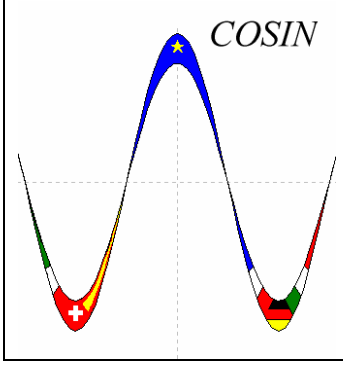

COSIN

IST–2001-33555

Coevolution and Self-Organization in Dynamical Networks

http://www.cosin.org

Periodic Progress Report N°:2

Covering period 1.3.2003-29.2.2004

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	CR8 (UPSUD) Université de Paris Sud *France*

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CONTENTS

1. Executive Summary

The project is entering its third year of life and we want to provide here a general overview of the second year of activities. As an introductory remark it is important to mention that the detailed presentation of the progress of the project, consisting of the achieved results, as well as the description of deliverables, is reported in the following *work progress overview*. In this section we aim at picturing the general strategy of coordination and the axis of research and collaboration fostered in the consortium. In particular, we want first to address the most important achievements and the work carried out, including re-modulation of activities due to changes in the state of the art at the world-wide level. Furthermore, we intend to illustrate the level of coordination and collaboration achieved within the consortium. Finally we report on the impact and dissemination of the project activities in the scientific community at large.

Research activities and achievements

During the second year the project has significantly advanced in all the main objectives, developing a more coordinated effort among the teams. COSIN revolves around three main axes concerning complex network theory, network analysis tools and the study and characterization of real networked structure. This research plan is intended mainly to be developed in the technological and social domains and problems at the interface of these disciplines. The various works and deliveries obtained during the first year, while still in a non-organic perspective, have allowed the project to build a large ensemble of informatics tools, data sets and theoretical results that are at the forefront of the research field. This ensemble of results is now merging in a more structured way into the second year deliverables. This is particularly clear from deliverables **D10, D14** and **D15**.

D10 contains a discussion of the *state of the art* in the field of network theory and characterization. The contained analysis of the world-wide activities readily shows that the COSIN results are largely contributing to shape the general understanding of complex networked structures. The groups CO1, CR2, CR3, CR4, CR5 and CR8 have all contributed to field of network characterization, modelling and theory with relevant work both of a very general nature or applied to specific systems (Internet, WWW, social systems). In this area the consortium has reached a good level of collaboration with several papers co-authored among the various groups.
The analysis of the activities in the network field supports the vision of the COSIN project in the social science area. Indeed, the application in the social system domain of ideas developed in the context of technological networks has been energetically pursued in recent time in the network community. This is reflected also in the hectic research activity devoted to communities' identification in complex networks that has a particular importance in the analysis of social systems. In this area the COSIN consortium is very active. Several groups CO1, CR3, CR4, and CR5 can be considered at the forefront in this research front. Here it is worth emphasizing the activities by CR3 on community analysis and the recent work on community detection by the CO1 node. Along with these works, the coordinated activities summarized in the deliverables D15 and D16 are another successful example of the COSIN activities in the field of social networks analysis and modelling.
The high levels of discussion in the consortium and the many results obtained in the modeling effort have lead to a re-modulation of part of the research activities of the project in this area. As specified in the D10 discussion, the network modelling effort is pursuing new paths at the world-wide level. In particular, new models that go beyond the growing paradigm and the simple topological representation are being proposed. These modelling efforts are stimulated by the new empirical evidences on complex networks which are highlighting the importance of disorder and

weights in the shaping of the networks architecture. In this perspective the COSIN consortium has been extremely active in two different paths. The first one, pursued by CO1, CR3 and CR4, concerns the formulation of models including disorder and the possible onset of complex topological properties from this ingredient. Another research line, involving the nodes CR3 and CR8, refers to the analysis and modelling of weighted networks in which the architecture is characterized beyond the bare topological properties by introducing specific weights representing the traffic capacities and strength of the various elements of the networks. These research lines were not detailed in the original COSIN proposal; however, the recent developments in the network science have made these studies a very important addition to the consortium activities. The re-modulation of the research activity in the network modelling and the delay in the starting activity of node CR3 have induced a delay on the deliverable **D11** (self-organized criticality in network formation), that is strongly depending on the results concerning network modelling. We thus decided to postpone the deliverable to the next year. Indeed, it is plausible that the consortium will pursue an active research on the subject until the end of the project and it would be unreasonable to close prematurely such an interesting area of investigation.

Noticeable effort has been devoted to the deliverables **D15** and **D16**. These deliverables are framed within the **WP4**, dynamics of social networks. The deliverables consist in the application of many of the concepts developed for the characterization of complex networks to some prototypical examples of social networks. It is interesting to note that metrics related to connectivity correlations, clustering and weights provide a much deeper understanding of the properties of social networks and dynamical phenomena occurring on top of them (decision making processes, emergence of consensus, etc.). The level of collaboration on social networks within the consortium has been particularly fostered, strengthening the collaboration among the **WP4** leading group CR5 and the group CO1, CR3, and CR8. As for now the research flow is still in one direction with ideas and tools developed in the context of statistical physics and information technology that find application and use in the social science context. We are aiming in the next year to a reverse process in which network evolution models may be complemented with elements of the social dynamics, game theory in order to provide a better framework for networks such as the Internet and WWW where elements from social sciences and market competition are surely extremely relevant.

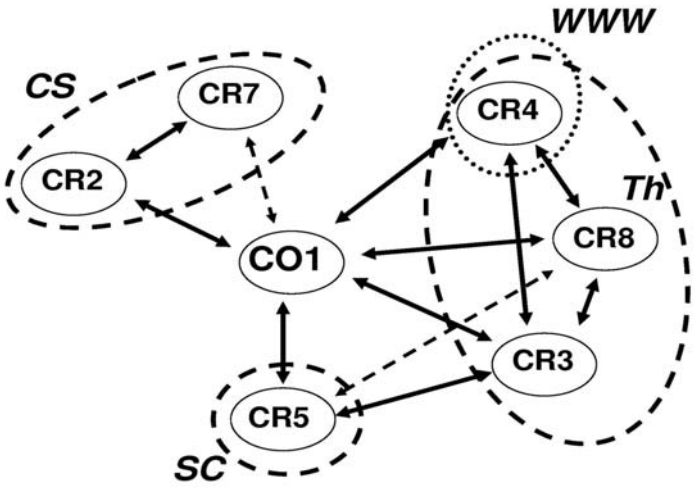
Deliverables **D12** and **D13** are a consistent step forward in the context of the **WP2** concerning data and tools collection. In both deliverables, the COSIN project is finally providing a consistent array of data sets (**D12**) and software tools (**D13**). These deliverables, along with the re-modeling and improvements of the COSIN web-site, provide a first core of utilities available for the research community at large. In particular we have made publicly available a set of informatics tools aimed at handling large graphs stored in secondary memory and an ensemble of data sets covering different domains ranging from technological to biological networks. We have also enriched the database with in-house gathered data concerning Internet spanning trees and WWW communities. In this respect we have to stress that, as outlined in the first year report and the relative discussion with the reviewers, data acquisition projects have taken into account the existence of similar initiatives by larger and more funded project, especially in the US. This has called for a re-definition of some objectives in this area in order to avoid useless duplications and competitions. In particular, large scale Internet and WWW mapping projects have been abdicated. These endeavours require large money and equipment investments to be competitive with analogous initiatives that are popping up in US, private companies and large European Networks. We have therefore opted for establishing partnership with other larger scale projects (CAIDA, Fermi Institute) and foster in-house data acquisitions which privilege novel perspective. This is the case of specific web-crawls for semantic research on subset of the WWW. The source of this web-crawl is already available on the COSIN web-site, while data will be gathered in the next few months.

Finally, we want to mention the important advancement made with **D14** and **D17**. The deliverable **D14** is a first step in the direction to obtain a customization of software tools used in

the analysis and representation of networks to the case of large complex networks such as the Internet and the WWW. This is a very challenging task. Many of the algorithms customarily used in the field of network drawing have serious limitations in the size of the network that can be represented. In a few cases it is possible to obtain very interesting pictures of large networks that despite the aesthetical value offer very limited intelligibility of the network topology and structure. The UNIKARL node CR7 has started a series of test and efforts toward the customization of the *Visone* tool for the analysis of very large networks. This effort benefits of continuous discussion and collaboration with the other partners and we forecast that the interaction will be strengthened in the next year with practical application and implementation with real data sets and models. As well, the deliverable **D17** represents a very nice application of the "expertises" accumulated within the project to tackle real problems in the analysis of the Internet network. Namely, the reliability of Internet data gathered from probing experiments and the analysis of the type of relationships among Autonomous Systems in the Internet. Also **D17** is representing the merging of efforts from different nodes such as CO1, CR2 and CR7.

Coordination and collaboration in the Consortium

The consortium has put a particular effort in fostering the collaboration and interaction among the various partners in the project. The first year has witnessed the natural wiring of subgroup of partners according to their specific domains and specialization. In addition collaborations and interactions supported by the mediation of the CO1 started to develop. It is natural that the first year has been used to set up a common background and language that during the second year has actually started to solidify in more pragmatic and direct collaboration. The analysis of projects and the decision making process concerning the research lines of the consortium is now involving all partners in a very good collaborative perspective. Each team is benefiting and taking advantage from the knowledge and skills of all the other partners. In terms of direct collaborations (co-authored papers and projects) the consortium has still margins of improvements. This is in the natural physiology of the COSIN project timeline. In the figure we report a graph representation of the COSIN project. Nodes are the various partners and links are actual collaborations as identified by co-authored papers or specific research products. Dashed links represents collaborations at an advanced stage for which a preliminary output is already available or due in a short time. The node CO1 is clearly the hub with strong ties to all the partners. The CO1 node has also made a particular effort to wire up with CR5 and with CR7. In this last case the output of direct collaboration is expected soon. The other nodes can be clearly grouped in terms of their scientific profile: network theory (Th), computer science and informatics (CS), social science (SC). The partners in the network theory area have formed a collaborative clique since the beginning of the project as it is very easy to recognize in the figure. In the last year, an effort has been put to wire up the partner CR5 that represents the social science expertise with the network theory area. This effort produced visible results with several collaborative links among the two areas. The computer science area is interacting via the CO1 hub; however, it has little direct collaboration with the other areas. While this lack of direct collaboration points out to possible path for improvement, it must be taken into account that tools, data sets and algorithms developed in the computer science area had a considerable impact in the activity of network theory. At the same time, models and concepts developed by network theory groups have affected the analysis and work of CR7 and CR2. A "meta-collaboration" is therefore existing between the various groups given the high level of discussion and continuous scientific exchanges. Finally, the peculiar role of node CR4 should be noted, that actively participates to many projects since it is taking care of the project web-site. Despite it is not possible to characterize this work in the form of direct collaborations, it is clear that a continuous and close interaction among CR4 and all other groups is in place.



The previous discussion highlights a few initiatives that should be adopted in the consortium management to foster even more the level of collaboration during the project. First of all, the effort adopted in supporting common projects between partner CR5 and the other partners should be continued. This appears natural for the remaining of the COSIN project since the introduction of social science ingredients in network modelling is an attractive as well as priority issue in the third year of the project. Moreover, it is important to foster the level of collaboration among network theory partners and the computer science partners. This has already started by defining some common projects concerning data gathering (WWW communities), realistic models for the Internet and the WWW and theoretical and numerical approaches devoted to the assessment of experimental data collection methods (Internet mapping, WWW crawlers). Finally, co-organized topical conferences and activities are envisioned for the next year in a continuing effort of communication and common background establishment.
Several other initiatives concerning the coordination and management of the projects are outlined in section 3 of the present report. We mention here the creation of a new Paris node (CR8). This node will help in the developing of collaborative interactions with the partner CR5 and in taking care more closely of the dissemination and exploitation of results. The WP structure has been reinforced with a more direct involvement and control of WP leaders. Additional WP and WP leaders meeting have been established in order to provide an efficient and timely coordination of the project, able to cope with re-modulation of research objectives, deliverables and WP due to changes in the world-wide state of the art in the field.

Dissemination and impact of the project

In the second year, the dissemination of the COSIN activities has received a considerable boost. The project has organized a large conference (the MIDTERM conference) held in Rome in September 2003. The conference has represented, together with the Los Alamos conference, the largest event in the network area and has gathered all the leading experts in the field. The COSIN project has benefited of the advertisement related to the conference and has established links and contacts with parallel initiatives worldwide. The conferences have also been the occasion for the publication of a special thematic issue of the European Physical Journal devoted to networks. This issue is more than the usual proceedings volume since published papers are containing novel and interesting results previously unpublished. Also in this issue, the COSIN activities are very well represented with many papers from several groups of the consortium. Many other experts are contributing to the issue that will surely be a reference publication in network science.
Along with the organized conference, various COSIN participants have been involved in conference organization and program committee of other conferences. In addition the COSIN

project has been represented with invited talks and seminars to almost all relevant conferences in the field. Just to mention a few the Annual Los Alamos conferences, the APS march meeting, IEEE, WWW conference and IPS 2004.
Collaboration between the CR3 and CR8 partners has led to the publication of the book
"Evolution and structure of the Internet" published by Cambridge University Press. This book is the first scientific monograph attempting to provide a general overview of the analysis of the large scale structure of the internet network. It contains references to several activities developed within the COSIN project and it is going to help the dissemination of these results worldwide.
Very relevant is the major reshaping of the COSIN web-site. A detailed report on the new features and the implementation of the past year reviewers' suggestions are reported in sec.2.7 and sec.3. We believe that the site is now offering an attractive and user friendly interface. Most important, data and tools gathered by the project are now available on the site. More features will be added in a short time including a news section reporting updating on the COSIN project and timely pointers to initiative and conferences in the area of network science.
Finally, we have an extensive planning for the next year activities including a new scientific book summarizing the COSIN activities, the final project conference (Tarragona -Catalunya, March 2005) and two topical conferences; WWW04 to be held in Rome and the Bertinoro workshop in collaboration with the BISON European project.

2. Work Progress overview

2.1 Specific Objectives met in the second year

Within the various deliverables scheduled in the second year, several main results and objectives of the COSIN proposal have been achieved. A first set of them concerns the WP1, mathematical tools for complex systems. In this area the project has proved to have a leading role worldwide, with an impressive number of works and publications on high impact journals (see **D10**). Specific results of particular relevance concerns the definition of new models of evolving networks that includes the traffic and interaction features in the dynamical evolution. A new class of models with disorder has been extensively discussed, showing the possibility of having self-developing complex properties in static graphs with a fitness driven wiring mechanism. Finally, innovative methods and algorithms for communities and organization detection in large complex networks have been introduced.

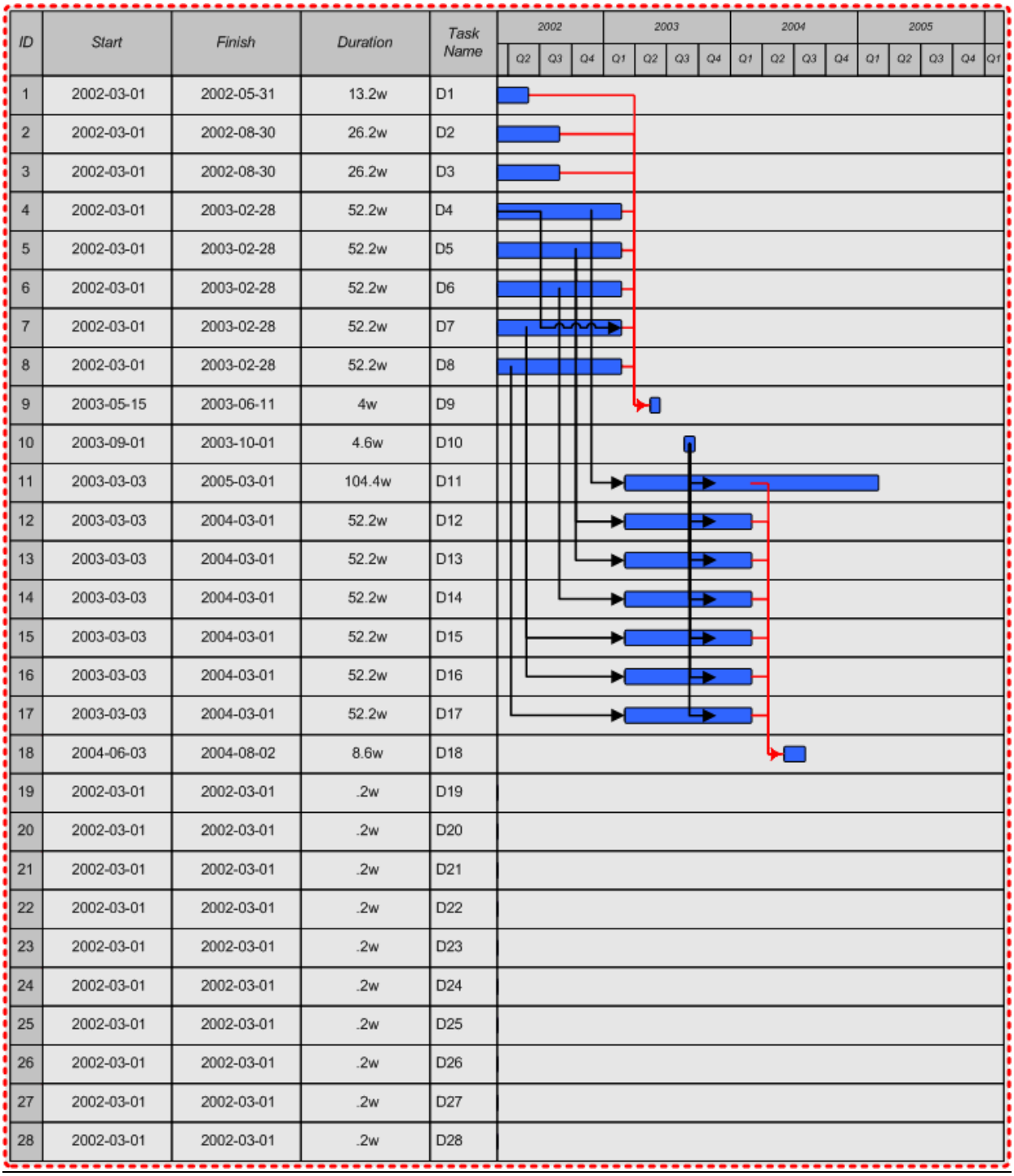
According to the project and to the developments in the state of the art we increased as a consortium the study and analysis of social networks as paradigmatic example of complex systems (WP4, Dynamics of social networks. Here several interesting results have been obtained by using metrics and tools developed to characterize large information networks in the context of social networks (see **D15** and **D16**). A specific effort has been made in this case in order to fulfill the project schedule and accomplish the reviewer request to establish a better collaboration between nodes. This resulted in a series of joined activities (especially with node CR5 ENS) eventually published in several scientific papers.

The project is being successful also in offering in a publicly available fashion an extensive set of networks datasets and a library of software tools (see **D12** and **D13**) . Along with the remodeling of the COSIN website we believe to finally offer a useful array of data and algorithms to the scientific community. The project will continue to enrich is libraries and databases and to ameliorate the web-site until the end of the project. Other important achievements are related to the deliverables **D14** and **D17**, which opens the path to practical application and developments of very innovative tools such as customized tools for large graphs visualization and analysis. In the following, a detailed list of all results and objectives is stated in the short and detailed deliverables description.

2.2 Progress during the second year

Following the Guidelines for periodic progress report we indicate here a short description of the deliverables made. An updated Grant chart and some basic information can be found as required by templates in Appendices 2 and 3 of the above Guidelines.

Gantt Chart



ID	Start	Finish	Duration	Task Name
1	2002-03-01	2002-05-31	13.2w	D1
2	2002-03-01	2002-08-30	26.2w	D2
3	2002-03-01	2002-08-30	26.2w	D3
4	2002-03-01	2003-02-28	52.2w	D4
5	2002-03-01	2003-02-28	52.2w	D5
6	2002-03-01	2003-02-28	52.2w	D6
7	2002-03-01	2003-02-28	52.2w	D7
8	2002-03-01	2003-02-28	52.2w	D8
9	2003-05-15	2003-06-11	4w	D9
10	2003-09-01	2003-10-01	4.6w	D10
11	2003-03-03	2005-03-01	104.4w	D11
12	2003-03-03	2004-03-01	52.2w	D12
13	2003-03-03	2004-03-01	52.2w	D13
14	2003-03-03	2004-03-01	52.2w	D14
15	2003-03-03	2004-03-01	52.2w	D15
16	2003-03-03	2004-03-01	52.2w	D16
17	2003-03-03	2004-03-01	52.2w	D17
18	2004-06-03	2004-08-02	8.6w	D18
19	2002-03-01	2002-03-01	.2w	D19
20	2002-03-01	2002-03-01	.2w	D20
21	2002-03-01	2002-03-01	.2w	D21
22	2002-03-01	2002-03-01	.2w	D22
23	2002-03-01	2002-03-01	.2w	D23
24	2002-03-01	2002-03-01	.2w	D24
25	2002-03-01	2002-03-01	.2w	D25
26	2002-03-01	2002-03-01	.2w	D26
27	2002-03-01	2002-03-01	.2w	D27
28	2002-03-01	2002-03-01	.2w	D28

SHORT DESCRIPTION OF DELIVERABLES

- **D10 Check of the state of the art (WP1).**

The study of the state of the art for a new field of research such as the one of the growing networks is a crucial task in order to keep updated the scientific challenges of a research project. Here we present some analysis of the field as perceived by the project members as well as the opinion of the major experts worldwide as collected during our midterm conference (see Appendix A and Appendix B) at month 18. The main results are that the future development of research will very likely proceed along the following lines

  - **Social Networks.** Recently, surveys carried on collaboration networks (authors linked by co-authorships), communication networks (Internet users exchanging e-mail messages) and markets (economic interactions connecting market agents), have confirmed that also social networks display complexity in the degree distribution *P(k)* and other quantities of interest. Social networks represent then a paradigmatic example for the study of the onset of complexity in artificial networks as the technological ones. A suitable modelization and possible optimisation of the latter ones can only come after a careful study of social structures.
  - **Beyond "Preferential Attachment".** Mechanisms generating complex features in networks (above all, the power-law degree distribution) have been deeply studied in the previous years, focusing mainly on evolving networks, whose size grows with time. This caused a very rapid development of the scientific field at its start. A seminal paper by A.-L. Barabási et al. introduced the idea that growth and preferential attachments were necessary to the occurrence of fat tails in the degree distribution. Nowadays, such approach is no more a priority: growing networks with various additional mechanisms have been introduced and reproduce almost any of the parameters measured in real networks. Nevertheless, the hypothesis of a dynamically evolving network is not always verified in reality.
  - **Clustering and Communities.** Measurements and exact results concerning the clustering patterns of networks mainly concern the occurrence of regular motifs and their correlations. However, many social and information networks, such as the World Wide Web, turn out to be approximately partitioned into communities of irregular shape: for example, web pages focusing on similar topics are strongly mutually connected and have a weaker linkage to the rest of the Web. The design of methods to partition a graph into several meaningful highly inter-connected components have then become a compelling application of graph theory to biological, social and information networks.
  - **Weighted networks**. While complex networks are usually characterized by their topological complexity, they also often display a large heterogeneity in the capacity and intensity of the connections. In the Internet or in the Web, in ecosystems, or in the world-wide airport network, the strength of interactions varies greatly. This diversity in the weights of the interaction adds a complexity which cannot be overlooked in the study and description of these networks. Studies of this phenomenology as well as new models of complex networks explaining this heterogeneity are therefore necessary.

