MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Die Tagung fand unter der Leitung von Arie Hordijk (Leiden) und Rolf Schaßberger (Braunschweig) statt.

Die Vorträge behandelten zum überwiegenden Teil Themen aus der Theorie der Markovschen Prozesse und der Bedienungstheorie. Besonders stark vertreten waren Fragestellungen zur ergodischen Stabilität. Darüber hinaus gab es auch eine Reihe von Vorträgen aus anderen Gebieten, so etwa zu anwendungsbezogenen Fragen der Theorie der Punktprozesse und zum Scheduling. Insgesamt lagen die Anwendungsbereiche vorwiegend in der Informatik, dem Operations Research und der Telekommunikation. Das gesamte Spektrum dessen, was der Thematik der Applied Probability zugerechnet werden mag, konnte und sollte nicht repräsentiert sein. So waren zum Beispiel die Theorie der Verzweigungsprozesse und die Risikotheorie nicht vertreten.

An der Tagung nahmen 42 Wissenschaftler aus 12 Ländern teil.

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Vortragsauszüge

E. ALTMAN, A. HORDIJK

Applications of Borovkov's renovation theory to non-stationary recursive sequences and their control

We investigate the stability of non-stationary stochastic processes, arising typically in applications of control. The setting is known as stochastic recursive sequences, which allows to construct on one probability space, stochastic processes that correspond to different initial states and different control policies. A natural criterion for stability for such processes is that the influence of the initial state disappears after some finite time. In other words, starting from different initial states, the process will couple after some finite time to the same limiting (not necessarily stationary) stochastic process. We investigate this as well as other types of coupling, and present conditions for them to occur uniformly in some class of control policies. We then use the coupling results to establish new theoretical aspects in the theory of non Markovian control.

F. BACCELLI, A.A. BOROVKOV, J. MAIRESSE

On the large tandem queueing systems

We consider the basic properties of tandem systems containing k stations $\cdot/\mathrm{GI}/1$ with i.i.d. service times when $k \to \infty$. The main subject of investigation are sequences of interarrival times $t_n(k)$ on station k (interdeparture times on station $k-1$) and of waiting times $W_n(k)$ of the n-th customer on station k. There has been observed a duality property by which $W_n(k)$ and 'idle times' $Y_n(k)$, associated with $t_n(k)$ play a symmetrical role in the problems. Two versions of tandem problems are considered: a nonstationary (boundary valued) version, when the initial conditions $W_1(k)$, $k = 1, 2, \ldots$ and $t_n(1)$, $n = 1, 2, \ldots$ are given; and a stationary version, when only the stationary sequence $\{t_n(1)\}$ is given, $-\infty < n < \infty$. The ergodic theorems for both versions are obtained. The second version of the problem is still quite far from its complete solution. The ergodic theorem implies for instance the existence of a fixed point for the map, generated by single server queue G/GI/1.

F. BACCELLI, V. SCHMIDT

Taylor series expansions for Poisson-driven (max,+)-linear systems

We represent the second-order variables W of a stationary open (max,+)-linear sys-

tem as a functional of the input point process. We then use the method of Taylor expansions (in the intensity parameter λ of the input point process) in order to represent the expectation of these stationary variables as

$$E[W] = \sum_{n=0}^{k} \lambda^n \varphi_n + O(\lambda^{k+1}).$$

Two equivalent expressions are given for the φ_n coefficients. The most explicit one involves a class of polynomials which are the sum of certain monomials present in the multinomial formula and which are invariant by cyclic permutation and by translations along the $(1, 1, \ldots, 1)$ vector.
The method extends to the case of Laplace transforms and to the case of higher order moments. Examples are provided in queueing theory and in manufacturing models.

