


<i>Crescco</i>	<b>CRESCCO</b> <b>IST-2001-33135</b> <b>Critical Resource Sharing for Cooperation in Complex Systems</b>
<p><b>Workpackage 6: Dissemination of Results</b></p> <p><b>Deliverable D6.3</b>  <b>Workshop on resource sharing methods and algorithms</b></p> <p><b>Responsible Partner: Christian-Albrechts-Universitaet zu Kiel (D)</b></p>	
<p><b>Report Version: 1.0</b>  <b>Report Preparation Date: 15/03/05</b>  <b>Classification: INT</b>  <b>Contract Start Date: 01/01/02 Duration: 41 months</b>  <b>Project Co-ordinator: University of Patras</b></p>	
<p><b>Partners:</b>  <b>Computer Technology Institute (GR)</b>  <b>University of Geneva (CH)</b>  <b>Centre National de la Recherche Scientific (F)</b>  <b>Universite de Nice-Sophia Antipolis (F)</b>  <b>Christian-Albrechts-Universitaet zu Kiel (D)</b>  <b>Universita degli studi di Salerno (IT)</b>  <b>Universita degli studi di Roma "Tor Vergata" (IT)</b></p>	
 <p>The logo for the Information Society, featuring three stylized icons (a yellow arrow, a green waveform, and a red squiggle) on a blue background, with the text "Information Society" below.</p>	<p>Project funded by the European Community under the "Information Society Technologies" Programme (1998-2002)</p>

The third workshop of CRESCCO was held in Rome, Italy, on October 16, 2004, collocated with the 45th Annual IEEE Symposium on Foundations of Computer Science (FOCS 2004). Sixteen key researchers, junior researchers, and PhD students from all partners as well as an invited speaker participated in the workshop. Also, about twenty FOCS participants attended the CRESCCO workshop. The workshop was mainly devoted to technical presentations but also informal discussions on issues related to the project took place.

The subjects of the technical presentations fell into the thematic workpackages of CRESCCO, i.e., they were related to algorithms for resource sharing on wireless networks (WP1), distributed computing using selfish agents (WP2), scheduling in networks (WP3), and network design (WP4). Eight 45-minutes talks with short additional time for discussions were given. These included an invited talk and talks on specific scientific results (the corresponding papers recently appeared or are going to appear soon in conference proceedings and journals), work in progress, and surveys of particular fields. In addition to the presentation of theoretical developments, many of the presentations contained experimentation for the validation of algorithms, simulations and visualization of solutions. In the following, we give a brief overview of the presentations.

Pierre Fraigniaud, who was the invited speaker, presented a survey of recent results related to routing in augmented graphs. Special emphasis was given to  $d$ -dimensional meshes augmented with links chosen at random. Greedy routing in these graphs aims at modeling the behavior of entities looking for information in a societal network, and at giving formal support to Milgram's experiment. He surveyed the different types of greedy routing strategies and their applications to the design of overlay networks for P2P applications.

Scheduling in networks was the subject of the talk given by Aleksei Fishkin (CAU). The speaker addressed the problem of packing of a list of rectangles with weights into a dedicated rectangle, so that the weight of the packed rectangles is maximized. He considered the case of large resources, and presented an algorithm which finds a packing of a sublist of rectangles whose total weight is at least  $(1 - \epsilon)$  of the optimal weight and obtains running time polynomial in  $n$  and  $1/\epsilon$ . This problem has important applications to a number of fields including bandwidth allocation in communication networks.

Jean-Claude Bermond (UNSA/CNRS) addressed the design of networks to be placed on satellites, a problem proposed by Alcatel Space Industries. These networks should connect inputs (corresponding to signals arriving at the satellite) to outputs (corresponding to Travelling Wave Tube Amplifiers), even in the case of failures of amplifiers. The networks are made of links (wave guides) and expensive switches. In such a setting, the aim is to minimize the number of switches subject to the following conditions: each input and each output is connected to exactly one switch; each switch is adjacent to exactly four links; there are  $n$  inputs and  $n + k$  outputs; among the  $n + k$  outputs,  $k$  can fail permanently; and finally all the input signals should be sent to valid amplifiers (outputs) via disjoint paths. The speaker provided an extensive overview of recent results obtained within the project.

