INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS

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The IMA was founded by and receives major support from the National Science Foundation.

IMA NEWSLETTER # 319

1–30 April 2003

2002–2003 Program

OPTIMIZATION

See http://www.ima.umn.edu/optimization/ for a full description of the 2002–2003 program on Optimization.

IMA schedules are subject to revision, particularly during workshops. See http://www.ima.umn.edu/~seminar/sched and http://www.ima.umn.edu/newsltrs/ for the latest scheduling information.

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PART I: NEWS AND NOTES

The IMA's 20th Birthday Party

This year the IMA turns 20, and to celebrate this milestone, we are, on 6 and 7 June, running a special event called "The IMA at 20: Mathematics and its Impact". This event will feature an impressive list of speakers, including a public lecture by Charles S. Peskin entitled "Secrets of the Heart Revealed - by Mathematics and Computer Simulation". For more information, point to:

http://www.ima.umn.edu/optimization/spring/ima20th-anniversary.html

IMA Update

The spring issue of the IMA's quarterly "Update" publication is now ready. It has features on the New Directions program, the Data-Driven Control Workshop, the IMA's 20th birthday party, the program for graduate students at Banff in math modeling, and other stories. You can also find information about the IMA's upcoming programs, its recent programs and its publications. To view the new Update, point your browser to

http://www.ima.umn.edu/newsltrs/updates/spring03/

PARTICIPATING INSTITUTIONS: Centrum voor Wiskunde en Informatica (CWI), Consiglio Nazionale delle Ricerche, 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, 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: Boeing, Ford, General Motors, Honeywell, IBM, Lockheed Martin, Lucent, Motorola, Schlumberger, Siemens, Telcordia Technologies, 3M.

Version of May 6, 2003

IMA Tutorial:

Network Management and Design

6 April 2003
Speakers: Martin Grötschel, Jennifer Rexford, and Tim Griffin,

See http://www.ima.umn.edu/optimization/spring/t4.html

IMA Workshop:

Network Management and Design

7–11 April 2003
Organizers: Daniel Bienstock, Tami Carpenter, David S. Johnson, Clyde Monma, Bruce Shepherd,

See http://www.ima.umn.edu/optimization/spring/op6.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.

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PART II: Schedule for 1–30 April 2003

Tuesday, April 1

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

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15-12:15 **Tamon Stephen**, IMA — The Lift-and-Project Approach to Integer Programs

Abstract: In this survey talk, we discuss the "lift and project" approach for solving 0-1 integer programs. Our main example is the method of semi-definite matrix relaxations proposed by Lovasz and Schrijver.

The IMA Postdoc Seminar is organized by M. Yvonne Ou and Olga Brezhneva.

Wednesday, April 2

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

BROWN BAG SEMINAR, Lind Hall 409:

12:00	**Montaz Ali** Witwatersrand and IMA	Features of the Direct Search Method for Global Optimization

Thursday, April 3

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

Friday, April 4

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

Sunday, April 6

IMA Tutorial:

Network Management and Design

6 April 2003

Speakers: Martin Grötschel, Jennifer Rexford, and Tim Griffin,

See http://www.ima.umn.edu/optimization/spring/t4.html

This tutorial serves as an introduction to the IMA workshop on Network Management and Design.

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

10:00 am	**Coffee and Registration**	Reception Room EE/CS 3-176
10:30 am	**Martin Grötschel** K-Z-Z für Info & Technische U	Mathematical Challenges in Telecommunication

Abstract: This talk will begin with a survey of mathematical challenges that arise in telecommunication. Mathematics is involved, e. g., in the design and manufacturing of chips, devices and network components, the choice of locations, the planning of the network topology, and the dimensioning of the equipment involved. Adequate cryptography, the need of fast data processing, demand routing and failure handling require efficient and reliable mathematical algorithms on the operational side.

The presentation will focus on the problem of designing low-cost telecommunication networks that provide sufficient capacity to serve a given demand, are based on a chosen technology mix, satisfy various technical side constraints, and survive certain failure situations. This problem is difficult in theory and practice. It will be indicated how algorithms integrating polyhedral combinatorics, linear and integer programming, and various heuristic ideas can help solve real-world instances within reasonable quality guarantees in acceptable running times.

The lecture will also address issues such as: balancing the load of signaling transfer points, issues arising in packet switching, modeling optical switches and all optical networks.networks

This talk is based on work of the telecommunications research group at ZIB, the examples discussed and the computational results reported are from joint projects with several telecommunication companies.

12 noon **Lunch Break**

1:30 pm **Jennifer Rexford** Traffic Measurement for IP Operations
AT&T

Abstract: Traffic measurement is an essential tool to guide the operators of large IP networks in detecting and diagnosing performance problems, and evaluating potential control actions. Measurements help operators identify under provisioned links, denial-of-service attacks, flash crowds, and shifts in user demands. This tutorial focuses on measurement techniques and traffic models that provide a comprehensive view of large IP networks where the operator has full administrative control. The tutorial starts with a brief overview of the basic tasks involved in operating a large IP network and derives requirements for network measurement. We argue that the very properties responsible for the Internet's success also make it difficult to control and manage.

