On Inferring TCP Behavior

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TBIT: TCP Behavior Inference Tool

An *active* tool to infer TCP behavior of Internet hosts.

In this talk:

- Motivation
- How it works and what makes it different
- Selected results from a survey of TCP behavior of web servers

Motivation

- TCP handles a majority of today’s Internet traffic
- Understanding TCP behavior is important:
  - OS vendors and customers: better/correct implementations
  - Networking research: measurement, modeling
  - Standards organizations
- TCP behaviors of web servers is of special interest

Understanding TCP behavior

- TCP is a complex protocol. Many variants.
- Standards document specify many options.
- Need to understand TCP behavior on two fronts:
  - Mathematical modeling
  - **Understanding real implementations**

Example

- Initial window used by TCP: amount of data sent out in a “burst” before any ACKs are received.
- RFC 2414: min (4*MSS, max (2*MSS, 4380 bytes))
- We have found TCPs that send 8000+ bytes with MSS of 512!
- Large bursts of packets ⇒ buffering problems, loss, delays.

How to test implementations?

- Passive monitoring [Paxson 97]
  - Right conditions must occur during test period
- Controlled laboratory tests [Gao and Madhavi 2000]
  - Can not uncover information about popular configurations etc.
- Active testing [TBIT]

Salient features of TBIT

- Ability to test any web server at will
  - No special privileges needed on servers
  - Robust to prevailing networking conditions
  - Traffic generated should not appear hostile
- Modular, extensible architecture

How it works: The basic idea

- Send “fabricated” TCP packets over raw IP sockets.
- Host firewall prevents kernel from seeing response packets.
- BPF delivers blocked packets to user process.
- Net effect: a user-level, user-controllable TCP, without kernel changes.

Based on “Sting” project at Univ. of Washington by Stefan Savage

How it works: An example

Determine TCP initial window used by a web server.

- Send SYN. Wait to receive SYN-ACK.
- Send HTTP 1.0 GET request for “/”
- Do not ACK any incoming packets.
- Wait until first retransmission.
- Initial window $=$ Max. sequence number received.

How it works: Difficulties

- Too few packets: set smaller MSS?
- Lost packets: repeat test multiple times.
- Multiple hosts answering same IP address: non-repeatable results?
- No easy way to test without a web server.

Tests implemented so far

- **Handshake tests:** Timestamp used? SACK-capable?
- **Congestion response:** Reduce congestion window? NewReno/Reno/Tahoe?
- **SACK:** Construct SACKs correctly? Respond to SACKs correctly?
- **Other:** Initial window? ECN-capable?

Experimental setup: 1

- Several lists of web sites:
  - 100hot.com
  - ISP proxy trace (Dax Kelson)
  - List from [Arlitt and Krishnamurthy 2001]
- Total 4550 unique IP addresses
- Each host returns at least 3000 bytes when base page is requested.