Ioannis Caragiannis (UoP) presented recent results on the problem of energy-efficient communication in ad-hoc wireless networks. In these networks, efficiently supporting communication patterns (such as broadcasting, multicasting, gossiping, and multiconnectivity) that are common in traditional (wired) networks is an important engineering problem. Since establishing communication in ad hoc wireless networks strongly depends on the use of energy, the important question to be solved is to guarantee a desired communication pattern minimizing the total energy consumption. Depending on the properties of the desired communication pattern, the speaker defined a series of communication problems where the minimization of energy is the main concern and presented approximation algorithms and inapproximability results.

Miriam Di Ianni (Rome) also considered the problem of computing minimal energy-cost range assignments in ad-hoc wireless networks for performing broadcasting (one-to-all communication) and anti-broadcasting (all-to-one communication) operations in at most a constant number  $h$  of hops. In particular, the well-studied case in which the stations are located on the plane and the cost to transmit from one station to another is proportional to some constant power of the distance between the stations was considered, a problem which is known to be computationally hard. The speaker presented recent theoretical results including polynomial-time algorithms, approximation schemes and lower bounds for important special cases of both problems and their generalizations. Extensive experimental results were also discussed.

Pierre Leone (Geneva) in his presentation considered the dynamic modelling of wireless sensor networks. He described some applications and discussed capacity and stability of wireless networks considering the classical ALOHA protocol. He presented recent work of Geneva on a dynamical model for wireless sensor networks and explained how they analyze the broadcast process in such networks using sophisticated mathematical tools such as martingale theory and Markov chains.

Paolo Penna (UNISA) talked on the design of truthful mechanisms. Several problems related to large distributed systems (such as the Internet) turn out to be problems involving the so called selfish agents, that is, problems in which a set of players can possibly misreport some information to the system in order to get some benefit (i.e., a better utility). Such a selfish behavior of the agents can lead the system to compute non-optimal (or unfeasible) solutions. The speaker presented several algorithmic results and lower bounds for dealing with this selfish behaviour.

Viki Papadopoulou presented recent results of CTI on three important communication problems. For the frequency assignment problem in ordinary and succinct networks, where the frequencies are the critical resources. The objective is to establish communication using minimum bandwidth. The speaker reviewed recent results concerning the complexity and approximability of the problem. The second problem studied was routing of selfish flows. Here the communication links are the critical resources and the problem is considered as a selfish routing game or a congestion game, where  $n$  players, corresponding to flows, wish selfishly to be satisfied (routed in the minimum expected latency). The speaker presented statements about the existence and tractability of Nash Equilibria in such games. Finally, problems related to the accomplishment of large sensing tasks (data propagation) in sensor networks were discussed. Here the critical resource is the energy. The speaker presented energy efficient load balancing communication protocols for data propagation.

The agenda of the workshop also contained discussions on specific issues related to the project. Key researchers from all partners participated in these discussions and assessed the project directions and results during the third year of the project, discussed on the research and dissemination strategy, the continuation of experimental work, and project management issues.

Also, preparation and scheduling of the work that must be done for the final review of the project were made along with a detailed review of the comments and recommendations in the second periodic review report. Discussions and further planning were carried out with respect to the project deliverables, the coordination of collaborations between partners and cooperations in the context of different workpackages which are somehow interrelated, the project dissemination actions (e.g., the project's web site, participation in conferences and workshops, CRESCCO book etc.), and the monitoring of concurrencies and interactions with other GC projects.

In the following, we give the list of abstracts of the technical presentations as well as the list of participants.

