BIONETS E-News

Bio-Inspired Networks and Services   `www.bionets.eu`   Issue 2, February 2007

Dear BIONETS members,
As always, we welcome your comments and suggestions. If you would like to participate or contribute to the content of the E-Newsletter, please feel free to contact us at bionets-website@create-net.org

BIONETS News

- BIONETS innovative approach to security problems got exposure on IST Results. BIONETS team members were interviewed on the relevance of their research on security for dynamic networks. You can find an excerpt from the interview at `http://istresults.cordis.lu/index.cfm/section/news/tpl/article/BrowsingType/Features/ID/82946`

- In June 2006, E. Altman was invited to give a plenary lecture at ISDGA (International Symposium on Dynamic Games and Applications). The lecture was entitled "On Stochastic Games in Wireless Telecommunications".

- K. Avranchekov was invited to give a plenary talk at the first International Conference for Young Researchers in Computer Science, Control, Electrical Engineering and Telecommunications, September 18-20, 2006, Zielona Gora, Poland, on "PageRank".

- D. Schreckling gave an invited speech at ESAS, Sept. 20-21, 2006, Hamburg, on "Security in Biologically-Inspired Networks and Services". The slides can be found at `http://www.bionets.eu/docs/esas2006.pdf`

- A Workshop/Brainstorming on Internet of the Future took place in Montréal, Canada, on September 29th 2006, featuring an exchange of opinions and extensive discussions between IST and Canadian projects. A presentation on BIONETS, entitled "BIONETS: From Pervasive Computing Environments to the Internet of the Future" was given by D. Miorandi and can be found at `http://www.bionets.eu/docs/miorandiMontreal.pdf`. Material from the workshop can be found at `http://www.iitelecom.com/index.php?id=339&L=`

- The IST 2006 conference took place in Helsinki, Finland, featuring more than 4500 delegates from all over Europe. An advertisement of the BIONETS project appeared in the November issue of the Parliament Magazine, freely distributed to all IST delegates. An invited talk,

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entitled "BIONETS - Running Services in a Disappearing Network: Anything to Learn from Nature?" was given by D. Miorandi in the Networking Session on "Opportunistic Networking for Pervasive Communications and the Future Internet". The slides are available at `http://www.bionets.eu/docs/miorandiHelsinky.pdf` All the material presented can be found at

`http://www.haggleproject.org/index.php/SAC_Helsinki`

- An invited talk, featuring BIONETS innovative approach to service evolution, was given by F. Baude at the Grids@WORK III conference. The presentation, entitled "Autonomous Services. Feedback from some on-going EU projects" is accessible to consortium members through BSCW.

Upcoming Project Meetings

First Technical Review Meeting

Zurich, March 8-9

The first project review will take place in Zurich, Switzerland, on March 8-9. The review will be preceeded by a joint SAC meeting focusing on the forthcoming Future Internet Research Experimentation (FIRE) initiative. The BIONETS consortium will also hold a preparatory meeting in Zurich on March 5-6, kindly hosted by ETH Zurich.

Contact person: Elena Murelli, Davide Mandato, Daniele Miorandi (CN).

New Deliverables & Publications

Note: for more details and PDF version, where available, please check the project Web site `www.bionets.eu`

The initial mathematical models of new BIONETS network elements and algorithms

Authors: V. Simon, S. Szabo, E. Varga, T. Csvorics, M. Berces, L. Bacsardi, B. Tujner (BUTE), F. De Pellegrini, D. Miorandi, I. Carreras (CN), A. Panagakis, A. Vaios (NKUA), E. Altman, M. Debbah, F. Baude (INRIA)
Type: Deliverable (D1.3.1)

The main goal of BIONETS project is to provide a biologically inspired open network paradigm for the creation, dissemination, execution and evolution of autonomic services. The goal of this document is to analyze the performance of the new networking concepts and methods introduced in the project. The analysis relies on two major types of activities: mathematical modeling and simulation. The performance analysis/evaluation results can provide useful feedback on the design of the protocols. In this deliverable the first mathematical models developed for the BIONETS environment are presented, focusing on mobility modeling, on specific mobility management schemes (the way data are spread in the system) and on power transmission control. The first part of the mathematical modeling is the mobility modeling, which is indispensable to validate and analyze the performance of the new network paradigm and techniques introduced in BIONETS. In this part, two novel mobility models were developed, modifying the existing mobility models and creating new ones based on real-life user movements, in order to fulfill the requirements of modeling the behavior of U nodes. The outcome of this task is utilized in the mathematical analysis and in the simulator, too. We then study the efficiency of these information dissemination algorithms with respect to information availability, scalability and induced overhead. The second part of the deliverable deals with the mobility management solutions for BIONETS, considering that the diffusion of raw data relies heavily on user mobility in order to reach all the intended destinations. Therefore, information dissemination has a very important role in the entire system. Basically, the entire operation depends on the effective spreading of information as the system has very special attributes. In a non-centralized network like BIONETS there is no entity that knows the entire system's state. So our main focus is on one node and on its decisions. Three different forwarding schemes were considered: the first is a modified flooding algorithm; the second is a new family of protocols, the third one is two-hop relaying. 'Flooding' means that a node of

