Application

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2015-04066	**Como, Giacomo**	**NT-14**

Information about applicant

Name: Giacomo Como

Doctorial degree: 2008-03-13

Birthdate: 19810201

Academic title: Docent

Gender: Male

Employer: Lunds universitet

Administrating organisation: Lunds universitet

Project site: Reglerteknik 107161

Information about application

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Project title (english): Resilient control of dynamical network flows

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Funds applied for

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Descriptive data

Project info

Project title (Swedish)*

Motståndskraftig reglering av dynamiska nätverk flöden

Project title (English)*

Resilient control of dynamical network flows

Abstract (English)*

Road traffic as well as water, gas, and power distribution networks are large-scale interconnected systems and will become more so in the foreseeable future due to technical developments, government policies, and depleting resources. While such networks exhibit good performance in terms of both efficiency and robustness in business-as-usual operations, they tend to be fragile in response to unusual perturbations, which potentially give rise to large instabilities. This behavior is rooted in the inherent stochastic and nonlinear nature of such systems and in the topology of their interconnections, which tend to propagate and amplify small idiosyncratic perturbations, a phenomenon known as systemic risk; and is exacerbated by the fact that some of their constituents represent correlated random variables. Instabilities and fragility are likely to be highly damaging to the economy, the environment and to the quality of life of individuals. They may contribute to suboptimal use of renewable energy and resources, blackouts, traffic jams coupled with an underutilised parts of the transport system.

Rapid technological advancements in terms of smart sensors, high speed communication enabling the transfer of massive data sets in almost real time, and real-time decision capabilities have made it possible to endow such complex networked systems with intelligence at unprecedented levels. This intelligence has the potential to vastly improve the efficiency and resilience of these networks.

This highly interdisciplinary project aims at developing novel mathematical tools for network dynamics that allow for modeling of complex phenomena, including cascading failures and systemic risk, as well as for developing analytical tools for resilient control design. The project has also an educational impact on the undergraduate and PhD curricula at Lund University with the development of new courses in this area.

Popular scientific description (Swedish)*

Trafik, vatten, gas och kraftnätverk är idag alla storskaliga sammankopplade system. Teknisk utveckling, myndighetskrav och begränsad tillgång av resurser kommer att göra nätverken ännu större och mer sammankopplade inom en snar framtid. Medan dessa nätverk vanligtvis uppvisar bra prestanda både gällande effektivitet och robusthet, tenderar de att vara känsliga till osedvanliga störningar, vilket kan orsaka kollapser. Små störningar kan fortplantas och förstärkas, ett fenomen som brukar benämnas systemrisk. Störningarna förvärras också av det faktum att även om några av nätverkens beståndsdelar beter sig slumpartat, finns det ett samband mellan dessa slumpvisa händelser. Instabiliteter och känsligheter i dessa nätverk kan orsaka stor skada på ekonomin, miljön och livskvalitén för den enskilda individen. De kan bidraga till ineffektiv användning av förnybar energi och naturresurser, strömavbrott och trafikstockningar.

Snabb teknisk utveckling med smarta sensorer, snabba kommunikationer som möjliggör överföring av stora datamängder nästan i realtid, och kapacitet att fatta beslut i realtid har öppnat upp möjligheterna att förse dessa komplexa system med intelligens på nivåer som aldrig tidigare har varit möjligt. Denna intelligens har potential att förbättra effektiviteten och motståndskraften mot störningar hos dessa nätverk enormt. Dock så har existerande tillvägagångssätt brister gällande utnyttjandet av sådana nya tekniker, då tillvägagångssätten antingen är heuristiska utan några formella garantier gällande presentanda eller så antar de ett statiskt perspektiv och är således bara användbara vid långsiktig planering. I de fall då dynamiska modeller har används, har de oftast bara används för simulering och analysering utan eller med liten hänsyn till reglering.

För att åtgärda dessa briser, syftar detta projekt till att utveckla ett teoretiskt fullvärdigt ramverk för dynamiken i nätverk. Ramverket möjliggör modellering av komplexa fenomen, inklusive negativa kaskadeffekter och systemrisker, och utveckling av analytiska verktyg för att utforma motståndskraftiga reglerlösningar med hänsyn till en mängd av pratiska begränsningar. Kandidatens föreslagna tillvägagångssätt använder koncept och verktyg ifrån ett flertal olika vetenskapsgrenar, såsom nätverksflöden, tillämpad sannolikhetslära, statistiskt fysik, flödesdynamik, dynamiska system, reglerteori, transport, spelteori och optimering. Projektet har också inverkan på både grund och doktorandutbildningen vid LTH, genom de nya kurserna som kandidaten har utvecklat i detta tvärvetenskapliga område.

Project period

Number of project years*

4

Calculated project time*

2016-01-01 - 2019-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*	2. Teknik > 202. Elektroteknik och elektronik > 20202. Reglerteknik

Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

scalable control

Keyword 2*

robust control

Keyword 3*

network flows

Keyword 4

distributed control

Keyword 5

network resilience

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

The research of this project does not raise any ethical issues.

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Resilient Control of Dynamical Network Flows

Giacomo Como (giacomo.como@control.lth.se)

1 Purpose and aims

This VR Project's objective is to achieve a breakthrough in the scalable control design of dynamical network flows with provable performance guarantees in terms of efficiency and resilience. The problem is motivated by applications in societal-scale infrastructure systems such as road traffic networks and distribution networks (e.g., of gas, power, or water), whose level of complexity is bound to increase in the foreseeable future. While performing well under normal operations, such complex networked systems exhibit fragility in response to certain disruptions that can lead to cascades of failures and possibly to system breakdown. The challenge of designing networked control systems that combine efficiency with scalability and resilience to such systemic risks is attracting wide interest within and beyond the control theory community. We intend to pursue a novel research approach using a unique combination of newly developed methodologies integrating control systems theory —particularly, nonlinear, optimal, and robust control— with stochastic networks, convex optimization, and game theory.

The first issue we intend to address concerns the parsimonious yet physically accurate modeling of dynamical flows in infrastructure networks. Answers to this question will provide models that account for relevant complex phenomena such as propagation of shocks and cascading failures, as well as performance metrics that are to be optimized by the system designer. The second question concerns the scalable synthesis of control strategies with provable performance guarantees. Answers to this question will provide design principles and specifications of flow controls, routing and scheduling policies, and incentive mechanisms that are both efficient under a variety of constraints and resilient to disruptions. Focused on methodology and foundations, this project draws on applications –primarily in road traffic networks, and secondarily in water and gas distribution networks– both as a motivation and as a target for impact.

The research goal can be further broken down into the following objectives:

- Tractable and robust modeling of dynamical network flows including cascading failures;
- Measures of performance including efficiency, systemic risk, and resilience;
- Design of resilient decentralized flow control and scheduling policies;
- Distributed synthesis of flow controls;
- Design of pricing and incentive mechanisms to influence users' behavior;
- Dissemination of the results through publications in the highest-impact journals and presentations in major conferences in the specific application disciplines.

To achieve these goals, the technical approach of the project builds on a set of results recently obtained by the PI and coauthors, as well as the PI's collaboration network at Lund University, and with research groups in major European and US institutions.

2 Survey of the field

Resilient control of complex networked systems
The complex interaction between physical systems, cyber layers, and human decision makers has created new challenges in achieving efficiency and optimality while maintaining reliability in contemporary societal-scale networked control systems. Recent technological advancements in terms of smart sensors, high-speed communication, and real-time decision capabilities have exacerbated the large-scale, interconnected, and optimized nature of these systems that are fast becoming the next generation cyber-physical architecture for a number of critical infrastructures such as road traffic networks and gas, power and water distribution systems. While performing well under normal operation conditions, such networked systems can exhibit fragility in response to certain disruptions that may lead to system breakdown and cascades of failures. The propagation of failures can be caused not only by malicious interventions or large disruptions, but it often results from the interaction of the interconnected subsystems as they respond to small shocks. The term *resilience* refers to the ability of these systems to absorb such shocks and autonomously reconfigure themselves without permanently loosing performance.

