Stochastic Models for Generating Synthetic HTTP Flows

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http://cm.bell-labs.com/stat/InternetTraffic



HTTP Source Traffic Generation

Source traffic generation is a critical missing component of today's network simulators.

HTTP

- a significant source of Internet traffic
- model both HTTP 1.0 and 1.1

closed-loop

- HTTP source-level models are layered over TCP for end-to-end packet delivery
- TCP end-to-end congestion control affects the low-level packet arrivals

connection-based

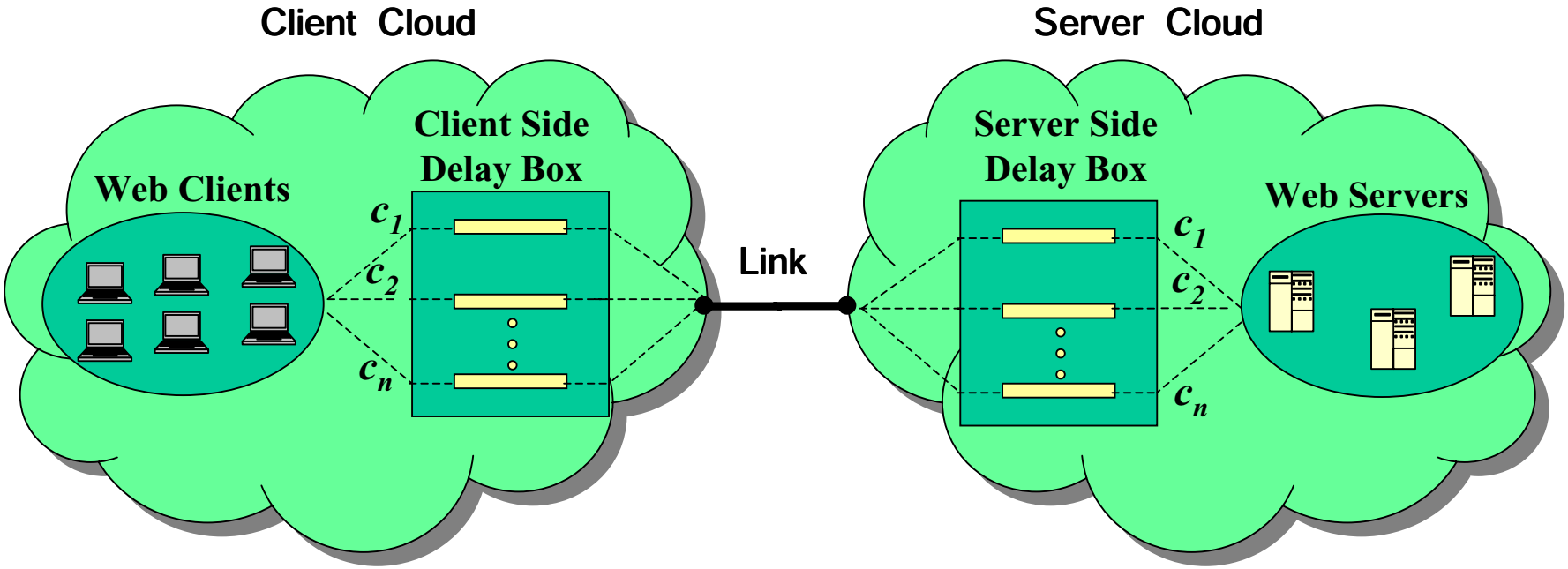
- model HTTP source variables *in aggregate* as a function of connection rate
- stochastic properties of HTTP source variables change with the connection rate
- big saving in computation time by using a single stream regardless of traffic load; much more scalable than page based models

realistic

- deriving source-level models *empirically* using measurement data
- extensive source-level and packet-level validation of synthetic traffic

Two components: network architecture and HTTP source models.

