Measurements of IPv6 Path MTU Discovery Behaviour

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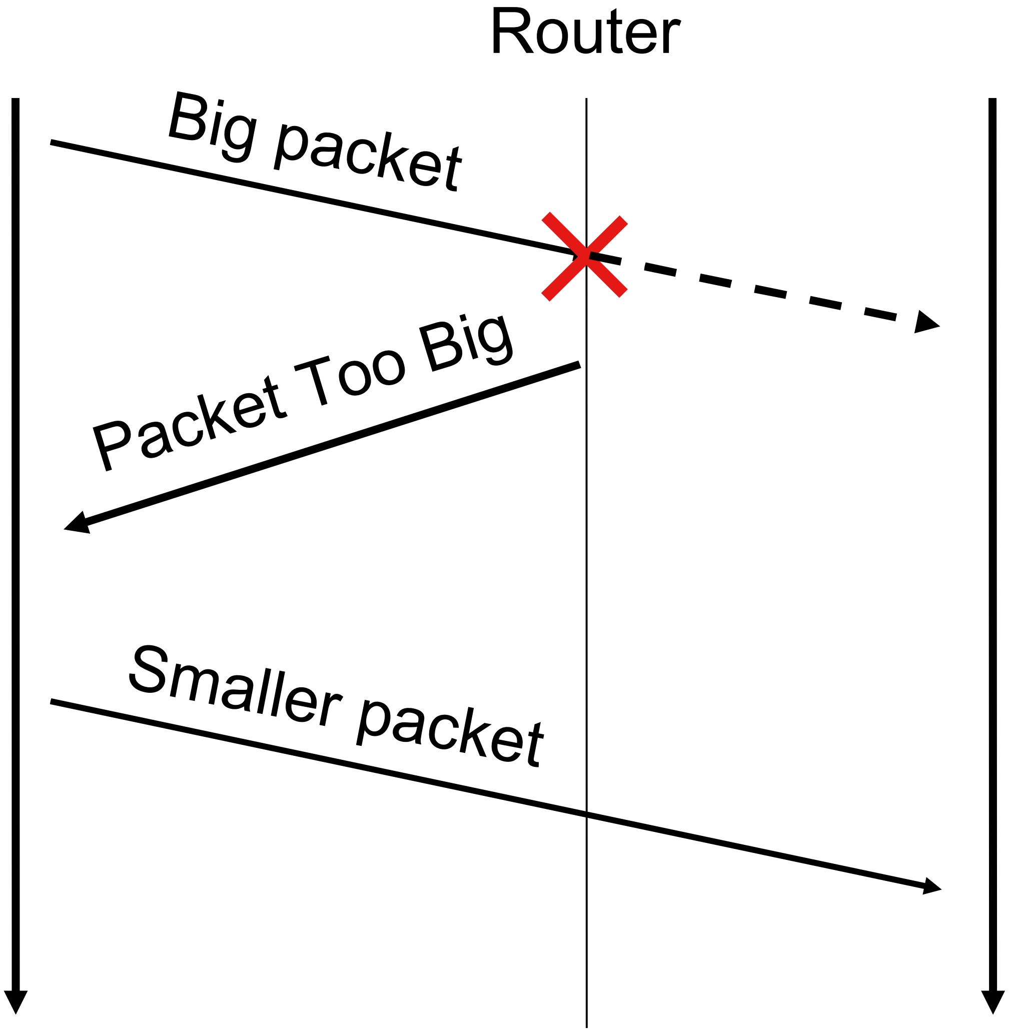
Introduction

- Internet communications are most efficient when the largest possible packet size is used.
- Path MTU Discovery (PMTUD) used to find the largest packet size an Internet path can accommodate.
- Common perception that PMTUD is unreliable in IPv6.
- Implemented a PMTUD test and used it to survey a number of dual-stacked servers on the Internet.

PMTUD Recap



Fragmentation

IPv4

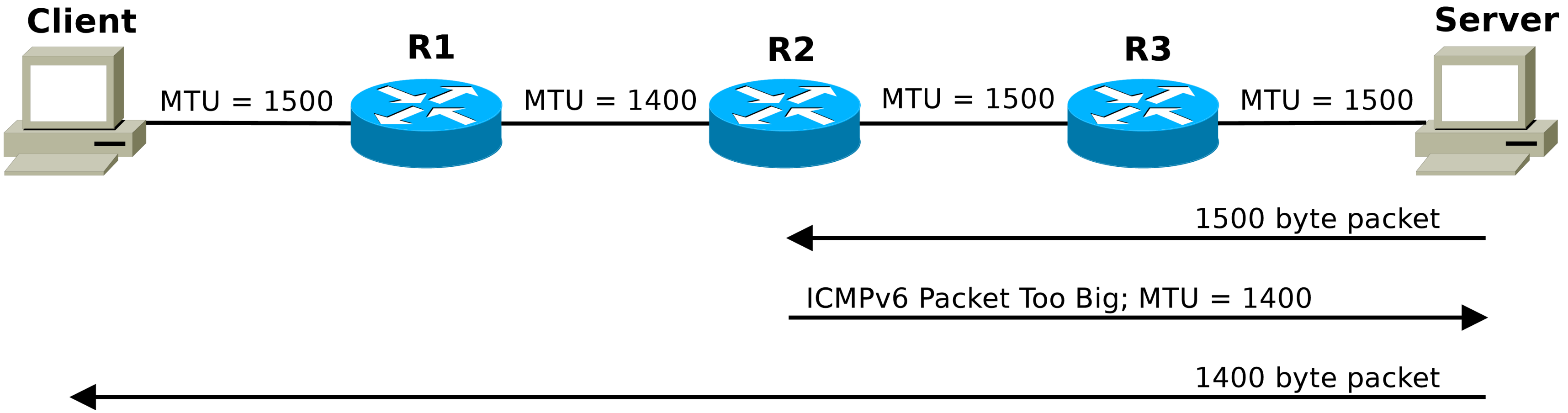
- Intermediate routers **can** fragment packets.
- A packet whose size exceeds the next-hop MTU will be fragmented unless the IP-DF bit is set.
- Fragmentation has an adverse effect on performance.
- About 97% of web servers set the DF bit.

