MOBILEMAN

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Mobile Metropolitan Ad hoc Networks

MOBILEMAN

Intermediate Evaluation Report

Deliverable D9

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Abstract: The aim of this deliverable is to document and review the second year of the MOBILEMAN project. Specifically, it documents the project self-assessment procedure: i) to verify the alignment with the project goals; ii) to control the quality of what is produced; and iii) to identify and manage the project risks. To this end it takes as inputs the results produced and compare them with the project success criteria.

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SUMMARY

The aim of this deliverable is to document the second year of the MOBILEMAN project. As reported in D4, during the first year, the partners successfully fulfilled to the major promised project goals. D4 also presented the evaluation criteria for the second year, as enhancement of the project goals (as defined in the deliverable D2 "*Project Plans*") and the first year experience. In D4, it was shown that the project was able to dynamically adapt itself to new and external ideas and findings, in order to continue to produce relevant and innovative results. This was mainly performed by introducing some changes that substantially modified the original design and plans. Here we show that, thanks to these modifications during the second year, we produced additional results with respect to the expected ones at the beginning of the project. However, in this second year, we faced serious difficulties mainly due to the discrepancy between the promised functions and performances of existing HW and SW, and the real ones. As detailed in this document, this required a conspicuous effort, much higher than expected, and some countermeasures in order to achieve relevant quantitative and qualitative results. Furthermore, we experiences some slight delays with respect our schedule in some tasks completion.

1. MOBILEMAN AT WORK

The project, through the analysis and research of major Mobile Ad hoc NETwork (MANET) characteristics, is developing a metropolitan area, self-organizing, and totally wireless network that gives name to the project: *Mobile Metropolitan Ad hoc Network* (MobileMAN).

In this document we analyse the work done during the second year of the project to verify if and how the project success criteria were met. Details of the activities performed by the project partners are described in the *Second Year Progress Report*.

During the second year, as planned, we started the activities of WP4 (Integration, Evaluation and Social Analysis) and WP5 (Dissemination and Exploitation), too. Hence, all workpackages were active during the second year. They produced results according to Annex 1 and our plans. More precisely, five deliverables were produced in the project second year:

- D6 *MobileMAN functionalities – a minimal set*
- D7 *Socio-economic research methodology*
- D8 *MobileMAN first phase*
- D9 *MobileMAN intermediate evaluation report*
- D10 *MobileMAN architecture, protocols, and services intermediate report*

All of them have been made publicly available at the web site of the project (http://www.iit.cnr.it/mobileman). In addition, to render available the methods, tools, and software produced by MobileMAN, some thematic web sites have been created:

- Social studies : http://mobileman.projects.supsi.ch
- Software: http://keskus.hut.fi/tutkimus/MobileMan/

The "Social studies" web site, designed and maintained by SUPSI-DSAS, is devoted to facilitate the interaction with users. The website has an interactive section which enables 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 software related to the ad hoc routing framework (see D6). This web site has two parts: a public and private ones. The latter contains the software which is still under testing and available for project internal use only. Currently, all the software is still in the private area as software is continuously updated and testing phases are ongoing (see D8 and D10).

MobileMAN results have been disseminated in international fora, both technical as well as more broad and widely accessed by people out of the field. On one side, both the innovative cross-layering approach of MobileMAN and the fact of being one of the first real efforts for building up

a mobile ad hoc network produced original and relevant results, and thus accepted for publication in several conferences and journals (as illustrated in the *Second Year Progress Report*). On the other side, the social methodology and the users proximity of our solution generated large interest around the project, as confirmed by several seminars and presentations.[1]

This deliverable summarizes the results of the project self-assessment procedure: i) to verify the alignment with the project goals; ii) to control the quality of what is produced; and iii) to identify and manage the project risks. Moreover, after the second year experience, we were also able to better detail the success criteria for the third year of the project.

In Section 2, we first present the success criteria identified by the project partners at the end of the first year, and the recommendations and concerns of the project reviewers during the project review meeting. Then, we introduce the revised success criteria that have been defined to take into account the reviewers' concerns and recommendations. In Section 3, we present a critical analysis of the activities we performed during the second year. To this end, we first report the obstacles we encountered and the countermeasures we adopted. Then, we compare and contrast the results achieved with the success criteria we have defined for this year. When appropriate, we discuss the deviations from expected results. Section 3 reports the lessons learned from the second year of the project and presents a detailed planning for the third year of the project with the full list of the project success criteria.

[1] See Deliverable D8 and the *Second Year Progress Report*.