a network transmits a message not considering addressing, i.e. all the neighbors will get the packet. In BIONETS a "controlled or adaptive" flooding was used: all the nodes gather information about their environment, and according to this knowledge they decrease or increase the interval time between broadcasts. The second solution is a new family of protocols called InfOrmation Dissemination Protocol for BIOlogically Inspired autonomic Networks and Services (IOBIO). The motivation behind this method is to save bandwidth and extend battery life. It also provides protection against spamming, e.g. when a node spreads too many and basically not useful messages. The IOBIO is based on a three-stage handshake and some kind of meta-information. According to one of the types of movement model, we operate with different interesting groups and it is assumed that each node belongs to at least one of these groups. In the third solution two-hop-relaying algorithms are presented Finally the third part of this deliverable addresses the issue of power control. In the BIONETS networks, the data transfer between numerous, cheap T-Nodes, and the moving U-Nodes are expected to generate heavy traffic on the radio interface in heavily populated areas. It is important hence, to optimize the traffic on the radio channel. In multi-user systems networks CDMA (Code Division Multiple Access) is an applicable technology. We therefore present a study of the application of CDMA in BIONETS, by optimizing the radio transmission based on Random Matrix Theory.

Specification of Service Life-Cycle

Authors: Heiko Pfeffer, David Linner, Ilja Radusch, Stephan Steglich (TUB), Lidia Yamamoto (UBASEL), Janne Lathi (VTT), Daniele Miorandi (CN), Antonietta Mannella (TI), Francoise Baude, Viet Dung Doan, Ludovic Henrio, Paul Naoumenko (INRIA), David Villegas (SUN), Juanjo Aparicio (SUN)
Type: Deliverable (D3.2.1)

The objective of this deliverable is to introduce a biologically inspired service lifecycle enabling services to cope with challenges arising due to the assumptions made for the future bio-inspired computing environments such as high mobility and heterogeneity with regard to devices and services themselves. The BIONETS service life therefore builds upon providing a high level of autonomy in terms of service evolution and adaptation as well as service self-control and self-management. Since services should become the main entity within a BIONETS computing environment, service interaction models are outlined able to meet the requirements implied by an autonomous service design. Based on these objectives, a service

architecture as well as a service interaction framework are modelled implementing the introduced services and service interaction schemes, respectively. However, this deliverable does not lay claim to cover all introduced aspects entirely; it rather is intended to provide a solid and coherent starting point for more detailed investigations within different aspects of the service life cycle.

Trust and Reputation Management System Definition

Authors:Anurag Garg, Roberto Battiti, Alberto Montresor, Mauro Brunato, Roberto Cascella (CN-UNITN)
Type: Deliverable (D4.1)

This document defines the BIONETS trust and reputation management system and summarizes the work performed in Task 4.2 to identify the security challenges unique to the BIONETS architecture and to define solutions to these challenges through the trust and reputation management system that will be used to provide soft security management of resources in BIONETS. As such, trust and reputation management is not a substitute for hard security mechanisms that will be used to protect BIONETS from external and internal threats but is a complementary technique that encourages the "right" behaviour by BIONETS components.

This document is not intended to provide detailed algorithms or implementation details of the trust and reputation management systems. Instead, it looks at the BIONETS node and system architecture from the point of view of trust and reputation management, examines the suitability (or lack thereof) of existing trust and reputation management techniques in this context and finally presents a system definition incorporating existing know-how and novel techniques that are necessitated by the unique evolutionary (and revolutionary) nature of BIONETS. In defining the trust and reputation management system, we take into account the heterogeneous capabilities of the nodes that participate in the system. As the types of the nodes are different, including T-Nodes, U-Nodes and AP-nodes, the reputation system reflects this heterogeneity by defining different types of reputation associated with each type of node. In addition, services in BIONETS also have reputation values that are an indicator of the service demand, quality and reliability. BIONETS services are autonomic, and evolve to adapt to the surrounding environment, like living organisms evolve by natural selection. One of the primary mechanisms through which this natural selection takes place is service reputation. A service that has a low reputation will not find any clients

and would gradually disappear from the network. A service that meets demand in a satisfactory manner will find its reputation increase and more resources will be allocated to it as a result. The BIONETS reputation management system will also be used to provide flexible soft-management mechanisms that are appropriate for a highly disconnected network. Disconnected operation will be common in BIONETS and there will often be isolated "clouds" of nodes that are only able to communicate with each other and are unable to communicate with anyone outside the cloud. In this situation, a transient trust network will be setup which will allow nodes to store all local transactions value or to calculate temporary reputations of other nodes until reconnection to the rest of the network when reputation values for the nodes can be synchronized and updated. To show how the reputation management architecture defined in this document will respond to attacks we present a threat analysis. In this analysis, many typical attacks on autonomic systems are listed and we show how the BIONETS reputation management system reacts to them. It must be noted that this response may not be adequate to secure the network as a full response to all of these attacks will necessarily involve the BIONETS security architecture and is out of scope of this document. Nevertheless, this document provides an important component of the overall BIONETS security architecture.

