INFORMATION SOCIETY TECHNOLOGIES
(IST)
PROGRAMME

Contract for:

Shared-cost RTD

Annex 1 - "Description of WORK"

Project Acronym: **COSIN**

Project full title: **COevolution and Self-organization In dynamical Networks**

Proposal/Contract no.: **IST-2001-33555**

Related to other Contract no.:

Date of preparation of Annex 1: **16/11/2001**

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Major changes from original version:

- **CHANGES OF 17/06/2003**
  - **Description of Subcontractor UR3 (University of Roma 3) for partner UDRLS (University of Roma "La Sapienza")**
  - **End of collaboration with partner UKON (University of Konstanz)**
  - **Added new partner UNIKARL (University of Karlsruhe)**
  - **Added new partner UPSUD (University of Paris Sud)**
- **CHANGES OF 17/10/2004**
  - **Shift of 6 months in final date of contract and delivery of deliverable D19,D20,D21,D22,D23,D24,D26,D27,D2**
  - **End of Collaboration with partner UNIL (Universite' de Lausanne)**
  - **Added partner EPFL (Ecole Polytechnique Federale de Lausanne)**

Operative commencement date of the contract: 01/03/2002

Content List

1 Project Summary

1.1 Objectives

The aim of this project is to develop a unified set of Complex Systems theoretical methodologies for the characterization of Complex Networks, helping addressing fundamental question about stability, efficiency and functionality of these networks. We shall concentrate the research activity on the structures originated by the) interplay of different agents in information society as the Internet network, the World Wide Web structure and the social and economic networks. In particular we intend to find a set of new tools for the analysis and the simulation of very large networks; devise efficient algorithms for measuring the relevant characteristics of such networks and for visualizing their evolution at different scales. We shall also show that such tools can help in addressing the real-world problems faced in ITS technology as well as in the social studies.

1.2 Description of Work

The study of the dynamics of complex networks requires an interdisciplinary approach that will use methodologies developed in different areas. Complex Systems theory is the natural candidate framework for the study of such networks. It provides a unified language and a set of operative tools to address the fundamental issues involved in the study of such systems. In this framework we want to devise common methodologies for running empirical simulations, computing the relevant quantities on the simulated models and on real samples and visualizing the evolution of networks even on very large dimensions. The unifying feature of these networks is that their global structure and dynamical evolution are the result of locally interacting agents distributed in the system. Shape of the network and agent requests co-evolve to form the final structure. We plan to devise new stochastic models for Internet to be validated through an extensive comparison with a multi-view observation from different locations. We also want to devise content sensitive stochastic models of the world Wide Web where documents link to other documents that are relevant for a common subject of interest. The study of such large networks require the development of ad-hoc visualization algorithms and data structures for drawing and browsing virtually infinite structures rapidly evolving in time. We shall also consider the analysis of social and economic networks as cyber communities, correlations between stocks and firm etc. We finally want to test the existing models for the Internet and the World Wide Web by comparing the behaviour of suitable quantities identified through theoretical analysis and large computer simulations. In particular we refer to the various frequency distributions observed in real samples as the degree distribution, the number of hops required to reach boundary of the system etc.

1.3 Milestones and expected results

- Realization of a stochastic model for the Internet.
- Realization of a stochastic model for the World Wide Web.
- Realization of a stochastic model for the social networks.
- Tools for visualizing large scale networks.

We expect at the end of this project to have also a common framework of knowledge in order to proper describe growing networks and Complex Systems in general.

2 Project Objectives

Dynamics and growth of networks shape today's informational and social phenomena, ranging from the Internet and the WWW to economical networks and financial networks. The unifying feature of these networks is that their global structure and dynamic evolution are the result of locally interacting agents. Under this respect growing networks represent a particular case of the class of complex systems. The main challenge we approach in this project is to give a quantitative description of complexity through the study of the networks with the goal of describing how complex behaviour could arise from microscopic interactions.

The field of growing network represents the paramount case of study of this class of phenomena and furthermore present the possibility to validate the different theories and models on the onset of complexity through the huge amount of data available (for the Internet mapping see for example [1,2,3]). As for a non-rigorous characterization of complexity at least in Physics, we refer to the class of phenomena, like deposition, corrosion, cracking, growth of colonies and in general all the phenomena where the simple basic interactions between agents are such that to produce self-similar structures [4]. These self-similar or fractal (i.e. they show the same shape at any level) structures are rather peculiar since they show correlation in shape at large distances both in space and in time (*a priori* this correlation is unpredictable from the microscopical dynamics). This mathematical property of self-similarity (i.e. to look the same at different scales) has been also called *criticality* in physics in relationship with the critical phenomena of phase transitions in thermodynamics. The mathematical signature of complexity is the presence of power-law distributions for the quantities of interest. Whilst for few of these phenomena the fundamental reason of the onset of complexity has been recovered in the interplay between a Laplacian field (i.e. diffusion of agents) with a random environment [5], for a large class of phenomena the reason of this self-organisation still has to be presented [6,7].

Growing networks presents all the properties that we introduced in a non-rigorous way here. They effectively start from a small collections of vertices (or nodes) and arcs (or links) and through continuous growth, they develop some nontrivial *complex* features whose signatures are several power-law distributions [8,9,10] as for example in the distributed frequency function of the number of links per node and of the in-degree distribution (the set of nodes "uphill" in the spanning tree of the subgraph connected to a node in a oriented graph). These are only few of the possible measure in order to quantitatively characterise networks. Others measures of interest that are computationally harder to model and to test are the clusterisation of the vertices, the distribution of cliques in order to evaluate size and distributions of communities [11,12,13] or phenomena like the small-world [14] (suitable shortcuts reduce the main distance between vertices to a characteristic small value [15,16]) that arises as soon as the network reaches a stationary state and can be used to measure the efficiency of the net.

From a mathematical point of view, complex networks are sets of many interacting components whose elaborate collective behaviour cannot be directly predicted and characterised in terms of the behaviour of their individual components. When the interaction between single components are suitably modelled, components can describe many different real-world units such as Internet providers, electricity providers, economical agents, ecological species, etc. and the dynamics of the whole system can describe the emerging global behaviour such as the Internet traffic, electricity supply service, market trend, environmental resources depletion etc.

This project will study complex networks focusing its attention on specific networks like Internet and WWW that are critical in the IST and on social networks that model relationships in company. Namely, the aim of this project is threefold:

1. we intend to develop a unified set of Complex Systems theoretical methodologies for the characterisation of all Complex Networks, helping addressing fundamental questions about stability, efficiency and functionality of a network. There are, in particular two basic questions extremely relevant for the applications, besides their theoretical interest:

    - How local interactions can be put in relation with a specified global behaviour?
    - What features of the local interaction makes a network stable against perturbations, thus preserving its functionality?

2. we intend to develop a set of tools for the analysis, the simulation and the visualization of very large networks. In particular we will devise efficient algorithms for measuring the relevant characteristics of such networks, and we will use these algorithms to collect data on Internet and WWW.

    Furthermore we will study efficient visualizing methods for such large networks. The study of graph drawing algorithms has produced a several layout tools and many algorithms that can be applied in many areas [17] [18], the visualization of huge networks is still at a preliminary state and many open questions remain [19][20]. In this project we focus on how the underlying structure of the network can be exploited in the design of graph drawing tools and how it is possible to design tools that allow visualizing their evolution at different scales.

3. we will show how such tools can be applied to real-world problems faced in IST technology and economical and social networks. We will consider social networks that model the relationships in a firm and in firms in the same business area. In particular we will focus our attention on the study of how the evolution of the network influences its dynamic properties (i.e. the parameters that characterise the interactions among the agents).

   We will also consider the communication networks focusing our attention on Internet and WWW. Internet can be naturally modelled as a network whose vertices are the routers and whose arcs are the links connecting the routers. For its role in the IST society, the efficiency and robustness of Internet is extremely important; however we remark that the size of Internet is such that the study of parameters that describe its efficiency and robustness can be done using the tools of complex networks.

   Similar considerations hold if we consider the WWW; in this case suitable models of the WWW are the base for the design of tools such as search engines [21], [22]. Finally we observe that the definition of suitable mathematical models that adequately represent Internet and WWW allows to simulate new applications and protocols whose efficiency is influenced by the structure of the network (e.g. proxy cache).

We believe that it is extremely important, for future development and investments, that the European Union could benefit from a community of scientists sharing a common expertise in this field and a realistic view on the possible practical applications. Our project extends on a period of 3 years and we therefore request a RTD project.

3 List of Participants

List of Participants

Partic. Role	Partic. No.	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	1	Istituto Nazionale per la Fisica della Materia	INFM	Italy	Start of project	End of Project
CR	2	Università di Roma "La Sapienza"	UDRLS	Italy	Start of project	End of Project
CR	3	Universitat de Barcelona	UB	Spain	Start of project	End of Project
CR	4	Universitè de Lausanne	UNIL-EPFL	Switzerland	Start of project	24
CR	5	Ecole Normale Superieure	ENS	France	Start of project	End of Project
CR	6	Universitaet Konstanz	UKON	Germany	Start of project	Month 12
CR	7	Universitaet Karlsruhe	UNIKARL	Germany	Month 13	End of Project
CR	8	Université Paris Sud	UPSUD	France	Month 13	End of Project
CR	9	Ecole Polytechnique Federale de Lausanne	EPFL	Switzerland	Month 25	End of Project

Partner CR2 UDRLS (Universit di Roma "La Sapienza") is going to subcontract UR3 (University of Rome 3) for the activity on graph drawing.

The partner CR4 UNIL (Université de Lausanne) has been absorbed by the Ecole Polytechnique Federale de Lausanne, who agreed in honouring all the existing contracts stipulated by UNIL. No modification whatsoever is then happening in the scientific activity of the partner EPFL.

4 Contribution to Programme/Key Action objectives

The main contribution is to the objectives of the action "Future and Emerging Technologies", where projects are required to be "of a longer-term or particularly high risk nature, but which promise major advance and potential for significant industrial and societal impact".

Our research is clearly of a longer-term nature and parts of it are also risky since our goals are well-ahead of the current state of the art. However, we do expect methodological breakthroughs in the area of modeling and visualizing complex networks such as Internet and the WWW. We also think that the collected data and the the tools that will be developed will be an important contribution to the rapid transfer of data and techniques aimed at future and emerging technologies. In fact there is a general expectation from firms and governments about the possibility of a rational optimisation of performances and of visualizing such networks.

Our research addresses, on a long-term base, the objectives of some of the key actions of the IST Programme. In fact, the dissemination of the WWW and Internet has deeply modified the society allowing a simple and universal access to great amounts of information and services. This resulted in a new economy based on services supplied through the network, in new possibility for education and training. Improved communication between individuals also affected the modalities of job in the old economy and the relationship with the institutions.

Understanding the structure of the WWW and of Internet must therefore be considered of great importance for the objectives of the key action (ii) "New methods of work and electronic commerce", that is "to enable both individuals and organisations to innovate and be more effective and efficient in their work and businesses, thus increasing their competitiveness while improving the quality of the individuals working life and consumer confidence."

Our project also aims to collect data and to provide tools that will help in the design and test of new services and products. In fact public data on the Internet and on the WWW are a valuable source of information for companies and for the study of cyber-communities. We also refer to the design of improved search engines that base their strategy of classification of the importance of the pages by knowing the WWW structure (e.g. Google at `http://www.google.com`).

In this way we contribute - on a longer term base - to the goals of the key action (iv) "Essential technologies and infrastructures", by contributing to "the development of these technologies and infrastructures common to more than one application, enhance their applicability and accelerate their take-up in Europe".

5 Innovation

Complex web-like structures describe a large series of natural phenomena. Some example can range from the complex networks of routers and computers that form Internet and the hyper-links that connect the WWW pages to the social networks where nodes are represented by persons connected by various kinds of social relationships.

We also observe that networks are present in many aspects of the nature, from the watershed where the rivers water is collected, to the veins and lymphatic channels that distribute blood and nutrition in animals and plants, to the telephone or electricity or Internet webs that transport in our houses the services we need. Even in biology one can describe proteins and macromolecules as a complex series of nodes (basis chemicals) connected by chemical reactions.

This project is innovative in at least the following respects

- the content of the project
- the concrete research ideas and objectives
- the interdisciplinary approach

We expect a significant, innovative and "trend-setting" contribution from the project in all three respects.

Content of the project

A burst of activity recently prompted by the scientific community in order to understand the mechanisms that determine the topology of networks such as Internet and WWW. The desire to understand such interwoven systems has brought along significant challenges that are still open and that will have a long term impact on the IST. Also the huge dimensions of Internet and of the WWW makes their visualisation a tantalizing problem.

The project aims to provide satisfactory new models for complex networks such as WWW and Internet and to provide new tools that allow to visualise such huge networks. We remark that existing models are not completely adequate. For instance WWW web pages are characterised by the presence of cliques that can be only partially reproduced by the clustering coefficient and are not satisfactorily explained by any of the known models. On the other side, Internet present a regularity in the structure of connections at a large scale that is ignored by the present state of art.

The most important aspect with respect to the research goals is the identification of the mutually related aspects of characterising and visualising several evolving complex networks. The goal is to develop tools and methodologies that are applicable to different networks. We do not expect that different networks (e.g. Internet and WWW) share the same characteristics and behaviour; however we believe that the above different complex systems are able to self-organise in states with similar properties that we want to identify, measure and exploit in their visualisation.

These goals are strongly related to the objectives of the program key action iv whose goal is "the development of these technologies and infrastructures common to more than one application, enhance their applicability and accelerate their take-up in Europe".

Concrete research ideas and objectives

The work-plan contains several innovative concrete research ideas. We mention just the most important ones:

- To collect a "European" set of data concerning the Internet network and Internet data traffic that will be publicly available.

  Even though there exists several views of the Internet graph from a United States perspective, to the best of our knowledge, a European perspective is still missing.

- To develop a visualisation tool that is applicable to extremely large networks. The ability of drawing very large computer networks is of great significance in visualizing the evolution of stochastic models for evolving networks. We intend to develop systems that show maps of the Web and support the user during 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.