3:15 pm **Timothy Griffin** What are the Semantics of Interdomain Routing?
AT&T

Abstract: Inter-domain routing in the Internet is currently implemented with the Border Gateway Protocol (BGP). This protocol allows every autonomous administrative domain to define local routing policies that are consistent with its own interests. The first part of this tutorial is a basic introduction to interdomain routing issues, and how BGP is used to implement typical routing policies in the Internet. No previous knowledge of BGP will be assumed. Locally defined routing policies can interact in ways that cause various kinds of global routing anomalies — nondeterministic routing and protocol divergence. These anomalies can span multiple autonomous domains, making them very difficult to debug and correct. Analysis of BGP is complicated by the fact that routing messages carry a number of semantically rich attributes that play a role in the rather complex BGP route selection algorithm and in the implementation of local routing policies.

The second part of this tutorial presents a simple formal model of BGP routing policies called the Stable Paths Problem (SPP). This formalism can be viewed as a simple kind of game or as a generalization of the stable matching problem. I'll argue that the BGP protocol can be modeled as a distributed algorithm that attempts to solve instances of the Stable Paths Problem. If the Stable Paths Problem has no solution, the protocol will not converge. The protocol can also diverge when there is a solution but it gets "trapped" down a blind alley. Nondeterministic routing is associated with Stable Path Problems that have multiple solutions. I'll also show that several interesting questions related to SPP (and BGP) solvability are NP-complete.

Bio: Tim Griffin received a B.S. in Mathematics from the University of Wisconsin, Madison. He went on to earn a Ph.D. in Computer Science from Cornell. He has done research in the areas of programming languages, database theory, and internet routing.

Monday, April 7

IMA Workshop:

Network Management and Design

7–11 April 2003

Organizers: Daniel Bienstock, Tami Carpenter, David S. Johnson, Clyde Monma, Bruce Shepherd,

See http://www.ima.umn.edu/optimization/spring/op6.html

This workshop will bring together research mathematicians and telecommunications experts to discuss the methodologies needed to support the efficient management and design of communication networks. The topics will include bandwidth allocation problems, wireless/mobile computing, the design of resilent networks, optical networking (routing and wavelength assignments), interconnection networks, and internet routing and protocols

This workshop will include applications from game theory, combinatorics, graph theory, linear algebra, algorithms (including approximation algorithms), polyhedral combinatorics, and coding theory. Specific methodologies would include graph coloring, very large scale linear programming, multi-commodity flow, combinatorial heuristics, and general integer programming.

NETWORK DESIGN

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

8:30 am	**Coffee and Registration**	Reception Room EE/CS 3-176
9:15 am	**Douglas N. Arnold, Scot Adams, and Organizers**	Welcome and Introduction
9:30 am	**Howard Karloff** AT&T Labs-Research	On the Fractal Behavior of TCP

Abstract: I will speak on a simple dynamical system which models the Internet protocol TCP. The simple model embodies TCP's "additive increase, multiplicative decrease" rule. Two sources s1 and s2 send packets at varying rates r1 and r2 to a recipient; whenever packets are lost, the sender halves its sending rate.

We prove that for infinitely many choices of the parameters, the set of feasible rate pairs that can occur in the limit is a fractal. (This does not mean, however, that the traffic is statistically self-similar.)

No previous knowledge of TCP or of fractals will be assumed.

This is joint work with Anna Gilbert of AT&T Labs-Research.

10:20 am	**Discussion**	
10:30 am	**Coffee**	Reception Room EE/CS 3-176
11:00 am	**Andreas Eisenblaetter** ZIB, Germany	UMTS Radio Network Planning

Abstract: The new Universal Mobile Telecommunications System (UMTS) is a 3rd generation cellular system for mobile telecommunication. UMTS supports all services of the worldwide predominant, 2nd generation GSM and GPRS networks. It is more powerful, more flexible, and more radio spectrum efficient than its predecessors. Unlike with GSM and GPRS, radio transmissions are not separated in time or frequency. Instead, they are superimposed in time and frequency, separable only by means of their encoding (an example of code devision multiple access or CDMA, in short). For this to work, a minimum ratio between radio transmission signal strength as perceived by the receiver and the interference must be achieved. In consequence, UMTS radio cell capacity and coverage are strongly inversely coupled through system self-interference.

In this talk, we present the governing interference constraints for UMTS radio network planning and introduce a mixed integer programming model for UMTS radio network design. The scope of this model is to select base station locations (from a list) and to configure base stations, including antenna types, heights, azimuths, and tilts as well as the cell's dominance areas. We discuss how this model is used within an integrated planning loop to minimize network costs while satisfying coverage and capacity constraints, which are given in the form of statistical distributions. Finally, we show how we exploit standard mixed integer programming tools for (heuristically) solving realistic planning problems.

This joint work with Alexander Martin (TU Darmstadt, Germany) and Thorsten Koch (ZIB, Germany) is carried out within the EU-funded project MOMENTUM (http://momentum.zib.de).

11:50 am	**Discussion**	
12:00 pm	**Lunch Break**	
1:30 pm	**Anupam Gupta** Carnegie Mellon University	Designing Networks Without Knowing the Traffic Matrix

Abstract: In a classical network design problem, we specify a matrix of pairwise demands (and possibly some added restictions on the network structure) and ask for the "best" network. However, giving one demand matrix is often very restrictive (volatility in traffic cannot be handled, etc); furthermore, estimating pairwise traffic matrices is a bit of a bother at the best of times.

A natural alternative is to use the following model: each user v specifies an upper bound$_b(v)$ on the traffic that it takes part in, and the objective is to find the cheapest network that handles all traffic matrices that respect the upper bounds at the individual nodes.

We will talk about known exact and approximation algorithms, and some (of the many) open directions for research.

