An Experimental Study of Home Gateway Characteristics

NOKIA

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Motivation

- CPE boxes ("home gateways") are **everywhere**
- their characteristics and behaviors vary widely
- they control the quality and performance of consumer Internet access
- most "standards" are about the control plane – but the data plane counts
- very few studies of home gateway behavior are (publicly) available
- just lots of second-hand hear-say

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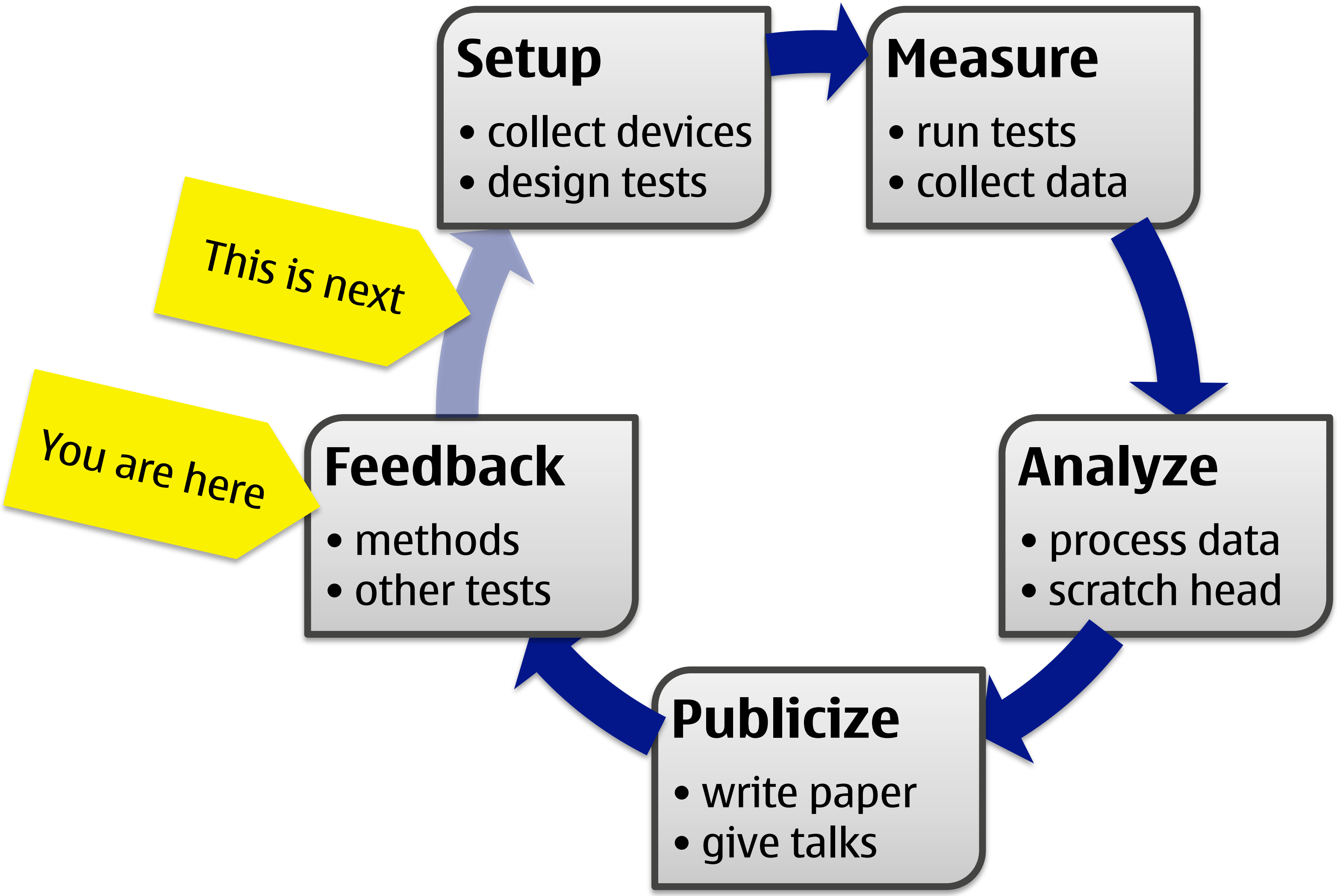
Approach


Setup
• collect devices
• design tests
Measure
• run tests
• collect data
Analyze
• process data
• scratch head
Publicize
• write paper
• give talks
Feedback
• methods
• other tests
This is next
You are here

