

INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS

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IMA NEWSLETTER # 327

1–31 January 2004

2003–2004 Program

PROBABILITY AND STATISTICS IN COMPLEX SYSTEMS

See <http://www.ima.umn.edu/complex/> for a full description of the 2003–2004 program on Probability and Statistics in Complex Systems: Genomics, Networks, and Financial Engineering

IMA schedules are subject to revision, particularly during workshops. See

<http://www.ima.umn.edu/~seminar/sched> and

<http://www.ima.umn.edu/newsletters/> for the latest scheduling information.

PART I: NEWS AND NOTES

IMA and Institute of Technology Public Lecture:

Sync: The Emerging Science of Spontaneous Order

7 January 2004

Speaker: Steven H. Strogatz (Cornell University),

See <http://www.ima.umn.edu/public-lecture/2003-04/strogatz/>

Special IMA Short Course:

The Internet for Mathematicians

7-9 January 2004

Organizers: Walter Willinger (AT&T Labs – Research), Bruce Hajek
(University of Illinois, Urbana-Champaign),

See <http://www.ima.umn.edu/complex/winter/sc1.html>

IMA Tutorial:

Measurement, Modeling and Analysis of the Internet

11 January 2004

Organizers: Bruce Hajek (University of Illinois, Urbana-Champaign),
Donald Towsley (University of Massachusetts),

See <http://www.ima.umn.edu/complex/winter/t2.html>

IMA Workshop:

Measurement, Modeling and Analysis of the Internet

12-16 January 2004

Organizers: Bruce Hajek (University of Illinois, Urbana-Champaign),
Donald Towsley (University of Massachusetts),

See <http://www.ima.umn.edu/complex/winter/c4.html>

IMA Website

Comments or suggestions concerning the IMA website may be addressed to
webmaster@ima.umn.edu.

In particular, we appreciate any information about World-Wide Web links appropriate to current and upcoming IMA programs.

PARTICIPATING INSTITUTIONS: Consiglio Nazionale delle Ricerche (CNR), Georgia Institute of Technology, Indiana University, Iowa State University, Kent State University, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Michigan State University, Mississippi State University, Northern Illinois University, Ohio State University, Pennsylvania State University, Purdue University, Rice University, Sandia National Laboratories, Seoul National University (BK21 Math-SNU), Seoul National University (SRCCS), Texas A&M University, University of Chicago, University of Cincinnati, University of Delaware, University of Houston, University of Illinois (Urbana), University of Iowa, University of Kentucky, University of Maryland, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, University of Wisconsin, University of Wyoming, Wayne State University.

PARTICIPATING CORPORATIONS: ExxonMobil, Ford, General Electric Company, General Motors, Honeywell, IBM, Lockheed Martin, Lucent, Motorola, Schlumberger, Siemens, Telcordia Technologies, 3M.

Version of February 4, 2004

PART II: Schedule for 1–31 JANUARY 2004

Thursday, January 1

New Years Day, a University of Minnesota holiday. IMA offices will be closed.

Friday, January 2

Floating Holiday. IMA offices will be closed.

Monday, January 5

The 3:00 IMA break will be in Lind Hall 400.

Tuesday, January 6

The 10:30 IMA break will be in Lind Hall 400.

Wednesday, January 7

IMA and Institute of Technology Public Lecture:
Sync: The Emerging Science of Spontaneous Order
7 January 2004
Speaker: Steven H. Strogatz (Cornell University),
See <http://www.ima.umn.edu/public-lecture/2003-04/strogatz/>

What caused hundreds of Japanese children to fall into seizures while watching an episode of the cartoon show Pokemon? Why do women roommates sometimes find that their menstrual periods occur in sync?

The tendency to synchronize is one of the most mysterious and pervasive drives in all of nature. Every night along the tidal rivers of Malaysia, thousands of fireflies flash in silent, hypnotic unison; the moon spins in perfect resonance with its orbit around the Earth; the intense coherence of a laser comes from trillions of atoms pulsing together. All these astonishing feats of synchrony occur spontaneously – almost as if the universe had an overwhelming desire for order.

On the surface, these phenomena might seem unrelated. After all, the forces that synchronize fireflies have nothing to do with those in a laser. But at a deeper level, they are all connected by the same mathematical theme: self-organization, the spontaneous emergence of order out of chaos. Steven Strogatz, professor of applied mathematics at Cornell University and author of *Sync: The Emerging Science of Spontaneous Order*, will convey the excitement of this new field in a lecture aimed at a general audience. He has been hailed as “a gifted and inspiring communicator” (New Scientist) and “a first-rate storyteller and an even better teacher” (Nature). Popular Science called *Sync* “the most exciting new book of the spring... masterful... a gem.”

A question and answer period follows the presentation.

Special IMA Short Course:
The Internet for Mathematicians

7-9 January 2004

Organizers: Walter Willinger (AT&T Labs – Research), Bruce Hajek (University of Illinois, Urbana-Champaign),

See <http://www.ima.umn.edu/complex/winter/sc1.html>

This three-day course is mainly aimed at a mathematical audience that wants to know more about how the Internet works – its architecture and protocols that have (in part) been designed some 20-30 years ago, the dominant technologies and applications that have been responsible for (much of) the Internet’s explosive growth throughout the last 10-20 years, and the hardware and software components that have supported a development that has transformed the Internet into (one of) the largest, complex, man-made system.

The short course will feature a range of highly informative tutorials that will deal with topics of relevance to and will prepare the participants for the upcoming workshops. Topics will include

- Architecture, protocols, design principles, evolution (4 hours)
- Measurements, simulation, analysis (4 hours)
- Control theory, traffic dynamic, topology (4 hours).