B. BLASZCZYSZYN, A. FREY, V. SCHMIDT

Light-traffic approximations for Markov-modulated multi-server queues

A general concept is considered of expanding the expectation of a wide class of functionals of marked point processes, which expresses this expectation by a sum of integrals over higher-order factorial moment measures of the underlying point process. This idea is applied in order to derive approximation formulas for stationary characteristics of multi-server queues with Markov-modulated arrival process and FIFO queueing discipline. Besides real-valued queueing characteristics like waiting time and total work load, we also give approximations for the Kiefer-Wolfowitz work-load vector. If the service times have phase-type distributions, the factorial moment expansion provides a useful computational technique for approximations of moments of the stationary work-load vector. Numerical examples are given which show how the algorithm works in light traffic.

O. BOXMA

The M/G/1 queue with negative customers - a Wiener-Hopf approach

We consider an M/G/1 queue with the special feature that negative customers arrive, according to a Poisson process. Negative customers require no service, but they lead to the removal of some ordinary customers or work. We study two variants of the model that can be analyzed in detail.
(i) At the arrival of a negative customer, a stochastic amount of work is instantaneously removed from the system. For this case we determine the workload distribution. The problem gives rise to a Wiener-Hopf equation. Equivalence with a

GI/G/1 queue with only ordinary customers is exploited.
(ii) At each service completion, not only the completed customer leaves but also just as many customers (up to the number of customers present) are removed as there have been negative arrivals during the past service period. For this case we determine the queue length distribution of ordinary customers, solving a Riemann boundary value problem.

H. CHEN, H. ZHANG

Stability of multiclass queueing networks under FIFO service discipline

In this paper, we establish some sufficient conditions for the stability of a multiclass queueing network under a first-in-first-out (FIFO) service discipline. The results extend the previous work on the single class network and the single station network, and complement the previous work on the queueing network under general work-conserving and priority service disciplines. In addition, we formally identify a FIFO fluid network that corresponds to the queueing network under FIFO service discipline, and prove a fluid limit theorem for the queueing network under FIFO service discipline.

D. CHENG, R. RIGHTER

Coupling characterizations of stochastic orders and tandem queues

We describe characterizations of several stronger stochastic orderings in terms of the usual stochastic ordering and give examples where they can be used to show stochastic optimality of designs and policies. In particular, we show how the reversed hazard rate ordering characterization leads naturally to the optimal ordering of some of the servers in a tandem queueing network, where optimality means minimization of the departure process in the stochastic pathwise sense.

H. DADUNA

Tandem queues in discrete time where moving units don't see time averages

I consider closed and open tandems of BERNOULLI servers under FCFS- regime. The equilibrium distribution of these systems is of a specific product-form, which is (for identical node characteristics) symmetric in the nodes. In contrast to continuous time systems, customers' arrival distributions show an asymmetric product-form; in both cases: open and closed tandems.
For closed tandems this leads to a cycle time distribution, which depends on the

node, where the cycle starts; the Laplace-Stieltjes transform of the cycle time is asymmetric.
The cycle time result is used to obtain the passage time distribution for the open tandem. It is shown, that from the asymmetric arrival time distribution and the asymmetric cycle time distribution eventually a symmetric (in the nodes) passage time distribution is obtained.

D.J. DALEY, L.D. SERVI

Transactional datasets and queues

A transactional dataset for a service system consists of the time epochs I where services start and where services finish (hence, customers depart). Larson (1990) proposed the name Queueing Inference Engine to describe the problem of finding estimates of the queue size or waiting time, for example, these being quantities that cannot be determined from the data. Assuming a Poisson arrival process, the mean queue size at service finish (or start) times can be estimated conditional on the dataset $I \cup \infty$. The arrival rate parameter λ can be estimated by either a method-of-moment estimator or a Maximum Likelihood Estimator (MLE). The model can be made more realistic by allowing balking with propability ϖ for arrivals who would otherwise wait for service, or reneging from the waiting line at rate η. When the queueing model is a stationary M/M/k system, no distinction in estimating the customer loss rate between a balking and reneging model is possible (use birth-and-death equations). More generally, assuming only Poisson arrivals and balking, both moment and ML estimators of λ and ϖ are available, via simple expressions. Replacing balking by reneging, the algebra is more complex: A closed form expression for the likelihood of a busy period of length N is available, but as the sum of 2^{N-1} terms, half positive and half negative, it is not computationally efficient nor numerically stable for N larger than 5 to 10. Direct computation from the transition probabilities offers hope.

