MAESTRO

models for performance analysis and control of networks

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Team

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- Giovanni Neglia (CR INRIA)

N. Choungmo-Fofack (2nd year), M. El Chamie (1st year), J. Gaillard (1st year), M. Hanawal (3rd year), M. Sokol (3rd year): PhD students

- Administrative Assistant: Laurie Vermeesch

Overall goal

Modeling, performance evaluation, optimization and control of networks

Contributions

Theoretical (new models, formalisms)

Applied (algorithms, patents, software)

Quantitative & qualitative elements

Publications	2008	2009	2010	2011	2012	Total
Journals	15	12	16	22	13	78
Conferences	38	68	53	49	8	214
Books					1	1
Patents		1	2	1		4

- Infocom (21 papers), WiOpt (15), Networking (9), ITC (6), …
- IEEE/ACM Trans. Networking (3), IEEE JSAC (7), PEVA (7), …
- 3 Best Paper Awards, 1 Best Student Paper Award

Funding (kEuros)	2008	2009	2010	2011
	333	549	521	299

Quantitative & qualitative elements (cont')

Industrial grants:

- Alcatel Lucent Bell Labs
  - Semantic networking
  - Self-optimizing wireless networks
- Orange Labs
  - Content-centric networking
  - QoS and quality of experience

European grants:

- FP6 IST FET « BIONETS »
- FP7 ICT STREP « ECODE »

…

ANR (national research initiatives) grants:

- ANR Verso « ECOCELLS »
- ANR Syscom « MODECOL »
- ANR Multimedia « VOODDO »
- ANR Telecommunications « WINEM » …

Quantitative & qualitative elements (end)

10 Phd theses awarded in [2008-2011]:

Amar Azad (Post-doc at UCSC)
Dinesh Kumar (Staff Researcher at IBM TJ Watson)
Dorian Mazauric (Post-doc at Univ. Columbia)
Alonso Silva (Post-doc at UC Berkeley)
…

Former postdoctoral researchers in [2008-2011]:

Utku Acer (Staff Researcher at Bell Labs, Antwerpen)
Alberto Blanc (Assistant Professor at Telecom Bretagne)
Damiano Carra (Assistant Professor at Univ. Verona)
Vincenzo Mancuso (Staff Researcher at IMDEA, Madrid)
...

Research topics (2008-2011)

1 - IP networks
2 - Wireless networks
3 - Information networks
4 - Game theory applied to networking
5 - Stochastic processes, queueing, control theory and game theory

Outline

A - Sample of our research

1 - Estimation in social networks

2 - Flow-aware traffic management

3 - Internet access : Interplay between law and technology

B - Objectives for next four years

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Sample of our research

1 - Estimation in social networks

- society opinion (e.g. political survey)
- distributions (degree dist., income distribution, …)
- subpopulation size of a certain type (gender, age, …)

Uniform sampling

- exhaustive list of members may not exist
- members have privacy concerns
- targeted population small w.r.t. general population

Alternative: use graph of social connections

⇒ Random walker (RW)

Connect all nodes with weight α/n (n # nodes)

When at node i RW goes
• with prob. $d_i/(d_i+\alpha)$ uniformly to outgoing link if any (i.e. if $d_i>0$.)
• with prob. $\alpha/(d_i+\alpha)$ uniformly to an artificial link (uniform restart)

WAW 2010

Hybrid solution: combines good features of both uniform sampling and RW

Variation of Google PageRank algorithm:

- Uniform restart does not occur with fixed prob. but with prob. depending on node degree
- Reversible (undirected graph), explicit stationary distr.
- Improve algebraic connectivity (= less graph distortion)
- Faster convergence to steady-state (= smaller statistical bias w.r.t. pure RW)

Hybrid RW applies to other problems like search in network (e.g. nodes with high degree)

Example of multidisciplinary research on networked data (networking, social sciences)

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2 – Flow-aware traffic management (with ALU, 3 patents)

Customers demand better quality of service/experience

Mice-elephants phenomenon:

- majority of flows (80%) short-lived (mice), but 20% total vol.
- rest (20%) are long-lived TCP flows (elephants), but 80% of total volume