2. MOBILEMAN OBJECTIVES

MobileMAN's full objectives are listed and discussed in Deliverable D2: "*Project Plans*". Furthermore, according to the lessons learned during the first year of the project, in Deliverable D4 "*Intermediate Evaluation Report*" we translated the project objectives in a set of success criteria for the activities to be performed during the second year of the project. These success criteria, during the first project meeting, have been integrated to take into account the reviewers' concerns and recommendations as emerged after the first year project review (see, Review Report N°: 1). Hereafter, we first recall the second year objectives and the criteria we have identified for assessing project success during the second year in terms of project execution and stable results. In addition, we list the additional requirements emerged during the review meeting.

2.1 Second Year Objectives and Success Criteria

The objectives reported below constitute the criteria for evaluating the success of the second year of the project defined in Deliverable D4.

MobileMAN architecture implementation

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

New applications and services

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

Middleware

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

Co-operation Model

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

Networking services

- Include the cross-layering view at network/transport layer
- Design of packet forwarding schemes suitable for MobileMAN.
- Implementation and validation of location scheme defined during the first year.

- Development and testing of a complete ad hoc network

Wireless Technologies

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

Socio-economic Model

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

2.2 Actions to Address Reviewers Concerns and Recommendations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.3 Second Year Refined Objectives and Success Criteria

By taking into account the discussions during the review meeting, and the actions identified to tackle the reviewers concerns and recommendations, in the first project meeting of the second year the success criteria identified at the end of the first year of the project were refined to align them to results of the review meeting. During the second year, we acted keeping in mind the message received from reviewers at the end of the first year: "the cross layering reference model is very appealing, but it is more important to return first the results depicted in the project proposal, which refers to the legacy architecture". Therefore, we first tried to fulfil to these objectives, and then, if compatible with the project resources, to realize the cross layering architecture issues.

To summarize, in addition to include in our work plan the new action lines required to address reviewers concerns, we refined our objectives related to the extension of the MobileMAN architecture to include cross-layer interactions. As this activity represents an extra effort for the project partners, and the reviewers considered it interesting and its implementation of high value, we decided to concentrate our "cross-layering" efforts on a set of activities that will allow us to realize and test a proof-of-concept prototype. Specifically, as cross layer interactions among the middleware and the network layer seem to be the most promising to achieve this target, the following activities were identified for implementing and testing the cross layer approach (see D10 for details):

- Cross Layering at Middleware layer
    - Adaptation of Pastry middleware for the MobileMAN environment to exploit network topology information through cross layering interactions;
    - Definition and implementation of a Service Discovery Module exploiting cross layer interactions with the network layer;
- Cross Layering at Network layer
    - Definition and implementations of routing protocol supports for cross layer interactions (topology and services information);
- Definition and implementation of the Network Status (NeSt) services and API to guarantee cross layer interactions between Middleware and Network layers.

The full achievements of the above results is expected for mid third year

To better achieve our targets, we designed an architecture that integrates both the legacy and the cross layering reference models. The resulting MobileMAN architecture is shown in Figure 2.1 below. Specifically, we have a basic architecture that follows the original reference architecture defined in Annex 1. This architecture can be enhanced with cross-layer interactions if the *NeSt* is implemented and protocols implement the interfaces to interact with it.