## List of presentation abstracts

**Title:** A Survey of Routing in Small Worlds

**Speaker:** Pierre Fraigniaud (Invited Speaker, Universite Paris-Sud/CNRS, France)

**Related workpackage:** WP3, WP4

**Abstract:** This talk will survey the recent results related to routing in augmented graphs. From the seminal work of Kleinberg, we will mostly concentrate our attention on  $d$ -dimensional meshes augmented with links chosen at random. Greedy routing in these graphs aims at modeling the behavior of entities looking for information in a societal network, and at giving formal support to Milgram's experiment. The many different types of greedy routing strategies will be surveyed, and their applications to the design of overlay networks for P2P applications discussed.

**Title:** On efficient weighted rectangle packing with large resources

**Speaker:** Aleksei Fishkin (CAU)

**Co-authors:** Olga Gerber (CAU) and Klaus Jansen (CAU)

**Related workpackage:** WP3

**Abstract:** We address the problem of packing of a list  $L$  of  $n$  rectangles with weights into a dedicated rectangle  $R$  so that the weight of the packed rectangles is maximized. We consider the case of large resources, that is,  $R$  has width  $a > 0$  and height  $b > 0$ , whereas each rectangle in  $L$  has width in  $(0, a]$  and height in  $(0, \epsilon^3 \cdot b]$ , for some small  $\epsilon > 0$ . We present an algorithm which finds a packing of a sublist of  $L$  whose total weight is at least  $(1 - \epsilon)(L)$ , where  $(L)$  is the optimum. The running time of the algorithm is polynomial in  $n$  and  $1/\epsilon$ .

**Title:** Design of fault-tolerant networks for satellites

**Speaker:** Jean-Claude Bermond (UNSA/CNRS)

**Related workpackage:** WP4

**Abstract:** This talk deals with the design of networks to be placed on satellites, a problem proposed by Alcatel Space Industries. These networks should connect inputs (corresponding to signals arriving at the satellite) to outputs (corresponding to Travelling Wave Tube Amplifiers), even in the case of failures of amplifiers. The networks are made of links (wave guides) and expensive switches. Hence, we want to minimize the number of switches subject to the following conditions: each input and each output is connected to exactly one switch; each switch is adjacent to exactly four links; there are  $n$  inputs and  $n+k$  outputs; among the  $n+k$  outputs,  $k$  can fail permanently; and finally all the input signals should be sent to valid amplifiers (outputs) via disjoint paths. We survey the results obtained by the MASCOTTE team on this subject. There are variants of the problem according to whether each signal needs a specific amplifier or can be sent to any of the amplifiers (that is, all the amplifiers have the same function). In the first case we show how the problem is related to the construction of permutation networks. Furthermore, we also construct networks tolerating blocking of switches. In the case of identical amplifiers, the aim is to design networks having as few switches as possible and satisfying the following property: there exist  $n$  edge-disjoint paths from the  $n$  inputs to any set of  $n$  outputs chosen from the  $n+k$  total number of outputs. We show how to use flow theory and various tools to

determine the minimum number of switches for small fixed  $k$ . We also show that in the case  $k = n$ , the problem is related to the existence of expanders.

**Title:** Approximation algorithms for energy-efficient communication in ad hoc wireless networks

**Speaker:** Ioannis Caragiannis (UoP)

**Co-authors:** Christos Kaklamanis (UoP) and Panagiotis Kanellopoulos (UoP)

**Related workpackage:** WP1

**Abstract:** Efficiently supporting communication patterns that are common in traditional (wired) networks is an important problem in ad hoc wireless network as well. These patterns include broadcasting, multicasting, gossiping (all-to-all communication), and multiconnectivity. Since establishing communication in ad hoc wireless networks strongly depends on the use of energy, the important question to be solved is to guarantee a desired communication pattern minimizing the total energy consumption. Depending on the properties of the desired communication pattern, we define a series of communication problems where the minimization of energy is the main concern and present approximation algorithms and inapproximability results.