IPv6

- Intermediate routers **cannot** fragment IPv6 packets. Only the sending node can.
- A packet whose size exceeds the next-hop MTU will be discarded and cause an ICMPv6 PTB to be sent.

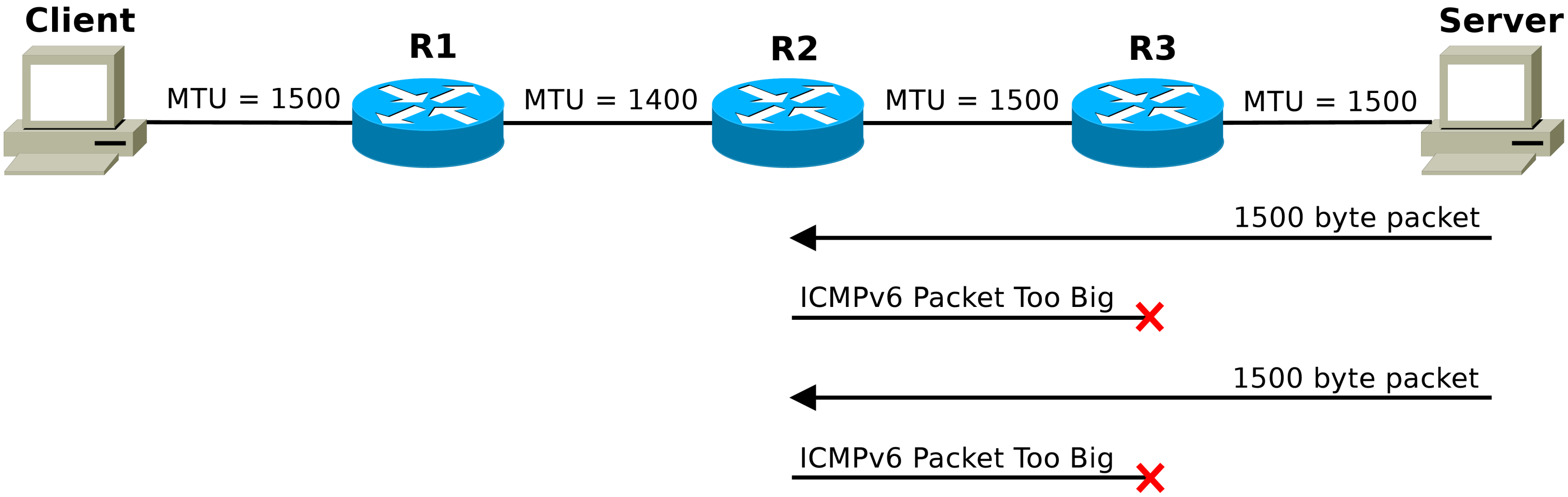
PMTUD in IPv6

- The success of PMTUD is particularly important in IPv6!
- Tunneled IPv6 connectivity is currently common.
  - These tunnels have smaller MTUs
  - Packets are more likely to be too big (and discarded)
  - Therefore PMTUD is needed more often in IPv6



Problems

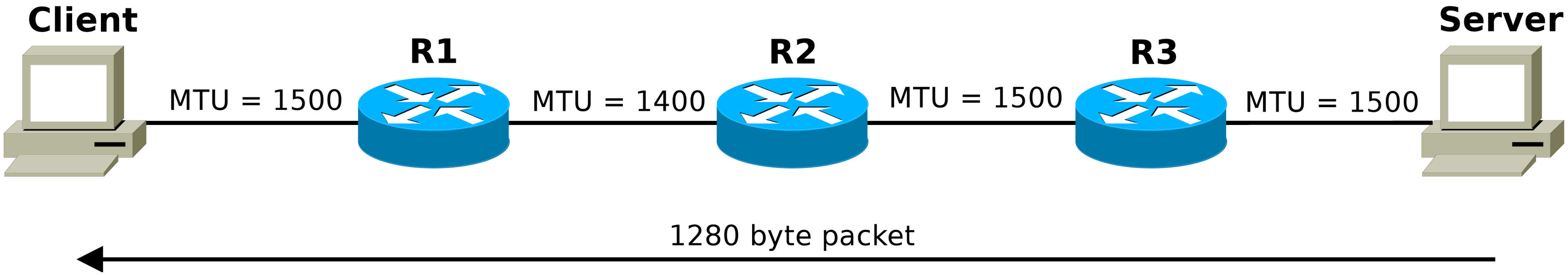
- Firewalls filtering PTB messages.
- IPv6 Tunnels not sending PTB messages
- Creates PMTUD black holes
- Bewildering to the end user
  - Connection successfully establishes but then hangs.



IPv6 PMTUD Workarounds

1. Clamp MTU on IPv6 interfaces to 1280 bytes.
2. Rewrite the MSS in SYN packets to 1220 bytes.
   - Only affects TCP

- Not ideal: reduced communication efficiency.
- Preferable to fix the ICMP filtering problem.
  - If we hope to use larger MTUs one day.



PMTUD Test

- Test implemented in Scamper.
  - http://www.wand.net.nz/scamper/
- Tests an Internet host's ability to do PMTUD.
  - Supports PMTUD testing in IPv4 and IPv6.
  - Can test HTTP, SMTP and DNS servers.
  - Easy to add support for other application protocols.
- Runs on systems that use the IPFW firewall.
  - Mac OS X and FreeBSD