- To develop tools for the identification and the study of cyber-communities. This point focuses primarily on the evaluation of cliques distribution and clustering in the WWW graph.

- To study dynamical aspects of communication flow in complex networks: for instance flow of packets in the Internet or virus spreading through the web or email-address-book networks.
- To develop tools for the study of the Internet graph that allows to study the change in time of some state variable of the nodes. We mean that we want to monitor the dynamics of the evolution in order to detect if some optimisation of some cost function takes place during the network dynamics.

  We remark that features like robustness against external solicitation are of enormous importance for each of the systems considered. Furthermore the topology of such networks could be shaped by the request to optimise global functional cost functions. All this points are new in the literature and they will be investigated; the collected data will be made public.

In this way we comply with the strategy of the IST Programme to characterise “a specific European added value” and to increase European competitiveness by developing applications “accessible and usable by anyone, anywhere, anytime, whether it be for business or individual use”.

Interdisciplinary approach

The interdisciplinary approach to the study of complex networks is based on tools and methodologies arising in the different areas of complex systems, combinatorial algorithms and visualisation methods. The consortium behind the project consists of members with a different background (Physics, Computer Science, Social Science) that will share their expertise to tackle the project goals with an interdisciplinary approach.

The motivation for such an approach is twofold. First models of complex networks such as WWW and Internet have been proposed in different communities, but none of the known approaches is adequate; secondly the visualisation problem of such huge networks require a tight cooperation between experts in the modeling and in the design of visualisation tools.

The starting point of this study of complex networks can be found in the graph theory. Random graphs[23] were introduced by the seminal work of the mathematicians P. Erdős and A. Rényi. The graph is composed by N nodes fixed, and the connected two by two with a probability p. The randomness of connections, whilst useful to describe properties of static networks, fail completely to describe evolving situation where the number of nodes grows continuously. Such complex systems displays some organizing principles which should be at some level encoded in their topology. Since the topology of these networks indeed deviates from a random graph, the state of the art today is to develop tools and measures to capture in quantitative terms the underlying organizing principles.

A class of models, collectively called small world models, have been proposed in the sixties to describe the fact that despite their often large size, in most networks there is a relatively short path between any two nodes. The most popular manifestation of ”small worlds” is the ”six degrees of separation” concept, uncovered by the social psychologist Stanley Milgram [16], who showed that there was a path of acquaintances of length about six between most pairs of people in the United States [15]. The small world property appears to characterise most complex networks: the actors in Hollywood are on average within three co-stars from each other, or the chemicals in a cell are separated typically by three reactions. The small world concept, while intriguing, is not an indication of a particular organizing principle and is not adequate to completely model the networks studied in the project.

More recently, the discovery of the power-law degree distribution has led to the construction of various scale-free models that, by focusing on the network dynamics, aim to explain the origin of the power-law tails and other non-Poisson degree distributions observed in systems such as the WWW and Internet.

Given the current state of the art, Information Technology with the background of knowledge in traditional graph theory and Physics through its reductionist approach seems to be the natural candidate to face the challenge to find a unifying view in the framework of Complexity, for the above described phenomena. Namely, our approach will be to adopt the tools and frameworks of the unifying framework of Complex Systems; this approach would help to apply the results in different fields and to better understand problems whose underlying structure is clearly similar.

This interdisciplinarity is an innovative aspect of the project that as suggested by the IST Programme “properly reflects and exploits the EU’s cultural diversity and many languages”.

6 Community added value and contribution to EC policies

The dissemination of the WWW and Internet has deeply modified the society allowing a simple and universal access to great amounts of information and services. This resulted in a new economy based on services supplied through the network and in new possibility for education and training. Improved communication between individuals also deeply affected the modalities of jobs in the old economy and the relationships with the institutions. WWW and Internet are two examples of growing networks; other examples are economic networks, social networks but examples are known also in other areas such as biology. The unifying feature of these networks is that their global structure and dynamic evolution are the result of locally interacting agents. Under this respect they represent a particular case of the class of complex systems.

The main challenge of this project is to give a quantitative description of these networks studying the related issues of modelling, and visualizing. We remark that the current dimensions of these networks makes the problem of their representation and their visualization a tantalizing problem that is beyond the current state of the art. Such a challenge is not of interest for a theoretical community interested in understanding such networks but has also a (long-term) economic and social impact that will contribute to the EC's policies. Indeed communication is a major resource for European business activity and the number of individuals and enterprises using Internet and WWW pages is expected to significantly increase over the next years. Under this respect even little progress in the knowledge of the properties of communication networks may cause a substantial improvement in their features, and will allow to give the opportunity to expand business activities in Internet, to define new business practices and to provide high quality and affordable services of general interest for the citizen.

This fits with the cross Programme theme of Future and Emerging Technologies giving *"new research ideas for tomorrow"* with *"a visionary and exploratory perspective"* that promise *"major advance and potential for significant industrial and societal impact"*. We will motivate this expectation with few striking examples that are not exhaustive.

Searching the WWW

The dramatic growth in the available information in the WWW is such that access to this information is not always possible for the interested users or it is inefficient and requires a long time of navigation. In fact it is well known that search engines often fail because the information requested by the user is hidden in a large amount of related but not interesting information and that there are a number of ways for artificially increasing the visibility in the WWW. This issue is also related to the possibility of giving voice to the typical unheard whose opinion is hidden and that limits the "apparent" democracy of the WWW.

We observe that related issues that will allow to develop new business opportunities are represented by the possibility of developing tools that actively support the user in her/his search by filtering non interesting information and/or providing possible relevant information that was unknown to the user.

In this way we contribute - on a longer term base - to the key action "New methods of work and electronic commerce" *by enabling both individuals and organisations to innovate and be more effective and efficient in their work and businesses"*.

Representing Internet

The test of new Internet protocols and services of can be better performed if a subset of the network representative of the whole structure is available. Unfortunately this is a problem of very difficult solution, since even a uniform sampling of one single page of the WWW is not available at the moment. The determination of a mathematical model of the structure of the WWW would supply therefore an important step in order to produce the samplings desired.

We observe that nowadays there are representation of the Internet graph that have a North-American perspective (i.e. they represent Internet form the point of view of a US node) but an "European" point of view of Internet is missing. We observe that in current representations of Internet most of European links are missing and, therefore the possibility of representing and visualizing Internet traffic is a necessary support for its rational optimization and exploitation.

In this way we contribute - on a longer term base - to the key action " Essential technologies and infrastructures" *by furthering the development of these technologies and infrastructures common to more than one application, enhance their applicability and accelerate their take-up in Europe"*.

Social network characterization

The study of social networks focusses on the patterning of social linkages among agents. These agents could be comprised of different types such as animals, humans, artificial agents, firms or organizations and it is assumed that the behavior and lives of social entities are affected by their position in the overall social structure.

We plan to study these networks by studying their dynamic behaviour and the emergence of structure throughout evolution. We will focus our attention on networks arising in firms and we will examine the consequences of structural forms, of the location of entities within these structures, and of the formation and dynamics of ties that make up these structures.

We also observe that the WWW has allowed the development of social relationships commonly known as "cyber-communities". The traditional way of identifying such a community is based on the detection of a set of WWW pages (the "community") that are highly linked among themselves. Preliminary study observed that the number of such highly interconnected pages is quite large in the current WWW. However, the necessary information on such communities is not available to social researchers for the difficulties in developing/accessing the sophisticated technological tools that are necessary for studying the WWW network. We observe that the study of cyber-community will also provide useful information to government for developing new services for the citizen.

In this way we contribute - on a longer term base - to the key action "Systems and services for the citizen" *by meeting the needs and expectations of European citizens for high quality and affordable services of general interest"*.

European dimension

We believe that such a research can be carried out only with a unifying common view that can be formed by joining people from different areas as Physics and Information Technology. In fact, the breadth, the depth and the interdisciplinarity approach of the project makes sense if it is carried out at a community level: no individual member has the required number of researchers and different expertise. It is therefore crucial to reach a critical mass in Europe of people with the required interdisciplinary attitude in order to establish a common language and knowledge that could set the trend for the research in the field. COSIN consortium is sufficiently big and the expertise of the partners are sufficiently complementary to represent the sufficient critical mass for a successful project.

Moreover, since the consortium involves six leading partners from five countries (France, Germany, Italy, Spain and Switzerland) it has an European dimension that is also important to achieve the critical mass for the dissemination and the exploitation of its results in a wide European community.

7 Contribution to Community social objectives

EC has acknowledged the WWW and Internet as important platforms for promoting and improving the quality of life and employment. The integrated efforts for advancing the knowledge and for its exploitation will have significant results in the long term: it will affect working conditions, it will improve the sharing of information among citizens improving the quality of life, health system and the environment. As a result it will further expand business activities and define new business practices.

COSIN is a long term project and as such we do not expect a direct contribution of COSIN to the above social objectives such as the improvement of quality of life and health and safety or improving employment or preserving or enhancing the environment. However 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. We expect that the contribution of COSIN is applicable to several aspects of IST.

We also think that the results of COSIN are also of increasing the knowledge about the importance of modelling and visualizing complex networks that arise in many different areas. For this reason we think that the result of the project might be used by firms, agencies, research institutions whose interest is not limited to the IST. For example, one of the main theme of the project concerns the study and the visualization of social networks that arise in firms and among firms of the same business area. We believe that the methodologies and the our results can be extended to other areas as well.

For this reason we think that the result of the project might be used by firms, agencies, research institutions whose interest is not limited to the IST and we consider the dissemination of results a major goal of the project.

8 Economic development and scientific and technological prospects

The study of Complexity of networks has produced and impressive base of knowledge. The main dissemination and exploitation objective of the consortium is to transfer this knowledge from academia to the rest of society. For this reason the dissemination of the results of the project is a crucial task that will be under the direct responsibility of the Coordinator node and it is based on four different actions.

1. **Training of young researchers.** In fact since the interdisciplinarity of the project, it is important to establish a common language and fix the standards of the field. This will not be limited to the students belonging to the consortium partners, but will be done outside the consortium through the school and the open workshops.
2. **Publication of influential papers and books.** The consortium has the scientific strength and critical mass to be a reference point in Europe for the study of networks and their applications to the IST; however we also aim in reaching other communities and to exchange ideas and results with the publication of papers about the general topics of COSIN and with the participation of scientists outside the consortium to the workshops, the conference and the school. Amongst the possible candidate areas there are Biology, Ecology, Economics, and Protein design. Collaboration and exchange of ideas would certainly help both in the achievement of the challenges proposed but also trigger progresses in the above-mentioned areas.
3. **Realization and maintaining of COSIN web site.** In fact we plan to realize a WWW site that collects all information concerning the project and that we plan will be an "authority" for all researchers in the area providing useful information on the topic of growing networks and their applications. The site will have a friendly interface to access all collected data, the software tools and all technical reports and deliverables of the project. We also expect to add a rich list of pointers to other significant activities in the area that are carried outside the project.
4. **Exchange of results.** We plan to organise Workshops open to scientist from related areas. In this Workshops young researchers and WP-leaders of the different nodes will report their results and, more importantly, they describe the work in progress. Scientists of related fields are expected to present their research that could be potentially affected by COSIN results. Scientists with a common background to those of the COSIN consortium that are currently working in the above fields are for example R. Solé, A.J. McKane, J. West, D. Farmer, A.L. Barabasi, E. Domany, P.Raghavan, A.Fiat, J.Kleinberg.

We think that the impact of COSIN is not only scientific but our results will be helpful in the construction of efficient and reliable systems and will contribute indirectly to "accelerating [the] emergence [of IST for Europe] by ensuring that the needs of individuals are met".

In fact WWW and Internet represent two examples of networks whose social and economic impact is already very large and this impact is also increasing with time. We believe that there are new business areas related to the possibility to model and visualise such complex systems. Such exploitation plans are of long term nature and can be realized at the end of the project by spin-offs that will focus on the exploitation of specific results of COSIN or by subsequent projects proposed by some COSIN partners with other industrial partners; these projects will focus on the technological transfer of COSIN in specific results. As an example we foresee the following potential applications:

- tools for improved search and filtering information that will allow to select the relevant information for the user;
- tools for visualizing huge networks that are easy to use and that provide layouts of good quality;
- tools to analyse network traffic that are useful for the network analysis and for improving network efficiency;
- tools for analysing and improving network design;
- tools for the determination and analysis of cyber-communities;
- tools for the visualization of social networks that are capable to adequately represent its dynamic behaviour.

We remark that some of the partners of the consortium have a significant experience in technology transfer mainly achieved through the participation to EC industrial projects and through research contracts with industries.

9 Work Plan

9.1 General Description

As sketched in the introduction we would like at the end of this project to have a quantitative description of complexity and reliable data set for Internet and WWW. The current state of the art of the literature deals mainly with preliminary analysis in very different fields of possible underlying network structures. These studies range from Internet and WWW structure to stocks price correlations, firms structure, catalytic reaction for protein formation and scientific cooperation. Unfortunately, in many cases, little attention is paid to quantitative characterisation, Internet and WWW webs are often confused, fundamental network structures like clusters are not identified and the quality of data is sometime rather poor. In order to meet the challenges presented in this proposal we intend to start the project by collecting afore the Internet and WWW structure a reliable set of data. Currently different models and theory have been proposed to explain these peculiar properties, but in order to assess the validity of these agent based models a remarkable set of data should be collected.

To achieve the objectives of the proposal we decide to divide COSIN in eight different Workpackages with the months/persons division between teams as shown in Tab.1.

Work division										
	C01	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	Tot.
WP1	14	2	36	4	4	0	1	4	2	67
WP2	6	6	6	24	7	0	1	2	12	64
WP3	0	13	0	4	5.5	12	24	0	0	58.5
WP4	20	0	10	3	36	0	2	0	1	72
WP5	6	36	10	3	2	0	1	6	1	65
WP6	8	2	2	2	2	1	1	2	0	20
WP7	7	2	2	2	2	1	1	2	1	19
WP8	3	3	3	3	3	1	2	5	1	23
Tot.	64	64	69	43	61.5	15	33	21	18	388.5
cost 0	13	17.7	3	2	2.9	1.5	0.4	6	1.1	28.7
EU	48	46.3	66	41	58.6	13.5	32.6	15	16.9	357.8

Table 1: Figures in month/persons in total with cost 0 months explicitly considered (when applicable). In the last two rows the months with requested contribution from EU and those at cost 0 are explicitly shown. Figures are rounded to 0.5 months/person.