- **D11 Self-Organization in Networks (WP 1)**

Given the hectic activity in the field in the interest of the project we decide to proceed with this deliverable until the end of the project, thereby delaying the due date to March 2005. Already now the quantities of publications and research made in this area by the consortium have been rather impressive. Since this is one of the most interesting subject, and we will certainly keep on working on that presumably even after the end of the project it makes more sense to wait for final conclusion on this topic. Complex networks found in nature and

society show lack of characteristic scales and have grown following rules that depend on the behavior of single nodes, not on the whole structure of the network. This is what makes many complex networks to be viewed as self-organized critical systems. These aspects are made evident usually in the form of power-law distributions of node connectivities; however, some other properties, such as the size distribution of community sizes, have become quite important. On the other hand, simple self-organizing network models that can explain the characteristics of observed data are still necessary. At the moment a couple of these kinds of models have been presented by the people within the consortium. They resulted in more activity within and outside the project in order to describe and solve these models. Future development in this area will be obtained by focusing on the self-organization of node properties keeping fixed the topology of the network, related to well-known models of neural networks.

- **D12 Database formation for Internet and WWW (WP 2)**

The database of collected data by COSIN is divided in several sections. For the Internet section we collected traceroute data (2001-2002) and ping data (2001-2004), the data available can be considered a snapshot of a part of the Internet. For the World-Wide Web section we searched and analyzed more than 300000 web pages, looking for the URLs they contained and detecting communities. We have included in the Protein Network section the first protein network data taken from the Database of Interacting Proteins. In the database are also available a series of miscellaneous data related to Food Webs, Social Networks and U.S. Patents.
Our future action during the third year will be to have, alongside the "data" database, a "link" database: an annotated repository of links to sites that provide high quality data about various kinds of networks. On the other hand we are also collecting sensible subsets of the WWW to be put in a downloadable form on the website. At the moment we have collected some thematic subsets by looking at all the pages related to a certain topic. We hope to be in condition (by collaboration with provider companies) at the end of the project to present also subset of the WWW as seen by single providers.

- **D13 Library of Software Tools (WP 2)**

The Webgraph is the graph whose nodes are the (static) HTML pages and the (directed) edges are the hyperlinks between pages. In order to study the statistical and topological properties of the Webgraph and to study models for the Webgraph we need to generate and measure graphs with more than one billion edges. We developed a collection of routines that are able to deal with massive graphs stored in files in secondary memory. In particular, our routines can generate graphs according to many of the models presented in the literature; we also provide programs that can measure these graphs (the ones generated according to known models) as well as real samples of the Webgraph. We present a "multifile" format to represent graphs in secondary memory; we include routines that convert some graph file formats from/to our .ips multifile format. Binaries and source code of all the program of this library are freely available; to compile them the gcc compiler (at least version 2.9) and linux operating system are needed. The library has been tested with graphs up to 2 billion edges.

- **D14 Customization in Visualization Tools (WP 3)**

The ability of drawing very large networks as e.g. large computer networks is of great significance in visualizing the evolution of stochastic models for evolving networks. One focuses on designing and implementing new algorithms and innovative software systems that display a large graph at different abstraction levels. For example, there is an increasing need of systems that show maps of the Web and support the user during his/her navigation, of systems that display and monitor the traffic on the Internet, and of systems that draw portions of the Internet as a graph. Until now, the vast majority of graph drawing algorithms that have been deeply studied and experimentally tested in the literature, like for instance for database schemes, can efficiently handle graphs of only hundreds of vertices. We aim at devising

general algorithmic techniques for drawing large graphs and to experiment their usage in new visualization systems, thus contributing to devising the technology transfer from the algorithmic research on graph drawing to its application in networks visualization.

- **D15 Modelling Interactions and Dynamics inside Firms (WP 4)**

In this research line CR5 (ENS, Paris) has focused on the decision making process within the board of directors of a firm. Starting from the existing literature we have developed a simple theoretical framework in which is possible to ask and answer quantitative questions about the impact of well connected minorities within the board and about the impact of external forces, such as the information about decisions previously made in other boards. These studies have possible applications in corporate governance policy making.

- **D16 Inter-firms Network Dynamics (WP4)**

For this deliverable node CR5 (ENS, Paris), responsible for WP4, has worked in close collaboration with C01 (INFM Rome) and CR3 (Barcelona) focusing on the study of two kinds of firm networks: the network of corporate boards and directors and the network of firm ownership in the stock market. The first network is involved in strategic decision making while the second one concerns the capital control structure. We have worked both at the level of characterizing the topological properties of such networks and at the level of developing models of dynamical processes taking place on them. The structure of corporate board network has also an impact on the internal dynamics within firms, a topic which belongs to deliverable D15. For the convenience of the reader the description of this topic in D15 and D16 have some overlap. Other directions of research developed by node CR5 in deliverable D16 include exploring the effect of network externality in a simple monopolistic market model and the dynamics of continuous opinion propagation in networks of economic agents.

- **D17 Algorithms for Network Traffic Analysis (WP5)**

As routing in the Internet follows a hierarchical scheme, the analysis of the Autonomous System graph, where routing is determined at the higher level, is the first step towards the study of traffic flows, routing changes, and routing instabilities occurring in the Internet. In order to consolidate the theoretical foundations of such studies, we first address the problem of obtaining correct data from the available data sources. Second, we investigate the problem of computing the types of the relationships between Autonomous Systems (ASes), showing the NP-hardness of the problem and producing effective and efficient heuristics to approach it. Finally, we study how clustering techniques can be adapted and improved in order to be used in this domain and show how the clustered view of the AS graph can provide high level information about the network evolution at different time scales

- **D18 Second Progress Report (WP7, WP8)**

This document

DELIVERABLES TABLE

Project Number:	**IST-2001-33555**
Project Acronym:	**COSIN**
Title:	**Coevolution and Self-Organization in Dynamical Networks**

Del. No.	Revision	Title	Type[1]	Classifi-cation[2]	Due Date	Issue Date
10		**State of the Art**	**R**	**Pub**	**18**	**18**
11		**Self-Organization in Networks**	**R**	**Pub**	**24**	**36**
12		**Database formation for Internet and WWW**	**R**	**Pub**	**24**	**24**
13		**Library of Software Tools**	**R**	**Pub**	**24**	**24**
14		**Customization in Visualization Tools**	**R**	**Pub**	**24**	**24**
15		**Modeling Interactions and Dynamics inside firms**	**R**	**Pub**	**24**	**24**
16		**Inter-firm Network Dynamics**	**R**	**Pub**	**24**	**24**
17		**Algorithms for Network Traffic Analysis**	**R**	**Pub**	**24**	**24**
18		**Second Progress Report**	**R**	**Pub**	**24**	**24**

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

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	10 **Check of the state of the Art**
Due date:	18 Month
Delivery Date:	24 Month

Short Description:

A complete copy is downloadable from project site

http://www.cosin.org/wp/deliverables/D10.pdf

The study of the state of the art for a new field of research such as the one of growing networks is a crucial task in order to keep updated the scientific challenges of a research project. In the document we present the various lines of research developed in these years. We also report the result of a round table on the open perspective in the research. This round table held in Roma at the Midterm meeting reports the opinion of leading experts in the field within and outside the project.

In summary we can indicate as the most active lines of research in this field

- **The extension to social systems of notion and ideas developed for technological webs.**
- **The connection between disorder and the onset of self-similarity in networks.**
- **The characterization of communities and clustering in the graph.**
- **The characterization and study of weighted networks.**

These new perspectives as realized by people within the project have been also confirmed by experts outside the project as witnessed in the midterm meeting

In order to take into account these updates requests from the community we planned a slight reschedule of the deliverables dates.

Partners owning: **CR3 (UB)**

Partners contributed:

C01 (INFM), CR2(UDRLS), C4(UNIL), C5(ENS), C7(UNIKARL), C8(UPSUD)

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	11 **Self-Organized Criticality in Network formation**
Due date:	24 Month
Delivery Date:	36 Month

Due to the delay in the starting activity of node C03, and to the great interest in the field on this topics it has been made necessary to delay the due date of such deliverable. A draft is nevertheless ready and a copy can be downloaded

at: http://www.cosin.org/wp/deliverables/D11.pdf

Complex networks found in nature and society show lack of characteristic scales and have grown following rules that depend on the behaviour of single nodes, not on the whole structure of the network. This is what makes many complex networks to be viewed as self-organized critical systems. These aspects are made evident usually in the form of power-law distributions of node connectivities; however, some other properties, as the size distribution of community sizes, have become quite important. On the other hand, simple self-organizing network models that can explain the characteristics of observed data are still necessary. Finally, we have also focused on the self-organization of node properties keeping fixed the topology of the network, related to well-known models of neural networks.

Amongst the various publications related to such deliverable we suggest

M. Boguñà and R. Pastor-Satorras,
Class of correlated random networks with hidden variables, Phys. Rev. E **68**, 036112 (2003).

G. Caldarelli, C.C. Cartozo, P. De Los Rios, V.D.P. Servedio,
Widespread occurrence of the inverse square distribution in social sciences and taxonomy,
Phys. Rev. E **69**, 035101(R) (2004)

A. Arenas, L. Danon, A. Díaz-Guilera, P.M. Gleiser, and R. Guimerà,
Community analysis in social networks, European Phys. J. B (in press).

J.J. Ramasco, S.N. Dorogovtsev, and R. Pastor-Satorras,
Self-organization of collaboration networks, preprint cond-mat/0403438.

Partners owning: **CR3 (UB)**

Partners contributed:

C01 (INFM), CR2(UDRLS), C4(UNIL), C5(ENS), C7(UNIKARL), C8(UPSUD)

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	12 **Database formation for Internet and WWW**
Due date:	24 Month
Delivery Date:	24 Month

Downloadable at:

http://www.cosin.org/wp/deliverables/D12.pdf

The database of collected data by COSIN is divided in several sections. For the Internet section we collected traceroute data (2001-2002) and ping data (2001-2004), the data available can be considered a snapshot of a part of the Internet. For the World-Wide Web section we searched and analyzed more than 300000 web pages, looking for the URLs they contained and detecting communities. We have included in the Protein Network section the first protein network data taken from the Database of Interacting Proteins. In the database are also available a series of miscellaneous data such related to Food Webs, Social Networks and U.S. Patents.

Our future action during the third year will be to have, alongside the "data" database, a "link" database: an annotated repository of links to sites that provide high quality data about various kinds of networks.

Partners owning: **CR4 (UNIL)**

Partners contributed:

C01 (INFM), CR2(UDRLS), C3(UB), C5(ENS), C7(UNIKARL), C8(UPSUD)

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	13 **Library of Software Tools**
Due date:	24 Month
Delivery Date:	24 Month

Downloadable at:

http://www.cosin.org/wp/deliverables/D13.pdf

The main core of these tools is represented by algorithms able to deal with the huge size of a Webgraph crawl. Webgraph is the graph whose nodes are the (static) HTML pages and the (directed) edges are the hyperlinks between pages. In order to study the statistical and topological properties of the Webgraph and to study models for the Webgraph we need to generate and measure graphs with more than one billion edges. We developed a collection of routine that are able to deal with massive graphs stored in files in secondary memory. In particular, our routines can generate graphs according to many of the models presented in the literature; we also provide programs that can measure these graphs (the ones generated according to known models) as well as real samples of the webgraph. We present a ”multifile” format to represent graphs in secondary memory; we include routines that convert some graph file formats from/to our .ips multifile format. Binaries and source code of all the program of this library are freely available; to compile them the gcc compiler version >= 2.9 and linux operating system are needed. The library has been tested with graphs up to 2 billion edges.

Partners owning: **CR2 (UDRLS)**

Partners contributed:

C01 (INFM), CR3(UB), CR4(UNIL), CR5(ENS), CR7(UNIKARL), CR8(UPSUD)

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	14 **Customization of software tools**
Due date:	24 Month
Delivery Date:	24 Month

Downloadable at: http://www.cosin.org/wp/deliverables/D14.pdf

Customization and usability study of general purpose software tools for visualization of large networks. The ability of drawing very large networks as e.g. large computer networks is of great significance in visualizing the evolution of stochastic models for evolving networks. One focuses on designing and implementing new algorithms and innovative software systems that display a large graph at different abstraction levels. For example, there is an increasing need of systems that show maps of the Web and support the user during navigation, of systems that display and monitor the traffic on the Internet, and of systems that draw portions of the Internet as a graph. We aim at devising general algorithmic techniques for drawing large graphs and to experiment their usage in new visualization systems, thus contributing to devising the technology transfer from the algorithmic research on graph drawing to its application in networks visualization. As a first step, we collected information and links of existing visualization software. In a case study, the advantages and disadvantages of these packages are illustrated. The results are made public at the COSIN web page. See http://i11www.ira.uka.de/cosin/tools.

Within the software tool "visone" we implemented a collection of algorithms for visualizing networks in order to support the analysis. Current efforts are devoted to the customization of visone for large networks. For various large data sets such as link structures in the World Wide Web and metabolic pathways we developed new algorithms and prototype visualization methods.

U. Brandes and S. Cornelsen. Visual Ranking. J. of Graph Alg. & Appli. 7(2), pp 181-201, 2003.

U. Brandes, T. Dwyer and F. Schreiber. Visualizing Related Metabolic Pathways in Two and a Half Dimensions. Proc. 11th Intl. Symp. Graph Draw. (GD'03), LNCS 2912, pp 111-122, Springer, 2004.

U. Brandes, T. Dwyer and F. Schreiber. Visual Triangulation of Network-Based Phylogenetic Trees. To appear in Proc. 6th Joint Eurographics – IEEE TCVG, Symp. Visualization (VisSym'04).

U. Brandes and D. Wagner. visone – Analysis and visualization of social networks. In: P. Mutzel and M. Jünger (eds.) Special issue on Graph Draw. Software, Math. and Vis., Springer, 2003.

D. Wagner. Analysis and Visualization of Social Networks. Proceedings of the 2nd International Workshop on Experimental and Efficient Alg. (WEA'03), LNCS 2647, pp 261-266, Springer, 2003.

Partners owning: **CR7 (UNIKARL)**

Partners contributed:

CR2(URDRLS)

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	15 **Modeling dynamics and interactions in firm structures**
Due date:	24 Month
Delivery Date:	24 Month

Downloadable at:

http://www.cosin.org/wp/deliverables/D15.pdf

In this research line CR5 (ENS, Paris) has focused on the decision making process within the board of directors of a firm. Starting from the existing literature we have developed a simple theoretical framework in which it is possible to ask and answer quantitative questions about the impact of well connected minorities within the board and about the impact of external forces, such as the information about decisions previously made in other boards. These studies have possible applications in corporate governance policy making. In particular in this context, unlike previous works, CR5 has worked on models in which the opinion dynamics takes place on an empirical heterogeneous network organized in interconnected groups.

Battiston, S., Bonabeau, E., Weisbuch G., *Decision making dynamics in corporate boards*, *Physica A*, **322**, 567 (2003).

Battiston S. and Catanzaro M., *Statistical properties of board and director networks*, 2004, European Physical Journal B (in press)

Battiston, S., Weisbuch G., Bonabeau, E., *Decision spread in the corporate board network*, 2003, to appear on Adv.Compl.Syst. **6,4** 2003

Partners owning: **CR5 (ENS)**

Partners contributed:CO1(INFM)

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	16 **Inter-firm Network Dynamics**
Due date:	24 Month
Delivery Date:	24 Month

Downloadable at:

http://www.cosin.org/wp/deliverables/D16.pdf

For this deliverable node CR5 (ENS, Paris), responsible for WP4, has worked in close collaboration with C01 (Rome) and CR3 (Barcelona) focusing on the study of two kind of firm networks: the network of corporate boards and directors and the network of firm ownership in the stock market. The first network is involved in strategic decision making while the second one concerns the capital control structure. We have worked both at the level of characterizing the topological properties of such networks and at the level of developing models of dynamical processes taking place on them. The structure of corporate board network has also an impact on the internal dynamics within firms, a topic which belongs to deliverable D15. For the convenience of the reader the description of this topic in D15 and D16 have some overlap. Other directions of research developed by node CR5 in deliverable D16 include exploring the effect of network externality in a simple monopolistic market model and the dynamics of continuous opinion propagation in networks of economic agents.

Battiston S., *The inner structure of capital control networks*, 2003, to appear on Physica A.

Battiston S. and Catanzaro M., *Statistical properties of board and director networks*, 2004, European Physical Journal B (in press)

Battiston, S., Weisbuch G., Bonabeau, E., *Decision spread in the corporate board network*, 2003, Adv.Compl.Syst. 6,4

Battiston, S., Caldarelli G., Garlaschelli D., The *hidden topology of shareholding networks*, 2003, submitted.

Garlaschelli D., Battiston S., Castri M., Servedio V.D.P., Caldarelli G., *The scale free nature of market investment network*, 2003, submitted, cond-mat/0310503

Caldarelli G., Battiston S., Garlaschelli D., Catanzaro M., *Emergency of complexity in financial networks*, to appear in Lecture Notes in Physics, spring 2004

Phan D., Pajot S. Nadal J.P., "*The Monopolist's Market with Discrete Choices and Network Externality Revisited: Small-Worlds, Phase Transition and Avalanches in an ACE Framework*", Ninth annual meeting of the Society of Computational Economics, University of Washington, Seattle, USA, July 11 - 13, 2003, http://digemer.enst-bretagne.fr/ phan/papers/ppn2003.pdf

G. Weisbuch, Bounded confidence and Social networks, 2004, Europena Physical Journal B (in press)

Partners owning: **CR5 (ENS)**

Partners contributed: CO1, CR3

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°:	17 **Algorithms for network traffic analysis**
Due date:	24 Month
Delivery Date:	24 Month

Downloadable at:

http://www.cosin.org/wp/deliverables/D17.pdf

As routing in the Internet follows a hierarchical scheme, the analysis of the Autonomous System graph, where routing is determined at the higher level, is the first step towards the study of traffic flows, routing changes, and routing instabilities occurring in the Internet. In order to consolidate the theoretical foundations of such studies, we first address the problem of obtaining correct data from the available data sources. Second, we investigate the problem of computing the types of the relationships between Autonomous Systems (ASes), showing the NP-hardness of the problem and producing effective and efficient heuristics to approach it. Finally, we study how clustering techniques can be adapted and improved in order to be used in this domain and show how the clustered view of the AS graph can provide high level information about the network evolution at different time scales.

Partners owning: **CR2 (UDRLS)**

Partners contributed:CO1,CR3

Made available to: public

DELIVERABLE SUMMARY SHEET

Project Number:	IST-2001-33555
Project Acronym:	COSIN
Title:	Coevolution and Self-Organization in Dynamical Networks

Deliverable N°: 18 **Second year report**

Due date: 24 Month

Delivery Date: 24 Month

Short Description:

This document

Downloadable at

http://www.cosin.org/wp/deliverables/D18.pdf

Partners owning: **CO1 (INFM)**

Partners contributed:CR2,CR3,CR4,CR5,CR7

Made available to: public

2.3 Comparison with planned activities

Some changes have been produced with respect to the planned activity. The total flow of the project has been very partially affected by these adjustments. The reasons for those changes are different and can be summarized as follows

- **DELAY IN DUE DATE OF DELIVERABLE D11.** As regards the deliverable D11 the delay in the starting of the activity of node CR3 resulted in a delay on the delivery date. It has to be noticed though that the activity of both node CR3 (University of Barcelona) and the other sites in this topic has been very productive. Several different publications have been produced and they represent the state of the art until now. Still several kinds of networks are present and a unifying feature for all of them is difficult to be found. As for example, for the onset of scale free behaviour at least two different active ingredients can be identified. One is the traditional growth and preferential attachment rule, while the other is the interplay between quenched disorder and graph growth. In some cases indeed the preferential attachment rule does not apply. So different approaches must be taken in order to explain a similar effect. Therefore in order to accomplish in the better possible way this task we agreed to delay the delivery date of this deliverable.
- **EXTENSION TO OTHER SUBJECTS OF DELIVERABLES D15, D16.** As regards the study of inter-firm network dynamics, a new perspective has been developed in the last years. Instead of studying only the correlation given by different board of directors we are also considering now the dynamics given by the network of stock ownerships as well as the more general case of the web of world trade. This results in a series of different publications on these topics. In our view this represents the first possible applications of social networks analysis within the project.
- **DELAY IN INTERNET MEASUREMENT.** The data analysis of the Internet suffered a substantial delay for our underestimation of the computer facilities needed in order to accomplish such a task. An immediate action has been to look for collaboration with established institution as the Centro Fermi and CASPUR. Using their apparatus and machines we are now in condition to accomplish the proposed research. In particular a series of traceroutes is presently running, thanks to efforts of Dr. Fabrizio Coccetti, using at the moment the machines of Centro Fermi. Those preliminary data are already available on the project site.
- **CHANGE IN WWW MEASUREMENTS.** The crawl of the WWW is an enormous task to be accomplished in a competitive way. As suggested by the reviewers in the first project report we have to focus on more sensible way to approach the problem of the study of the WWW. We collected data on the whole web through companies like AltaVista and we devoted our efforts in order to collect data for thematic subset of the WWW as for example all the pages with the same topic. Some of these measurements have been already done, others are running. In a short time we plan to present these data in a coherent way on the web site.
- **CHANGE IN SELF-ASSESMENT PROCEDURES.** Questionnaires for students following project schools resulted not to be a reliable way to self-assess the validity of our research. While this feedback would be very important for the project we now believe that a reliable source of self-assessment could be given by increasing the interaction with the advisory board (possibly increasing and changing their components).