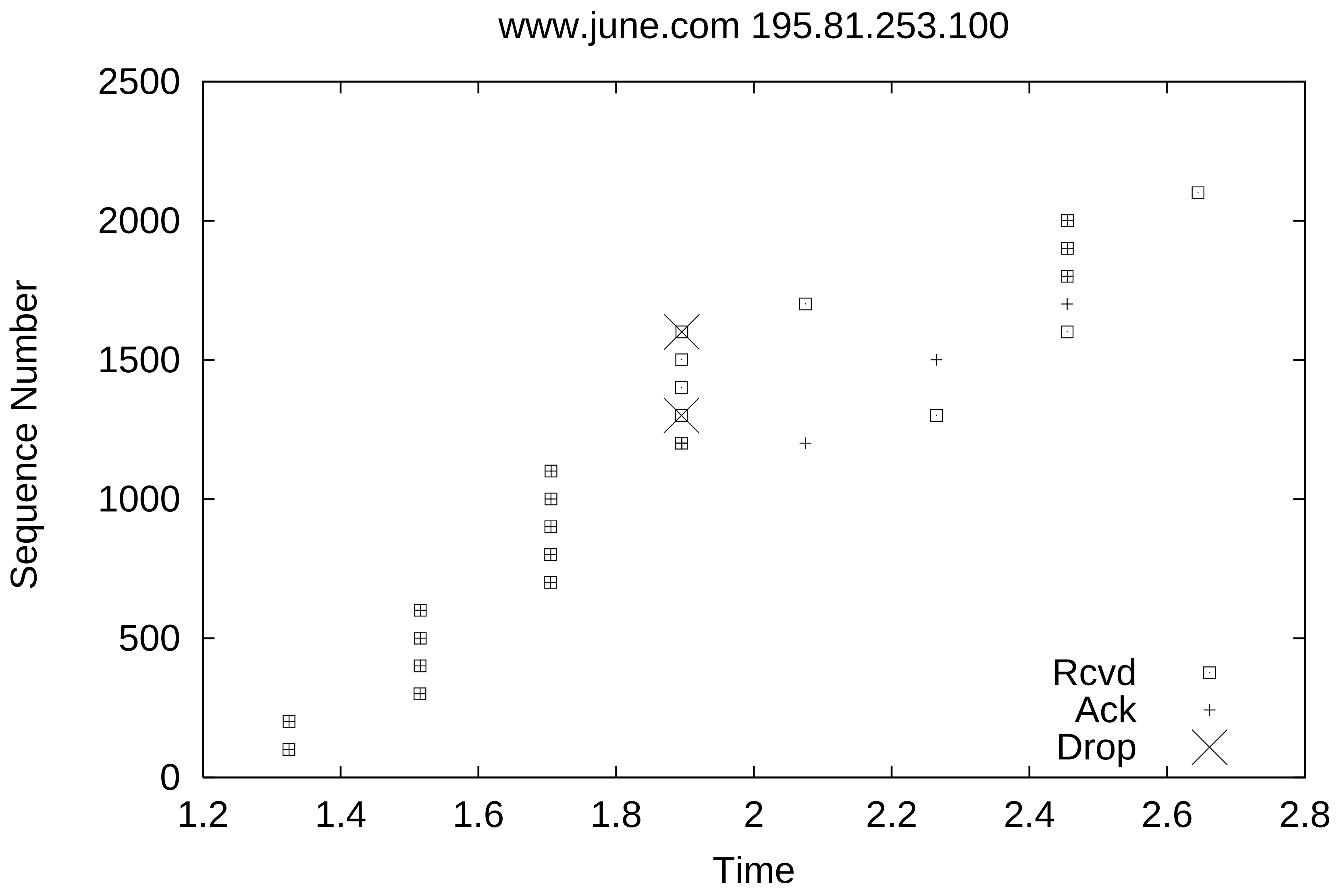
Experimental setup: 2

- NMAP ran against each host to provide OS guess
- Each tests repeated at least five times.
- Results reported only if at least three tests complete, and all completed tests return consistent results.

TCP flavor

- Based on tests in [FF96]
- Results based on 3728 hosts. (out of 4550).
- NewReno most popular
- Surprise: 1010 show no fast retransmit: timeout for any packet loss in a window
- Windows bug (for small transfers?). Microsoft acknowledges, but not fixed.