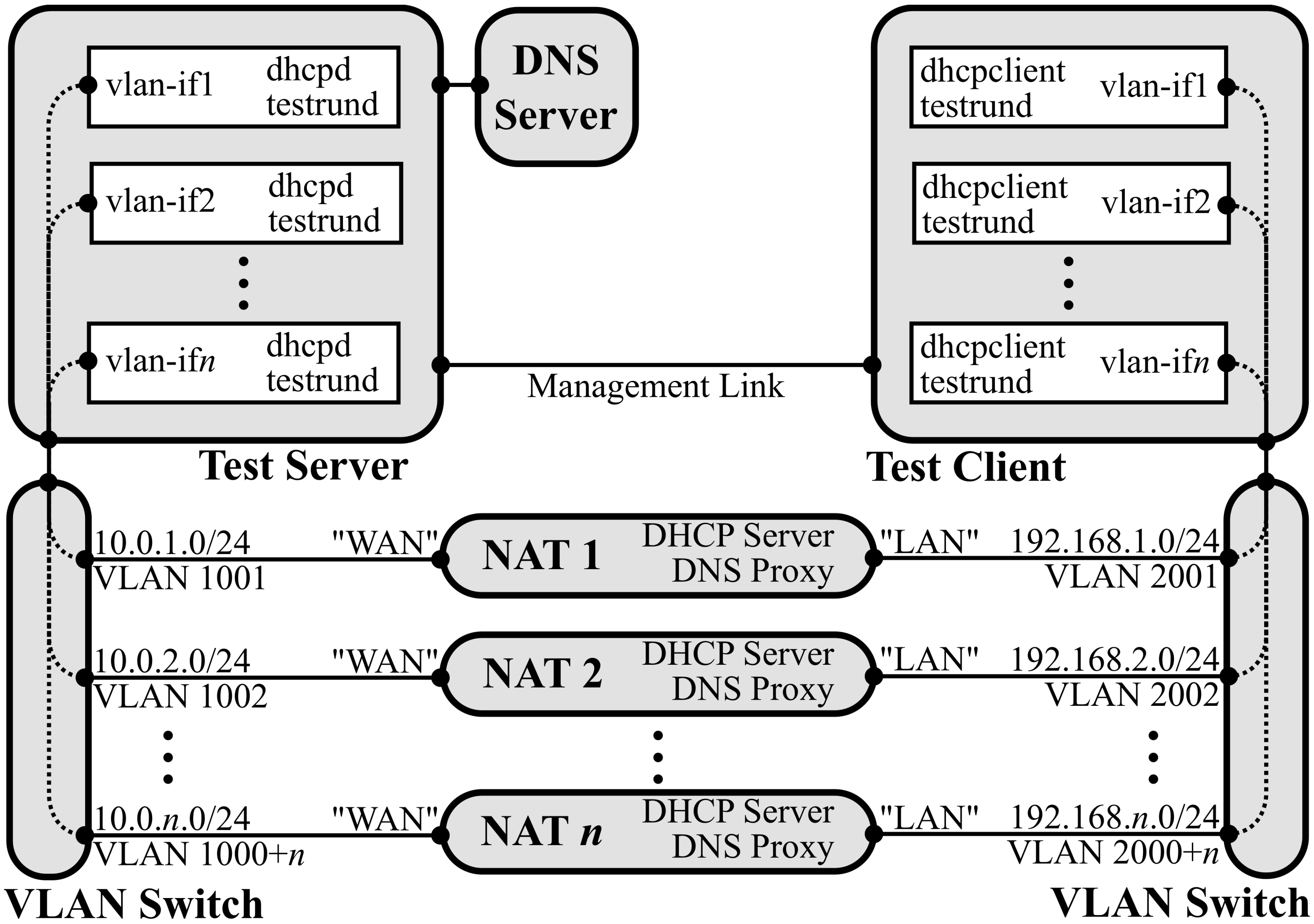
Setup: Device Collection

- HU and Nokia bought 20 devices to seed the testbed
- another 14 were donated
- 34 devices tested in total

- follow-up studies planned; many more donations in the meantime
- **talk to me if you have a spare box!**

Vendor	Model	Firmware	Tag
A-Link	WNAP	e2.0.9A	*al*
Apple	Airport Express	7.4.2	*ap*
Asus	RT-N15	2.0.1.1	*as1*
Belkin	Wireless N Router	F5D8236-4_WW_3.00.02	*be1*
	Enhanced N150	F6D4230-4_WW_1.00.03	*be2*
Buffalo	WZR-AGL300NH	R1.06/B1.05	*bu1*
D-Link	DIR-300	1.03	*dl1*
	DIR-300	1.04	*dl2*
	DI-524up	v1.06	*dl3*
	DI-524	v2.0.4	*dl4*
	DIR-100	v1.12	*dl5*
	DIR-600	v2.01	*dl6*
	DIR-615	v4.00	*dl7*
	DIR-635	v2.33EU	*dl8*
	DI-604	v3.09	*dl9*
	DI-713P	2.60 build 6a	*dl10*
Edimax	6104WG	2.63	*ed*
Jensen	Air:Link 59300	1.15	*je*
Linksys	BEFSR41c2	1.45.11	*ls1*
	WR54G	v7.00.1	*ls2*
	WRT54GL v1.1	v4.30.7	*ls3*
	WRT54GL-EU	v4.30.7	*ls5*
	WRT54G	OpenWRT RC5	*owrt*
	WRT54GL v1.1	tomato 1.27	*to*
Netgear	RP614 v4	V1.0.2_06.29	*ng1*
	WGR614 v7	(1.0.13_1.0.13)	*ng2*
	WGR614 v9	V1.2.6_18.0.17	*ng3*
	WNR2000-100PES	v.1.0.0.34_29.0.45	*ng4*
	WGR614 v4	V5.0_07	*ng5*
Njetwjork	54M	Ver 1.2.6	*nw1*
SMC Barricade	SMC7004VBR	R1.07	*smc*
Telewell	TW-3G	V7.04b3	*te*
Webee	Wireless N Router	e2.0.9D	*we*
ZyXel	P-335U	V3.60(AMB.2)C0	*zy1*