2.4 Activity in the second year

The activity in the various nodes has been summarized as requested in the following Work Progress Overview. Here we present the activity of the various Work Packages. Since a different Work Package has been assigned to every node, a partial overlap between the two reports is present.

WP1 **Mathematical Tools for Complex Systems.** This is the Work Package where we can witness a great activity and therefore the feedback with other scientists is necessary in order to keep research on the state of the art. Many sites are working on these topics and the scientific production of the project is very large. Amongst the many papers produced (often between different sites) we can already find some very important and interesting contributions.

- Fitness model The idea is that the presence of disorder in the agents forming the network is responsible of the onset of the scale-free behaviour. It is possible to show that, in many cases of interest, the connectivity power-law behavior is neither related to dynamical properties nor to preferential attachment. Assigning a quenched fitness value x_i to every vertex, and drawing links among vertices with a probability depending on the fitnesses of the two involved sites, gives rise to what we call a good-get-richer mechanism, in which sites with larger fitness are more likely to become hubs. Vertices can represent people, proteins, species, routers, or html documents, while arcs correspond to acquaintances, physical interactions, predation relationships, cable connections, or hyperlinks, respectively. Yet although in some contexts preferential attachment can be a very reasonable assumption, in many others it is certainly not. In particular, in some situations, the information about the degree of each and every single vertex is not available to newly added sites, neither in a direct nor in an effective way. Instead, it is reasonable that two vertices are connected when the link creates a mutual benefit (here we restrict ourselves to bidirectional links) depending on some of their intrinsic properties (authoritativeness, friendship, social success, scientific relevance, interaction strength, etc.). Therefore, it is reasonable to expect that for some of these systems the scale-free behavior (when existing) has an origin unrelated to preferential attachment.
- Communities and Clustering Measurements and exact results concerning the clustering patterns of networks mainly concern the occurrence of regular motifs and their correlations. However, many social and information networks, such as the World Wide Web, turn out to be approximately partitioned into communities of irregular shape: for example, web pages focusing on similar topics are strongly mutually connected and have a weaker linkage to the rest of the Web. The design of methods to partition a graph into several meaningful highly inter-connected components have then become a compelling application of graph theory to biological, social and information networks. For this reason, algorithms able to find communities in large networks could have a strong scientific and technological impact. Methods have been introduced to solve this problem, with different approaches: communities in networks can be identified by recursively splitting the whole original graph. In this case, links are progressively removed until disconnected components corresponding to different clusters appear. Links to be removed are usually chosen according to their centrality, that is, the fraction of shortest paths passing through each of them. Alternatively, it is possible to study the spectral properties of the adjacency matrix or related ones: the structure of the eigenvectors associated to the largest eigenvalues reveal how nodes can be optimally clustered, according to different criteria.

- Modeling of weighted networks While complex networks are usually characterized by their topological complexity, they also often display a large heterogeneity in the capacity and intensity of the connections. In the Internet or in the Web, in ecosystems, or in the world-wide airport network, the strength of interactions varies greatly. This diversity in the weights of the interaction adds a complexity which cannot be overlooked in the study and description of these networks. New quantities to characterize weighted networks and to study this phenomenology, as well as new models of complex networks explaining this heterogeneity have been introduced.

WP2 **Data Collection.** As already mentioned, we are at the moment collecting the data for the WWW in a series of thematic crawls and we are starting the traceroute measurement of the Internet. For both cases a much more substantial action was needed in order to have reliable and competitive with the state of the art data set. This task is of enormous importance, since the whole field is affected by poor quality data sets. Therefore even if delayed we believe that publication of such analysis of the networks will have a great impact in the field. Just now, partial data sets at the level of the Autonomous Systems have been collected by node CR4 (UNIL) and resulted in several publications within and outside the project. The code for data collection is already working on the computers of CASPUR and Centro Fermi and they are downloadable from the project web site. As regards the WWW a large collection of pages is almost impossible to collect with the machines available and on the other hand would be impossible to put in a downloadable form on the web site. As regards the crawl realized by AltaVista and analysed by CR2 we are therefore asking permission to give it to anyone intending to do a specific request. We plan in the next months to put on the web site the data already collected on topic subsets of the WWW (i.e. a collection of pages about physics, about football, about Latin language etc.). At the same time we are about to formalize a collaboration with the company Tiscali in order to collect a collection of www pages hosted on their provider in order to have another well defined subset of WWW page to analyze.

WP3 **Large Networks Visualization Tools**

Current software tools for analyzing and visualizing networks have three major design issues: interactivity, range of analysis and layout methods. Unfortunately, interactivity is a large bottleneck with respect to the size of the networks. Several tools like Pajek [1] deal with this restriction by omitting a graph editor; networks can only be imported. Doing so, they can easily analyze networks with 10,000 actors or more. However, most included layout algorithms are only suitable for graphs up to medium sizes.

As a first attempt to this deliverable, CR6-CR7 collected information and links of existing visualization software. Furthermore they worked on a new platform of graph visualization called visone. In contrast to more conventional mathematical software in the social sciences that aim at providing a comprehensive suite of analytical options, the emphasis is on complementing every option provided with tailored means of graphical interaction. User feedback indicates that many who usually regard data exploration and analysis complicated and unnerving enjoy the playful nature of visual interaction. Consequently, much of the tool is about graph drawing methods specifically adapted to facilitate visual data exploration. The origins of visone lie in an interdisciplinary cooperation with researchers from political science which resulted in innovative uses of graph drawing methods for social network visualization, and prototypical implementations thereof.

With the growing demand for access to these methods, we started implementing an integrate tool for public use. It should be stressed, however, that visone remains a research platform and test bed for innovative methods, and is not intended to become

a standard tool with all due consequences such as extensive user-support and product marketing. Essentially all components are in development and therefore subject to change. In a nutshell, visone is a

• tool for interactive analysis and visualization of networks, in which
• originality is preferred over comprehensiveness, and that
• caters especially to social scientists.

WP4 Dynamics of Social Networks

As it has been conceived in the project, WP4 includes the investigation of network dynamics both within single firms (D15) and across firms (D16), the setting of new methods to determine centrality of socio-economical actors (D7) and the characterization of cyber-communities (D23). Deliverables D7, D15, D16 have been accomplished as scheduled. Deliverable D23 is due by March 2005 and was supposed to be already in progress since March 2003. Node CR5, responsible for WP4, has worked in close collaboration with C01 (INFM Rome) and CR3 (Barcelona). Such collaboration has focused on the study of two networks that have a major impact in socio-economical systems: the network of corporate boards and directors and the network of firm ownership in the stock market. The first network is involved in strategic decision making while the second one concerns the capital control structure. CR5 worked both at the level of characterizing the topological properties of such networks and at the level of developing models of dynamical processes taking place on them. Moreover, CR3 has also contributed to WP4 in the direction of modeling the formation of social networks including the emergence of community structures. In the context of choices in market networks, some of us has studied a model of a simple market with a single homogeneous product and a single seller (the monopoly case) exploring the effect localized network externality. Another direction of study taken by CR5 team concerns the dynamics of continuous opinion propagation in social networks.

We sketch in the following some of the main issues concerning this work package.

The boards and the directors of the largest corporations of a country form a highly interwoven bipartite network (a link represents the fact that a director serves on a board. When a director serves on several boards there is a so-called "interlock"). After recent cases of bankruptcy in the western countries (Enron, Vivendi, Parmalat), the role of boards is under discussion in the public opinion. It is a prominent goal to address the issue of how the structure of these networks affects the decision making process in which directors are involved.

On the other hand, we apply a statistical physics approach to the study of the structure of capital ownership in stock markets, unveiling a number of unexpected properties. Despite the obvious importance in economics of issues like the robustness of such networks against failure avalanches, surprisingly, no similar study had been previously carried out. We find evidence for power laws distributions and power law relationships that in these networks cannot be explained in terms of growth and preferential attachment. We also focus on the weights of the edges and we introduce two indices analogous to in-degree and out-degree for graphs that allow us to answer the following questions:

1. how small is the subset of top investors that controls most of a market
2. how such top investors share out the market among themselves (whether each one controls different companies or if instead they control the same companies).

Future applications of both lines of research include suggesting simplified scenarios to institutional policy makers trying to increase firm networks efficiency and stability. Davis and collaborators have shown that the director network and the board network of the Fortune 1000 corporations has Small World properties. Newman, Watts and

Strogatz have applied on the same data set a generalized random graph model, reproducing very accurately the degree distribution of the director network, but failing in predicting the degree distribution of the board network. Newman and Park have recently argued that the presence of groups or communities in a social network is able to produce alone both assortativity and clustering. However such model explains only about 40% of the observed assortativity in the Fortune 1000 network and this means that the sociological mechanisms which are at work in shaping the topology of the network can not be neglected.
Battiston (CR5) and Catanzaro (CR3) have performed an extensive and comparative analysis of both a novel data set (the boards and directors of the companies in Italian Stock Market) and the data set previously analyzed by Davis and Newman. They show that several statistical properties are common to the different data sets despite the fact that they refer to different years and countries. These facts suggest that some universal formation mechanism is at work for this kind of networks, a mechanism which is not captured in a satisfactory way by the existent models of social network formation.

WP5 **Models for Communication Networks** Information Systems like the physical Internet, the World Wide Web, telephone networks, mobile ad-hoc networks, or peer-to-peer networks have reached a level that puts them beyond our ability to deploy them, manage them, and keep them functioning correctly through traditional techniques. Their large size with millions of users and interconnected devices and their fast dynamics makes them a paradigmatic example of the so called complex systems. Therefore a reliable modelization of Internet and WWW as reported in the proposal can be only obtained through a careful comparison with other models (essentially developed in statistical physics) of complex systems. For the case of the Internet there has been a certain activity in order to reproduce the largest possible number of physical quantities through simple automata models. In particular on top of the degree distribution, the communities, the correlation and the clustering we tried to reproduce the typical distribution of loops ("motifs") in the Internet Graph. The preliminary activity in this topic resulted already in some publications. At the same time we are also trying to modelize the correlations and communities present in the world wide web. We are now continuing to work on the multilayer model we introduced in the first year of activity. A further publication is attended in few months.

WP6 **Dissemination of the Results.** As usual the main vehicle of result dissemination has been the production of a whole series of publications also presented in various conferences. It has to be noticed though that in this second year a book on Internet has been published by Romualdo Pastor-Satorras and Alessandro Vespignani and another one directly on the topic of COSIN has been approved for publication on World Scientific Press. A school in Bertinoro (Bologna Italy) has been organized by the Fet open project BISON together with the support of COSIN project

WP7-8 **Management-Assessment and Evaluation.** In order to help the project to develop the scientific potential acknowledged by the commission a series of actions have been necessary. They are listed in section of Management and can be reassumed as follows. Clear responsibilities in the organization of the WP and the maintenance of respective web-pages have been given to the Work Package leaders. At the same time a more strict control of actions of leaders with respect to the proposal presented has been stressed. Finally a specific scientific effort has been made (these requirements drove the choice of postdoc positions in node C01) in order to form a critical mass to solve the problem of analysis and data collection for the Internet and WWW, where the project risked to be in large delay with respect to the due date. Finally whenever it

was impossible to solve the problems arising within the project we looked for collaboration with external institutions as the CASPUR or Centro Fermi.
As pointed out in the last project meeting, Assessment and Evaluation has been one of the Work packages where most of the action has to be concentrated in order to allow the project to maintain the challenges described in the proposal. In doing so, the coordination site has been helped by the action of the new site entered in the project CR8 University of Paris Sud. The activity of all the nodes for such work packages has been to present in the best and more coherent way the research done in this Periodic Project Report**.**

As reported in the Guidelines we indicate in the following templates the status of progress of work per project site.

Progress Overview Sheet (Partner CO1 INFM)

PROGRESS OVERVIEW SHEET[1]

Organisation: Istituto Nazionale Fisica Per la Materia

Workpackage/ Task	Planned effort[2]	Planned Date[3]		Actual Date[4]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	14	1	36	1	36	6	8
WP 2	6	1	36	1	36	2	4
WP 3	0	1	36	1	36	0	0
WP 4	20	1	36	1	36	7	11
WP 5	6	1	36	1	36	3	4
WP 6	8	1	36	1	36	3	6
WP 7	7	1	36	1	36	2	4
WP 8	3	1	36	1	36	1	2
Total	64					24	39
One person month is equal to		170 [5]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 1	***Mathematical Tools for Complex Systems***
Task 1.1,1.2,1.3	We realized a series of basic research on the onset of scale free behaviour in simple model of graph formation. These new growth rules are also able to explain some properties of optimisation of the observed networks.
WP 2	***Data Collection and Analysis***
Task 2.1,2.2,2.3	We collected some new data about Internet and WWW in collaboration with Dr. Fabrizio Coccetti of Fermi Institute in Rome. These data are currently analysed and will be published on the web site
WP 4	***Dynamics of Social Networks***
Task 4.1	We studied the network of Firm ownerships, collecting new data on this social network.
WP 5	***Model for Communication Networks***
Task 5.1	We are working on Web layer model together with CR2. We are starting analysis of WWW archive
WP 6	***Dissemination of the Results***
Task 6.1-6.2	Books of proceeding of midterm meeting + Book about COSIN in preparation
WP 7-8	***Management-Assessment and Evaluation***
	Special meeting held in Lausanne to improve quality of report

[1] Each partner should fill in its own Progress Overview Sheet for a period in question. The Project Co-ordinator will check and approve the forms and attach them to the corresponding PPR.
[2] In person months (or in person hours)
[3] Project month when the activity was planned to be started or to be completed
[4] Project month when the activity was actually started or completed
[5] Give a figure used for converting person hours to a person month

Deliverables due this period		
Deliverable number	**Title of Deliverable**	**Status (Draft Final, Pending)**
D18	Second-year report	Final

Dissemination actions (articles, workshops, conferences etc.)

Publications:

1. Detecting communities in large networks.
   A. Capocci, V.D.P. Servedio, G. Caldarelli, F. Colaiori,
   submitted to *Physical Review Letters* ArXiv:cond-mat/0402499 (2004).
2. Preferential Exchange: Strengthening Connections in Complex Networks
   G. Caldarelli, F. Coccetti and P. De Los Rios,
   submitted to *Physical Review Letters* ArXiv:cond-mat/0312236 (2004)
3. Number of *h*-cycles in the Internet at the Autonomous System Level.
   G. Bianconi, G. Caldarelli, A. Capocci,
   submitted to *Europhysics Letters* ArXiv:cond-mat/0310339 (2004).
4. Generation of Scale Free Random Networks within the Formalism of Hidden Variables.
   V.D.P. Servedio G. Caldarelli, P. Buttà,
   submitted to *Physical Review Letters* ArXiv:cond-mat/0309659 (2004).
5. The scale-free topology of market investments.
   D. Garlaschelli, S. Battiston, M. Castri, V.D.P. Servedio, G. Caldarelli,
   submitted to *Physical Review Letters* ArXiv:cond-mat/0310503 (2004).
6. Generalized Network Growth: Microscopic Strategies and Real Internet Properties.
   G. Caldarelli, P. De Los Rios, L. Pietronero,
   submitted to *Physical Review Letters* ArXiv:cond-mat/0307610 (2004).
7. Networks of equities in financial markets
   G. Bonanno, G. Caldarelli, F. Lillo, S. Micciché, N. Vandewalle, R. N. Mantegna,
   in press on *European Physical Journal B,* ArXiv:cond-mat/0401300 (2004).
8. Assortative model for social networks.
   M. Catanzaro G. Caldarelli, L. Pietronero,
   in press on *Physical Review E* ArXiv:cond-mat/0308073 (2004).
9. Cycles structure and local ordering in complex networks.
   G. Caldarelli, R. Pastor-Satorras, A. Vespignani,
   in press on *European Physical Journal B,* ArXiv:cond-mat/0212026 (2004).
10. The Drainage Basins Trees in Mars Channel Networks.
    G. Caldarelli, P. De Los Rios, M. Montuori, V.D.P. Servedio,
    in press on *European Physical Journal B,* ArXiv:cond-mat/0107228 (2004).
11. On the Widespread Occurrence of the Inverse Square Distribution in Social Sciences and Taxonomy.
    G. Caldarelli, C. Caretta Cartozo, P. De Los Rios and V.D.P. Servedio
    Physical Review E 69 035101(R) (2004).
12. Dynamic Fracture Model for Acoustic Emission.
    M. Minozzi, G. Caldarelli, L. Pietronero, S. Zapperi,
    European Physical Journal B 36 203 (2003).
13. Quantitative description and modeling of real networks.
    A. Capocci, G. Caldarelli, P. De Los Rios,
    Physical Review E 68 047101 (2003).
14. Topology of correlation based minimal spanning trees in real and model markets.
    G. Bonanno, G. Caldarelli F. Lillo, R. Mantegna,
    Physical Review E 68 046130 (2003).
15. Universal Scaling Relations in Food Webs.
    D. Garlaschelli, G. Caldarelli, L. Pietronero,
    Nature **423** 165 (2003).

Deviations from the planned work schedule/reasons/corrective actions/special attention required

The creation of a new node from the budget of node C01, substantially changed the schedule of the planned activities. We use the labour support left hiring a postdoc devoted to the study and analysis of WWW.

Planned actions for the next period

We want to devote most of the time in order to collect, analyze and model thematic crawls of the WWW. This part already mentioned in the project resulted eventually the most difficult one. At the momemt two postdocs are working on it.

Progress Overview Sheet (Partner CR2 UDRLS)

PROGRESS OVERVIEW SHEET[1]

Organisation: Università di Roma "La Sapienza"

Workpackage/ Task	Planned effort[2]	Planned Date[3]		Actual Date[4]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	2	1	36	1	36	1	2
WP 2	6	1	36	1	36	10	15
WP 3	13	1	36	1	36	5	10
WP 4	0	1	36	1	36	0	0
WP 5	36	1	36	1	36	5	24
WP 6	2	1	36	1	36	0.5	1
WP 7	1	1	36	1	36	0.4	0.7
WP 8	1	1	36	1	36	0.4	0.7
Total	61					22.3	53.4
One person month is equal to		170 [5]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 2	***Data Collection and Analysis***
Task 2.2	We have delivered a library of software tools for the analysis of large networks. The library is specifically customized for the study of very large crawls of the Web Graph. It contains a set of implementations of algorithms working even with data stored on secondary memory that allow to measure the most relevant obeservables and to simulate models for communication networks at very large scale.
WP 3	***Large Networks Visualization Tools***
Task 3.2	Visualization tools for analysising the flictuations of internet routes at the Autonomous System level
WP 5	***Models for Communication Networks***
Task 5.1	We have studied the Autonomous System graph, a first step towards the study of traffic flows, routing changes, and routing instabilities occurring in the Internet. We have addressed the problem of obtaining correct data from the available data sources, investigated the problem of computing the types of the relationships between Autonomous Systems (ASes). Finally, we have studied how clustering techniques can be adapted and improved in order to be used in this domain.
WP 6	See Dissemination Actions Below.

Deliverables due this period		
Deliverable number	**Title of Deliverable**	**Status (Draft Final, Pending)**
D13 D17	A Library of software tools Algorithms for traffic analysis	Final Final

Dissemination actions (articles, workshops, conferences etc.)

1. G. Caldarelli, P. De Los Rios, L. Laura, S. Leonardi. *A Multi-layer model for the Webgraph*. 2nd International

[1] Each partner should fill in its own Progress Overview Sheet for a period in question. The Project Co-ordinator will check and approve the forms and attach them to the corresponding PPR.
[2] In person months (or in person hours)
[3] Project month when the activity was planned to be started or to be completed
[4] Project month when the activity was actually started or completed
[5] Give a figure used for converting person hours to a person month

Workshop on Web Dynamics, Honolulu, Hawaii, May 2002.
2. G. Caldarelli, P. De Los Rios, L. Laura, S. Leonardi e S. Millozzi. *A study of stochastic models for the Web Graph*. Technical Report 04-03, dipartimento di Informatica e Sistemistica, Universita' di Roma ``La Sapienza", 2003.
3. G. Caldarelli, P. De Los Rios, L. Laura, S. Leonardi, and S. Millozzi. *A study of the properties of Web graphs*. 2nd Workshop on Algorithms and Models for the Web-Graph (WAW 2003), Budapest, Hungary, May 2003.
4. D. Donato, L. Laura, S. Leonardi, S. Millozzi. *Large Scale properties of the Webgraph.* To appear in European Journal of Physics B.
5. Luigi Laura, Stefano Leonardi, Stefano Millozzi, Ulrich Meyer and Jop Sibeyin. *Algorithms and Experiments for the Webgraph*. Proc. of the 11th Annual European Symposium on Algorithms (ESA03)

Deviations from the planned work schedule/reasons/corrective actions/special attention required

We decided to be in charge of deliverable D13 and we exchanged with CR4 the deliverable D24 on modelling Internet

Planned actions for the next period

We plan to study in deeper details the connectivity structure of the World Wide Web. We also plan to study the properties of ranking algorithms on specific models for the Web graph. Visualization tools for internet network analysis will be furtherly enhanced.