I. ELIAZAR, U. YECHIALI

Randomly-timed gated queueing systems

A new general model, called Randomly-Timed Gating (RTG), is introduced for M/G/1-type queues with server intermissions: whenever the server re-enters the system (after a general intermission-interval), a timer is activated for a random exponential duration. When the time allocated by the timer expires, the queue is gated. The server leaves for another intermission-interval as soon as either the queue becomes empty, or the service of the jobs present in the system at the instant of gating has been completed, whichever occurs first.

This model defines a continuum class of queueing systems that spans the entire spectrum between the gated and the exhaustive regimes, and leads to several application-models never studied before.
Following a thorough analysis, the model is used to studying polling systems where each station is governed by an independent RTG regime. A communication-type application and several extensions are described.

S. FOSS

SLLN for a class of stochastic sequences arising in polling models

We consider a polling system with a single server, stationary ergodic input, Markovian-type routing mechanism and with the 'monotone' policies on all nodes. We show that (under some mixing conditions) the average number of 'active cycles' in the model with n customers converges a.s. to some constant when $n \to \infty$. This statement allows us to obtain the stability of the system in consideration (if $\rho < 1$).

R. GIBBONS, F. KELLY, P. REICHL

Network programming methods for loss networks

We describe how some of the insights available from stochastic analyses of dynamic routing may be incorporated into the classical network programming approach to the design of networks. The basic tool is a performance bound, developed from a network synthesis of various Markov decision processes, one for each resource of the network. Several examples are described.

K. HINDERER, A. MÜLLER

A Markovian decision process for cost-minimal immunization

We generalize the Greenwood model of Dayanauda and Hogarth (1977) and of Lefèvre (1979) in several respects, notably by the introduction of two types K_1, K_2 of (non-trivial) fixed costs and a natural choice of the terminal cost function.
Among the new results are the following ones:

1. A scheme is provided which generates in the case of continuous state space an infinitely of examples satisfying the basic assumptions, needed for the simple solution in the case $K_1 = K_2 = 0$.

2. In the case of discrete state space, the limit for $N \to \infty$ of the N-stage cost functions and a stationary, asymptotically optimal policy can be found by

recursion in state space.

3. Structural results for the minimal cost functions (lower semicontinuity, bounds) and for the smallest minimizers (state-bang-bang type, behaviour for large and, if $K_1 = 0$, for small states) are given.

Some variations and extensions are indicated.

L. KALLENBERG

Markov decision problems and linear programming

A finite Markov decision problem is considered with the average reward criterion in the general (multichain) case. After introducing the model, we first discuss the standard linear programming formulation. The main part of this talk deals with separable problems. A problem is called separable if for some pairs (i, a) of a state i and an action a:

1. the immediate reward is the sum of two terms, one term only due to the current state and the other term only to the chosen action;

2. the transition probabilities only depend on the chosen action and not on the current state;

3. the sets of these separable actions are nested.

We give a linear programming formulation which can be viewed both as a generalization and as a specification of the standard program, and we will interpret the inequalities and equalities in this formulation. We derive relations between the primal and dual program, and we show how an optimal policy can be obtained from an optimal solution of the linear program.
Finally, we will give some examples of replacement and inventory models which can be formulated as separable problems and for which the linear programs have much less variables than in the standard formulation.