To exemplify the challenge, consider the road transport infrastructure of a large urban area under three different scenarios: 1) a business-as-usual regime with periodic traffic loads dictated, e.g., by peak hours for work-home commute; 2) a large but predictable perturbation caused, e.g., by a major public event —such as a sport game or concert— attracting large crowds in a specific area of the city; and 3) an unexpected disruption —such as an accident or a malicious attack— causing the sudden closure of a road, whose effect can spill back and quickly cascade through the transport network, causing massive congestion. Based on historical and real-time data —e.g., collected by magnetic traffic sensors and cameras, cellphone companies, and smart devices installed on vehicles— what should the design guidelines be for control policies to be actuated through a combination of different devices such as adaptive signal control at traffic intersections, ramp metering at the entrance of highways, variable speed limits, dynamical pricing, as well as information provided to the drivers? What is the robustness of such controls with respect to the quality of sensory information, the drivers' behavior and other modeling parameters? And what is their resilience to the unexpected disruptions and the potential systemic risks they imply? What are the relevant performance metrics for the system?

Traditional feedback control thinking does not provide satisfactory answers to these questions, e.g., because of its lack of scalability with respect to the number of interacting subsystems, or because of its inherent assumption that all information is available simultaneously in one place. The recognition of these limitations has lead to the emergence of new research directions within the control community. In particular, control with information constraints specifically deals with the challenges implied by the fact that controlled system, actuators, and sensors are not necessarily co-located but connected over a communication network with its limited bandwidth, delays, and losses, [7], while distributed control design addresses questions related to whether local feedback controllers can be synthesized without knowledge of the entire system and to what level of performance can be achieved this way. [16]

Optimization and control of network flows
Network flows are a ubiquitous mathematical model for transportation phenomena in many

branches of physical, engineering, economical, and life sciences. Network flow optimization —i.e., the minimization of a function of the network flow variables subject to conservation laws, positivity, capacity, and possibly additional constraints— is recognized as a central area of mathematical programming. [1, 3] Recently, there has been a growing interest in applications of these techniques to large-scale distribution infrastructures such as power [19], gas [2, 20], and water networks. Besides centralized notions of optimality for network flows, a key role is played by game-theoretic concepts such as the *Wardrop equilibrium* [34] in road traffic networks. This is an equilibrium flow characterized by the constraint —modeled as a set of variational inequalities— that the aggregate congestion costs of all paths from origin to destination taken by a positive fraction of flow is the minimum possible. This notion plays a central role in transportation network planning [24].

These optimization and game-theoretic frameworks concern static network flows. Available results about dynamics are limited for adjustable rates at the end points or route choices. In particular, the Wardrop equilibrium can be interpreted as the Nash equilibrium of a convex potential game, and, as a consequence, it is a globally asymptotically stable equilibrium for standard game-theoretic learning processes, such as best response dynamics. [21] On the other hand, a theory of flow control in communication networks has been developed in the last two decades, based on a bottom-up view of the Internet *network as an optimizer*, whereby existing congestion control protocols are reverse-engineered as distributed algorithms solving a convex optimization problem: the maximization of an aggregate utility function across all sources, subject to link capacity constraints. These ideas have then been abstracted and generalized into a novel architecture paradigm for complex engineering networks based on the concept of *layering as optimization decomposition*, [6] where the different network layers are interpreted as solving subproblems of the optimization in their upper layers, and interfaces among layers are parametrized in terms of the variables coordinating these problems.

While providing fundamental insight into the structural properties of network flows — including their efficiency, robustness, and sensitivity to model parameters— the main limitation of these frameworks is that they are concerned with *static* flows, with network congestion and resource-sharing models reduced to simple systems of linear equations, thanks to an inherent assumption of time-scale separation. Therefore, these frameworks are not able to account for dynamical phenomena emerging *within* the network such as the propagation of shock waves and cascading failures.

Dynamics and control in traffic networks

Dynamical models of traffic flows have long been studied in road traffic networks. The most celebrated model is the Lighthill-Whitham-Richards (LWR) model [17], which describes traffic flow dynamics on a road as a hyperbolic partial differential equation. The LWR model has been extended to road networks by careful consideration of the boundary conditions at the nodes [13]. Among deterministic finite-dimensional models, of particular relevance is the Cell Transmission Model [11, 12], which was initially proposed as a space discretization for numerical implementation of LWR model, and has recently been found amenable for stability analysis and distributed control synthesis [14, 15, 25, 18].

A separate line of research is concerned with urban traffic signal control [23, 30]. Classical strategies consist of using extensive surveys to obtain network parameters, which are then used to design traffic light plans, which are either fixed [26], or constantly re-tuned as in SCOOT [5]. However, these works do not provide any guarantees with respect to performance metrics of interest such as throughput, delay, and resilience to disruptions. Recently, ideas from stochastic networks, in particular throughput-optimal scheduling policies developed for packet-switched data networks —most notably Tassioulas and Ephremides' back-pressure algorithm [31]— have been adapted to the traffic signal control setting [32]. Such signal control policies have the double advantage of being decentralized, i.e., relying on local feedback information only, and universal, i.e., able to stabilize any traffic demand that is stabilizable without requiring knowledge of it. Our preliminary results [27, 28] show that other signal control policies with an analogous decentralized architecture can provably achieve similar or better performance without requiring knowledge of turning rates. Analogous results have independently appeared at about the same time in the stochastic networks literature [33].

Summary of the state of the art
Contemporary societal-scale infrastructures are networked systems whose complexity is fast increasing due to the interactions of physical systems, cyber layers, and human decision makers. Their interconnectedness makes these systems fragile to cascading failures possibly originated by small localized disruptions, and the challenge is to design controls that improve their resilience and efficiency. While classical control thinking is not applicable, e.g., because of its lack of scalability, novel distributed control approaches are more promising. On the other hand, network flow optimization and game theory provide insight into equilibrium analysis of transportation phenomena in infrastructure networks but are inherently static theories and fail short to deal with dynamical phenomena such as shock waves and cascading failures. In road transport networks, such phenomena are captured by the main traffic flow models, some of which have been found amenable to distributed control synthesis. A separate line of research, concerned with resilient traffic signal control, is recently emerging revealing deep analogies and synergies with scheduling policies in packet-switched data networks.

3 Project description

Challenging as the problem is to design scalable and resilient control strategies for complex dynamical flow networks, we believe that a unique combination of techniques from nonlinear, optimal, and robust control theory with ideas from other disciplines such as stochastic networks, convex optimization, and game theory can result in a set of novel tools to successfully attack the problem. The potential of the proposed approach has been explored in the recent work [8]–[10], [18] where a framework for *dynamical flow networks* was introduced. We detail below the main stages of our approach.

Modeling
A first thrust of this project concerns the mathematical modeling of dynamical network flows. The challenge here consists in developing models that are detailed enough to capture the basic physical phenomena and at the same time sufficiently tractable from an analytical viewpoint and amenable to scalable control synthesis. Most of the dynamical models of flow dynamics developed in different fields of science fit in one of the three classes: partial differential equations (PDEs); ordinary differential equations (ODEs), or stochastic queuing networks. While different in many technical aspects, these classes of models show structural analogies that go beyond the simple fact that they all model systems with conservation of mass. Indeed, a well-developed branch of numerical analysis deals with the spatial discretization of PDEs and fluid limits in stochastic analysis allow one to consider the ODE and PDE

approximations of certain queuing systems in the appropriate asymptotic regime. As a consequence, analysis and design techniques developed in one context can be fruitfully exported to another. Examples include monotonicity and contraction properties of the LWR model of road traffic that carry over to its CTM discretization [8] and the use of separable Lyapunov functions in back-pressure policies for traffic signal control [33]. In this project we intend to systematically explore these connections among the different models.