Progress Overview Sheet (Partner CR3 UB)

PROGRESS OVERVIEW SHEET[1]

Organisation: Universidad de Barcelona

Workpackage/ Task	Planned effort[2]	Planned Date[3]		Actual Date[4]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	36	1	36	1	36	12	24
WP 2	6	1	36	1	36	2	4
WP 3	0	1	36	1	36	0	0
WP 4	10	1	36	1	36	3	7
WP 5	10	1	36	1	36	3	7
WP 6	2	1	36	1	36	1	1
WP 7	2	1	36	1	36	0	0
WP 8	3	1	36	1	36	0	0
Total	69					21	43
One person month is equal to		170 [5]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 1	***Mathematical Tools for Complex networks***
Task 1.1	• Continue the analysis of community structures in more social networks (apart from the email network analyzed in the previous period) and taxonomy, looking for universal features. Particular emphasis has been put in the distribution of community sizes. • When considering universal properties of networks, as the power-law degree distribution, one has to be aware of the reliability of the measurement techniques that can bias such distributions.
Task 1.2	• Influence of the topology on the performance of neural networks. We have showed that scale-free networks outperform random networks with the same number of synapses. This performance is one of the signatures of complexity, since it is not a superimposed effect of the single role played by the nodes, but a global effect, that hence can be viewed as an emergence of complex behaviour. • Proposition of models of: o Correlated networks: the establishment of edges is controlled by hidden variables that characterize the vertices. Analytical expressions of the main topological properties are obtained which compare very well with simulations of the model o Social networks: a model of social networks based on the concept of social distance is constructed. Social networks present special features that make them different from technological or biological ones: a high clustering coefficient, positive degree correlations, and community structure. Furthermore, we compare our assumptions with a social network based on trust: the Pretty Good privacy (PGP) web of trust. • Related to Task 1.1 power-law distribution of community sizes is related to the self-organization of some social networks.

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[5] Give a figure used for converting person hours to a person month

Task 1.3	• During the previous period we studied optimal network structures where packet flow was considered. This packet flow could correspond to either packet in a computer network or problems in an organization. During the present period we have extended our previous work to situations where the knowledge radius of the agents is increased, showing that new structures become optimal. • In a different context we have studied the interplay between structure and dynamics in a problem of diffusion of technological evolution. Clearly, the structure and the dynamics cannot be considered as separated ingredients, and random "small-world" networks perform very well in the problem considered.

Deliverables due this period

Deliverable number	Title of Deliverable	Status (Draft Final, Pending)
D11	Self-Organization in Networks	Draft

Dissemination actions (articles, workshops, conferences etc.)

- J. J. Torres, P. L. Garrido, J. Marro, J. Cortes, F. Ramos, and M. A. Muñoz. Effects of static and dynamic disorder on the performance of neural network automata. Preprint.
- J. J. Torres, M. A. Muñoz, J. Marro, and P. L. Garrido. Influence of topology on the performance of a neural network. *To appear in Neurocomputing.*
- M. Boguñá and R. Pastor-Satorras. Class of correlated random networks with hidden variables. *Phys. Rev. E*, 68, 2003.
- M. Boguñá, R. Pastor-Satorras, A. Díaz-Guilera, and A. Arenas. Models of social networks based on social distance attachment. Preprint.

Deviations from the planned work schedule/reasons/corrective actions/special attention required

Due to the delay in contracting the post-docs we experienced some problems in this deliverable. Nevertheless, during the current period we have obtained some very interesting results (about social models and neural networks) that will be extended during the next period, and hence accomplishing the objectives proposed in the project..

Planned actions for the next period

During the next period, we will pursue on the study of social models and neural networks. Furthermore, we will consider the rules of self-organization in models of technological evolution, where agents can change their neighbourhood of connections in order to achieve a better local performance

Progress Overview Sheet (Partner CR4 UNIL)

PROGRESS OVERVIEW SHEET[1]

Organisation: Université de Lausanne

Workpackage/ Task	Planned effort[2]	Planned Date[3]		Actual Date[4]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	6	1	36	4	39	2	2
WP 2	36	1	36	4	39	12	20
WP 3	4	1	36	4	39	2	2
WP 4	4	1	36	4	39	2	2
WP 5	4	1	36	4	39	2	2
WP 6	2	6	36	6	39	1	1
WP 7	1	1	36	4	39	0	0
WP 8	1	1	36	4	39	1	1
Total	58					22	30
One person month is equal to		170 [5]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 1	***Mathematical Tools For Complex Systems***
Task 1.2	We have contributed with rigorous results about the self-similar structure of taxonomic trees used to classify network communities. We have also rigorously analysed the effects of single-view measurements on the mathematical properties of networks
WP 2	The deliverables due this term are D12 and D13
Task 2.1	A database of data collected by the consortium and a collection of links to state-of-the art data repositories (D12)
Task 2.2	A library of various downloadable tools to analyse model and real networks (D13)
Task 2.3	We are currently working toward the identification of the right procedure to reduce the number of nodes in very large networks so to make them suitable to be visualized by current packages.
WP 5	The coupling of social system dynamics to the formation of the weight of network edges is our main contribution in this area.
Task 5.1	We have contributed to this package by proposing multilayers models of the WWW and new, clustered models of the Internet.
WP 6	Work on protein networks, and participation at various congresses and at schools (among others of biology to talk about networks in these disciplines)

Deliverables due this period		
Deliverable number	**Title of Deliverable**	**Status (Draft Final, Pending)**

[1] Each partner should fill in its own Progress Overview Sheet for a period in question. The Project Co-ordinator will check and approve the forms and attach them to the corresponding PPR.
[2] In person months (or in person hours)
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[4] Project month when the activity was actually started or completed
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D12	Database of Network Data	Final (in Progress)

Dissemination actions (articles, workshops, conferences etc.)

Publications:

1. G. Caldarelli, A. Capocci and P. De Los Rios, Quantitative description and modelling of real networks, Phys. Rev. E 68, 047101 (2003).
2. G. Caldarelli, C. Caretta Cartozo, P. De Los Rios and V.D.P. Servedio, Widespread occurrence of the inverse square distribution in social sciences and taxonomy, Phys. Rev. E, accepted for publication, 2004.
3. T. Petermann and P. De Los Rios, Exploration of Scale-Free Networks, Eur. Phys. J. B, accepted for publication, 2004.
4. T. Petermann and P. De Los Rios, Cluster approximation for probabilistic systems, J. Theor. Biol., accepted for publication 2004.
5. T. Petermann and P. De Los Rios, Role of clustering and grid-like ordering in epidemic spreading, Phys. Rev. E, accepted for publication, 2004.
6. G. Caldarelli, P. De Los Rios, M. Montuori and V.D.P. Servedio, The drainage basin trees in Mars channel networks, Eur. Phys. J. B, accepted for publication, 2004.

Submitted manuscripts:

1. G. Caldarelli, P. De Los Rios and L. Pietronero, Generalized network growth: from microscopic strategies to the real Internert, Phys. Rev. Lett., submitted 2003.
2. G. Caldarelli, F. Coccetti and P. De Los Rios, Preferential Exchange: Strengthening connections in complex networks, Phys. Rev. Lett., submitted 2003.
3. P. De Los Rios and G. Caldarelli, Comment on "Preferential Attachment in the Protein Network Evolution", Phys. Rev. Lett., submitted 2003.

Conferences and schools:

1. Second Mini-school of biophysics, Firenze, March 2003, Statistical Physics of Complex Networks.
2. The Twelfth International World Wide Web Conference, Budapest, 20-24 May 2003, Scale-free Networks: good-get-richer.
3. Conference on Growing Networks and Graphs in Statistical Physics, Finance, Biology and Social Systems, Rome 1-5 Septermber 2003, Exploration of Scale Free-Networks.

Deviations from the planned work schedule/reasons/corrective actions/special attention required

We have collected data within COSIN, available from the project home page. Yet large consortia have been setup in the community dedicated to multi-view Internet data collection. Since these data are of extremely high quality, our database is complemented with links to these repositories of data. The database is planned to evolve more and more into an Information Hub where to find links to interesting data. The Web Interface (D21) will evolve accordingly.

Planned actions for the next period

The next period (to month 36, actually 29 for CR4) will see the continuous development of D12 and D13 (this is the reason why, although month 24 was the due date for these deliverables, they stay "in Progress" because the Database and the Library of tools will be updated and expanded).
We exchanged deliverable D13 and D24 with node CR2 (UDRLS).

Month 36 is also the delivery date for D20 (Statistical analysis of data) and D21 (Web Interface).
D20 has been tackled, during the second year, with the same strength as during the first, and we plan to continue into the third without particular changes and reorganisations.
D21 will face some reorganisation related to the shift of focus of the database. Since many data will not be kept locally, and since the number of visualisation tools freely available for download is growing, we do not believe it to be a good "editorial" choice to have too much data storage and visualization integration. So, the Web Interface should rather become an Information Hub where interested people can link to and find all relevant information useful to find the data they are interested in, with a collection of annotated links.

Progress Overview Sheet (Partner CR5 ENS)

PROGRESS OVERVIEW SHEET[1]

Organisation: Ecole Normale Superiéure

Workpackage/ Task	Planned effort[2]	Planned Date[3]		Actual Date[4]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	4	1	36	1	36	1	2
WP 2	7	1	36	1	36	3	5
WP 3	5.5	1	36	1	36	2	4
WP 4	36	1	36	1	36	13	24
WP 5	2	1	36	1	36	0	0
WP 6	2	1	36	1	36	1	1
WP 7	1	1	36	1	36	0	0
WP 8	1	1	36	1	36	0	0
Total	58.5					20	42
One person month is equal to		170 [5]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 2	***Data Collection***
Task 2.1	Co-evolutionary games on networks with continuous strategies: we are developing a model to characterize equilibria in the space of strategies from the study of a subset of players.
WP 3	***Large Network Visualization Tools***
Task 3.1	Pre-elaboration of a world-wide firm database to perform firm network analysis (in collaboration with Scuola Superiore Sant'Anna di Pisa, Economics Dept.)
WP 4	***Large Network Visualization Tools***
Task 4.1	Matlab interface for firm network visualization. Methods for extracting the backbone of large ownership networks.
WP 6	***Dynamics of Social Networks***
	Spread of decisions in firm networks. Formation and topology of shareholder networks. Continuous Opinion Dynamics on Networks. Network Externalities in a Monopolistic Market.

Deliverables due this period		
Deliverable number	**Title of Deliverable**	**Status (Draft Final, Pending)**
D15	Modelling interaction and dynamics within firms	Final
D16	Firm network dynamics	Final

Dissemination actions (articles, workshops, conferences etc.)
9 articles, 7 of which accepted (see deliverables for detailed list). 10 conference talks.
Planned actions for the next period
Pursue study in Firm network dynamics with more realistic models. More effort will be put in the future on groups and communities (see D23). Some methods to detect communities in networks are being developed in the scientific community. We will work at classify these methods, developing specific methods adapted for socio-economic networks and for the www. We will also develop models in which such communities emerge as a self-organized phonomenon.

[1] Each partner should fill in its own Progress Overview Sheet for a period in question. The Project Co-ordinator will check and approve the forms and attach them to the corresponding PPR.
[2] In person months (or in person hours)
[3] Project month when the activity was planned to be started or to be completed
[4] Project month when the activity was actually started or completed
[5] Give a figure used for converting person hours to a person month

Progress Overview Sheet (Partner CR7 UNIKARL)

PROGRESS OVERVIEW SHEET[1]

Organisation: Universitaet Karlsruhe

Workpackage/ Task	Planned effort[2]	Planned Date[3]		Actual Date[4]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	1	12	36	12	36	0	0
WP 2	1	12	36	12	36	0	0
WP 3	24	12	36	12	36	10	10
WP 4	2	12	36	12	36	1	1
WP 5	1	12	36	12	36	1	1
WP 6	2	12	36	12	36	1	1
WP 7	1	12	36	12	36	0	0
WP 8	1	12	36	12	36	0	0
Total	33						
One person month is equal to		170 [5]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 3	***Large Networks Visualization Tools***
Task 3.1	Realization of the software visone as well as publication of algorithms and results
WP 6	***Dissemination of the results***

Deliverables due this period		
Deliverable number	**Title of Deliverable**	**Status (Draft Final, Pending)**
D06	Algorithms for representing Network Centrality	Final

Dissemination actions (articles, workshops, conferences etc.)

1. Thomas Erlebach, Alexander Hall and Thomas Schank, "Classifying Customer-Provider Relationships in the Internet" Proceedings of the IASTED International Conference on Communications and Computer Networks (CCN 2002), Cambridge, USA, November 4-6, 2002, pp. 538-545.
2. Thomas Erlebach, Alexander Hall, Thomas Schank: Classifying Customer-Provider Relationships in the Internet. TIK Report Nr. 145, July, 2002.
3. Giuseppe Di Battista, Maurizio Patrignani, and Maurizio Pizzonia, "Computing the types of the Relationships between Autonomous Systems", Technical Report RT-DIA-73-2002, Dipartimento di Informatica e Automazione, Università di Roma Tre, Rome, 2002.
4. Giuseppe Di Battista, Maurizio Patrignani, and Maurizio Pizzonia, "Computing the Types of the Relationships between Autonomous Systems", in Proceedings of IEEE INFOCOM 2003, The Conference on Computer Communications, The 22nd Annual Joint Conference of the IEEE Computer and Communications Societies.
5. Ulrik Brandes, Marco Gaertler, and Dorothea Wagner. Experiments on Graph Clustering. In Proceedings of the 11th Annual European Symposium on Algorithms (ESA'03), volume 2832 of Lecture Notes in Computer Science, pages 568-579. Springer-Verlag, 2003
6. Di Battista, Federico Mariani, Maurizio Patrignani, and Maurizio Pizzonia, "Archives of BGP Updates: Integration and Visualization" in Proceedings of IPS 2003, International Workshop on Inter-domain Performance and Simulation, Salzburg, Austria, 20-21 February, 2003, pages 123-129.
7. Marco Gaertler and Maurizio Patrignani, "Dynamic Analysis of the Autonomous System Graph", to appear in Proceedings of IPS 2004, International Workshop on Inter-domain Performance and Simulation, Budapest, Hungary, 22-23 March, 2004 Analysis of the Autonomous System Graph", to appear in Proceedings of IPS 2004, International Workshop on Inter-domain Performance and Simulation, Budapest, Hungary, 22-23 March, 2004

Deviations from the planned work schedule/reasons/corrective actions/special attention required

Planned actions for the next period

[1] Each partner should fill in its own Progress Overview Sheet for a period in question. The Project Co-ordinator will check and approve the forms and attach them to the corresponding PPR.
[2] In person months (or in person hours)
[3] Project month when the activity was planned to be started or to be completed
[4] Project month when the activity was actually started or completed
[5] Give a figure used for converting person hours to a person month

Progress Overview Sheet (Partner CR8 UPSUD)

PROGRESS OVERVIEW SHEET[6]

Organisation: University of Paris Sud

Workpackage/ Task	Planned effort[7]	Planned Date[8]		Actual Date[9]		Resources employed[2]	Cumulative Resources[2]
	Whole Project	Start	End	Start	End	This Period	Since start
WP 1	4	12	36	12	36	0	0
WP 2	2	12	36	12	36	0	0
WP 3	0	12	36	12	36	0	0
WP 4	0	12	36	12	36	0	0
WP 5	6	12	36	12	36	0	0
WP 6	2	12	36	12	36	0	0
WP 7	2	12	36	12	36	0	0
WP 8	5	12	36	12	36	0	0
Total	21						
One person month is equal to		170 [10]		Person hours			

Main contribution during this period	
Workpackage/Task	**Action**
WP 6	***Dissemination of the results***
WP 8	***Assessment and Evaluation***

Deliverables due this period		
Deliverable number	**Title of Deliverable**	**Status (Draft Final, Pending)**
D18	Second Progress Report	Final

Dissemination actions (articles, workshops, conferences etc.)

*Barrat A, Barthélemy M, R. Pastor-Satorras R, A. Vespignani A
The architecture of complex weighted networks
PNAS **101** 3747 (2004).
*Boguna M, Pastor-Satorras R, Vespignani A
Absence of epidemic threshold in scale-free networks with degree correlations
PHYS REV LETT **90** (2) 028701 (2003).
* Castellano C, Vilone D, Vespignani A
Incomplete ordering of the voter model on small-world networks
EUROPHYS LETT **63** (1): 153-158 (2003).
* Percacci R, Vespignani A
Scale-free behavior of the Internet global performance
EUR PHYS J B **32** (4): 411-414 (2003).

Deviations from the planned work schedule/reasons/corrective actions/special attention required

A substantial delay (about ten months) in transferring of resources verified. Therefore we had some delay in the procedure of postdoc hiring and starting of the activities

Planned actions for the next period

Modeling and understanding of weighted networks.

[6] Each partner should fill in its own Progress Overview Sheet for a period in question. The Project Co-ordinator will check and approve the forms and attach them to the corresponding PPR.
[7] In person months (or in person hours)
[8] Project month when the activity was planned to be started or to be completed
[9] Project month when the activity was actually started or completed
[10] Give a figure used for converting person hours to a person month

Effort in person months reporting period 01/03/2003-29/02/2004

	CO1 INFM				CR2 UDRLS				CR3 UB				CR4 UNIL			
	Period		Total		Period		Total		Period		Total		Period		Total	
WP/Task	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.
WP1	**4**	**6**	**8**	**8**	**1**	**1**	**1**	**1**	**12**	**18**	**36**	**36**	**2**	**2**	**2**	**2**
Task 1.1	2	2	2	2	0	0	0	0	6	6	18	18	2	2	2	2
Task 1.2	0	2	4	4	0	0	0	0	0	12	12	12	0	0	0	0
Task 1.3	2	2	2	2	1	1	1	1	6	0	6	6	0	0	0	0
WP2	**1**	**2**	**4**	**4**	**4**	**10**	**4**	**10**	**2**	**2**	**2**	**2**	**12**	**12**	**20**	**20**
Task 2.1	0	1	2	2	1	2	1	2	0	0	0	0	6	6	14	14
Task 2.2	0	0	0	0	3	8	3	8	0	0	0	0	4	4	4	4
Task 2.3	1	1	2	2	0	0	0	0	0	0	0	0	2	2	2	2
WP3	**0**	**0**	**0**	**0**	**4**	**5**	**16**	**13**	**3**	**3**	**3**	**3**	**2**	**1**	**2**	**1**
Task 3.1	0	0	0	0	4	5	16	13	3	3	3	3	2	1	2	1
WP4	**7**	**7**	**11**	**11**	**0**	**0**	**0**	**0**	**3**	**3**	**3**	**3**	**2**	**1**	**2**	**1**
Task 4.1	7	7	11	11	0	0	0	0	3	3	3	3	2	1	2	1
WP5	**3**	**3**	**4**	**4**	**5**	**5**	**13**	**12**	**0**	**0**	**0**	**0**	**2**	**2**	**2**	**2**
Task 5.1	3	3	4	4	5	5	5	5	0	0	0	0	2	2	2	2
WP6	**3**	**3**	**6**	**6**	**0,6**	**0,6**	**0,6**	**0,6**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
WP7 - WP8	**3**	**3**	**6**	**6**	**0,8**	**0,8**	**0,8**	**0,8**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Total	**21**	**24**	**39**	**39**	**15,4**	**22,4**	**35,4**	**37,4**	**22**	**28**	**46**	**46**	**22**	**20**	**30**	**28**

Effort in person months period 01/03/2003-29/02/2004

	CR5 ENS				CR7 UNIKARL				CR8 UPSUD				Total			
	Period		**Total**		**Period**		**Total**		**Period**		**Total**		**Period**		**Total**	
WP/Task	Est.	Act.	Est	Act.	Est.	Act	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.
WP1	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**2**	**3**	**2**	**3**	**22**	**31**	**50**	**51**
Task 1.1	1	1	1	1	0	0	0	0	1	2	1	2	**0**	**0**	**0**	**0**
Task 1.2	0	0	0	0	0	0	0	0	1	1	1	1	**0**	**0**	**0**	**0**
Task 1.3	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**
WP2	**3**	**3**	**5**	**5**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**23**	**30**	**36**	**42**
Task 2.1	3	3	5	5	0	0	0	0	1	1	1	1	**0**	**0**	**0**	**0**
WP3	**2**	**2**	**4**	**4**	**11,5**	**11,5**	**19,5**	**19,5**	0	0	0	0	**22,5**	**22,5**	**44,5**	**40,5**
Task 3.1	2	2	4	4	11,5	11,5	19,5	19,5	0	0	0	0	**0**	**0**	**0**	**0**
WP4	**11,5**	**13**	**23,5**	**24**	**0**	**0**	**0**	**0**	0	0	0	0	**24**	**24**	**40**	**39**
Task 4.1	11,5	13	23,5	24	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**
WP5	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**3**	**1**	**3**	**1**	**13**	**11**	**23**	**20**
Task 5.1	0	0	1	1	0	0	0	0	3	1	3	1	**0**	**0**	**0**	**0**
WP6	**1**	**1**	**4**	**4**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**7,6**	**7,6**	**13,6**	**13,6**
WP7 - WP8	**0**	**0**	**3**	**3**	**0**	**0**	**0**	**0**	**3**	**3**	**3**	**3**	**8,8**	**8,8**	**14,8**	**14,8**
Total	**16,5**	**17,5**	**39,5**	**39,5**	**11,5**	**11,5**	**19,5**	**19,5**	**10**	**9**	**10**	**9**	**118,4**	**132,4**	**219**	**218,4**

Period: Est.: estimated effort in contract for period Act.: effort actually spent in period
Total: Est.: estimated cumulative effort to date in contract Act.: cumulative effort to date actually spent

2.5 World-Wide State of the art

Network research, in recent times, has been focusing on deeper analysis of networks structure, with new approaches in real data surveys and in mathematical models able to reproduce them. Recent empirical studies concerned mainly social networks, that is, networks built by human interactions. Moreover, new models for complex networks have been introduced, in order to reproduce the features of real networks where growth and preferential attachment (believed to be responsible of the power law degree distribution) are absent. Finally, other features of real networks such as the clustering have been studied, with relevant practical applications. The attempt to model and understand the origin of the observed topological properties of real networks has led to a radical change of perspective, shifting the focus from static graphs, thought as snapshot of the structure of the network in a certain moment, to modelling network evolution. This new approach is the outcome of the realization that most complex networks are the result of a growth process. As a result, we currently view networks as dynamical systems that evolve through the subsequent addition and deletion of vertices and edges. The set of dynamical rules defining these processes thus outlines the dynamical theory required for the description of the macroscopic pro
perties of networks. This methodology that is akin to the statistical physics approach to complex phenomena appears as a revolutionary path in our understanding of networked systems and provides new techniques to approach conceptual and practical problems in this field. Following these lines the research has developed in the last years in a burst of activity across different fields. Now it starts to be the time for some considerations. Many results need to be formally proved and some of the data analysed were found to be inconsistent. Some new ideas arose in order to explain these phenomena. The situation is explicitly described in the deliverable D10. Here we report again the short description of this deliverable.
The study of the state of the art for a new field of research such as the one of the growing networks is a crucial task in order to keep updated the scientific challenges of a research project. Here we present some analysis of the field as perceived by the project members as well as the opinion of the major experts worldwide as collected during our midterm conference (see Appendix A and Appendix B) at month 18. The main results are that the future development of research will very likely proceed along the following lines

- **Social Networks.** Recently, surveys carried on collaboration networks (authors linked by co-authorships), communication networks (Internet users exchanging e-mail messages) and markets (economic interactions connecting market agents), have confirmed that also social networks display complexity in the degree distribution *P(k)* and other quantities of interest. Social networks represent then a paradigmatic example for the study of the onset of complexity in artificial networks as the technological ones. A suitable modelling and possible optimisation of the latter ones can only come after a careful study of social structures.
- **Beyond "Preferential Attachment".** Mechanisms generating complex features in networks (above all, the power-law degree distribution) have been deeply studied in the previous years, focussing mainly on evolving networks, whose size grows with time. This caused a very rapid development of the scientific field at its start. A seminal paper by A.-L. Barabási et al. introduced the idea that growth and preferential attachments were necessary to the occurrence of fat tails in the degree distribution. Nowadays, such approach is no more a priority: growing networks with various additional mechanisms have been introduced and reproduce almost any of the parameters measured in real networks. Nevertheless, the hypothesis of a dynamically evolving network is not always verified in reality.

