaele Bruno, Claude Chaudet, Marco Conti and Enrico Gregori, "Fair MAC Protocols for 802:11-based Multi-Hop Ad hoc Networks: Challenges and Solutions" in *Performance Analysis of Mobile Ad Hoc Networks*, Chita Das, Yi Pan Chansu Yu (Editors) Nova Science Publishers Inc. (to appear) . (partner(s): CNR) 3) M. Conti, Peer-to-peer Computing in Mobile Ad Hoc Networks, in *Mobile Middleware* Antonio Corradi and Paolo Bellavista (Editors), CRC Press (to appear) . (partner(s): CNR) 4) P. Michiardi, R. Molva, "Ad hoc network security"Chapter in Book: Handbook of information security IEEE Press, Wiley & Sons (to appear) . (partner(s): Eurecom)
3. Impact on Innovation and Micro-economy		
A - Patents		
Question 3.1. Patents filed and pending	0	When and in which country(ies): Brief explanation of the field covered by the patent*:

Question 3.2. Patents awarded	0	When and in which country(ies): Brief explanation of the field covered by the patent* (if different from above):
Question 3.3. Patents sold	0	When and in which country(ies): Brief explanation of the field covered by the patent* (if different from above):
Questions about project's outcomes	**Number**	**Comments or suggestions for further investigation**
B - Start-ups		
Question 3.4. Creation of start-up	No	If YES, details: - date of creation: - company name: - location: - headcount: - turnover: - profitable : yes / no
Question 3.5. Creation of new department of	Yes	Name of department:

research (ie: organisational change)		A Joint laboratory has been created between IIT-CNR and the University of Pisa: *Pervasive Computing & Networking Lab*. (PerLab); http://www.perlab.it Currently, the procedures for the creation of a research association "ANTARES: Association for NeTworking Advanced RESearch" between IIT-CNR and Univeristy of Pisa are ongoing.
C – Technology transfer of project's results		
Question 3.6. Collaboration/ partnership with a company ?	Yes	Which company : BTexact Technologies, Nokia, Siemens, ST Microelectronics What kind of collaboration? Project Industrial Advisory Board Which company : Intel Reseach, Thomson, Telecom Italia What kind of collaboration? Project activities
4. Other effects		
A - Participation to Conferences/Symposium		
Question 4.1. Active participation[8] to Conferences in **EU** (specify if one partner or "collaborative" between partners)	6	Names/ Dates/ Country: - The Second Conference on Wireless On-demand Network Systems and Services (WONS 2005), Saint Moritz (Switzerland) January 19-21, 2005 (partner(s): CNR, SUPSI). - The 6th IEEE Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM 2005), Taormina, Italy June 2005. (partner(s): CNR).

[8] 'Active Participation' in the means of being an invited speaker or organising a workshop / session / stand / exhibition directly related to the project (apart from events presented in section 2).

		- The 1st IEEE ICPS Workshop on Multi-hop Ad hoc Networks: from theory to reality (REALMAN 2005), July 14, 2005, Santorini, Greece (partner(s): CNR, Cambridge). - 1st Conference on Wireless Internet (WICON 2005), Budapest, Hungary, 10-15 July 2005 (partner(s): Cambridge). - 1st IEEE WoWMoM Workshop on Autonomic Communications and Computing (ACC 2005), (partner(s): CNR, SUPSI). - 1st IEEE WoWMoM Workshop on Trust, Security and Privacy for Ubiquitous Computing (TSPUC2005) (partner(s): Eurecom).
Question 4.2. Active participation to Conferences outside the **EU** (specify if one partner or "collaborative" between partners)	3	Names/ Dates/ Country: - Third IEEE Conference on Pervasive Computing and Communications (PerCom) 2005, Kauai, Hawaii, March 8-12, 2005. (partner(s): CNR). - Special track on *Energy Management in Mobile and Pervasive Computing Systems* at the 38th Annual Hawaii International Conference on System Sciences, 2005. (partner(s): CNR). - Fourth Workshop on Hot Topics in Networks (HotNets-IV), November 14-15, 2005 College Park, MD USA (partner(s): Cambridge).
B – Training effect		
Question 4.3. Number of PhD students hired for project's completion	7	In what field : Computer Science Computer Engineering Telecommunications