WP1 on **Mathematical Tools for Complex Systems**, coordinated by CR3, is going to provide the unifying framework for the consortium and therefore sees the coordination of all the members of consortium. The possibility to find a unifying mathematical framework for all the above systems represents an important issue of the modern Statistical Physics. CR3 is one of the leading centres for the study of complexity in Statistical Physics and can use the experience in the study of Self-Organised phenomena to approach in a novel and successful way the problem of the dynamics of growing network.

WP2 deals with **Data Collection and Analysis**, under the coordination of CR4 and later CR9 and the collaboration of all the partners. CR4 established a reputation in the field of Self-Organised Criticality and analysis of data therefore representing the ideal choice for this WP. We aim to develop a data base with some data on the Internet traffic as recorded in Europe, some data about WWW a software library and a benchmark database. In our opinion the spirit should be the one of the US CAIDA, the Cooperative Association for Internet Data Analysis (sponsored by NSF and Cisco amongst the others) whose web site `http://www.caida.org` is currently the main authority in the world on this topic.

Particular attention would be paid then also to the formation of an analogous data-base for the topology of WWW. This information is not currently available to the public, being one of the key factor in the success of search engines. Scientific analysis of the system are currently taking place, but since the very poor quality of data, there is some debate on the interpretation of the results (butterfly shape vs small world). We plan to effectively contribute to that analysis by providing for scientists and firms our information on this subject. We do not see for this part of the project failure particular risks associated. It instead could be the case that new analysis tools are available at the time of investigation. We therefore decide to meet the consortium very often in order to check the WP progresses and possibly decide small modifications. The above specified tasks are presented in detailed form below.

The responsible of **WP3** on **Large Networks Visualisation Tools** is CR6 one of the leading authority in Europe in this field, similar competences are present also in CR2 that would contribute to this specific area. It is clear how the possibility to visualise large networks is crucial to understand the statistical properties of the system. In the case of interest for us one needs particular skill in order to deal in real time with huge number of points. The main task would then the one to reconstruct the paths of traceroute Secondly we aim to develop a software that allow us to represent a whole network from spanning trees. All these skills will be adopted to start a project to map in the best possible way the Internet and the WWW networks. In particular the topology of Internet can be approached at the level of autonomous systems. Starting from autonomous systems has the advantage that accurate snapshots of this topology are present in the literature. They could then be used for testing the tools that will be developed for visualising evolving networks.

As soon as the results of the above WP's are available it would be possible to achieve the specific results expected in the other 3 WP's. Namely for the **WP4 Dynamics of Social Networks** we aim to start to develop the quantitative basis of the investigation of Social Systems. This new topic has in the node represented by CR5 one of the centres in Europe. In particular we study the statistical properties of firms structures. As an example cooperation between firms in economic sectors like the pharmaceutical research can be represented by graphs. The topological properties of these and in particular the cliques distribution and degree connectivity can measure the development and the European interconnection of private research, thereby helping in pointing out the sector or firms that could improve their business.

The main topic of **WP5** would be on the **Models for Communication Networks**. This topic would be addressed by CR2 mainly and by the other teams. As a matter of fact is extremely important for this topic to share different competence from Statistical Physics, Theory of Random Graphs, Control Theory, Management Assessment. This is one of the WP's more likely to disseminate results in other fields. While starting to approach the new networks of Internet and WWW and the one more traditional of telephone connections we believe that most of the results can be extended to different networks as well.

Workpackage **WP6** is devoted to dissemination of the results through WWW, workshops, publications and conferences. Particular stress will be given in distributing the collected data and the software libraries through the web site of the project, by providing a user friendly interface.

WP7 is devoted to the management of Consortium in order to meet the challenges of the project and to provide self-assessment in the research objectives.

WP8 as requested is devoted to assessment and evaluation. The evaluation of the ongoing results will be obtained through students evaluation at the schools organised by COSIN and through referral of scientist of the field.

9.2 Workpackage list

Workpackage 1: "Mathematical Tools for Complex Systems"								
Workpackage number: WP1	**Starting date:** 0							
Participant number:	CR3	CO1	CR2	CR4	CR5	CR7	CR8	CR9
Person-months per participant:	36	14	2	4	4	1	4	2

Objectives:
We want to provide a unified framework and a set of operative tools to address the fundamental issues involved in the study of complex in the network dynamics. This framework should be accessible to scientist in various fields in order to detect universal behaviours.

Description of Work:
To investigate the universality in the network properties of different systems in nature, we preliminary need a reliable characterisation of such systems. Different measures of interest can be the connectivity degree, the average path length, betweenness, spectrum of the connectivity matrix. Then we want to investigate the basic ingredients that establish complex behavior in the system investigated. Main candidates are the Self-Organisation and the peculiar distribution of disorder and minimisation of functionals.

Deliverables:

- **D4** *Measuring and modelling universality in network formation.*
- **D10** *Check of the state of the art.*
- **D11** *Self-Organised Criticality (SOC) in network formation.*
- **D19** *Characterisation of optimisation as a driving force in network shaping.*

Milestones and Expected Results:
Expected results concerns the quantitative description of parameters that characterise different systems, their dynamical evolution from microscopical interactions and their optimisation.
The first meeting of the Consortium Board after 6 months will act as milestone for D4, while the second meeting after one year will be the point to monitor D11 and the third meeting (month 24) for D19. Between the first and the second meeting we intend to discuss in a Consortium Board meeting how to apply the results of this mathematical characterization to the other workpackages. This is the topic of the Deliverable D10.

Workpackage 2 "Data Collection"								
Workpackage number: WP2	**Starting date:** 0							
Participant number:	CR4	CO1	CR2	CR3	CR5	CR7	CR8	CR9
Person-months per participant:	24	6	6	6	7	1	2	12

Objectives:

We want to produce a reliable data set for Internet and WWW that will be used to test these networks and to suggest evaluation of network features. The EU based data set should be available to public in the spirit of the United States CAIDA project. Applications are several ranging from the design of the European backbone for Internet to suitable mirroring for the European firms.

Description of Work:

We intend to send a series of traceroute probes from several European universities in order to deal with several spanning trees describing Internet from a European point of view. We also perform similar tests on WWW. Apart the statistical analysis for each set, we plan to compare views originated in different points in order to reconstruct the whole net. We also design a user-friendly WWW interface to access the collected data.

Deliverables:

- **D5** *Publication on the preliminary measures of collected data.*
- **D12** *Database describing complex networks including Internet, WWW.*
- **D13** *A library of software tools for performing measures on large networks. In particular visualization systems, available through the Web, for the display of computer networks at different levels.*
- **D20** *Statistical properties of the collected data.*
- **D21** *User-friendly web interface for the access to a repository of large data sets on networks in different application domains integrated with tools for their visualisation.*

Milestones and Expected Results:

We expect an extensive set of data to be collected on Internet and WWW. This database would be publicly available together with the source codes that allowed to facilitate the collection of new data. We expect that our tools will be easy to use also for researchers outside the consortium. D5 is expected after 12 months and will be monitored after 6 months. D12 and D13 are expected after 24 months and we expect to monitor their progress after 12 months. D20 and D21 are expected at the end of the project; we will monitor progresses at month 24. We expect to have a core of measures for the first milestone, and to be able to extract part of the information at this stage.

Workpackage 3: "Large Networks Visualisation Tools"					
Workpackage number: WP3	**Starting date:** 0				
Participant number:	CR6	CR2	CR4	CR5	CR7
Person-months per participant:	12	13	4	5.5	24

Objectives:

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

Description of Work:

Models for the visualisation of structural parameters and roles will be developed. This task involves fundamental research on algorithmic models and the design of new algorithms. We want to study of ad-hoc visualisation algorithms and data structures for drawing and browsing graphs whose size can be considered "infinite" de-facto and that may rapidly change over time. We also want to find algorithms that could in a short time redirect the traffic in on the available paths. This can be done using in the best possible way the local information and therefore with an approximated optimisation.

Deliverables:

D6 *Algorithms for representing network centrality, groups and density and clustered graph representations.*

D14 *Customisation and usability study of general purpose software tools for visualisation of large networks.*

D22 *Algorithms to find paths and connections from local information.*

Milestones and Expected Results:

We expect to quantitatively describe those parameters that characterise the i visualization of large networks. We will also perform the usability study of existing general purpose tools to visualise large graphs characterised by a hierarchical structure. Finally we plan to compute paths queries using only local information of the network.

D6 will be monitored after 6 months, whilst progresses of D14 will be checked after one year. For D22 the second general conference will act as a milestone.

Workpackage 4: "Dynamics of Social Networks"						
Workpackage number: WP4	**Starting date:** 0					
Participant number:	CR5	CO1	CR3	CR4	CR7	CR9
Person-months per participant:	36	20	10	3	2	1

Objectives:

We want to characterise empirical economic and social networks in terms of their static structure and dynamical properties. We want also model network evolution under local optimisation criteria and study the outcome of the dynamics in connection with the environment constraints. Paramount examples of this systems that we are going to consider are the internal firms structure and the cooperation net between firms in the same area (e.g. pharmaceutical).

Description of Work:

Data collection concerning the interconnections of firms in different sectors of interest (e.g. the pharmaceutical sectors in Europe) and of the correlations of their stock price fluctuations. Building models of economic network formation and evolution in connection with the short term dynamics of flows across these networks.

Deliverables:

D7 *Inter-firm network dynamics: risk propagation, fusion/outsourcing dynamics.*

D15 *Algorithms for centrality groups and density in social networks.*

D16 *Modelling interaction and dynamics inside firms Directors.*

D23 *Cyber-communities in the WWW.*

Milestones and Expected Results:

We expect to quantitatively characterise and analyse the emergence of complexity in dynamical social networks. We will focus our attention on internal firms structure and inter firms cooperation. We expect to describe the emergence of strong relationships and the dynamics of flows across the networks.

D7 is expected after 12 months, and would be discussed in the Consortium Board after six months. D15 and D16 are expected after 24 months, D23 after 36 months+6 months of shift in the final delivery; they will be monitored after 12 and 24 months respectively.

Workpackage 5: "Models for Communication Networks"								
Workpackage number: WP5	**Starting date:** 0							
Participant number:	CR2	CO1	CR3	CR4	CR5	CR7	CR8	CR9
Person-months per participant:	36	12	10	4	2	1	6	1

Objectives:

We want to devise and validate stochastic models for large communication networks. We also want to produce suitable models for the traffic demands generated by users The two above topics apply to the Internet and WWW as for instance to the network of a large telephone company. The devise of realistic stochastic model for communication networks would also allow to test network applications on generated benchmarks of limited size.

Description of Work:

The overall graph will then be obtained by merging the graphs formed for the various topics. The new stochastic model will be validated by comparing the probability distributions observed in the simulation of the model and on real data describing relevant properties of the Web graph. Our interest is also in finding algorithms to recognise clusters in different graphs. We want to find partitions that exhibit a strong relationship between nodes in the same cluster and a low coupling between clusters.

Deliverables:

D8 *Modelling and visualising WWW.*

D17 *Design of clustering algorithms for network traffic analysis.*

D24 *Modelling of the Internet graph.*

Milestones and Expected Results:

Based on the comparison of existing models of the Internet and WWW graphs with real data, we plan to devise and validate new stochastic models of the Internet and WWW graphs. We also plan to study the traffic generated by users focussing our attention on bottlenecks applying clustering algorithms on the traffic matrix.
D8 will be expected for the first meeting, D17 is expected after 24 months and its status will be monitored after 12 months. D24 will be checked after 24 months.

Workpackage 6: "Dissemination of the Results"								
Workpackage number: WP6	**Starting date:** 6							
Participant number:	C01	CR2	CR3	CR4	CR5	CR6	CR7	CR8
Person-months per participant:	8	2	2	2	2	1	1	2

Objectives:
The main purpose of this WP is twofold. On one side we want to distribute the results that we find in the area of growing network to researchers in areas different from physics or information technology such as Biology, Economics, Social Networks researchers, etc. On the other side we are open to address new and challenging issues arising in the next three years. For that reason we plan to organise workshops, school for young researchers and conference open to the widest possible audience. We also plan to write papers and a student book for the mathematics of complexity.

Description of Work:
The main way to bring together people from different areas as physics, information technology, management and biology, would be through workshops and cooperation. We plan every 12 months to present some of the results and the open problems in workshops and conferences mainly for students (at PhD level) and scientist from other areas. By collecting the deliverables produced at any stage we plan to publish a book at the end of the project. Another tool for the dissemination of results will be the realisation and maintaining of the WWW COSIN site, that will collect all the activities of the Consortium.

Deliverables:

D2 *Dissemination and use plan*

D3 *Setup and Procedure for Advisory Board*

D25 *Organisation of two Workshops (month 12, 24) a School (month 24) and one final general conference (month 36).*

D26 *Papers and a book on the mathematics of Complexity.*

D27 *Realisation and maintaining of WWW server collecting all the information related to the project including the data collected and software tools as in D7 and D15*

D28 *Technology implementation plan*

Milestones and Expected Results:
We expect that the project results will be used by researchers in a wide community and that will be of interest also for IST industries. Namely we expect a significant and "trend-setting" impact of our scientific results for researchers in Physic and Information technology; we also expect that the collected data and the visualization tools will be used by a wider community of researchers and IST industries. Finally we expect that the workshops, the school and the conference that we plan to organise will allow a significant dissemination of results to Ph.D students and young researchers.
This workpackage will be continuously monitored by the Coordinator; the Consortium Board meetings will act as milestone.

Workpackage 7: "Management"									
Workpackage number: WP7	**Starting date:** 0								
Participant number:	CO1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR8
Person-months per participant:	7	2	2	1	2	1	1	2	1

Objectives:

To meet the challenges of this proposal, overcoming the problems that could arise in coordinating the different sites.