- **Clustering and Communities** Measurements and exact results concerning the clustering patterns of networks mainly concern the occurrence of regular motifs and their correlations .However, many social and information networks, such as the World Wide Web, turn out to be approximately partitioned into communities of irregular shape: for example, web pages focusing on similar topics are strongly mutually connected and have a weaker linkage to the rest of the Web. The design of methods to partition a graph into several meaningful highly inter-connected components have then become a compelling application of graph theory to biological, social and information networks.
- **Weighted networks**. While complex networks are usually characterized by their topological complexity, they also often display a large heterogeneity in the capacity and intensity of the connections. In the Internet or in the Web, in ecosystems, or in the world-wide airport network, the strength of interactions varies greatly. This diversity in the weights of the interaction adds a complexity which cannot be overlooked in the study and description of these networks. Studies of this phenomenology as well as new models of complex networks explaining this heterogeneity are therefore necessary.

2.6 Suggestions by Reviewers in the First Report

The integral version of the report is attached in the Appendix C. We report here a summary of the main criticisms raised in an overall quite positive report.

- Improvement of presentation for the periodic progress reports
- Overall Scientific Progress should be presented
- Common goals in the project need to be stressed
- Level of collaboration to be increased with CR5 (ENS) and CR6 (UKON) (now CR7 UNIKARL)
- Administrative changes should be reported
- Improve the quality of presentation of the work
- Follow guidelines for the presentation and deliverables
- Rewrite Dissemination and Use Plan

The above criticisms resulted in the following recommendations

1. Rewrite the dissemination and use plan.
2. In the next meeting, try to figure out how the different parts of the consortium can work better together and try to define common goals for all consortium members.
3. Designate clear responsibilities for the next year concerning WP.
4. Include Karlsruhe better in the COSIN collaboration. This could be achieved in a jointly developed plan how to make the transition from small network to large network visualization possible.
5. How to include ENS better in the collaboration?
6. Make better use of the advisory board. E.g. the substantial input from e.g. Marc Buchanan was not taken up (at least not up to now).
7. Additions to advisory board could be useful. Identify and contact potential users – who should be interested in the results of your work. As mentioned by A. Vespignani representatives of ISP providers.
8. Put more resources and more thought in the web-site. A meaningful redesign of the website could involve three main areas addressing *Community, Output,* and *Input*.

2.7 Actions taken with respect to suggestions and planned work

We are particularly grateful to the board for the work done. We report hereafter a point to point answer to both advisors suggestions

- As regards the general task of improvement of the quality of the report, we followed carefully the guidelines as downloadable from the FET web site. The present version of this report follows carefully such indications.
- In this report the whole first section is devoted to the discussion of the common perspectives of the project as a whole. Deliverable D10 as well as the section 2.5 of this report focuses on the state of the art of the field. The round table that was made at the meeting in Rome in order to check the consensus of the expert produced many interesting results. For example, from this external feedback we noticed that COSIN is already seen as a single entity rather than a bunch of scientists. People ask about

next meetings, want to be involved in dissemination activity and many students ask for position within the consortium. We therefore believe that most of the activity of management should be directed towards a better presentation of the common scientific activity.

- As reported in the project the possibility of visualization of large graphs is an essential task in their study. The role of providing concepts and tools for such issue is played in the project by the UNIKARL node. Unfortunately in the state of the art there are no tools able to completely represent graph as huge as the Webgraph (10^9 nodes) or even the Internet (at AS level about 10^4 nodes). In order to improve the level of collaboration with this node we started considering new ideas to overcome such problem. One possibility that we are exploring at the moment is to use the scale invariance of such objects in order to produce a visualization tools for large graph. Being scale-invariant means that the graph has the same aspect (in a statistical sense) at different length scales. One can imagine then a coarse-grained procedure in order to represents after several steps a graph of huge size, through a series of rescaled sites. This kind of renormalization group for graphs is currently under study and we plan to have a prototype of it during the third period of activity.
- Administrative changes occurred are now reported in the next section, but were not present in the first year report. Mainly we had a modification on the project given by the change of place of Prof. Wagner who moved from Konstanz to Karlsruhe. More importantly we added as explicit node Alessandro Vespignani in the University of Paris-Sud. This resulted in a substantial reduction of budget of coordination node.
- Dissemination and Use Plan has been rewritten, any document presented follows carefully the prescribed Guidelines.

ANSWER TO SUGGESTIONS

1. A new version of Dissemination and Use plan has been rewritten taking into account the possible interaction with ISP providers. The most promising contact has been made with Tiscali company that show some interest in possible future common collaboration. This interest is particularly focussed on the detection of cyber-communities and in the structure and dynamics of peer to peer networks.
2. We plan to have part of the next meeting devoted to the discussion of the common objectives to be reached in the time left to the project. Following the development of the state of the art, the challenge most likely to be reached is to provide a tool of visualization and modelization tools to describe social networks. Another issue to be discussed is the management of the web site. We also plan to define a regular schedule of updating for the various WP page and the central one.
3. We distributed the various efforts for project presentation and web site amongst the different nodes and WP leaders. The new version of the web site is already on-line. We want to discuss the new features in the next meeting and since its present structure it should be possible to take into account in real time any suggestion arising. New data (the most visited part of the site) have been added according to deliverable D12. New software tools have been added, they work mainly under linux even if source code in principle can be compiled under any operating system. This family of software tools produce and visualize a series of simple networks from Erdos Renyi to scale free graph. This series of tools is particularly useful for creation of synthetic datasets for basic research or didactical purposes.

4. As reported above we are currently planning to apply the ideas of Renormalization Group to represent (at least for scale invariant graphs) large networks in a coarse grained form. This is a truly interdisciplinary effort, since the definition of the sensible quantities to be rescaled and the exact procedure in order to maintain the invariance of self-similar graph, need a remarkable theoretical analysis.
5. Since the increased interest in the community about social networks properties, we are quite confident that in the near future the level of collaboration will increase. Even now in this second year we have been able to find a common ground of collaboration on a topic related to the firm dynamics and in particular the study of the network of property in various stock markets. The experience of the node in the field of social dynamics could be used with profit in further study of financial structures (see for example the World Trade Web defined by node CR3 UB (University of Barcelona).
6. This is a point where a misunderstanding happened. As in the first project report we received the input one week in advance with respect to the report and one month in advance with respect to the meeting. So there has been very little room to take into account the suggestions. Our view of the report is to consider both of them very positive. Suggestions of Mark Buchanan were to try to involve more closely social and natural sciences. In this year we tried to involve in the activity of the project as many sociologists and ecologists as possible given the information technology area of EC funding. Scientific collaboration started and we plan to report them in the future meeting, To overcome this misunderstanding in time schedule for the future we plan now to submit the report at the same time to advisory board and to the commission. This should allow the reviewers to have also the advisory suggestions to judge the activity made in the second year. At the moment one of the board, i.e. Dr. Mark Buchanan is likely to be present at the review meeting.
7. We experienced some logistic problems with László Barabási. Since his location is in United States, it is not very simple to organize small short meetings in Europe for suggestions and discussion. On the other hand, as reported in other parts of this report, this project has been rather successful in collecting (at least for the statistical physics) all the communities working in Europe at the time of presentation of the project. Looking for leading scientists nearby but not involved in the project is nevertheless necessary. We are now contacting Stephen Bornholdt and Janosz Kertesz as possible new entries in the Advisory Board.
8. The web site has been reshaped. The main and immediate change is that the content has been redirected to local home pages of the various WP. While the contract and the scientific part of the proposal (Annex 1) are really internal issues of the consortium and therefore have been removed from the home page, we still keep the structure of the Deliverables directly accessible from the home page. Deliverable are the most visible product of the Consortium activity and in their form of small self-contained reports represent the best introduction to the publications they contain. Therefore they are a very good presentation for the project for the people crawling the web. The input part of information in the activities is left to the various WP leaders. The hosting institution of the coordination node has the responsibility to present in a coherent way the efforts made in the consortium. For a more detailed list of the changes made see the next section on Management and Coordination.

2.8 Assessment of Project results and Achievements

Questions about project's outcomes	Number	Comments
1. Scientific and technological achievements of the project (and why are they so ?)		
Question 1.1. Which is the 'Breakthrough' or 'real' innovation achieved in the considered period	4	• We defined some new active ingredients (the presence of disorder) able to explain the onset of scale-free behaviour. This means that scale-free graph can arise also without the rules of growth and preferential attachment • We are currently realizing algorithms based on the ideas of renormalization procedure in order to visualize large graphs as those of the Internet and the WWW. • We also started the characterization of communities presence in graphs with a variety of different approaches ranging from divisive methods to spectral analysis. • We have started the study and modeling of weighted networks; this is an important step forward since many networks display a strong heterogeneity of interactions.
2. Impact on Science and Technology: Scientific Publications in scientific magazines		
Question 2.1. Scientific or technical publications on reviewed journals and conferences		See attached excel sheet
Question 2.2. Scientific or technical publications on non-reviewed journals and conferences		See attached excel sheet
Question 2.3. Invited papers published in scientific or technical journal or conference.		See attached excel sheet
3. Impact on Innovation and Micro-economy		
A – Patents		
Question 3.1. Patents filed and pending	None	When and in which country(ies): Brief explanation of the field covered by the patent:
Question 3.2.		When and in which country(ies):

Patents awarded	None	Brief explanation of the field covered by the patent* (if different from above):
Question 3.3. Patents sold	None	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 - subject of activity: - location: - headcount: - turnover: - profitable : yes / no / when expected
Question 3.5. Creation of new department of research (ie: organisational change)	No	Name of department:
C – Technology transfer of project's results		
Question 3.6. Collaboration/ partnership with a company ?	No	Which partner : Which company : What kind of collaboration ?
4. Other effects		
A - Participation to Conferences/Symposium/Workshops or other dissemination events		
Question 4.1. Active participation[1] to Conferences in EU Member states, Candidate countries and NAS. (specify if one partner or "collaborative" between partners)	No	Names/ Dates/ Subject area / Country:
Question 4.2. Active participation to Conferences outside the above countries (specify if one partner or	No	Names/ Dates/ Subject area / Country:

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

"collaborative" between partners)		
B – Training effect		
Question 4.3. Number of PhD students hired for project's completion	3	In what field : theoretical physics
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.)	Yes	References: Some papers have been discussed in Nature News and Views Some other article on national newspapers Some Tv interviews (rai edu national Italian tv company) See attached zip file Press.zip
Question 4.5. Web-pages created or other web-site links related to the project	Yes	References: http://www.cosin.org/
Question 4.6. Video produced or other dissemination material	Yes	References: Pdf series of lectures at http://www.cosin.org/networks.html
Question 4.7. Key pictures of results	Yes	References: See Appendix D
D - Spill-over effects		
Question 4.8. Any spill-over to national programs	Yes	PAIS of INFM statistical properties of Mars River Networks
Question 4.9. Any spill-over to another part of EU IST Programme	Yes	IP project DELIS
Question 4.10. Are other team(s) involved in the same type of research as the one in your project ?	Yes	Notre Dame University, North Western University, Los Alamos National Laboratory, University of Cambridge

3. Project Management and Coordination

In order to respect the project schedule and to take into account the reviewer suggestions in the first year report we had to take a series of different actions resulting in some changes both of the administration and of the project.
It has been noticed that there was clearly a lack of control within the different WP's. Also the kind of presentation and the dissemination of results needed a substantial improvement. These topics have been discussed during the Midterm Meeting and during a periodic meeting of WP leaders held in Lausanne in November 2003. During this meeting where G. Caldarelli, Albert Diaz-Guilera, Paolo De Los Rios, Gerard Weisbuch, Stefano Battiston, Marco Gaertler and Alessandro Vespignani were present we made the following considerations:

- The structure of the WP needs to be reinforced, every WP leaders (one per node) is now in charge to supervise the work of the whole consortium in their area, to collect the papers and contributions made in the WP and to present the results obtained in such a way to make possible a rationale overall presentation in the reports. The whole structure of this report comes from a bottom up process from the nodes to the coordination site.
- The reports must be considered as the *main occasion of self-assessment and evaluation*, so that their preparation must start well in advance the deadline. It would be ideal to organize also small scientific meetings for every WP in order to disseminate most recent results amongst young researchers and students.
- WP leaders and therefore their nodes are responsible for the content of their WP pages. This is the part of the web site where external communities and feedback can easily enter the community. It is left to WP leaders to involve people in their departments and their colleagues in the COSIN project at least as data and publications repository.
- One of the main targets of the project was to form a coherent community on theory of complexity. While collaboration between some of the nodes is already working well, scientific interchange with CR5 and CR6-CR7 has been until now more problematic. This is of course related to the different scientific background, but since we have been able to find some different common grounds all nodes must do a specific effort to exchange ideas and information and form a common vocabulary and tools of analysis and modelization.
- The challenge of COSIN was to represent a common recipient for the research on growing network in Europe. While this more or less worked properly until now, the efforts to keep updated and running the web site and the data repository (the only one available together with that of A-L Barabási) started to be judged very requiring. The request is to understand what could be the possible future of the consortium once arrived at the end of the project.
- As regards the opinion of the WP leaders about the future activity in the field we collected as a general opinion that the most immediate application of these researches will be in the field of social networks and protection of critical infrastructures.

What follows is a description of all the actions taken by coordination node in order to keep in track the project and help it develop the great scientific potential of the participants.

MANTAINING THE PROJECT CHALLENGES

The scientific role of the coordination site has been designed in order to provide help and support to other sites during the development of the respective Workpackages. The main delay in the research as was scheduled in the project regards the study and analysis of the World Wide Web. Also in the measurement sets for the Internet Structure we need some more effort to meet the project challenges. During this period we take the following actions in order to maintain what we planned.

- For the measurement of the Internet it has been necessary to invest a rather large sum of money in order to have a proper set of computer and routers to start the traceroute analysis. Being beyond the budget of the consortium, we had to start collaboration on that point with other institutions. In particular we established collaboration with Centro Studi e Ricerche E. Fermi. They will take charge of the computers and routers and we will collaborate mainly with Dr. Fabrizio Coccetti.
- While we had to give up the idea of a whole series of web crawls, Dr. Coccetti realized some web crawlers for a semantic research of suitable subsets of the web. The crawler source has been put on the web site as will be the data in a very short time.
- On the same issue the coordination site has hired a couple of postdocs (Luciana Salete Buriol and Ramon Cancho) whose activity will be mainly focused on the analysis of the World Wide Web. The first one will perform an analysis of the growth and development of the Web crawling the archive of web pages at www.archive.org. The second one will perform an analysis of the semantic of the different web pages

WEB SITE MANAGEMENT

We believe that especially for a project based on Information Technology it is crucial to have a web site properly maintained. The activity of coordination site once delivered the contents of the Work Package to various nodes is to present in a coherent way all the activities made.
In our view the main challenge of COSIN is to use (and actually contribute to formalize) the theory of complex systems to model and optimize Information Networks. For that reason a visitor of the web site must find basic information not only on the activity of the consortium but on the basis of research. Amongst the new addition to the home page we have now a series of links to the "*keywords"* that in our opinion should represent COSIN

- A page devoted to **Complexity**. Since the nature of this field, we present here only our idea of the field, but nevertheless present some basic knowledge to understand and appreciate the work made in the project.
- A complete course in **Scale Free Networks** in pdf format. This course of 14 hours of lectures has been given at Swiss PhD students for their Troisieme Cycle de Physique Theorique en la Suisse Romande.
- Some basic information on the basis of the **visualization** problems and the representation of a graph.
- On top of the basic keywords it would be useful to have a news page where is collected information about conferences, lectures and positions opened within the project and in the area. This page has to be maintained on a weekly basis. The way to obtain such maintenance is by communicating any of these news to the secretary of the project Ms Sara Sidoretti sidoretti@pil.phys.uniroma1.it

- Links to other group starting working in the field, apart the US groups of A.-L. Barabási, L. Amaral. G. Stanley, Z. Toroczkai, M. Newman there are the pages of the EC projects BISON, EXYSTENCE, ECAGENTS, EVERGROW and DELIS

ADMINISTRATIVE CHANGES

It has to be noticed that partly due to burocratic problems with the Coordination Institution the request amendments to the contract required in the first year of activity resulted in a substantial delay of transfer of funds to the two new nodes CR7 UNIKARL (University of Karlsruhe) and CR8 UPSUD (University of Paris Sud). These two nodes managed nevertheless to afford travel and labour expenses in order to keep the project running, but this delay could result in a substantial (i.e. 1 year) delay in the allocation of expenses in the budget of the two administrations.

- The first change is related to the shift from the University of Konstanz to the University of Karlsruhe due to the new appointment of Prof. D. Wagner. This resulted in an amendment to the contract introducing a new node CR7 for the University of Karlsruhe. Node CR6 University of Konstanz ended its participation to the contract at month 12 and transferred funds and obligations to the new node.
- A second substantial change is related to the addition of the new node CR8 (University of Paris-Sud) due to the new position of Prof. Alessandro Vespignani. While Alessandro Vespignani was originally supposed to collaborate to C01 (INFM) it turned out for the success of the project that it was convenient to have a more formal collaboration with him and his group in Paris. This resulted in a specific commitment for the writing of Dissemination and Use Plan as well as this scientific report. Since the whole budget for this new node has been transferred from coordination node C01 INFM (Istituto Nazionale Fisica per la Materia, Italy) it is possible that some small remodulation of the budget of this institution would be necessary in the immediate future.
- The third change **not happened yet** will affect the node CR4 UNIL. Since the change of legal status of the University of Lausanne that is now part of the École Polytechnique Federale de Lausanne a new signature for the new insititution would be necessary in the immediate future. This amendment has been postponed in order not to delay further the transfer of funding to CR7 and CR8. We will report detail of this amendment in the next periodic report
- Minor amendments to the contract refer to change from net to gross figures for labour costs.

4.Cost Breakdown

Comparative Information on Resources (Costs)

Costs in euro for reporting period 1/3/2003 -29/2/2004

	CO1 INFM				CR2 UDRLS				CR3 UB				CR4 UNIL (1)			
	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	48793	35206.67	84005	59474	69078	70599.9	150221	151991.96	66500	47764.86	99085	55464.55	54241	22042	105669	45346.78
2. Durable equipment	0	1437.03	4000	2123.01	0	3561.43	12000	5160.94	0	4290.00	13000	8580	0	0	0	0
3. Subcontracting	0	0	0	0	0	0	7300.00	7300.00	0	0	0	0	0	0	0	0
4. Travel and subsistence	3000	5556.31	6000	10914.76	5620.00	6473.12	11240	9251.95	6000.00	8053.49	12000	13538.23	4560	1732.01	8920.00	3474.88
5. Consumables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. Computing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Protection of knowledge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8. Other specific costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	**51793**	**42200.01**	**94005**	**72511.77**	**74698**	**80634.45**	**180761**	**173704.85**	**72500**	**60108.35**	**124085**	**77582.78**	**58801**	**23774.01**	**114589**	**48821.66**
Indirect costs																
9. Overheads	10359	8440.01	18802	14502.36	55262	56479.92	120177	121593.57	14500	12021.67	24817	15516.56	5880	2377.40	16197	4130.73
Total	**62152**	**50640.02**	**112807**	**87014.13**	**129960**	**137114.37**	**300938**	**295298.42**	**87000**	**72130.02**	**148902**	**93099.34**	**64681**	**26151.41**	**130786**	**52952.39**

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 cost to date

(1) The Cost Statement of CR4 UNIL is not complete. For details see the attached note.