New generation of high speed routers + few hundreds of long-lived flows ➔ "Flow-aware" traffic management

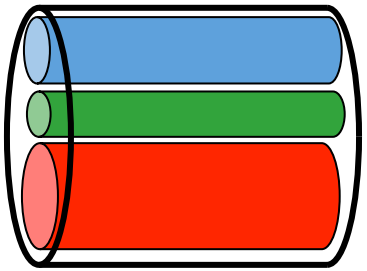
Short-lived flows: high priority

Long-lived flows: flow-aware

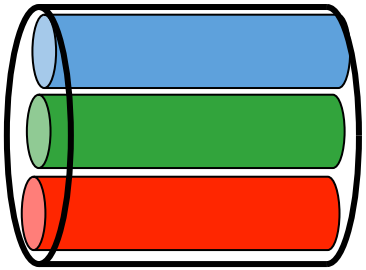
TCP unfair to long RTTs

Flow-aware: any fairness policy can be implemented

Today



Flow-aware management



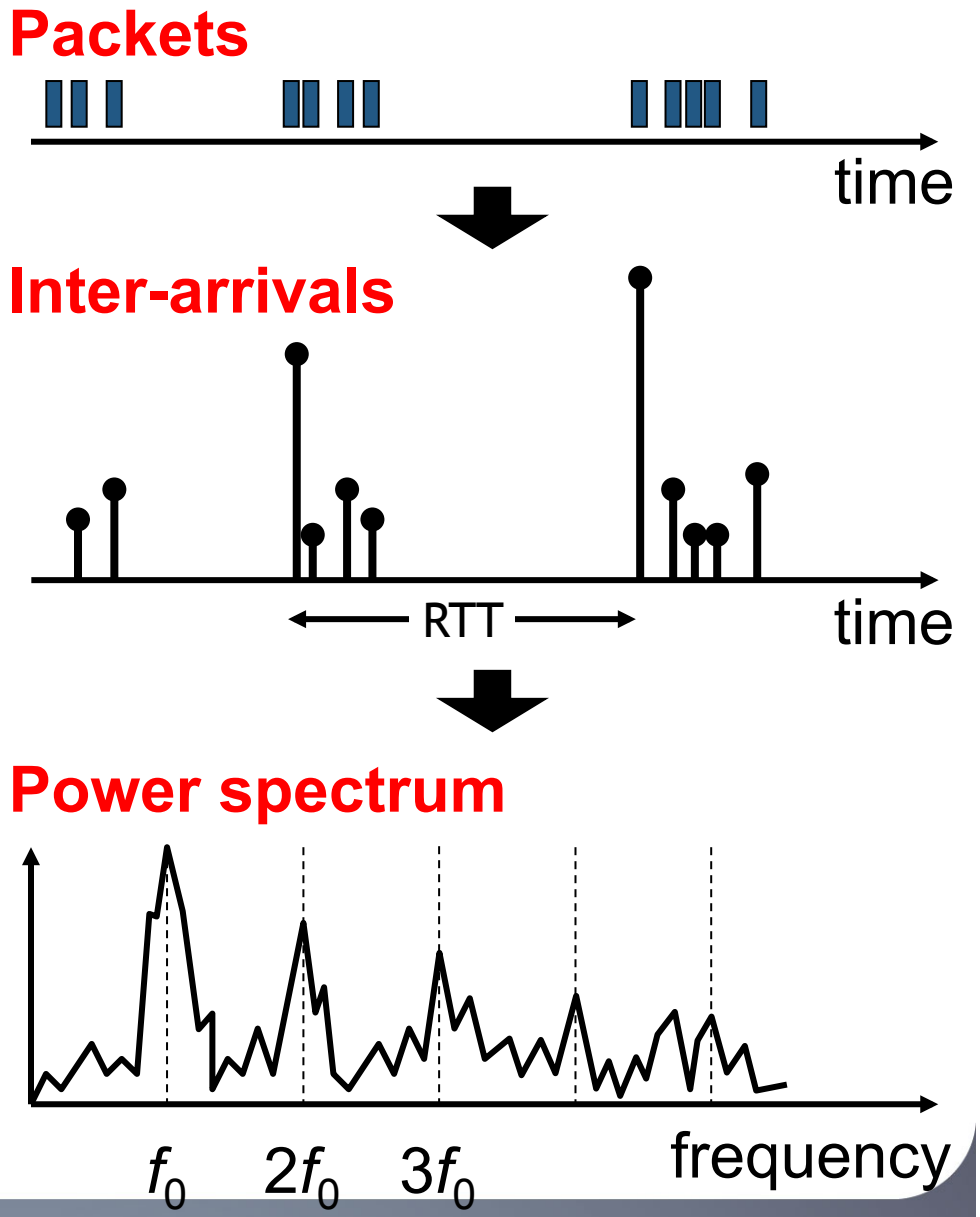
Need to estimate short-term sending rate = #pkts/RTT