Description of Work:

The Consortium Board manages the consortium,monitors the scientific activities of all workpackages and help in the flowing of ideas and solution to problems. Since every node is responsible for the delivery of a WP, they will act as Workpackage Leaders and they will be responsible for the research in their area and the production of deliverables. The consortium board is going to meet at months 0, 6, 12, 24, 36. The coordinator continuously checks the status of research with the Workpackage leaders and reserves the right to organise other meetings whenever deemed necessary in order to meet the challenges of the project.

Deliverables:

D9 *First Project Workshop.*

D18 *Second Project Workshop.*

D29 *Third Project Workshop.*

Milestones and Expected Results:

The milestones of the management WP are the meetings of the Consortium Board during which self-assessment activity of the whole project is performed.

Workpackage 8: "Assessment and Evaluation"									
Workpackage number: WP8	**Starting date:** 0								
Participant number:	C01	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9
Person-months per participant:	3	3	3	3	3	1	2	5	1

Objectives:
We want to measure in an independent way the results obtained in the COSIN activity.

Description of Work:
We plan to distribute questionnaire to the students of the schools organised by COSIN. This first feedback on the quality of the dissemination of results will be integrated by a consortium of independent referees chosen in various fields. Results of the referral will be discussed in the Consortium Board, and presented in the Workshop meetings.

Deliverables:

D9 *First Project Workshop.*
D18 *Second Project Workshop.*
D29 *Third Project Workshop.*

Milestones and Expected Results:
We expect to have a constant feedback from potential users about the quality of research and the dissemination of COSIN.

9.3 Workpackage description

WP1 **Mathematical Tools for Complex Systems**
Coordinator: *CR3*; **Contributors:** *CO1, CR2, CR4, CR5, CR7, CR8, CR9*
Manpower(months/person): *36 Coordinator, 31 Contributors , 67 total*

The necessity for developing this proposal stems from the ascertainment that the integration of achievements and research results requires an interdisciplinary approach that will used methodologies developed in different areas. Complex Systems Theory is the natural candidate framework for the study of Complex Networks, providing a unified framework and a set of operative tools to address the fundamental issues involved in the study of such systems. Computer science and mathematics provide some basic tools for modeling and measuring such complex systems. In particular they provide the basic methodologies for running empirical simulations and computing the relevant measures on the simulated models and on real samples of such networks and for visualizing the evolution of networks even of very large dimension.

Complexity in networks can have different origins: topology of the links and/or of the nodes, aging, diversity of the elements, dynamical effects. The first item corresponds to the inherent complex topology of real-world networks. The second case corresponds to the variations in time of the connections of the networks or the possible removal or addition of new nodes. By diversity we understand that not all the nodes or links will have the same structure and finally, there can be some dynamical effects in the sense that nodes can have complex dynamics. It is however very important to differentiate all this effects and trying to understand them separately.

There is another interesting aspect which is self-organisation. One of the purposes of the work is to be able to find the structure that optimises the dynamical behavior of the network. The introduction of "smart" agents can help to arrive to the desired optimised structure. This can be achieved if we are able to identify the optimisation with the topological structure of the network, which has to be characterised by some of the observables discussed above. As for the requested contribution CR3 is going to appoint one person full time and another for about half time to work on this workpackage (and the collaboration to other WP's) at the level of PhD or higher. These persons will need an average travel money of 2 week visit in one of the others nodes, 2 participation to conferences, and 2 to consortium meetings per year. Other nodes C01, CR2, CR4, CR5, CR7, CR8, will collaborate for respectively 14, 2, 4, 4, 1, 4, 2 months both with people employed with EU contribution and both with people already present in the various nodes.

T1.1: Quantitative characterisation of different networks in Nature
In order to investigate the universality in the network properties of different systems in nature, we need to deal with a reliable characterisation of such systems. Different measures can be the connectivity degree, the average path length, betweenness, spectrum of the connectivity matrix.

T1.2: Onset of Complexity from microscopical interactions
We want to investigate the basic ingredients that establish complex behavior in evolving networks. Main candidates are the Self-Organisation and the peculiar distribution of disorder. We plan to describe this process through agent based computer simulations and through analytical analysis of network growth models.

T1.3 Optimisation
We want to establish relationships between the parameters that characterise the network with its dynamical properties. The goal is to discover whether the evolution of a network can be predicted from its statistical properties at the initial stages. The final aim is to detect if the stationary state can be such that to optimise some cost function that would then act as an "energy functional" that drives the network evolution.

Deliverables

D4 Measuring and modelling universality in network formation.

D10 Check of the state of the art in order to have a larger feedback with other WP's.

D11 Self-Organised Criticality (SOC) in network formation.

D19 Characterisation of optimisation as a driving force in network shaping.

Deliverables **D4,D11,D19** will consist in the realization of models whose parameters and rules will be tuned and derived after a careful consideration of the properties collected in WP2. These models will be tested through numerical simulation and the behaviour will be presented in at least one publication each on international journals. As regards the link with the other Wp's the deliverable **D5** and **D12** will be the basis of the modelisation required to produce **D4** and **D11** and **D19**. **D10** will be discussed in a specific Consortium Board meeting at month 18.

WP2 **Data Collection and Analysis**

Coordinator: *CR4-CR9*; **Contributors:** *CO1, CR2, CR3, CR5, CR7, CR8*

Manpower(months/person): *36 Coordinator, 26 Contributors, 62 total*

We intend to collect data and develop tools of analysis for large complex networks. In particular, we plan to consider data retrieved from several contexts where large networks arise, e.g., the Internet, the WWW, social networks, economics, and network of traffic demands. In order to be able to produce a realistic model for these networks, a large set of measures should be available. We intend to made a set of algorithmic tools and data structures available to the public in a software library. Both data and tools will be made available to scientific and educational users and firms through an advanced Web interface. In particular, we intend to allow the access to the collected data and to the software library through a web interface that also incorporates some of the visualisation tools developed in WP3. As for the requested contribution CR4-CR9 is going to appoint one person full time and another for about half time to work on this workpackage (and the collaboration to other WP's) at the level of PhD or higher. These persons will need an average travel money of 2 week visit in one of the others nodes, 2 participation to conferences, and 2 to consortium meetings per year. Other nodes C01, CR2, CR3, CR5, CR7 will collaborate for respectively 6, 6, 6, 5, 1 months each and CR8 with 2 months. Both people employed with EU contribution and people already present in the various nodes will be devoted to this WP.

T2.1: Collection of large data sets

We intend to collect large data sets describing meaningful instances of large networks in several application domains. First of all, we will refer to already available sources reporting data on Internet registers (e.g. BELL, CABLE&WIRE, MCI, RIPE), Internet routing tables (RIS, Oregon Univ), World Wide Web topology (Webbase Stanford), and Social and economics data (NIST, Matrix Market), assessed for reliability and critically evaluated. We also intend to monitor the Internet performing traceroute analysis from a number of European Internet nodes in order to reconstruct a multi view of the Internet at the present not available, and reconstruct large portions of the WWW through Random Walk analysis.

T2.2: Library of software tools for network analysis.

The study of the mathematical properties of large networks requires the development of algorithmic and software tools able to perform measures on large data sets. We intend to collect several tools for network analysis in a software library available to the public. The tools that will be developed will compute the distribution of measures such as the degree, connectivity, clustering, and dense subgraphs. They will also provide the basic algorithmic tools for mapping the geography of Internet and of the WWW. In this workpackage, we will use the expertise of CR2 and CR6 for the development of external memory algorithms and data structure for data sets, such as large networks, that do not fit in the main memory during the execution of the algorithm.

T2.3: Database available to public and firms (http://www.cosin.org)

We plan to make available the data collected in Task **T2.1** and the tools and software libraries developed in Task **T2.2** through an advanced Web interface. In particular, the main dissemination device of the project will be a Web site, `http://www.cosin.org` , designed to make available on-line a large and neatly categorised repository of information, project research reports, papers, links to a number of related resources over the Web, and a well documented archive of software tools and libraries available for down-load. We plan to integrate visualisation facilities developed in WP3 to enhance user interaction and presentation of data.

Deliverables

- **D5** Publication on preliminary measures of Internet, WWW.
- **D12** Database describing complex networks including Internet and WWW.
- **D13** A software library to make available algorithmic tools for performing measures on large networks (diameter, degree, connectivity) integrated with the visualization tools developed in **D14** of WP3 and **D17** of WP5. In particular it will include visualization systems, available through the Web, for the display of computer networks at different levels.
- **D20** Report on statistical properties of the collected data.
- **D21** User-friendly web interface for the access to a repository of large data sets on networks in different application domains integrated with tools for their visualisation.

The deliverables of this WP will be presented to the scientific community both with publications on international journals and with web pages in the home page of the project. We intend to publish the results of deliverable **D5**.

More specifically, measures of deliverable **D12** will be the basis of the deliverable **D23** in the WP4. The deliverable **D21** is very important for the project COSIN. As a matter of fact this deliverable will affect the whole WP8 since it is devoted to the dissemination of the results. Furthermore all the other deliverables will be the presented also in the site delivered as **D21**. Particular effort then will be devoted in the realization of such a site that is is necessary for WP8. In this perspective **D13** will show and will make available the tools produced in **D6 D22**(WP3) and **D7** (WP4).

WP3 **Large Networks Visualisation Tools**
Coordinator: *CR6-CR7*; **Contributors:** *CR2, CR4, CR5*
Manpower(months/person): *36 Coordinator, 22.5 Contributors, 58.5 total*
Visualisation is an important aspect of both exploration and communication in large networks. The ability of drawing very large computer networks is of great significance in visualizing the evolution of stochastic models for evolving networks. One focuses on designing and implementing innovative software systems that display a computer network at different abstraction levels, such as the application level or the infrastructure level. For example, there is an increasing need of systems that show maps of the Web and support the user during 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 and thousands of edges.

For the visualisation of large networks, a crucial point is the understanding of the underling structure. In the case of evolving networks like the Web, the fact that the underlying structure is a social network has to influence the design of efficient visualisation methods. We therefore aim for developing visualisation algorithms involving techniques from social network analysis. On one hand, visualisations of large networks should reflect network parameters like *density, centralisation* or *inclusiveness* resp. structural roles like *brokers, bridges* and *groups*. On the other hand, the knowledge of these parameters offers support for the automated construction of readable visualisations. We aim at devising general algorithmic techniques for drawing large graphs and at experimenting their usage in new visualisation systems, thus contributing to devising the technology transfer from the algorithmic research on graph drawing to its application in networks visualisation. As for the requested contribution CR6 is going to appoint one person full time to work on this workpackage (and the collaboration to other WP's) at the level of PhD student or higher. After the first year CR7 will be in charge of coordination. The rest of the months required for collaborations in others WP's will be done by persons already present in the institution. These persons will need an average travel money of 2 week visit in one of the others nodes, 2 participation to conferences, and 2 to consortium meetings per year. Other nodes CR2, CR4, CR5 will employ person to collaborate for respectively 13, 4, 5.5 months.

T3.1: Models for visualizing structured networks
Existing graph drawing algorithms focus on layout criteria not necessarily appropriate for evolving networks or social networks. Models for the visualisation of structural parameters and roles will be developed. This task involves fundamental research on algorithmic models and the design of new algorithms.

T3.2: Visualisation of huge networks
The study of ad-hoc visualisation algorithms and data structures for drawing and browsing graphs whose size can be considered "infinite" de-facto and that may rapidly change over time.

T3.3: Network reconstruction from single users view
We intend to monitor Internet from a small number of single users views. Geographical constraints can play a role in the physical representation of the Net. We aim to find algorithms that in a short time redirect the traffic on the available paths through only local information and therefore with an approximated optimisation.

Deliverables
D6 Algorithms for representing network centrality, groups and density and clustered graph representations.
D14 Customisation and usability study of general purpose software tools for visualisation of large networks.
D22 Algorithms to find paths and connections from local information.

The deliverables of this WP focus on specific problems in the field of visualization. Therefore the progress expected will result in publications on international conferences and journals and also in computer programs that will be made available on the project site. More specifically, for **D14** we are planning to build specific libraries of computer programs downloadable from the project site as described in **D13** of WP2. The algorithms themselves will be made available to the community and delivered from the project site.

WP4 **Dynamics of Social Networks**
Coordinator: *CR5*; **Contributors:** *CO1, CR3, CR4, CR6, CR7, CR9*
Manpower(months/person): *36 Coordinator, 36 Contributors, 72 total*

This work package concerns the relation between the dynamics of economic networks and the emergence of structures throughout evolution. By dynamics we mean the change in time of the state variable of the nodes when the parameters of interaction are constant, whereas by evolution of the network we mean the change of the interaction parameters through optimisation of some fitness function depending on the outcome of the dynamics. Think for instance of an economic network in which economic agents exchange goods through connections which strength varies with the success of the performed transactions. The outcome of the evolution process is a learned structure which should be appropriate to the challenges of production in an environment without any central authority. (The equivalent issue concerning the Internet is routing tables). We also want to figure out under which conditions these links will become permanent (resulting in strong relationships or even absorption in the same firm as in vertical integration) or when such links would become loosen resulting in outsourcing. We also want to characterise the dynamics of flows across the network, and its robustness against fluctuations in external demand and resources, or local nodes failures. In other words, we are also interested in risk propagation across the network, an issue of tremendous importance in real economics. (in the case of the Internet the same issue of robustness of information propagation arises). We plan to complement simulations and formal approaches (using some of those developed in WP1) by comparison with empirical data (collected partly using techniques developed in WP2) concerning various industries.

In addition we want to focus also on the other case of the cyber-communities present in the web. The specific work in this area will be devoted both to produce algorithm for the measure of fast changing networks in general and in concrete analysis of the WWW structure together with the work of WP2.

As for the requested contribution CR5 is going to appoint one person full time and another for about half time to work on this work package (and the collaboration to other WP's) at the level of PhD student or higher. These persons will need an average travel money of 2 week visit in one of the others nodes, 2 participation to conferences, and 2 to consortium meetings per year. Some funding to invite specialists dealing with economic networks in "new" industries (media, Internet, bio-technologies) from an empirical perspective is also needed (2 weeks per year). Other nodes CO1, CR3, CR4, CR6, CR7, CR9 will employ persons to collaborate for respectively 20, 10, 3, 1, 1, 1 months.