Comparative Information on Resources (Costs)

Costs in euro for reporting period 1/3/2003 -29/2/2004

	CR5 ENS				CR7 UNIKARL				CR8 UPSUD				TOTAL			
	Period		Total		Period		Total		Period		Total		Period		Total	
Cost category	Est.	Act. (2)	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.
Direct costs																
1. Personnel	77030	78774.19	152922	131436.94	59328	50570.1	59328	50570.1	21473	0	21473	0	396443	304957.72	672703	494284.33
2. Durable equipment					0	0	0	0	1333.00	0	1333.00	0	1333	9288.46	30333	15863.95
3. Subcontracting					0	0	0	0		0		0	0	0	7300	7300
4. Travel and subsistence					7799.00	2543.74	7799.00	2543.74	2783.00	0	2.783.00	0	29762	24358.67	48742	39723.56
5. Consumables					0	0	0	0	0	0	0	0	0	0	0	0
6. Computing					0	0	0	0	0	0	0	0	0	0	0	0
7. Protection of knowledge					0	0	0	0	0	0	0	0	0	0	0	0
8. Other specific costs					0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	**77030**	**78774.19**	152922	131436.94	**67.127**	**53113.84**	**67127**	**53113.84**	**25589**	**0**	**25589**	**0**	427538	338604.85	759078	557171.84
Indirect costs													0	0	0	0
9. Overheads	61625	51625.48	122339	93755.48	13425	10113.6	13425	10113.6	5118.00	0	5118.00	0	166169	141058.08	320875	259612.3
Total	138655	130399.67	275261	225192.42	80552	63227.44	80552	63227.44	30707	0	30707	0	593707	479662.93	1079953	816784.14

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

(2) In the actual personnel cost has been included also the adjustment from the previous cost statement. For details see the attached note

5.Information dissemination and exploitation of results

The following list of activities of the consortium is divided according to publications, conferences and schools. Most of the publications produced are downloadable from the project site at http://www.cosin.org/publications.html and reported in Appendix D
We present here the proposal for a dissemination book on the COSIN activity that has been favourably considered by World Scientific Press.

5.1 CONFERENCES AND SCHOOL

- In The year 2003 COSIN organized its **midterm conference in Rome 1-5 September 2003.** The conference has been attended by a vast representatives of researchers active in several areas concerned with networked structures. It is worth stressing that invited speakers at the conference were including a large number of leading expert worldwide in the network science area. The conference has represented a very interesting analysis of the state of the art in the field and a window over the activities at the forefront in the area of networks. The conference has efficiently contributed to advertise the COSIN project and to establish links and connections with similar activities in US, Europe and private and governmental institution. The conference has also offered a podium to show recent results and works to young researchers. The poster of the conference is reported in the **Appendix A.** In concomitance with the conference, a special volume of the European Journal of Physics B has been edited (see **Sec.5.2**).

- In this year 2004 COSIN has been involved together with the FET project BISON in the organization of the workshop **SELF-STAR:International Workshop on Self-* Properties in Complex Information Systems 31 May - 2 June 2004.** This "by-invitation-only" Bertinoro workshop will bring together a small interdisciplinary group of researchers and practitioners active in different fields in an effort to identify the conceptual and practical foundations for modelling, analyzing and achieving self-* properties in complex information systems. Some of the key questions we will be trying to answer include:
  - Is there a valid scientific basis for self-* computing or is it mainly hype?
  - What are some real (computing or otherwise) problems that have been effectively solved through self-* techniques?
  - Are there any "negative results" for specific self-* properties or techniques in certain contexts? Ù
  - What are the limits for achieving self-* properties in complex information systems?

Additional conferences and workshops are under consideration. In addition, many COSIN members are actively involve in organization and program committee of national and international conferences.

5.2 EDITED VOLUMES

In occasion of the COSIN midterm conference, the **European Physical Journal** has devoted a topical issue to network science. We put all the relevant information on this publication on **Appendix B**. From the contents page it is evident the presence of the whole community in the field of growing networks. The volume contains also a paper reporting a round table discussion, followed by several follow up and editing works, outlining the relevant questions in the area and the possible future directions in network research. We believe that the volume will be a useful reference to the network scientific community at large

5.3 BOOKS

5.3.1 Evolution of Internet

A collaboration between partners CR3 and CR8 has produced the first scientific monograph reviewing the large scale properties of the Internet and the WWW.
The book has been published by Cambridge University Press in early 2004 with the title:

"**Evolution and structure of the Internet: a statistical physics approach**"

Author: Romualdo Pastor-Satorras and Alessandro Vespignani

The book describes the application of statistical physics and complex systems theory to the study of the evolution and structure of the internet. Using a statistical physics approach the internet is viewed as a growing system that evolves in time through the addition and removal of nodes and links. This perspective permits the definition of the dynamical theory required for a description of the macroscopic evolution of the internet. The book is of interest to graduate students and researchers in statistical physics, computer science and mathematics studying in this subject.
The **contents** are
Preface
1.A brief history of the Internet
2. How the Internet works
3. Measuring the global Internet
4. The Internet large scale topology
5. Modeling the Internet
6. The Internet robustness
7. Virtual and social networks in the Internet
8. Searching and walking on the Internet
9. Epidemics in the Internet
10. Beyond the Internet's skeleton: traffic and global performance
11. Outlook
Appendix 1. Graph theory applied to topology analysis
Appendix 2. Interface resolution and router topology
Appendix 3. Numerical analysis of heavy-tailed distributions

Appendix 4. Degree correlations
Appendix 5. Scale-free networks: scaling relations
Appendix 6. The SIR model of virus propagation
Bibliography
Index.

5.3.2.Proceedings Book

The project has also submitted a proposal for a **dissemination book** on the COSIN activity that has been favourably considered by World Scientific Press.

"Co-evolution and Self-Organization in Dynamical Networks"

Edited by Guido Caldarelli (INFM, Rome) and Alessandro Vespignani (CNRS, Paris)

Aims and general overview

Networks have been recently recognized as playing a central role in understanding a wide range of systems spanning diverse scientific domains such as physics and biology, economics, computer science and information technology. Specific examples run from the structure of the Internet and the WWW to the interconnections of finance agents and ecological food webs. Networks are made by many components whose microscopic interactions give rise to global structures and dynamical evolutions often characterized by emergent collective behaviours and complex topological properties. In this context the statistical physics approach finds a natural application since it attempts to explain the various large-scale statistical properties of networks in terms of the local interactions governing the dynamical evolution of the constituent elements of the system. It is not by chance then that many of the seminal papers in the field have been published in the physics literature, and nevertheless made a considerable impact on other disciplines. Indeed, a truly interdisciplinary approach is required in order to understand each specific system of interest, leading to a very interesting cross-fertilization among the different scientific areas defining the emergence of new research field sometime defined as *network science*.

In this context the Information Technology section of the European commission has been a main actor in fostering the development of interdisciplinary researches and collaborations among European institutions with a focus on network science. In particular, the FET open project Coevolution and Self-Organization in Dynamical Networks (COSIN IST-2001-33555) is representing a major initiative in the study of a wide spectrum of network research.
One remarkable situation that seldom verifies in science was that at a certain point in many fields and disciplines the same questions and problems started to appear. Computer scientists became interested in large scale statistical properties of Internet and World Wide Web. Ecologists studied the universal behaviour in Food Webs as well as Social Scientists started to approach quantitatively the study of formation and evolution of

communities. All of them looked for a reliable Graph Theory able to reproduce the phenomena observed in the data.
Interestingly, this theory had to be fully developed yet, and that is the reason for which several mathematicians and physicists became involved in this game.
This was the field when we started this project financed by European Commission.
Different scientists from different fields decide to collaborate in order to form a common set of knowledge that could be used in order to describe different phenomena.
The structure of this cooperation is the most natural possible

- Start from a reliable set of data (since in many cases data sets fully available to researchers are few, incomplete and biased) and provide them publicly to other researchers.
- Define a set of sensible measures that must be considered whenever we would like to describe a network. Some quantities have an immediate "physical meaning" in their field. So that the centrality importance of a vertex refer to the authority of a person in a social network being a little more vague for proteins. Alongside with these quantities a pressing problem was also to provide a set of visualization tools in order to represent the various situations.
- Finally in order to arrive to a theory of Growing network we planned to realize models of the various situations

While the project is cut in order to tackle principally issues related to networks arising in the information technology domain, it is fully pursuing an interdisciplinary approach where research activity in the field of ecological, economical and social systems cannot be neglected. Results obtained in each of these fields could turn to be applicable or prospect innovative solutions and understanding in the other domains.
Various nodes of the project work on fields as different as Protein Interaction Networks, the network of e-mails, the Internet Graph and the financial networks present in the stock exchange.
The purpose of this volume is twofold. First we intend to provide a snapshot of the forefront research activities in the area of complex networks, provide a good sampling of the disciplines involved, and the kinds of problems that form the subject of inquiry. In doing this, we organized the book in thematic chapter, each one addressing a special system or domain in the networks area, On the other hand, we want to present the many research achievements obtained within the COSIN project as well as the new problems opened and the various research directions still in their initial stages. In this spirit, chapters will be co-authored by leading scientists who have been involved, in a stage or the other, in the COSIN project. This will also allow us to emphasize the value of the interdisciplinary approach by showing a specific piece of research realized in a particular situation. On the other hand the reader will find a common structure and approach as a sign that this common set of frameworks started to circulate at least within our restricted community. We hope that this presentation of the field will attract the interest of colleagues within and outside the network community, and serve to further improve our understanding of this fascinating subject.

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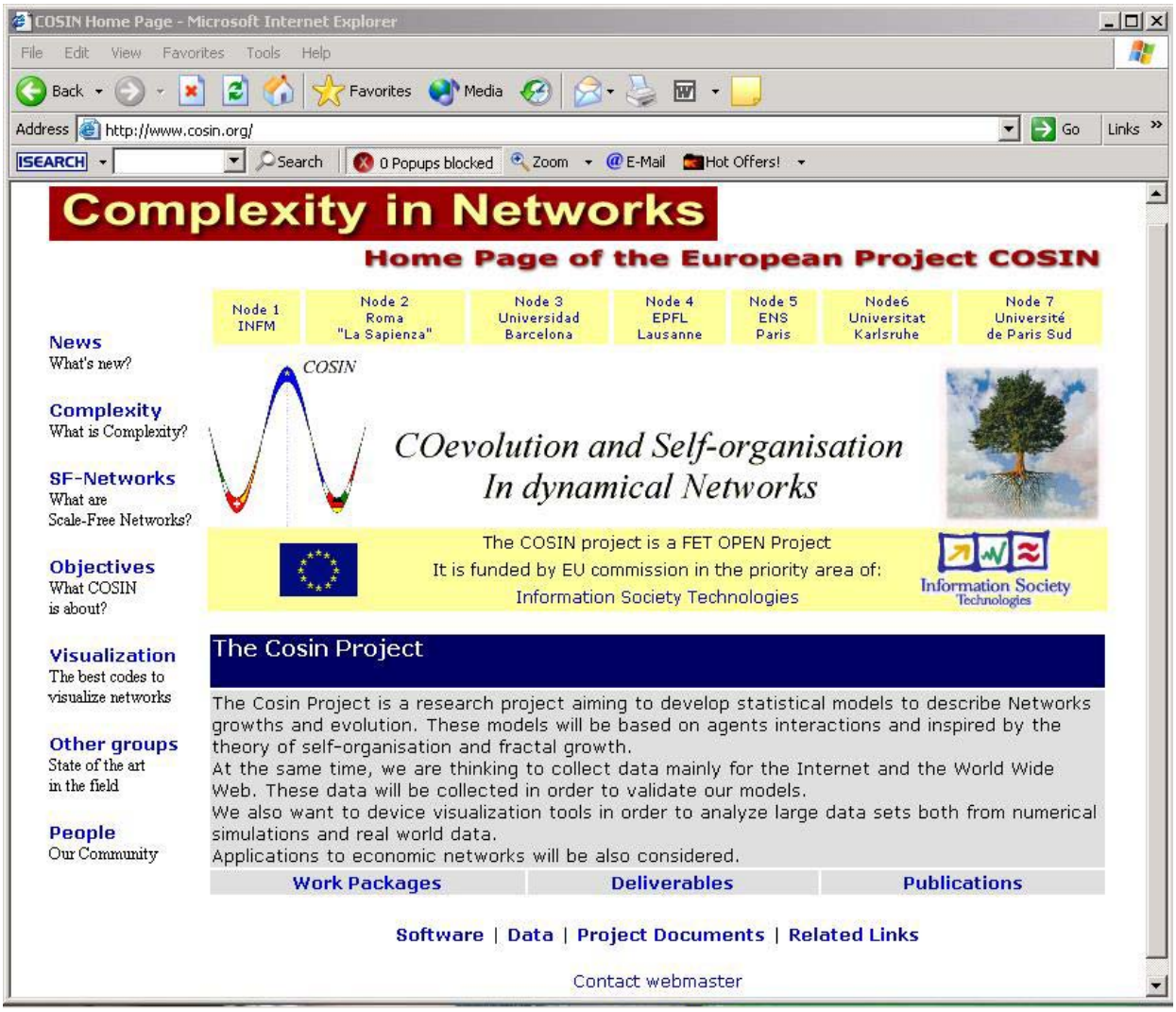
List of contributors

A. Arenas, A. Barrat, M. Barthélemy, S. Battiston, M.Boguna, G. Caldarelli, P. De Los Rios, A. Diaz-Guilera, P. Di Battista, R. Dum, S. Leonardi, R. Pastor-Satorras, A. Vespignani, D. Wagner, G. Weisbuch.

5.4 WEB SITE



The appearance and structure of Web site have been changed according to the requests of the reviewers. As a general feedback we received from people external to the project, this website is mainly visited in order to download the data and the publications. This means that the visitors already know about the themes of the COSIN project. We tried therefore to put some effort in explaining what COSIN is about for all the people that might be potentially interested but are not familiar either with complexity, or with growing networks. Amongst the changes made we have

- On the left a series of links to the keywords of project **News, Complexity, Scale-Free Networks, Visualization, Other Groups, People.** This is the part of the web site devoted to what has been called *"Community"* by the reviewers in the last meeting.
- On the centre of the home page there is the main production (*"Output")* of the Project that is the activity made in the **Work Packages**, resulting in **Deliverables** and **Publications**.
- On the bottom of the home page there are the links to what has been called *"Input"* that is the instruments of the activity: the **software** used, the **data** for download, a commented list of **links.**

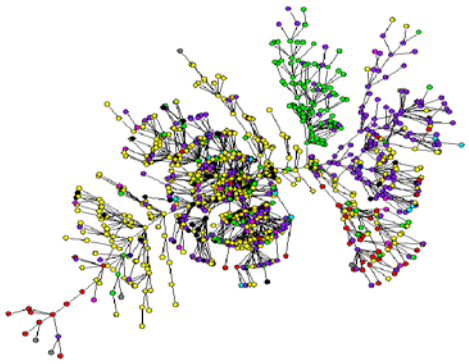
Appendix A. The midterm conference

MIDTERM CONFERENCE COSIN (FET Open Project IST-2001-33555)

Conference on Growing Networks and Graphs in Statistical Physics, Finance, Biology and Social Systems

Organizing Committee: **G. Caldarelli, S. Leonardi, R. Pastor-Satorras, L. Pietronero, A. Vespignani**

Sponsored by: ***Istituto Nazionale Fisica per la Materia (INFM), Università "La Sapienza"***



Roma 1-5 September 2003

Aule S. Pietro in Vincoli, Facoltà di Ingegneria, Università di Roma "La Sapienza" v. Eudossiana 18

http://www.cosin.org/midterm.html

Tentative List of Invited Speakers

L. ADAMIC *(HP Palo Alto)*	**A. ERZAN** *(Istanbul Univ.)*	**S. REDNER** *(Boston University)*
L. AMARAL *(NorthWestern University)*	**S. HAVLIN** *(Bar Ilan Univ.)*	**R. V. SOLÉ** *(UPF Barcelona)*
A. ARENAS *(Univ. Tarragona)*	**B. KAHNG** *(Seoul Univ.)*	**A. M. SPACCAMELA** *(Roma)*
A.-L. BARABÁSI *(Notre Dame)*	**J. KERTESZ** *(Eotvos Institute)*	**H. E. STANLEY** *(Boston Univ.)*
B. BOLLOBAS *(Memphis)*	**R. KUMAR*** *(IBM Almaden)*	**Z. TOROCZKAI** *(LANL)*
A. BRODER* *(Altavista)*	**R. MANTEGNA** *(Palermo)*	**D. WAGNER** *(Konstanz Univ.)*
W. R. CHESWICK *(Lumeta)*	**N. MARTINEZ*** *(S. Francisco Univ.)*	**D. WATTS*** *(Columbia)*
P. DE LOS RIOS *(IPT, Lausanne)*	**F. MENCZER*** *(Iowa Univ.)*	**G. WEISBUCH** *(ENS)*
S. DOROGOTSEV *(Porto)*	**J. J. MENDES** *(Porto)*	

Appendix B. Preface and contents of Proceeding Book

Figure: The cover of the Journal hosting the Midterm Proceedings

Preface

Networks have been recently recognized as playing a central role in understanding a wide range of systems spanning diverse scientific domains such as physics and biology, economics, computer science and information technology. Specific examples run from the structure of the Internet and the WWW to the interconnections of finance agents and ecological food webs. Despite a truly interdisciplinary approach is required in order to understand each specific system of interest, statistical physics in particular has recently contributed enormously to our understanding of networked structures

Indeed networks are made by many components whose microscopic interactions give rise to global structures and dynamical evolutions often characterized by emergent collective behaviors and complex topological properties. In this context the statistical physics approach finds a natural application since it attempts to explain the various large-scale statistical properties of networks in terms of the local interactions governing the dynamical evolution of the constituent elements of the system. For this reason, statistical physicists are extremely active in the area of complex networks and can be considered as leading actors in the emergence of this new field sometime defined as *network science*. It is not by chance that many of the seminal papers in the field have been published in the physics literature, and nevertheless made a considerable impact on other disciplines. At the same time, new problems arising in other disciplines are taken up by the statistical physics community, leading to a very interesting cross-fertilization among the different scientific areas.

The present special issue of European Journal of Physics B is devoted to the recently emerging field of complex networks. Many of the papers contained in this issue have been selected from the contributions presented at the midterm conference of the IST-FET open project COSIN (Coevolution and Self-Organization in Dynamical Networks), which met in Rome during the first week of September 2003. Several other papers have been invited by the issue's editors in view of the relevance of the reported results and in order to provide a comprehensive coverage of the various aspect of networks research.
The purpose of this special issue is twofold. First, we would like to provide a snapshot of the forefront research activities in the area of complex networks, and provide a good sampling of the disciplines involved, and the kinds of problems that form the subject of inquiry. Indeed, the present issue is arriving at a moment in which we can consider that the network area has reached a degree of scientific maturity, and that many important results are being established in the field. On the other hand, we want to emphasize the many problems left open and the various research directions still in their initial stages. We hope that this presentation of the field will attract the interest of colleagues within and outside the network community, and serve to further improve our understanding of this fascinating subject.

We wish to thank all the colleagues (authors, referees) that in different ways have contributed to the preparation of this issue. We want to express our warmest gratitude to Antonio Paoletti and Petra Rudolf, editors in chief of European Physical Journal B, for their support in the decision to devote a special thematic issue of the journal to network science. We thank the IST-FET open project COSIN for the generous support provided during the Rome meeting. Finally, we wish to thank the constant editorial guidance of

M.me Veronique Conde' and the unfailing support of the outstanding editorial staff at the European Physical Journal.

Contents (headings)

Appendix C 1st YEAR REVIEW REPORT

CONSOLIDATED 1st year REVIEW REPORT

Project COSIN IST-2001-33555

Ralph Dum

This report is based on input from O. Babaoglu and M. Speh Birkenkrahe.

Overall appraisal of the status of the project

The overall judgement of the results after year 1 is very positive. In particular, some of the scientific results presented were state of the art in the emerging field of analysis of complex networks. Judging from the material presented both during and before the meeting, including the comments of the Advisory Board members, the project is well on track with regard to the scientific results achieved in a number of the WPs. Several interesting and important results have been obtained through collaborations among several of the participating members. Judging from feedback by US scientists, this project puts Europe on track regarding this emerging field.

The presentation of results could be significantly improved to be brought on par with the scientific achievements. We found it difficult to evaluate the overall scientific progress of the individual work-packages. To improve this, it needs to be shown concisely and coherently how the work done during the first year furthered the project goals as detailed in Annex 1 of the contract. Unfortunately, the "Periodic Progress Report" and the review meeting where such a global account of work should be given, seemed to be based on specific deliverables seen as independent achievements, and on a collection of articles which were not put in perspective and in relation to each other. Thus, reviewers had to deduce the overall scientific progress from the collection of publications loosely attributed to work-package deliverables.

As a result, both the reviewers and I felt that the interest of having the individuals financed as a consortium trying to achieve an overall goal need to be more clearly developed. A loose collection of articles (even if of high standard) cannot per se be considered a sufficient result. Good research needs to be open to new ideas, but such openness can only be achieved by establishing an overall vision and a benchmark of what one wants to achieve and by comparing results (including articles) with those benchmarks and visions. Doing this would benefit the presentation of results. Not doing it might severely limit the high potential of the scientific work done.

Level of Collaboration

The scientific cooperation among the partners appears to be overall fine and is reflected in the joint publications that have resulted. Three nodes, INFM (C01, CR3, CR4) seem to have a strong collaboration, while collaboration among the remaining nodes appears sporadic – at least when judging by the papers only.

With this measure, Konstanz (CR6) and ENS (CR5) seem somewhat isolated from the other nodes. This picture was confirmed by the character of the results obtained by the partners. It is not obvious for all partners how the promise with regard to an interdisciplinary consortium are fulfilled in this project in terms of actual research performed and results obtained.

Management

Administrative coordination for the project must certainly be improved, as revealed by the questionable quality of the management deliverables.
Rather than being a mere bureaucratic necessity, producing an account of the work done adds scientific value and puts forward the quality of results achieved. Putting research in perspective of intended goals and the state of the art helps develop a research context which will amplify the impact of the research outside of the project. Therefore the hostile attitude of the consortium against producing such reports needs to change in the coming period in the best interest of the project.

It seems that there is no clear responsible for each WP, and that as a consequence the coordinator is busy collecting the results of each individual WP and cannot concentrate on a higher level coherent presentation of project results.

The two management deliverables D02 and D03 could be much stronger (indeed one of the recommendations is to rewrite the dissemination and use plan).
The "Dissemination and Use Plan" (D02) does not conform to the structure indicated in the "Guidelines for Preparing Project Reports" document. While this is not a requirement (and often not even desirable), the new structure that is chosen needs to have adequate and relevant content. In the present form, most of the suggested points (e.g., "Self-Evaluation and Advisors") are left without a clear indication on how to implement them. Ideas given by M. Buchanan could be taken up in a rewritten version.
The "Periodic Progress Report" (D03) also deviates from the structure indicated in the "Guidelines for Preparing Project Reports" document and - apart from the flaws mentioned earlier - fails to include a "Project Management and Coordination" section indicating deviations from the work schedule and accounting of proposed work for the next reporting period.