Questions about project's outcomes	Number	Comments or suggestions for further investigation
C - Public Visibility		
Question 4.4. Media appearances and general publications (articles, press releases, etc.)	10	References*: **Almanacco della Scienza** Rivista on line del Consiglio Nazionale delle Ricerche 8 Giugno, 2005 http://150.146.47.106/rivistaonline/documenti/storiadicopertina/06_8_2005.htm **La Nazione** (national newspaper)– Firenze 23 May, 2005 (page 16) "Ecco il cellulare gratuito. Crea la rete da solo e può avere mille usi" - not available on line Il **Tempo** (national newspaper)– Roma 9 August 2005 "Mobileman» la rete senza fili e infrastrutture" http://www.iltempo.it/approfondimenti/index.aspx?id=746320&editionId=5&SectionId=4 **La Repubblica** – Affari e Finanza 7 November 2005 http://www.repubblica.it/2005/j/sezioni/scienza_e_tecnologia/wifi/senzaintern/senzaintern.html - The web site of the Italian public TV: • http://www.rai.it/accessibile/news/articolonews/0,9217,107754,00.html

		• http://www.raifiction.rai.it/news/articolonews/0,9217,107754,00.html – Adnkronos news agency web site http://www.adnkronos.com/Speciali/Scienza/NotizieManuali/01_2504.html – Portals devoted to ICT technologies • http://www.i-dome.com/flash-news/pagina.phtml?_id_articolo=8559 • http://www.heos.it/tecno_05/tecno_12.htm • http://www.weekit.it/index2.php?option=com_content&do_pdf=1&id=36334
Question 4.5. Web-pages created or other web-site links related to the project	8	References*: http://cnd.iit.cnr.it/mobileMAN/ http://mobileman.projects.supsi.ch http://keskus.hut.fi/tutkimus/MobileMan/ http://www.cl.cam.ac.uk/Research/SRG/netos/sla/mobileman/mobileman.pdf http://www.ti.edu.ch/servizi/ricerca/ricerca_attualita/progettomese/2/ricerca_progetto.htm http://www.aramis-research.ch/d/17406.html http://pi.ijs.si/ProjectIntelligence.Exe?Cm=Project&Project=MOBILEMAN

Question 4.6. Video produced or other dissemination material	0	References*:
Question 4.7. Key pictures of results	0	References*:
D - Spill-over effects		
Question 4.8. Any spill-over to national programs	Yes	If YES, which national programme(s): CNR: Virtual Immersive Communications (VICOM) is a three years Italian project (Nov. 2002 – Nov. 2005) funded by the Italian Ministry for Research (MIUR) in the FIRB framework Italian Ministry for Research - three-year Italian national plan for research (2005-2008). Eurecom : CNRS / ACI SPlaSH: Sécurisation des ProtocoLes dans les réseAux mobileS ad Hoc. HUT : national projects: *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/
Question 4.9. Any spill-over to another part of EU IST Programme	Yes	If YES, which IST programme(s): **WIDENS**: WIreless DEployable Network System, Proposal acronym, The project is supported by the European Commission under the IST Framework Programme 6. http://www.widens.org/ **E-NeXT:** Network of Excellence Emerging Network Technologies http://www.ist-e-next.net/ E-NEXT is an FP6 Network of Excellence **HAGGLE:** IST – FET proactive "Situated and Autonomic Communications" project http://www.haggleproject.org **BIONETS:** IST – FET proactive "Situated and Autonomic Communications" project http://www.create-net.org/create-net/bio-nets/
Question 4.10. Are other team(s) involved in the same type of research as the one in your project ?	Yes	If YES, which organisation(s): **EQUATOR.** This is a six-year Interdisciplinary Research Collaboration (IRC) supported by The Engineering and Physical Sciences Research Council (EPSRC) of the UK Government. http://www.interaction.rca.ac.uk/equator/ **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. http://www.mmapps.org/

		ROMANTIK: ResOurce Managment and AdvaNced Transceiver algorIthms for multihop networKs (IST-2001-32549) funded from the EU Fifth RTD Framework Programme. http://www.ist-romantik.org/ **UCAN**: Ultra-wideband Concepts for Ad-hoc Networks (**IST-2001-32710**), funded from the EU Fifth RTD Framework Programme http://www.ucan.biz/ **BROADWAY:** The way to broadband access at 60GHz (**IST-2001-32686**) funded from the EU Fifth RTD Framework Programme. http://www.ist-broadway.org/ **6HOP**: Protocols for Heterogeneous Multi-Hop Wireless IPv6 Networks (**IST-2001-37385**) funded from the EU Fifth RTD Framework Programme. http://www.cwc.oulu.fi/projects/6hop/ **WIDENS:** WIreless DEployable Network System, Proposal acronym () The project is supported by the European Commission under the IST Framework Programme 6. http://www.widens.org/