Setup: Testbed

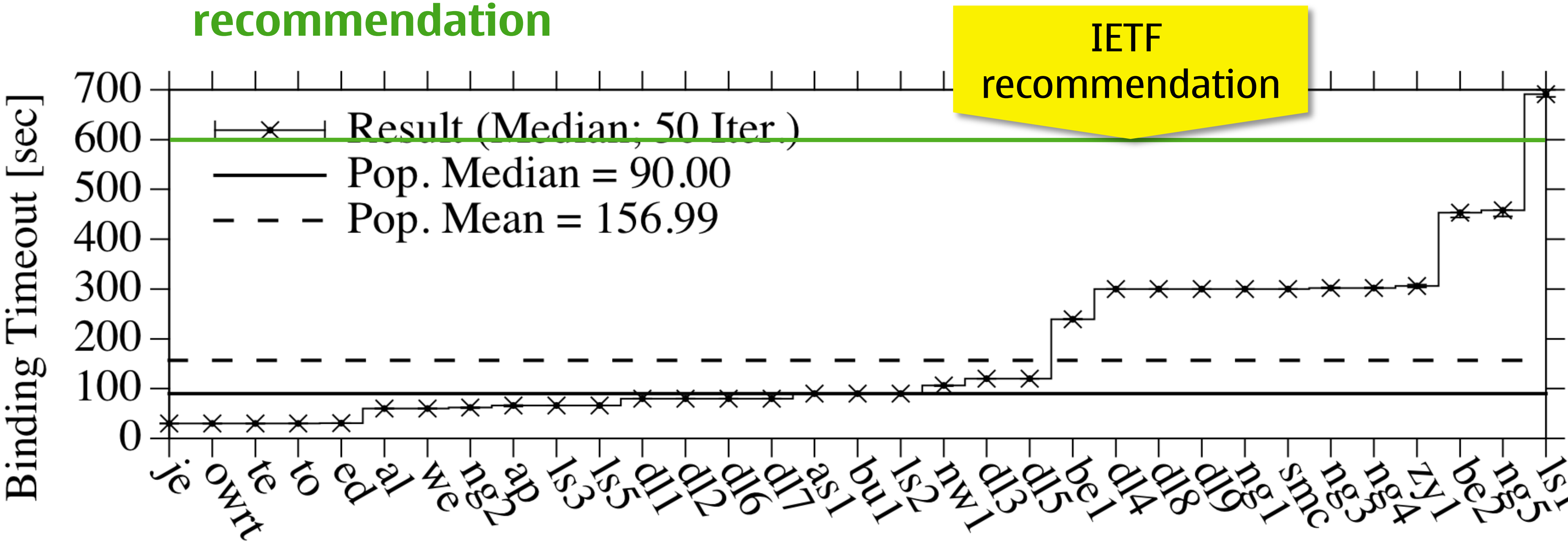


Tests & Results

UDP Binding Timeouts

UDP-1: Single packet, outbound only

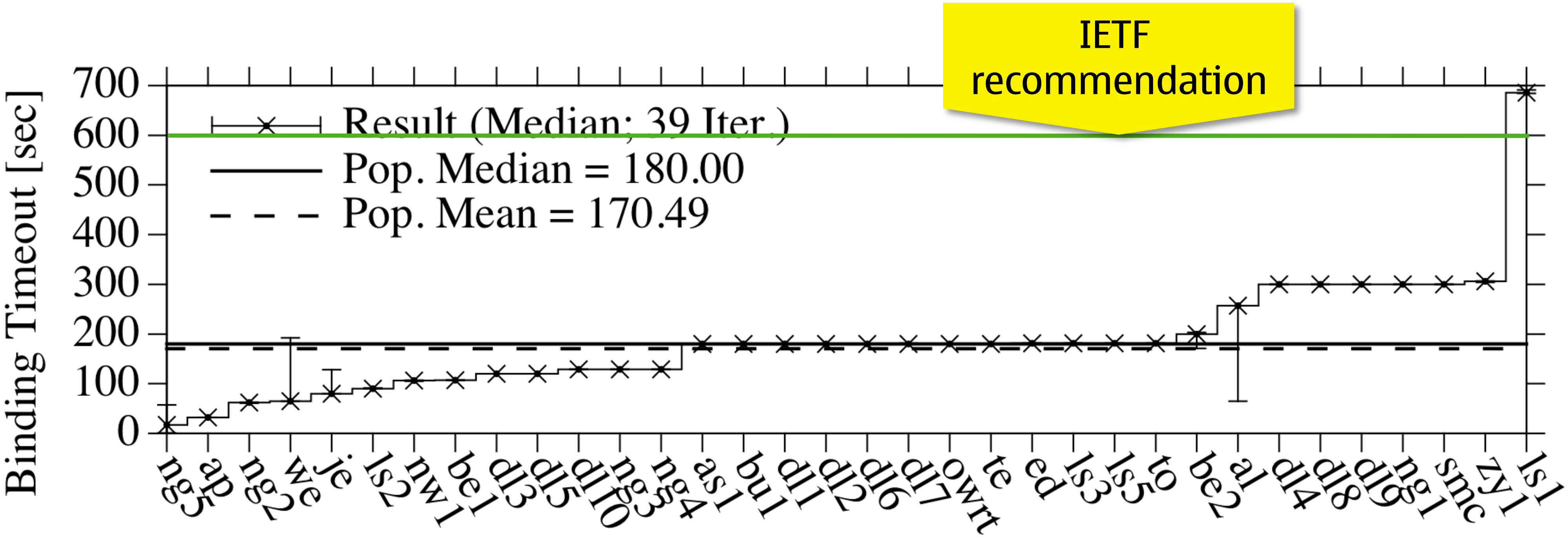
- measures NAT UDP binding timeout after client sends a single packet
- server sends no return traffic
- **result: very short timeouts (min = 30 sec), almost all less than IETF recommendation**