T4.1: Structure of Production and Distribution and Hierarchical Decision networks

We want to study the production and distribution networks inside one firm, in the context of assignment of tasks to teams for given projects on one hand and of adaptive supply chain on the other hand. Another example of network is formed by all the directors sitting on the boards of a set of firms. Directors are the nodes of the network and there is a link between two directors if they sit on the same board. We model the dynamics of decision making with a simple statistical model and we investigate how the probability that the decision of each board is in favour of the executives' opinion is affected by the level of mutual membership.

T4.2: Algorithms for centrality in social networks

While network indices like centrality or density can be computed efficiently in static social networks - at least for not too large networks - not much is known about the algorithmic aspects of those indices in dynamic networks.

First of all, accurate models for the dynamics of social networks are required.

In a dynamic social network, centrality of actors for example may change over the time. However, in order to have complete knowledge about all centrality values at any time, one possibly need not compute all values again and again for each state in time. Depending on the measure of centrality considered, methods from dynamic algorithms might be applicable. For example, betweenness centrality is based on shortest path computations, where very efficient algorithms exist also for dynamic graphs.

We want to design algorithms to compute indices like centrality, density, groups etc. in dynamic social networks using the information from the past. In very large dynamic social networks, such algorithms might only use part of the input. Beside the question of computing network indices, also the visualization aspect of dynamic networks will be considered in a later phase of the project.

T4.3: Mining the social structure in the web

The World Wide Web is also a very large and valuable source of sociological data. In particular the Web harbors a large number of communities – groups of content creators sharing a common interest – that manifest itself as a set of interlinked pages. Some of these communities are explicitly manifested through newsgroups, or as a resource collection often made available by Internet portals. Most of the communities are however hidden in the web, they only manifest themselves by linking documents that are authoritative for a specific common topic of interest. Mining the cyber communities hidden in the web and recognizing the common interests of the content creators belonging to such communities is a challenging task that can be accomplished by analyzing the hyper-linked structure of the Web. Finding such cores and tracing the related "cyber" communities and their evolution is one of the objective of our analysis of the dynamic of socio-economic networked data. This objective is also related to the design of new models for the WWW carried out in WP5. A realistic model of the hyper-linked structure of the Web must generate a large number of cores indicating the existence of Web communities.

Deliverables

D7 Efficient computation of network indices like centrality, groups and density in dynamic social networks.
D15 Modelling dynamics and interactions in firms structures.
D16 Inter firm network dynamics: risk propagation fusion/outsorcing dynamics.
D23 Characterisation of cyber-communities in the WWW.

These deliverables will consist of publications and possibly a database for **D23** to be included in **D21**. Publications and software tools also made available as described in **D13** of WP2. Also in this case as for the WP3 we expect for deliverables **D7** to have algorithms represented by codes sources downloadable from the project site.

WP5 **Models for Communication Networks**
Coordinator: *CR2*; **Contributors:** *CO1, CR3, CR4, CR5, CR7, CR8, CR9*
Manpower(months/person): *36 Coordinator, 29 Contributors, 65 total*

The objective of the workpackage is to devise and validate stochastic models for large communication networks. We look at the Web as a very large graph where documents are represented by vertices and hyper-links by directed edges between vertices. The Internet is naturally modelled by a network whose vertices are the routers and the edges are the communication links connecting the routers. Traffic demands generated by users can also be modelled as a network where users are represented by vertices and communication requests by links between the two communicating parties. This applies to the Internet as for instance to the network of a large telephone company.

Understanding the structure as a graph of communication networks is a key issue for their design, management and usability. For instance the structure of the Web as a graph is indeed a source of valuable information. A hyper-link to a document is an indication of the relevance granted to the linked document by the author of the document that contains the hyper-link. The use of this kind of information is at the basis of the success of some of the most advanced search engines (e.g. Google). Web navigation itself can be viewed as the process of exploring paths in the graph of the Web. Knowing the topological properties of the Internet graph has a clear application to the planning of network updates in order to improve network connectivity. Knowing the structure of a network modelling the traffic generated by the users also allows a better planning of the underlying physical network in order to meet the user demands. We finally stress that sampling a portion of a network of limited size holding the statistical properties of the whole network, like for instance sampling uniformly at random a web page, is a very difficult task. The devise of realistic stochastic model for communication networks would also allow to test network applications on generated benchmarks of limited size. As for the requested contribution CR2 is going to appoint one person full time to work on this workpackage (and the collaboration to other WP's) at the level of PhD student or higher. the rest of the work will be carried out by people already present in the institution with the status of Research Assistant or higher. These persons will need travel money for 2 week visit in one of the others nodes, 2 participation to conferences, and 2 to consortium meetings per year. Nodes CO1, CR3, CR4, CR5, CR7, CR8, CR9 will employ persons to collaborate for respectively 6, 10, 3, 2, 1, 6, 1 months.

T5.1 Suitable Models for the Internet. The models proposed in literature for the Internet graph fail to reproduce the different statistical properties of the backbone and of the terminal routers. The proposed models mostly deal with a single view model of the Internet graph. They represent the collection of all possible routing paths connecting a single root vertex to every possible IP destination. Such network is well represented by Stochastic Cayley trees. However, it is still missing a convincing multi-view model of the Internet graph, capturing the structure of the Internet as a whole. We plan to produce a multi-view model of evolving networks holding the ingredients observed on real data that is also able to reproduce the observed scale-free distributions.

T5.2: Suitable models for the WWW. We intend to compare the two major models proposed so far (i.e. the growing network model of Barabasi and Albert and the so called copying model proposed by Kumar et al.) by sampling the frequency distribution of several measures on extensive computer simulations.

These stochastic models look at the Web as a flat graph. They model the evolution of the Web graph by allowing every vertex to connect to whatever other vertex in the graph even if the two vertices are not relevant for a common subject. We intend to devise a new model for the graph of the Web in which documents link each other with some probability that is proportional to a measure of the relevance of the two pages for a common subject. The tools developed for the visualisation of the hyper-linked structure of the Web will be applied in order to visually compare the models with the real structure of the Web.

T5.3 Networks of traffic demands. There has been renewed interest in the analysis of complex networks based on the study of the traffic generated by their users. Understanding the nature and the bottlenecks of network traffic is indeed critical in order to properly design networks and network services and traffic analysis is a key task for network management in different fields: transportation planning, optimisation of telecommunication networks (e.g., the telephone call graph) and of the Internet backbone represent just a few examples. Independently of the application at hand, the traffic of a network is recorded in the so-called traffic matrix, that can be easily interpreted as the adjacency matrix of a weighted graph. We intend to face the problem of traffic analysis by applying cluster identification techniques to the traffic matrix. Differently from the usual trend, we do not require clusters to have balanced size, but we rather concentrate on the identification of the "natural" clusters of a (weighted) graph, that correspond to high traffic regions.

Deliverables

D8 Design, computer simulation and experimental analysis of stochastic models describing the evolution of the network of the WWW.

D17 Design and implementation of clustering algorithms for network and traffic analysis.

D24 Design and experimental analysis of multi-view models of the Internet graph.

Deliverable **D8** is connected with the WP1 on theoretical aspects, and WP2 on data collection, whose preliminary results will affect the modelisation of WWW. The same holds for **D24**. The deliverable **D17** will be also included in the library of software tools described in **D21**

WP6 **Dissemination of Results**

Coordinator: *C01*; **Contributors:** *CR2, CR3, CR4, CR5, CR6, CR7, CR8*

Manpower(months/person): *10 Coordinators, 10 Contributors, 20 total*

Since network structures arise in several contests, it is extremely important to exchange continuously the knowledge with researchers in other fields. The most immediate way in order to meet and share results is by participating and organising workshops and round tables with groups not present in this project but working on similar subjects. These workshops will represent a possibility of interaction also for those not physicist or engineers, that nevertheless could fruitfully apply the ideas of the theory of growing networks.

Few examples of the areas that will be explored during this project are protein networks, food webs and railways networks. As regards proteins, it has been recently provided evidence that gene deletion in microorganisms is affected essentially by by the topological position of its protein product in a hierarchical web of molecular interactions. A similar structure holds also for food webs, where species represents the nodes and links are given by predation relationships. Stability of network in this case reflect to the stability of ecosystem with respect to mass extinctions. Another field that could be potentially affected is that of the transport and in particular the possibility to optimise the rail service timetable or the utilisation of rail-tracks.

We believe that progress in the research of COSIN can trigger substantial improvement in the state of art. Under this respect, the final dissemination of the result would greatly benefit from the repository of technical reports, deliverables, collected data, software and statistical data accessible through web interface as described in WP2. Coordinator node will take care of this Workpackage through the action of persons already present in the institution. Node CO1 is going to employ one person full time and another half time to work on the collaborations to the other workpackages at the level of PhD student or higher. These persons will need an average travel money to participate to workshops and schools. Part of the budget will be devoted to the organization of conferences meetings and a school for young researchers. The administrative part of the work for the meting organisation will be devoted for a total amount of 2 months to the Project assistant employed for WP7. Other nodes will collaborate for 2 months each to this WP.

T6.1: Conferences, School and Workshops
In order to disseminate the results we are planning to organise one self-assessment meeting of the consortium (see WP7) every year. We also plan to organise a final conference after 36 months in order to present the final results of our project. We will also organise a school for PhD students and young researchers in order to train a class of scientist with a common framework to disseminate COSIN results in different fields. Whilst workshops will be devoted to possible specific applications that could still be approached within the project scheme, the final conference is intended to be for a wider audience that could be interested in the application in very different fields of our results. The first school has already been organized in Udine from 17 to 22 of June in the International Center for Mechanical Studies, The title of the school is: "Models and Algorithms for the World Wide Web".

T6.2: Publications Apart the technical reports that we plan to publish on major technical conferences and journals about the above deliverables, we also intend to write on specific large audience journals, some non technical papers, on the importance of the network properties. At the end of the project will also plan to publish a textbook on the subject that should serve as useful tool for students in the mathematical approach to complexity.

Deliverables

D2 Dissemination and Use Plan.

D25 Organisation of two Workshops (month 12, 24) a School (month 24) and one final general conference (month 36).

D26 Papers and a book on the mathematics of Complexity.

D27 Realisation and maintaining of WWW server collecting all the information related to the project including the data collected and software tools. This deliverable is in strict contact with **D21** and **D13** of WP2.

D28 Technology Implementation Plan.

In order to disseminate the results of this project a strong effort will be put in advertising the site of the project as specified in deliverable **D27**. Of course this site will collect all the results of the other WP's making the work of other WP's necessary for **D27**. A first school organized by COSIN will take place at month 24, possibly in collaboration with NoE Exystence at ISI foundation in Turin. A school already organized will see the presence of COSIN project in Udine (Italy) in June 2002.

WP7 **Management of Consortium,**
WP8 **Assessment and Evaluation**

Coordinator: *C01-CR8*; **Contributors:** *CR2, CR3, CR4, CR5, CR6, CR7, CR9*
Manpower(months/person): *6 Coordinator, 21 Contributors, 27 total*

The COSIN Consortium Board consists of one representative for each node (they will be indicated in section 9.7) plus the coordinator acting as a chairman. Every participant is responsible of the workpackage(s) in charge of his/her node and would then act as Workpackage Leader coordinating all the activities and the deliverable production of the WP.

The coordinator is responsible of the control of the activities of the consortium and represents it with EC authorities. The Consortium Board will exchange communication on a regular and frequent basis in order to discuss ongoing matters. It will meet at the beginning of the project (kick-off meeting) and after six months and later at least once every year and whenever it is necessary to monitor the evolution of the project. In the case where actions need to be taken to respect the schedule of deliverables or to meet the objectives of the project the Consortium Board will decide by simple majority vote. The Consortium Board will also act as consultant and approving body for the coordinator in the development of proposal, budget and reports.

In order to assist the operations and the administrative work in the consortium a Project assistant will be appointed on a part-time basis at the coordination site for a total amount of 15 months/person over the three years. The same Project assistant will help in the organization of conference for dissemination of results as explained in WP6. Nodes participants to Consortium board will devote a total amount of 2 months each to these workpackages.

T7-8.1: Assessment and Evaluation
Self-assessment will take place continuously and will be reported with the yearly project workshops. Project workshops are organised in connection with specialised and general workshops described in Task 6.1 of the previous WP. These project workshops together with the conferences and the feedback from evaluators represents the milestones of COSIN. The consortium Board will also ask assessment to students following the COSIN schools in order to evaluate the dissemination of results in the scientific environment. Assessment will also be monitored by

the number of users of the Web site. We are also planning to form an advisory board with people involved both in academia and industry. The procedure to setup such a board it is the deliverable **D3** and will be discussed in the first Consortium Board after 6 months. Suggestion of advisory Board will be collected during the network meetings **D9**, **D18**, **D29**. By inviting the advisory Board to such meetings we could also disseminate the results of the COSIN project in the industry and in other academic areas.

Progress reports will address the status of the project with respect to the schedule of activities, publication records and joint PhD and young researchers training. We expect that the COSIN consortium will play a major role in the field worldwide and PhD students and young research perform frequent visits and exchanges in order to improve the circulation of ideas and interdisciplinary attitude.

Deliverables

D3 Setup and procedure for Advisory Board.
D9 First progress report.
D18 Second progress report.
D29 Third and final progress report.