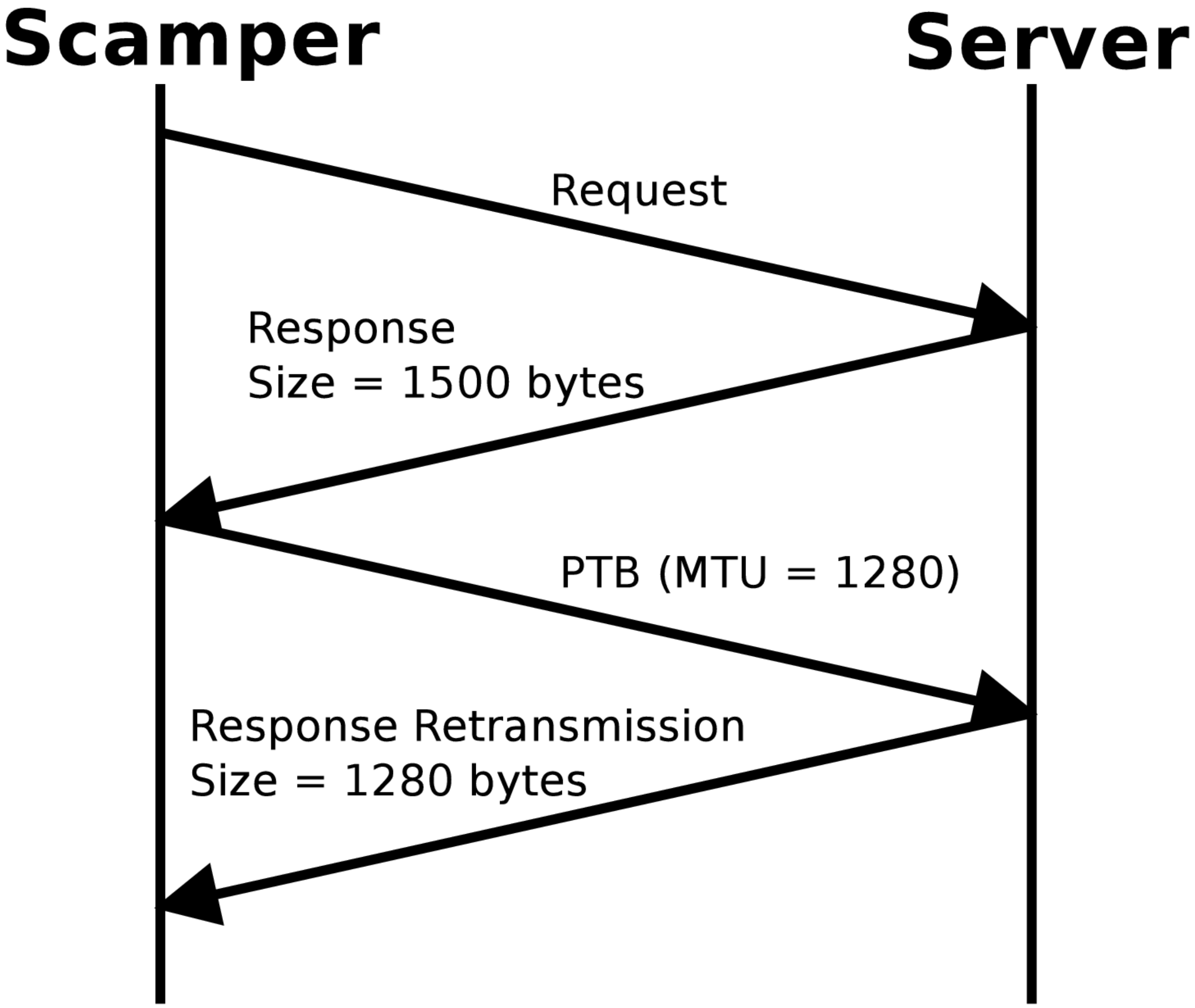
PMTUD Test - Operation

- Establish a TCP connection to the target server.
  - TCP Maximum Segment Size (MSS) = 1440 bytes
- Send a request packet
  - Specially crafted in an attempt to elicit a large response.
- Algorithm used for determining PMTUD success/failure depends on the response packet size:
  - Larger than 1280 bytes - Reduce Packet Size (RPS)
  - Less than or equal to 1280 bytes – Frag Header
- Post-test analysis used to detect additional successes and failures (not part of Scamper).

