Assessing Active Bandwidth Estimation Tools in High Speed Networks

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TERENA Networking Conference (TNC 2004)
Rhodes, Greece. June 7, 2004
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Active Measurement Tools

- How they work:
  - End-to-end.
  - Infer path properties from the reaction of probe packets.

- Advantages:
  - Accessible to end users.
  - Lower infrastructural requirements as compared to passive measurement.

- Drawbacks:
  - Depend on a good packet traffic dynamics model.
  - Sensitive to measurement errors.
Active Bandwidth Estimation Tools

- **Beginnings:**
  - ~1997: pathchar
  - ~1998: clink
  - ~1999: pchar

- **Proliferation of active bandwidth estimation tools while research is conducted, metrics are defined, and estimation techniques are developed. Terminology and models differ.**

- **Bandwidth Metrics:**
  - Capacity
  - Available Bandwidth
  - Bulk Transfer Capacity (BTC)
Active Measurement Initiatives and Infrastructures:

- SLAC (Stanford Linear Accelerator Center): Internet End-to-end Performance Monitoring - Bandwidth to the World.
- CAIDA (Cooperative Association for Internet Data Analysis).
- Internet2: End-to-end Performance Initiative and Abilene Measurement Measurement Infrastructure.
- TERENA: User Level Network Performance Monitoring Program.

Mostly other performance metrics: connectivity, one-way delay, round-trip time, jitter, packet loss.
State of the Art and Applications

Plenty of techniques and tools, many of them variations of others.

Expected for the near future:

- Network operation.
- End users/applications can perform load balancing and server selection tasks.
- Overlay networks adaptation.
- Supporting service for QoS, congestion control, grid, etc.
- SLA (Service Level Agreement) checks.
- Lead to advances in research on Internet traffic dynamics.
Motivation and Design Overview

**Motivation**
- Bandwidth estimation: complex and under development.
- Can current tools be used as reliable basis for providing a bandwidth estimation service? How much bandwidth can be accurately estimated?
- Towards a systematic approach to performance evaluation and unification of interfaces.

**Design Overview**
- Comparative (suit different tools and techniques), including:
  - Practices and procedures for evaluation of tools.
  - Helper tools and integration software.
- Simultaneous analysis of tools for capacity, available bandwidth and BTC.
- Consider a wide subset of active bandwidth estimation tools, network paths and experimental conditions.
- Set of comparison criteria.
- Evaluation (numeric, statistical, fuzzy logic/neural networks).
## Tools and Scenarios Under Evaluation

<table>
<thead>
<tr>
<th>Capacity</th>
</tr>
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<tbody>
<tr>
<td>BPROBE, clink, Nettimer, pathrate, pchar, pipechar, SPProbe</td>
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<tr>
<th>Available Bandwidth</th>
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<tbody>
<tr>
<td>CPROBE, IGI/PTR, NetDyn, netest, pathChirp, pathload, Spruce.</td>
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<tr>
<th>BTC</th>
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<tr>
<td>Iperf, netperf, Treno, nttcp.</td>
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- Scenarios: Hosts at the Spanish NREN, RedIRIS, with connections to GÉANT and private ISPs. Also LAN within research institutions, and cable modem, ADSL endpoints, as well as emulated scenarios with NIST Net and dummynet.
Comparison Criteria

- Basic set of properties (for classification purposes: name, technique, time, etc).
- Consistency (as an indicator of robustness).
- Accuracy.
- Intrusiveness.
- Required estimation time.
- Interdependence of parameters above.
- Dependence of parameters above on
  - Path properties (hops, round-trip time).
  - End host capacity and load.
Component based framework.

Automation, classification, post-processing, visualization, etc.

Low level framework (does not consider authentication and security, administration task, scalability, etc).

Ruby Language + Helper tools: sing, nslookup, etc.

Record experiment context (scenario description, time, routes, system properties and load, pings).

Analysis: GNU Octave/Matlab.

Next version soon available (GPLed) from http://www.imse.cnm.es/~fedemp/abet/
User Interfaces, Design and APIs

- Unify user interfaces.
- Common Design Components.
- Consider development of APIs. Estimation libraries.
- Standard output formats.
  - XML DTDs/schemas (Global Grid Forum Network Measurements Working Group (NMWG)).
  - NetLogger ULM format.
  - Bandwidth estimation as a web service.
- Code reuse.
Overall Limitations

- Impact of system performance and load.
- Near real-time requirements in some cases.
- Modelling errors and limitations (interrupt coalescence, layer-2 devices, aggregated traffic models).
- Infrastructures (ICMP rate limits, firewalls, NAT, etc).
- Traffic shapers. Class of Service Based Queueing.
Some Observations

- General conclusions are hard (and daring) to draw from so many differing implementations.
- Can achieve high consistency and accuracy
  - Up to 100 Mbps links: (errors $\sim 5\%$).
  - Up to 1 Gbps links: can achieve same accuracy but needs better hardware and low system load.
- Consistency decreases linearly (for the best case) as bandwidth increases. Real-time requirement.
- SProbe can provide the fastest capacity estimates.
- Available bandwidth tools may show low consistency.
- BTC tools impose high overhead.
- Performance of VPS (Variable Packet Size) based tools decreases as path length increases.
Conclusions and Future Steps

▶ Conclusions
  ▶ Framework for comparative analysis of techniques and tools.
  ▶ Need for common user interfaces, output formats, APIs and design components. Before widespread use!
  ▶ Network capacities improving faster than estimation tools.
  ▶ Known limitations as future research topics.

▶ Future Steps
  ▶ Clean up and release the evaluation software.
  ▶ Finish the test classification, storage system and database interface.
  ▶ Benchmarks for active bandwidth estimation?
Questions