SENG, the SGX-Enforcing Network Gateway: Authorizing Communication from Shielded Clients

Fabian Schwarz and Christian Rossow

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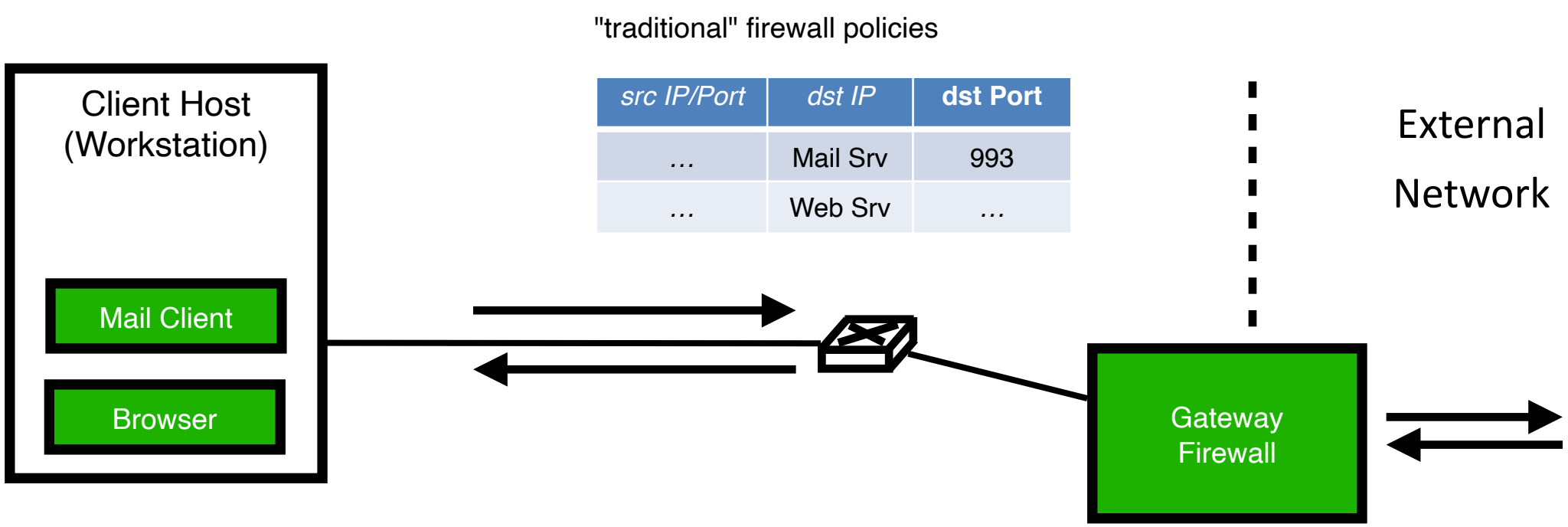
Network Firewalls: What are the origins of corporate network communication?

Client Workstations (Enterprise Network)



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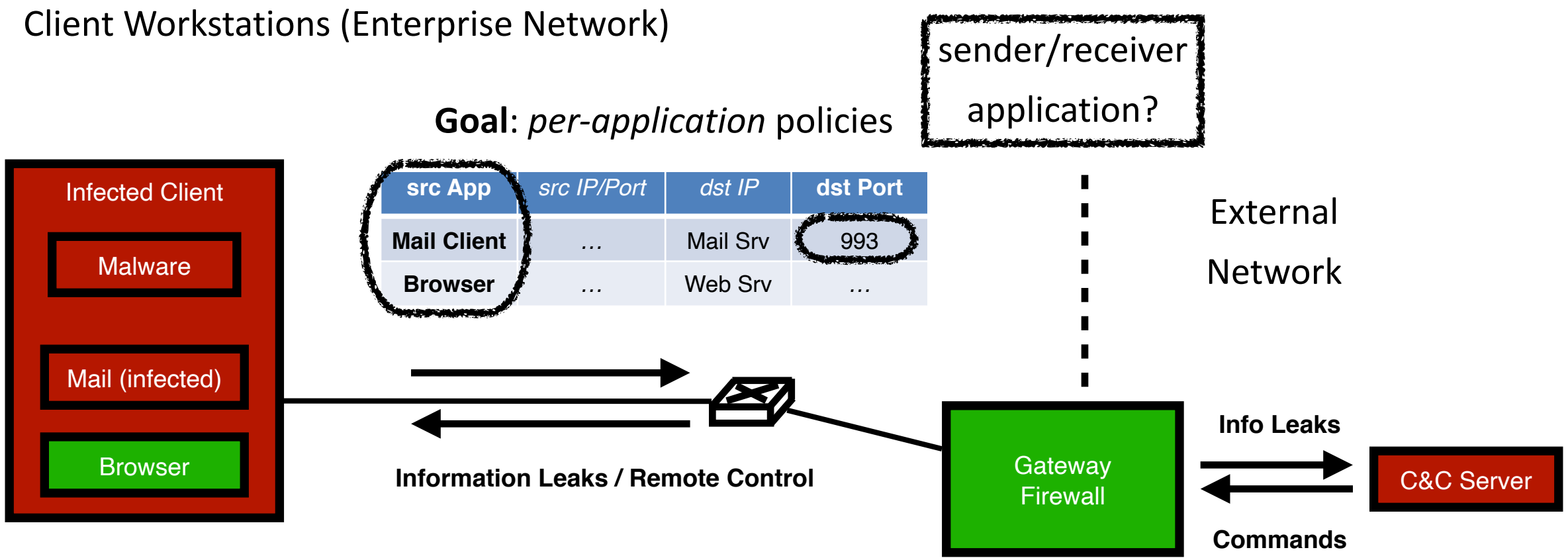
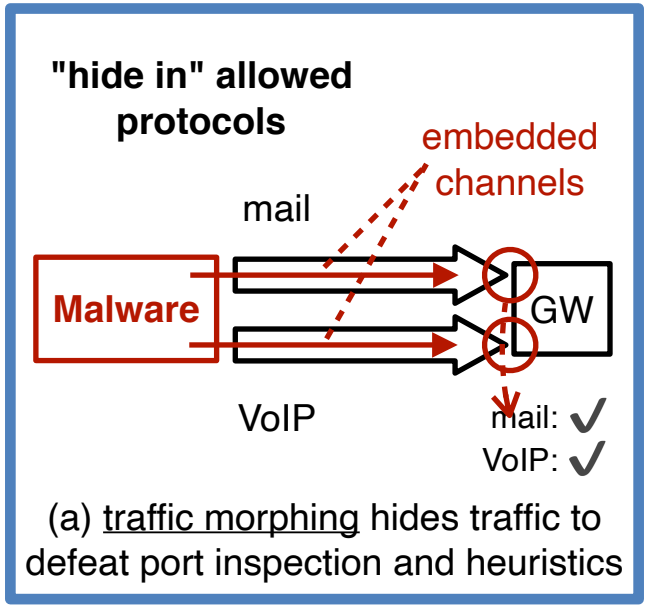
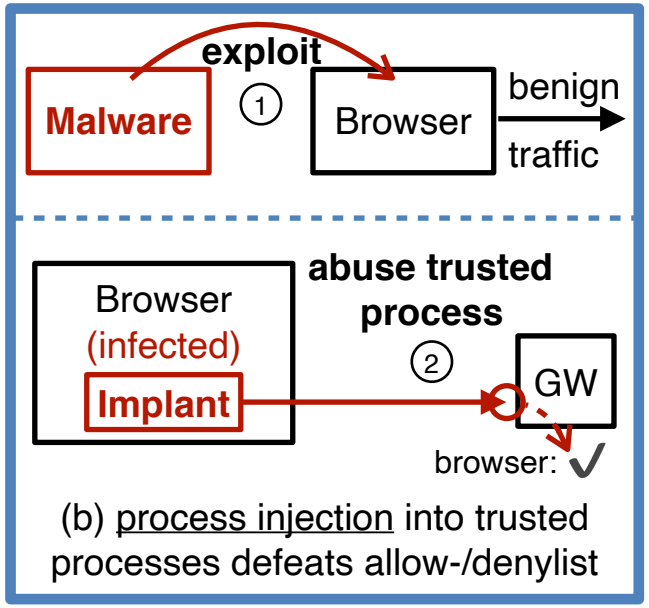


The Problem: Secure Traffic-to-Application Attribution is Challenging!