Two important issues in this project are related to introducing models of disruptions, dynamical mechanisms for cascading failures, and meaningful metrics of efficiency and resilience. In our works on dynamical flow networks, [9, 8] disruptions are modeled as link capacity reductions and inflow increments at the origins and cascading failures are deterministic and determined by the density hitting some pre-specified buffer capacity. Moreover, the notion of *margin of resilience* is defined as the minimum aggregate link capacity reduction that makes the network loose throughput. Other measures can be more suitable in some contexts, e.g., accounting for stochastic disruptions and cascading failures. Performance is typically measured in terms of a separable function of the equilibrium densities. This includes delay at equilibrium. However, other efficiency metrics will be explored in this project such as measuring transient performance or gains. Finally, while the works are focused on single-commodity flows, a challenging problem that will be studied is how to best extend the framework to multicommodity flows, modeling, e.g., heterogeneous driver behaviors. Our preliminary results [22] both point out the difficulties and suggest some solutions.

Control design 1: Resilient decentralized strategies

A fundamental question in the design of large-scale network systems concerns which global performance measures can be optimized by feedback control strategies that are completely decentralized, i.e., such that local controls are function of only *local information* on the state variables, without requiring either explicit feedback on the global state of the system or coordination with other controllers. In [8], we show that a combination of fully decentralized adaptive routing and flow control strategies can be designed that is throughput optimal and thus maximally resilient to link capacity losses and perturbations on the arrival flow rates. This surprising result is reminiscent of an analogous optimality property of back-pressure and max-weight scheduling properties in communication networks. [31] In this project, we intend to extend our result in several directions. First, we will design throughput-optimal decentralized scheduling policies for traffic signal control application which are robust to adaptive routing behaviors of the drivers, extending our preliminary results [27, 28]. Second, we aim at designing decentralized control policies that conjugate throughput and resilience optimality with provable guarantees in terms of other performance measures such as average delay in equilibrium.

Control design 2: Scalable synthesis of optimal strategies

While fully decentralized control strategies can be designed that are throughput-optimal and maximally resilient, communication among the different local control units may result in better efficiency with respect to other performance measures such as delay, evacuation time, etc. In our recent work [18], which is currently under review for journal publication, we study the optimal control problem for dynamical network flows in a setup that includes the cell transmission model of road traffic. The novelty of our contribution consists in showing that, with a suitable reparametrization of the state space, such open-loop optimal control problem can be cast as a convex optimization problem (in fact, as a linear program in a relevant special case) in the space of trajectories. This result paves the way to the use of convex optimization techniques, such as the alternating direction method of multipliers (ADMM), to develop scalable distributed algorithms for the optimal control synthesis of traffic controls. In this project, we intend to pursue this line of research in variety of directions. On the one hand, we plan to develop computationally efficient algorithms implementing this optimization, possibly improving on the convergence rates of a standard implementation of the ADMM. Such algorithms will then be used as a basis for efficient model predictive control strategies as well as for the development of closed-loop control policies. On the other hand, we intend to extend the theoretical investigation of this problem primarily addressing two main issues: robustness of the resulting optimal control to model assumptions; and extension of the framework to transportation networks where only parts of the network are observable or controllable. In particular, the second point addresses a feature which is known to be a practical constraint in real-world applications to transportation networks.

Control design 3: Dynamic pricing and incentives for drivers

Routing actions in road traffic networks are driven by drivers' self-interests and bounded-rational behaviors that are not completely controllable by the system authority, but rather influenceable, e.g., through pricing and incentive mechanisms. It is a classical result in game theory that appropriate choice of link tolls allow for aligning the Wardrop equilibrium with any desired static network flow configuration, including a socially optimal one. Dynamic pricing has been successfully exploited in the context of communication networks, where the dynamics is limited to adjustment of inflow rates rather than routing behaviors. In this project, we plan to develop tools for the design of dynamic feedback pricing and incentive mechanisms that are updated in real-time in response to the current congestion status of the network with the aim of influencing the drivers' route choice and stir them to a social optimum. Robustness to drivers' behavior models is a key challenge here. In the recent work [10], we model drivers behavior as a multi-scale dynamical system where drivers react both to relatively infrequent global information about the network congestion state and to real-time local information as they transit through the network. With minimal assumptions of bounded rationality on the drivers' behavior, global asymptotic stability of the Wardrop equilibrium is established. We plan to build on this result and expand it in several directions including introducing dynamics in the toll mechanisms and dealing with heterogeneity of users' behaviors.

Model validation and data

While focused on methodology and foundations, this project will also benefit from empirical analysis, in particular in collaboration with research laboratories with access to relevant large data-sets on traffic flows. In particular, the PI plans to extend his ongoing collaboration with the INRIA–GIPSA lab in Grenoble, as well as the Department of Civil Engineering at University of Southern California. A fundamental challenge in data analysis for transportation networks consists in how to learn users' behavior from the available data. In particular, in transportation, classical estimation problems concern driver's velocity adjustment in response to perceived congestion. Another relevant problem is how to learn driver route choices in equilibrium, e.g., how to learn the utility functions that explain their behavior as a Wardrop equilibrium [4]. A challenging, and so-far rather unexplored, problem which we will be particularly interested in in this project is how to learn the out-of-equilibrium behavior of drivers, in particular in response to disruptions.

4 Significance

In order to develop novel design tools for the resilient and efficient control of dynamical flow networks, we propose an approach which combines techniques from nonlinear, optimal, and robust control with ideas from stochastic networks, convex optimization, and game theory. The proposed methodology has proven successful in a series of results recently obtained by the PI and coauthors. This unique synergy of different disciplines has the potential to lead to a breakthrough in many areas of application.

Focused on foundations, this project draws on applications –primarily in road traffic networks, and secondarily in water and gas distribution networks– both as a motivation and as a target for impact. The output of this research will be disseminated with publications in the top-ranked journals and presentations in the highest-impact conferences both on automatic control and the application domains. Moreover, the PI plans to write a survey paper on dynamical network flows, revisiting classical and recent results in a unifying framework.

Impact is also expected through teaching activities both at undergraduate and graduate level. Currently, the PI is teaching a newly developed new course in network dynamics, of which dynamical network flows is one of the main themes. Preparation of lecture notes for this course and its advanced PhD-level analogous is already ongoing, and the goal is for PI to collect these notes (incorporating feedback and suggestions collected from students and colleagues) into a textbook by the end of the project.

5 Preliminary results

Preliminary results obtained by the PI and collaborators include those reported in the publications [8, 9, 10, 18, 22, 27, 28, 29]. In particular, in [9] we introduced a framework for the analysis of resilience of dynamical flow networks and studied distributed routing policies. In [8], [29], and [22] we extended these results allowing for flow control, cascading failures, and multi-commodity flows, respectively. In [10] we studied traffic networks with multi-scale driver behaviors in response to both local and global information. In [27, 28], we analyzed the performance of decentralized universal traffic signal control strategies. And in [18], we introduced a framework for formulating the traffic network equilibrium selection and optimal control as convex problems, thus paving the way to their distributed solution. As explained in detail in Section 3, this project builds on these results and aims at extending them in several directions both within traffic network applications and for other infrastructure networks.

6 Equipment

The project is focused on foundational aspects and is not expected to require special equipment other than personal computers and possibly some research books.

7 Need for infrastructure

The project is mostly focused on foundations and will rely on the basic research infrastructure of the Automatic Control Department and Lund University, including libraries, access to publications, and computer machines. As mentioned in Sections 3 and 8, the project will rely on data collected by other labs in the EU with whom the PI is already actively collaborating.

8 International and national collaboration

The project will be conducted within the Department of Automatic Control at Lund University by the PI and one PhD student (see budget for details). It will also benefit from collaborations with other groups both at Lund University, and in other Swedish, European, and US institutions. At Lund University, the PI has ongoing collaborations with other faculty members, some of which on themes connected to this project. In particular, collaboration with Prof. Anders Rantzer on the themes of distributed control in general, and applications to transportation networks in particular, are particularly relevant and witnessed, e.g., by the recent work [18] and can certainly be predicted to intensify during the project.