BIONETS network framework implementation

Authors: Juanjo Aparicio (SUN), David Villegas (SUN)
Type: Deliverable D5.1

The goal of this deliverable is to provide a network framework that validates the ideas introduced in previous deliverables, such as D1.1.1 and D3.1.1. BIONETS network framework provides a low level implementation for the BIONETS architecture where services can be built upon. In this implementation our efforts will be headed towards having a model which supports the requirements introduced in the mentioned documents in order to simulate the network behavior and proof the theoretical outcome of BIONETS project. For this reason, we do not intend to implement a framework that depends on concrete node architecture -although this approach is not discarded for future versions- instead of that this deliverable consists in a high level implementation of the BIONETS network.

Service Evolution in Bio-Inspired Communication Systems

Authors: D. Miorandi, L. Yamamoto and P. Dini
Type: Conference Paper (Proc. of SOAS 2006)
Note: also in Int. Trans. Syst. Sc. and Appl. , vol. 2, n. 1, pag. 51-60, Sep. 2006

An autonomic network must work unsupervised, therefore must be able to respond to unpredictable situations. The BIONETS project is working towards resilient network services that are able not only to perform short-term adaptations to the environment but also long-term evolution of new functionalities. To this end, a bio-inspired approach is proposed, based on an extension of evolutionary computing to a pervasive environment where disconnected operation is common, and where the fitness of a service is evaluated at runtime. Crossover or recombination of existing services occurs as opportunistic exchange of parameters or code, producing new generations of services which proliferate in the network or are discarded by a mechanism similar to natural selection. In this paper we review the research lines related to autonomic service evolution currently in progress within BIONETS. A catalytic graph model describes the flow of opportunistic evolutionary interactions, shaped by cascade fitness evaluations. We present a research agenda and possible avenues leading to self-evolving services, and discuss their potential impact on future service engineering

Understanding the Spread of Epidemics in Highly Partitioned Mobile Networks

Authors: I. Carreras, D. Miorandi, G. Canright and K. Engo-Monsen
Type: Conference Paper (Proc. of BIONETICS 2006)

In this paper we introduce a model for analyzing the spread of epidemics in a disconnected mobile network. The work is based on an extension, to a dynamic setting, of the eigenvector centrality principle introduced by two of the authors for the case of static networks. The extension builds on a new definition of *connectivity matrix* for a highly partitioned mobile system, where the connectivity between a pair of nodes is defined as the number of *contacts* taking place over a finite time window. The connectivity matrix is then used to evaluate the eigenvector centrality of the various nodes. Numerical results from real-world traces are presented and discussed.

A Graph-Based Model for Disconnected Ad Hoc Networks

Authors: F. De Pellegrini, D. Miorandi, I. Carreras and I. Chlamtac
Type: Conference Paper (to appear in Proc. of IEEE INFOCOM 2007)

Recently, research on disconnected networks has been fostered by several studies on delay-tolerant networks, which are designed in order to sustain disconnected operations. We focus on the emerging notion of connectivity which exists in such networks, where the message exchange between nodes is enforced by leveraging storage capabilities at intermediate relays, with the aim of achieving connectivity over time. The problem, under the constraint of intermittent connectivity, is hence to devise efficient mechanisms for message delivery, and evaluate the performance thereof.

In this paper, we introduce a graph-based model able to capture the evolution of the connectivity properties of such systems over time. We show that, for most networks of interest, such connectivity graphs can be modeled as Erdös-Renyi random graphs. Furthermore, we show that, under a uniformity assumption, the time taken for the connectivity graph to become connected scales as $\Theta(n \log n)$ with the number of nodes in the network. Hence we found that, using epidemic routing techniques, message delay is $O(n \log^2 n / \log \log n)$. The model is validated by numerical simulations and by a comparison with the connectivity patterns emerging from real experiments.

undersound: Music and Mobility Under the City

Authors: Bassoli, A., Brewer, J. and Martin, K.
Type: Poster Presentation (in Proc. of Ubicomp 2006)

3 million people each day travel through London by means of the Underground, the oldest subway system in the world —people hate it, people love it. Still, the Tube is one of the most widely recognized symbols of the city, and practically one of the most used transport systems. With the project undersound we are exploring the experience of riding the Underground and the mediated perception of the urban space through the design of a highly contextualized interactive syste —a music-based application that encourages people to interact with others and with the Underground itself. The aim of the project is to make people reflect on their experience through the use of music, to see people's behaviours and patterns of movement in new ways.