By the end of this short course, the participants should have a basic understanding of the main difficulties associated with measuring, operating, modeling, and analyzing large-scale communication networks such as today’s Internet. They will also appreciate the fact that while the Internet has become a gold mine for new, exciting and challenging mathematical problems, solving them in a way that is relevant for networking engineers will in general require new mathematics.

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:00–10:00	Bruce Hajek University of Illinois, Urbana-Champaign	Networking 101
10:30–11:30	Timothy G. Griffin Intel Research Laboratory at Cambridge	On IP Routing
1:30–2:30	Bruce Hajek University of Illinois, Urbana-Champaign	Networking 101
3:00–4:00	Timothy G. Griffin Intel Research Laboratory at Cambridge	On IP Routing
5:00–6:30	IMA Reception	IMA East, 400 Lind Hall
7:00 pm Smith Hall 100	IMA Public Lecture: Steven H. Strogatz Cornell University	Sync: The Emerging Science of Spontaneous Order

Abstract: What caused hundreds of Japanese children to fall into seizures while watching an episode of the cartoon show Pokemon? Why do women roommates sometimes find that their menstrual periods occur in sync?

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rivers of Malaysia, thousands of fireflies flash in silent, hypnotic unison; the moon spins in perfect resonance with its orbit around the Earth; the intense coherence of a laser comes from trillions of atoms pulsing together. All these astonishing feats of synchrony occur spontaneously – almost as if the universe had an overwhelming desire for order.

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Thursday, January 8

All talks are in Lecture Hall Lind 409 unless otherwise noted.

9:00–10:00	Jennifer Rexford AT&T Labs-Research	On Measurements for Network Operations
10:30–11:30	David Moore CAIDA	On Measuring the Internet
1:30–2:30	Jennifer Rexford AT&T Labs-Research	On Measurements for Network Operations
3:00–4:00	David Moore CAIDA	On Measuring the Internet

Friday, January 9

All talks are in Lecture Hall Lind 409 unless otherwise noted.

9:00–10:00	R. Srikant University of Illinois, Urbana-Champaign	On a Control Theory for the Internet
10:30–11:30	Walter Willinger AT&T Labs-Research	On Internet Traffic Dynamics and Internet Topologies
1:30–2:30	R. Srikant University of Illinois, Urbana-Champaign	On a Control Theory for the Internet
3:00–4:00	Walter Willinger AT&T Labs-Research	On Internet Traffic Dynamics and Internet Topologies

Sunday, January 11

IMA Tutorial:
Measurement, Modeling and Analysis of the Internet

11 January 2004

Organizers: Bruce Hajek (University of Illinois, Urbana-Champaign), Donald Towsley
(University of Massachusetts),

See <http://www.ima.umn.edu/complex/winter/t2.html>

Paul Barford (Department of Computer Science, University of Wisconsin) will describe available tools for making measurements on the Internet, and he will describe the measurement infrastructures that are in place around the Internet. Vishal Misra (Department of Computer Science and Department of Electrical Engineering, Columbia University) will describe many of the mathematical models of various aspects of the Internet that have aided in understanding it, and provide a basis for the design and evaluation of the Internet as it evolves. This tutorial sets the stage for the workshop of the same title, January 12-16, and it is meant to complement the short course of January 7-9: The Internet for Mathematicians.

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:00–10:00	Paul Barford	Measurement, Modeling and Analysis of the Internet
10:30–11:30	University of Wisconsin-Madison	

Abstract: There are many reasons for taking measurements in the Internet; from serving as a basis for scientific study to performing day to day operational management tasks. While taking measurements in the Internet can be as simple as running “pings” from a single desktop system, systematic large scale measurements are fraught with difficulty. In this tutorial we will describe the standard tools and techniques for taking measurements of a variety of Internet features and behaviors. We will also present the major infrastructures that have been deployed recently (and not so recently) for taking large scale measurements of the Internet. These infrastructures are principally used to gather data on Internet topology, routing, and traffic behavior. We will follow this with an overview of the standard techniques for organizing and analyzing Internet measurement data. We will conclude with a discussion of the many challenges facing researchers who wish to conduct Internet measurement studies or to use data gathered in Internet measurement infrastructures.

1:30–2:30	Vishal Misra	Measurement, Modeling, and Analysis of the Internet:
3:00–4:00	Columbia University in the City of New York	Part II

Abstract: In this tutorial we will cover some of the important developments in the mathematical modeling and analysis of aspects of the Internet. We will be focusing on three areas (i) There has been a great deal of interest in the “self-similar,” “fractal,” or more appropriately long range dependent (LRD) nature of Internet traffic. We will introduce various models that have attempted to explain the LRD phenomena (ii) Measurements of the Internet topology have led to a number of modeling efforts to understand and explain the power law nature of the connectivity graph. We will look at some of the well known models (iii) TCP carries upwards of 90% of Internet traffic. Modeling TCP specifically, and congestion control on the Internet in general, has been a hot area of networking research in the past few years. We will outline the important and well known efforts in the area in the tutorial.