2:20 pm	**Discussion**	
2:30 pm	**Coffee Break**	Reception Room EE/CS 3-176
3:00 pm	**Second Chances**	Speakers of the day respond to further questions, suggestions, re-frame their main points, look toward future directions.
3:30 pm	**IMA Tea/Reception/Poster Session**	IMA East, 400 Lind Hall
poster session	**William Yurcik** NCSA/University of Illinois at Urbana-Champaign	Visual Network Monitoring for Situational Awareness with Netflows

Abstract: Netflow data, once only available from routers and now available from independent platforms, provides fundamental network management information especially for the identification of known traffic signatures and unknown but anomalous network traffic when compared to a statistical profile. At NCSA, we have developed a flexible tool that visualizes an entire IP address space on one screen including drill-down capabilities for subnets and individual machines.

Tuesday, April 8

NETWORK ROUTING

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

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**Mikkel Thorup** AT&T Labs-Research	Internet Traffic Engineering by Optimizing OSPF Weights

Abstract: Shortest Path First protocols such as OSPF and IS-IS are the most commonly used intra-domain internet routing protocol. Traffic flow is routed along shortest paths, splitting flow at nodes where several outgoing links are on shortest paths to the destination. The weights of the links, and thereby the shortest path routes, can be changed by the network operator. The weights could be set proportional to their physical distances, but often the main goal is to avoid congestion, i.e. overloading of links, and the standard heuristic recommended by Cisco is to make the weight of a link inversely proportional to its capacity.

Our starting point was a proposed AT&T WorldNet backbone with demands projected from previous measurements. The desire was to optimize the weight setting based on the projected demands. We showed that optimizing the weight settings for a given set of demands is NP-hard, so we resorted to a local search heuristic. Surprisingly it turned out that for the proposed AT&T WorldNet backbone, we found weight settings that performed within a few percent from that of the optimal general routing where the flow for each demand is optimally distributed over all paths between source and destination. This contrasts the common belief that OSPF/IS-IS routing leads to congestion and it shows that for the network and demand matrix studied we cannot get a substantially better load balancing by switching to the proposed more flexible Multi-protocol Label Switching (MPLS) technologies.

Our techniques were also tested on synthetic internetworks, based on a model of Zegura et al. (INFOCOM'96), for which we did not always get quite as close to the optimal general routing. However, we compared with standard heuristics, such as weights inversely proportional to the capacity or proportional to the physical distances, and found that, for the same network and capacities, we could support a 50%-110% increase in the demands.

Our assumed demand matrix can also be seen as modeling service level agreements (SLAs) with customers, with demands representing guarantees of throughput for virtual leased lines.

We will also discuss how our techniques can be adapted for link-failures and changes in the demand matrix.

Part of the above work was presented at the IEEE INFOCOM 2000, and other parts were published IEEE J. Selected Areas in Communications (Special Issue on Fundamentals of Network Management) 40(10):118–124, October 2002. Also, there are some recent developments to be presented at SIGMETRICS 2003.

10:20 am	**Discussion**	
10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Aravind Srinivasan** University of Maryland, College Park	Fast Distributed Algorithms for (Weakly) Connected Dominating Sets and Linear-Size Skeletons

Abstract: Motivated by routing issues in ad hoc networks, we present polylogarithmic-time distributed algorithms for two problems. Given a network, we first show how to compute connected and weakly connected dominating sets whose size is at most $O(\log \Delta)$ times optimal, Δ being the maximum degree of the input network. This is best-possible under standard complexity-theoretic assumptions, and if the processors are limited to polynomial-time computation. We also show how to construct dominating sets which satisfy the above properties, as well as the "low stretch" property that any two adjacent nodes in the network have their dominators at a distance of at most $O(\log n)$ in the network. Our time bounds are shown to be near-optimal.

This is joint work with Devdatt Dubhashi, Alessandro Mei, Alessandro Panconesi and Jaikumar Radhakrishnan.

11:50 am	**Discussion**	
12:00 pm	**Lunch Break**	
1:30 pm	**Lisa K. Fleischer** Carnegie Mellon University	Multicommodity flows with holding costs

We consider a broad class of separated continuous linear programs (SCLP) that arise as fluid relaxations of multiclass queueing networks, and are used to find approximate solutions to complex job shop scheduling problems. One example of a problem we consider is the multicommodity flow problem with holding costs: Given a capacitated network with node queues, linear flow costs and linear, per-unit-time holding costs, drain the queues to minimize total holding costs. The complexity of this problem is not well understood, but there is evidence to suggest that optimal solutions may have exponential size. Existing algorithms for SCLP do not have polynomial time or space guarantees.

For given constants a ¿ 0 and b ¿ 0, we present an algorithm that finds a solution with value at most (1+a)OPT + b, where OPT is the value of the optimal solution. The complexity of our algorithm and the size of the solution we produce are polynomial in the size of the input network, 1/a, and log(1/b). We introduce a natural discretization of polynomial size and prove that this discretization produces a solution with low cost. This is the first polynomial time algorithm with a provable approximation guarantee for solving fluid relaxations.

This is joint work with Jay Sethuraman of Columbia University.