Exploring in-between-ness: the experience of riding the London Tube

Authors:Bassoli, A. and Martin, Karen
Type: Position Paper (in Proc of ExUrban Noir, Ubicomp 2006)

Research on the design of future technologies has been recently directed toward the identification of what space and place mean in relation to people and ubiquitous technologies. However, mostly the workplace and the domestic sphere have been well defined and studied so far, with a smaller number of projects focusing on social spaces. We believe these categories only address a narrow range of people's daily experience. More specifically, the transition from one place to another has not been much considered, yet it is these transitions which structure people's daily life as a continuous flow rather than a series of discrete moments. We are using the concept of in-betweenness to explore these passages between meaningful places and events. In-between spaces such as public transport, lobbies, shopping plazas and underpasses are typically overlooked and relegated to the background; only by virtue of their unimportance are they considered to be related. Rather than classing them as the void between more 'meaningful' places, we are considering them in their own right.

Imaging Spatial and Social Relationships Under the City

Authors: Martin, K. and Bassoli, A
Type: Position Paper (in Proc. of Imaging the City, CHI 2007)

In this paper, and the undersound project it describes, we are trying to identify a method for mapping the interrelationship of space, social and informational networks that increasingly co-exist in our cities. We define space as being the gaps between physical objects. While this seems obvious, we suggest that taking this view emphasizes flow, or movement, through the city as the primary way of experiencing and encountering the city. By picturing the flow of people and information around the city we wonder if this will reveal new inspiration and opportunity for the design of mobile and situated urban technologies.

Reactive Search: Machine Learning for Memory-Based Heuristics

Authors:Roberto Battiti, Mauro Brunato
Type: Book Chapter (in Approximation Algorithms and Metaheuristics, CRC Press, to be published, 2007.)

Most state-of-the-art heuristics are characterized by a certain number of choices and free parameters, whose appropriate setting is a subject that raises issues of research methodology. In some cases, these parameters are tuned through a feedback loop that includes the user as a crucial learning component: depending on preliminary algorithm tests some parameter values are changed by the user, and different options are tested until acceptable results are obtained. Therefore, the quality of results is not automatically transferred to different instances and the feedback loop can require a lengthy "trial and error" process every time the algorithm has to be tuned for a new application. Parameter tuning is therefore a crucial issue both in the scientific development and in the practical use of heuristics. In some cases the role of the user as an intelligent (learning) part makes the reproducibility of heuristic results difficult and, as a consequence, the competitiveness of alternative techniques depends in a crucial way on the user's capabilities. Reactive Search advocates the use of simple sub-symbolic machine learning to automate the parameter tuning process and make it an integral (and fully documented) part of the algorithm. If learning is performed on line, task-dependent and local properties of the configuration space can be used by the algorithm to determine the appropriate balance between diversification (looking for better solutions in other zones of the configuration space) and intensification (exploring more intensively a small but promising part of the configuration space). In this way a single algorithm maintains the flexibility to deal with related problems through an internal feedback loop that considers the previous history of the search. In the following, we shall call reaction the act of modifying some algorithm parameters in response to the search algorithm's behavior during its execution, rather than between runs. Therefore, a reactive heuristic is a technique with the ability of tuning some important parameters during execution by means of a machine learning mechanism. It is important to notice that such heuristics are intrinsically history-dependent; thus, the practical success of this approach in some cases raises the need of a sounder theoretical foundation of non-Markovian search techniques.

GOSH! Gossiping Optimization Search Heuristics

Authors: Mauro Brunato, Roberto Battiti, Alberto Montresor
Type: Conference Paper (in Proc. of LION 2007)

While the use of distributed computing in search and optimization problems has a long research history, most efforts have been devoted to parallel implementations with strict synchronization requirements or to distributed architectures where a central server coordinates the work of clients by partitioning the search space or working as a status repository. In this paper we discuss the distributed implementation of global function optimization through decentralized processing in a peer-to-peer fashion, where relevant information is exchanged among nodes by means of epidemic protocols. A key issue in such setting is the degradation of the quality of the solution due to the lack of complete information about the global search status. A tradeoff between message complexity and solution quality must be investigated. Preliminary computational results in a simplified setting, reported in the experimental section, show that research in the field is motivated.