Monday, January 12

IMA Workshop:
Measurement, Modeling and Analysis of the Internet

12-16 January 2004

Organizers: Bruce Hajek (University of Illinois, Urbana-Champaign), Donald Towsley
(University of Massachusetts),

See <http://www.ima.umn.edu/complex/winter/c4.html>

This workshop will bring together a group of researchers working in specialized problem areas at the interface between mathematics/statistics and networking research to discuss recent progress and outline the main challenges associated with measuring, simulating, modeling, and analyzing large-scale, heterogeneous, and complex internetworks such as the global Internet. Topics will include modeling of component technologies such as network protocols and routers, modeling and simulation of large-scale networks, and measurement of network traffic and performance. Mathematical topics include stochastic modeling, statistical inference, and dynamical systems.

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:30	Coffee and Registration	Reception Room EE/CS 3-176
9:15	Douglas N. Arnold, Scot Adams, and Organizers	Welcome and Introduction
9:30	Mark Crovella Boston University	Structural Analysis of Network Traffic Flows

Abstract: Network traffic arises from the superposition of Origin-Destination (OD) flows. Hence, a thorough understanding of OD flows is essential for modeling network traffic, and for addressing a wide variety of problems including traffic engineering, traffic matrix estimation, capacity planning, forecasting and anomaly detection. However, to date, OD flows have not been closely studied, and there is very little known about their properties.

In this talk, I will present the first analysis of complete sets of OD flow timeseries, taken from two different backbone networks (Abilene and Sprint-Europe). Using Principal Component Analysis (PCA), we have found that the set of OD flows has small intrinsic dimension. In fact, even in a network with over a hundred OD flows, these flows can be accurately captured in time using a small number (10 or less) of independent components or dimensions.

I will then show how to use PCA to systematically decompose the structure of OD flow timeseries into three main constituents: common periodic trends, short-lived bursts, and noise. Such a decomposition provides insight into how the various constituents contribute to the overall structure of OD flows. Finally, I will explore the extent to which this decomposition varies over time.

This is joint work with Anukool Lakhina, Konstantina Papagiannaki, Christophe Diot, Eric D. Kolaczyk and Nina Taft.

10:20	Discussion	
10:30	Coffee Break	Reception Room EE/CS 3-176
11:00	James Roberts France Télécom R&D	Flow Level Modelling and Control of IP Traffic

Abstract: It proves most convenient to characterize and model IP traffic at flow level. We distinguish streaming flows,

where the network requirement is to preserve the transmitted signal by limiting packet loss and delay, and elastic flows, where the requirement is to transmit a quantity of data as fast as possible. In the talk we will review recent results from stochastic flow level models for elastic traffic and for a mixture of elastic and streaming traffic. Of particular interest are the conditions under which performance measures are insensitive to precise traffic characteristics.

The modelling results enable an understanding of how performance targets can be realizable and provide guidelines for network sizing. They also suggest that current proposals for QoS differentiation do not take sufficient account of the statistical nature of traffic. This leads us to propose an alternative flow-aware architecture based on the joint use of per-flow admission control and fair queueing in routers. The resulting enhanced best effort network meets the respective performance requirements of streaming and elastic flows without the need for explicit packet marking. We describe the proposed router architecture called Cross-protect and discuss scalability issues.

11:50	Discussion	
12:00	Lunch Break	
1:30	Andrew M. Odlyzko University of Minnesota	The Economics of the Internet

Abstract: The Internet is governed by a multiplicity of feedback loops operating on wildly varying time scales. Economics plays a key role, as it affects decisions of users, network managers, and financial decision makers. A survey of some of the main economic factors, and how they are likely to influence the development of the Internet, will be presented.

2:20	Discussion	
2:30	Coffee Break	Reception Room EE/CS 3-176
3:00	Second Chances	Speakers of the day respond to further questions, suggestions, re-frame their main points, look toward future directions.
3:30	Group Photo	
3:40	IMA Tea and more (with Poster Session)	IMA East, 400 Lind Hall
poster	Mark Coates McGill University	Deterministic Packet Marking for Congestion Price Estimation

Abstract: Several recent price-based congestion control schemes require relatively accurate path price estimates for successful operation. The proposed addition of the two-bit Explicit Congestion Notification (ECN) field in the IP header provides routers with a mechanism for conveying price information. Recently, two proposals have emerged for probabilistic packet marking at the routers; the proposals allow receivers to estimate path price from the fraction of marked packets. In this poster we introduce an alternative deterministic marking scheme for encoding path price. Under our approach, each router quantizes the price of its outgoing link to a fixed number of bits. We then make use of the IP identification (IPid) field to map data packets to different probe types, and each probe type calculates a partial sum of the path price bits. A router deduces its marking behaviour according to the IPid and the TTL (Time To Live) field of each packet. We evaluate the performance of our algorithm in terms of its error in representing the end-to-end price, and compare it to probabilistic marking. We show that based on empirical Internet traffic characteristics, our algorithm performs better when estimating

obtained from nodes located on its periphery. This is an example of a large-scale statistical inverse problem. We introduce a new flexible class of probing schemes, which is shown to be computationally efficient for collecting the necessary data in global network monitoring problems. Several methods of estimation for loss rates and delay distributions will be described, including the use of EM-algorithms for the Maximum Likelihood estimators and several classes of least-squares estimates for loss rates. Some practical issues regarding the design of probing experiments on different network topologies and results from simulation studies will also be discussed.

poster	Sanjay Shakkottai University of Texas at Austin	Time-Scale Decomposition and Equivalent Rate Based Marking
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Abstract: Differential equation models for Internet congestion control algorithms have been widely used to understand network dynamics and the design of router algorithms. These models use a fluid approximation for user data traffic, and describe the dynamics of the router queue and user adaptation through coupled differential equations.