The research in this project also finds potential synergies with the activity of some of the other Automatic Control groups in Sweden. In particular, as emerged in a recent visit of the PI, natural collaborations can be expected with some of the faculties at the Automatic Control lab at KTH, including ProF. Karl-Henrik Johansson, Prof. Mikael Johansson, Prof. Alexandre Proutiere, and Prof. Henrik Sandberg. Potential collaborations are foreseeable with Prof. Claudio Altafini's group at Linköping University. Moreover, the PI is engaged in collaborations with other control groups in the EU that will be relevant for the project, including Prof. Sandro Zampieri's group in the University of Padova, and the INRIA GIPSA lab in Grenoble, led by Prof. Carlos Canudas de Wit. Collaborations with the latter are of special interest because of the large data-bases that the GIPSA lab has on traffic flows whose complementarity with the methodological research conducted in the project has a huge potential of impact. Interaction with this group is already ongoing –as witnessed by the fact that two of the PI's coauthors including his former postdoc Enrico Lovisari are currently members of the GIPSA lab, and by the the PI's visits to the lab within the FP7 Hycon2 network of excellence and as PhD committee member– and can be expected to intensify.

Finally, the project will also benefit by the collaborations of the PI with some leading research groups in US, that were initiated during the PI's postdoctoral tenure and are still ongoing. Particularly relevant to this project are the collaborations with Prof. Ketan Savla's research group at the Sonny Astani Department of Civil Engineering at the University of Southern California and with the research groups of Prof. Munther Dahleh and Prof. Emilio Frazzoli at the Massachusetts Institute of Technology.

9 Other grants

The applicant is the PI of the VR-funded Junior Research Grant 'Information Dynamics in Large-Scale Networks' for the period 1/1/2012—31/12/2015 (621-2011-3632). While both concerned with dynamical phenomena emerging in large-scale networks, the main difference between the two projects is that the focus of the Junior Research Grant is on information flows and aggregation (with emphasis on socio-economic applications), while the second one is on physical flows and their efficient/resilient control (with applications on infrastructure networks). The two themes are related at some level since in cyber-physical architectures information and physical flows are intertwined, and indeed some of the preliminary results of this proposal where obtained by the PI during the time when the Junior Research Grant was running. However, the specific objectives of the two projects remain distinct.

The applicant is also a participant in the VR-funded Framework Grant 'Scalable and Resource-Constrained Control' led by Prof. Anders Rantzer for the period 1/1/2013—31/12/2016 (621-2012-5357). Within this project, some of the PI's own research activities and of those of the PhD student and postdoc advised by him have been focused on the stability analysis and control synthesis of traffic flow networks. The outcome of these activities are closely related to the project, in particular they resulted in some of the aforementioned preliminary results. This project will build upon these preliminary results and both expand their range of applicability within the control traffic flow networks as well explore new directions related to the design of cyber-physical infrastructures for network flows of other commodities, such as power, water and gas.

Finally, the PI is also a member of the VR-funded Linneaus Excellence Center LCCC (Lund Center for Control of Complex Engineering Systems, 2008-2018). In particular, the Pi is a member of the board of LCCC and has been active in the organization of focus periods, workshops, bi-weekly seminars, as well as coordinating an LCCC research group on Traffic control and distributed decision-making.

10 Independent line of research

The research line of this proposal is completely independent from the PI's PhD work. Some of the preliminary results are related to his postdoctoral work. Independence of the PI's current research in the field from that of his postdoctoral advisor (Prof. M.A. Dahleh) is witnessed, e.g., by the fact the latest publications (both journal and conference) are coauthored with other collaborators including PhD students and postdocs working under the PI's supervision.

References

[1] R. Ahuja, T. Magnanti, J. Orlin. *Network Flows: Theory, Algorithms, Applications.* Prentice Hall, 1993.

[2] F. Babonneau, Y. Nesterov, and J.-P. Vial. Design and operations of gas transmission networks. *Optimization Research*, 60(1):34–47, 2012.

[3] D. Bertsekas. *Network Optimization: Continuous and Discrete Models.* Athena Scientific, 1998.

[4] D. Bertsimas, V. Gupta, and I. Paschalidis. Data-driven estimation in equilibrium using inverse optimization. *Mathematical Programming Series A*, DOI: 10.1007/s10107-014-0819-4, 2014.

[5] R. Bretherton, K. Wood, and G.T. Bowen. Scoot version 4. In *Proceedings of 9th International Conference on Road Transport Information and Control*, 1998.

[6] M. Chiang, S.H. Low, A.R. Calderbank, and J. C. Doyle. Layering as optimization decomposition: a mathematical theory of network architectures. *Proceedings of the IEEE*, 95(1):255–312, 2007.

[7] G. Como, B. Bernhardsson, A. Rantzer (Ed.s). *Information and Control in Networks.* Springer, 2014.

[8] G. Como, E. Lovisari, and K. Savla. Throughput optimality and overload behavior of dynamical flow networks under monotone distributed routing. *IEEE Trans. Cont. Network Sys.*, 2 (1), pp. 57-67, 2015.

[9] G. Como, K. Savla, D. Acemoglu, M. A. Dahleh, and E. Frazzoli. Robust distributed routing in dynamical networks — Part i: Locally responsive policies and weak resilience. — Part ii: Strong resilience, equilibrium selection and cascaded failures *IEEE Trans. Automat. Cont.*, 58(2):317–332 333–348, 2013.

[10] G. Como, K. Savla, D. Acemoglu, M. A. Dahleh, and E. Frazzoli. Stability analysis of transportation networks with multiscale driver decisions. *SIAM J. Control and Optimization*, 51(1):230–252, 2013.

[11] C.F. Daganzo. The cell transmission model: A dynamic representation of highway traffic consistent with the hydrodynamic theory. *Transportation Research B*, 28 (4):269–287, 1994.

[12] C.F. Daganzo. The cell transmission model, part II: network traffic. *Transp. Res. B*, 29 (2):79–93, 1995.

[13] M. Garavello, B. Piccoli. *Traffic Flow on Networks*. American Institute of Mathematical Sciences, 2006.

[14] G. Gomes and R. Horowitz. Optimal freeway ramp metering using the asymmetric cell transmission model. *Transportation Research Part C*, 14(4):244–268, 2006.

[15] G. Gomes, R. Horowitz, A.A. Kurzhanskiy, P. Varaiya, and J. Kwon. Behavior of the cell transmission model and effectiveness of ramp metering. *Transportation Research Part C*, (16):485–513, 2008.

[16] R. Johansson and A. Rantzer (Ed.s). *Distributed Decision Making and Control*. Springer, 2012.

[17] M.J. Lighthill and G.B. Whitham. On kinematic waves. ii. a theory of traffic flow on long crowded roads. *Phil. Trans. R. Soc. A*, 229(1178):317–345, 1955.

[18] E. Lovisari, G. Como, A. Rantzer, and K. Savla. Stability analysis and control synthesis for dynamical transportation networks. *Transp. Res. Part B*, in review (av. at http://arxiv.org/abs/1410.5956), 2014.

[19] S.H. Low. Convex relaxation of optimal power flow—part i: Formulations and equivalence. *IEEE Transactions on Control of Network Systems*, 1(1):15–27, 2014.

[20] S. Misra, M.W. Fisher, S. Backhaus, R. Bent, M. Chertkov, and F. Pan. Optimal compression in natural gas networks: a geometric programming approach. *IEEE Trans. Cont. Net. Sys.*, 2 (1), pp. 47–56, 2015.

[21] D. Monderer and L. Shapley. Potential games. *Games and Economic Behavior*, 14:124–143, 1996.

[22] G. Nilsson, G. Como, and E. Lovisari. On resilience of multicommodity dynamical flow networks. In *Proceedings of 53rd Conference on Decision and Control, CDC'14*, 2014.