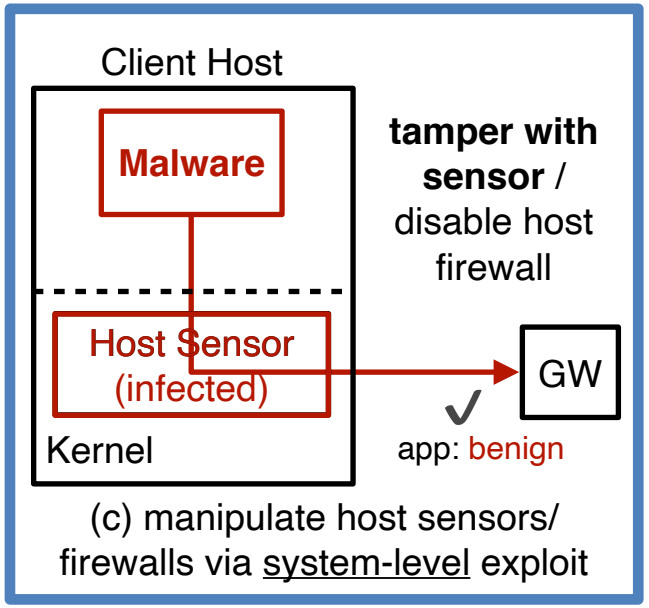
Malware evades traffic-to-application attribution:



(a) traffic morphing hides traffic to defeat port inspection and heuristics



(b) process injection into trusted processes defeats allow-/denylist



(c) manipulate host sensors/ firewalls via system-level exploit

Reliable and secure attribution requires:

(I) protection of applications and their traffic from system/MITM attackers

(II) precise, unforgeable application identifiers (exposed to firewall)

Threat Model

- MITM network attackers
- fully compromised client system, only trust hardware (Intel® SGX) and user
- trusted central gateway ("bastion host")

Our Idea(s):

Run applications in TEE and shield network traffic until the perimeter firewall.

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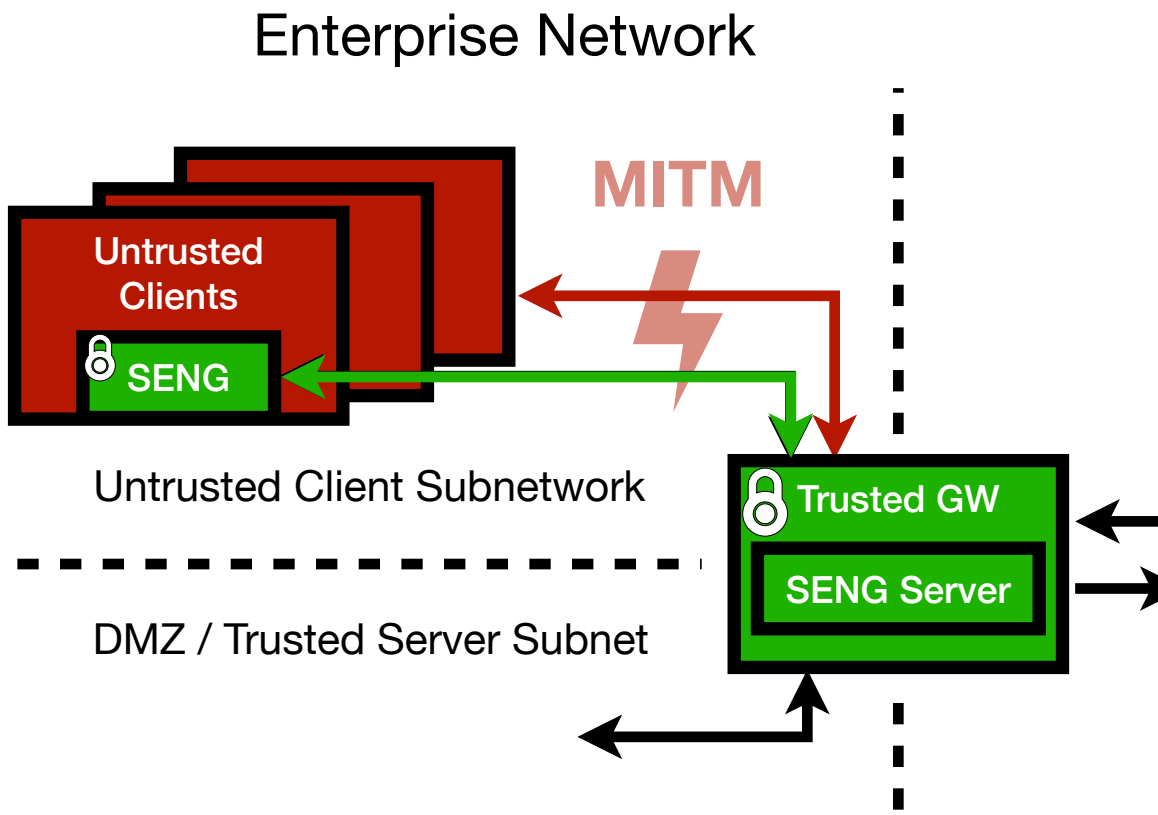
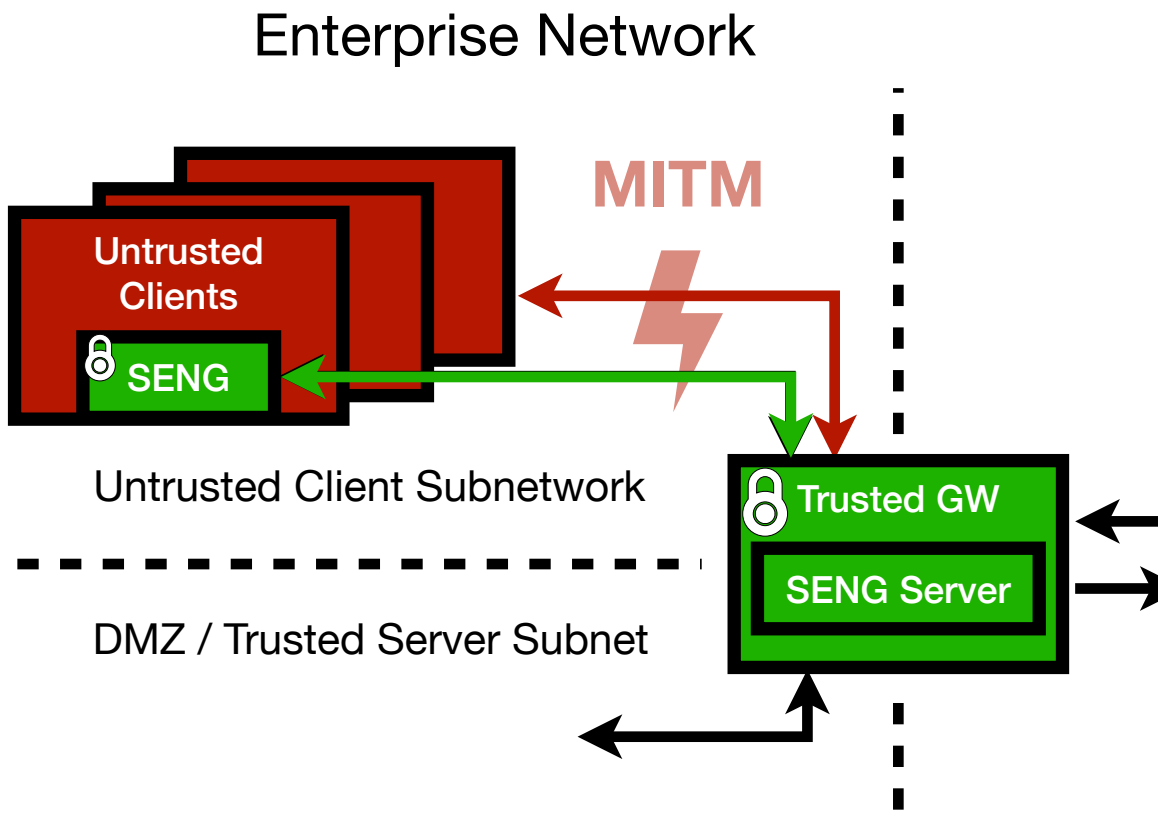
Root application identities in HW trust anchor and expose them to the gateway services.