9.4 Deliverables list

Deliverable list							
Del. No	Deliverable Name	WP No.	Lead part.	Est. pers/m	Del. type	Security	Del. (month)
D1	Project Presentation	WP6	C01	3	report	Pub	3
D2	Dissemination and Use Plan	WP6	C01	6	report	Pub	6
D3	Setup advisory board	WP7,WP8	C01	6	report	Pub	6
D4	Universality in networks	WP1	CR3	12	report	Pub	12
D5	Preliminary analysis of collected data	WP2	CR4	12	report	Pub	12
D6	Algorithms for Network centrality	WP3	CR6	12	report	Pub	12
D7	Centrality and groups in social networks	WP4	CR5	12	report	Pub	12
D8	Modelling WWW	WP5	CR2	12	report	Pub	12
D9	First Progress report	WP7,WP8	CO1	1	report	Pub	12
D10	Check of the state of the art	WP1	CR3	18	report	Pub	18
D11	Self-Organisation in Networks	WP1	CR3	24	report	Pub	24
D12	Database formation for Internet and WWW	WP2	CR4	24	report	Pub	24
D13	Library of software tools	WP2	CR4	24	report	Pub	24
D14	Customization in visualization tools	WP3	CR6	24	report	Pub	24
D15	Modeling interactions and dynamics inside firms	WP4	CR5	24	report	Pub	24
D16	Inter-firm network dynamics	WP4	CR5	24	report	Pub	24
D17	Algorithms for network traffic analysis	WP5	CR2	24	report	Pub	24
D18	Second Progress report	WP7,WP8	CO1-CR8	1	report	Pub	24
D19	Optimisation and network shaping	WP1	CR3	24	report	Pub	42
D20	Statistical properties of collected data	WP2	CR9	24	report	Pub	42
D21	Web interface for data sets	WP2	CR9	24	report	Pub	42
D22	Algorithms for path finding	WP3	CR7	24	report	Pub	42
D23	Cyber-communities in WWW	WP4	CR5	24	report	Pub	42
D24	Modelling Internet	WP5	CR2	24	report	Pub	42
D25	Workshops Schools and Conferences	WP6	CO1	3	report	Pub	36
D26	Papers on networks and complexity	WP6	CO1	24	report	Pub	42
D27	WWW site for COSIN results	WP6	CO1	36	report	Pub	42
D28	Technology Implementation Plan	WP6	CO1	1	report	Pub	42
D29	Third Progress report	WP7,WP8	CO1-CR8	1	report	Pub	42

9.5 Project planning and timetable

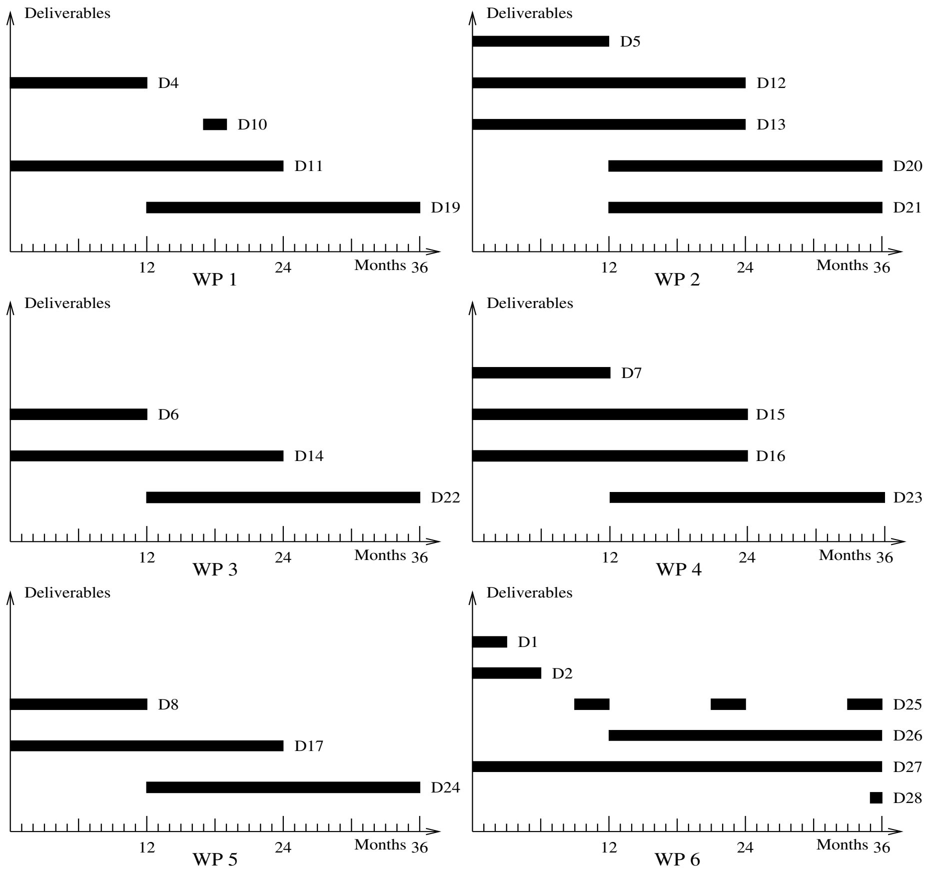

Figure 1: Deliverable time table in the Workpackages

9.6 Graphical presentation of project components

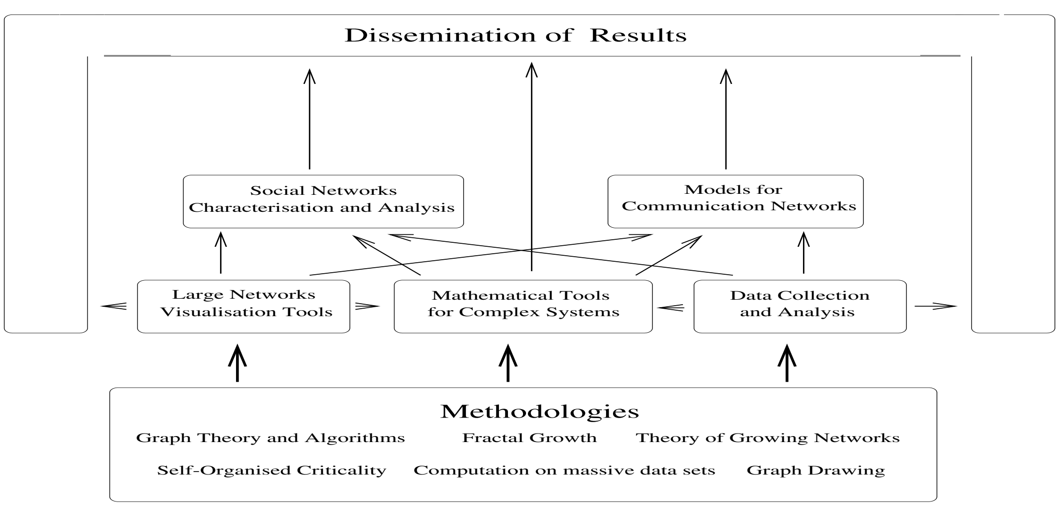

Figure 2: Relationship between the Workpackages.

9.7 Project Management The COSIN Consortium Board consisting of one representative for each node. The Consortium Board is chaired by the representative of the coordinating contractor site that can nominate a nominate a person of her/his site that will act as Secretary of the Board. The Consortium Board decides by simple majority vote, taking normal principles of careful consultation into account.

The Board members are responsible for the operations of the project at the site they represent. Since every site is responsible for one WP (with the exception of the Coordinator that is responsible of WP6 and WP7) the Board members are also Work Package leaders (*WP-leader*). Each WP-leader will be in charge of the tasks that are critical to achieve the objectives of the work package. The Consortium Board communicates frequently about all ongoing matters. It meets at least once a year, and otherwise when deemed necessary by the coordinating contractor and/or the consortium. These meetings will act as milestones of the project, where results are presented and necessary actions would take place if necessary.

Whereas the coordinating contractor is a regular partner in the consortium as far as the research action is concerned, it has the additional formal responsibility of managing and controlling the activities of the consortium as a whole and of performing all management reporting from the project to the EC authorities. The coordinating contractor will hire a Project Assistant for supporting the coordination activities.

Work-Package leaders
The WP-leaders are

WP1 Mathematical Tools for Complexity: Albert Diaz Guilera, University of Barcelona, Spain.

WP2 Data Collection and Analysis: Paolo De Los Rios, University of Lausanne, Switzerland.

WP3 Large Networks Visualization Tools: Dorothea Wagner, University of Konstanz, Germany.

WP4 Social Networks Characterisation and Analysis: Gerard Weisbuch, Ec. Norm. Sup., Paris France.

WP5 Models for Communication Networks: Stefano Leonardi, University of Rome, Italy

WP6 Dissemination of results: Luciano Pietronero, Istituto Nazionale per la Fisica della Materia, Italy.

WP7 Management of Consortium: Guido Caldarelli, Istituto Nazionale per la Fisica della Materia, Italy.

WP8 Assessment and Evaluation: Alessandro Vespignani, Universit de Paris Sud, France. della Materia, Italy.

The members of the consortium Board act as WP-leaders and are responsible for:

- Coordinating activities within a task, with the aim of achieving and maintaining coherence of the objectives.
- Coordinating the dissemination activities of their WP (e.g., specialised workshops, technology transfers to industry and users, etc.) with emphasis on the effectiveness of the take-up of results.
- Assembling and organising reports and deliverables on specific research tasks according to the work plan and the milestones.

Policies of operation
The partners are responsible for carrying out the planned research in the project and for the activities of scientific interchange and information dissemination (workshops and meetings).

The management of the project is carried out by the Consortium Board. The following policies are agreed by the partners:

- Each partner is responsible for carrying out his part of the intended research and for executing his responsibilities as stated in this programme.
- Each partner is responsible for carrying out the appropriate administration of the research action at its site, under formal responsibility and control of the partner's institution.
- The partners are bound by the maximum expenditure figures for costs chargeable to EU funds set by the Consortium Board, within the further constraints of the project budget. Any expenditures chargeable to EU funds in excess of the allowed maximum for a partner will be for the sole responsibility of the particular site and will not be paid for from project funds, unless explicitly approved by the Consortium Board.

Workpackage list							
WP No	*Workpackage Title*	*Lead* Contr.	Persons Months	Start Pd	End Pd	Phase	Deliverable No
WP1	Mathematical Tools for Complex Systems	CR3	67	0	42	R	D4, D10, D11, D19
WP2	Data Collection and Analysis	CR4-CR9	64	0	42	R	D5,D12,D13,D20,D21
WP3	Large Networks Visualisation Tools	CR6-CR7	58.5	0	42	R	D6,D14,D22
WP4	Dynamics of Social Networks	CR5	72	0	42	R	D7,D15,D16,D23
WP5	Models for Communication Networks	CR2	65	0	42	R	D8,D17,D24
WP6	Dissemination of Results	C01	20	3	42	R	D1,D2,D25 D26,D27,D28
WP7, WP8	Management and Assessment and Evaluation	C01-CR8	42	10	42	R	D3,D9,D18,D29
/	TOTAL	/	388.5	/	/	/	/

- The coordinating contractor shall, without delay after receipt of the advance payment or any other payment, pass on the appropriately apportioned shares to the accounts of the partners, after receipt of the corresponding payments for partner expenditures.
- The funds for the joint Consortium Activities are managed and administered by the coordinating contractor. The coordinating contractor is bound to sponsor, to the extent established by the Consortium Board, the main scientific events devoted to the dissemination and transfer of the project activities. The coordinating contractor shall do so by transferring the proper amount of funds to the sites organizing the event. The organizing sites shall be responsible for providing the coordinating contractor with the documentary evidence of the expenses incurred.

The Consortium board will also organise self-assessment meeting open to all the participants of the consortium at the end of every year.

10 Clustering

Since some of the contractors of COSIN (C01 and CR5) are also involved in the NoE EXYSTENCE, we expect to start a collaboration between this project and the above mentioned NoE, that will be based mainly in the organization of meetings and exchange of results between the two consortia.

11 Other contractual conditions

As required by the Rules in the IST Programme, node 2 (UDRLS) and node 5(ENS) had to allocate 8000 Euros for the cost of the Audit certificate.

Node 1 (INFM), node 2(UDRLS), node 3(UB) and node 8 (UPSUD) require also to buy some PC's that would be used for the following reasons:

INFM Two Pc's. One Pc will be the workstation of the administrative person employed to help in the management of the project. Spare CPU time for such a workstation will be employed to realize numerical simulations and data collections as required by the deliverables in which INFM takes part. Another Pc will be the workstation of the postdoc involved in the project and will be devoted to host the server of the website of the project. This Pc will be also used for numerical simulations and data collection.

UDRLS Four Pc's. They will be the workstations of the postdoc involved in the project and will be devoted to develop visualization codes as specified in the project. These Pc's will be also used for numerical simulations and data collection.

UB Four Pc's. They will be mainly devoted to realize numerical simulations and to collect data and they will be the workstations for the person employed by the project. Two of them will have double CPu's in order to improve the computational power required for the numerical simulation of the models.

UPSUD One Pc. This Pc will be the workstation of the postdoc that will work on data analysis and computer simulation of statistical models for networks.

Such a project will also require frequent interchanges of people in order to help the exchange of the results to realize the interconnections of deliverables in the different workpackages. On the average any node will have at least a couple of week/year of visit to the other nodes for scientific collaboration. In particular each of Node 1 (INFM), Node 2 (UDRLS), Node 3 (UB), Node 4 (UNIL-EPFL), Node 6 (UKON) Node 7 (UNIKARL) Node 8 (UPSUD) will ask the following money for:

- two weeks of visit to other nodes for scientific collaboration;
- two participations to conferences;
- two participations to consortium meetings.

In addition to that there is to consider one meeting per year and only for the WP leaders one meeting of the consortium board.

We are currently planning a world conference on this topic for the year 2003. This conference will be based outside Europe (some of the node have an established collaboration with the Department of Physics in the University of l'Habana Cuba) part of the money for travel will be used for such a reason.