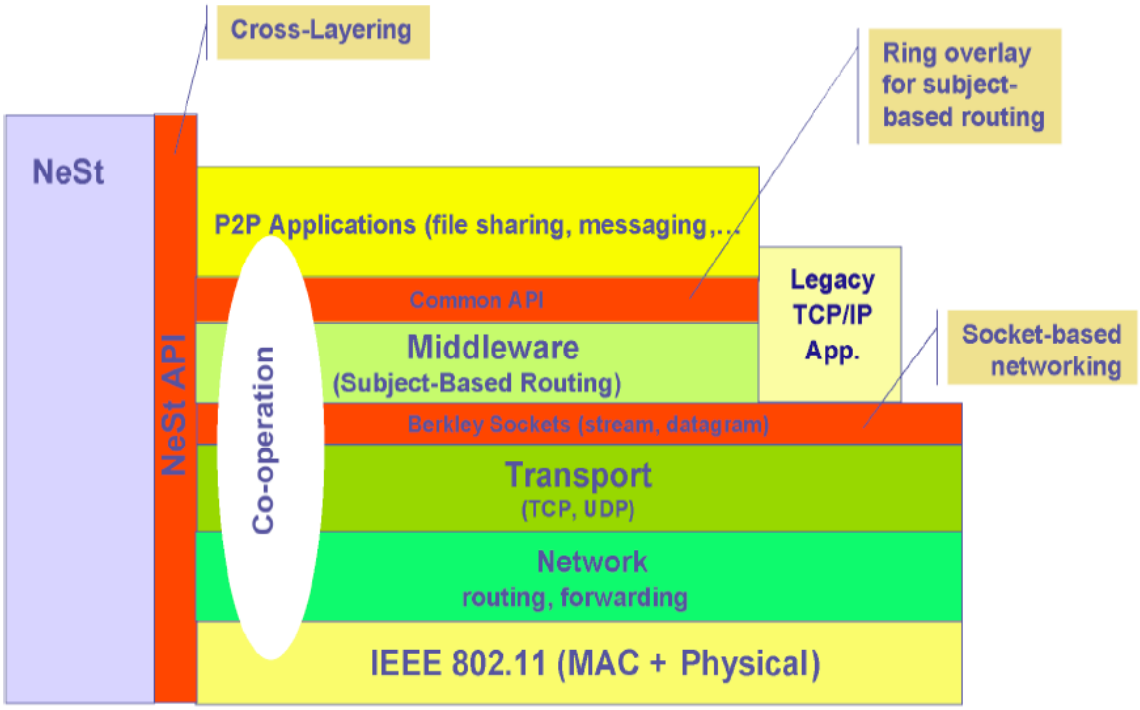

Figure 2.1: MobileMAN Architecture

3. SECOND YEAR ACHIEVED OBJECTIVES

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

- The design and implementation of protocols and mechanisms at different layers (in some case even with measurements on real testbeds).
- The realization and measurement of effective solutions for the relevant technical issues of self-organizing networks: routing and forwarding, medium access control protocol, services, and cooperation.
- The realization of a first trial.
- The realization of a social methodology for analysing the impact of MobileMAN.

3.1 Difficulties Encountered, Choices and Correcting Actions

Before presenting the second-year project results it is worth presenting and discussing the problems we encountered during the second year, and the impact they have on the accomplishment of the planned tasks according to the schedule defined in Annex 1 and Deliverables D2 and D4.

1. Software testing difficulties

During the second year of the project, each project partner started to build small testbeds to experiment and validate the developed solutions. Some problems emerged. Each partner was able to involve in the testbeds' realization only a limited number of laptops/PDAs and few researchers. The latter being the most critical constraint. As a consequence of these resources' limitations only very small tesbeds (i.e., 3-4 nodes) could be set up, with the possibility to investigate only a limited set of software functions. In addition, this isolated approach does not allow efficient software integration and experimentation.

Our Action: To cope with these problems, in the MobileMAN meeting in Helsinki (7-8 June, 2004), we decided to set up a group of junior researchers that should regularly meet to integrate the developed software, and set up a "reasonable" size MobileMAN to validate the developed solutions. This group of people coordinated by CNR research assistants, Eleonora Borgia and Franca Delmastro, met twice in Pisa

- at the end of June for a 7-day (24 June - 2 July) MobileMAN first testing phase, and
- at the end of September (29 September – 1 October).

Researchers from CNR, Cambridge, Eurecom, HUT and Netikos participated to these experimental activities that provided valuable inputs for software testing and integration (see, e.g., D8).

2. HW Platforms are not very robust

Both PDAs and wireless card technologies introduce not expected problems in software developing and testing.

PDA problems. Two types of problems were experienced in using PDAs. The most severe one is related to the existence of critical situations in which, if an error condition occurs during software updating (e.g., battery discharge), the PDA enters in a "crash" status that requires the direct intervention from the device producer to fix it. This implies a long stop (about one month) to recover from the problem and have the device again available. For example Eurecom experienced this type of situation, and this caused a delay in their developing operations.

Another (less critical) problem we experienced with PDAs is the difficulty in modifying software configurations during testing phases. Operations with PDAs are much more cumbersome than with laptops.

Wireless card technology when operating in ad hoc mode was in some operating scenarios not robust. During testing we experienced several times situations in which the cards started stopped working correctly. Furthermore, in outdoor experiments the cards show a high sensitiveness to the heat. Several times (during summer) we have to stop the experiments because the cards were not able to work correctly due to the environment temperature. Other problems were experienced due to changes in the cards chipsets. For new chipsets, reliable LINUX driver were not available. Then we had problems when we needed additional cards to increase the size of our testbed.

Our Action: Use as much as possible laptops for developing and testing. PDA seems suitable only for end-users. We made a set of cards comparative analyses that are now completed to identify the more robust solutions.