H. KASPI, O. KELLA, W. WHITT

Stochastic fluid networks

The general model considered is $W^X = X + (1 - P')L^X$ where X is cádlág and (W^X, L^X) are a solution to the dynamic complementarity problems (P substochastic with $P^n \to 0$). Some new structural properties are exhibited, in particular monotonicity properties. As a result, for the case in which $X(0) = 0$, X having stationary increments, W^X is stochastically increasing (in t), $(1 - P')^{-1}W^X$ is stochastically

increasing and subadditive (SIS) and that $(1-P')^{-1}EW^X$ (if exists) is concave. For the feedforward case with $X(t) = J(t) - (1-P')rt$ and J being a subordinator, under the condition $(1-P')^{-1}EJ(1) < r$ the process W^X is stable and convergence to the distribution holds in total variation. For the stationary distribution product form holds only in trivial setups (and never holds otherwise). For a 2-dim network (not feedforward) similar results are shown. In addition the stationary distribution has a positive mass at zero and the origin is reached in finite expected time starting from every finite mean initial condition.

G. KOSHEVOY, K. MOSLER

Lorenz orderings in $\mathbb{R}^d$

For distributions F, G in $\mathbb{R}^d_+$, G is a dilation of F if $\int \varphi(x)\,dF(X) \leq \int \varphi(x)\,dG(x)$ holds for every convex $\varphi : \mathbb{R}^d_+ \to \mathbb{R}$. When $d = 1$, dilation is equivalent to equality of the means (provided they exist and are positive) and ordering of the Lorenz functions, $L_F \geq L_G$, where $L_F(t) = \frac{1}{\mu_F}\int_0^t F^{-1}(s)\,ds$. We extend the Lorenz ordering to $d \geq 2$.
For this, we define the Lorenz zonoid of F, and say that G is larger than F in Lorenz ordering if its Lorenz zonoid includes that of F. The ordering is proved to be equivalent to directional dilation in every direction $p \in \mathbb{R}^d$. Also, it is equivalent to $\int \varphi(x)\,dF(x) \leq \int \varphi(x)\,dG(x)$ for every $\varphi = \psi \cdot \ell$ where $\psi : \mathbb{R} \to \mathbb{R}$ is convex and ℓ is linear $\mathbb{R}^d \to \mathbb{R}$. Thus the ordering is weaker than dilation. By restricting ℓ to subsets of linear functions, further orderings are obtained. They form a flexible class of orderings which can be used for diverse applications.

J. LASSERRE

New tests of optimality in Markov decision processes

We consider finite state and action spaces MDPs with both discounted and average cost criterion. We present two new tests that permit to detect optimal actions and non-optimal actions. Those tests are different from the standard MacQueen type tests for the discounted case and new in the average cost case. We use a result by Cheng, proposed for general linear programs. The tests have a simple interpretation in terms of local improvement of the criterion (discounted or average cost case).

G. LAST, R. SZEKLI

Coupling methods in reliability

We consider replacement policies on the real line, which is a classical topic in the theory of reliability. One considers a working item subjected to failure and having a fixed life time distribution. Upon failure the item is, without delay, replaced by a new one or by a 'used' one. In addition to unplanned replacements some planned replacements may be applied, for example at fixed times or if the age of the working item exceeds a prescribed level. The problem is to compare processes of 'unplanned' failures for different replacement policies.
We derive comparison results of the above type using new in this area methods, which are coupling methods for point processes. We use an inverse construction of Poisson processes and a thinning construction utilizing in both cases the corresponding compensators. Our model introduces a rather general unperfect repair policy, which is allowed to depend on the history of the process. The assumptions needed are some ageing properties of lifetimes and monotonicity properties of the repair process. Our results generalize many classical results in this area offering at the same time an alternative method.

V. MALYSHEV

Fluid models and dynamical systems

It is shown that a fluid model is a particular case of a more general dynamical system approach. A fluid model exists only if some conservation law holds in the initial stochastic model. Various complication can exist in the fluid model:
1. Nondeterministic fluid (Scattering Phenomena),
2. Continuum of invariant measures for the 'normalized' fluid model (radial projection on the simplex and time change).
In the case when the number of invariant measures is finite, general theorems exist providing necessary and sufficient conditions for ergodicity and recurrence.