We show that the randomness due to short and unresponsive flows in the Internet is sufficient to decouple the dynamics of the router queues from those of the end controllers. This implies that a time-scale decomposition naturally occurs such that the dynamics of the router manifest only through their statistical steady-state behavior.

The interaction between the routers and flows occur through marking, where routers indicate congestion by appropriately marking packets during congestion. We show that the time-scale decomposition implies that a queue-length based marking function such as Random Early Detection (RED) or Random Exponential Marking (REM) have an equivalent form which depend only on the data arrival rate from the end-systems and do not depend on the queue dynamics. This leads to much simpler dynamics of the differential equation models (there is no queueing dynamics to consider), which enables easier simulation (the state space is reduced) and analysis.

Tuesday, January 13

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:00	Coffee	Reception Room EE/CS 3-176
9:30	Nicholas G. Duffield AT&T Labs-Research	Challenges for Using Sampled Traffic Measurements

Abstract: Traffic measurements are increasingly sampled due to ever growing line rates and concomitant traffic volumes. On the other hand, measurement-based applications increasingly depend on fine grained traffic characterization. Can these applications work effectively with existing sampled measurements? And if not, can we better match sampling techniques to applications? This talk describes the challenges and limitations for using sampled traffic measurements, and some recent approaches that move beyond traffic sampling methods in predominant use today.

10:20	Discussion	
10:30	Coffee Break	Reception Room EE/CS 3-176
11:00	Sally Floyd ICSI	Internet Research Needs a Critical Perspective Towards Models

Abstract: The underlying modeling assumptions used in analysis, simulations, and experiments can have a huge effect on the results of Internet research. However, as a community we often do not understand how the underlying modeling assumptions affect results for the specific research issues under investigation. Further, in a diverse and fast-changing Internet, we often don't understand which modeling assumptions are relevant for the current Internet, much less for the future Internet in which our newly-proposed protocols will find themselves. This talk does not provide answers, but argues for a more critical evaluation of network models as a key issue in network research.

11:50	Discussion	
12:00	Lunch Break	
1:30	David M. Nicol University of Illinois at Urbana- Champaign	Models of Internet Worm Defense

Abstract: Internet worms propagate by scanning IP address space, looking for vulnerable hosts. On finding a susceptible host, the worm infects it, essentially replicating itself, and the newly infected host begins scanning, itself. Epidemic models have been used to describe worm propagation, and have the attraction of capturing at a gross scale the pattern of worm spread. We are interested both in modeling worm propagation, and the effect of worm defenses on that propagation. We consider models of both passive and active defenses (e.g. counter-worms), with an eye towards comparing their effectiveness with respect towards both the number of hosts ultimately infected, and the overall impact on the network of scan behavior. We consider models where the worm is slow enough so that network topology does not matter, and models that explicitly account for topology, bandwidth constraints, and failures of the infrastructure.

2:20	Discussion	
2:30	Coffee Break	Reception Room EE/CS 3-176
3:00	Jennifer Rexford AT&T Labs–Research	Dynamics of Hot-Potato Routing in IP Networks

Abstract: The separation of intradomain and interdomain routing is a key feature of the Internet routing architecture. However, intradomain routing protocols such as OSPF and IS-IS do have a (sometimes significant) influence on the path-selection process in the Border Gateway Protocol (BGP). This talk presents an analysis of the influence of OSPF on BGP routing a large tier-1 ISP network. We propose a general methodology for associating BGP update messages with events visible in OSPF. Then, we apply our methodology to streams of OSPF link-state advertisements and BGP update messages from AT&T's domestic IP backbone. Our analysis shows that (i) "hot potato" routing is sometimes a significant source of BGP updates, (ii) BGP updates can lag 60 seconds behind the related OSPF event, which can cause delays in forwarding-plane convergence, (iii) OSPF-triggered BGP updates have a nearly uniform distribution across destination prefixes, and (iv) the fraction of BGP messages triggered by OSPF varies significantly across time and router locations, with important implications on external monitoring of BGP. We also describe how certain network designs and operational practices increase the impact that internal OSPF events have on BGP routing.

This is joint work with Renata Teixeira, Aman Shaikh, and Tim Griffin.

3:50	Discussion	
4:00	Second Chances	Speakers of the day respond to further questions, suggestions, re-frame their main points, look toward future directions.

Wednesday, January 14

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:00	Coffee	Reception Room EE/CS 3-176
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9:30 **Andre Broido** Applications of Network Spectroscopy
 CAIDA

Abstract: Interpretation of spectra is practiced since Noah's time. Quantum mechanics, chemistry, geophysics and communication owe it many of their successes. Spectroscopy paradigm is now becoming popular among Internet scientists. Properties of sources, links and switches (e.g. Layer 2 technologies, link bitrates, paths, OSes) can be inferred from periods and quantizations of packet timings and header fields. Network conditions from traffic congestion to DDoS attacks are studied with these and related techniques of spectral analysis.

In this talk, we give an overview of results obtained by other groups working in the field. We then describe two applications that identify network properties via delay spectra. In one case, we prove that spurious DNS updates at root and blackhole servers come from the Microsoft Win2000 DNS implementation. The method is based on a binary autocorrelation of interarrival times. In another case, we apply spectroscopy to the bitrate estimation of an end-user access in DSL and cable infrastructures. We use entropy minimization for Radon transformed marginals of the delay distributions and packet arrival times and find delay quanta that identify provisioned bitrates.

This is a joint work with Evi Nemeth, Ryan King, and kc claffy.

10:20 **Discussion**

10:30 **Coffee Break** Reception Room EE/CS 3-176

11:00 **Laurent Massoulié** End-System Emulation of Low-Priority Data Transport
 Microsoft Research Ltd.