NewReno


www.june.com 195.81.253.100
Sequence Number
Time
0
500
1000
1500
2000
2500
1.2
1.4
1.6
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2
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2.4
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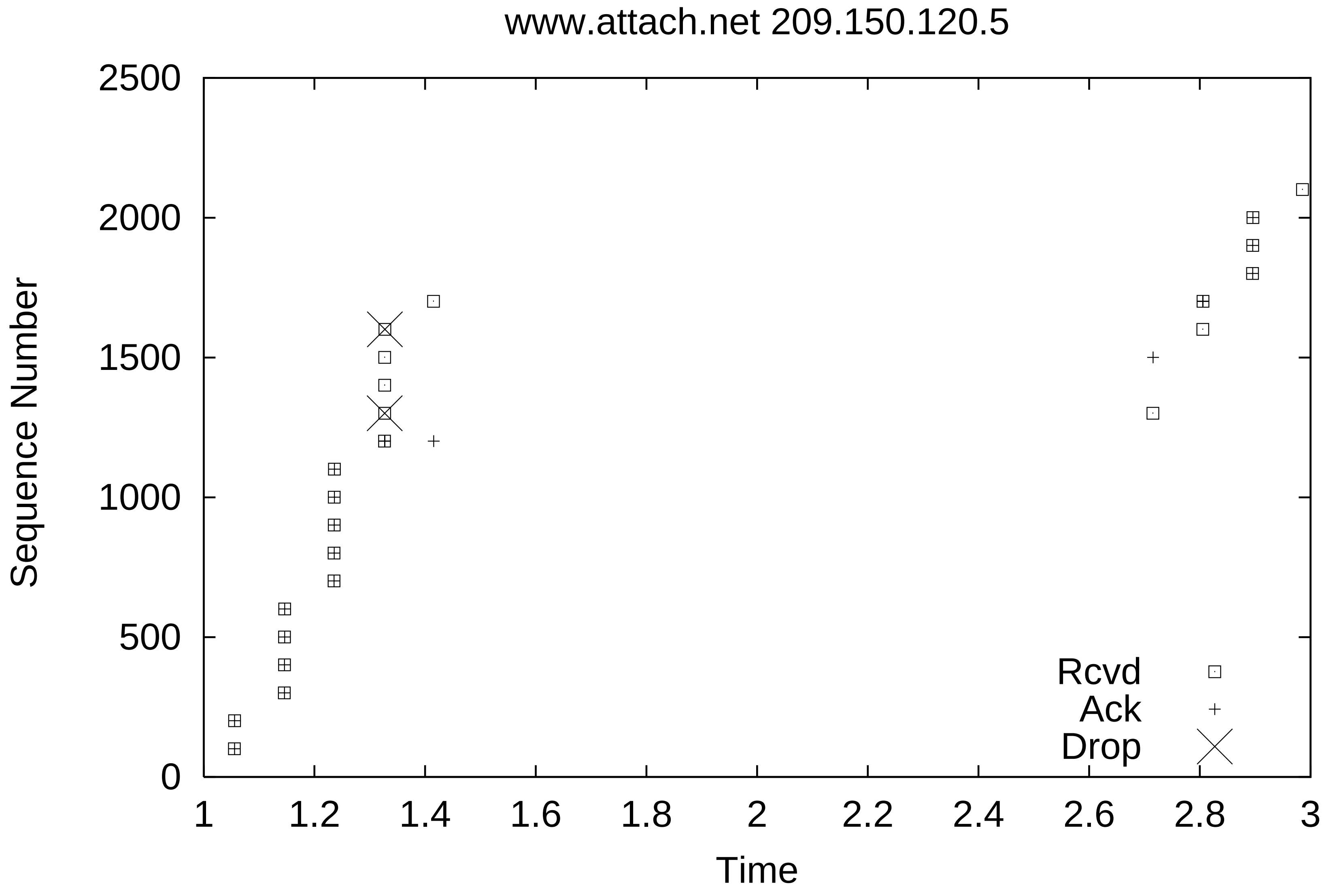
2.8
Rcvd □
Ack +
Drop ╳