UDP Binding Timeouts

UDP-2: Single packet outbound, multiple packets in- bound

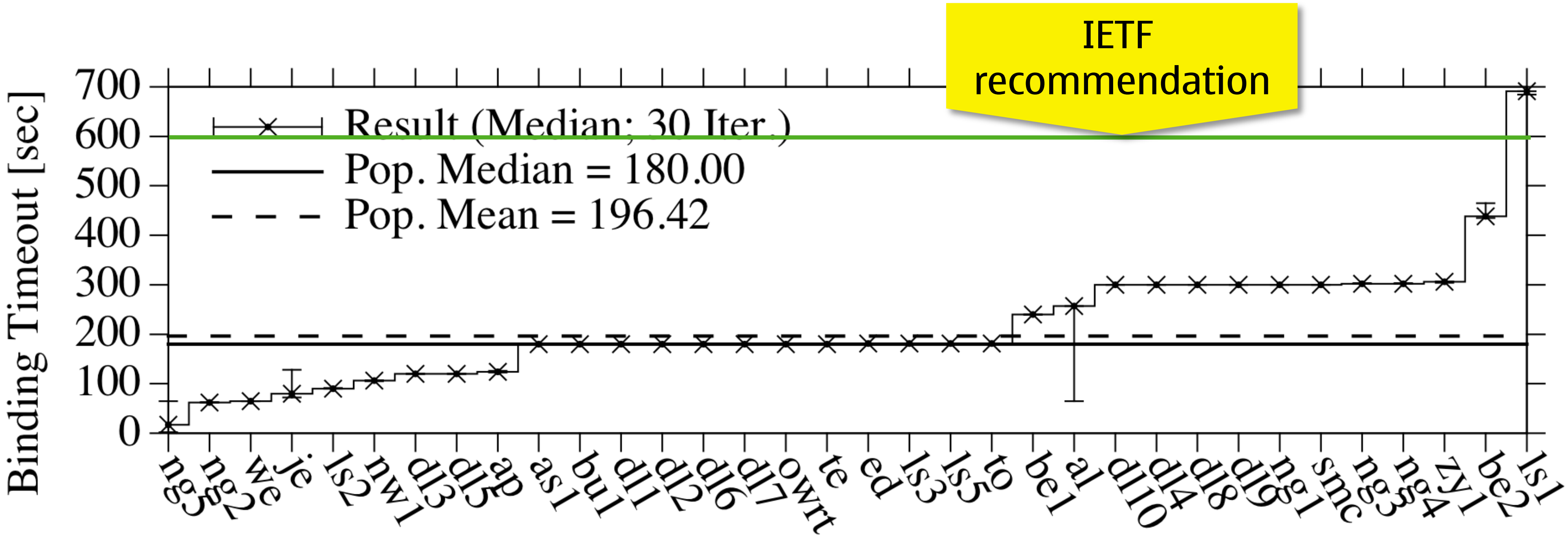
- client sends a single UDP packet to the test server and then remains silent
- server then sends a stream of responses, increasing delay between each
- **result: longer timeouts overall; some boxes *shorter* compared to UDP-1**