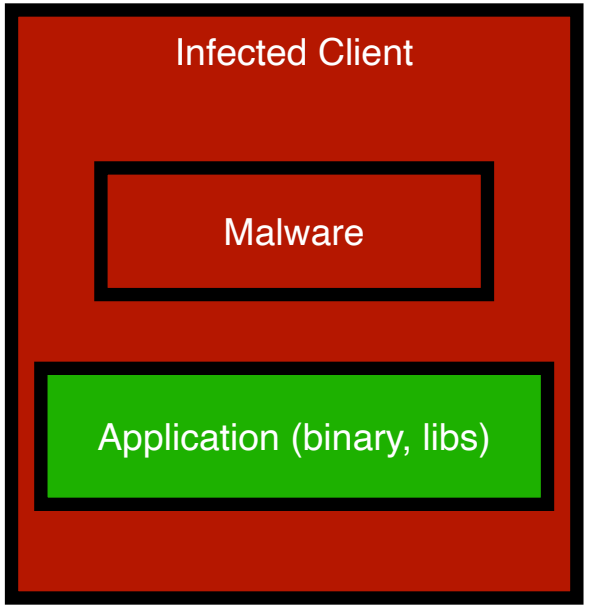
Ultimate Goal:

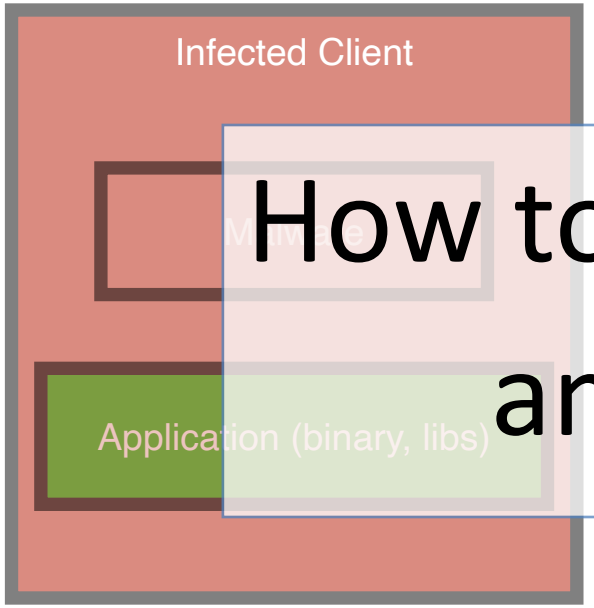
Enable *precise and secure per-application* policies at the perimeter firewall to prevent info leaks / remote control



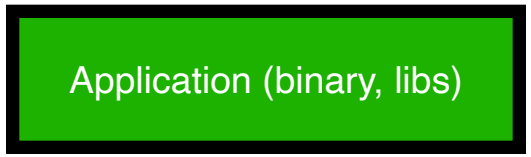
Easy Deployment

- no client application modifications
- compatible with existing firewalls and gateway services


Infected Client
Malware
Application (binary, libs)



How to shield client applications and their connections?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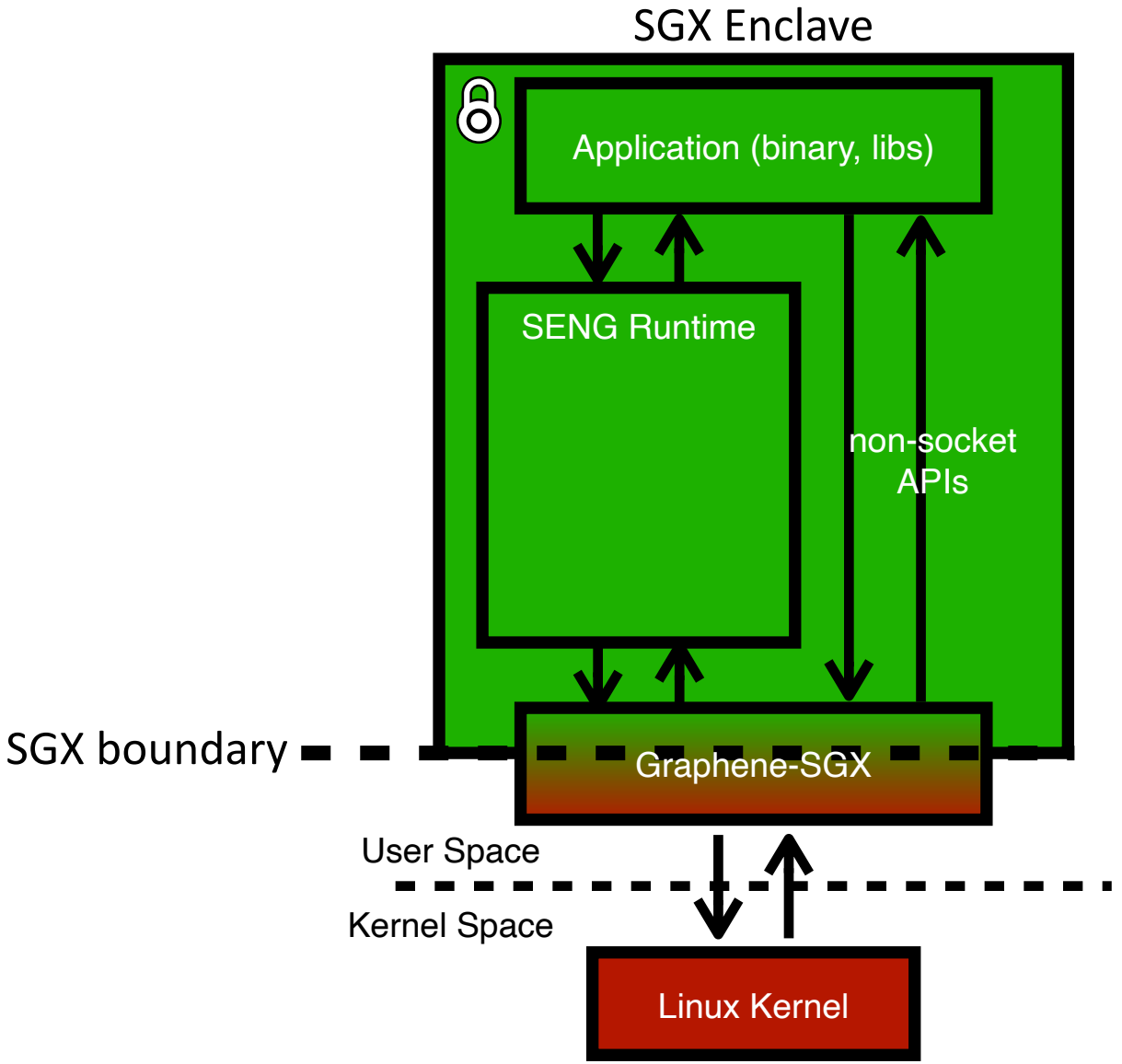
SENG Runtime: Shielding Client Application Traffic from System-level Attackers



- shields app in SGX Enclave via library OS (Graphene-SGX)
- dynamic loading, threading, syscalls, and file system shield
- **BUT: relies on host network stack**

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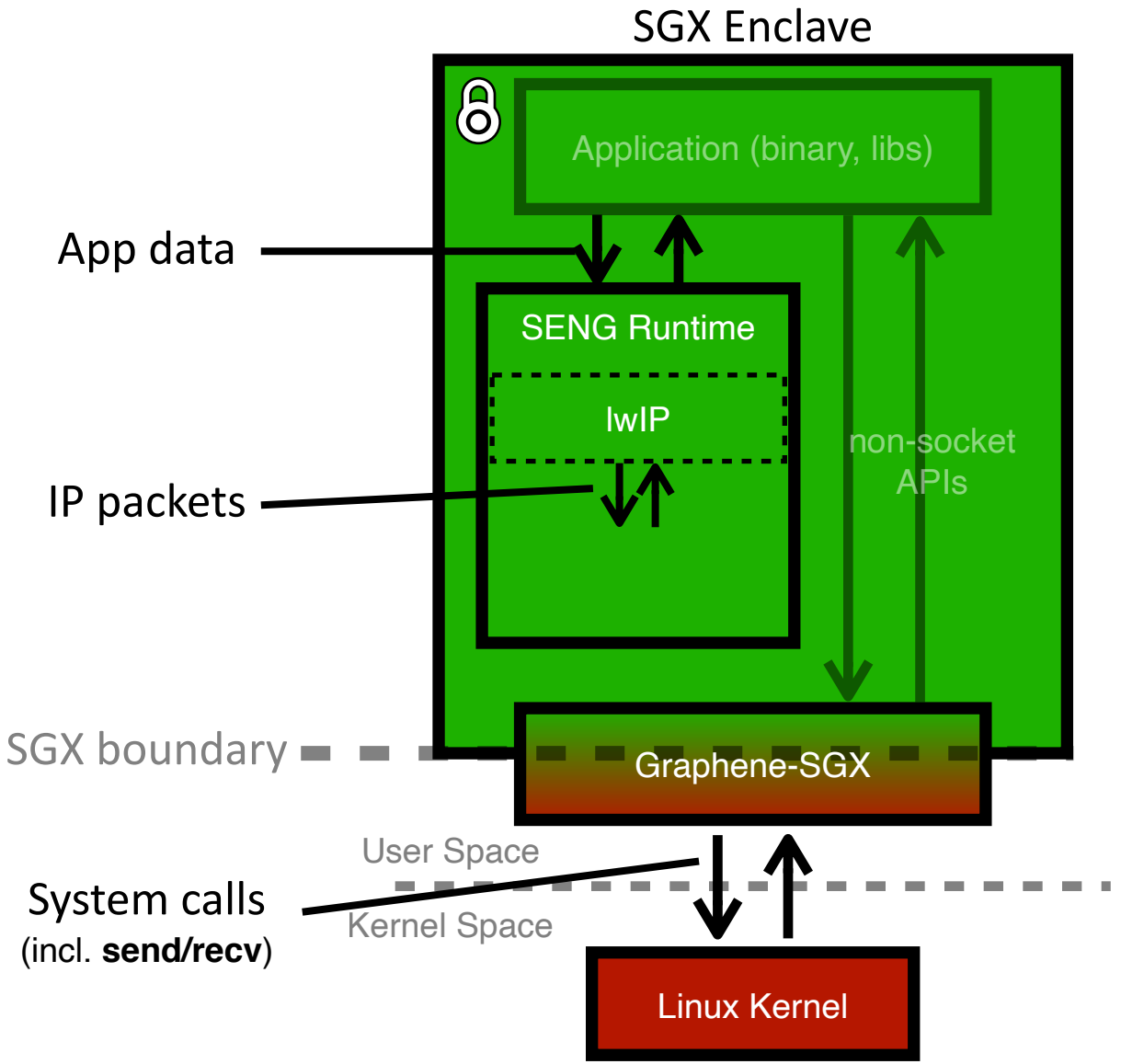