A TCP Connection-Based Architecture (Simple Case)



1 client cloud, 1 server cloud, 1 modeled link

HTTP requests for transfer

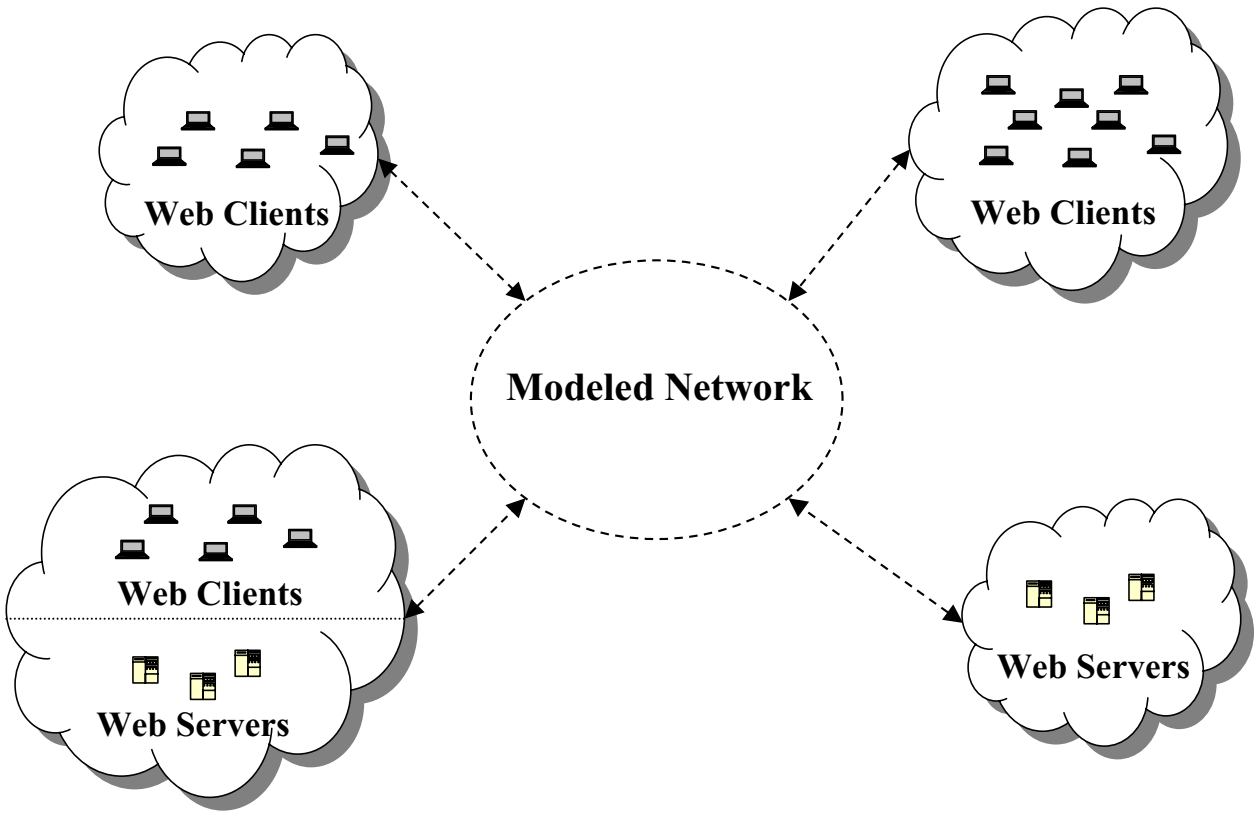
- source variables: connection arrival time, request/response sizes, etc
- stochastically generated using source models that depend on the connection rate

packet delivery handled by TCP

network effects for packet delivery

- emulated by a client/server delay box for delaying, queuing and dropping packets
- source variables: client/server side round trip time, bandwidth and loss probability
- stochastically generated using source models

The General Architecture (An Example)



architecture

- 2 client clouds, 1 server cloud, 1 cloud (bottom left) that has both a set of servers and a set of clients sharing the same ingress-egress link to the modeled network
  - number of client clouds n_c=3; number of server clouds n_s=2;
- dashed lines: ingress-egress links
- modeled network (together with the ingress-egress links) represents how the clouds interact with the other

For each $n_c n_s$ client-server pairs, the source model is used to generate the source traffic for the pair that traverses the modeled network.