K. MENGERSEZ, G. ROBERTS, R. TWEEDIE

Application of Markov chain convergence results in Markov chain Monte-Carlo algorithms

To implement a Hastings-Metropolis algorithm to simulate from a density $\pi(x)$ on $\mathbb{R}^d$, we take any candidate transition law $q(x,y)$ and accept moves generated by q

with probability

$$\alpha(x,y) = \begin{cases} \pi(y)q(y,x)/\pi(x)q(x,y) \ \wedge 1, & \pi(x)q(x,y) \neq 0 \\ 1 & \pi(x)q(x,y) = 0. \end{cases}$$

If $P(x,y) = q(x,y)\alpha(x,y)$ and $P(x,\{x\}) = 1 - \int q(x,y)\alpha(x,y)\,dy$ then π is invariant for P. We discuss conditions leading to irreducibility and aperiodicity in which case $||P^n(x_j) - \pi|| \to 0$. We consider conditions under which this convergence is geometrically fast in n. In particular

1. if $q(x,y) \equiv q(y)$ (the independence case) then we show geometric ergodicity is essentially equivalent to $q(x)/\pi(x) \geq \beta$,

2. if $q(x,y) = q(x-y) = q(y-x)$ (the random walk case) then for symmetric π in $d = 1$, geometric ergodicity is essentially equivalent to exponential decrease in the tails of π,

3. in the random walk case with $d > 1$, geometric ergodicity is implied by geometric decrease in π together with a smoothness condition on the contour of π.

M. MIYAZAWA

Queues with interruptions and response time problems

Stationary distributions for queueing networks, GSMP (Generalized Semi-Markov Processes) and queues with symmetric service discipline have been extensively studied in the 70's and 80's. One of the interesting results is the equivalence between
(i) insensitivity of macrostate distributions w.r.t. lifetime distributions,
(ii) local balance of stochastic flows,
which leads to
(iii) decomposability of the joint distribution of macrostate and remaining lifetimes, where decomposability means that the joint distribution splits into independent components of the marginals. A major intention of this talk is to shed light on the classical results above from an extended formulation of GSMP, called RGSMP, which covers a wide range of queueing models which can not be accessed by GSMP. It is shown that the classical theory still works for the equivalence between (ii) and (iii) but not for (i) and (ii), if we change the notion of local balance suitably.
We apply this result to queues with negative customers and mean response time of a customer at a given node of a queueing network.

P. POLLETT

Analytical and computational methods for modelling evanescent random processes

There are many stochastic systems arising in areas as diverse as wildlife management, chemical kinetics and reliability theory, which eventually 'die out', yet appear to be stationary over any reasonable time scale. The notion of a quasistationary distribution has proved to be a potent tool in modelling this behaviour. In finite-state systems the existence of a quasistationary distribution is guaranteed. However, in the infinite-state cases this may not always be so, and the question of whether or not a quasistationary distribution exists requires delicate mathematical analysis. The purpose of this paper is twofold: to present simple conditions for the existence of quasistationary distributions for continuous-time Markov chains, and, to describe an efficient computational procedure for evaluating them. The computational method I shall describe is a variant of Arnoldi's algorithm and it is particularly suited to problems where the transition-rate matrix is both large and sparse, but does not exhibit a banded structure which might otherwise be usefully exploited. The analytical and computational methods will be illustrated with reference to a variety of examples, including birth-death process, the birth-death and catastrophe process, and an epidemic model for which I shall compare the computed quasistationary distribution with an appropriate diffusion approximation.

U. RIEDER

General bandit processes in discrete time

We introduce the well-known multi-armed bandit problem and present a simple proof for the optimality of the Gittins index policy.
Important special cases are Bayesian nonparametric bandit problems. The processes are assumed to be Dirichlet processes. By means of a suitable stochastic dynamic program we show the monotonicity of the value functions and of optimal policies. Then we extend the stopping-property and the stay-on-a-winner-property, which are well-known for Bernoulli-bandits. the results are based on a new ordering concept on $\mathbb{N}_0^k$. Finally, an open bandit model (or single-server queueing network) with a general arrival distribution is considered. We combine the formulation of Whittle (1981) with ideas of Tsitsiklis (1986) to obtain a new and constructive proof for the optimality of a largest-index policy. The indices can be computed by the so-called largest-remaining-index method.