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- provides trusted Socket + DNS API

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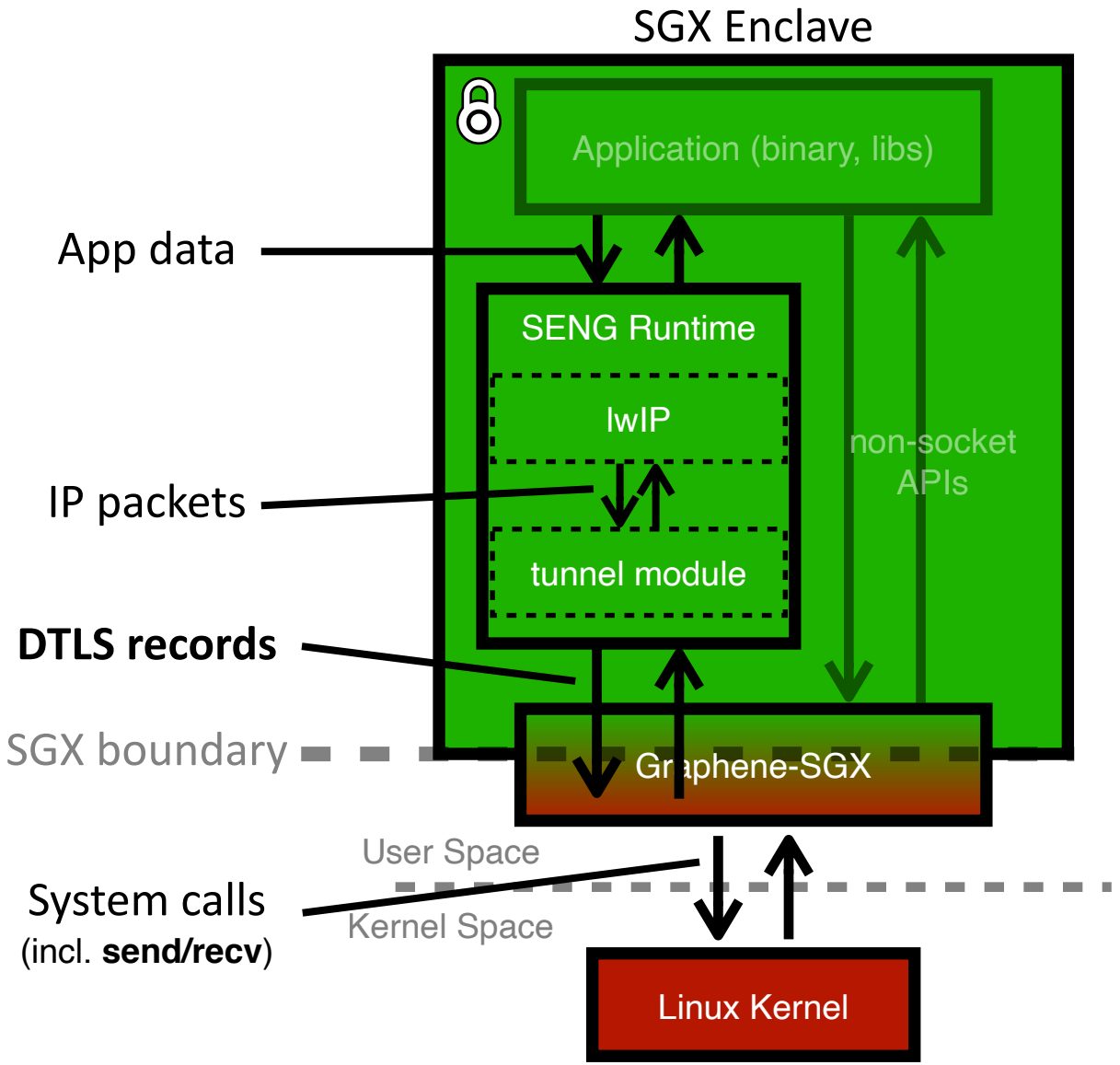

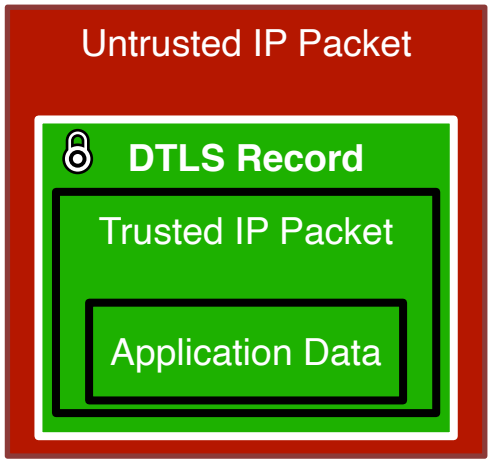

Shielded App Network Packet

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- provides trusted Socket + DNS API
- **DTLS protected IP-level tunnel**

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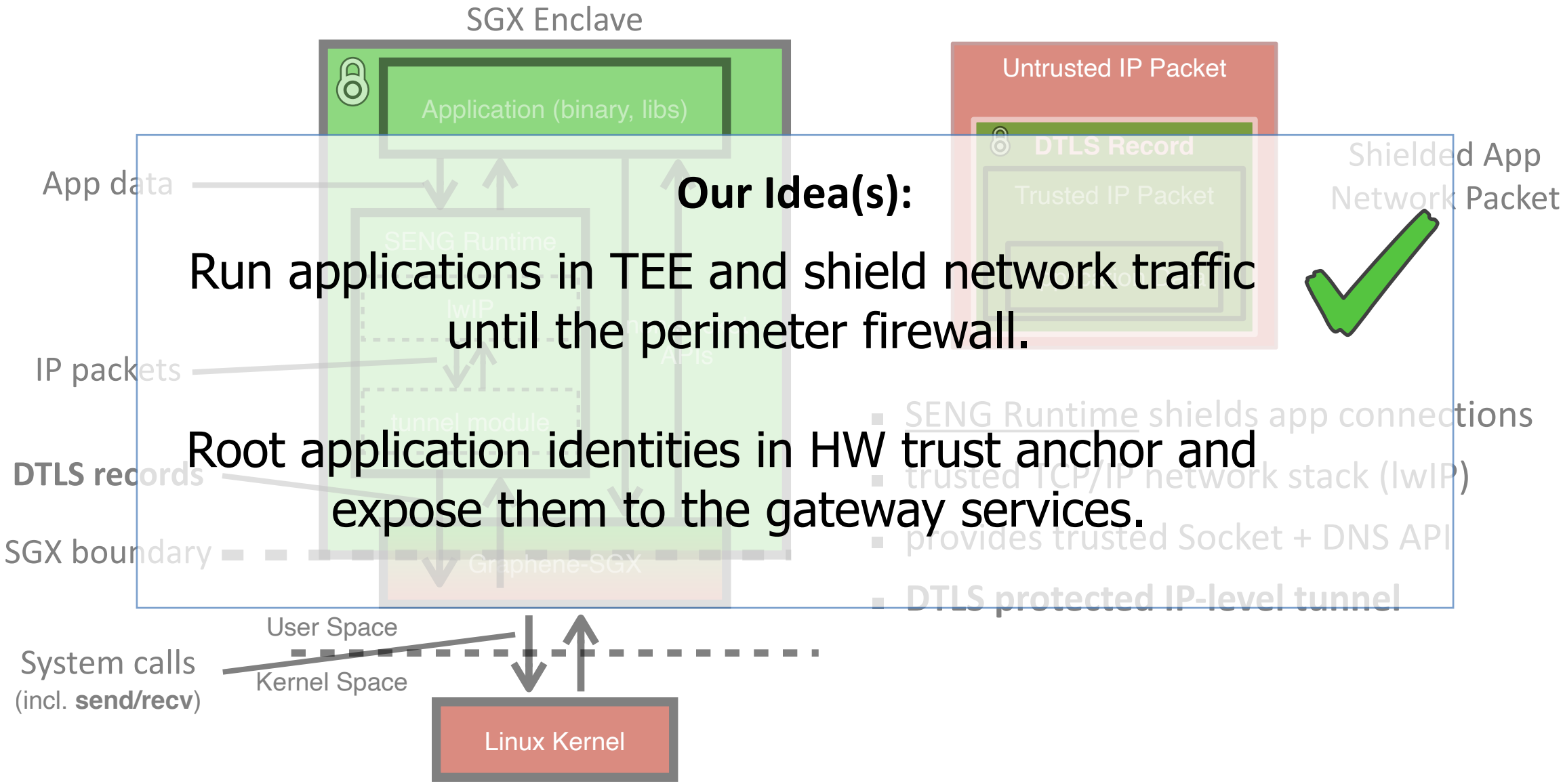