References

[1] Cooperative Association for Internet Data Analysis, http://www.caida.org
[2] BURCH/CHESWICK map of the Internet, http://www.cheswick.com/map/index.html, Lucent Technologies.
[3] Geography of Cyberspace Directory, http://www.cybergeography.org
[4] B.B. MANDELBROT *The Fractal Geometry of Nature* Freeman, New York, (1983).
[5] L. PIETRONERO, E. TOSATTI (EDS). *Fractals in Physics* North-Holland, Amsterdam, New York (1986).
[6] I. RODRIGUEZ-ITURBE, A. RINALDO. *Fractal River Basins,chance and Self-Organization* Cambridge University Press, Cambridge (1997).
[7] P. BAK. *How Nature Works* Springer-Verlag New York (1999); H. J. JENSEN *Self-Organised Criticality* Cambridge

University Press, Cambridge (1998).
[8] M. Faloutsos, P. Faloutsos and C. Faloutsos *On Power-Law Relationships of the Internet Topology* ACM SIGCOMM (1999).
[9] R. Albert, H. Jeong and A. L. Barabasi *Diameter of the World Wide Web* Nature 401, 130 (1999); A. L. Barabasi and R. Albert, *Emergence of Scaling in Random Networks* Science 286, 509 (1999).
[10] G. Caldarelli, R. Marchetti and L. Pietronero, *Fractal properties of Internet*, Europhysics Letters, 53, 386 (2000).
[11] R. Kumar, P. Raghavan, S. Rajagopalan, D. Sivakumar, A. Tomkins and E. Upfal *Stochastic Models for the Web Graph.* Proc. of IEEE Foundations of Computer Science, 2000.
[12] S.R. Kumar, P. Raghavan, S. Rajagopalan, and A. Tomkins *Trawling the Web for Emerging Cyber Communities.* Proc. of the 8th WWW Coneference, pp. 403-416, (1999).
[13] A. Broder, R. Kumar, F. Maghoul, P. Raghavan, S. Rajagopalan, R. Stata, A. Tomkins and J. Wiener. *Graph Structure in the Web.* Proceedings of the Ninth International World-Wide Web Conference WWW9, (2000).
[14] D.J. Watts, S. H. Strogatz *Collective dynamics of 'small-world' networks*, Nature 393, 440 (1998). [15] M. Kochen, (ed.), *The Small World* (Ablex, Norwood, NJ) (1989).
[16] S. Milgram, Psych. Today 2, 60 (1967).
[17] G. Di Battista, Peter Eades, Roberto Tamassia, Ioannis G. Tollis: *Graph Drawing. Algorithms for the Visualization of Graphs.* Prentice Hall, (1999).
[18] Linton C. Freeman: *Visualizing Social Networks.* Journal of Social Structure, 1(1), (2000). `http://www.heinz.cmu.edu/projec`
[19] Peter Eades, Qing-Wen Feng: *Multilevel Visualization of Clustered Graphs*, in Stephen North, in *Proceedings of the Symposium on Graph Drawing, GD'96, Berkeley, California, USA, September 18-20, 1996*, pp. 101–112. Springer-Verlag, Lecture Notes in Computer Science, vol. 1190, (1997).
[20] Tamara Munzner, P. Burchard: *Visualizing the structure of the world wide web in 3D hyperbolic space*, in *Proceedings of the VRML'95 Symposium, San Diego, CA, December 13-16*, pp. 33–38. ACM SIGGRAPH, (1995).
[21] John M. Kleinberg: *Authoritative Sources in a Hyperlinked Environment. J. of the Association for Computing Machinery*, 46(5):604–632, (1999).
[22] K. Bharat, A.Z. Broder, M. Rauch-Henzinger, P. Kumar, S. Venkatasubramanian: *The Connectivity Server: Fast Access to Linkage Information on the Web.* Computer Networks, 30:469–477, (1998).
[23] B. Bollobas. *"Random Graphs"*, Academic Press, London, 1985.

Appendix 1
Consortium Description

This consortium links in a innovative way knowledge in the field of complex systems with knowledge in the specific field of engineering optimisation. Given the WP division of the project we believe that the following international recognized groups are the ones with the necessary competences to face the different Workpackages.

Node 1 Coordinator node

G. Caldarelli (General Coordinator) and L. Pietronero (Leader of WP6) at *Sezione di Roma "La Sapienza" of the National Institute for Condensed Matter (INFM) Italy.*
This group of about 10 - 15 people amongst collaborators, research assistants, PhD and undergraduate students, has a long term activity in the field of Complexity with respect to the Statistical Mechanics and Self-Similar structures.

Node 2

S. Leonardi (Leader of WP5) and A. Marchetti-Spaccamela at *Dipartimento di Informatica and Sistemistica, University of Rome "La Sapienza" Italy.*
The group of about 10 people together with collaborator G. Di Battista has a strong scientific background in the analysis and design of algorithms and in their application to networks and to the World Wide Web. They are responsible for WP5: Models for Communication Networks.

Node 3

A. Diaz-Guilera (Leader of WP1) and A. Arenas at *University of Barcelona, Spain.*
This group of about 10 people including collaborators and PhD students has long term expertise in the field of the Self-Organised Criticality. That is they worked on the identification of the key ingredients that drive the growth dynamics of complex systems in their non trivial stationary state. They are responsible for WP1: Mathematical Tools For Complex Systems.

Node 4

P. De Los Rios (Leader of WP2) at *University of Lausanne, Switzerland.*
This group had a great experience in the physics of random systems. It will collaborate with T. Erlebach whose experience is in the analysis of network data and Yi-Cheng Zhang working in the topic of complexity in finance. They are responsible for WP2: Data Collection.

Node 5

G. Weisbuch (Leader of WP4), J.P. Nadal and S. Battiston at *CENECC, Ecole Normale Superieure, Paris, France.*
The group of CENECC works in the application of statistical physics concepts and methods to cognitive and social systems. For that reason they will be responsible of WP4: Social Networks Characterisation and Analysis.

Node 6 - Node 7

D. Wagner (Leader of WP3) and U. Brandes at *Universität Konstanz, Germany and (DW only) at Universität Karlsruhe, Germany.*
This group of about 7 people together with collaborator M. Kauffmann has a strong scientific reputation in the field of algorithm engineering and automatic graph visualization tools. They will be responsible for the WP3: Large Networks Visualization Tools.

Node 8

A. Vespignani (Leader of WP8) and A. Barrat at *Universit de Paris Sud, France.*
Even if this group is starting at the time of the revision of this annex, the people has a solid reputation in the field. They will be responsible for the WP8: Self Assessment and Evaluation.

Description of Participants

1 Sezione INFM, Dipartimento di Fisica, Università di Roma "La Sapienza".

Guido CALDARELLI, General Coordinator

Italian, born on April 8 1967, INFM Research Assistant at Dipartimento di Fisica, Università di Roma "La Sapienza". Graduated in 1992 on statistical properties of fractures, he then moved to SISSA Trieste, where he obtain the degree of Magister philosophiae in 1994 and the PhD in 1996 with studies on the formation of fractal clusters in Nature. In particular the statistical properties and the Self-Organization of River Networks were investigated He then moved to Manchester and Cambridge (UK) as a postdoc. From 1998 is Research Assistant in National Institute for Condensed Matter (INFM) in Rome. His main activity focuses in the complex systems, mainly with application to biological and financial systems. His studies on stock market models and matching problems attracted interest from the media (BBC, The Times, Die Zeit, New Scientist). In recent times this research focussed on the emergence of non trivial behaviour in complex systems and in particular on the statistical properties of Internet and WWW.

Luciano PIETRONERO, Leader of WP6

Italian, born on December 15 1949, Full Professor at Dipartimento di Fisica, Università di Roma "La Sapienza" . Graduated in Roma in 1972, he then moved to Xerox Research Center and later to Brown Boveri (now ASEA) where he worked in the scientist staff of the research center until 1983. In that year he was called as Full Professor in Condensed Matter theory in the University of Groningen. In 1987 he became Full Professor in Rome. From 1995 to 2000 he was director of the local unit of National Institute for Condensed Matter (INFM). General Coordinator of the European Network on: Fractal Structures and Self-Organization cn:FMRXCT980183. This Network involves 11 Teams from 8 European countries. His main activity is in the study of statistical properties of complex structures and high Tc superconductivity. His main contribution are in the study of the electric breakdown and the formation of fractal clusters and in the study of the fractal properties of galaxy distributions in the Universe.

The group is general coordinator of the TMR NETWORK "Fractal structures and self-organization" cn:FMRXCT980183 that links all the other group active in EU. The main line of research about complex systems has been stimulated by the great successes reached in 70's in the study of critical phenomena, related to equilibrium phase transitions. The introduction of the concept of scale invariance was fundamental in this respect and it has represented the basis for the development of the Renormalization Group concepts. In phase-transitions, we have scale-invariance only for a precise value of the critical control parameter (e.g. temperature), while in nature we observe the spontaneous and irreversible growth of a large variety of structures with this property. The natural development of this field was in the direction of fractal growth models and self organised critical phenomena. For these systems however, it does not seem possible to use Renormalization Group and it is necessary introduce and develop new theoretical concepts.

a) Fractal growth theory. Fractal growth models , based on a stochastic growth process in which the probability is defined through Laplace equation (e.g. Diffusion Limited Aggregation (DLA) and Dieletric Breakdown Model (DMB)), are considered the prototypes of a many physical phenomena, that generate fractal structures. These models pose theoretical problems of a new type, mainly because their irreversible dynamics is not reducible to a Hamiltonian formalism and does not allow the definition of a statistical weight like the Boltzmann one. Recently, we have introduced a new theoretical scheme based on the so-called "Fixed Scale Trasformation (FST)" that allows to deal with the irreversible dynamics of these processes and to calculate analytically the fractal dimension. The actual activity is dedicated to a theoretical deepening of this method and to its extension to other phenomena.

b) Self-organised critical systems A problematic analogous to the fractal growth processes is that of the so-called self-organised critical systems (e.g. sandpile models). In these systems, a state with critical properties is reached spontaneously by through an irreversible dynamical evolution of a complex system. Using theoretical methods inspired to the previous ones (FST), we could define the asymptotic dynamics of these models, analyse their universality classes and compute their critical exponents.

One particular line of research where the group has been active in the past and that represents a novel approach to the study of the network is the one of drainage networks. The drainage network in river basins has a tree-like structure which provides an efficient means of transportation. Over the years, experimental analyses of river networks have shown examples of fractal behavior characterised by the absence of a single well-defined length scale. Progress in this area would not only lead to a detailed understanding of the fractal attributes of river basins but also shed light on the general questions of where fractals come from and why scale-free structures are ubiquitous in nature.

2 Dipartimento Infomatica e Sistemistica, Università di Roma "La Sapienza".

Stefano LEONARDI, Leader of WP5
Italian, born on July 31 1965. Research Assistant in the Dipartimento di Informatica e Sistemistica Università di Roma "La Sapienza". Stefano Leonardi took his PhD in Computer Engineering at the University of Rome "La Sapienza" in 1996 with Prof. Giorgio Ausiello. During 1996 he was a post-doc at the International Computer Science Institute of Berkeley, and has visited for long periods the Max-Planck-Insitut für Informatik (Saarbrücken) and Tel-Aviv University. He has co-authored about 40 publications in leading international journal and conferences and he has served in the program committees of international conferences. His main research interests are in the design and analysis of off-line and on-line approximation algorithms for network resource management and scheduling problems. In particular his current work is aimed to exploit combinatorial techniques for the modelling large complex networks such as the Internet and the World Wide Web and to network design problems.

Alberto MARCHETTI-SPACCAMELA
Alberto Marchetti-Spaccamela graduated in Electrical Engineering cum laude in 1977 at the University of Rome "La Sapienza". He has been Researcher from 1981 to 1987; from 1987 to 1991 he has been Full Professor in Computer Science at the University of L'Aquila; since 1991 he is with the University of Rome "La Sapienza". Alberto Marchetti-Spaccamela has (co-)authored about 70 papers in journals and international conferences. His current research interests concern the design and the analysis of algorithms (mainly approximate, on-line and dynamic algorithms) and their applications to computer networks and to Internet and in resource management and scheduling problems. He is responsible for EC research contracts (HCM - project MAP, RTN - project AMORE, IST - project APPOL).

The research group involved in COSIN is the Group on Algorithm Engineering at the *Dipartimento di Informatica e Sistemistica* (DIS), one of the major research institutions in Computer and System Science in Italy that includes about 60 faculty members and 50 Ph.D students. The Algorithm Engineering group consists of six faculty members and four more people (PhD students and post doc). The research group has many EC funded research contracts (in the last few years we mention the IT project ALCOM IT- coordinator, IST project ALCOM FT, RTN project AMORE, IST project APPOL and APPOL II) and several national funded research grants. The group has also strong cooperations with IT industries; in the proposed topic of the project DIS currently cooperates with major companies such as Alenia, CM Group and Etnoteam.

The Algorithm Engineering group has a strong scientific background in the analysis and design of algorithms and in their application to networks and to the World Wide Web. Namely the research that is in the interest of the COSIN project can be divided in several areas: Distributed and network algorithms, Graph and combinatorial algorithms, Approximation and on-line algorithms.

The research activity on network and distributed algorithms is focussed on providing algorithmic solutions to several resource management problems arising in computer networks, ranging from quality of service on high speed networks, wavelength assignment in optical networks, managing multicast communications, and distributing shared network resources.

An important goal of the research activities in all above areas is to bridging the gap between theoretical results and their practical effectiveness on specific relevant test cases. In fact, developing rigorous formal techniques for the implementation and the empirical analysis of algorithms is on of the major goals of Algorithms Engineering. In addition, a special effort is devoted to bridging the gap between theoretical results and their practical effectiveness on specific relevant cases.

Subcontractor UR3 (University of Roma 3) Giuseppe DI BATTISTA Giuseppe Di Battista received the Ph.D. in Computer Science from the University of Rome "La Sapienza". He is currently a faculty member in the Department of Computer Science and Automation at the Third University of Rome. His research interests include Graph Drawing and Information Visualization and the Design and analysis of Algortihms. He has (co-)authored about 100 papers in leading international journals and conferences and he has served in the program committees of many international conferences. He co-author of a book on Graph Drawing (Prentice Hall, 1999). He served on program committees of international conferences and symposia, for some of which he has been Program Chair and he is editor and guest editor of international journals. He is a founding member of the steering committee for the Graph Drawing Symposium. Over the years, his research has been supported by several sources, including the Italian National Research Council, the MURST, the NATO, the Esprit Program of the EC, and several industrial sponsors.