UDP Binding Timeouts

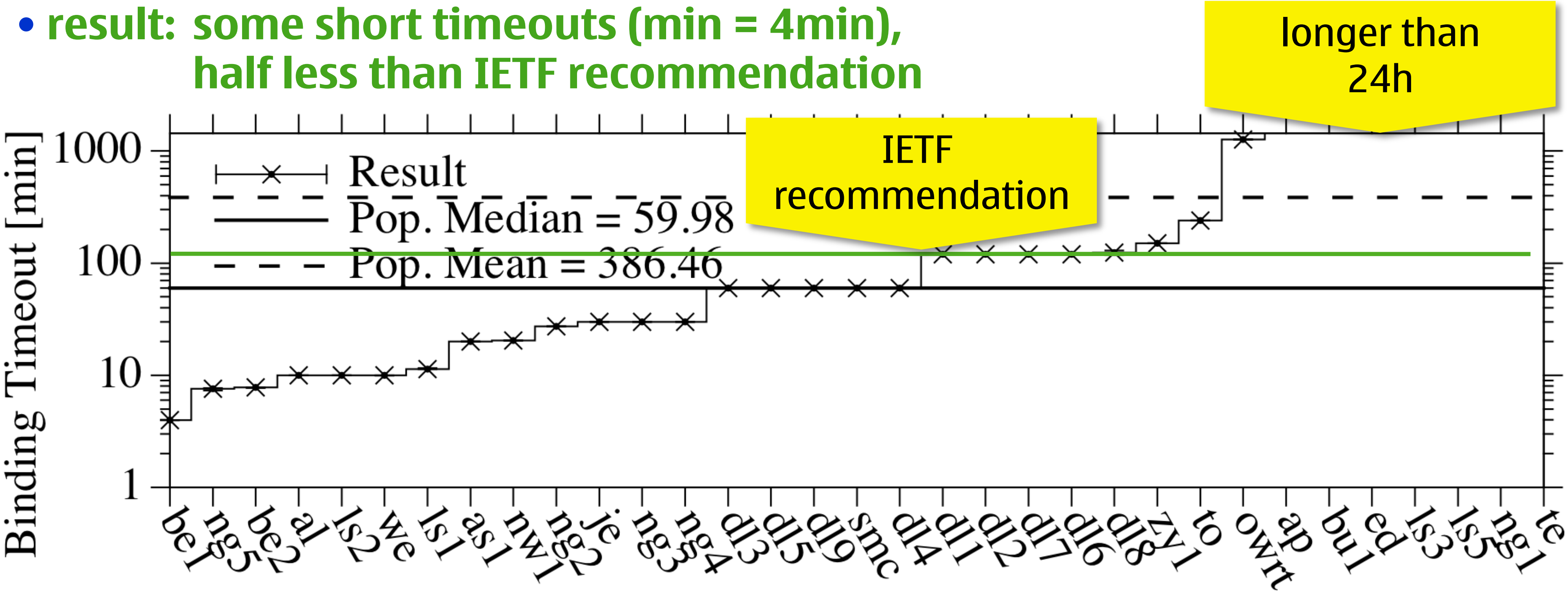
UDP-3: Multiple packets out- and inbound

- similar to UDP-2, except that client sends response to each server packet
- intent is to determine whether outbound traffic refreshes a binding
- **result: longer timeouts overall; *no* boxes shorter compared to UDP-2**