2:20 pm	**Discussion**	
2:30 pm	**Coffee Break**	Reception Room EE/CS 3-176
3:00 pm	**James B. Orlin** Massachusetts Institute of Technology	Very Large Scale Neighborhood Search

Abstract: Many optimization problems of practical interest are computationally intractable. Therefore, a practical approach for solving such problems is to employ heuristic (approximation) algorithms that can find nearly optimal solutions within a reasonable amount of computation time. An improvement algorithm is a heuristic algorithm that generally starts with a feasible solution and iteratively tries to obtain a better solution. Neighborhood search algorithms (alternatively called local search algorithms) are a wide class of improvement algorithms where at each iteration an improving solution is found by searching the "neighborhood" of the current solution. This talk focuses on neighborhood search algorithms where the size of the neighborhood is "very large" with respect to the size of the input data and in which the neighborhood is searched in an efficient manner. We survey several broad classes of very large-scale neighborhood search (VLSN) algorithms and give applications to partitioning and to fleet assignment problems in airline scheduling.

3:50 pm	**Discussion**	
4:00 pm	**Coffee Break**	Lind Hall 400
4:30 pm	**Second Chances**	Speakers of the day respond to further questions, suggestions, re-frame their main points, look toward future directions.

Wednesday, April 9

HALF AND HALF DAY
(AM Session: Network Pricing and Economics)
(PM Session: Ad Hoc and Mobile Networking)

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

9:00 am	**Coffee**	Reception Room EE/CS 3-176

9:30 am	**Eva Tardos** Cornell University	Network Design Games

Abstract: In this talk we will consider several network design games with selfish agents. Maybe the simplest network design games are facility location and spanning tree-games when goal of each player is to connect a terminal to a facility or to a common source in the graph. Facilities, and potential edges in the network have costs and each agent's goal is to pay as little as possible, while having his terminals connected. We will consider these and related games mostly from the perspective of cost sharing. The result on cost-sharing presented are joint work with Martin Pal.

10:20 am	**Discussion**	
10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Andrew Odlyzko** University of Minnesota	Different Types of Efficiency in Data Networks

Abstract: What should be optimized in network design and management? High rates of growth in traffic volumes, lumpy nature of network capacity, distribution of costs, and the utility users derived from data networks (as shown by their usage patterns) argue that traditional goals of high utilization and guaranteed quality of service should not be the dominating ones. Instead, minimizing the complexity of the network and providing redundancy are most desirable.

11:50 am	**Discussion**	
12:00 pm	**Lunch Break**	
1:30 pm	**Michel Goemans** Massachusetts Institute of Technology	Load-Balancing in Content Delivery Networks

Abstract: Load balancing is a crucial component of content delivery networks. It is a highly complex task because of a number of reasons, including the unpredictability and sudden surges in traffic, random events and failures in the internet, scalability issues, the highly distributed nature and constant evolution of these networks, and the heterogeneity of the services provided and their resource requirements. This talk discusses the challenges of building an appropriate model for load balancing and the design of efficient, reliable and scalable algorithms. The speaker will draw upon his experience at Akamai Technologies.

2:20 pm	**Discussion**	
2:30 pm	**Coffee Break**	Reception Room EE/CS 3-176
3:00	**Jens Vygen** Universitat Bonn	Global Routing in VLSI Design

Thursday, April 10

NETWORK DESIGN OR ROUTING

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

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**Luis Goddyn** Simon Fraser University	Some Network-Flow-Like Optimization Problems

Abstract: We consider a load balancing problem for a network in which data can flow in one of two directions on each edge, where the direction of flow must be specified at the outset of its use. One desires that the flow on each edge be as "close" to its capacity as possible. If edge-capacities are constant, and flow is conserved at each node, then we are in the realm of the graph invariant "circular flow number."

This notion is dual in the matroidal sense to "circular chromatic number," an invariant which arises in certain scheduling problems such as in traffic light sequencing. Variations of these problems arise from variable edge capacities and traffic streams. The two problems are closely because of matroidal duality.

In each case, to find an good solution, a selection of edge directions is followed by the solving of a certain linear program. It is crucial that such LPs be quickly soluble to get a practical circular flow (or chromatic) number estimator. We also present several bounds and relationships for certain classes of graphs, surface embedded graphs, and more general structures called oriented matroids. Some of these bounds are obtained through probabilistic methods.

10:20 am	**Discussion**	
10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Oktay Gunluk** IBM Research	Network Design with Small Number of Flow Paths

Abstract: We describe a network design and routing problem where each commodity has to be routed on a small number of node-disjoint paths from its source to its sink.

We describe an integer programming formulation and several relaxations. We also introduce a simple mixed-integer set related to this formulation and study its polyhedral structure.

We present (preliminary) computational results.

Joint work with F. Barahona, IBM Research.

APPL. MATH. AND NUM. ANALYSIS SEMINAR, Vincent Hall 313:

1:30pm	**Tim Elston** Univ of NC, Chapel Hill	Noise in Biochemical Networks

Abstract: Fluctuations due to small molecule numbers are an inherent property of all biochemical networks. This talk will provide an introduction to the mathematical and computational methods used to understand stochastic effects in regulatory networks. Transcriptional regulation will be considered as an application of these techniques. In particular, it will be shown how activator fluctuations at DNA promoter regions can account for both the binary and graded responses found in inducible genes and how intrinsic fluctuations change the bifurcation structure of simple auto-regulated systems.

11:50 am	**Discussion**	

12:00 pm **Lunch Break**

1:30 pm **S. Muthu Muthukrishnan**
AT&T Labs-Research
Data Stream Algorithms for Network Traffic Analysis

Abstract: Abstract: There is an emerging theory of algorithms that work on data streams, that is, data that arrives as a series of observations at high speed. Such algorithms exist for finding heavy hitters and outliers, estimating the number of rare or distinct items, summarizing traffic trends, and clustering. I will review these algorithms and explore their application for IP network traffic analysis.