Constraints: one-way traffic, online estimation, passive

RTT estimation: Our approach

Basic idea

- Exploit TCP's self-clocking mechanism
- Signal represented by inter-arrival times **at router** (**one-way traffic**)
- Use spectral analysis to compute power spectrum and extract periodic components
- Identify fundamental frequency $f_0=1/RTT$



Computing power spectrum

Signal = packet inter-arrival times

- New sample at each packet arrival $h_k = t_k - t_{k-1}$
- Signal irregularly sampled ($\{h_k\}$ unevenly spaced)

Several offline methods for irregularly sampled signal

Our contribution:

online version of Lomb periodogram (patent)

Experimental validation

source Inria, destination Trento, via Eurecom

(flow-aware router, RTT estimation)

Follow up

Two schemes for controlling long-lived flows

(2 patents)

In ALU prototype

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A sample of our research

3 - Internet access : Interplay between law and technology*

Context:

Help legislators to make decisions (also) based on scientific grounds

* in collaboration with jurist

Legal background

Conflict between two legislation approaches to copyright infringement, both aiming at protecting copyright holders

Confrontation approach

Actions to decrease offer/demand for unauthorized content

Cooperative approach

Install tax for right to access unauthorized music/films.

Revenues would go to copyright holders

Confrontation approach

Hadopi law in France (2009):

sends warnings prior to sanctions (content limitation, disconnection, fines)

Ethic behind confrontation approach:
unauthorized download of music/movies should be regarding as steeling CD/DVD in shop

Alternative approach: why?

Important fraction of Internet traffic due illegal content transfer (P2P, streaming)

• Great economic factor for ISPs: sell expensive subscriptions with fast access.

Challenge: find way to benefit from this huge demand rather than spend resources to destroy it?

What are we working on

- Mathematical analysis of impact of measures against illegal downloads

- Economic analysis of alternative approaches (sampling, pricing using Shapley value, …)

Key tool: game theory

A sample of our research

Impact of measures against illegal downloading in P2P networks

Markov epidemic-like model:

X(t) = # peers with file at time t (seeds)

Y(t) = # peers without file at time t (leechers)

(**X(t)**,**Y(t)**) → (**X(t)**+1,**Y(t)**-1) rate λ**X(t)Y(t) (one more seed)**

→ (**X(t)**-1,**Y(t)**) rate μ**X(t)** **(seed departure)**

A - **Branching** process

Take care of situation where not many seeds at time t=0 (high risk of extinction)

B - **Mean-field** approach

Take care of situation where many seeds at time t=0 (case of large population)

B - **Mean-field** approach (N peers including 1 initial publisher)

- $\lambda = N^{-1}\beta$ $\quad (X(t) := X_N(t),\ Y(t) := Y_N(t))$

If $\lim_N N^{-1}X_N(0) = x_0$, $\lim_N N^{-1}Y_N(0) = y_0$, $x_0 + y_0 = 1$

$$(N^{-1}X_N(t), N^{-1}Y_N(t)) \rightarrow_{prob.} (x(t), y(t)) \quad (N \rightarrow \infty)$$