Abstract: This talk is concerned with providing low priority data transfer across wide-area networks. Although this is straightforward when the underlying network supports service differentiation, it becomes more challenging without such network support. We will describe an application level approach to providing such service differentiation in the current Internet, solely based on receivers adapting their receive window. This approach is motivated and analysed using fluid flow models and a utility maximization framework, which allows us to identify resulting rate allocations, and asymptotic stability, for candidate adaptation strategies.

This is based on joint work with Peter Key and Bing Wang.

11:50 **Discussion**

12:00 **Lunch Break**

1:30 **Yuval Shavitt** Internet Dynamics: Missing Data, Missing Models
 Tel Aviv University

Abstract: In the recent years there were several passive and active measurement efforts that attempted to acquire an accurate connectivity map of the Internet. I will argue that none reached the point that allows us to safely determine what the Internet AS graph looks like. Even the definition of what constitutes a connection between two ASs is debatable, I will suggest one myself.

However, an accurate topology description by itself is not sufficient to explain many dynamic aspects of the Internet operation and we need to develop models that combine topology, constraints, and network dynamics. In this talk I will introduce our vision for creating such a model, discuss one simple example of the Internet resiliency to attacks and failures, and hint at some of our future work in this direction.

2:20 **Discussion**

2:30	Coffee Break	Reception Room EE/CS 3-176
3:00	Second Chances	Speakers of the day respond to further questions, suggestions, re-frame their main points, look toward future directions.

Thursday, January 15

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:00	Coffee	Reception Room EE/CS 3-176
9:30	Robert Nowak University of Wisconsin-Madison	Network Tomography from Multiple Sources

Abstract: The problem of identifying network topology and inferring link-level loss/delay parameters from end-to-end measurements is commonly referred to as network tomography. This talk reviews the basic principles of network tomography and describes a new approach based on collaborative probing from multiple sources. Most work in network tomography to date is based on probing a network from a single source. However, using multiple sources can potentially provide a more accurate and refined characterization of the network. A novel probing strategy is proposed which utilizes end-to-end packet arrival order and loss/delay metrics in order to jointly estimate network topology and link-level parameters. The theoretical performance of the estimator is studied via an asymptotic analysis, and experiments demonstrate the potential of our method in practical, small-sample settings.

This work is joint with Michael Rabbat and Mark Coates.

10:20	Discussion	
10:30	Coffee	Reception Room EE/CS 3-176
11:00	François Baccelli INRIA-Ecole Normale Supérieure	Mean-Field Interaction Models for Large TCP Networks

Abstract: This presentation will review various dynamical interaction models allowing one to analyze the throughputs obtained by a large collection of TCP controlled flows sharing many links and routers, from the sole knowledge of the network parameters (capacity, buffer sizes, topology) and of the characteristics of each flow (RTT, route, etc.).

In the droptail case, the mean-field limit can be described geometrically as a billiards in the Euclidean space. This billiards has as many dimensions as the number of flow classes and as many reflection facets as there are routers and links. This allows one to determine the possible stationary behaviors of the interacting flows and provides new ways of assessing TCP's fairness.

The RED case can also be investigated by such mean-field techniques. In the single link case, this allows one to determine in closed form the stationary distribution of the stationary throughputs obtained by the flows.

When aggregated, the traffic generated by these models exhibits TCP and network-induced fluctuations that will be compared to statistical properties observed on real traces.

11:50	Discussion	
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12:00	Lunch Break	
1:30	Donald Towsley University of Massachusetts	Analysis and Detection of Internet Worms

Abstract: In recent years, fast spreading worms have become major threats to the security of the Internet. In order to defend against future worms, it is important to understand how they propagate and how different scanning strategies affect their propagation. In this talk, we analyze worm propagation behavior under various scanning strategies, such as idealized scan, uniform scan, divide-and-conquer scan, local preference scan, sequential scan, etc. We also address the problem of worm detection. Based on the premise that one should look for the exponential growth trend, we develop Kalman filters to detect the propagation of a worm at an early stage. Last, we address some of the issues that arise in applying this technique to different scanning strategies.

This work is joint with W. Gong and C. Zou.

2:20	Discussion	
2:30	Coffee Break	Reception Room EE/CS 3-176
3:00	Second Chances	Speakers of the day respond to further questions, suggestions, re-frame their main points, look toward future directions.
6:00	Workshop Dinner	Kikugawa Restaurant in Riverplace, 43 Main St. SE.

Friday, January 16

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:30	Coffee	Reception Room EE/CS 3-176
9:00	Bill Woodcock Packet Clearing House	Design and Deployment of a Global Data-Collection Infrastructure

Abstract: Bill will discuss Packet Clearing House's experiences in their last ten years of collecting data about Internet topology, focusing specifically on the practical aspects of constructing a supportable, global-scale data collection platform. PCH is a research institute and development aid agency, which has worked to support both the academic and operational communities' needs for robust and instrumented Internet infrastructure. PCH's data-collection and experiment-hosting platforms are present at more than thirty Internet exchanges around the world, including both large regional exchanges in cities like Palo Alto, Tokyo, London, and Johannesburg, and smaller local exchanges in Kathmandu, Dar es Salaam, Dhaka, and Wellington. These are collectively managed instances of an identical installation package, and participate in the global BGP routing system using unicast IPv4, IPv6, anycast, and multicast routing.