Code Regulation in Open Ended Evolution

Authors: L. Yamamoto
Type: Poster Presentation (to appear in Genetic Programming, Proceedings for the 10th European Conference, EuroGP 2007)

We explore a homeostatic approach to program execution in computer systems: the "concentration" of computation services is regulated according to their fitness. The goal is to obtain a self-healing effect so that the system can resist harmful mutations that could happen during on-line evolution. We present a model in which alternative program variants are stored in a repository representing the organism's "genotype". Positive feedback signals allow code in the repository to be expressed (in analogy to gene expression in biology), meaning that it is injected into a reaction vessel (execution environment) where it is executed and evaluated. Since execution is equivalent to a chemical reaction, the program is consumed in the process, therefore needs more feedback in order to be re-expressed. This leads to services that constantly regulate themselves to a stable condition given by the fitness feedback received from the users or the environment. We present initial experiments using this model, implemented using a chemical computing language.

Decentralized Enforcement of Security Policies for Distributed Computational Systems

Authors: A. Orlovsky, D. Raz
Type: Conference Paper (to appear in Proc. of ACM Symposium on Applied Computing)

The shift from single server environments to globally distributed systems presents a great challenge in terms of defining and enforcing appropriate security policies. This is, among other things, due to the fact that the actual order of events in an asynchronous distributed environment is not always defined. In addition, security policies often depend on the actual information exchange among the distributed entities. In this thesis we study the problem of adapting security policies to distributed environments such as grids and mobile code systems. We define what a global security policy is, and indicate some of the difficulties in translating local policies to the entire distributed environment. Then, we propose efficient and scalable security mechanisms for the enforcement of global security policies in distributed computational systems. These mechanisms are based on multiple instances of execution monitors (smart sandboxes) running on the distributed entities and on efficientsecurity information sharing among them. We show that the subclasses of EM policies enforceable by these mechanisms, contain useful and real live security policies such as global information flow policies.

Study of Two-Hop Message Spreading in DTNs

Authors: A. Panagakis, A. Vaios and I. Stavrakakis
Type: Conference Paper (to appear in Proc. of WiOpt 2007).

In this paper, a Delay Tolerant Network environment is considered where the source is in full control of the two-hop spreading mechanism by setting key parameters such as the number of copies allowed to be spread in the network and the delay bound of the messages. The analysis allows for a differentiation between the source of the message and the intermediate nodes (in terms of e.g. transmission power or speed). Analytical expressions for the cumulative distribution function (cdf) of the delivery delay and the induced overhead are extracted. In addition, for the cdf of the delivery delay, a fairly accurate approximate expression is also derived. The analytical results are validated via simulations

On the Effects of Cooperation in DTNs

Authors: A. Panagakis, A. Vaios and I. Stavrakakis
Type: Conference Paper (in Proc. of COMSWARE 2007).

In a Delay Tolerant Network (DTN) the nodes may behave autonomously deciding on their own whether to implement or not the rules of a routing algorithm. In this paper, the effects of node cooperation (or lack of it) are explored for three well-known routing algorithms proposed for DTNs with respect to the message delivery delay and the transmission overhead incurred until message delivery or the termination of the message spreading process. The results show that the sensitivity of the algorithms to the cooperation degree can be high, to the point of making them inferior to algorithms they typically outperform under a fully cooperative environment. Finally, it is demonstrated how a simple mechanism that incorporates the cooperation degree can help improve effectiveness.

Analysis of a Topology Control Paradigm in WLAN/WPAN Environments

Authors: A. Vaios,   K. Oikonomou   and   I. Stavrakakis
Type: Journal Article (in Computer Communications, vol. 29, 11, July 2006, pp. 2096-210).

The coordinated coexistence of WLANs and WPANs in a dual-mode network is a recently introduced idea and is expected to increase the overall system performance by allowing for the efficient cooperation of both WLANs and WPANs. Topology control (e.g., power control, smart antennas, and different frequency channels) needs to be employed to allow for the simultaneous operation of both modes. In this paper, different frequency channels that allow for high data rates within a small transmission range are considered in order to create multiple WPAN environments inside a WLAN cell. The latter environment requires the support of a second mode of operation which introduces additional overhead that may degrade the overall system performance. Certain conditions, under which system performance improvement is achievable, are established here. In particular, an analytical mobility model for WPAN environments is proposed and employed in the analytical studies. It is shown that the system may be effective when node mobility is low and the traffic load among nodes is high. The corresponding upper and lower bounds on mobility and traffic are also analytically derived. Simulation results for a variety of scenarios support the claims and expectations of the aforementioned analysis and demonstrate that

performance improvement is possible when WLANs and WPANs coexist and cooperate in a network.

Loosely Coupled Service Provisioning in Dynamic Computing Environments

Authors: D. Linner, I. Radusch, S. Steglich, C. Jacob
Type: Conference Paper (in Proc. of ChinaCom 2006).

Heterogeneous smart and mobile devices increasingly form a pervasive computing environment. Service Oriented Architecture (SOA) provides a unified view on the resources and services of those environments to make them easily available for applications. However, variations in the reliability and the availability of these services result in special requirements for the interactions of Service Providers and Service Requesters. In this paper we propose a SOA approach that is based on temporally and spatially uncoupled interactions, and supports a loose coupling in the terminology of exchanged data. For that purpose we define a service model as well as an interaction model and present an approach for their implementation.