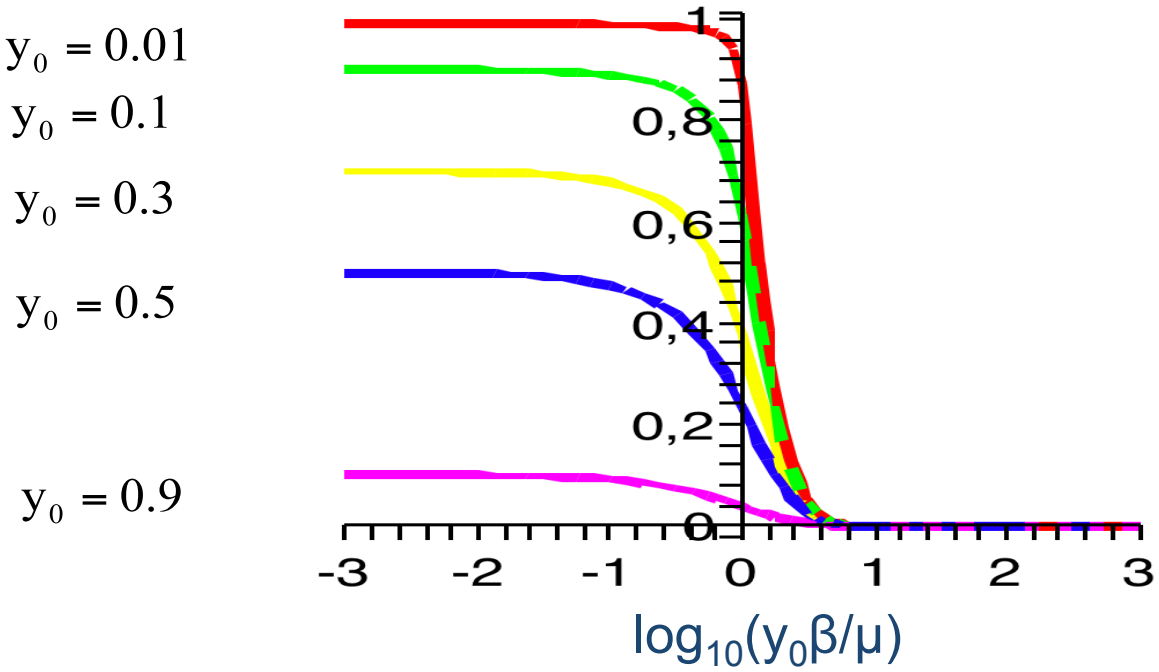
with

$$dx/dt = x(\beta y - \mu), \qquad x(0) = x_0$$

$$dy/dt = -\beta yx, \qquad y(0) = y_0$$

Result holds for $t = \infty$ [Kurtz, 70]

Ratio of peers that never get file: a phase-transition



y_o= fraction of leechers at time 0
β = pairwise seed-leecher connection rate
μ = seed departure rate

Infocom 2011

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Objectives for next four years

1– Network Science

Understanding structural properties/dynamics of variety of large-scale networks in various contexts (telecommunications, social science, ..)

Many general questions common to various disciplines (e.g. epidemy spreading/content dissemination)

Game theory, distributed optimization, random graphs, …

2 – Network Engineering Games

New branch of game theory

Use game theory to engineer communication networks

Main axis on routing games
- non-additive costs
- non-conservative flows (packet losses, multicast)
- non-increasing link costs

2 – Network Engineering Games (cont')

Second axis involves Bio-inspired paradigms:

- Evolutionary games to engineer evolution (not just predict/explain). E.g. evolving protocols

- Epidemic games (e.g. virus anti-virus)

3 – Information Centric Networks (ICN)

Provide design criteria for network operators

- cache replacement/placement policies (mobile context)

- routing (of requests)

Q: is it worth deploying ICNs?

Ongoing grant with Orange Labs

4 – Green Networking

Pursue systematic ‘green approach’ when solving optimization problems

- energy cost

- environmental impact

along with classical criteria (throughput, delay, fairness, …)

5 – Advances in Methodological Tools

Optimal control and game-theoretic models for optimal scheduling, resource allocations

Going beyond networking applications: biology, economics

General purpose modeling algorithms & software for controlled/uncontrolled systems

Questions?