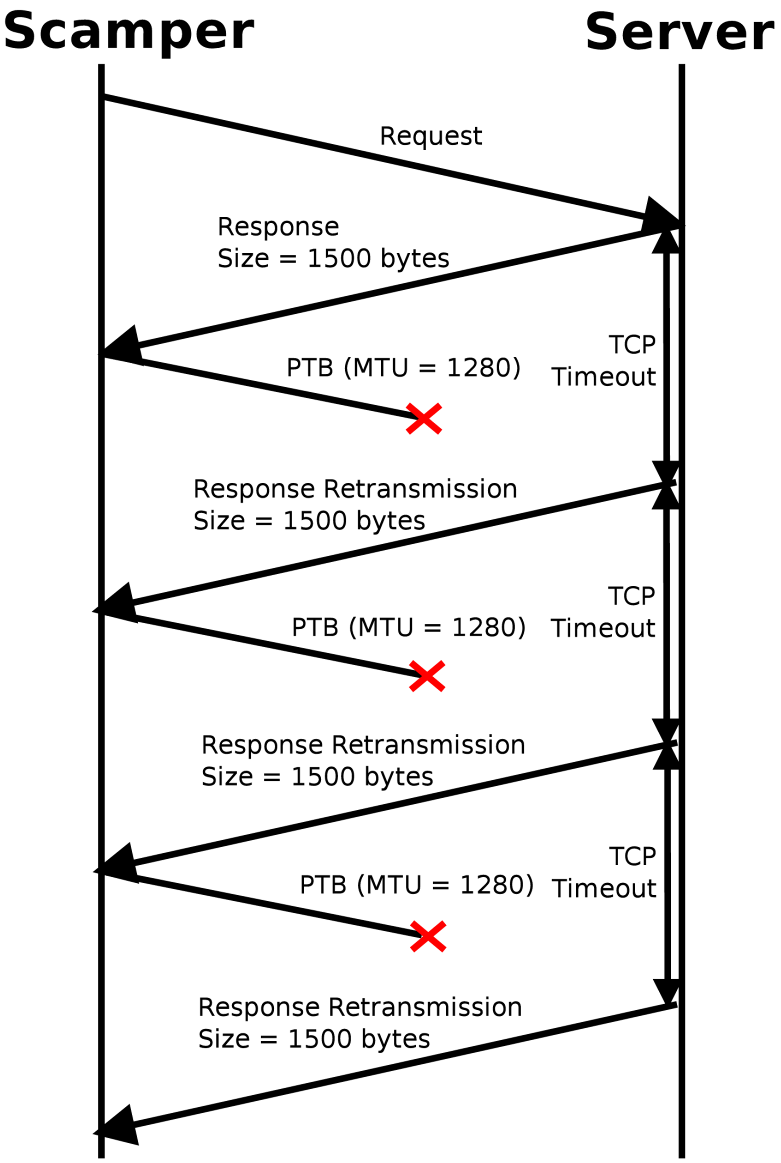
Reduce Packet Size (RPS) Algorithm

- Does the server use smaller response packets after it is sent a PTB message asking it to do so?
  - Yes – PMTUD Success
  - No – PMTUD Failure (likely due to ICMP filtering)
- Requires large response packets from the server:
  - IPv6 – Larger than 1280 (IPv6 Minimum PMTU) bytes
- Idea taken from:
  - Measuring the evolution of transport protocols in the Internet
    Alberto Medina, Mark Allman, Sally Floyd
    ACM/SIGCOMM Computer Communication Review 35 (2)
    2005

Reduce Packet Size - Inferring Success



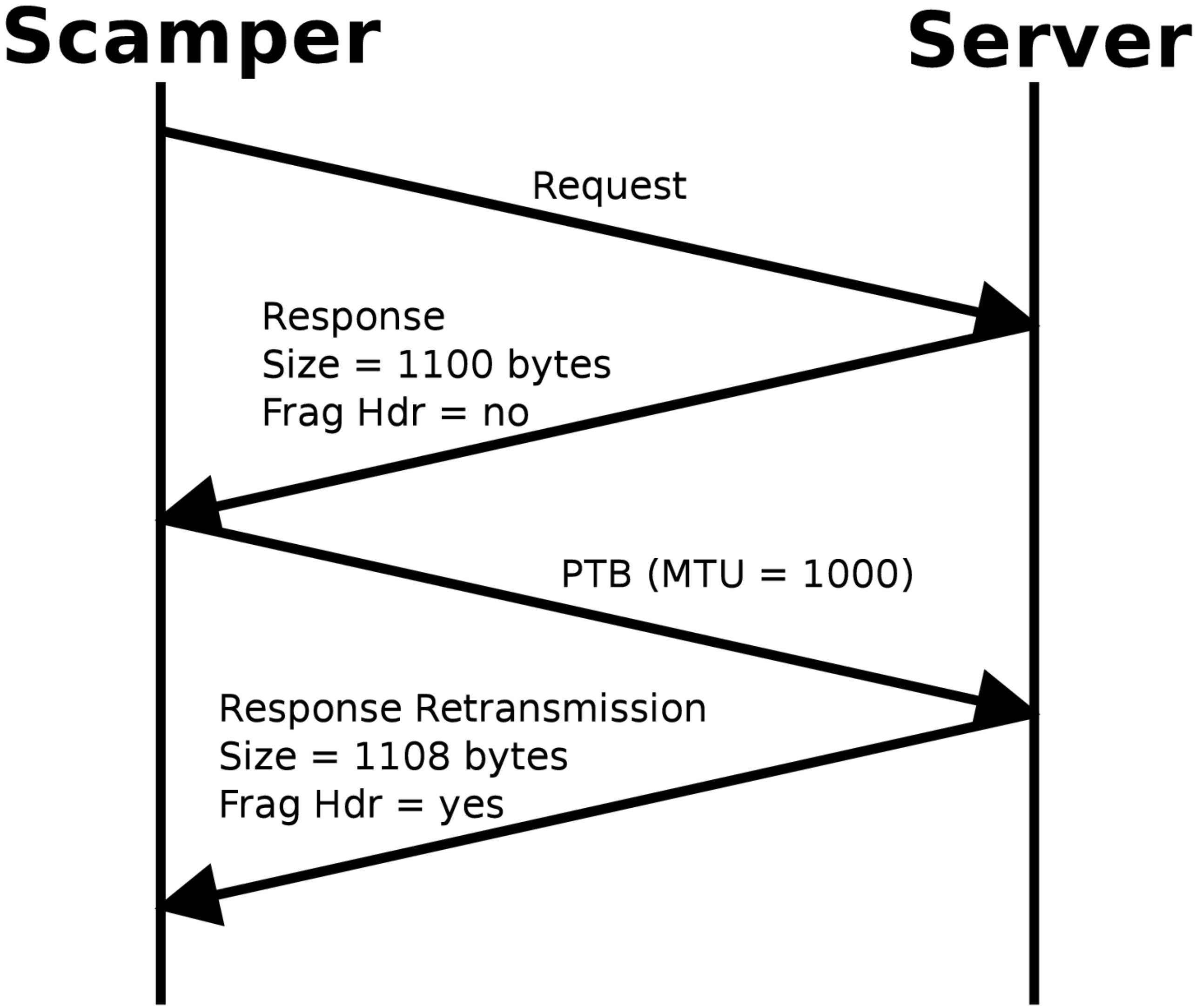
Reduce Packet Size – Inferring Failure



Frag Header Algorithm (IPv6 Only)

- Does the server include a fragmentation header in its response packets after it is sent a PTB specifying an MTU < 1280 bytes? (See RFC 2460 Section 5)
  - Yes – PMTUD Success
  - No – Too Small
- Can only be used to infer PTMUD success.
  - Testing to 688 IPv6-enabled web servers found that less that half of them exhibited this behaviour.
  - Using it to infer failure would result in many false positives
- Does not require large response packets.

Frag Header – Inferring Success



Post-test Analysis – Inferring Success

- Through successful PMTUD a server can learn of a smaller MTU in the path between it and Scamper.
- Scamper was not involved and is unaware of this
  - It only sees the end result – a smaller response packet.
- The following criteria is used to infer when a server learns of a 1280 byte tunnel (PMTUD Success):
  - Server MSS > 1220
  - Received a 1280 byte response packet from the server.
  - Another data packet followed it.