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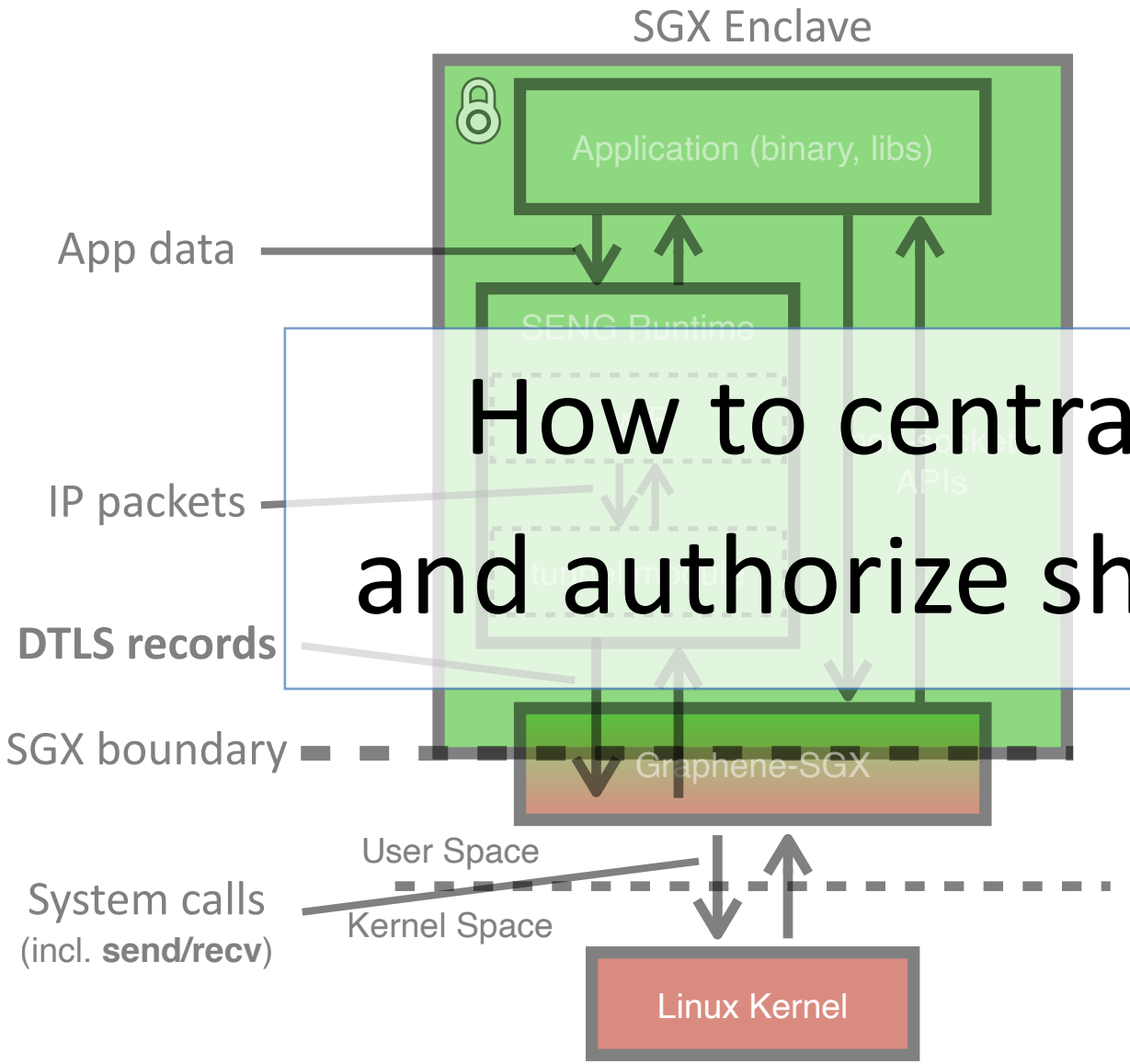
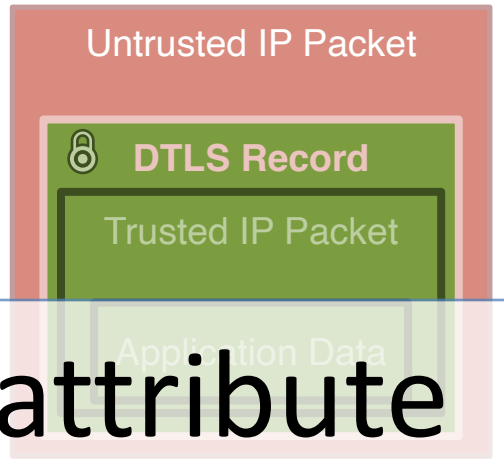


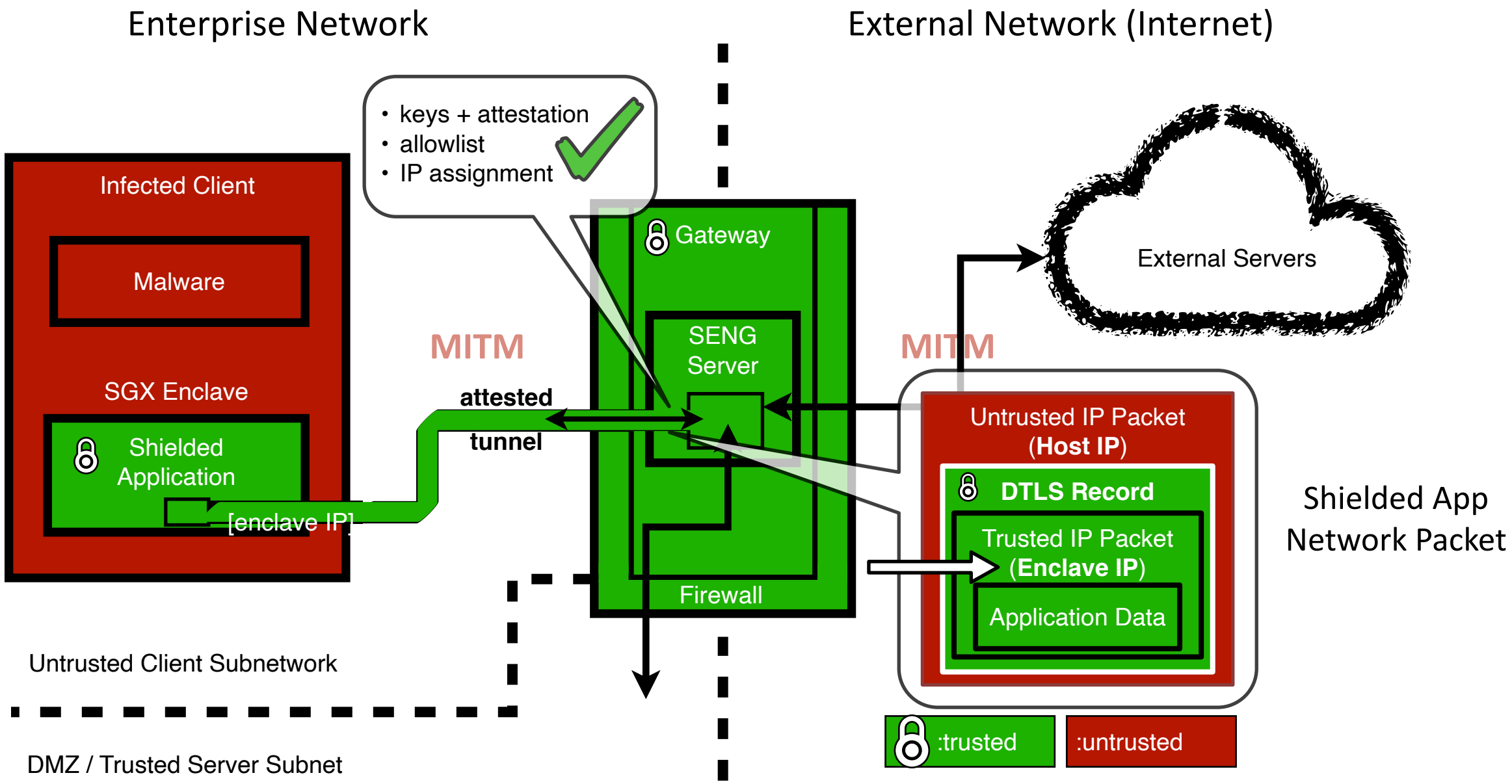


Shielded App Network Packet

How to centrally attribute and authorize shielded traffic?