Information Dissemination

During its first year, the project has organized or co-organized numerous schools and conferences. More are planned for the future (including the "Midterm Conference" scheduled for September 2003). These conferences attracted high-level scientists and show the interest in the kind of research proposed by the COSIN consortium.

The web site for the project is poorly designed and maintained. It is far from being a "community portal" or the "source-forge of complex networks" that is envisioned in the work description. Despite the numerous criticisms raised during the review meeting, the site has not benefited from a redesign or update one full month later (for example, there is still no list of consortium members). The pages "Codes" (intended to mean "Software") with the two Fortran fragments and "Objectives" with the blank "The COSIN Scientific background" are particularly embarrassing and would be better served in a "private" area.

Within the thematic focus, the website is a central platform to both the project partners and to connect to a wider community in particular towards an application of the scientific results obtained. The website does not meet these intentions at this stage. A substantial rethinking and reworking of the website will be necessary. To decide on a proper strategy one needs to decide and define (i.e. articulate) the purpose of the website. Better define a moderate goal than an ambitious goal and not meet it.

Tasks and Activities

1) Technical Deliverables

The technical deliverables have been presented as "collections" selected from the 43 publications that have resulted during the first year. It is a remarkable feat for a new project to produce such a high number of publications (including numerous journal articles in high impact journals like 'Physical Review Letters') in its first year.

As mentioned earlier, this selection was presented without comments and covered partially overlapping results. Not all articles sent to the reviewers were genuinely new results (e.g. the date of submission of one article preceded the beginning of the project, and some articles were submitted in the web-archive and in their final published version) and no attempt was made to position the articles with respect to the state of the art and - even worse- with respect to the intended goals of the project.

Seen in this perspective, it would have been much better to present only the most pertinent publications and put them in perspective with the intentions of the project. Including only those publications that resulted truly from work performed during the first year would have been equally admirable in terms of number and would have allowed a better overall appreciation of the project. The role of a technical deliverable is to present the project results in a *unified, self-contained* and *coherent* manner, rather than to impress with a large number of publications that are stapled together.

Furthermore, in the early phases of a project, there is no reason to insist that only published material are worthy of inclusion in deliverables. Concern was expressed that this "publications only" attitude towards deliverables will jeopardize certain future deliverables (e.g., D13, D21) that promise more 'tangible' results like software and interfaces. For these to be truly useful, they need to be packaged using modern software engineering tools and techniques including real documentation and not just publications describing them.

The technical work during the first year can be grouped into 6 areas (largely following the Work packages): models, data collection/analysis, network visualization, social-economic networks, internet topologies and WebGraphs.

WP1: *Mathematical Tools for Complex Systems*.
Among others, first year work has produced promising results on measuring and modeling universality in networks. Progress appears to be good and of high quality.

WP2*: Data Collection and Analysis*.
First year work has concentrated on data analysis of various data sets. The analyzed data includes internet autonomous system topologies, WWW crawls, food webs, protein interaction maps, US patents, board of directors and Italian stock exchange. Progress here appears to be good and in general of high quality.

As for data collection, task T2.1 appears to have been redefined by removing the "WWW random walk" activity. Therefore, effort has to be shifted to the other two tasks (Library of Software Tools and Web access to data-sets).

Data collection during the first year has been limited to "trace-route" analysis of portions of the internet. The appropriateness of this simple technique for a global analysis of the internet is questionable given its limitations. During the review meeting, it became evident that the data collection activities of WP2 will be redefined given that the difficulty of performing Web crawls had been underestimated and given that the project has ready access to data collected by others (Webbase at Stanford). This is a perfectly reasonable readjustment of the project tasks but it should have been discussed in the "Periodic Progress Report".

WP3: *Large Networks Visualization Tools*.
First year work has been limited to the development of the *visone* tool for social networks. While this is a rather sophisticated tool with an elaborate and polished implementation suitable for small-to-medium scale social-economic networks, it appears to have intrinsic characteristics that limit its development to "huge networks" as defined in task T3.2. There is no hint as to how the work-package plans to overcome this obstacle, with or without *visone*.

WP4: *Dynamics of Social Networks.*
The work presented is of high quality and of potentially high impact (as exemplified by the strong feedback to some of the results). One problem is that it appears to be somewhat isolated and not well integrated with the rest of the project. The work on social-economic networks is lacking some hint of relevance or connection to the other activities in the project. This is regrettable as it seems a priori obvious that such links exist and could be developed within COSIN

As an article referenced on the COSIN website shows, there is an ongoing debate among social scientists regarding the validity of 'socio-physics'. One technical issue in this debate is the use of intelligent agents for simulation purposes vs. models of statistical physics. COSIN should position itself in this debate and also find better ways to connect to possible users of such methods. At this stage, lack of a clear interaction plan with groups potentially interested in such results reduces the potential impact of the research performed.

WP5: *Models for Communication Networks.*
First year work has produced excellent results on analyzing and modeling WebGraphs. The "multi-layer" model that has been proposed for the web appears to be particularly interesting and captures many of the crucial features of real networks. This result could have very important implications not only for web modeling but also for web algorithms including search engines.
This WP most clearly demonstrates the high potential of the project COSIN and it might be worthwhile to regroup future efforts of COSIN around this WP.

Application Perspectives

At the end of the first year of a three-year project, it is not too early to expect at least a well-defined audience, a go-forward plan (or roadmap) and at least a preliminary list of potential customers and collaborators for application and exploitation.
Unfortunately this issue was treated very sloppy (see dissemination and use plan). The only real attempt in this direction is the intention of A. Vespigniani to contact ISP providers and try to understand how work performed by COSIN could be of use to them.

In the first Periodic Progress Report, there is no response to a substantive comment by one of the Advisory Board members, Mark Buchanan, regarding dissemination and use of COSIN results to social scientists. With the exception of Konstanz (visualisation tools), neither academic members of this group nor business practitioners seem to have been involved in the selection of some work done by COSIN members in the area of social networks. In order to achieve the goals of the project as specified in Annex I (p. 5, *Project Objectives*): "We will consider social networks that model the relationships in a firm and in firms in the same business area." And later (p. 12, *Contribution to Community social objectives)*: "We think that COSIN's results will be exploited by spin-off companies and/or industrial projects that will exploit specific results and/or will address the technological transfer of COSIN results" much stronger effort is necessary to relate to the most pertinent user groups involved and to articulate the interest of work in this areas for such user groups.

Whilst one would not expect to see much actual exploitation of COSIN results within the three-year frame of the project, relevant contacts and connections which help guide the focus of the scientific work and the choice of data/example cases, need to be made early on.

Recommendations

The following recommendations (and also the above criticism) are based on the firm belief that this project has high potential - both scientific and technological - and the reviewers and myself feel we have to help the project unleash this potential by insisting on a more coordinated effort in the next two years.

- Rewrite the dissemination and use plan and put suggestions there into action asap.

- In the next meeting, try to figure out how the different parts of the consortium can work better together and try to define common goals for all consortium members.

- Designate clear responsibilities for the next year concerning WP. In particular make sure that the coordinator can concentrate on developing an overall appraisal of the project by getting input from each WP responsible on the scope of work and on the contribution of work done in a given WP to the overall project goal.

- Include Karlsruhe better in the COSIN collaboration. This could be achieved in a jointly developed plan how to make the transition from small network to large network visualization possible and what criteria such large scale visualization tools would have to meet. ENS and Karlsruhe could collaborate stronger as the social network visualization tools could be beneficial for ENS.

- How to include ENS better in the collaboration? One way could be by addressing the social role(s) of the Internet & the WWW as a complexity phenomenon (this is indeed foreseen in the technical annex!). One possible approach could be to test new propositions for virtual/cyber-communities. It could be also very beneficial to attempt to work directly with creative, speculative social scientists. Appoint a social scientist, management thinker as an advisory board member (e.g. from INSEAD or OECD).

- Make better use of the advisory board. E.g. the substantial input from e.g. Marc Buchanan was not taken up (at least not up to now).

- Additions to advisory board could be useful. Identify and contact potential users – who should be interested in the results of your work. As mentioned by A. Vespignani representatives of ISP providers.

- Put more resources and more thought in the web-site (see appendix below). Only a well-designed and well-maintained website makes sense. If you feel you are not willing to engage in this effort it might be better to drop the website activity than leave it in this unfinished stage.

Appendix (MSB) : remarks on website

A meaningful redesign of the website could involve three main areas addressing *Community, Output,* and *Input*. For example: *Community* corresponds to a plaza and includes *People*. It is personalized listing COSIN members, board members and, increasingly, a wider audience of collaborators, etc. *Input* (don't choose this

name!) includes data and codes, but also other items that provide context for your work – for example, *Links* are commented upon and validated. In other words, there is a stronger emphasis on the added value for the reader, be it a scientist or a casual surfer. *Output* includes the scientific results (summarised and explained !), press releases (a digested format for journalists) and publications etc. Again, context would be helpful. These pages are not centrally produced and maintained, but farmed out to COSIN members, if possible in alignment with the work packages. The areas are linked in a meaningful way that supports COSIN's objectives

- *General*: the website structure is derived from the contract with the Commission. This is an internal issue for COSIN – it might be helpful to develop a more effective to address the building of an interdisciplinary community, and for good dissemination of results. This site is ready to evolve more conceptually and structurally.
- *Home*: this pages refers to the 'topic' of investigation and gives a collection of statistical data. Mention the objective and purpose of COSIN. The information should provide an incentive to look further; right now it looks like a site for internal use only.
- *Objectives*: the objective, *"to approach the complexity appearing in nature"* could be more specific. The subsequent unstructured list: e.g. the "Scientific Proposal (Annex I)" might not mean much to anyone outside COSIN.
- *Visualisation*: this is the only page that links directly to a COSIN member (the Univ. of Konstanz) and its locally maintained pages. This works well - doing it on other pages would exploit a key advantage of the web, namely decentralized maintenance and distributed responsibility.
- *Press:* it is good to see this activity! It would probably be good to provide a linked response to the critique which is contained in at least one of the articles here.
- *Links:* An unstructured list of links. The reader would appreciate a qualification of these links, a context of some sort

Appendix D. Publications

2002 publications

- Decision making dynamics in corporate boards.
  S. Battiston, E. Bonabeau and G. Weisbuch
  ArXiv:cond-mat/0209590 (2002).
- Number of Loops of size *h* in growing scale-free networks.
  G. Bianconi and A.Capocci
  ArXiv:cond-mat/0212028 (2002).
- Epidemic spreading in correlated complex networks.
  M. Boguñá and R. Pastor-Satorras
  Physical Review E **66** 047104 (2002).
- Topology of correlation based minimal spanning trees in real and model markets.
  G. Bonanno, G. Caldarelli, F. Lillo and R. Mantegna
  ArXiv:cond-mat/0211546 (2002).
- Introduction to Complex Networks.
  G. Caldarelli
  Proceedings of the 7th Conference on Statistical and Computational Physics Granada (2002).
- Scale-Free Networks from Varying Vertex Intrinsic Fitness.
  G. Caldarelli, A. Capocci, P. De Los Rios and M. A. Muñoz
  Physical Review Letters **89**, 258702 (2002).
- Cycles structure and local ordering in complex networks.
  G. Caldarelli, R. Pastor-Satorras and A. Vespignani
  ArXiv:cond-mat/0212026 (2002).
- Quantitative description and modelling of real networks.
  A.Capocci, G. Caldarelli, and P. De Los Rios
  ArXiv:cond-mat/0206336 (2002).
- Visualization of the High Level Structure of the Internet with Hermes.
  A.Carmignani, G. Di Battista, W. Didimo, F. Matera and M. Pizzonia
  Journal of Graph Algorithms and Applications **6**,281 (2002).
- How Can Extremism Prevail? A study based on the relative agreement interaction model.
  G. Deffuant, F. Amblard, G. Weisbuch and T. Faure
  Journal of Artificial Societies and Social Simulation **5** (2002).
- Exploration bias of Complex Networks.
  P. De Los Rios
  Proceedings of the 7th Conference on Statistical and Computational Physics Granada (2002).
- Drawing database schemas.
  G. Di Battista, W. Didimo, M. Patrignani and M. Pizzonia
  Software-Practice and Experience. **32**, 1065 (2002).
- Archive of BGP Updates: Integration and Visualization.
  G. Di Battista, F. Mariani, M. Patrignani and M. Pizzonia
  Preprint (2002).
- Computing the types of the Relationships Between Autonomous Systems.
  G. Di Battista, M. Patrignani and M. Pizzonia
  Technnical Report University of Rome 3 **RT-DIA-73**(2002).
- Dynamical properties of model communication networks.
  R. Guimerà, A. Arenas, A. Díaz-Guilera and F. Giralt
  Physical Review E **66**, 026704 (2002).
- Optimal network topologies for local search with congestion.
  R. Guimerà, A. Díaz-Guilera, F. Vega-Redondo, A. Cabrales, and A. Arenas
  Physical Review Letters **89**, 248701 (2002).
- A Multi-layer model for the Web Graph

L. Laura, S. Leonardi, G. Caldarelli and P. De Los Rios
Contribution to 2nd Web Dynamics Workshop (2002).

- Critical load and congestion instabilities in scale-free networks.
  Y. Moreno, R. Pastor-Satorras A. Vázquez and A. Vespignani
  ArXiv:cond-mat/0209474 (2002).
- Scale-free behavior of the Internet global performance.
  R. Percacci and A. Vespignani
  ArXiv:cond-mat/0209619 to be published in European Journal of Physics B (2002).
- Epidemics and immunization in scale-free networks.
  R. Pastor-Satorras and A. Vespignani
  Handbook of Graphs and Networks: From the Genome to the Internet, eds. S. Bornholdt and H. G. Schuster, Wiley-VCH, Berlin, pp. 113-132 (2002).
- Topology and correlations in structured scale-free networks.
  A. Vázquez, M. Boguñá, Y. Moreno, R. Pastor-Satorras and A. Vespignani
  ArXiv:cond-mat/0209183 (2002).
- Large-scale topological and dynamical properties of the Internet.
  A. Vázquez, R. Pastor-Satorras, and A. Vespignani
  Physical Review E **65**, 066130 (2002).
- Internet topology at the router and autonomous system level.
  A. Vázquez, R. Pastor-Satorras, and A. Vespignani
  ArXiv:cond-mat/0206084 (2002).
- Adjustment and social choice.
  G. Weisbuch and D. Stauffer
  submitted to *Physica A* (2002).

2003 publications

- Size of Quantum Networks.
  G. Bianconi
  ArXiv:cond-mat/0301551.
- Absence of Epidemic threshold in scale-free networks with degree correlations.
  M. Boguñá R. Pastor-Satorras and A. Vespignani
  Physical Review Letters **90**, 028701 (2003).
- Epidemic spreading in complex networks with degree correlations.
  M. Boguñá R. Pastor-Satorras and A. Vespignani
  ArXiv:cond-mat/0301149 to appear in Lecture notes in Physics (2003).
- Topology of the World Trade Web.
  M. A. Serrano, and M. Boguñá
  ArXiv:cond-mat/0301015.
- GraphML Progress Report: Structural Layer Proposal.
  Ulrik Brandes, Markus Eiglsperger, Ivan Herman, Michael Himsolt, and M. Scott Marshall
  Proc. 9th Intl. Symp. Graph Drawing (GD '01), LNCS 2265, pp. 501-512. © Springer-Verlag, 2002.
- Guide - Changes
  Volker Maag and Thomas Willhalm
  preprint
- visone - Analysis and Visualization of Social Networks.
  U. Brandes and D. Wagner
  accepted on Graph Drawing Software Springer Series "Mathematics and Visualization" M. Junger P. Mutzel (eds).
- Analysis and Visualization of Social Networks
  Dorothea Wagner
  to appear in Proceedings of WEA 2003, LNCS
- A Multi-Layer Model for the Web Graph
  L. Laura, S. Leonardi, G. Caldarelli and P. De Los Rios
  Proceedings of the 2nd International Workshop on Web Dynamics
- Communicating Centrality in Policy Network Drawings.
  U. Brandes, P. Kenis and D. Wagner
  accepted on IEEE transactions on Visualization and Computer Graphics.
- On Clustering Large graphs.
  U. Brandes, M. Gaertler and D. Wagner
  preprint.
- Universality in Food webs
  D. Garlaschelli, G. Caldarelli, L. Pietronero
  accepted on Nature.
- Self-similar community structure in a network of human interaction
  R. Guimerà, L. Danon, A. Diaz-Guilera, F.Giralt, A.Arenas
  Phys. Rev. E 68, 065103 (2003)
- Quantifying the creation of social capital in a digital community
  R. Guimerà, X. Guardiola, A. Arenas, A. Diaz-Guilera, D. Streib, L.A.N. Amaral
  Preprint
- A study of stocastic model for the Web Graph
  G. Caldarelli, P. De Los Rios, S. Leonardi, S. Millozzi, A. Vespignani
  Preprint
- Topology of Protein Protein Interaction Networks from Physical Principles
  G. Caldarelli, P. De Los Rios, F. Squartini
  Preprint
- Statistical Properties of Shareholders Network.
  S. Battiston, G. Caldarelli, M. Castri, D. Garlaschelli, L. Pietronero
  preprint

- Evolving Protein Interaction Networks through gene duplication.
  R. Pastor-Satorras, E. Smith and R. V. Sole
  In press Journal of Theoretical Biology
- Co-evolutionary Differential Games on Networks,
  Battiston S., Weisbuch G.
- The hidden topology of shareholding networks
  Battiston, S., Caldarelli G., Garlaschelli D.
- The scale free nature of market investment network
  Garlaschelli D., Battiston, S., Caldarelli G.
  http://arxiv.org/abs/cond-mat/0310503
- Statistical properties of board and director networks
  Battiston S. and Catanzaro M.
  to appear on European Journal of Physics B.
- Emergence of Complexity in Financial Networks
  Caldarelli G., Battiston S., Garlaschelli D., Catanzaro M.
  to appear in Lecture Notes in Physics, special volume on "Complex Networks", Springer.
- Decision spread in the corporate board network
  Battiston, S., Weisbuch G., Bonabeau, E.
  to appear on Adv. in Complex Systems, http://arxiv.org/abs/cond-mat/0312228
- Visual Ranking of Link Structures
  Ulrik Brandes and Sabine Cornelsen
  Journal of Graph Algorithms and Applications 7(2):181-201
- Visual Unrolling of Network Evolution and the Analysis of Dynamic Discourse
  Ulrik Brandes and Steven R. Corman
  Information Visualization 2(1):40-50, 2003.
- Communicating Centrality in Policy Network Drawings
  Ulrik Brandes, Patrick Kenis, and Dorothea Wagner
  IEEE Transactions on Visualization and Computer Graphics 9(2):241-253.
  © IEEE Computer Society, 2003.
- Analysis and Visualization of Social Networks
  Ulrik Brandes and Dorothea WagnerIn Michael Jünger and Petra Mutzel
  (Eds.): Graph Drawing Software, pp. 321-340. © Springer-Verlag, 2003.
- Experiments on Graph Clustering Algorithms.
  Ulrik Brandes, Marco Gaertler, and Dorothea Wagner
  Proc. 11th Europ. Symp. Algorithms (ESA'03), LNCS 2832, pp. 568-579. © Springer-Verlag
- Topology of correlation based minimal spanning trees in real and model markets.
  G. Bonanno, G. Caldarelli F. Lillo, R. Mantegna,
  Physical Review E 68 046130 (2003).
- Quantitative description and modeling of real networks.
  A. Capocci, G. Caldarelli, P. De Los Rios,
  Physical Review E 68 047101 (2003).
- Dynamic Fracture Model for Acoustic Emission.
  M. Minozzi, G. Caldarelli, L. Pietronero, S. Zapperi,
  European Physical Journal B 36 203 (2003).
- The Drainage Basins Trees in Mars Channel Networks.
  G. Caldarelli, P. De Los Rios, M. Montuori, V.D.P. Servedio,
  in press on European Physical Journal B ArXiv:cond-mat/0107228 (2003).
- Generalized Network Growth: Microscopic Strategies and Real Internet Properties.
  G. Caldarelli, P. De Los Rios, L. Pietronero,
  submitted to Physical Review Letters ArXiv:cond-mat/0307610 (2003).
- Assortative model for social networks.
  M. Catanzaro G. Caldarelli, L. Pietronero,
  submitted to Physical Review Letters ArXiv:cond-mat/0308073 (2003).
- Generation of Scale Free Random Networks within the Formalism of Hidden Variables.
  V.D.P. Servedio G. Caldarelli, P. Buttà,
  submitted to Physical Review Letters ArXiv:cond-mat/0309659 (2003).