Bio-inspired Context Gathering in Loosely Coupled Computing Environments

Authors: C. Jacob, D. Linner, S. Steglich, I. Radusch
Type: Confrence Paper (in Proc. of BIONETICS 2006).

Context-awareness is a key requirement of human-centric computing systems. Applications may ease user interaction or even anticipate the behavior of the user when utilizing information about the current context. The pervasive provision of context data represents a major challenge in this scope. For that reason we introduce an approach for gathering, disseminating, and interpreting context data in dynamic, highly distributed systems, which are mostly disconnected from central networking infrastructures. On the one hand we describe architectural consideration addressing functional elements and their organization in the computing environment. On the other hand we incorporate a model for request-driven context gathering and a biologically-inspired approach for weighting, storing and forwarding context data. The conceptual considerations are complemented with a description of our first efforts in realizing our approach on top of a peer-to-peer framework.

Autonomous Context Data Dissemination in Heterogeneous and Dynamic Environments

Authors: C. Jacob, D. Linner, S. Steglich and I. Radusch
Type: Conference Paper (in Proc. of IEEE CCNC 2007).

The intelligent dissemination of context information to enable context-aware applications is a topic often discussed in current research. However, related approaches are not able to cope with the unknown and dynamically changing nature often found in ad-hoc peer-to-peer environments. In this paper, we propose a flexible means of gathering, interpreting, and providing context information in a distributed manner. For this purpose, we describe a request-driven model for the interaction of context providers and requesters. We incorporate a bio-inspired pheromone-based approach of intelligently storing and disseminating information based on the data really requested and needed. Semantic Web technology is utilized to obtain a loosely coupled interaction pattern and an adaptable representation of context information. Thus, desired information can be accessed by external applications and services in a flexible and transparent manner.

Multi-Resolution Data Management for Opportunistic Networking

Authors: I. Carreras, D. Tacconi, D. Miorandi and I. Chlamtac
Type: Conference Paper (to appear in Proc. of MDM 2007)

In this paper, we propose an innovative mobile data management scheme for efficiently storing and diffusing sensors gathered information over a disconnected wireless network. The proposed strategy implements a lossy and location-dependent storage model by leveraging the multi-resolution properties of the discrete wavelet transform and the intrinsic localized nature of information augmenting pervasive services. This allows for a significant reduction of the storage and communication resources that are needed for running context-aware applications. The performance of the proposed mechanism is evaluated by means of an extensive simulative study. Recently, research on disconnected networks has been fostered by several studies on delay-tolerant networks, which are designed in order to sustain disconnected operations. We focus on the emerging notion of connectivity which exists in such networks, where the message exchange between nodes is enforced by leveraging storage capabilities at interme-

diate relays, with the aim of achieving connectivity over time. The problem, under the constraint of intermittent connectivity, is hence to devise efficient mechanisms for message delivery, and evaluate the performance thereof.

Supporting the Sink Mobility: a Case Study for Wireless Sensor Networks

Authors: D. Tacconi, I. Carreras, D. Miorandi, I. Chlamtac, F. Chiti and R. Fantacci
Type: Conference Paper (to appear in Proc. of IEEE ICC 2007)

This paper deals with a system level design solution to support information gathering in the presence of a mobile querying node that experiences frequent disconnections from a Wireless Sensor Network (WSN), an application scenario that embraces the area of Intelligent Transportation Systems (ITS). The proposed scheme basically relies on the network capability of autonomously adapting to sink mobility in order to properly deliver the requested data. The system is defined as far as its functional elements and related communications protocols, together with validating its effectiveness by means of a simulative study. In particular, the performance in terms of delivering latency and packet delivery ratio has been investigated for several network topologies, architecture and mobility pattern, always highlighting a remarkable quality of provided services together with robustness with regard to operative conditions.

Spectral Efficiency of CDMA Downlink Cellular Networks with Matched Filter

Authors: N. Bonneau, M. Debbah and E. Altman
Type: Journal Article (in EURASIP Journal on Wireless Communications and Networking, Volume 6 , March 2006, pp. 85 - 94)

In this contribution, the performance of a downlink Code Division Multiple Access (CDMA) system with orthogonal spreading and multi-cell interference is analyzed. A useful framework is provided in order to determine the optimal base station coverage for wireless frequency selective channels with dense networks where each user is equipped with a matched filter. Using asymptotic arguments, explicit expressions of the spectral efficiency are obtained and provide a simple expression of the network spectral efficiency based only on a few meaningful parameters. Contrarily to a common misconception which asserts that to increase spectral efficiency in a CDMA network, one has to increase the number of cells, we show that, depending on the path loss and the fading channel statistics, the code orthogonal gain (due

to the synchronization of all the users at the base station) can compensate and even compete in some cases with the drawbacks due to inter-cell interference. The results are especially realistic and useful for the design of dense networks.