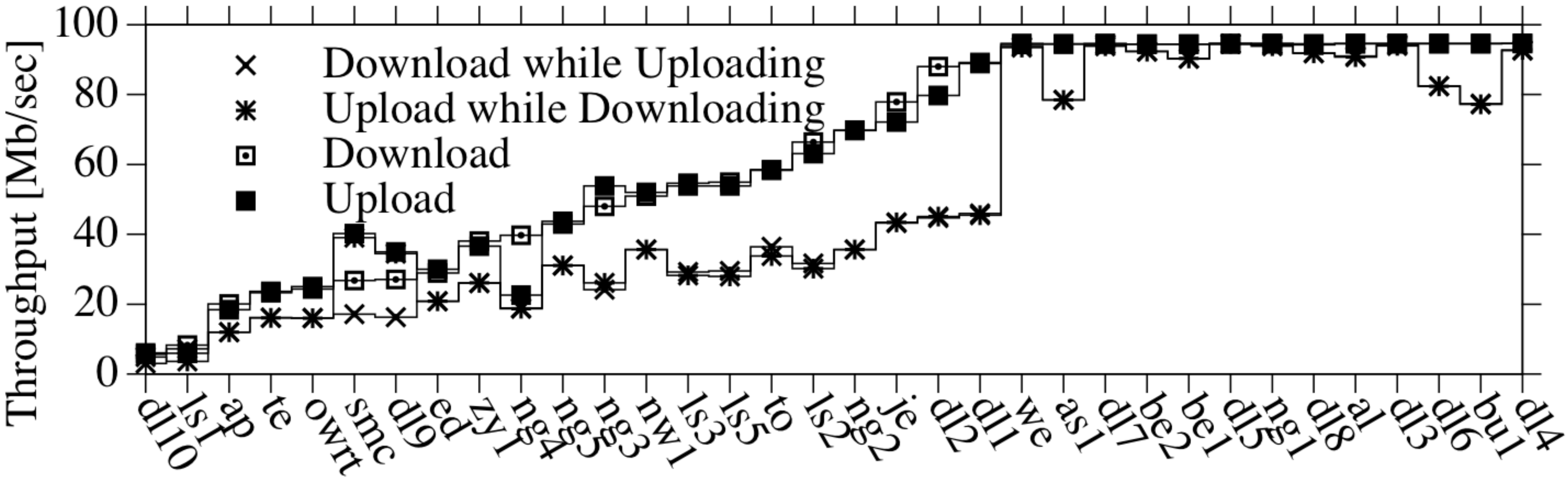
TCP Binding Timeouts

- similar to UDP-1, except TCP connection (no keep-alives)
- note: log scale and unit different!
- **result: some short timeouts (min = 4min), half less than IETF recommendation**



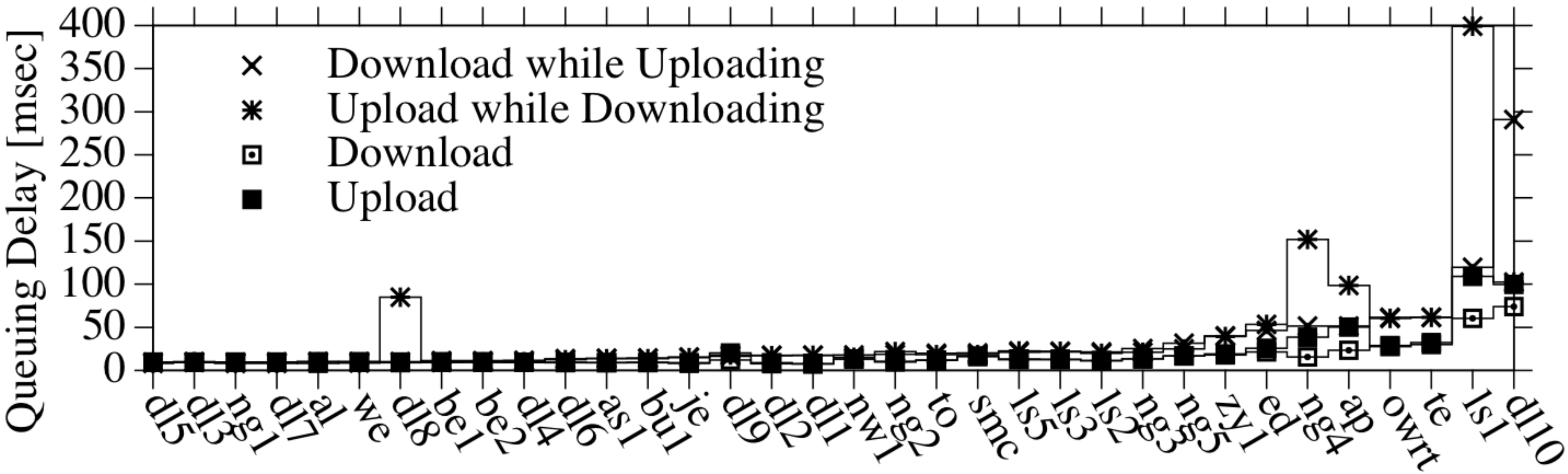
TCP Throughput

- throughput over of a 100 MB bulk transfer (2x unidirectional, 1x bidirectional)
- **result: 1/3 of boxes reaches max, median in bidirectional case much less than when sending unidirectional, lots of weirdness**