[23] M. Papageorgiou *et al.*. Chapter 11: ITS and traffic management. In C. Barnhart, G. Laporte, ed.s, *Transportation*, *Handbooks in Operations Research and Management Science*, 14, pp. 715–774, 2007.

[24] M. Patriksson. *The Traffic Assignment Problem: Models and Methods*. Dover, 2015.

[25] D. Pisarski and C. Canudas de Wit. Analysis and design of equilibrium points for the cell-transmission traffic model. In *Proceedings of the American Control Conference (ACC)*, pages 5763–5768, June 2012.

[26] D Robertson. The transyt method of coordinating traffic signals. *Traffic Eng. & Cont.*, 38:76–77, 1997.

[27] K. Savla, E. Lovisari, and G. Como. On maximally stabilizing adaptive traffic signal control. In *51st Allerton Conference on Communication, Control, and Computing*, pp. 1562–1566, 2013.

[28] K. Savla, E. Lovisari, and G. Como. On maximally stabilizing adaptive signal control for urban traffic networks under multi-movement phase architecture. In *19th IFAC World Congress*, pp. 1849–1854, 2014.

[29] K. Savla, G. Como, and M.A. Dahleh, "Robust network routing under cascading failures", IEEE Trans. Network Science and Engineering, 1(1), pp. 53-66, 2014.

[30] A. Stevanovic. *Adaptive traffic control systems: domestic and foreign state of practice*. Number Project 20-5 (Topic 40-03). 2010.

[31] L. Tassiulas, A. Ephremides. Stability properties of constrained queueing systems and scheduling policies for maximum throughput in multihop radio networks. *IEEE Trans. Aut. Cont.*, 37(12):1936–1948, 1992.

[32] P. Varaiya. The max-pressure controller for arbitrary networks of signalized intersections. In *Advances in Dynamic Network Modeling in Complex Transportation Systems*, pages 27–66. Springer, 2013.

[33] N. Walton. Concave switching in single and multihop networks. *ACM SIGMETRICS Performance Evaluation Review*, 42(1):139–151, 2014.

[34] J. G. Wardrop. Some theoretical aspects of road traffic research. *ICE Proceedings: Engineering Divisions*, 1(3):325–362, 1952.

Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

The applicant is the PI of the VR-funded Junior Research Grant `Information Dynamics in Large-Scale Networks' for the period 1/1/2012-31/12/2015 (621-2011-3632). While both concerned with dynamical phenomena emerging in large-scale networks, the main difference between the two projects is that the focus of the Junior Research Grant is on flows and aggregation of information (with emphasis on distributed computation and socio-economic applications), while the second one is on physical flows and their efficient/resilient control (with applications on infrastructure networks). The two themes are somewhat related since in cyber-physical architectures information and physical flows are intertwined, and indeed some of the preliminary results of this proposal where obtained by the PI during the time when the Junior Research Grant was running. However, the specific objectives of the two projects remain distinct. The main results obtained by the PI and collaborators so far within this project include both information theoretic analysis of the performance of low-complexity codes and multiple-access channels, and the study of models of social influence and polarization in large-scale social networks. They are reported in the peer-reviewed scientific journal articles [J1]-[J5] and conference proceedings [C1]-[C4]. The PI's activity in this field is also witnessed by the book [B] and the review paper [O]. The total amount granted by VR to this Junior Research project is 3280000 SEK over the period 2012-2015.

The applicant is also a participant in the VR-funded Framework Grant `Scalable and Resource-Constrained Control' led by Prof. Anders Rantzer for the period 1/1/2013-31/12/2016 (621-2012-5357). Within this project, some of the PI's own research activities and of those of the PhD student and postdoc advised by him have been focused on the stability analysis and control synthesis of traffic flow networks. The outcomes of these activities are closely related to the project, in particular they resulted in some of the preliminary results mentioned in the research plan, including decentralized routing and traffic flow controls, distributed traffic control synthesis, multi-scale analysis of decision making in transportation networks. This project will build upon these preliminary results and both expand their range of applicability within the control traffic flow networks as well explore new directions related to the design of cyber-physical infrastructures for network flows of other commodities, such as power, water and gas. The main results obtained by the PI and collaborators so far within this project are reported in the peer-reviewed scientific journal articles [J5]-[J10] and conference proceedings [C6]-[C13]. The total yearly amount granted by VR to this framework project is 2000000 SEK.

Finally, the PI is also a member of the VR-funded Linneaus Excellence Center LCCC (Lund Center for Control of Complex Engineering Systems, 2008-2018). In particular, the Pi is a member of the board of LCCC and has been active in the organization of focus periods, workshops, bi-weekly seminars, as well as coordinating an LCCC research group on Traffic control and distributed decision-making. The total yearly amount granted by VR to the LCCC center is 6375000 SEK.

[B1] G.Como, B.Bernhardsson, and A.Rantzer (Eds.), *Information and Control in Networks*, Springer Lecture Notes in Control and Information Sciences, 2014.

[J1] F.Garin, G.Como, and F.Fagnani, "The performance of serial turbo codes does not concentrate", *IEEE Transactions on Information Theory*, vol. 58 (5), pp.2570-2588, 2012.

[J2] D.Acemoglu, G.Como, F.Fagnani, and A.Ozdaglar, "Opinion fluctuations and persistent disagreement in social networks", *Mathematics of Operation Research*, vol. 38 (1), pp.1-27, 2013.

[J3] N.Sen, F.Alajaji, S.Yuksel, and G.Como, "Memoryless multiple access channel with asymmetric noisy state information at the encoders", *IEEE Transactions on Information Theory*, vol. 59 (11), pp.7052-7070, 2013.

[J4] G.Como and F.Fagnani, "Robustness of large-scale stochastic matrices to localized perturbations", provisionally accepted in *IEEE Transactions on Network Science and Engineering*, 2015.

[J5] G.Como, K.Savla, D.Acemoglu, M.A.Dahleh, and E.Frazzoli, "Robust distributed routing in dynamical flow networks - Part I: Locally responsive policies and weak resilience", *IEEE Transactions on Automatic Control*, vol. 58 (2), pp.317-332, 2013.

[J6] G.Como, K.Savla, D.Acemoglu, M.A.Dahleh, and E.Frazzoli, "Robust distributed routing in dynamical flow networks - Part II: Strong resilience, equilibrium selection, and cascaded failures", *IEEE Transactions on Automatic Control*, vol. 58 (2), pp.333-348, 2013.

[J7] G.Como, K.Savla, D.Acemoglu, M.A.Dahleh, and E.Frazzoli, "Stability analysis of transportation networks with multiscale drivers decisions", *SIAM Journal on Control and Optimization*, vol. 51 (1), pp.230-252, 2013.

[J8] K.Savla, G.Como, and M.A.Dahleh, "Robust network routing under cascading failures", *IEEE Transactions on Network Science and Engineering*, vol. 1 (1), pp. 53-66, 2014.

[J9] G.Como, E.Lovisari, and K.Savla, "Throughput optimality and overload behavior of dynamical flow networks under monotone distributed routing", *IEEE Transactions on Control of Network Systems*, vol. 2 (1), pp.57-67, 2015.

[J10] E.Lovisari, G.Como, A.Rantzer, and K.Savla, "Stability analysis and control synthesis for dynamical transportation networks," submitted to *Transportation Research Part B: Methodological*, 2014.

[O] "I sistemi multi-agente e gli algoritmi di consenso", *La Matematica nella Società e nella Cultura- Rivista dell'Unione Matematica Italiana*, Serie I, 5 (1), pp.1-29, 2012.

[C1] N.Sen, F.Alajaji, S.Yuksel, and G.Como, "Multiple access channel with various degrees of asymmetric state information", IEEE-ISIT 2012.

[C2] L.Stella, F.Bagagiolo, D.Bauso, and G.Como, "Opinion dynamics and stubbornness through mean-field games", (INVITED) IEEE-CDC 2013.

[C3] G.Como and F.Fagnani, "Robustness of large-scale stochastic matrices to localized perturbations", IEEE-CDC 2014.