9:45	Bill Woodcock Packet Clearing House	Interaction between Peering, Routing, Topology and Economics
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Abstract: Bill will discuss ways of differentiating between peering and transit from public datasets, and the relationships between economics and the topology of the global network as it evolves.

3:30 **Concluding Remarks by Organizers**

3:40 **End of Workshop**

Monday, January 19

Martin Luther King Day, a University of Minnesota holiday. IMA offices will be closed.

Tuesday, January 20

The 10:30 IMA break will be in Lind Hall 400.

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15-12:15 **Gerard Awanou** Trivariate Spline Approximations of 3D Navier-Stokes
IMA Equations

Abstract: We present numerical approximations of the 3D steady state Navier-Stokes equations in velocity-pressure formulation. We use trivariate splines of arbitrary degree d and arbitrary smoothness $r \leq d$. Using functional arguments, we derive the discrete Navier-Stokes equations in terms of B-coefficients of trivariate splines over a tetrahedral partition of any given polygonal domain. Smoothness conditions, boundary conditions and the divergence-free conditions are enforced through Lagrange multipliers. The discrete equations are solved by a variant of the augmented Lagrangian algorithm for which we prove a linear algebraic convergence rate. We have implemented this approach in MATLAB and present numerical evidence of the convergence rate as well as experiments on the lid driven cavity flow problem.

The IMA Postdoc Seminar is organized by
Antar Bandyopadhyay and Gerard Awanou.

Wednesday, January 21

The 10:30 IMA break will be in Lind Hall 400.

BROWN BAG SEMINAR, Lind Hall 409:

12:00 **Steen Moeller** Parallel Imaging in MRI/fMRI at 7T
University of Minnesota

Abstract: In this talk I will discuss a recent technique in MRI, that uses multiple surface coils (detectors) for decreasing the acquisition time with limited SNR loss. The detectors all see the same image (in this case the head), but due to their distinct locations, they make different intrinsic encodings of the image. This difference can be utilized to acquire faster but aliased images, that can be un-aliased using the difference in intrinsic encoding. The un-aliasing is performed by solving “small” and “simple” linear matrix systems, that have low condition numbers. The problem can be considered as a multichannel deconvolution technique, where each channel has a characteristic convolution kernel determined solely by the intrinsic spatial encoding properties of the surface coils. I will discuss different methods for determining these spatial encoding profiles and different regularization techniques for solving the matrix systems.

The IMA Brown Bag Seminar is organized by
Tim Garoni and Tamon Stephen.

Thursday, January 22

The 10:30 IMA break will be in Lind Hall 400.

COMPLEX SYSTEMS SEMINAR, Lind Hall 409:

1:30 pm	Hue Wang Brown University	Importance Sampling, Large Deviations, and Differential Games
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Abstract: (Joint work with Paul Dupuis.) Importance sampling is a variance reduction technique for efficient estimation of rare-event probabilities by Monte Carlo. In standard importance sampling schemes, the system is simulated using an a priori fixed change of measure suggested by a large deviation analysis. In this work, we consider adaptive importance sampling schemes. By “adaptive”, we mean that the change of measure depends on the sample history. The existence of asymptotically optimal adaptive schemes is demonstrated in great generality. The implementation of the adaptive schemes is carried out with the help of a limiting Isaacs equation. The idea of subsolution is also exploited for constructing implementation-friendly adaptive schemes.

Friday, January 23

The 10:30 IMA break will be in Lind Hall 400.

IMA/MCIM INDUSTRIAL PROBLEM SEMINAR, 570 Vincent Hall:

1:25pm	Ed Keyes Orisar / Semiconductor Insights	Open Algorithmical Problems in the Analysis of Integrated Circuits
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Abstract: In this talk, we will discuss several graph related problems that arise during the detailed reverse synthesis of integrated circuits (ICs). In a reverse synthesis process the electrical design schematics for an IC are reconstructed from the physical implementation of the IC (the “layout”). The process involves generation of a global circuit netlist from the physical layout followed by organization of the global netlist into recognizable circuits (amplifiers, buffer, adders etc).

Our first open problem is a general solution for the localization of mis-connections between two signals in the net list. Mis-connections occur due to errors in the reconstructed IC layout that are then incorporated into the reconstructed global netlist. In specific cases, false connections can be located as s-t cut in a network. A more general open global minimum cut like problem is presented.

The second open problem relates to the organization of the global netlist into individual circuits. We would like a method to locate a given circuit pattern within a large global netlist. This problem is essentially a generalized subgraph isomorphism problem on a netlist graph. We will present a survey of existing methods that successfully work (typically in linear time) for conventional netlists, and then consider the special problems of reconstructed netlists. Our special interest would be application of implicit breadth first relabeling techniques to limit the number of branches for brute force isomorphism approach. In particular, we will present an open problem from the error correction codes domain, which we believe is essential to obtaining efficient algorithm for the isomorphism problem.

Joint work with Vyacheslav Zavadsky.

Monday, January 26

The 3:00 IMA break will be in Lind Hall 400.

Tuesday, January 27

The 10:30 IMA break will be in Lind Hall 400.

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15-12:15 **Olga Brezhneva** Modified Methods for Nonlinear Optimization and Com-
IMA complementarity Problems in the Absence of Strict Comple-
mentarity

Abstract: For nonlinear constrained optimization and complementarity problems, we consider the case when the strict complementarity condition does not hold. In this situation, only a linear rate of convergence can be guaranteed for most classical algorithms. In this talk, we consider a Lagrange-Newton method and the modified Lagrangian method for nonlinear constrained optimization, and propose an approach that allows us to obtain modifications of these methods. The obtained modifications attain super-linear convergence even when the strict complementarity condition does not hold and subsume the case when this condition holds. Moreover, the proposed approach to modifying the methods can be applied to a variety of problems with some kind of degeneracy. We illustrate this by constructing a method for nonlinear complementarity problems in the absence of strict complementarity.