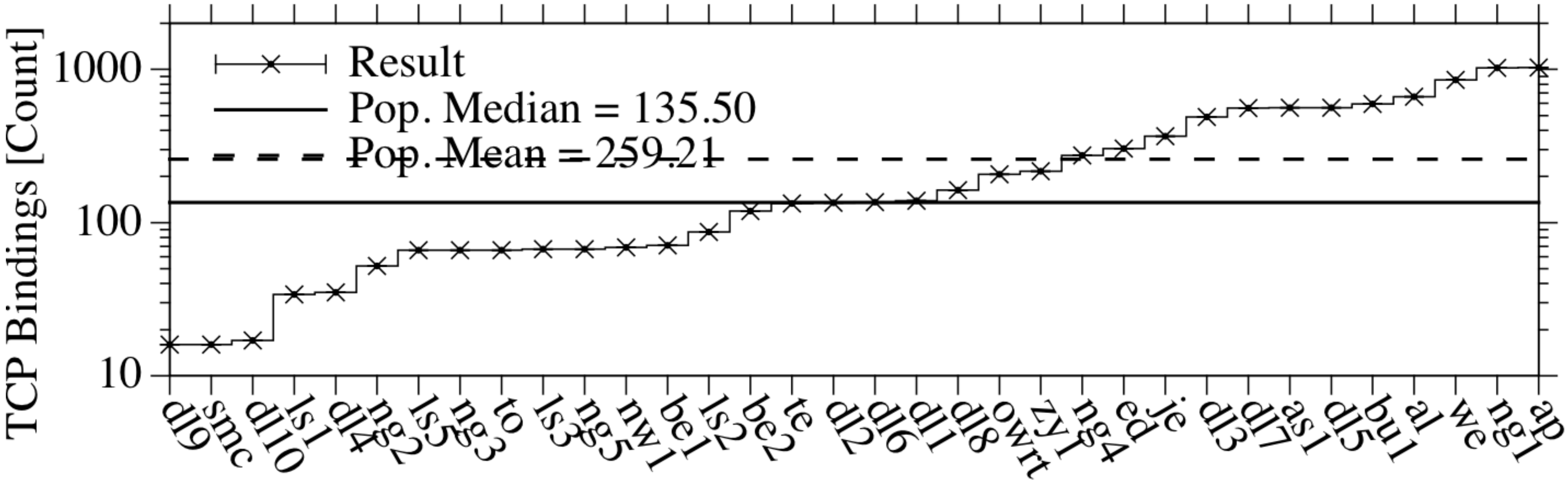
Queuing Delays

- queuing delay introduced by the box when fully loaded
- **result: mostly OK (< 50 ms); some boxes really bad/weird**



Max. Number of TCP Bindings

- maximum number of TCP bindings allowed to a single server port
- **result: some very low (16), max. is 1024**



Other Results

DCCP & SCTP

- **DCCP**: zilch
- **SCTP**: 18/34 ?!?
- theory: single SCTP association "works", because those 18 devices translate just the IP addresses for unknown IP protocol numbers
- **need to look deeper**

Tag	DCCP: Conn.	DNS over TCP	DNS over UDP	ICMP: Host Unreach.	SCTP: Conn.	TCP: Reass. Time. Ex.	TCP: Frag. Needed	TCP: Param. Prob.	TCP: Src. Route Fail.	TCP: Source Quench	TCP: TTL Exceeded	TCP: Host Unreach.	TCP: Net Unreach.	TCP: Port Unreach.	TCP: Proto. Unreach.	UDP: Reass. Time Ex.	UDP: Frag. Needed	UDP: Param. Prob.	UDP: Src. Route Fail	UDP: Source Quench	UDP: TTL Exceeded	UDP: Host Unreach.	UDP: Net Unreach.	UDP: Port Unreach.	UDP: Proto. Unreach.
al		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ap		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
as1			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
be1			●													●	●		●		●	●	●	●	●
be2			●													●	●		●		●	●	●	●	●
bu1		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl1			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl10			●								●			●							●			●	
dl2		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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dl5			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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dl7		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl8			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl9			●								●			●							●			●	
ed		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
je		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls1			●	●			●									●	●	●	●	●	●	●	●	●	●
ls2			●	●												●	●		●	●	●	●	●	●	●
ls3			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls5			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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zy1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Other Results

DNS

- **DNS over UDP**: worked

- **DNS over TCP**: so-so
- 14 accept connections on TCP port 53
- 10 respond to DNS queries
- one box forwards inbound DNS-over-TCP as DNS-over UDP

Tag	DCCP: Conn.	DNS over TCP	DNS over UDP	ICMP: Host Unreach.	SCTP: Conn.	TCP: Reass. Time. Ex.	TCP: Frag. Needed	TCP: Param. Prob.	TCP: Src. Route Fail.	TCP: Source Quench	TCP: TTL Exceeded	TCP: Host Unreach.	TCP: Net Unreach.	TCP: Port Unreach.	TCP: Proto. Unreach.	UDP: Reass. Time Ex.	UDP: Frag. Needed	UDP: Param. Prob.	UDP: Src. Route Fail	UDP: Source Quench	UDP: TTL Exceeded	UDP: Host Unreach.	UDP: Net Unreach.	UDP: Port Unreach.	UDP: Proto. Unreach.
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ap		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
as1			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
be1			●													●	●		●		●	●	●	●	●
be2			●													●	●		●		●	●	●	●	●
bu1		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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zy1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Other Results