- trusted TCP/IP network stack (lwIP)
- provides trusted Socket + DNS API
- **DTLS protected IP-level tunnel**

SENG Server: Shielded Traffic Attribution and Authorization



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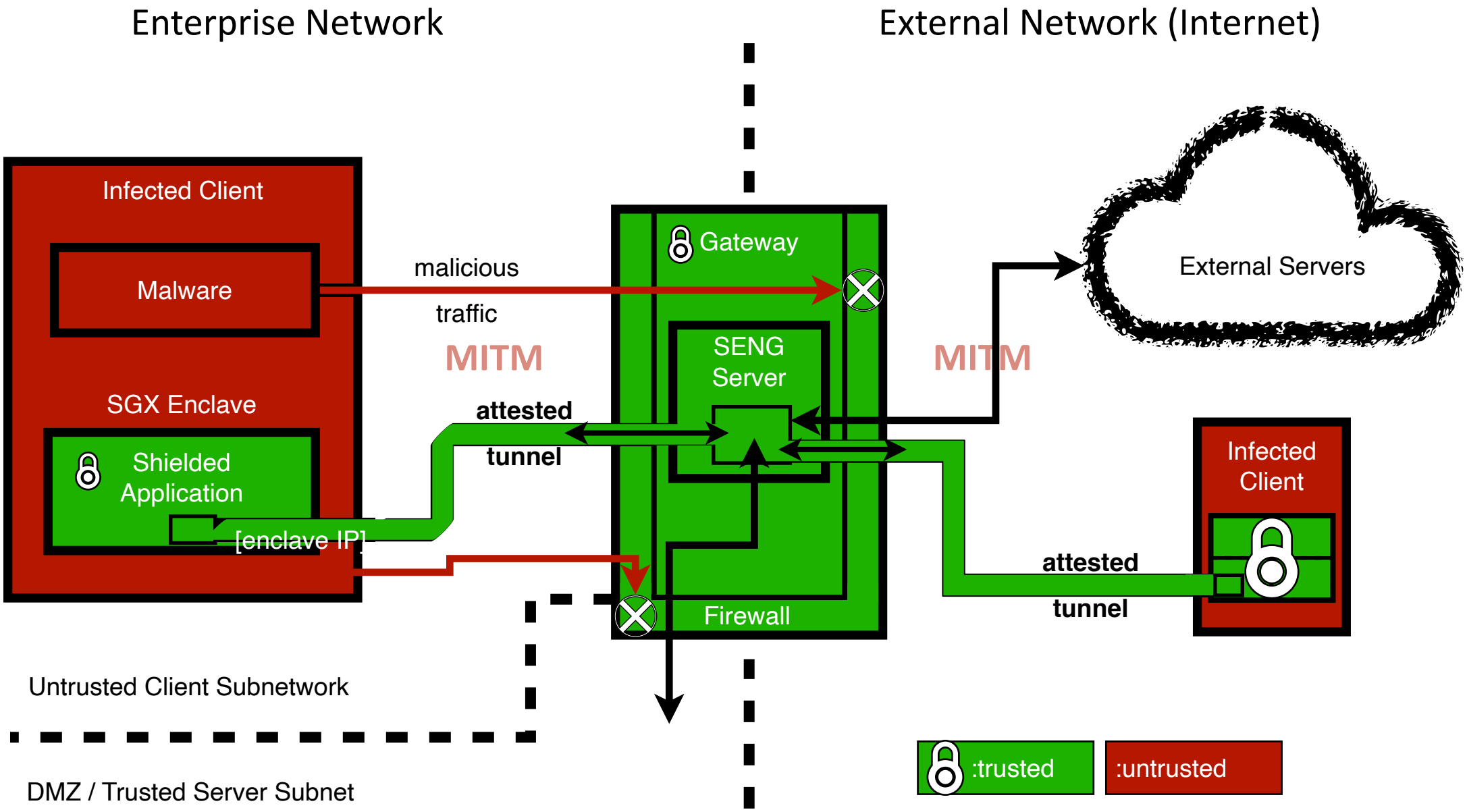

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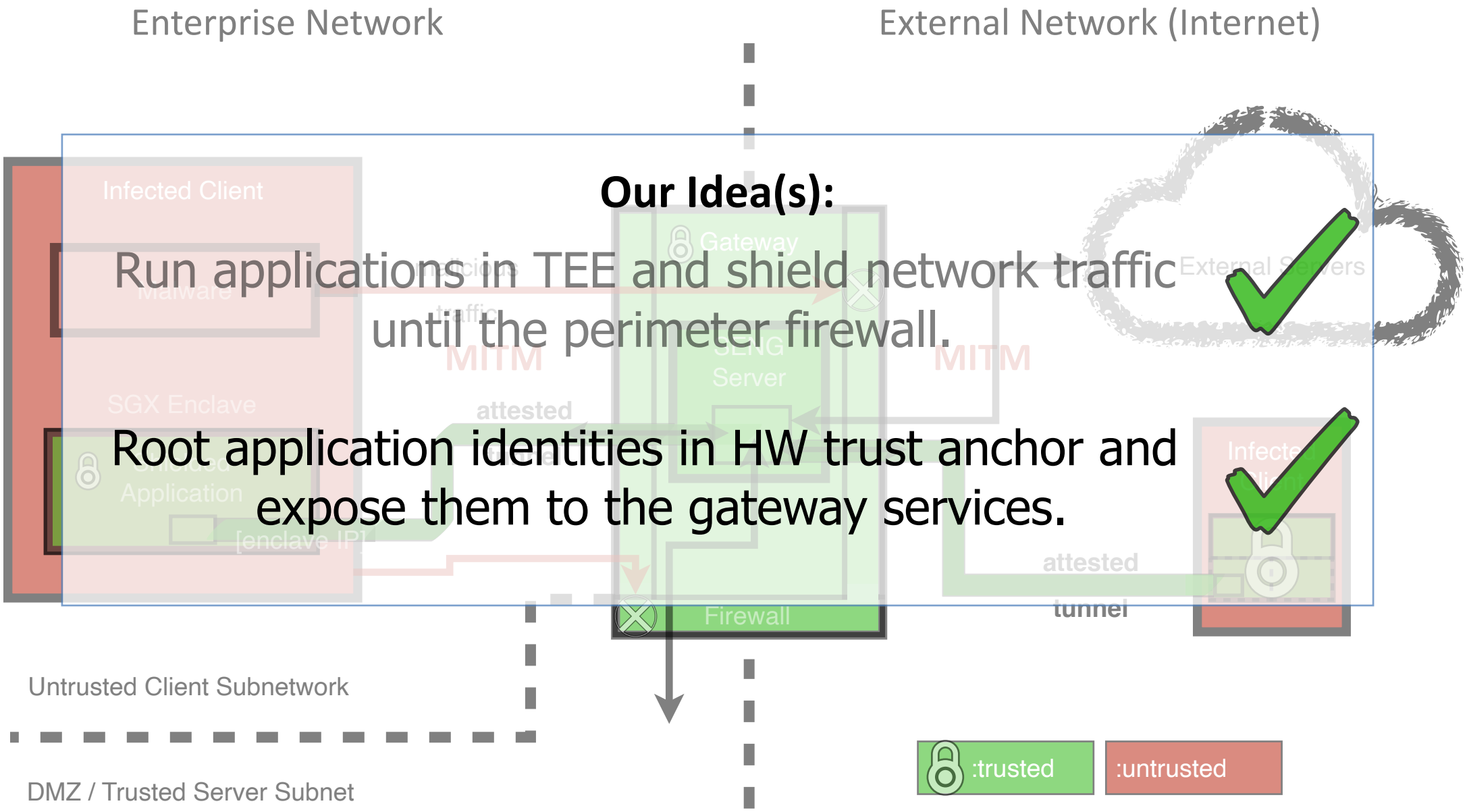

Our Idea(s):

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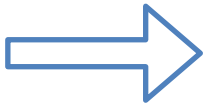
How to define and enforce per-application firewall rules?

SENG's Enclave Subnetworks: per-application firewall rules

"traditional" firewall rules

No.	**source**	destination	dst Port	…
1	$_workstations	**$_external**	443	…
2	$_workstations	**$_SQL_DB**	5432	…
3	**$_any**	$_FTP_Srv	989, 990	…



SENG's *per-application* rules (with enclave subnetworks)

No.	**source**	destination	dst Port	…
1	**$ws_Firefox72**	$_external	443	…
2	**$ws_psql_tls**	$_SQL_DB	5432	…
3	**$any_filezilla**	$_FTP_Srv	989, 990	…

Firewalls enforce SENG's per-application policies on the *application-specific subnetworks*.