[C4] G.Brero, G.Como, and F.Fagnani, "Dynamics in network games with local coordination and global congestion effects," (INVITED) IEEE-CDC 2014.

[C5] D.Acemoglu, G.Como, F.Fagnani, and A.Ozdaglar, “Harmonic influence in large-scale networks”, Sigmetrics 2014.

[C6] G.Como, K.Savla, D.Acemoglu, M.A.Dahleh, and E.Frazzoli, "Robust distributed routing in dynamical networks with cascading failures" (INVITED), IEEE-CDC 2012.

[C7] K. Savla, E. Lovisari, and G. Como, "On maximally stabilizing adaptive traffic signal control", (INVITED) Allerton 2013.

[C8] G.Como, K.Savla, M.A.Dahleh, and E.Frazzoli, "Distributed resilient control of network flows under deterministic cascade dynamics", (INVITED), IEEE-CDC 2013.

[C9] G.Como, E.Lovisari, and K.Savla, "Throughput optimal distributed routing in dynamical flow networks", in IEEE-CDC 2013.

[C10] K.Savla, E.Lovisari, and G.Como, "On Maximally Stabilizing Adaptive Signal Control for Urban Traffic Networks under Multi-movement Phase Architecture", in IFAC-2014.

[C11] K.Savla, G.Como, and M.A.Dahleh, "Robust network routing under cascading failures", in IEEE-CDC 2014.

[C12] G.Nilsson, G.Como, and E.Lovisari, "On Resilience of Multicommodity Dynamical Flow Networks", IEEE-CDC 2014.

[C13] E.Lovisari, G.Como, and K.Savla, "Stability of monotone dynamical flow networks", (INVITED) IEEE-CDC 2014.-29, 2012.

Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	Giacomo Como	20
2	Other personnel without doctoral degree	PhD student	80

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	2019	Total
1	Applicant	Giacomo Como	20	271,000	279,000	287,000	295,000	1,132,000
2	Other personnel without doctoral degree	PhD student	80	618,000	636,000	655,000	672,000	2,581,000
	Total			889,000	915,000	942,000	967,000	3,713,000

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

	Type of premises	2016	2017	2018	2019	Total
1	personal computers	15,000	15,000	15,000	15,000	60,000
2	research travels	135,000	135,000	135,000	135,000	540,000
	Total	150,000	150,000	150,000	150,000	600,000

Running Costs

Running Cost	Description	2016	2017	2018	2019

Depreciation costs

Depreciation cost	Description	2016	2017	2018	2019

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	2019	Total, applied	Other costs	Total cost
Salaries including social fees	889,000	915,000	942,000	967,000	3,713,000		3,713,000
Running costs					0		0
Depreciation costs					0		0
Premises	150,000	150,000	150,000	150,000	600,000		600,000
Subtotal	1,039,000	1,065,000	1,092,000	1,117,000	4,313,000	0	4,313,000
Indirect costs					0		0
Total project cost	1,039,000	1,065,000	1,092,000	1,117,000	4,313,000	0	4,313,000

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

The requested budget covers 20% of the PI's salary and 80% of a PhD student's salary for the duration of the project. That corresponds to the expected commitment in the project (the remaining 20% of the PhD student's commitment being usually devoted to teaching and other departmental service). The requested amounts have been computed using the current salaries as an estimation and predicting an yearly raise of about 3%. The budget also includes costs for the purchase of personal computers for the PI and and PhD student and funds for travel and publication costs. Such costs are meant to cover conference registration fees, article publication fees (when applicable), as well as other travel costs connected to dissemination of the results and research vosits to collaborating groups.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018	2019

CV and publications

CV

Curriculum vitae of Giacomo Como

1 HIGHER EDUCATION DEGREES

2004/12/17 **MSc (summa cum laude)**, Applied Mathematics, Politecnico di Torino, IT.

2002/09/19 **BSc (summa cum laude)**, Applied Mathematics, Politecnico di Torino, IT.

2 PHD DEGREE

2008/03/13 **PhD** from the Department of Mathematics, Politecnico di Torino, IT.

2 POSTDOCTORAL POSITIONS

2008/5–2011/7 Laboratory for Information and Decision Systems, Massachusetts Institute of Technology. Engaged on NSF-EFRI project 'Foundations for Cyber-Physical Systems'

4 QUALIFICATION REQUIRED FOR APPOINTMENT AS DOCENT: Dec. 2012.

5 CURRENT POSITION

2013/10– **Associate Professor** (Universitetslektor), Automatic Control, Lund Univ.

6 PREVIOUS POSITIONS

2011/8–2013/9 **Assistant Professor** (Biträdande lektor), Lund University.

2008/5–2011/7 **PostDoctoral Associate**, Massachusetts Institute of Technology, USA.

2008/1–2008/5 **Adjunct Professor**, Politecnico di Torino, IT.

2006/9–2007/5 **Visiting Assistant in Research**, Yale University, USA.

2005/1–2007/12 **PhD Student**, Politecnico di Torino, IT.

2004/9–2004/12 **Internship**, Istituto Superiore Mario Boella, Torino, IT.

8 SUPERVISION

August 2013– Gustav Nilsson (main supervisor) Ph.D. student.

September 2012– Christian Grussler (co-advised with Prof. A. Rantzer) Ph.D. student.

Past: Wilbert Rossi (co-advised with Prof. Fabio Fagnani), Ph.D. defended on March 20, 2015.

Enrico Lovisari (main supervisor) Post-Doctoral Associate, Sept. 2012 – August 2014.

Gianluca Brero (main supervisor) Master thesis defended on March 24, 2014.

Gustav Nilsson (main supervisor) Master thesis defended on August 19, 2013.

8 INTERRUPTION OF RESEARCH

9 OTHER MERITS OF RELEVANCE TO THE APPLICATION

TEACHING ACTIVITIES

Spring 2015 **Lecturer and Course Developer**, Network Dynamics, undergrad, Lund.

Fall 2014 **Lecturer**, Network Dynamics, PhD, Dutch Institute of Systems and Control.

Fall 2011,'13 **Lecturer and Course Developer**, Network Dynamics, PhD, Lund.

Spring 2012,'13,'14, Fall 2014 **Lecturer**, Nonlinear Control, undergrad, Lund.

Spring 2013 **Lecturer**, Mathematical Models, undergrad, Lund.

Fall 2012 **Lecturer and Course Developer**, Information Theory, PhD, Lund.

FELLOWSHIPS AND AWARDS

2012/1-2015/12 **Junior Research Grant**, Swedish Research Council (VR).

2005/1-2007/12 **Lagrange PhD Scholarship**, Compagnia di San Paolo, IT.

ORGANISATION OF SCIENTIFIC MEETINGS

Organiser and Scientific Committee Member:
− 2014 LCCC Focus Period and Workshop "Dynamics and control in networks", Lund.
− 2012 LCCC Focus Period and Workshop "Information and control in networks", Lund.

Organiser of invited sessions at:
− 21st MTNS International Symposium, July 7-11, 2014, Groningen, NL.
− 49th Control Decision Conference, December 15-17, 2010, Atlanta, GA, USA.
− 48th Allerton Conference, Sept. 29–Oct. 1, 2010, Monticello, IL, USA.

Organiser of mini-course at:
− 21st MTNS International Symposium, July 7-11, 2014, Groningen, NL.

INSTITUTIONAL RESPONSIBILITIES

2013 – **Board Member**, Lund Center for Control of Complex Engineering Systems.

2013 – **Board Member**, Department of Automatic Control, Lund University.

2015 **Ph.D. thesis Opponent**, School of Electrical Engineering, KTH, Stockhom.

2014 **Ph.D. thesis Committee member**, Université de Grenoble.

2014 **Ph.D. thesis Committee member**, School of Electrical Engineering, KTH.

2012 **Ph.D. thesis Committee member**, EIT Department, Lund University.