- Cycles structure and local ordering in complex networks.
  G. Caldarelli, R. Pastor-Satorras, A. Vespignani,
  submitted to Physical Review E ArXiv:cond-mat/0212026 (2003).
- Number of h-cycles in the Internet at the Autonomous System Level.
  G. Bianconi, G. Caldarelli, A. Capocci,
  submitted to Physical Review Letters ArXiv:cond-mat/0310339 (2003).
- The scale-free Topology of market investments.
  D. Garlaschelli, S. Battiston, M. Castri, V.D.P. Servedio and G. Caldarelli,
  submitted to Physical Review Letters ArXiv:cond-mat/0310503 (2003).
- On the Widespread Occurrence of the Inverse Square Distribution in Social Sciences and Taxonomy.
  G. Caldarelli, C. Caretta Cartozo, P. De Los Rios and V.D.P. Servedio
  submitted to Physical Review E ArXiv:cond-mat/0311486 (2003).
- Dynamic Graph Algorithms
  C. Demetrescu, I. Finocchi, and G.F. Italiano
  in Handbook of Graph Theory, chapter 10.2, J. Yellen e
  J.L. Gross eds., CRC Press, Discrete Mathematics and Its Applications,
  ISBN 1-58488-090-2, December 2003.
- Experimental Analysis of Dynamic All Pairs Shortest Path Algorithms,
  C. Demetrescu, S. Emiliozzi, and G.F. Italiano
  to appear in
  Proceedings of the 15th Annual ACM-SIAM Symposium on Discrete
  Algorithms (SODA'04), New Orleans, LA. January 2004. Also Technical
  Report ALCOM-FT, ALCOMFT-TR-03-9, July 2003.
- Combinatorial Algorithms for Feedback Problems in Directed Graphs,
  C. Demetrescu and I. Finocchi
  Information Processing Letters 86 (IPL), pp. 129-136
- A Portable Virtual Machine for Program Debugging and Directing,
  C. Demetrescu and I. Finocchi
  to appear in Proceedings of the 19th ACM
  Symposium on Applied Computing (SAC'04) - Software Engineering
  Track. Also technical Report ALCOM-FT, ALCOMFT-TR-03-1, March 2003.
- A System for Building Animated Presentations over the Web,
  B.A. Colombo, C. Demetrescu, I. Finocchi, and L. Laura
  Proceedings of the AICCSA'03 Workshop on Practice and Experience with
  Java Programming in Education, Tunis, July 2003.
- Optimization as a result of the interplay between dynamics and structure,
  Mateu Llas, Pablo M. Gleiser, Albert Diaz-Guilera, Conrad J. Perez,
  Physica A 326 (2003) 567.
- Search and Congestion in Complex Networks,
  R. Pastor-Satorras, M. Rubi, and A. Diaz-Guilera
  Proceedings of the
  Conference "Statistical Mechanics of Complex Networks", Sitges, Spain,
  June 2002; , eds., Springer (2003)
- Statistical Mechanics of Complex Networks, editor. Proceedings of
  the Conference "Statistical Mechanics of Complex Networks", Sitges,
  Spain, June 2002, Springer (2003)
- The Influence of Network Structures in a Model of Technological
  Evolution, Modelling and Control of Economic Systems, edited by
  R. Neck, Elsevier (2003).
- Nonequilibrium phase transition in a model for the propagation of innovations among economic agents,
  M. Llas, P. M. Gleiser, J. M. Lopez, A. Diaz-Guilera,
  Physical Review E 68 (2003) 066101.

- Self-similar community structure in a network of human interactions.
  R. Guimer`a, L. Danon, A. Diaz-Guilera, F. Giralt, and A. Arenas,
  Physical Review E 68 (2003), 065103(R).
- Comentarios a "El problema del mundo pequeño" de S, Milgram,
  Albert Díaz-Guilera, Alex Arenas, Roger Guimerà,
  Araucaria 10 (2003) 29.
- Community analysis in social networks
  Alex Arenas, Leon Danon, Albert Diaz-Guilera, Pablo M. Gleiser, Roger Guimera
  European Physics Journal B (in press), cond-mat/0312040
- Nonequilibrium phase transition in a model for the propagation of innovations among economic agents
  M. Llas, P. M. Gleiser, J. M. Lopez, A. Diaz-Guilera
  Phys. Rev. E 68 (2003), 066101
- Emergence of clustering, correlations, and communities in a social network model
  Marian Boguna, Romualdo Pastor-Satorras, Albert Diaz-Guilera, Alex Arenas
  cond-mat/0309263
- Experiments on graph clustering algorithms.
  In: Proceedings of the 11th Annual European Symposium on Algorithms (ESA'03), volume 2832 of Lecture Notes in Computer Science, pages 568 - 579. Springer-Verlag Heidelberg, September 2003.
  Joint work with Ulrik Brandes and Dorothea Wagner.
- Master curve for price-impact function,
  F. Lillo, J.D. Farmer and R.N. Mantegna
  Nature 421, 129-130 (2003).
- Topology of correlation-based minimal spanning trees in real and model markets
  Bonanno G, Caldarelli G, Lillo F, et al.
  PHYS REV E 68 (4): art. no. 046130 Part 2 OCT 2003
- Power-law relaxation in a complex system: Omori law after a financial market crash
  Lillo F, Mantegna RN
  PHYS REV E 68 (1): art. no. 016119 Part 2 JUL 2003
- Preface of the International Scientific Organizing Committee
  Stanley HE, Ausloos M, Kertesz J, et al
  PHYSICA A 324 (1-2): XV-XVI JUN 1 2003
- **Micciche S, Bonanno G, Lillo F, et al.**
  Degree stability of a minimum spanning tree of price return and volatility
  PHYSICA A 324 (1-2): 66-73 JUN 1 2003
- **Capocci A, Caldarelli G, De Los Rios P**
  Quantitative description and modeling of real networks
  PHYS REV E 68 (4): art. no. 047101 Part 2 OCT 2003
- **Moelbert S, De Los Rios P**
  Chaotropic effect and preferential binding in a hydrophobic interaction model
  J CHEM PHYS 119 (15): 7988-8001 OCT 15 2003
- **Moelbert S, De los Rios P**
  Hydrophobic interaction model for upper and lower critical solution temperatures
  MACROMOLECULES 36 (15): 5845-5853 JUL 29 2003
- **Yersin A, Hirling H, Steiner P, et al.**
  Interactions between synaptic vesicle fusion proteins explored by atomic force microscopy
  P NATL ACAD SCI USA 100 (15): 8736-8741 JUL 22 2003
- **Munoz MA, Pastor-Satorras R**
  Stochastic theory of synchronization transitions in extended systems
  PHYS REV LETT 90 (20): art. no. 204101 MAY 23 2003
- **Frigioni D, Marchetti-Spaccamela A, Nanni U**
  Fully dynamic shortest paths in digraphs with arbitrary arc weights
  J ALGORITHM 49 (1): 86-113 OCT 2003
- **Bonuccelli M, Marchetti-Spaccamela A**

Special Issue - Algorithmic Aspects of Communication - University of Bologna, Italy 12 July 1997 - Foreword
DISCRETE APPL MATH 129 (1): 1-1 JUN 15 2003

- **Antonio Turiel, Jean-Pierre Nadal and Nestor Parga**
  Orientational minimal redundancy wavelets: from edge detection to perception
  Vision Research 43:9 (2003) pp 1061-1079.
- **David Philipona, Kevin O'Regan and Jean-Pierre Nadal**
  Is there something out there? Inferring space from sensorimotor dependencies
  Neural Computation Vol 15:9 (Sept. 2003) pp 2029-2049.
- **Jean-Pierre Nadal, Denis Phan, Mirta B. Gordon and Jean Vannimenus,**
  WEHIA 2003, May 29-31, Kiel
  "Monopoly Market with Externality: an Analysis with Statistical Physics and Agent-based Computational Economics"
- **Phan D., Pajot S. Nadal J.P.**,
  Ninth annual meeting of the Society
  of Computational Economics, University of Washington, Seattle, USA,
  July 11 - 13, 2003
  "The Monopolist's Market with Discrete Choices and Network Externality Revisited: Small-Worlds, Phase Transition and Avalanches in an ACE Framework"
- **Boguna M, Pastor-Satorras R**
  Class of correlated random networks with hidden variables
  PHYS REV E 68 (3): art. no. 036112 Part 2 SEP 2003
- **Munoz MA, Pastor-Satorras R**
  Stochastic theory of synchronization transitions in extended systems
  PHYS REV LETT 90 (20): art. no. 204101 MAY 23 2003
- **Vazquez A, Boguna M, Moreno Y, et al.**
  Topology and correlations in structured scale-free networks
  PHYS REV E 67 (4): art. no. 046111 Part 2 APR 2003
- **Pastor-Satorras R, Smith E, Sole RV**
  Evolving protein interaction networks through gene duplication
  J THEOR BIOL 222 (2): 199-210 MAY 21 2003
- **Moreno Y, Pastor-Satorras R, Vazquez A, et al.**
  Critical load and congestion instabilities in scale-free networks
  EUROPHYS LETT 62 (2): 292-298 APR 2003
- **Boguna M, Pastor-Satorras R, Vespignani A**
  Absence of epidemic threshold in scale-free networks with degree correlations
  PHYS REV LETT 90 (2): art. no. 028701 JAN 17 2003
- **Tadic B**
  Modeling traffic of information packets on graphs with complex topology
  LECT NOTES COMPUT SC 2657: 136-143 2003
- **Vespignani A**
  Evolution thinks modular
  NAT GENET 35 (2): 118-119 OCT 2003
- **Castellano C, Vilone D, Vespignani A**
  Incomplete ordering of the voter model on small-world networks
  EUROPHYS LETT 63 (1): 153-158 JUL 2003
- **Percacci R, Vespignani A**
  Scale-free behavior of the Internet global performance
  EUR PHYS J B 32 (4): 411-414 APR 2003
- **Vazquez A, Boguna M, Moreno Y, et al.**
  Topology and correlations in structured scale-free networks
  PHYS REV E 67 (4): art. no. 046111 Part 2 APR 2003
- **Moreno Y, Pastor-Satorras R, Vazquez A, et al.**
  Critical load and congestion instabilities in scale-free networks
  EUROPHYS LETT 62 (2): 292-298 APR 2003
- **Weisbuch G, Stauffer D**

Adjustment and social choice
PHYSICA A 323: 651-662 MAY 15 2003

- **Battiston S, Bonabeau E, Weisbuch G**
  Decision making dynamics in corporate boards
  PHYSICA A 322 (1-4): 567-582 MAY 1 2003
- **A.Diaz-Guilera, R.Guimera, A.Arenas, F.Vega-Redondo, A.Cabrales**
  Search and congestion in complex networks,
  Proceedings of the conferences "Statistical mechanics and complex networks",
  Siteges Spain, Spring 2003

2004 publications

- **Caldarelli G., Battiston S., Garlaschelli D., Catanzaro M.,**
  Emergence of Complexity in Financial Networks,
  to appear in Lecture Notes in Physics, special volume on "Complex Networks", Springer.
- **Ulrik Brandes, Tim Dwyer and Falk Schreiber,**
  Visual Understanding of Metabolic Pathways Across Organisms Using Layout in Two and a Half
  Dimensions.
  Journal of Integrative Bioinformatics 0002, 2004.
- **Ulrik Brandes, Tim Dwyer, and Falk Schreiber**
  Visual Triangulation of Network-Based Phylogenetic Trees.
  Proc. 6th Joint Eurographics - IEEE TCVG Symp. Visualization (VisSym '04). © Eurographics, to appear.
- **Ulrik Brandes, Sabine Cornelsen, Christian Fieß, and Dorothea Wagner,**
  How to Draw the Minimum Cuts of a Planar Graph. Computational Geometry: Theory & Applications,
  to appear.
- **Ulrik Brandes, Frank Schulz, Dorothea Wagner, and Thomas Willhalm,**
  Generating Node Coordinates for Shortest-Path Computations in Transportation Networks. ACM Journal of Experimental Algorithmics,
  to appear.
- **Ulrik Brandes, Tim Dwyer, and Falk Schreiber**,
  Visualizing Related Metabolic Pathways in Two and a Half Dimensions. Proc. 11th Intl. Symp. Graph Drawing (GD '03), LNCS 2912, pp. 111-122. © Springer-Verlag, 2004.
- **Ulrik Brandes, Sabine Cornelsen, and Dorothea Wagner**
  Characterizing Families of Cuts that can be Represented by Axis-Parallel Rectangles. Proc. 11th Intl. Symp. Graph Drawing (GD '03), LNCS 2912, pp. 357-368. © Springer-Verlag, 2004.
- **Franz J. Brandenburg, Ulrik Brandes, Peter Eades, and Joe Marks**
  Graph Drawing Contest Report. Proc. 11th Intl. Symp. Graph Drawing (GD '03), LNCS 2912, pp. 504-508. © Springer-Verlag, 2004.
- **Phan D., Gordon M. B. and Nadal J.-P.**,
  "Social Interactions in Economic Theory: an Insight from Statistical Mechanics",
  in Cognitive Economics - an interdisciplinary approach,
  Bourgine P. and Nadal J.-P. eds., Springer
  2004 to appear,

Appendix E. Key figures

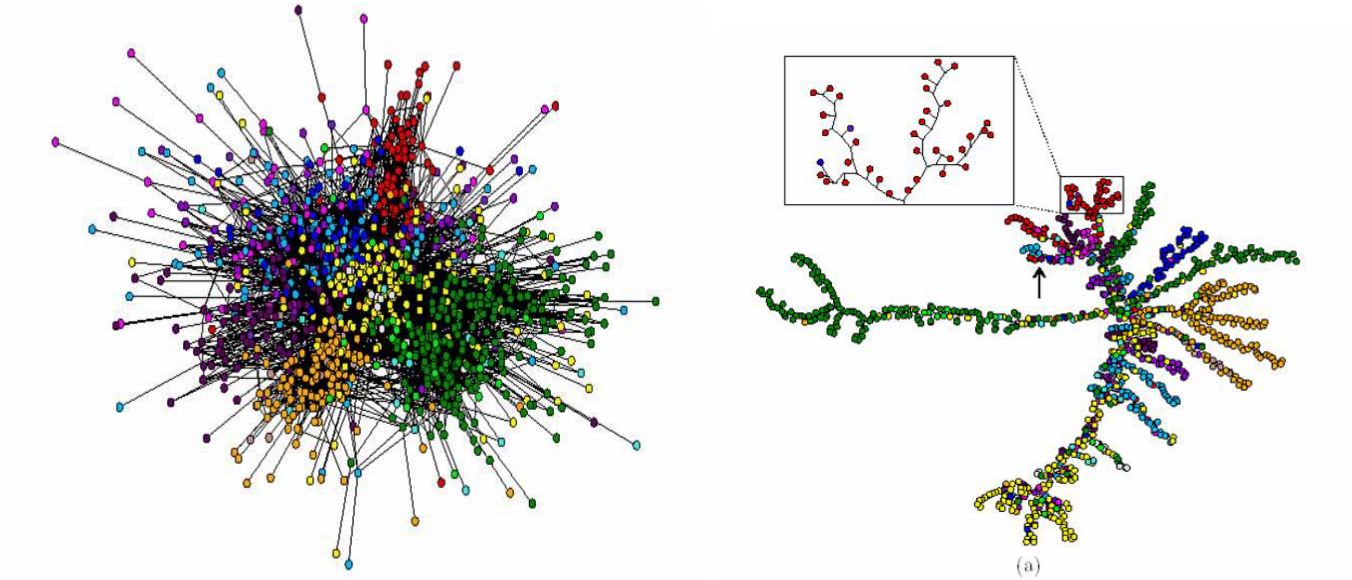


Figure 1:The network of different e-mails exchanged in the University of Tarragon. Different colors refer to different Departments. On the right the division of the graph in the main communities (After Arenas et al.)

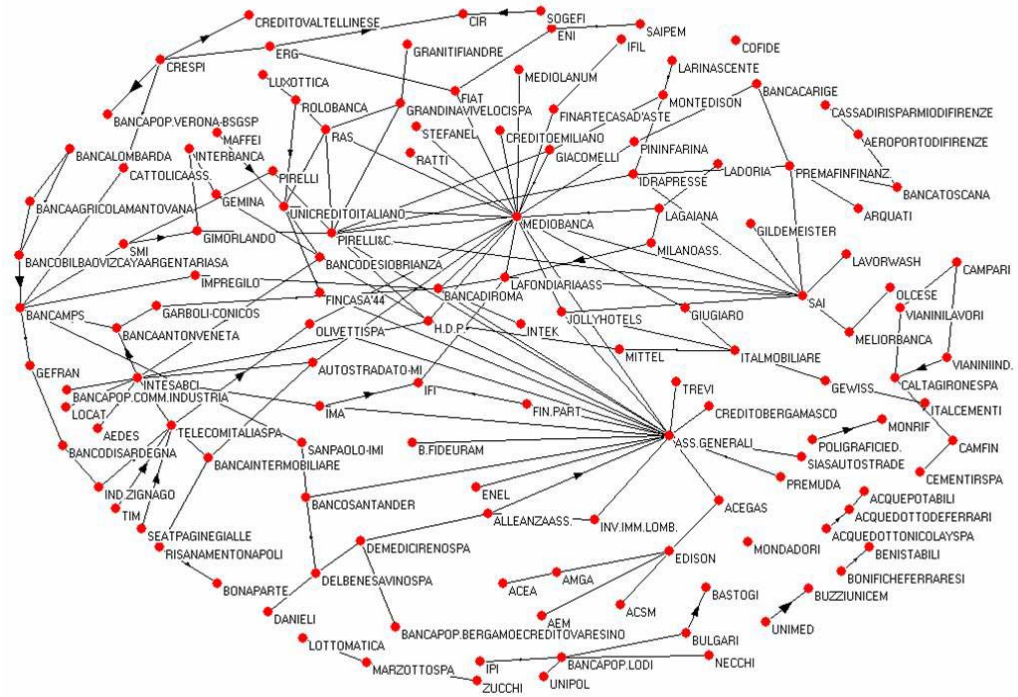


Figure 2:The network of ownerships between the companies traded at Milano(Italy) stock exchange

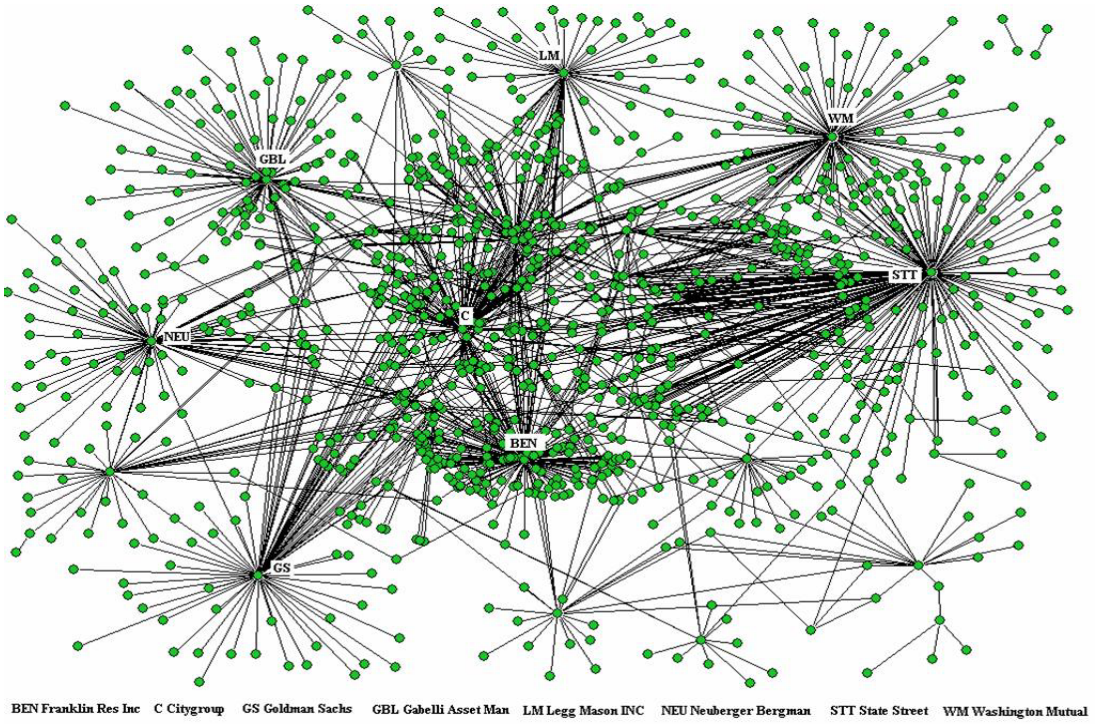


Figure 3:The network of ownerships between the companies traded at New York stock exchange

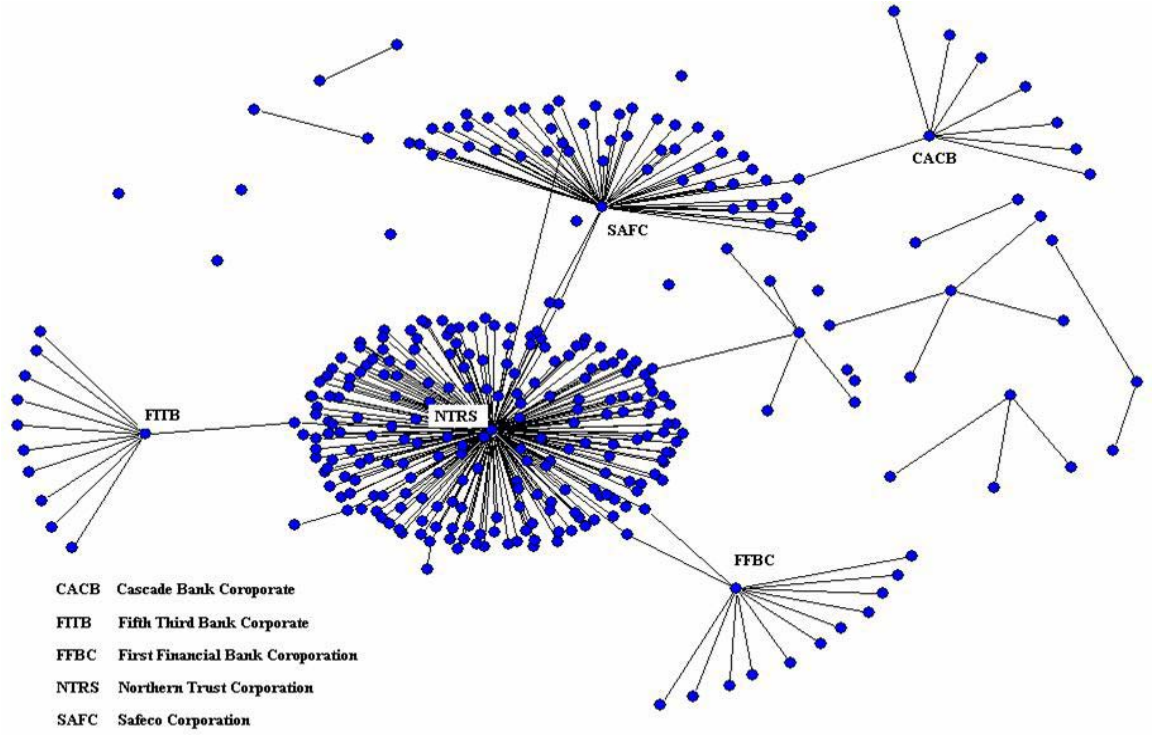


Figure 4:The network of ownerships between the companies traded at Nasdaq stock exchange