2:20 pm **Discussion**

2:30 pm **Coffee Break** Reception Room EE/CS 3-176

3:00 pm **Bruce Maggs**
Carnegie Mellon University
Designing Overlay Multicast Networks for Commercial Streaming

This talk begins with an overview of the architecture that Akamai uses to deliver video and audio streams to a world-wide audience. It then tackles the problem of how to measure stream quality, and once metrics are defined, it describes various mechanisms that are used to improve quality. The talk then shifts to a combinatorial problem that arises in optimizing the overlay network that Akamai uses for delivering live streams. We describe a polynomial time approximation algorithm for ”designing” such a network. The algorithm finds a solution that satisfies capacity and reliability constraints to within a constant factor of optimal, and cost to within a logarithmic factor.

Joint work with Konstantin Andreev, Adam Meyerson, and Ramesh Sitaraman.

3:50 pm **Discussion**

4:00 pm **Coffee Break** Reception Room EE/CS 3-176

4:30 pm **Andreas Bley**
Konrad-Zuse-Zentrum
A Polyhedral Approach to IP Network Optimization

Abstract: The standard routing protocol used in IP networks currently is OSPF. Given some administrative routing weights on the links of the network, data packages are sent along a shortest path with respect to these weights from their source to their destination. In this article, the case of non-bifurcated routing is considered, i.e., all data packages between two nodes are send along the same path.

We study the network design and the traffic engineering problem for IP networks, both arising naturally in planning and operating such networks. Given the node locations, the forecasted traffic demands, all possible links, the possible node and link hardware configurations, and various other technical and administrational constraints, the goal in the IP network design problem is to (simultaneously) decide the network’s topology, its hardware configuration, and the routing weights such that the overall network cost is minimized. In the traffic engineering problem for IP networks, the goal is to adjust the networks routing weights such that, for a given network and some forecasted traffic demands, the maximum congestion of the links is minimized. In both cases we not only consider the networks normal operating state but also scenarios where single network components may fail.

Mixed-integer linear programming models and solution methods are presented for both problems. Computational results obtained with these methods for German research network and other real-world network planning problems are reported.

6:00 pm **Workshop Dinner** Gardens of Salonica
19 Fifth Street NE, Minneapolis, Tel (612) 378-0611.

Friday, April 11

MEASURING TRAFFIC ON THE (INTER)NET
NOTE THE ABBREVIATED SCHEDULE FOR FRIDAY; FIRST TALK AT 9:10 AM.

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

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**Martin Farach-Colton** Rutgers University	Adventures at Google

Abstract: Google has changed the way search engines are built. I'll discuss some of the changes, as well as some experiences from my two years in the Google Research Department and the nature of research at a startup.

10:20 am	**Discussion**	
10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
10:45 am	**Carsten Lund** AT&T Labs-Research	Network Measurements and Sampling

Abstract: One important aspect of Network Management is Network Measurements. In order to design and manage a network we need to know the traffic on the network. For example, to design an efficient network it is crucial to know the traffic matrix, e.g., the edge router to edge router traffic load. A good traffic matrix requires detailed measurements of traffic flows. The good news is that most network elements are today capable of creating traffic flow statistics, the bad new is that we need to deal with a large amount of measurement traffic. This talk to describe one sampling approach to this problem, what reduces the resources needed in the measurement collection infrastructure, but still obtain accurate traffic matrix estimates.

11:35 am	**Discussion**
11:45 am	**Concluding Remarks by Organizers**
12:00 noon	**End of Conference**

Monday, April 14

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

Tuesday, April 15

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

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15-12:15 **Douglas N. Arnold** Talking math to people who don't know any
IMA

Abstract: Mathematicians are often criticized–by themselves and others–for being incapable of describing their work to non-mathematicians. In this seminar I will discuss ways to communicate mathematics to the public using as a case study a talk I gave recently on optimization for the IT Quarterly, a "forum for friends of the Institute of Technology".

The IMA Postdoc Seminar is organized by M. Yvonne Ou and Olga Brezhneva.

Wednesday, April 16

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

BROWN BAG SEMINAR, Lind Hall 409:

12:00 **Scot Adams** Semidefinite slices
University of Minnesota and IMA

Thursday, April 17

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

APPL. MATH. AND NUM. ANALYSIS SEMINAR, Vincent Hall 570:

11:15-12:15 **Michael P. Hennessey** Visualization of the Motion of a Unicycle on a Sphere and
Univ of St Thomas the Associated Lie Algebra

Abstract: The kinematics, dynamics, and control of a unicycle (with yaw and roll inputs) moving without slip on a planar surface has been studied extensively in the geometric mechanics and nonholonomic literature. In this talk we consider the kinematic extension to the case of a unicycle moving on a non-planar surface: specifically, a spherical surface and the associated visualization, including use of computer-aided design (CAD) software packages (e.g. SolidWorksTM & MATLABTM). Such a scenario allows one to move closer to an understanding of the motion of an actual multi-wheeled vehicle traversing over non-planar surfaces that may be approximated as spherical surface patches as well the realistic portrayal of virtual vehicles in computer graphics environments, in addition to other applications, such as those that employ kinematic inversion (e.g. industrial web handling). Differential equations of motion are derived based on the nonholonomic no-slip constraint and spherical trigonometry from which the associated Lie algebra is revealed and a related example foliation formulation is illustrated that offers further generalization. For a fixed body yaw rate it is shown that a circular trajectory of a specific radius results - this can also form the basis of an instantaneous center integration (ICI) algorithm. Numerical studies designed to exercise the equations of motion (using MATLABTM & SIMULINKTM) were performed based on combinations of several different types of input trajectories: constant (including non-infinitesimal Lie bracket maneuvers), sinusoidal, and that induced by a prescribed contact point trajectory. Finally, the resulting interesting motions were plotted in 2D and 3D and provide a source of qualitative corroboration of the equations in addition to elegant colorful computer generated artwork.