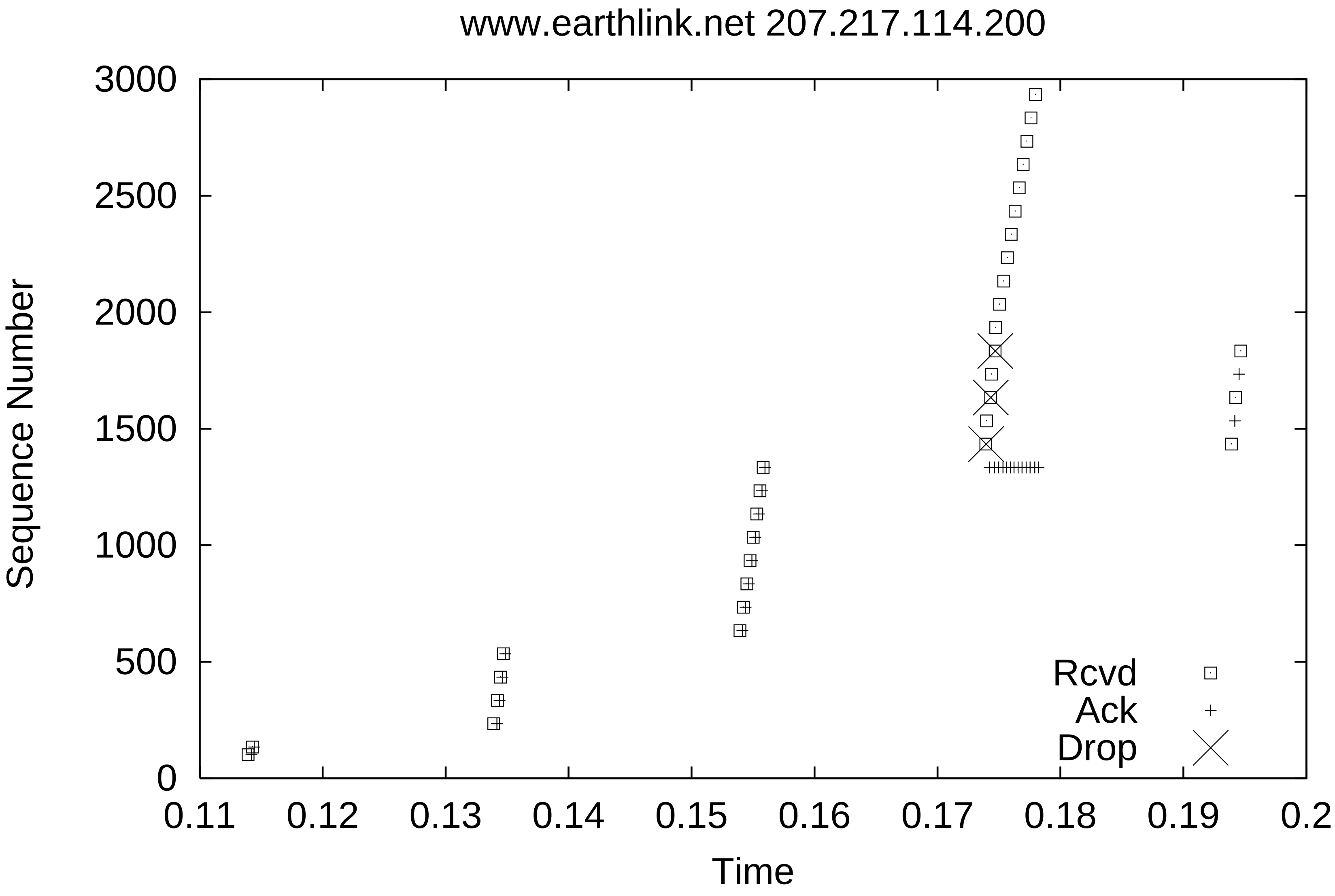
No Fast Retransmit



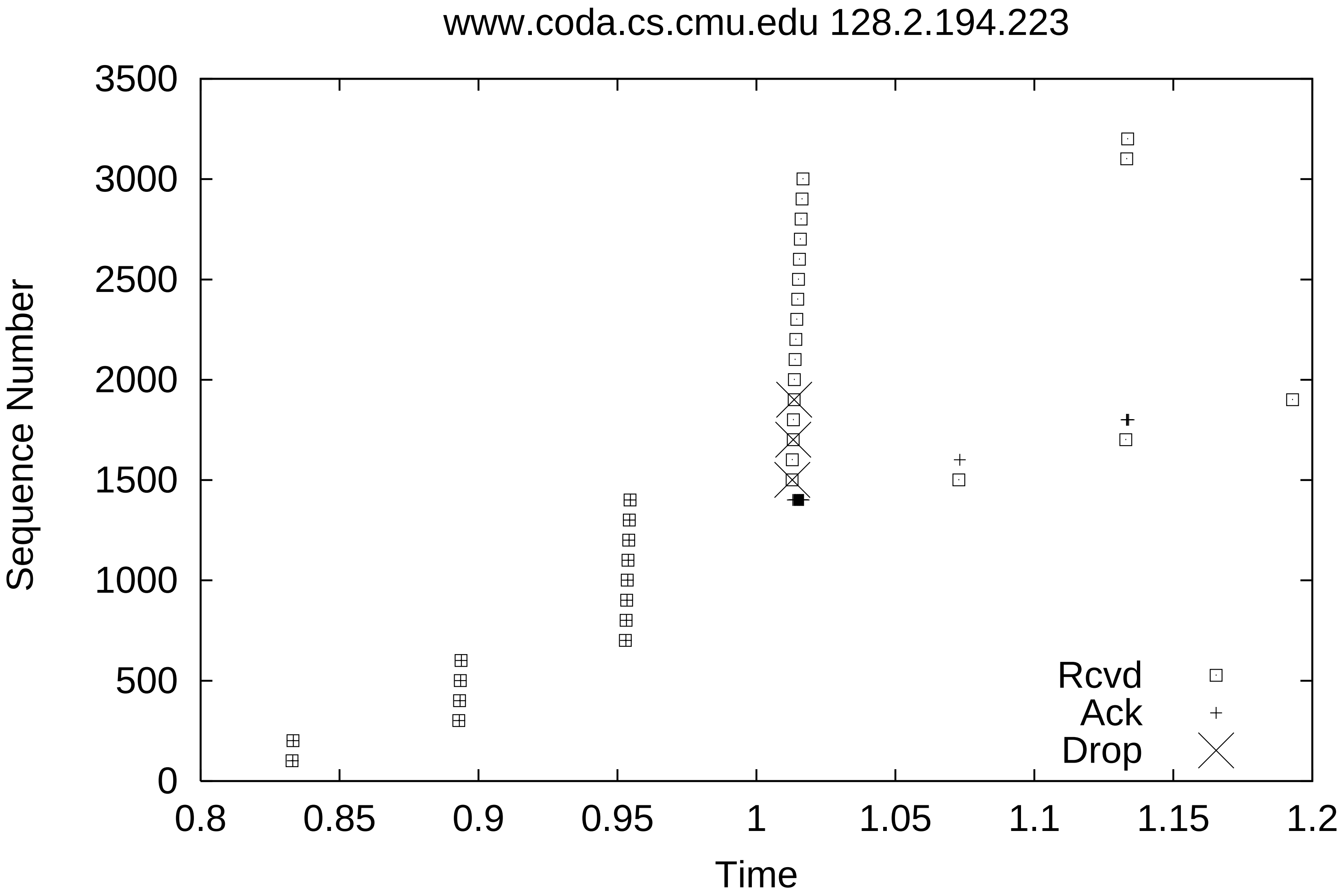
SACK usage

- 1759 of 4550 hosts negotiate SACK during SYN exchange. But do they use it correctly?
- Drop three packets from a large window
- Correct SACK usage: Packets retransmitted in a single RTT
- Results based on 1309 hosts
- 759 of these do not appear to use SACK information.

Correct SACK usage



SACK info not used



Result highlights: 1

Quantitative data regarding:

- Deployment of TCP variants: Tahoe, Reno, NewReno etc.
- SACK deployment in severs, SACK correctness
- Initial Window sizes
- MSL durations
- Delayed Acknowledgment

Result highlights: 2

Bug detection and fixes:

- IBM: Timestamp option processing.
- Microsoft: Fast Retransmit code.
- Sun: Response to single packet drop in Solaris 2.5
- Cisco: ECN option processing. (joint with Dax Kelson)

Future work

- Make tests more robust.
- Additional tests: Slow start, RTO . . ..
- A ”server” version of TBIT
- Automatic generation of NS models.
- Extend this approach to investigate other behaviors of the Internet infrastructure

Finally ....

- Source code and detailed results:

  http://www.aciri.org/tbit/

- We encourage people to use the software and add their own tests.