The main effort in this area is devoted to the design of efficient dynamic graph algorithms and in graph drawing algorithms. Given a graph and a property (e.g. connectivity), consider a sequence of changes of the structure of the graph. The challenge for a dynamic algorithm is to efficiently maintain, after any change of the sequence, a desired property in a way more efficient than applying a static algorithm for computing that property. The research in automatic graph drawing algorithms is mainly performed in cooperation with Prof. G.Di Battista (U.di Roma III) and his group; the research focuses on the automatic layout of very large (possibly infinite) graphs.

Due to their intrinsic complexity, for NP-hard optimization problems we cannot hope to find efficient general solution algorithms and we need to restrict ourselves to approximate solutions. Hence, the study of approximate algorithms for NP-hard optimization problems has a considerable importance both from the theoretical point of view, and with respect to the practical aim of designing efficient approximation algorithms, which are guaranteed to provide a solution within a maximum relative error.

3 Statistical Physics Group, Universitat de Barcelona.

Albert DIAZ-GUILERA Leader of WP1

Albert Diaz-Guilera Spanish nationality. Born in Barcelona, on August 24th, 1960. Assistant Professor at Departament de Fisica Fonamental, Universitat de Barcelona, since 1990. He got a PhD on 1987 at the Universitat Autonoma de Barcelona, studying fluctuations around nonequilibrium steady states, under the supervision of Prof. Miguel Rubi. He spent one year in Sherbrooke (Canada) working on the properties of anisotropic disordered media, specially on applications to high-T_c superconductors, under the supervision of Prof. A.-M.S. Tremblay. Since 1991 he worked mainly on applications of statistical physics on biological and economic problems. Synchronization of integrate-and-fire oscillators, self-organised criticality, models of technological evolution, and others have been my main interests. Right now, the main interest is on the study of flow of information (packets) in regular and irregular lattices. This has a potential application to the Internet flow.

The activity of this group has been devoted to the following fields:

Self-organised criticality: The phenomenon known as self-organised criticality is related to systems which spontaneously (self organised) evolve towards a stationary state without time and length characteristic scales; it is named critical because their analogies with critical phenomena, widely studied in equilibrium. The main differences are that now one deals with non- equilibrium systems, and hence equilibrium statistical mechanics can not be used, and that criticality appears without the necessity of tuning any external parameter. Within this subject our contributions can be divided in two distinct parts: Analysis of critical exponents: On one hand, we have performed extensive numerical simulations in order to measure the critical exponents. These exponents give the basic behavior of the different magnitudes describing the system. On the other, we have done theoretical calculations by means of the dynamic renormalization group, arriving to analytical expressions for these exponents. Relation between self-organised criticality and synchronization: Two phenomena, that in principle have nothing to do with each other, like self-organised criticality and synchronization (see next paragraphs) can be present simultaneously in the same system just changing some parameters of the dynamic evolution. This can explain why in Nature there are disordered (explained by means of self- organised criticality and fractals) as well as ordered (synchronization) phenomena, with the same simple dynamical rules.

Networks with hierarchical branching: Our interest in this subject is focused on the behavior of hierarchical structures formed by elements (or agents) that interact with each other via communication processes. This framework is specially adequate to study e.g. Internet flow, traffic networks, river networks, and even communication flows in organizations. We have proposed a simple model that includes only the basic ingredients present in a communication process between two elements: (i) information packets to be transmitted (delivered) and (ii) communication channels with finite capacity to transmit the packets. The model reproduces the main characteristics of the flow of information packets in a network and it is simple enough to allow analytical characterization. We can apply these ideas to the task of organizational design. It is interesting to notice that for a given hierarchical structure it is possible to calculate the maximum amount of information packets that can be generated at each time step without collapsing the organization. Two main features are observed: (i) the maximum number of packets per unit time the organization can deal with does not depend on the number of levels in the hierarchical structure and (ii) this critical number of packets is a monotonically increasing function of the branching factor, thus suggesting that, for a fixed size of the organization, the optimal structure is the flattest one, with only two levels. A different scenario arises when the more realistic situation of costly connections is considered by introducing a cost factor in the definition of agents capability. Although, as in the previous case, the maximum amount of information the organization is able to handle does not depend on the number of levels, it is not a monotonically increasing function of the branching factor. Thus the flattest structure is not the best in general. Actually, the steepness of the optimal structure is tuned by the intensity of the cost factor. As may be expected, the higher the cost of the connections, the steeper the optimal structure and vice versa. A different subjects where this framework can be applied is to the innovation capacity of an organization.

Thinking of an innovation as a combination of two complementary ideas that randomly appear in different nodes of an organization.

4-9 Institute de Physique Theorique, Université de Lausanne. (24-36) Ecole Polytechnique Federale de Lausanne

Paolo DE LOS RIOS Leader of WP2

Italian, born on December 1 1968, Assistant Professor at the Institute of Theoretical Physics, Université de Lausanne. Graduated in 1993 in Electronic Engineering, he then moved to SISSA Trieste, where he obtain the degree of Magister philosophiae in 1994 and the PhD in 1996 with studies on the statistical features of disordered systems, both at thermodynamic equilibrium and out of equilibrium. He then moved to Dresden (Germany) and Fribourg (Switzerland) as a postdoc. From September 2000 he is Assistant Professor at the University of Lausanne, Switzerland. His main activity focuses on statistical physics, mainly with application to biological macromolecules (proteins and DNA) and disordered systems, such as random trees and networks.

The University of Lausanne (Switzerland) decided in 1999 to start a group at the Institute of Theoretical Physics to work on various aspects of modern statistical physics, with an emphasis on complex and biological systems.

The activity of the group in Lausanne focuses mainly on two lines of research:

- Statistical Physics of Complex Systems: P. De Los Rios has a long time experience on out-of-equilibrium and non-equilibrium systems, in particular on problems related to self-organisation. His work in collaboration with various groups (Trieste and Rome in Italy, Brookhaven in the USA, Fribourg in Switzerland) has dealt with various problems ranging from Self-Organised Criticality (SOC) to statistical Game Theory. The latter is in connection with the flourishing field of Econophysics, which is well represented in Fribourg where a world-wide known Web repository of econophysics informations is managed (http://www.unifr.ch/econophysics). Moreover, he is interested in the statistical properties of random trees, networks and branched structures in general.
- Physics of Proteins: the group is trying to model the effects of the solvent on important issues of the physics of proteins, namely protein folding and protein-protein interactions. In particular, protein-protein interactions imply the presence of a complex protein network, that regulates the functioning of the cell. Unveiling the structure of this network is one of the paramount problems in cell biology, and the statistical analysis of data coming from gene arrays is one of the best routes to date: statistical physicists are beginning to use their methods to extract such informations. The emergence of networks even in this context stresses the relevance of these structures for our understanding of reality.

Since the administrative changes occurred in the Science Node of Lausanne, the whole group of Prof. Paolo De Los Rios has been taken in charge by the new institution EPFL. This change obviously has no impact on the scientific activity within this project.

5 CENECC, Ecole Normale Supérieure, Paris France.

Gérard WEISBUCH, Leader of WP4

Born in 1941, Gérard WEISBUCH, has a PhD in solid state physics (1967). As a professor in Marseilles university (1971-1985) he worked in polymer physics and disordered systems, boolean and formal neural nets. Since 1988 he has been a directeur de recherche at CNRS working in the department of Physics of the Ecole Normale. He also belong to the external faculty of the Santa Fe institute. In the last years a lot of his activity concerned the structure and dynamics of economic networks in the context of limited information, scarcity of resources, perishable goods. Involvement in other EC projects: IMAGES (1997-2000).

The *Ecole Normale Supérieure* is an institution of higher education created during the French Revolution. It is located in the heart of the Latin Quarter in Paris. The ENS educates students in both humanities and sciences and encourages multidisciplinary curricula. The vast majority of its students go on to become university teachers or high-level researchers, as is demonstrated by the numerous Nobel Prizes and Fields Medals awarded to former students of the Ecole Normale Supérieure. Louis Pasteur, Henri Bergson, Emile Durkheim, Jules Romains, Jean Giraudoux, Alain, Michel Foucault, Jean-Paul Sartre, Raymond Aron, the Fields Medals winners Laurent Schwartz, Jean-Pierre Serre and Ren, Thom, and Nobel laureates Romain Rolland, Alfred Kastler, Pierre-Gilles de Gennes and Claude Cohen-Tannoudji are all former students of the ENS. The group of CENECC works in the following fields. Living systems or social systems can be viewed as complex adaptive systems: They are composed of a large number of elements with intricate interactions which are not identical between several instantiations of the system (say between individual organisms of the same species for instance). Still, a number of their properties remain identical between individuals or equivalent systems. Concepts from statistical physics and non-linear dynamics accounts for these properties. The basic assumption of our approach is the interpretation of organization in real complex systems in terms of the attractors of the dynamics of a formal model system. Another field of interest is the one of Information Contagion. The simplest models of cultural diffusions, such as new technology adoption or commercial products are inspired from epidemiology. Diffusion is based on a contagion process occurring on the occasion of random encounters. Random encounters result in an S shaped dynamics for the adoption rate. Things get more intricate when one takes into account the existence of social networks which support influence propagation and the fact that some innovation does not benefit equally to all agents. For binary choices, the dynamics is described by the use of inhomogeneous automata networks. When only one neighbour is enough to transmit information, percolation phenomena control the dynamics. When economic adjustments are introduced, self-organised criticality and non Gaussian fluctuations are observed. In the case of non-binary opinions, either scalar or vectors, one observes social segregation when information contagion is restricted to close enough opinions. The group is also active in the field of theoretical immunology and in particular the Jerne networks. The basic assumption of Jerne networks is that lymphocytes and immunoglobulines interact via the same mechanisms, namely molecular recognition, as they interact with antigens. The immune response to antigen presentation can then be interpreted as an attractor in the dynamics of a network of a large number of connected entities. The analogy with memories and neural nets brings to the paradigm of an immune network proposed by N.Jerne in the early seventies. We started the study of economic networks in 1995, using a huge set of empirical data from Marseilles fish-market and established by formal modeling and numerical simulations the conditions for the emergence and maintenance of stable market relationships giving rise to distribution networks. Our main interest in the collaboration is to work on production and distribution networks, both from:

- the "inside the firm" perspective: distribution of work load and supply chain issues;
- the market perspective: how firms compete, but also interact positively to build an integrated economy.

Our general perspective is the role of information (or lack of information) in structuring economic and social relationships. We share with our colleagues in the collaboration an interest in the robustness of economic flows and structures. Another economic interpretation of structural stability we are interested in, concerns firms fusion/acquisition or outsourcing and subsidiaries dynamics.

The senior members of our team are Jean-Pierre NADAL and Gérard WEISBUCH, both directeur de recherche at CNRS (senior scientists). Several graduate students and post-doctoral scientists are also working in the group. Stefano Battiston is a graduate student working on the project under the supervision of G. Weisbuch and Eric Bonabeau (from EuroBios). He also maintains the connection with the team from Rome. We have been involved in neural nets studies since the early eighties. Apart from

studies in formal models, deriving storing and retrieving capacities of different models, we also developed models of biological neurons and technical application to visual data processing.

6-7 Group UKON(0-12)-UNIKARL(13-36) Konstanz, Karlsruhe, Germany.

Dorothea WAGNER, Leader of WP3

Dorothea Wagner is a full Professor of Computer Science at the Universität Konstanz. Her research interests include discrete optimization, graph algorithms and algorithms engineering particularly applied to transportation systems and visualization. She is Editor in Chief of Journal on Discrete Algorithms and member of the Editorial Board of Journal of Graph Algorithms and Applications. Since 2000, she is joint initiator and coordinator of the Research Training Network AMORE: Algorithmic Methods for Optimizing the Railways in Europe, (proposal no RTN1-1999-00446, contract no HPRN-CT-1999-00104), and since 2001 joint initiator and speaker of the DFG program "Algorithmik großer und komplexer Netzwerke", (SPP 1126, funded by the German Research Foundation, 2001–2006).

Within algorithms design and algorithms engineering, the group of worked on graph algorithms and computational geometry, visualization of graphs and aspects of implementing graph algorithms and geometric algorithms. Fields of applications are, among others, VLSI design, CAD, social network analysis and traffic engineering. There is a strong background in the area of *graph drawing* which includes all aspects of the visualization of structural relations between objects. The automated generation of graph drawings has important applications in many areas of computer science, such as compilers, data bases, software engineering, VLSI and network design, and graphical interfaces. Applications in other areas include graphical data analysis (e.g. in all fields of engineering, biology or social sciences) and the visualization of informations in general (e.g. by flow charts, schematic maps or all kinds of diagrams). In social network analysis, graphical representations were used already in the past in order to display in a compact way the relevant actors in a network, how they are related to each other, and what the overall structure looks like. Using visualizations as a support for network analysis is studied only very recently, and the automated generation of such visualizations is an important and non-trivial task. The group has a strong interest in sharing their recent research results on exploration and visualization of social networks. This expertise will be useful for the planned cooperation. However, there is a need to transfer these concepts to evolving networks, especially the World Wide Web. On the other hand, stochastic models must be taken into account for the design of new visualization algorithms for the Web.

8 Group UPSUD(13-36) Paris, France.

Alessandro VESPIGNANI, Leader of WP8

Prof. Alessandro Vespignani started the formation of a new group of research in the University of Paris Sud. This institution has a complete array of competences, ranging from the purest of exact sciences to clinical practices in medicine and covering life and health sciences, legal sciences and economics. The research at Paris-Sud extends to the IUT all of which pursue research in their area of expertise. Research at The Universit Paris-Sud, an essential part of academic understanding, is complemented by research activities with a high valorisation potential. Research contracts and partnerships with companies make the universit Paris-Sud a key actor and a major player in French research.

As regard the activity in the Laboratoire de Physique Thorique they range from system out of equilibrium to reaction diffusion processes to granular matter and the study of Network with particular stress on the Internet. Amongst the scientist in the institution that will work on the project there are

- Alain Barrat born in 1971 in Paris and presently permanent CNRS researcher, very active in the field of spin glasses and granular systems. He recently moved to the study of Network statistical properties.
- Alessandro Vespignani born in Rome in 1965 chargee de Researche at the Laboratory and author of a recent book on the Internet.