Friday, April 18

The 10:00 IMA break will be in Vincent Hall 502.

IMA/MCIM INDUSTRIAL PROBLEM SEMINAR, 570 Vincent Hall:

10:10 **Richard Chiao** Diagnostic Ultrasound: Technology and Applications
GE Medical

Monday, April 21

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

OPTIMIZATION SEMINAR, Lind Hall 409:

11:00-12:00	**Saif Benjaafar** University of Minnesota	Demand Allocation in Multiple-Product, Multiple-Facility Make-To-Stock Systems

Abstract: We consider the problem of allocating demand arising from N products to M production facilities with finite capacity and load-dependent lead-times. Production facilities can choose to manufacture items either to-stock or to-order. If items are stocked, demand is satisfied immediately if there is on-hand inventory. Otherwise, demand is backlogged with the production facility to which it is assigned. Products vary in their demand rates, holding and backordering costs, and service level requirements. We develop models and solution procedures to determine the optimal allocation of demand to facilities and the optimal inventory level for products at each facility. We consider two types of demand allocation, one in which we allow the demand for a product to be split among multiple facilities and the other in which demand from each product must be entirely satisfied by a single facility. We refer to the former as the demand allocation problem and to the latter as the demand partitioning problem. For each case, we offer a solution procedure to obtain optimal demand allocations and optimal inventory base-stock levels. We use the models to characterize analytically several properties of the optimal solution. In particular, we highlight seven principles that relate the effects of cost, congestion, inventory pooling, customer segmentation, multiple sourcing, and process and demand variability.

Tuesday, April 22

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

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15-12:15	**Luis Goddyn** Simon Fraser University	The Worst-Case Euclidean Traveling Salesman Problem

Abstract: How should a finite set X of points be arranged within a finite region R in Euclidean d-space, so as to maximize the length $L(X)$ of a TSP tour through X?

It turns out that, if the size n of X is large, then the shape of R becomes irrelevant, and if R has unit volume, then the assymptotic growth is

$$L(X) \approx \alpha_d n^{(d-1)/d}$$

(α_d depends only on the dimension d).

We discuss methods and issues involved in estimating the value of the fundamental coefficient α_d. This talk involves a mix of geometry, sphere packing, quantizers, heuristics and algorithm analysis.

The IMA Postdoc Seminar is organized by M. Yvonne Ou and Olga Brezhneva.

Wednesday, April 23

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

BROWN BAG SEMINAR, Lind Hall 409:

12:00	**Dacian Daescu** IMA	Adjoint Modeling for Sensitivity Analysis: Discrete Versus Continuous

Thursday, April 24

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

APPL. MATH. AND NUM. ANALYSIS SEMINAR, Walter Library 402:

2:30pm	**James A. Glazier** Indiana University	A Simple Approach to Modeling Tissues and Development

Abstract: During embryonic development, cells need to differentiate and to migrate long distances through tissues. How do they know where to go? Cells secrete and follow gradients of diffusible chemicals (chemotaxis) and secrete non-diffusing extracellular matrix. In addition, variable adhesion molecules expressed on cells' surfaces help them to form coherent structures by differential adhesion. We have developed a simple, energy minimization framework to implement these and related morphogenetic processes and are currently applying it to the problem of the development of the bone structure in the avian wing. The same method (by the Mathematical Biology Group of Maree and Hogeweg at the University of Utrecht) has succeded in simulating the entire life cycle of the simple organism, Dictyostelium discoideum. One attractive feature of this approach is that it can interface at small length scales with the increasingly sophisticated models for genetic regulation and biochemistry inside individual cells and at large length scales with continuum Partial Differential Equation and Finite Element models.

Friday, April 25

The 10:00 IMA break will be in Vincent Hall 502.

IMA/MCIM INDUSTRIAL PROBLEM SEMINAR, 570 Vincent Hall:

10:10	**Nicholas Bennett** Schlumberger	Posterior Uncertainty in Decimated Wavelet Model Parameterizations

Abstract: Solving a geophysical inverse problem means determining the parameters of an earth model given a set of measurements. In solving many practical inverse problems, accounting for the uncertainty of the solution is very important to aid in decision-making. In this work, we address the problem of determining the posterior uncertainty of the solution for models that arise from decimated wavelet bases using a simple 1-dimensional seismic travel time inversion problem.

Our inversion methodology is to pick a model decimation, prepare a prior mean and covariance matrix of the wavelet coefficients, compute a posterior mean and covariance, and then to sample from this posterior distribution. We also sample different choices of model decimation in proportion to their posterior probability. These samples span the uncertainty of the inverse problem solution, accounting for both the uncertainty in the choice of model decimation and of wavelet coefficients. We note that a re-normalization of the decimated prior covariance matrix of the wavelet coefficients is required to properly account for the amount of variance in the prior distribution. Further, we present a fast algorithm for computing this normalized decimated prior covariance matrix.