T. ROLSKI

Fluid models driven by a Gaussian process

We consider a fluid model of a single buffer in a random external environment modelled by a Gaussian process. The main example is when the external environment is an Ornstein-Uhlenbeck process or a linear combination of components of some multivariate Gauss-Markov processes. The Ornstein-Uhlenbeck model appears, for example, as the limiting case of the multiplexing model of Anick, Mitra and Sondhi in heavy traffic environment. The talk reports papers written jointly with V. Kulkarni, K. Debicki and Z. Palmoski.

A. RYBKO

Euler hydrodynamic limit for one class of neural networks

Let us consider a graph G with the set V of vertices and the set L of links. Let $D(i) = \{j : (j,i) \in L\}$ be the neighbourhood of i. Consider the following Markov chain. Its state space is R_+^V, we can say that there is a potential $s_i(t)$ at the point $i \in V$ at time t. If $s_i(t) > 0$ for all i, then $s_i(t)$ decrease linearly in time with constant speeds v_i until one (say $s_i(t+t_0)$) becomes 0. At this moment $t+t_0$ all $s_j(t+t_0+0)$, $j \in D(i)$ get some positive increments $\eta_{ij}(t+t_0+0)$ which are mutually independent but have the same distribution for fixed i,j. Denote its common mean value by $a_{ij} = E\eta_{ij}(t+t_0+0)$. We call this Markov chain M. After the consideration of Euler limits it is possible to prove the Theorem: If $A = \{a_{ij}\}$ is selfadjoint, the minimal eigenvalue of A is positive and the solutions of the equation $A\pi = v$ has all positive coordinates, then M is ergodic.

M. SCHÄL

Valuation of options in discrete-time financial markets

The price X_t of some stock at time $t = 0, 1, \ldots, T$ forms a process on $(\Omega, \mathcal{F}, P)$. The bank offers the option to buy 1 stock at time T for the price X_0 and for some extra price v at time 0. Then there is no risk for the bank if there is some investment plan ξ resulting in a gain $G(\xi)$ such that $v + G(\xi) \geq (X_T - X_0)^+$. The smallest such number v^* can be shown to be $\sup E_Q[(X_T - X_0)^+]$ where the sup is taken over all probability measures $Q << P$ such that X is a martingale under Q. For the proof we use an L^2-framework and ideas of Kramkov and Schachermayer.

P. SCHWEITZER

Queueing networks: Approximations and bottleneck analysis

Two approximations are described for large closed product-form networks with constant-rate servers. One is an asymptotic expansion in reciprocal powers of the population, and leads to easy identification of bottlenecks. The other consists of self-consistent approximation to the two sides of the exact mean value analysis recursion. It includes, as special cases, both linear and quadratic approximations.

A. SHWARTZ

New models and policies in discounted dynamic programming

Consider a standard discounted Markov decision process: under policy π, the cost is

$$V^i_{\beta_i}(\pi, x) = E^\pi_x \sum_{t=0}^{\infty} \beta_i^t c_i(x_t, a_t), \qquad \beta < 1$$

where x is the initial state, $\{a_t\}$ the control and $\{x_t\}$ the state sequence. If we now combine several discounted criterions, we obtain the multiple-discount criterion

$$V(\pi, x) = \sum_{i=1}^{k} V^i_{\beta_i}(\pi, x).$$

We show that there does not exist an optimal (max) stationary policy for V, but for the finite problem there is an optimal policy which is stationary from some time N onward, and Markov at $t = 0, 1, \ldots, N$.
If we add a constraint, with the same structure as V, then we need to randomize: the number of randomizations is the number of constraints. Finally, for the constrained, single discount problem, with countable state and compact action space (under continuity assumptions) we obtain a policy which is optimal and is, for M constraints,
- stationary deterministic after some time N,
- the action sets used by the policy are singletons, except at most M,
- there are at most M time-state pairs in which randomization occurs.