The talk will give an overview of results presented in the following papers:

1. I. Caragiannis, C. Kaklamanis, and P. Kanellopoulos. New Results for Energy-Efficient Broadcasting in Wireless Networks. In Proc. of the 13th Annual International Symposium on Algorithms and Computation (ISAAC '02), LNCS 2518, Springer, pp. 332-343, 2002.
2. I. Caragiannis, C. Kaklamanis, and P. Kanellopoulos. Energy-Efficient Wireless Network Design. In Proc. of the 14th Annual International Symposium on Algorithms and Computation (ISAAC '03), LNCS 2906, Springer, pp. 585-594, 2003.

**Title:** Algorithms for the Hop-Restricted Range Assignment Problems and other Extensions

**Speaker:** Miriam Di Ianni (Rome)

**Co-authors:** C. Ambuehl (Rome), A.E.F. Clementi (Rome), N. Lev-Tov (Rome), A. Monti (Rome), D. Peleg, G. Rossi (Rome) and R. Silvestri (Rome)

**Related workpackage:** WP1

**Abstract:** This talk concerns the problem of computing minimal energy-cost range assignments in ad-hoc wireless networks allowing a station to perform broadcast (one-to-all communication) and anti-broadcast (all-to-one communication) operations in at most a constant number ( $h$ ) of hops. In particular, the well-studied real case in which the stations are located on the plane and the cost to transmit from one station to another is proportional to some constant power ( $p$ ) of the distance between the stations is considered.

The general version of the  $h$ -hops broadcast range assignment problem (i.e., when transmission costs are arbitrary) is a well-known NP-hard problem, even for  $h=2$ . In this talk the results in [1] are presented, i.e. a polynomial-time algorithm for finding an optimal 2-hops broadcast range assignment and a polynomial-time approximation scheme (PTAS) for the the  $h$ -hops broadcast range assignment for any fixed constant  $h$ . The results hold independently from  $P$ . As to the anti-broadcast, an investigation on fast and easy-to-implement heuristics working for any constant  $h \geq 0$  and  $P=1$  has been performed in [2], on instances obtained by choosing at random  $n$  points in a square of side length  $L$ . This formulation

makes the anti-broadcast problem equivalent to that of computing height-bounded rooted minimum spanning trees of geometric graphs. The results of [2] are presented in this talk:

1. a general lower bound on the solution cost that holds with high probability
2. an easy-to-implement, very fast heuristic and the proof that its solution cost matches the lower bound;
3. the analysis of three simple heuristics based on classical greedy algorithms (Prim's and Kruskal's ones) for the MST problem. Rather surprisingly, they asymptotically do not do better (with high probability) than the trivial heuristic that connects all points directly to the root.

Finally, the weighted version of the previously mentioned range assignment problem is considered, in which the cost paid by a station to transmit to some other station does not depend only on their distance but also on the environmental conditions of the transmitting station. The set of algorithmic results for this more general version of the range assignment problems provided in [3] are discussed in this talk.

1. C. Ambuehl, A.E.F. Clementi, M. Di Ianni, N. Lev-Tov, A. Monti, D. Peleg, G. Rossi and R. Silvestri, "Efficient Algorithms for Low-Energy Bounded-Hop Broadcast in Ad-Hoc Wireless Networks", Proc. of STACS'04.
2. A.E.F.Clementi, M.Di Ianni, A.Monti, G.Rossi and R.Silvestri, "Analysis of Fast Heuristics for the Minimum  $h$ -Hops Spanning Tree Problem on Random Instances of the Plane", manuscript.
3. C.Ambuehl, A.E.F.Clementi, M.Di Ianni, A.Monti, G.Rossi and R.Silvestri, "The Range Assignment Problem in Non-Homogeneous Static Ad-Hoc Networks", Proc. of IPDPS-WMAN04.