Monday, April 28

The 10:00 IMA break will be in Lind Hall 400.

JOINT IMA AND DTC TALK, Walter Library 402:

3:30 pm	**Herve Kerivin** IMA	Partition inequalities and the network design problem with connectivity requirements

Abstract: The network design problem with connectivity requirements models a wide variety of celebrated combinatorial optimization problems including the minimum spanning tree, Steiner tree, and survivable network design problems. It has

applications to the design of reliable communication and transportation networks. Informally given requirements for the number of edge-disjoint paths between every pair of nodes, it consists in designing a minimum cost network that satisfies these requirements.

A way to formulate this problem is to use the well-known custset model which is based on the so-called cut inequalities. This formulation is known to be weak, that is the objective value of the linear programming relaxation is typically significantly less than the objective value of the integer program. Strong formulations are very useful in developing exact algorithm solution methods (i.e., branch-and-cut) since their use rapidly accelerates these solution techniques.

Partition inequalities generalize cut inequalities, and arise as valid inequalities or facets for optimization problems related to the network design problem with connectivity requirements. These inequalities have received special attention over the past twenty years as people investigated the polyhedral structure of the problem. This talk will give an overview of research on the partition inequalities, with a particular emphasis on their associated separation problem.

Tuesday, April 29

The 10:00 IMA break will be in Lind Hall 400.

Wednesday, April 30

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

BROWN BAG SEMINAR, Lind Hall 409:

12:00 **Gianpaolo Oriolo** Vertex Packing on a Superclass of Interval Graphs
Roma 'Tor Vergata', Italy

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PART III: CURRENT IMA PARTICIPANTS

FIRST YEAR POSTDOCTORAL MEMBERS

NAME	PREVIOUS INSTITUTION
Olga Brezhneva	Russian Academy of Sci.
Lisa Evans	Georgia Tech
Balaji Gopalakrishnan	Georgia Tech
Herve Kerivin	University Blaise Pascal-France
Tamon Stephen	University of Michigan
Jing Wang	University of Minnesota

SECOND YEAR POSTDOCTORAL MEMBERS

NAME	PREVIOUS INSTITUTION
Dacian Daescu	University of Iowa
Gregory S. Duane	University of Colorado
Daniel Kern	University of Illinois-Chicago
M. Yvonne Ou	University of Delaware
Toshio Yoshikawa	University of Utah

POSTDOCTORAL MEMBERS IN INDUSTRIAL MATHEMATICS

NAME	PREVIOUS INSTITUTION	INDUSTRIAL AFFILIATION
Yusuf Altundas	University of Pittsburgh	Schlumberger
Lili Ju	Iowa State University	VA Hospital
Aurelia Minut	Michigan State University	3M
Haewon Nam	Texas A & M University	GE
Jun Zhao	Texas A & M University	Schlumberger

LONG TERM VISITORS

NAME	HOME INSTITUTION
Montaz Ali	Witwatersrand University
Collette Coullard	Northwestern University
Luis A. Goddyn	Simon Fraser University
Seffi (Joseph) Naor	Technion
Peh Ng	University of Minnesota
Gianpaolo Oriolo	Roma “Tor Vergata”
Samuel Patterson	Carleton College
M. Nuri Sendil	Northwestern U

VISITORS IN RESIDENCE (as of 25 March 2003)

ADAMS, SCOT	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
ALI, MONTAZ	Witwatersrand Univ	NOV 1 2002 – OCT 31 2003
ALLEN, BETH E.	Univ of Minnesota	APR 6 2003 – APR 11 2003
ALTUNDAS, YUSUF BILGIN	IMA	SEP 3 2002 – SEP 2 2004
ARNOLD, DOUGLAS N.	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
ARONSON, DONALD	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
BARAHONA, FRANCISCO	Watson Research Center	APR 6 2003 – APR 11 2003
BELOTTI, PIETRO	Polytecnic of Milan	APR 5 2003 – APR 13 2003
BENNETT, NICHOLAS	Schlumberger	APR 24 2003 – APR 27 2003
BIENSTOCK, DANIEL	Columbia Univ	APR 6 2003 – APR 11 2003
BLEY, ANDREAS	Konrad-Zuse-Zentrum	APR 5 2003 – APR 13 2003
BREZHNEVA, OLGA	Univ of Minnesota	SEP 3 2002 – SEP 2 2004
CALDERER, M. CARME	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
CARPENTER, TAMI	Telcordia Technologies	APR 5 2003 – APR 9 2003
CHIAO, RICHARD	GE Medical Systems	APR 17 2003 – APR 18 2003
COULLARD, COLLETTE	Northwestern Univ	SEP 1 2002 – JUN 30 2003
DAESCU, DACIAN	IMA	SEP 1 2002 – JUN 30 2003
DASH, SANJEEB	IBM Research	APR 5 2003 – APR 10 2003
DUANE, GREGORY S.	IMA	SEP 1 2002 – JUN 30 2003
EISENBLAETTER, ANDREAS	Konrad-Zuse-Zentrum	APR 5 2003 – APR 13 2003
ERGUN, OZLEM	Georgia Tech	APR 6 2003 – APR 11 2003
EVANS, LISA	Univ of Minnesota	SEP 3 2002 – AUG 31 2003
FARACH-COLTON, MARTIN	Rutgers Univ	APR 6 2003 – APR 11 2003
FLEISCHER, LISA K.	Carnegie Mellon Univ	APR 6 2003 – APR 11 2003
GADE, KRISHNA	Univ of Minnesota	APR 6 2003 – APR 7 2003
GODDYN, LUIS A.	Simon Fraser Univ	APR 1 2003 – JUN 30 2003
GOEMANS, MICHEL	MIT	APR 6 2003 – APR 11 2003
GOLDSCHMIDT, OLIVIER	Make Systems Inc.	APR 5 2003 – APR 11 2003
GOPALAKRISHNAN, BALAJI	Univ of Minnesota	SEP 3 2002 – SEP 2 2004
GRIFFIN, TIM	AT&T	APR 6 2003 – APR 11 2003
GROETSCHEL, MARTIN	Konrad-Zuse-Zentrum fur Info	APR 5 2003 – APR 11 2003
GUNLUK, OKTAY	Watson Research Center	APR 5 2003 – APR 11 2003
GUPTA, ANUPAM	Carnegie Mellon Univ	APR 5 2003 – APR 9 2003
JU, LILI	IMA	SEP 3 2002 – SEP 2 2004
KARAKOSTAS, GEORGE	McMaster Univ	APR 5 2003 – APR 11 2003
KARLOFF, HOWARD	AT&T	APR 6 2003 – APR 11 2003
KERIVIN, HERVE	Univ of Minnesota	SEP 3 2002 – SEP 2 2004
KERN, DANIEL	IMA	SEP 1 2002 – JUN 30 2003
KIZZA, JOSEPH M.	Univ of Tenn-Chattanooga	APR 6 2003 – APR 12 2003
KRYLOV, NICOLAI	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
LI, TONG	Univ of Iowa	APR 5 2003 – APR 7 2003
LUND, CARSTEN	AT&T Labs-Research	APR 8 2003 – APR 11 2003