S. STIDHAM

Airline yield management as a problem in the control of queues

We formulate and analyze a Markov decision model for airline seat allocation (yield

management) on a single-way flight with multiple fare classes. Unlike previous models, ours makes no assumptions about the arrival patterns for various fare classes and also allow cancellations, no-shows, and overbooking. We show how to solve this problem exactly using dynamic programming. Under realistic conditions, we demonstrate that an optimal booking policy is characterized by state- and time-dependent booking limits for each fare class. Our approach exploits the equivalence to a problem in the optimal control of admission to a queueing system, which has been well-studied in the literature on queueing-control.

P. TAYLOR

An operator-geometric approach to product-form networks

We formulate an open Markovian network of queues as a quasi-birth-and-death process. Using results which give sufficient conditions for the level to be independent of the place, we characterize the product-form stationary distributions in terms of the spectral properties of the rate matrices. For a Jackson network, the conditions enforced by such a formulation are shown to be equivalent to the conditions imposed by the standard traffic equations. Generalisations for a wider class of product-form networks are also given, and a method for constructing new product-form networks is discussed.

H. TIJMS

On a conjecture about geometric tail behavior of state probabilities in a countable Markov chain

This lecture poses an open problem for a Markov chain with infinitely many states. Suppose you have an ergodic Markov chain with one-dimensional state space $I = \{0, 1, \ldots\}$ and equilibrium probabilities $\{\pi_j, j \in I\}$. Under what conditions there exist constants $\alpha > 0$ and $0 < \tau < 1$ such that $\pi_j \sim \alpha\tau^j$ for j large enough? Such an expansion is extremely useful when numerically solving the equilibrium equations of countable Markov chains arising in practice. The conjecture was posed that the above geometric tail behavior applies when there is a finite set K such that the mean recurrence time to this set is linear in the initial state. In applications the decay factor τ may be characterized by the smallest pole of the generating function of the state probabilities outside the unit circle.
Added note: In the discussion Professor Borovkov pointed out a characterization of general-state Markov chains for which the equilibrium distribution has a geometric tail.

J. WALRAND

Admission and routing in ATM networks

Asynchronous transfer mode (ATM) networks carry information in fixed-size packets, called cells, of 424 bits. The networks transport the cells of a given connection, or call, along a route assigned to that call. The user specifices some characteristics of the stream of cells and requests a quality of service specifying the delay and loss rate that is acceptable. The cells move along optical fibers connected by switchers equipped with buffers that store temporary bursts of cells.
Typically, the acceptable loss is small, of the order of 10^{-6}, and occurs when the buffer overflows at one switch. Overflows are large deviations and can be kept small by averaging (multiplexing) calls suitably. We explain a method for guaranteeing that the loss rates are acceptable in a network with two types of traffic distinguished by the dynamics of their fluctuations: slowly varying and fast varying. Losses in fast varying streams are kept small by using buffers. The theory of effective/decoupling bandwidth can be used to decide if a new call can be carried along a given path. For slowly varying calls, buffers do not help and losses are kept small by multiplexing many calls. Large deviation results are used to estimate if a new call can be accepted.
We also explain on-line estimation methods that the network can use to estimate its spare capacity when it does not have a model of the sources.

G. WEISS

Fluid models for re-entrant lines - stability & control

Re-entrant lines are queueing networks in which all customers follow the same route, which may re-visit each node several times. Recent results on the connection between stability of stochastic networks and the stability of their deterministic fluid limits motivate our research. We first analyze the Lu-Kumar re-entrant line and identify the global stability region for its fluid model. Next we discuss optimization: we formulate several optimization problems of which minimization of total inventory seems the most interesting. A three buffer example is solved. Typically the solution consists of piecewise constant controls; surprisingly switches between them can occur not only when buffers reach empty state.

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