Post-test Analysis – Inferring Failure

- PMTUD Failure can mean that Scamper does not receive a server's response packet.
  - These are real-world failures that cause connections to hang.
  - Test result = No Data.
- Repeat test but with smaller MSS of 1220 bytes
  - All server response packets can make it to Scamper without being discarded for being too big (IPv6 Min PMTU = 1280)
- If this time the response packet is received:
  - No Data → PMTUD Failure

HTTP - Eliciting Large Packets

- Prior to testing a web server a script finds a URL to a large object that it serves.
- An HTTP GET request for the object should result in a large response packet from the web server.
- This is done separately for IPv4 and IPv6.

SMTP - Eliciting Large Packets

Different MTAs require different methods:

- Sendmail
  - Send the commands **“HELP EHLO\r\nHELP\r\n”.**
- Exim
  - Specify a really long domain name in the EHLO.
- Postfix
  - Send multiple EHLOs in the same packet.
- All three techniques were implemented but in the end we only tested Sendmail. The techniques for Exim and Postfix might be considered a breach of mail server etiquette. Would like to hear your opinions on this.

DNS - Eliciting Large Packets

- Long TXT record configured for tbit.staz.net.nz
- A recursive query for this should result in a large packet.
- Can therefore use this to test recursive name servers.

```
tbit.staz.net.nz.          86400      IN          TXT         "TBIT-TBIT-TBIT-TBIT-TBIT-TBIT-
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```

Batch Test - Address Collection

- To qualify for testing a server must be:
  - Dual-stacked
  - Have global unicast IPv4 and IPv6 addresses.
  - Be reachable on both of these addresses.
- Started with the Alexa Top 1 Million Websites List.
  - 987,891 unique domains
- Web Servers – www.$domain
- Mail Servers – Query each domain for a MX record.
- DNS Servers – Query each domain for a NS record.

Batch Test - Vantage Points

Vantage Point	Location	IPv6 Connectivity
NZ1	New Zealand	Tunneled (6to4)
NZ2	New Zealand	Native
US1	United States	Native
NL1	Netherlands	Native
IE1	Ireland	Native

Vantage point has a significant effect on the results

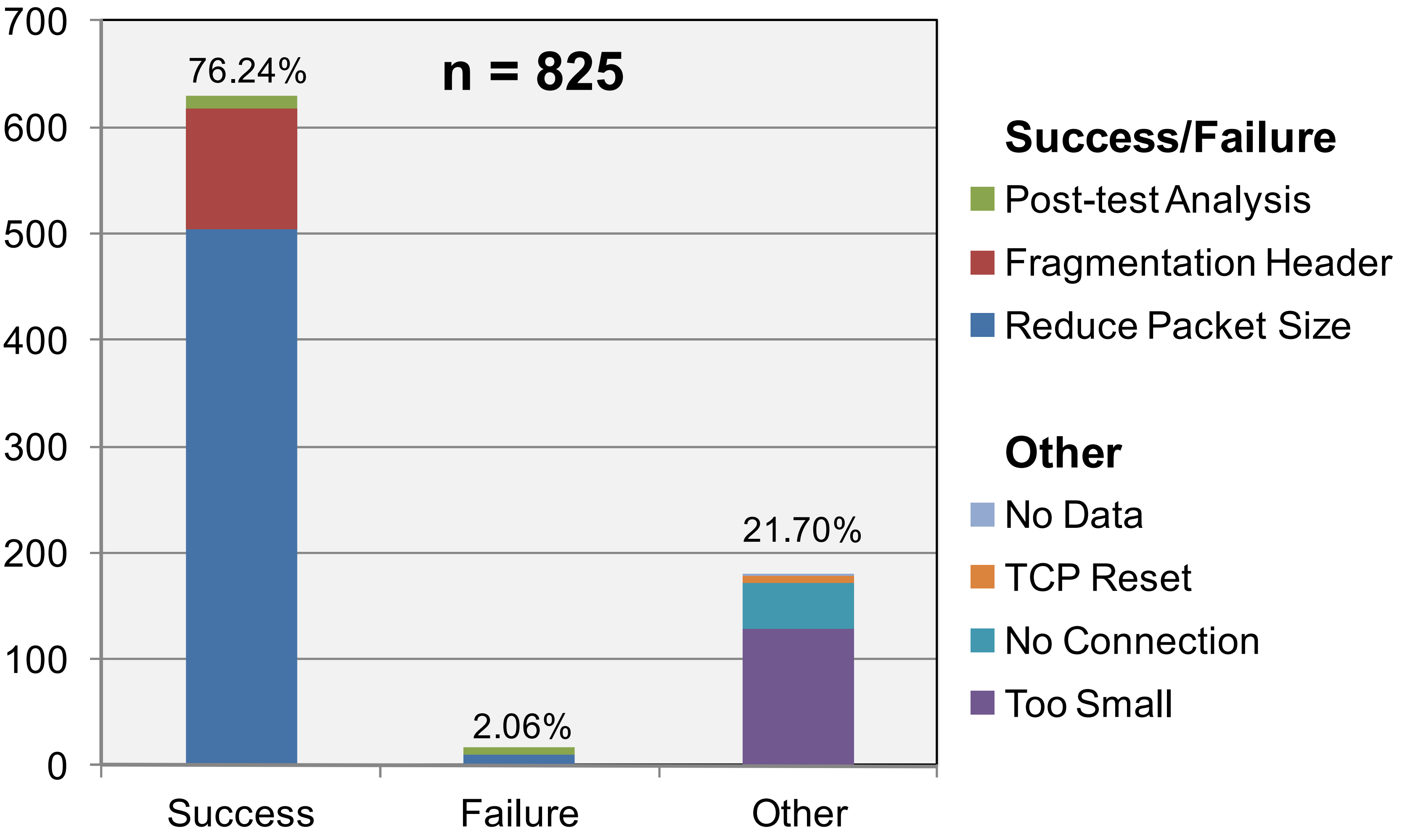
- NZ1 is behind a transparent web proxy.
  - All HTTP PMTUD tests went to the same host.
- IE1 has a 1280 byte tunnel configured on the next hop.
  - Server response packets limited to 1280 bytes