Correlated Equilibrium in Access Control for Wireless Communications

Authors: E. Altman, N. Bonneau, M. Debbah
Type: Conference Paper (in Proc. of Networking 2006)

We study a finite population of mobiles communicating using the slotted ALOHA-type protocol. Our objective is the study of coordination between the mobiles in both cooperative as well as non-cooperative scenarios. Our study is based on the correlated equilibrium concept, a notion introduced by Aumann that broadens the Nash equilibrium. We study ways in which signaling can improve the performance both in the cooperative as well as in the non-cooperative cases, even in the absence of any extra information being conveyed through these signals.

Performance of a Two-Hop Relaying Protocol with Limited Packet Lifetime

Authors: A. Al-Hanbali, P. Nain and E. Altman
Type: Conference Paper (in Proc. of ValueTools 2006)

Considered is a mobile ad hoc network consisting of three types of nodes (source, destination and relay nodes) and using the two-hop relay routing protocol. Packets at relay nodes are assumed to have a limited lifetime in the network. All nodes are moving inside a bounded region according to some random mobility model. Both closed-form expressions, and asymptotic results when the number of nodes is large, are provided for the packet delivery delay and the energy needed to transmit a packet from the source to its destination. We also introduce and evaluate a variant of the two-hop relay protocol that limits the number of generated copies in the network. Our model is validated through simulations for two mobility models (random waypoint and random direction mobility models), numerical results for the two-hop relay protocols are reported, and the performance of the two-hop routing and of the epidemic routing protocols are compared.

Web graph analyzer tool

Authors: K. Avrachenkov, D. Nemirovsky and N. Osipova
Type: Conference Paper (in Proc. of ValueTools 2006)

We present the software tool "Web Graph Analyzer". This tool is designed to perform a comprehensive analysis of the Web Graph structure. By Web Graph we mean a graph whose vertices are Web pages and whose edges are hyper-links. With the help of the Web Graph Analyzer we can study the local graph characteristics such as numbers and sets of incoming/outgoing links to/from a given page, the page level relative to a given root page, and the global graph characteristics such as PageRank, Giant Strongly Connected Component, the number of dangling nodes. The Web Graph Analyzer has a user friendly GUI that allows an easy collection of a part of WWW and its thorough investigation. The Web Graph Analyzer is based on the Oracle DBMS which scales well with the large volumes of data.

PageRank of scale-free growing networks

Authors: K. Avrachenkov, D. Lebedev
Type: Journal Publication (to appear in Internet Mathematics, 2007)

PageRank is one of the principle criteria according to which Google ranks Web pages. PageRank can be interpreted as a frequency of Web page visits by a random surfer and thus it reflects the popularity of a Web page. In the present work we find an analytical expression for the expected PageRank value in a scale free growing network model as a function of the age of the growing network and the age of a particular node. Then, we derive asymptotics that shows that PageRank follows closely a power law in the middle range of its values. The exponent of the theoretical power law matches very well the value found from measurements of the Web. Finally, we provide a mathematical insight for the choice of the damping factor in PageRank definition.

Discrete Power Control: Cooperative and Non-Cooperative Optimization

Authors: E. Altman, K. Avratchenkov, G. Miller and B. Prabhu
Type: Conference Paper (to appear in Proc. of IEEE INFOCOM 2007)

We consider an uplink power control problem where each mobile wishes to maximize its throughput (which depends on the transmission powers of all mobiles) but has a constraint on the average power consumption. A finite number of power levels are available to each mobile. The decision of a mobile to select a particular power level may depend on its channel state. We consider two frameworks concerning the state information of the channels of other mobiles: (i) the case of full state information and (ii) the case of local state information. In each of the two frameworks, we consider both cooperative as well as non-cooperative power control. We manage to characterize the structure of equilibria policies and, more generally, of best-response policies in the non-cooperative case. We present an algorithm to compute equilibria policies in the case of two non-cooperative players. Finally, we study the case where a malicious mobile, which also has average power constraints, tries to jam the communication of another mobile. Our results are illustrated and validated through various numerical examples.