PROFESSIONAL ACTIVITIES

Chair of the International Program Committee
IFAC workshop on Distributed Estimation and Control in Networked Systems (NecSys'15)

Technical Program Committee Member
− 2014 and 2013 IEEE International Symposium on Information Theory
− 2012 IEEE International Conference on Distributed Computing in Sensor Networks

Invited Member: IEEE–CSS technical committee on Networks and Communications

Member: SIAM, IEEE, IEEE Information Theory Society, IEEE Control Systems Society

Proposal Referee for Romanian Research Council and Israeli Science Foundation

SELECTED INVITED SEMINARS AND LECTURES

Massachusetts Institute of Technology, (Cambridge, MA, USA), March 2, 2015.

Systems and Control Center, University of Groningen (Netherlands), Dec. 2, 2014.

Invited PhD course, Dutch Institute of Systems and Control (Netherlands), Dec. 2014.

Technion (Haifa, Israel), November 11, 2014.

Boston University (Boston, MA, USA), October 28, 2014.

Istituto Superiore Sant'Anna, (Pisa, Italy), September 23, 2014.

ETH (Zürich, Switzerland), June 18, 2013.

Yale University (New Haven, CT, USA), April 1, 2013.

Keynote lecture at the Hycon2 workshop, Lille (France), August 30, 2012.

University of Illinois, (Urbana Champain, IL, USA), April 26, 2010.

Publication list

Publication list of Giacomo Como as of March 31, 2015

Citation numbers from Web of Science as of March 27, 2015.
An asterisk ($*$) marks the five publications that are the most relevant to the project.
Five most cited papers: [J1], [J2], [J3], [J4], [J8].

1 Peer-reviewed original articles

J17 G. Como and F. Fagnani, "Robustness of large-scale stochastic matrices to localized perturbations," provisionally accepted in *IEEE Transactions on Network Science and Engineering*, 2015. Number of citations: 0.

***J16** G. Como, E. Lovisari, and K. Savla, "Throughput optimality and overload behavior of dynamical flow networks under monotone distributed routing", *IEEE Transactions on Control of Network Systems*, 2 (1), pp. 57–67, 2015. Number of citations: 0.

***J15** K. Savla, G. Como, and M.A. Dahleh, "Robust network routing under cascading failures", *IEEE Transactions on Network Science and Engineering*, 1 (1), pp. 53–66, 2014. Number of citations: 0.

J14 N. Şen, F. Alajaji, S. Yüksel, and G. Como, "Memoryless multiple access channel with asymmetric noisy state information at the encoders", *IEEE Transactions on Information Theory*, 59 (11), pp. 7052-7070, 2013. Number of citations: 0.

***J13** G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "Stability analysis of transportation networks with multiscale drivers decisions", *SIAM Journal on Control and Optimization*, 51 (1), pp. 230–252, 2013. Number of citations: 0.

J12 D. Acemoglu, G. Como, F. Fagnani, and A. Ozdaglar, "Opinion fluctuations and persistent disagreement in social networks", *Mathematics of Operation Research*, 38 (1), pp. 1–27, 2013. Number of citations: 6.

***J11** G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "Robust distributed routing in dynamical flow networks – Part II: Strong resilience, equilibrium selection, and cascaded failures", *IEEE Transactions on Automatic Control*, 58 (2), pp. 333–348, 2013. Number of citations: 2.

***J10** G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "Robust distributed routing in dynamical flow networks – Part I: Locally responsive policies and weak resilience", *IEEE Transactions on Automatic Control*, 58 (2), pp. 317–332, 2013. Number of citations: 2.

J9 F. Garin, G. Como, and F. Fagnani, "The performance of serial turbo codes does not concentrate", *IEEE Transactions on Information Theory*, 58 (5), pp. 2570–2588, 2012. Number of citations: 0.

J8 G. Como and F. Fagnani, "Scaling limits for continuous opinion dynamics systems", *The Annals of Applied Probability*, 21 (4), pp. 1537–1567, 2011. Number of citations: 10.

J7 G. Como and S. Yüksel, "On the capacity of finite state multiple access channels with asymmetric partial state feedback", *IEEE Transactions on Information Theory*, 57 (3), pp. 1267–1273, 2011. Number of citations: 6.

J6 R. Carli, G. Como, P. Frasca, and F. Garin, "Distributed averaging on digital erasure networks", *Automatica*, 47, pp. 115–121, 2011. Number of citations: 5.

J5 G. Como, "Group codes outperform binary coset codes on non-binary symmetric memoryless channels", *IEEE Transactions on Information Theory*, 56 (9), pp. 4321–4334, 2010. Number of citations: 3.

J4 G. Como, F. Fagnani, S. Zampieri, "Anytime reliable transmission of real-valued information through digital noisy channels", *SIAM Journal on Control and Optimization*, 48 (6), 3903–24, 2010. Number of citations: 10.

J3 G. Como and F. Fagnani, "The capacity of Abelian group codes over symmetric channels", *IEEE Transactions on Information Theory*, 55 (5), pp. 2037–2054, 2009. Number of citations: 11.

J2 G. Como, S. Yüksel, and S. Tatikonda, "The error exponent of variable-length codes over Markov channels with feedback", *IEEE Transactions on Information Theory*, 55 (5), pp. 2139–2160, 2009.Number of citations: 9.

J1 G. Como and F. Fagnani, "Average spectra and minimum distances of low-density parity-check codes over Abelian groups", *SIAM Journal on Discrete Mathematics*, 23 (1), pp. 19–53, 2008. Number of citations: 10.

2 Peer-reviewed conference papers

C32 K. Savla, G. Como, and M.A. Dahleh, "Robust network routing under cascading failures," in *Proc. of 2014 Control Decision Conference*, pp. 2889–2894, (Los Angeles, CA, USA), December 15-17, 2014. Number of citations: 0.

C31 G. Nilsson, G. Como, and E. Lovisari, "On Resilience of Multicommodity Dynamical Flow Networks," in *Proc. of 2014 Control Decision Conference*, pp. 5125–5130, (Los Angeles, CA, USA), December 15-17, 2014. Number of citations: 0.

C30 E. Lovisari, G. Como, and K. Savla, "Stability of monotone dynamical flow networks," (INVITED) in *Proc. of 2014 Control Decision Conference*, pp. 2384–2389, (Los Angeles), December 15-17, 2014. Number of citations: 0.

C29 G. Brero, G. Como, and F. Fagnani, "Dynamics in network games with local coordination and global congestion effects," (INVITED) in *Proc. of 2014 Control Decision Conference*, pp. 2100–2105, (Los Angeles, CA, USA), December 15-17, 2014. Number of citations: 0.

C28 G. Como and F. Fagnani, "Robustness of large-scale stochastic matrices to localized perturbations," in *Proc. of 2014 Control Decision Conference*, pp. 3648–3653, (Los Angeles, CA, USA), December 15-17, 2014. Number of citations: 0.

C27 K. Savla, E. Lovisari, and G. Como, "On Maximally Stabilizing Adaptive Signal Control for Urban Traffic Networks under Multi-movement Phase Architecture," in *Proc. of 19th IFAC World Congress*, pp. 1849–1854, (Cape Town, South Africa), 2014. Number of citations: 0.

C26 G. Como, E. Lovisari, and K. Savla, "Throughput optimal distributed routing in dynamical flow networks," in *Proc. of 2013 Control Decision Conference*, (Florence, Italy), December 10–13, 2013. Number of citations: 0.

C25 G. Como, K. Savla, M.A. Dahleh, and E. Frazzoli, "Distributed resilient control of network flows under deterministic cascade dynamics" (INVITED), in *Proc. of 2013 Control Decision Conference*, pp. 7504–7509, (Florence, Italy), December 10–13, 2013. Number of citations: 0.

C24 L. Stella, F. Bagagiolo, D. Bauso, and G. Como, "Opinion dynamics and stubbornness through mean-field games", (INVITED), in *Proc. of 2013 Control Decision Conference*, pp. 2519–2524, (Florence, Italy), December 10–13, 2013. Number of citations: 0.