Batch Test

- Test Population
  - 825 dual-stacked web servers.
  - 643 dual-stacked mail servers.
  - 1504 dual-stacked name servers.

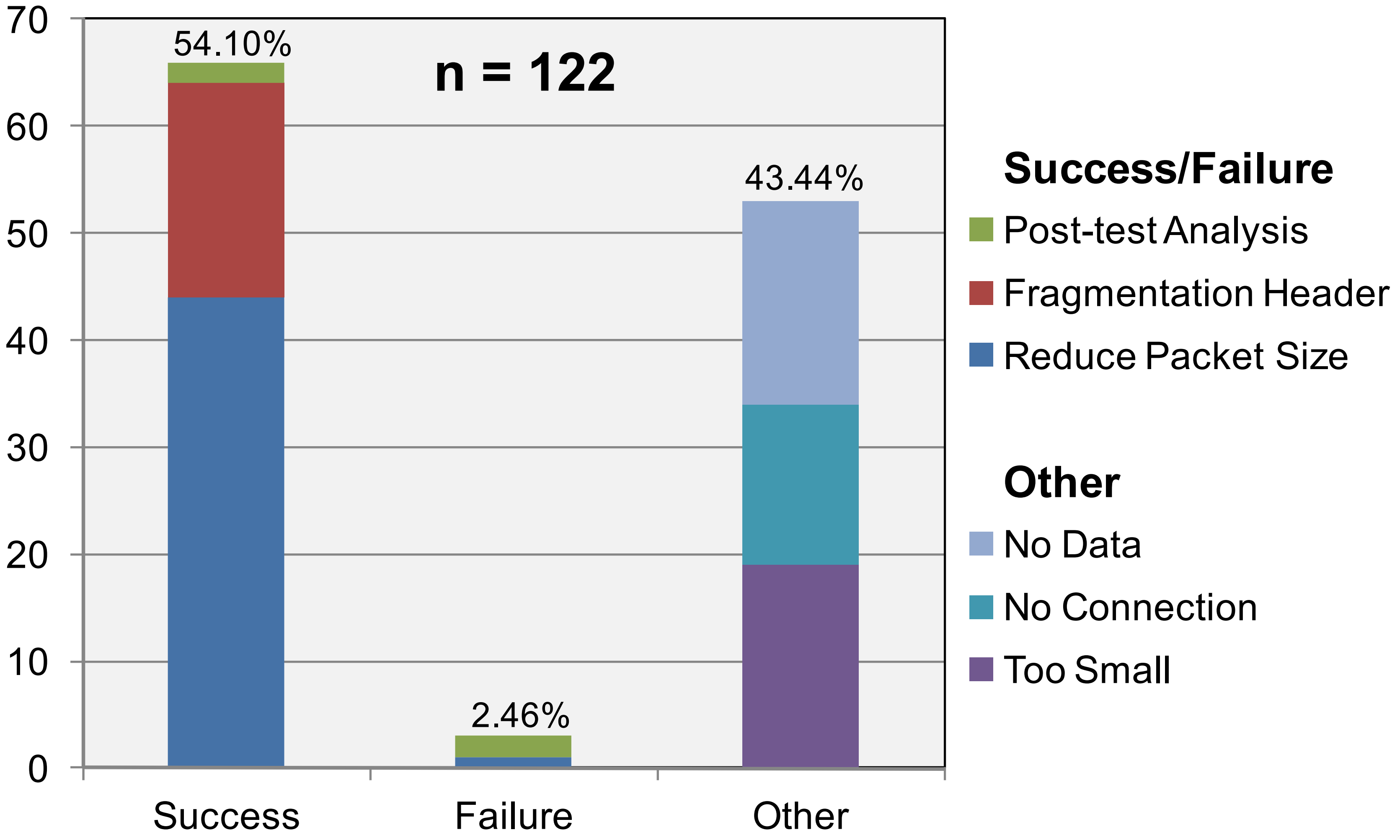
- Data collected for each test
  - Result of the PMTUD test
  - Server MSS
  - All packets sent and received during the test

PMTUD Test Results – HTTP IPv6



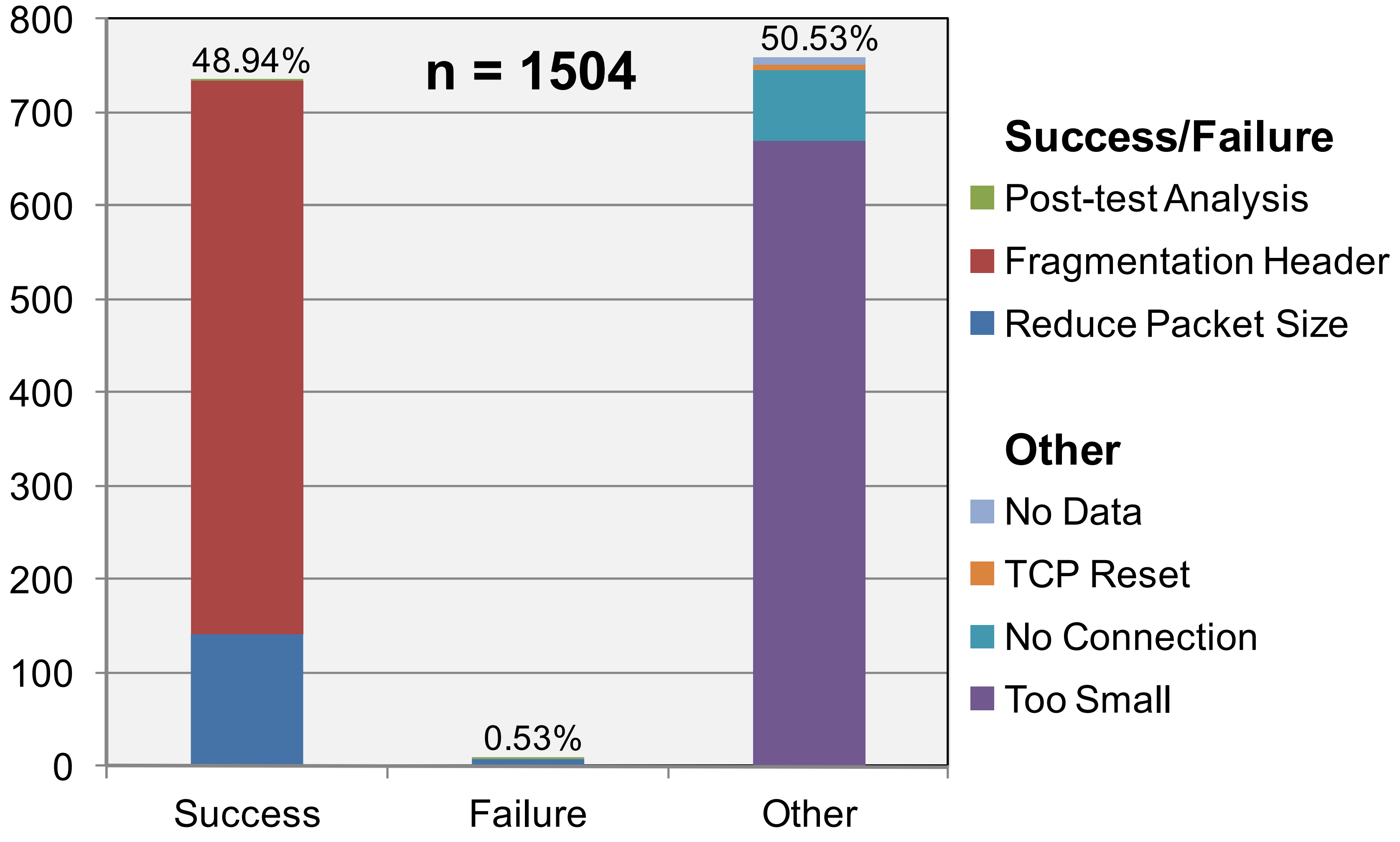
Failure Rate : 2.6%

PMTUD Test Results – SMTP IPv6



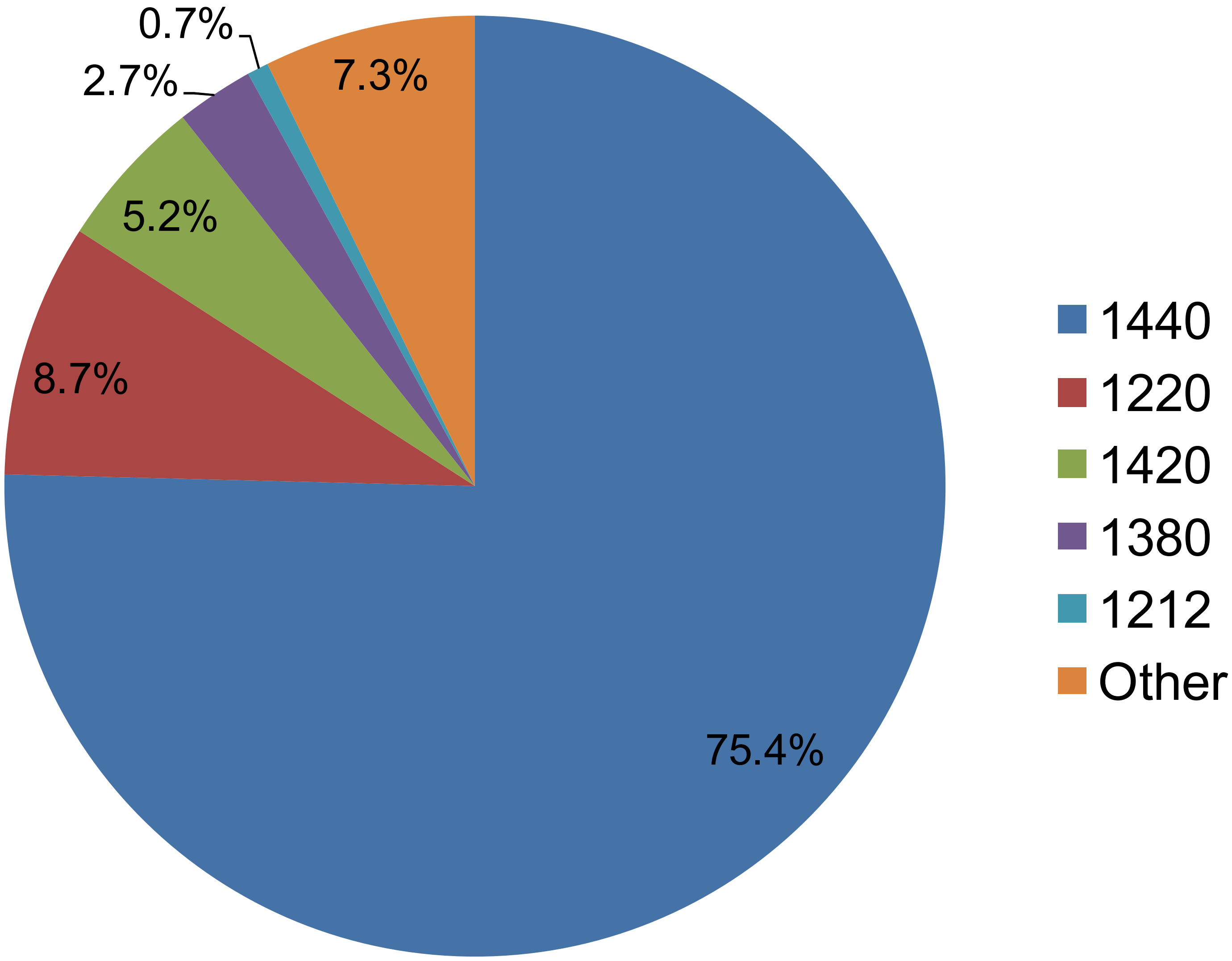
Failure Rate : 4.4%

PMTUD Test Results – DNS IPv6

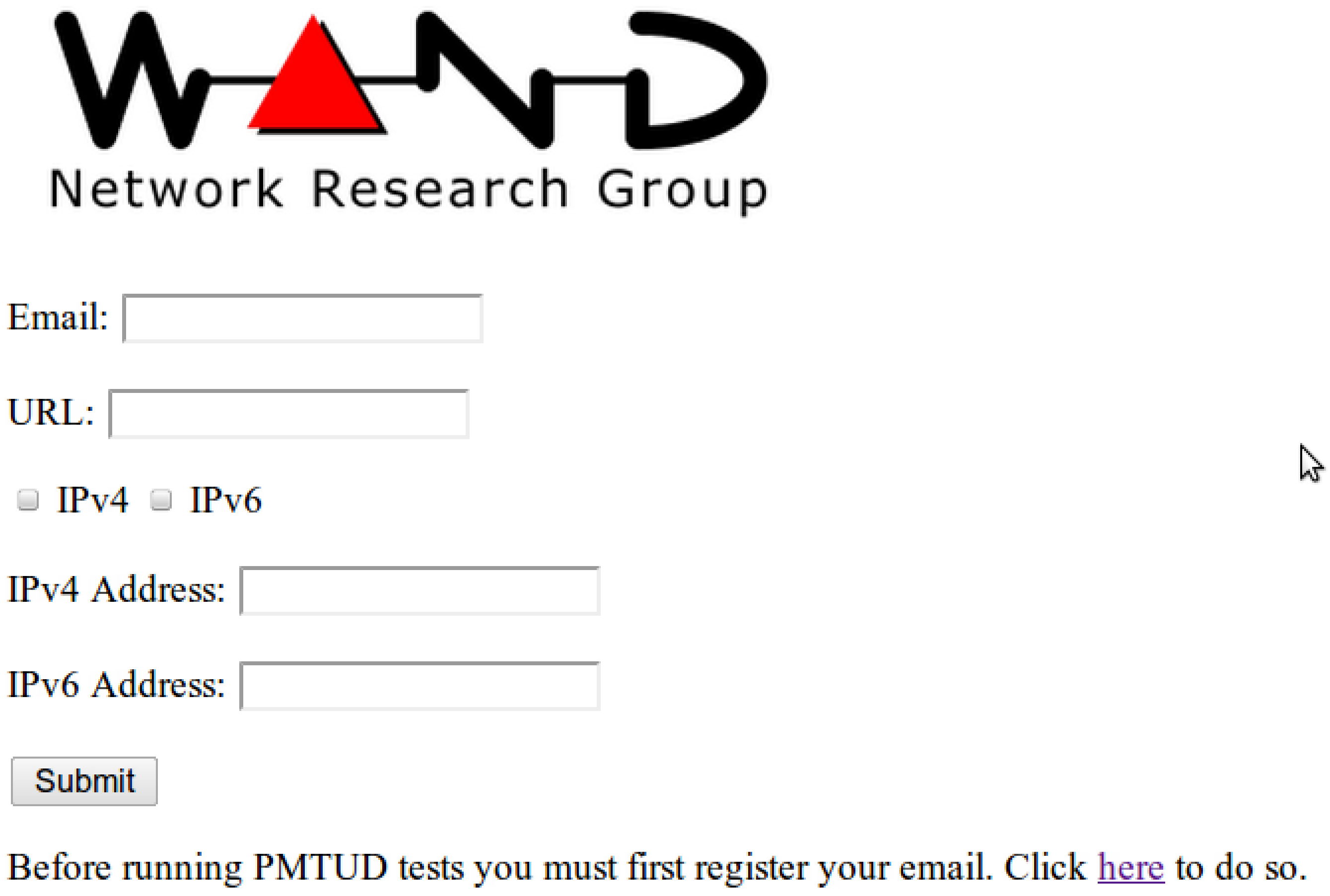


Failure Rate : 1.1%

Server MSS – HTTP IPv6



PMTUD Test Web Interface



Email:

URL:

□ IPv4 □ IPv6

IPv4 Address:

IPv6 Address:

Before running PMTUD tests you must first register your email. Click here to do so.

http://www.staz.net.nz/pmtud.php

Conclusion

- Results suggest that PMTUD failure in IPv6 is not as prevalent as widely believed.
    - Combined failure rate (HTTP, SMTP and DNS) is **1.9%**

What you can do to help:

- Run the PMTUD test to a host on your network.
    - using scamper yourself
    - using the web interface
- Read and implement RFC 4890
    - ICMPv6 Filtering Recommendations

Allow PTB Messages

ipfw