MAGGS, BRUCE MACDOWELL	Carnegie Mellon Univ	APR 6 2003 – APR 11 2003
MENDIRATTA, VEENA B.	Lucent Technologies	APR 6 2003 – APR 11 2003
MEYERSON, ADAM	Stanford Univ	APR 5 2003 – APR 11 2003
MINUT, AURELIA	IMA	SEP 1 2002 – AUG 31 2003
MONMA, CLYDE	Telcordia Technologies	APR 6 2003 – APR 11 2003
MUTHUKRISHNAN, MUTHU	AT&T Labs-Research	APR 6 2003 – APR 11 2003
NAM, HAEWON	IMA	SEP 3 2002 – SEP 2 2004
NAOR, SEFFI (JOSEPH)	Technion	APR 1 2003 – APR 30 2003
NG, PEH	Univ of Minnesota	AUG 1 2002 – JUL 31 2003
ODLYZKO, ANDREW	Univ of Minnesota	APR 6 2003 – APR 11 2003
ORIOLO, GIANPAOLO	Roma “Tor Vergata”	APR 6 2003 – MAY 4 2003
ORLIN, JAMES B.	MIT	APR 5 2003 – APR 11 2003
OU, M. YVONNE	IMA	SEP 1 2002 – AUG 31 2003
PATTERSON, SAMUEL	Carleton College	SEP 28 2002 – JUN 30 2003
PRYTZ, MIKAEL	Royal Inst of Tech	APR 6 2003 – APR 11 2003
RAVI, R.	Carnegie Mellon Univ	APR 6 2003 – APR 11 2003
REXFORD, JENNIFER	AT&T	APR 5 2003 – APR 11 2003
ROUGHGARDEN, TIM	Cornell Univ	APR 6 2003 – APR 11 2003
SANIEE, IRAJ	Lucent Technologies	APR 9 2003 – APR 11 2003
SANTOSA, FADIL	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
SENDIL, M. NURI	Northwestern Univ	SEP 2 2002 – JUN 30 2003
SHADER, BRYAN	Univ of Wyoming	APR 5 2003 – APR 12 2003
SHALLCROSS, DAVID	Telcordia Technologies	APR 5 2003 – APR 11 2003
SHEPHERD, BRUCE F.	Lucent Technologies	APR 5 2003 – APR 11 2003
SRINIVASAN, ARAVIND	U of MD, College Park	APR 6 2003 – APR 10 2003
STEIN, CLIFFORD	Columbia Univ	APR 6 2003 – APR 11 2003
STEPHEN, TAMON	Univ of Minnesota	SEP 3 2002 – SEP 2 2004
SVERAK, VLADIMIR	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
TARDOS, EVA	Cornell Univ	APR 6 2003 – APR 10 2003
THORUP, MIKKEL	AT&T Labs-Research	APR 6 2003 – APR 11 2003
TU, RONGQING	Univ of Wisconsin, Milwaukee	APR 5 2003 – APR 11 2003
VETTA, ADRIAN	MIT	APR 5 2003 – APR 11 2003
VYGEN, JENS	Universitat Bonn	APR 5 2003 – APR 11 2003
WANG, JING	Univ of Minnesota	SEP 3 2002 – SEP 2 2004
YOSHIKAWA, TOSHIO	IMA	SEP 1 2002 – JUN 30 2003
YURCIK, BILL	U of IL, Urbana-Champaign	APR 5 2003 – APR 11 2003
ZEITOUNI, OFER	Univ of Minnesota	SEP 1 2002 – JUN 30 2003
ZHAO, JUN	IMA	SEP 3 2002 – SEP 2 2004

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