SENG's Enclave Subnetworks: per-application firewall rules

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2	$_workstations	extPsqlDB	5432	…
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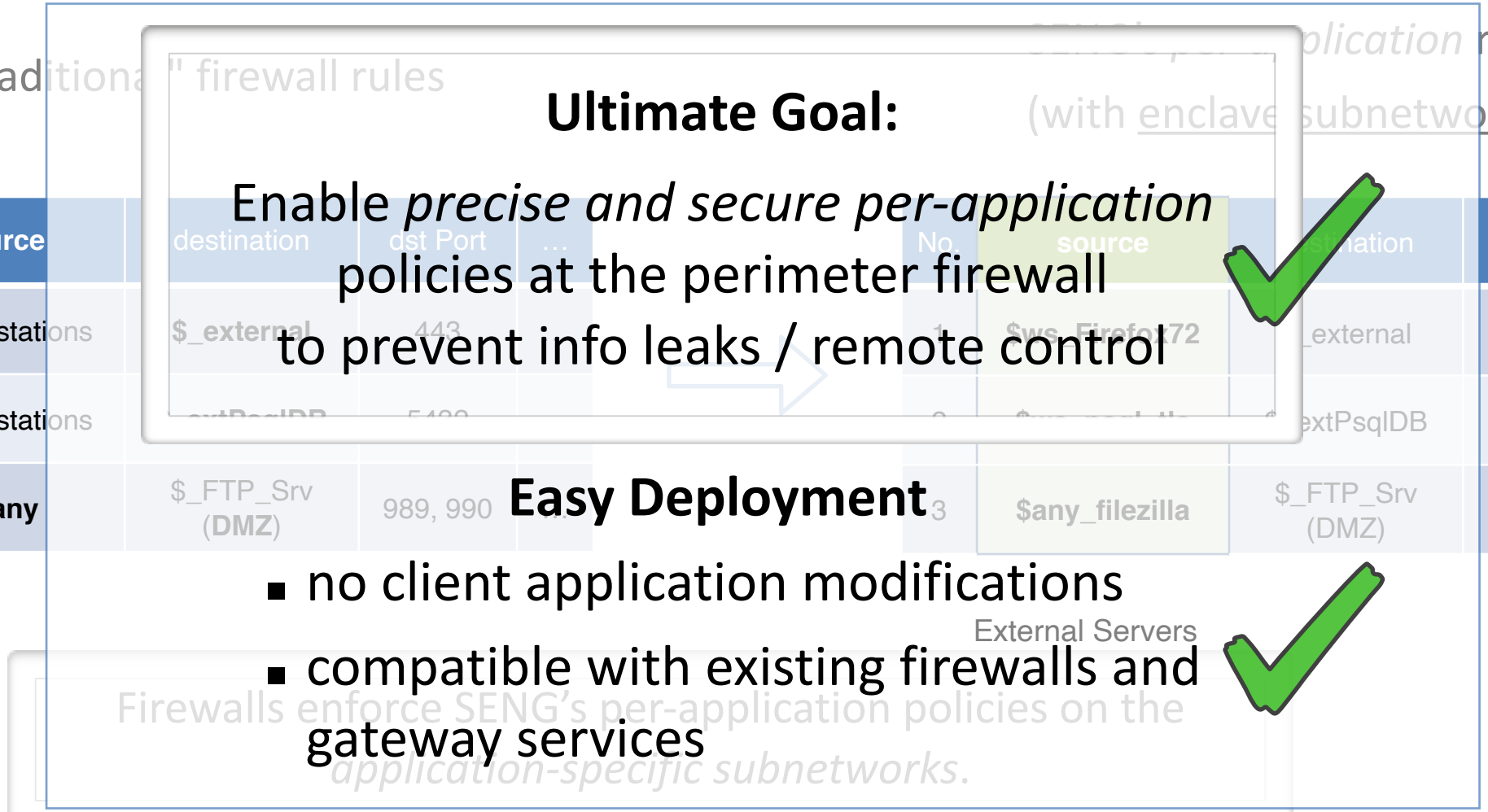


How does SENG perform compared … to Graphene-SGX? … to Native?

SENG Runtime Performance: Client Applications

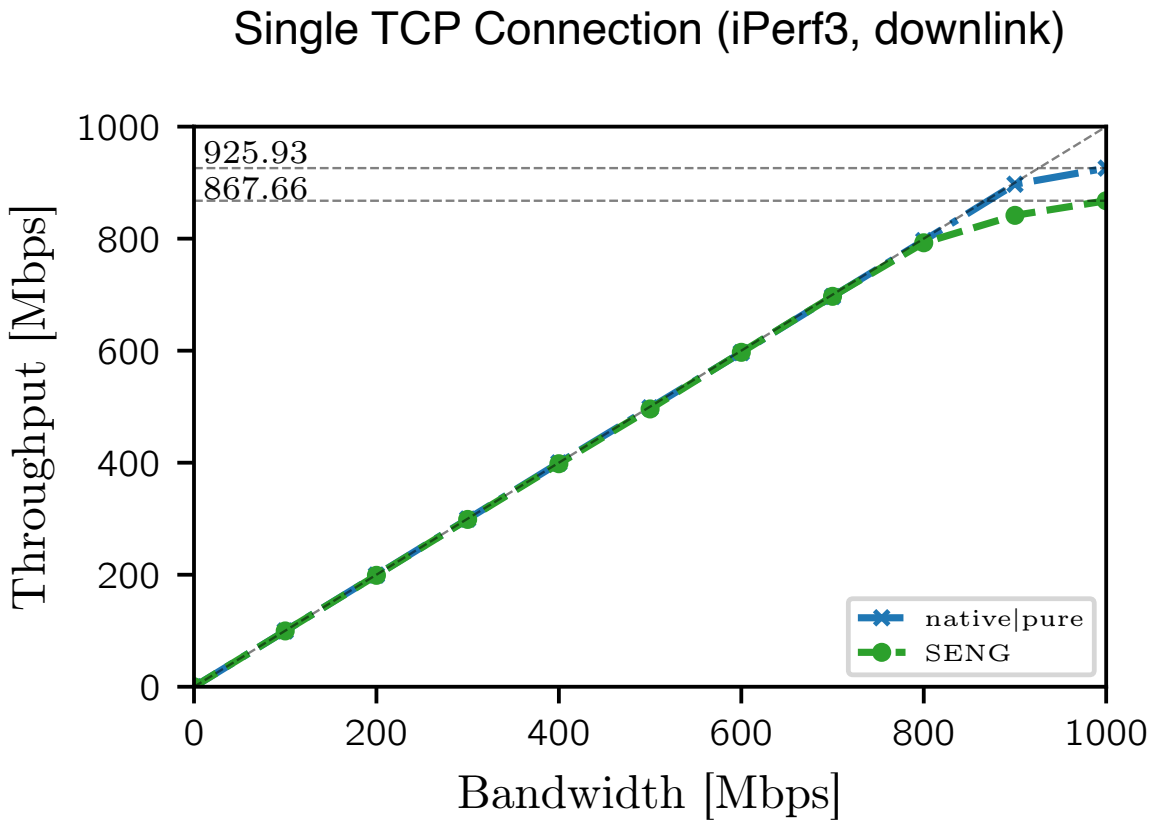
- "native": Linux native
- "pure": Graphene-SGX (LibOS)
- local setup, 1 Gbps LAN

<u>TCP throughput</u> (iPerf3):

- native == pure (avg. ~ 926 Mbps)
- SENG: ~ 93 - 97 % (avg. ~ 868 Mbps)

<u>HTTP download</u> (cURL):

- SENG: 8.8 - 14.1 % overhead (< 1sec)
- (files: 1 MB, 10 MB, …, 1 GB)