**Title:** Dynamical models for wireless sensor networks

**Speaker:** Pierre Leone (Geneva)

**Co-authors:** Jose Rolim (Geneva)

**Related workpackage:** WP1

**Abstract:** We start the talk with some general remarks related with dynamical modelling of wireless networks: various modelisations of the PHY and the MAC layers. We describe some applications and discuss capacity and stability of wireless networks considering the classical ALOHA protocol. Next, we turn to our contribution. We introduce a dynamical model for wireless sensor networks. We obtain a convergent martingale for the broadcast process in such networks. To our knowledge, such martingales were unknown previously. We look at a formal model using the formalisms of martingales, dynamical systems and Markov chains, each formalism providing complementary and coherent information with each other. The model is validated in its scope of application with numerical simulation of wireless sensor networks, we make explicit the situations where the model is realistic. We also provide a formal analysis of the quasi-stationary distribution. The model is based on hypothesis which are more fulfilled when the emission radius  $r$  becomes larger and emission angle  $\alpha$  smaller in order to keep the expected number of connections  $\frac{N}{2}\alpha r^2$  constant. In the situation where the hypothesis are 'almost' fulfilled good agreement between numerical experiments and results of the model are observed.

**Title:** Design of fault-tolerant networks for satellites

**Speaker:** Jean-Claude Bermond (UNSA/CNRS)

**Related workpackage:** WP4

**Abstract:** This talk deals with the design of networks to be placed on satellites, a problem proposed by Alcatel Space Industries. These networks should connect inputs (corresponding to signals arriving at the satellite) to outputs (corresponding to Travelling Wave Tube Amplifiers), even in the case of failures of amplifiers. The networks are made of links (wave guides) and expensive switches. Hence, we want to minimize the number of switches subject to the following conditions: each input and each output is connected to exactly one switch; each switch is adjacent to exactly four links; there are  $n$  inputs and  $n+k$  outputs; among the  $n+k$  outputs,  $k$  can fail permanently; and finally all the input signals should be sent to valid amplifiers (outputs) via disjoint paths. We survey the results obtained by the MASCOTTE team on this subject. There are variants of the problem according to whether each signal needs a specific amplifier or can be sent to any of the amplifiers (that is, all the amplifiers have the same function). In the first case we show how the problem is related to the construction of permutation networks. Furthermore, we also construct networks tolerating blocking of switches. In the case of identical amplifiers, the aim is to design networks having as few switches as possible and satisfying the following property: there exist  $n$  edge-disjoint paths from the  $n$  inputs to any set of  $n$  outputs chosen from the  $n+k$  total number of outputs. We show how to use flow theory and various tools to determine the minimum number of switches for small fixed  $k$ . We also show that in the case  $k = n$ , the problem is related to the existence of expanders.

**Title:** Efficient Assignment of Critical Resources: Frequencies, Links, Energy power

**Speaker:** Viki Papadopoulou (CTI)

**Related workpackage:** WP1

**Abstract:** We study important optimization issues on real network concerning the management and sharing of critical communication resources such as Frequencies, Links and Energy Power. We consider three basic fundamental relative problems:

- The Frequency Assignment Problem in ordinary and Succinct Networks, where the frequencies are the critical resources. The objective is to establish communication using minimum bandwidth. We review on important basic results obtained by our group concerning proving hardness results and providing exact or approximation algorithms.
- Routing of Selfish Flows. Here the links are the critical resources. We consider the problem as a selfish routing game or a congestion game, where  $n$  players, corresponding to flows, wish selfishly to be satisfied (routed in the minimum expected latency). We explore the existence and tractability of Nash Equilibria in such games.
- Accomplishment of Large Sensing tasks (data propagation) in Sensor Networks. Here the critical resource is the energy. We provide energy efficient load balancing communication protocols for data propagation.

## List of participants (from CRESCCO partners)

Vincenzo Auletta	UNISA
Jean-Claude Bermond	CNRS/UNSA
Ioannis Caragiannis	UoP
Andrea Clementi	Rome
David Coudert	CNRS/UNSA
Miriam Di Ianni	Rome
Aleksei Fishkin	CAU
Pierre Fraigniaud (invited speaker)	Paris-Sud/CNRS)
Olga Gerber	CAU
Christos Kaklamanis	UoP
Pierre Leone	Geneva
Viki Papadopoulou	CTI
Paolo Penna	UNISA
Pino Persiano	UNISA
Jose Rolim	Geneva
Gianluca Rossi	Rome
Michel Syska	CNRS/UNSA