C23 K. Savla, E. Lovisari, and G. Como, "On maximally stabilizing adaptive traffic signal control," (INVITED), in *Proc. of 51st Allerton Conference on on Communication, Control, and Computing*, pp. 1562–1566, (Monticello, IL, USA), Oct. 2–4, 2013. Number of citations: 0.

C22 G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "Robust distributed routing in dynamical networks with cascading failures" (INVITED), in *Proc. of 2012 Control Decision Conference*, pp. 7413–7418, (Maui, HI, USA), December 10–13, 2012. Number of citations: 0.

C21 N. Şen, F. Alajaji, S. Yüksel, and G. Como, "Multiple access channel with various degrees of asymmetric state information", in *Proc. of ISIT 2012*, pp. 1702–1706, (Cambridge, MA, USA), July 1–6, 2012. Number of citations: 0.

C20 D. Acemoglu, G. Como, F. Fagnani, and A. Ozdaglar, "Opinion fluctuations and persistent disagreement in social networks" (INVITED), in *Proc. of 2011 Control Decision Conference*, pp. 2347–2352, (Orlando, FL, USA), December 12–15, 2011. Number of citations: 0.

C19 G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "On distributed robust routing for transportation networks under local information constraint" (INVITED), in *Proc. of 2011 Control Decision Conference*, pp. 6290–6295, (Orlando), Dec. 12–15, 2011. Number of citations: 0.

C18 N. Şen, G. Como, S. Yüksel, and F. Alajaji, "On the capacity of memoryless finite-state multiple access channels with asymmetric noisy state information at the encoders," *Proc. of 2011 Allerton Conference on Communication, Control, and Computing*, pp. 1210–1215, (Monticello, IL, USA), Sept. 28–30, 2011. Number of citations: 0.

C17 G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "Stability analysis of transportation networks with multiscale driver decisions", in *Proc. of 2011 American Control Conference*, pp. 2436–2441, (San Francisco, CA, USA), June 29–July 1, 2011. Number of citations: 0.

C16 R. Carli, G. Como, P. Frasca, and F. Garin, "Distributed averaging on digital noisy networks", in *Proc. of Information Theory and its Applications Workshop*, (INVITED), (San Diego, CA, USA), Feb. 6-11 2011. Number of citations: 0.

C15 G. Como and B. Nakiboğlu, "Sphere-packing bound for block-codes with feedback and finite memory", in *Proc. of ISIT 2010*, pp. 251-255, (Austin, TX), June 13-18, 2010. Number of citations: 0.

C14 G. Como, K. Savla, D. Acemoglu, M.A. Dahleh, and E. Frazzoli, "On robustness analysis of transportation networks", in *Proc. of MTNS 2010*, pp. 2399-2406, (Budapest, Hungary), July 5-9, 2010. Number of citations: 0.

C13 G. Como and F. Fagnani, "Scaling limits for continuous opinion dynamics systems", in *Proc. of 2009 Allerton Conference on Communication, Control, and Computing*, pp. 1562-1566, (Monticello, IL, USA), Sept. 30 - Oct. 2, 2009. Number of citations: 10.

C12 R. Carli, G. Como, P. Frasca, and F. Garin, "Average consensus on digital noisy networks", in *Proc. of 1st IFAC Workshop on Estimation and Control of Networked Systems (NecSys '09)*, pp. 36-41, (Venice, Italy), Sept. 24-26, 2009. Number of citations: 0.

C11 G. Como and S. Yüksel, "On the capacity of finite state multiple access channels with asymmetric partial state feedback", in *Proc. of ConCom 2009*, (Seoul), June 27, 2009. Number of citations: 0.

C10 G. Como and M.A. Dahleh, "Lower bounds on the estimation error in problems of distributed computation", in *Proc. of Information Theory and its Applications Workshop*, (INVITED), pp. 70-76, (San Diego, CA, USA), Feb. 8-13 2009. Number of citations: 0.

C9 G. Como, F. Fagnani, and S. Zampieri, "Anytime reliable transmission of real-valued information through digital noisy channels", (invited), in *Proc. of Forty-Sixth Annual Allerton Conf. on Communication, Control, and Computing*, (INVITED), pp. 1473-1480, (Monticello, IL, USA), Sept. 23-26, 2008. Number of citations: 0.

C8 D. Capirone, G. Como, F. Fagnani, and F. Garin, "Non-binary decoding of structured LDPC codes: Density Evolution", in *Proc. of ISIT*, pp. 950-954, (Toronto), July 6-11, 2008. Number of citations: 0.

C7 D. Capirone, G. Como, F. Fagnani, and F. Garin, "Nonbinary decoding of structured LDPC codes", in *Proc. of IZS on Communications*, pp. 68-71, (Zurich), March 12-14, 2008. Number of citations: 0.

C6 G. Como, S. Yüksel, and S. Tatikonda, "On the error exponent of Markov channels with ISI and feedback", in *Proc. of ITW*, pp. 184-189, (Lake Tahoe, USA), Sept. 3-7, 2007. Number of citations: 0.

C5 G. Como, S. Yüksel, and S. Tatikonda, "On the Burnashev exponent of Markov channels", in *Proc. of ISIT 2007*, pp. 1871-1875, (Nice, France), June 25-29, 2007. Number of citations: 0.

C4 G. Como and F. Fagnani, "On the Gilbert-Varshamov distance of Abelian group codes", in *Proc. of ISIT 2007*, pp. 2651-2655, (Nice, France), June 25-29, 2007. Number of citations: 0.

C3 F. Garin, G. Como and F. Fagnani, "Staircase and other structured linear-time encodable LDPC codes: analysis and design", in *Proc. of ISIT 2007*, pp. 1226-1230, (Nice, France), June 25-29, 2007. Number of citations: 0.

C2 G. Como, F. Garin, and F. Fagnani, "ML performances of serial turbo codes do not concentrate!", in *Proc. of 4th Int. Symp. on Turbo Codes*, (Munich), April 3-7, 2006. Number of citations: 0.

C1 G. Como and F. Fagnani, "Ensembles of codes over Abelian groups", in *Proc. of ISIT 2005*, (Adelaide, SA, Australia), pp. 1788-1792, September 5-9 2005. Number of citations: 0.

3 Monograph

PhD "Ensembles of codes over Abelian groups", PhD thesis, advisor Prof. Fabio Fagnani, co-advisor Prof. Andrea Bacciotti, Politecnico di Torino, March 2008. Number of citations: 0.

4 Research review articles

5 Book

B1 G. Como, B. Bernhardsson, and A. Rantzer (Eds.), Information and Control in Networks, Springer Lecture Notes in Control and Information Sciences, 2014. Number of citations: 0.

6 Patents

7 Open access computer programs or databases

8 Popular science articles/presentation

O2 "I sistemi multi-agente e gli algoritmi di consenso", *La Matematica nella Società e nella Cultura- Rivista dell'Unione Matematica Italiana*, Serie I, 5 (1), pp. 1–29, 2012. Number of citations: 0.

O1 "Ensemble di codici su gruppi abeliani", *La matematica nella Società e nella Cultura: Rivista dell'Unione Matematica Italiana*, Serie I, 2 (2), pp. 227–230, 2009. Number of citations: 0.

CV

Name: Giacomo Como	**Doctorial degree:** 2008-03-13
Birthdate: 19810201	**Academic title:** Docent
Gender: Male	**Employer:** Lunds universitet

Research education

Dissertation title (swe)
Ensembles of Codes over Abelian Groups

Dissertation title (en)
Ensembles of Codes over Abelian Groups

Organisation	Unit	Supervisor
Politecnico di Torino, Italy Not Sweden - Higher Education institutes	Department of Mathematical Sciences	Fabio Fagnani

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
21199. Övrig annan teknik		2008-03-13

Publications

Name: Giacomo Como	**Doctorial degree:** 2008-03-13
Birthdate: 19810201	**Academic title:** Docent
Gender: Male	**Employer:** Lunds universitet

Como, Giacomo has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.