3. Off the shelf Software is not reliable/documented

To maximize the usefulness of project results we limited the software development to novel mechanisms and protocols we identified during the first year of the project, while we exploited as much as possible, valuable concepts/solutions (and the corresponding software implementations) already available in the literature. The use of these concepts/solutions was not straightforward due lack of testing, and/or lack of documentation. Furthermore, the SW evolution (e.g., new releases of routing protocols to follow the evolution of Internet drafts, or to fix software bugs) required us a not negligible amount of effort, as we were obliged to several iterative integrations in order to harmonize the whole solution.

Our Action: Some extra efforts have been dedicated to analyze the code and test off-the-shelf SW solutions before integrating them into the MobileMAN testbed. The group of people in charge of software testing has mainly performed these activities.

4. Users' Interaction

During the activities carried out (mainly by SUPSI-DSAS) to validate the MobileMAN paradigm with potential end-users, difficulties emerged to stimulate the users' participation. More precisely, users participated to the activities we planned in a sporadic way depending on the time they have available. After a seminar/presentation they started to interact with us but after some time they become absorbed by their duties, and without direct incentives they did no dedicate time to the tools we prepared.

Our Action: To cope with this problem we decided to focus these activities on groups of students, at HUT during the academic year starting in this September-October 2004. This would mean that the activity would be carried out later than first planned. However, it seemed a good solution to

gain collaboration from a community of students by formally placing the activity into a curriculum course and rewarding the students for their collaboration in credits, or similar ways. Indeed, rewards mechanisms seem to be necessary to guarantee the users participation in MobileMAN social testing activities in a not sporadic way.

3.2 Analysis of Second Year Results

With reference to the Second Year Refined Objectives and Success Criteria (see Section 2.3), during the second year we fulfilled the main objectives. As explained below some deviation from the original plans have been introduced to cope the problems we encountered.

MobileMAN architecture implementation

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

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

New applications and services

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

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

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

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

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

Middleware

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

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

Co-operation Model

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

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

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

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

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

Networking services

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

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

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

- We did not specifically covered the issue of a location scheme as (1) this can be considered as a one specific service realizable by SDM, and (2) as it emerged both from our experimental results and the literature with the current technology only small- medium-scale ad hoc network are realistic. For this type of networks, the location issue is no more a key aspect.

Wireless Technologies

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

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

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

Socio-Economic Model

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

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

4. LESSONS LEARNED AND PROJECT PLANS

Hereafter, we first summarize the lessons learned from the second-year project activities. These lessons gave us the elements to better understand how to complete the project during the third year.

4.1 Second Year Lessons

We can subdivide the lesson we learned during the second year in two classes:

- Lessons related to the Technical Activities
- Social lessons (users' interaction issues).

4.1.1 Lessons related to the Technical Activities

There seems to be a mismatch between what end users might find useful, and what research is currently addressing. Research is mainly based on simulation studies that analyze very large node scenarios (up to 1000 nodes) with CBR traffic. On the other hand realistic experiences of ad hoc networking are almost missing. Furthermore, with current technology, it has been pointed out[3] that exists an ad hoc horizon at two to three hops, and 10 to 20 nodes, where the benefit from wireless multihop ad hoc networking virtually vanishes. Scenarios consisting of a limited number of users wanting to form an ad hoc network for information sharing is simple, but much more probable and feasible.

Starting from these observations we believe that:

- With the current technology, we have to be careful to increase the size of our network, in order to significantly experiment our architecture in a real environment.
- The real tests have a very high value, as simulations do not provide sufficiently input on some contextual aspects and issues, which arise only when the solution is tested on the field.

4.1.2 Lessons related to the Social Activities

One main lesson emerged from all the activities that involved the class of users (university students) we identified for the first stage of MobileMAN evaluation: voluntary collaboration should not be taken for granted, but is a complex concept that we are currently studying in more details. With regard to the students, the limited collaboration was due to a number of factors: period of the year close to the examination phase, no incentives, etc. On the other hand, we observed that when the MobileMAN activities are part of the curricula tasks the students are willing to participate and dedicate more effort to them then requested.

To summarize, the incentives for the users are mandatory, as even in a simple phase as the social evaluation one, we were faced with some reticence in cooperating.

4.2 Third Year Success Criteria

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 two years 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:

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

b) additional goals that emerged during the project execution (Extra goals).

4.2.1 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.

4.2.2 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

- We plan to develop and integrate in a testbed a cross layer solution for the middleware layer (CrossRoad) that exploits cross layer interactions with the network layer (topology

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

information enhanced with services information). The software module supporting these interactions will be also developed.

- We plan to develop in the ns framework the model of the cross layer architecture to study, cross layer interactions between: middleware, transport and network layer. The simulation model will also enable the study of the cross layer architecture on a larger scale with respect to testbed experiments.