Wardrop Equilibrium for CDMA Systems

Authors: N. Bonneau, M. Debbah, E. Altman and A. Hjorungnes
Type: Conference Paper (to appear in Proc. of RAWNET 2007)

In this contribution, the performance of an uplink CDMA system is analyzed in the context of frequency selective fading channels. Using game theoretic tools, a useful framework is provided in order to determine the optimal power allocation when users know only their own channel (while perfect channel state information is assumed at the base station). We consider the realistic case of frequency selective channels. This scenario illustrates the case of decentralized schemes and aims at reducing the downlink signaling overhead. Various receivers are considered, namely the Matched filter, the MMSE filter and the optimum filter. The goal of this paper to derive simple expressions for the non-cooperative Nash equilibrium as the number of mobiles becomes large. To that end we combine two asymptotic methodologies. The first is asymptotic random matrix theory which allows us to obtain explicit expressions for the impact of all other mobiles on any given tagged mobile. The second is the theory of non-atomic games along with the Wardrop equilibrium concept which allows us to compute good approximations of the Nash equilibrium as the number of mobiles grow.

Simple Models for Performance Evaluation of a Class of Two-Hop Relay Protocols

Authors: A. Al-Hanbali, A. A. Kherani, P. Nain
Type: Conference Paper (to appear in Proc. of Networking 2007)

We evaluate the performance of a class of two-hop relay protocols for mobile ad hoc networks via simple models. The focus is on the multicopy two-hop relay protocol, where the source may generate multiple copies of a packet and use relay nodes to transmit the packet (or a copy) to its destination, and on the two-hop relay protocol with erasure coding, where a piece of information is fragmented into n blocks in such a way that the destination may decode the data if it receives at least k blocks. Performance metrics of interest are the time to deliver a single packet to its destination, the number of copies of the packet at delivery instant, and the total number of copies that the source generates; the latter number will be larger when TTLs are associated with the copies of a packet, a situation that we address. We also investigate the case where the number of copies of a packet currently in the network is limited so as to limit the energy consumption. Performance metrics are obtained in closed-from for the multicopy two-hop relay protocol in the case of exponential inter-meeting times, exponential TTLs and when the number of copies of the packet in the network is limited. We evaluate the impact of constant TTLs as opposed to exponential TTLs, and we develop an approximation analysis in the case where the inter-meeting times are arbitrarily distributed. In particular, we show that exponential inter-meeting times yield stochastically smaller delivery delays than hyper-exponential inter-meeting times; we also show that exponential TTLs yield larger expected delivery delays than constant TTLs. Finally, we characterize the delivery delay in the two-hop relay protocol with erasure coding and compare this scheme with the multicopy routing scheme.

Fractalising Fractal Controller for a Componentisation of the Non-Functional Aspects

Authors: F. Baude, D. Caromel, L. Henrio, M. Morel, P. Naoumenko
Type: Poster Presentation (in Proc. of Fractal Workshop in Conjunction with ECOOP 2006)

Dynamically changing execution environments requires adaptability of the components hosted by these environments; interactions with these environments may require complex relationships between controllers. In this work we focus on the adaptability of non-functional concerns. Examples include changing communication protocols, updating security policies, or taking into account new environments in case of mobile components. Adaptability implies that evolutions of the execution environments have to be detected and acted upon, and may also imply interactions with the environment and with other components for realizing the adaptation. In order to provide the tools for adaptation, complex and dynamic associations of controllers, we propose an approach and a framework for managing dynamicity at the control level and interactions between control membranes of various components, by using a standard component-oriented approach for both the application level and the control level.

Evolutionary dynamics and potential games in non-cooperative routing

Authors: E. Altman, Y. Hayel and H. Kameda
Type: Conference Paper (to appear in Proc. of the Wireless Networks: Communication, Cooperation and Competition (WNC3) workshop)

We consider a routing problem in a network with a general topology. Considering a link cost which is linear in the link flow, we obtain a unique Nash equilibrium and show that the non-cooperative game can be expressed as a potential game. We establish various convergence and stability properties of of the equilibrium related to the routing problem being a potential game. We then consider the routing problem in the framework of a population game and study the evolution of the size of the populations when the replicator dynamics is used.

Open CfPs and Submission Deadlines

- **AUTONOMICS 2007**
  Submission deadline: April 18th

Web site: www.autonomics.eu

- **ACM MOBICOM 2007**

Submission deadline: March 2nd
Web site: www.sigmobile.org/mobicom/2007/

- **Ad Hoc Networks Special Issue**
  Submission deadline: February 28th
  Special Issue of Elsevier Ad Hoc Networks

Journal on Bio-inspired Computing and Communication in Wireless Ad Hoc and Sensor Networks
Web site: www.elsevier.com/inca/publications/misc/CFPBio-Final.pdf

Upcoming Conferences and Symposia

- **IEEE INFOCOM07** *Anchorage, May 6th-11th*

- **ACM GECCO 2007** *London, UK, July 7th-11th*

- **ACM MobiSys 2007** *Puerto Rico, June 11th-14th*

- **IEEE AOC 2007** *Helsinki, Finland, June 18th*

- **IEEE ICAC 2007** *Jacksonville, FL, June 11th-15th*

- **IEEE ATC 2007** *Hong Kong,China, July 11th-13th*

- **EVO 2007** *Valencia, Spain, April 11th-13th*