ICMP handling

- **in a nutshell: many issues**
- one box doesn't translate ICMP *at all*
- all others translate at least "Port unreachable" and "TTL Exceeded"
- one box translates TCP-related ICMP messages into TCP RST
- 16 out of 34 do not correctly translate the transport header contained in the ICMP payload
- two do not correctly translate the IP checksum in the ICMP payload

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be2			●													●	●		●		●	●	●	●	●
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ls2			●	●												●	●		●	●	●	●	●	●	●
ls3			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls5			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ng1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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ng5			●	●												●			●		●	●	●	●	●
nw1			●																						
owrt		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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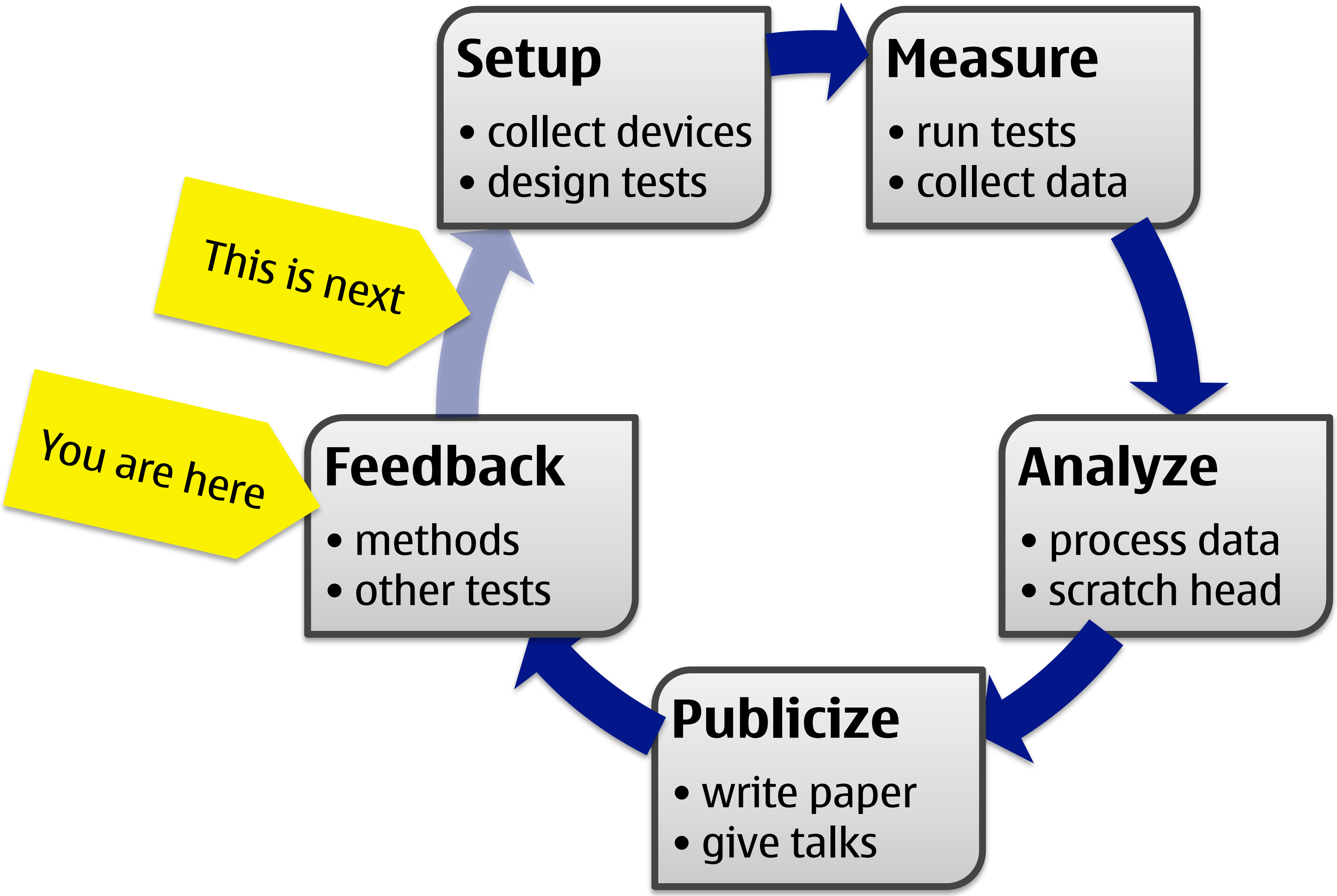
we		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
zy1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Next Steps: Refine & Expand the Study



Related Work

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Thank You

Talk to me if you have a spare home gateway to donate to the testbed.

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