```
ipfw add <num> allow icmp from <src> to <dst> icmptypes 3
ipfw add <num> allow ipv6-icmp from <src> to <dst> icmp6types 2
```

iptables

```
iptables -A <chain> -s <src> -d <dst> -p icmp –icmp-type fragmentation-needed -j ACCEPT
ip6tables -A <chain> -s <src> -d <dst> -p ipv6-icmp –icmpv6-type packet-too-big -j ACCEPT
```

IOS

```
access-list <id> permit icmp <src> <dst> packet-too-big
ipv6 access-list <id> permit icmp6 <src> <dst> packet-too-big
```

JUNOS

```
[edit firewall family inet filter <name>]
set term <name> from protocol icmp
set term <name> from icmp-type unreachable
set term <name> from icmp-code fragmentation-needed
set term <name> then accept
```

```
[edit firewall family inet6 filter <name>]
set term <name> from next-header icmp6
set term <name> from icmp-type packet-too-big
set term <name> then accept
```

Acknowledgements

Those who provided test machines for my use:

Dan Wing (Cisco) and Ken Key

Bill Walker (Snap Internet)

Those who ran PMTUD tests on my behalf:

Emile Aben (RIPE)

David Malone (National University of Ireland)

A big thank you to RIPE for giving me the opportunity to present at this conference!

Links

WAND	http://www.wand.net.nz/
Scamper	http://www.wand.net.nz/scamper/
Web Interface	http://www.staz.net.nz/pmtud.php
RFC 4890	http://www.ietf.org/rfc/rfc4890.txt

Any Questions?

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