The IMA Postdoc Seminar is organized by
Antar Bandyopadhyay and Gerard Awanou.

Wednesday, January 28

The 10:30 IMA break will be in Lind Hall 400.

BROWN BAG SEMINAR, Lind Hall 409:

12:00 **Vaidyanathan Ramaswami** Matrix Analytic Methods for Stochastic Models
AT&T Labs - Research

The IMA Brown Bag Seminar is organized by
Tim Garoni and Tamon Stephen.

Thursday, January 29

The 10:30 IMA break will be in Lind Hall 400.

COMPLEX SYSTEMS SEMINAR, Lind Hall 409:

1:30 pm **Maury Bramson** Application of Fluid Models to Recurrence and Central
University of Minnesota Limit Theorems of Queueing Networks

Abstract: Over the past decade, fluid models have become one of the main tools for analyzing queueing networks. They can be used to study the stability (i.e., recurrence) and heavy traffic limits (i.e., scaled diffusive limits) of queueing networks. In both cases, this provides a systematic approach for reducing problems in a random setting to simpler deterministic ones. The talk will provide a summary of the main results in the area.

Friday, January 30

The 10:30 IMA break will be in Lind Hall 400.

SPECIAL LECTURE, Lind Hall 409:

3-4 pm **V. Ramaswami** Protecting Emergency 911 calls from the Internet Deluge
AT&T Labs - Research (Danger in Using Limit Theorems Blindly)

Abstract: I will discuss some recent work at AT&T where we used queueing models etc., to contain the effects of congestion due to internet dial ups that impact even 911 calling. Besides its practical importance and the fact that it resulted in four patents related to call handling, the work reveals some interesting probabilistic insights justifying the very need for probabilistic thinking, and demonstrates the use of some recent approaches in the matrix analytic methods for queueing theory.

IMA/MCIM INDUSTRIAL PROBLEM SEMINAR, 570 Vincent Hall:

1:25pm **Dan Wack** Application of Inverse Electromagnetic Scattering to Critical Dimension Measurement and Control in Semiconductor Production
 KLA-Tencor

Abstract: Smaller device dimensions and tighter process control windows have created a need for metrology tools that measure more than just one-dimensional critical dimension (CD) features. The need to easily detect, identify, and measure changes in feature profiles is becoming critical to controlling current and future semiconductor lithography and etch processes. Measuring changes in sidewall angle and resist height, as well as detecting subtle phenomena such as line-rounding, t-topping, and resist footing, is now as important as the traditional CD line-width measurement. This additional profile information can be used to enhance process-control mechanisms and can also be used to evaluate and characterize the performance of a stepper/track module. Traditional CD metrology techniques give no indication of a measured feature's sidewall angle or height.

Spectroscopic CD (SCD) is an optical metrology technique that can address these needs. SCD is based on parallel data acquisition zero-order diffraction by spectroscopic ellipsometry (SE) over the spectral range 200-900 nm, a widely used optical technique for measuring film thickness and film properties. This talk presents the SCD measurement technique, which is an inverse electromagnetic wave scattering method to estimate the parameters describing the shape of a grating unit cell. SCD results are compared to results from a CD SEM and a cross-section SEM. Repeatability, long-term stability, and matching data from a gate-level nominal process are also presented. These repeatability and stability tests verify that SCD meets the roadmap requirements for current and future semiconductor processes.

I will describe the mathematical framework for both the "rigorous" forward solve, and the optimization techniques of the inverse method, as well as the computer resources required to achieve acceptable turn-around times on the production fab floor. Directions for research to accelerate the computational throughput will be assessed.

PART III: CURRENT IMA PARTICIPANTS

FIRST YEAR POSTDOCTORAL MEMBERS

NAME	PREVIOUS INSTITUTION
Gerard Awanou	University of Georgia
Karen Ball	Indiana University
Antar Bandyopadhyay	UC Berkeley
Tim Garoni	University of Melbourne
Chuan-Hsiang Han	North Carolina State University
Lea Popovic	UC Berkeley

SECOND YEAR POSTDOCTORAL MEMBERS

NAME	PREVIOUS INSTITUTION
Olga Brezhneva	Russian Academy of Sci.
Herve Kerivin	University Blaise Pascal-France
Tamon Stephen	University of Michigan
Jing Wang	University of Minnesota

POSTDOCTORAL MEMBERS IN INDUSTRIAL MATHEMATICS

NAME	PREVIOUS INSTITUTION	INDUSTRIAL AFFILIATION
Lili Ju	Iowa State University	VA Hospital
Haewon Nam	Texas A & M University	GE
Jun Zhao	Texas A & M University	Schlumberger

LONG TERM VISITORS

NAME	HOME INSTITUTION
Soochan Ahn	Seoul National University (SRCCS)
Greg Anderson	University of Minnesota
Maury Bramson	University of Minnesota
Hi Jun Choe	Yonsei University
Wanyang Dai	Nanjing University
Shmuel Friedland	University of Illinois - Chicago
Carla Gomes	Cornell University
Naresh Jain	University of Minnesota
Mohammad Kazim Khan	Kent State University
Dohyun Kim	Seoul National University (SRCCS)
Hye-Ryoung Kim	Seoul National University (BK 21 Math-SNU)
Thomas G. Kurtz	University of Wisconsin
Richard P. McGehee	University of Minnesota
Amir Niknejad	University of Illinois - Chicago
Greg Rempala	University of Louisville
Arnd Scheel	University of Minnesota
Hui Wang	Brown University
Yuhong Yang	Iowa State University
Ofer Zeitouni	University of Minnesota