HTTP Source Variables

Source Variables

connection request for transfer

- connection arrival or inter-arrival time
- number of pages requested
- number of request-response exchanges per page
- request/response size per exchange
- inter-exchange time gaps
- server delays

network effects for packet delivery

- sever/client side round trip time
- server/client side bottleneck linkspeed
- server/client side loss probability

per-request variables

- source variables that take one value per request/response exchange
- number of request-response exchanges per page, request/response sizes, server delays, inter-exchange time gaps

per-connection variables

- source variables that take one value per connection
- all other variables and some of the *first* per-request variables, i.e., 1st request/response size and 1st server delay

Modeling of HTTP Source Variables: Overview

model the sequence of HTTP source variables on the link as a single stream

- ordering defined by their connection arrival time



two databases: BELL and UNC

- architecture: clients and servers each on one side of the link, modeled link close to the clients
- BELL: access link of Bell Labs Research to Internet (500 5min-blocks, 0.18-34c/s)
- UNC: access link of UNC campus to Internet (318 5min-blocks, 2.4-230c/s)
- network-dependent aspects of source variables modeled *separately* for each database; network-independent aspects of source variables modeled using *both* databases

connection rate based models

- model stochastic property as a function of the connection rate

assumption

- different source variables are independent
- conditional on the first per-request variables of a given connection, subsequent per-request variables are independent of per-request variables from other connections

S-Net system for analysis and visualization

Summary of Source Models

per-connection models

- connection inter-arrival, 1st request/response size, server/client round trip time long-range dependent
- long range dependency modeled using Fractional Sum Difference models
- as connection rate increases
  - connection arrivals tend toward Poisson
  - other connection variables tend toward independence
  - FSD white-noise variance ratio parameter tends toward 1

per-request models

- stochastic property within a persistent connection DOES NOT change with the connection rate
- inter-exchange time gaps and server response sizes modeled using mixed effects model with random location and scales
- small change of client request sizes, server delays within a connection

PackMimeHTTP: Model Implementation in Network Simulators

PackMimeHTTP

- client/server cloud each represented by one or more nodes
- TCP-level interaction between web clients and servers modeled using the simulator
- delay-box module to emulate network-level effects: (bandwidth, delay, queue, drop)

ns implementation

- using Tcl to easily configure architecture and models
- 3-level model specification with increasing flexibility
  - level 1: connection rate, other parameters use default value
    - set connection rate to 8 c/s:

```
% $pm set-rate 8
```

  - level 2: connection rate and the mean of other source variables
    - server RTT: default 81.7 ms $\rightarrow$ 50 ms

```
% $db set-delay-mean 0.050
```

  - level 3: all parameters
- contributed to *ns2* (http://www.isi.edu/nsnam/ns/ns-contributed.html)
- detailed document in preparation

ongoing implementation in other network simulators

- *J-Sim* (UIUC): implementation finished and being validated.
- *GTNets* (Georgia Tech Network Simulator): implementation in the beginning stage.

Validation

ns simulation of the BELL link

- 18 traces: 9 connection rates, $1, 2, 4, \ldots, 256$ c/s, 2 runs/rate
- each trace: at least 1 million packets, at least 600 sec in duration
- delay-box: uniform[1,10]Mbps; uniform[0,1%] with 95% prob., 30% with 5% prob.
- network-dependent aspects of the source model specified using the BELL data

source-level model checking

packet-level validation

- packet/bit rate, number of active connections against connection rate
- packet inter-arrivals and sizes