VISITORS IN RESIDENCE (as of 31 December 2003)

Murat Alanyali	Boston University	1/11/04 – 1/16/04
David Alderson	California Institute of Technology	1/07/04 – 1/13/04
Virgilio A. F. Almeida	Federal University of Minas Gerais	1/11/04 – 1/13/04
Francois Baccelli	University Paris Sud	1/11/04 – 1/16/04
Paul Barford	University of Wisconsin	1/10/04 – 1/16/04
Stephan Bohacek	University of Delaware	1/11/04 – 1/16/04
Andres Broido	CAIDA	1/11/04 – 1/16/04
John Nevil Brownlee	University of Auckland	1/11/04 – 1/16/04
John Byers	Boston University	1/11/04 – 1/14/04
Jesus Orsely Carrero	University of Minnesota	1/07/04 – 1/09/04
Kim Claffy	CAIDA	1/11/04 – 1/16/04
Mark Coates	McGill University	1/11/04 – 1/16/04
Mark Crovella	Boston University	1/11/04 – 1/16/04
Dan Dobbs	University of Wyoming	1/06/04 – 1/09/04
Nick Duffield	AT&T Labs - Research	1/11/04 – 1/16/04
Robert B. Feinberg	U.S. Government	1/06/04 – 1/11/04
Sally Floyd	ICSI Center for Internet Research (ICIR)	1/10/04 – 1/16/04
Ayalvadi Ganesh	Microsoft Research	1/11/04 – 1/17/04
Weibo Gong	University of Massachusetts - Amherst	1/11/04 – 1/16/04
Tim Griffin	Intel Research Laboratory at Cambridge	1/06/04 – 1/09/04
Aric Hagberg	Los Alamos National Laboratory	1/11/04 – 1/16/04
Bruce Hajek	University of Illinois - Urbana-Champaign	1/06/04 – 1/16/04
Mor Harchol-Balter	Carnegie Mellon	1/11/04 – 1/14/04
Kevin Jeffay	University of North Carolina	1/12/04 – 1/16/04
Sabera Kazi	Honeywell	1/07/04 – 1/09/04
Edward Keyes	Semiconductor Insights	1/22/04 – 1/24/04

Srisankar Kunniyur	University of Pennsylvania	1/10/04 – 1/16/04
Jim Kurose	University of Massachusetts	1/11/04 – 1/16/04
Nick Laskin	University of Toronto	1/06/04 – 1/09/04
Laurent Massoulié	Microsoft Research	1/11/04 – 1/16/04
Mureil Medard	Massachusetts Institute of Technology	1/11/04 – 1/16/04
George Michailidis	University of Michigan	1/10/04 – 1/16/04
Vishal Misra	Columbia University	1/10/04 – 1/16/04
David Moore	CAIDA	1/06/04 – 1/09/04
David M. Nicol	University of Illinois - Urbana-Champaign	1/11/04 – 1/16/04
Robert Nowak	University of Wisconsin	1/11/04 – 1/16/04
Andrew M. Odlyzko	University of Minnesota	1/12/04 – 1/16/04
Andrew Ogielski	Renesys Corporation	1/11/04 – 1/16/04
Vaidyanathan Ramaswami	AT&T Labs - Research	1/24/04 – 1/31/04
Jennifer Rexford	AT&T Labs - Research	1/07/04 – 1/13/04
James Roberts	France Telecom	1/10/04 – 1/17/04
Bryan Shader	University of Wyoming	1/06/04 – 1/09/04
Sanjay Shakkottai	University of Texas - Austin	1/11/04 – 1/16/04
Yuval Shavitt	Tel Aviv University	1/11/04 – 1/16/04
Eran Shir	Tel-Aviv University	1/10/04 – 1/16/04
Ness Shroff	Purdue University	1/14/04 – 1/16/04
R. Srikant	University of Illinois - Urbana-Champaign	1/07/04 – 1/16/04
Steven H. Strogatz	Cornell University	1/06/04 – 1/07/04
Pieter Swart	Los Alamos National Laboratory	1/12/04 – 1/16/04
Donald Towsley	University of Massachusetts	1/10/04 – 1/16/04
Yolanda Tsang	Rice University	1/11/04 – 1/16/04
Pradyumna S. Upadrashta	University of Minnesota	1/07/04 – 1/09/04
Darryl Veitch	University of Melbourne	1/11/04 – 1/16/04
Daniel Wack	KLA-Tencor	1/29/04 – 1/31/04
Walter Willinger	AT&T Labs - Research	1/06/04 – 1/14/04
Youjip Won	Seoul National University SRCCS	1/11/04 – 1/16/04
Richard Yang	Yale University	1/10/04 – 1/17/04
Tesfay Yohannes	Government of Eritrea	1/11/04 – 1/16/04
A. N. K. Zaman	University of Rajshahi, Bangladesh	1/11/04 – 1/17/04
Vyacheslav L. Zavadsky	Semiconductor Insights	1/22/04 – 1/24/04
Bo Zeng	Purdue University	1/06/04 – 1/16/04
Zhi-Li Zhang	University of Minnesota	1/11/04 – 1/16/04
Eric van den Berg	Telcordia Technologies	1/11/04 – 1/16/04

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