NGINX Server Application: SENG Runtime performance

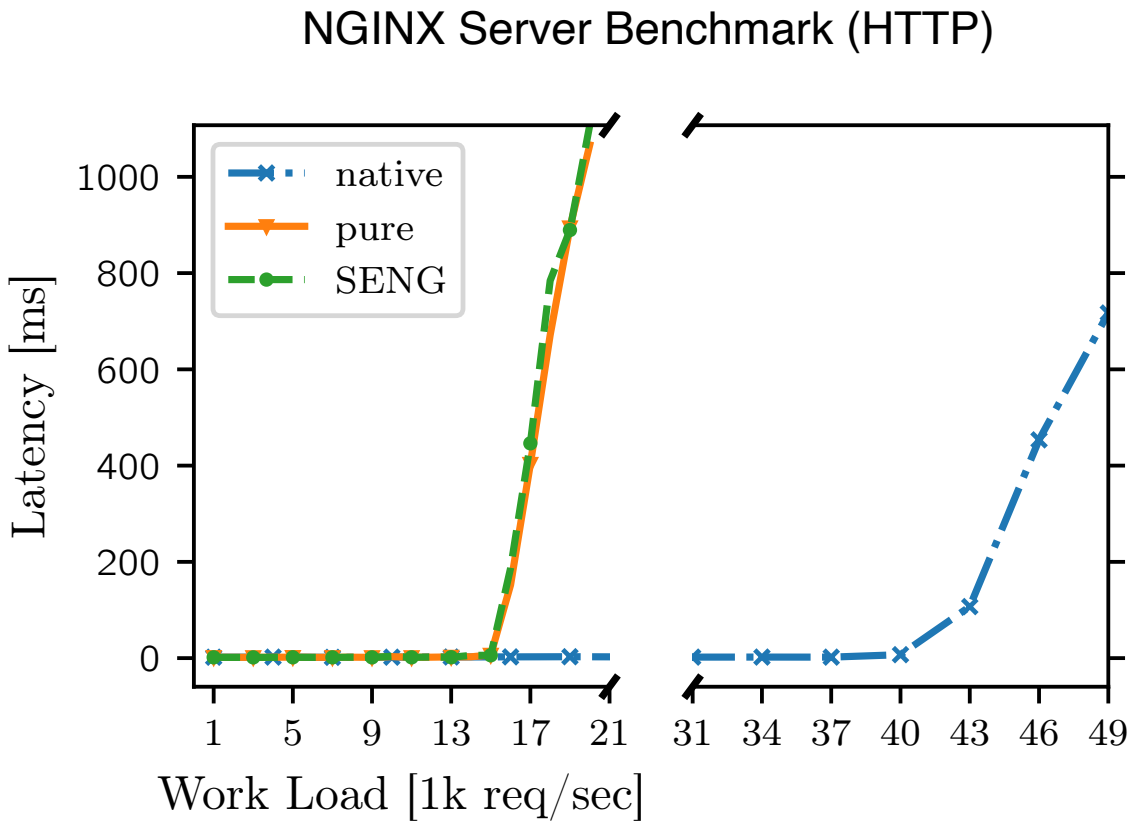
HTTP response latency (NGINX):

- app: NGINX, bench with wrk2
- native: ~ 40k req/sec
- SENG/pure: ~15k req/sec (~ 37.5% of native)

Problem:

Graphene-SGX (our version) only supports **synchronous syscalls, no batch mode**

==> Will faster primitives help?



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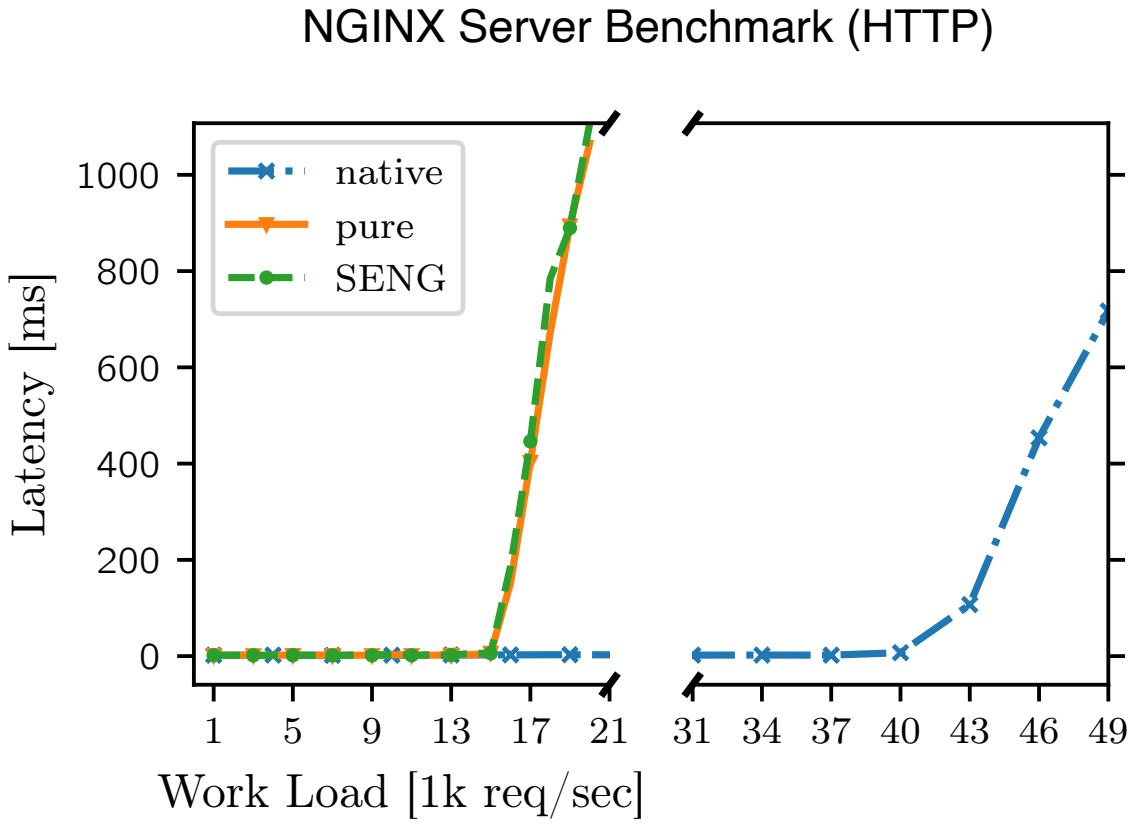

NGINX Server Application: SENG SDK (w/o LibOS)

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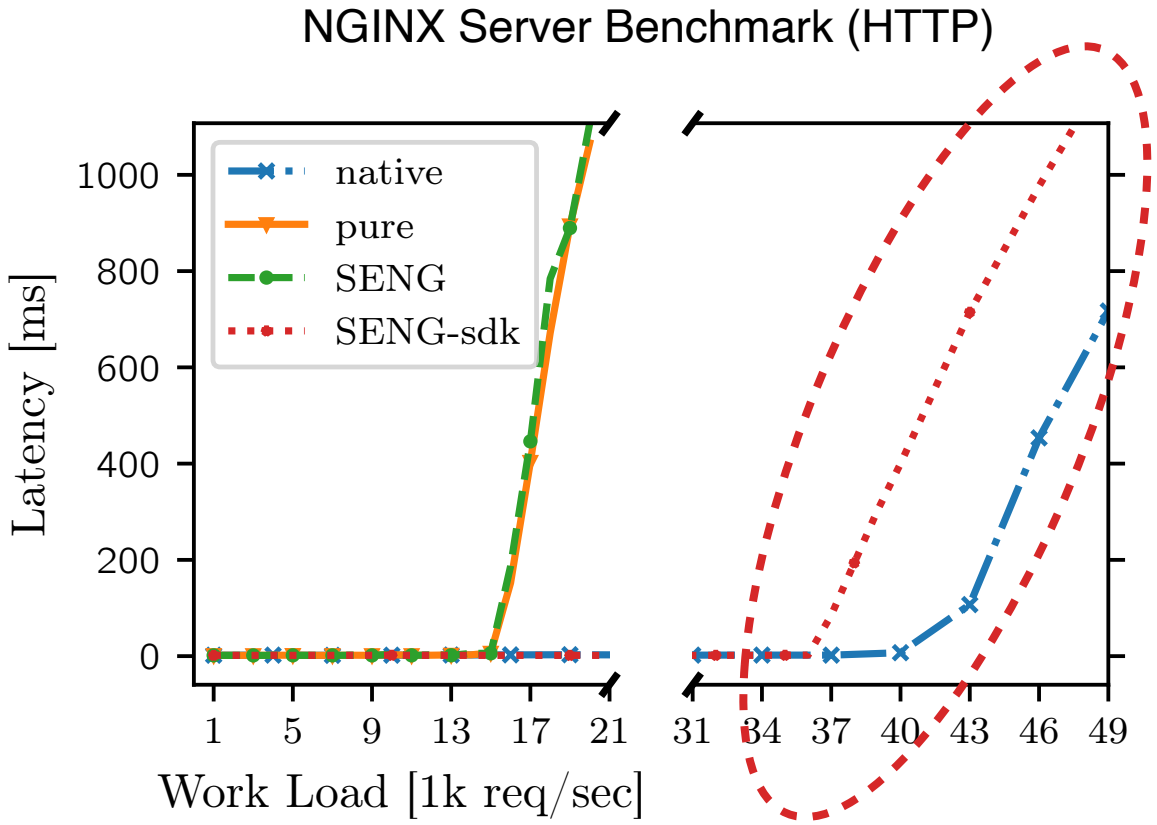
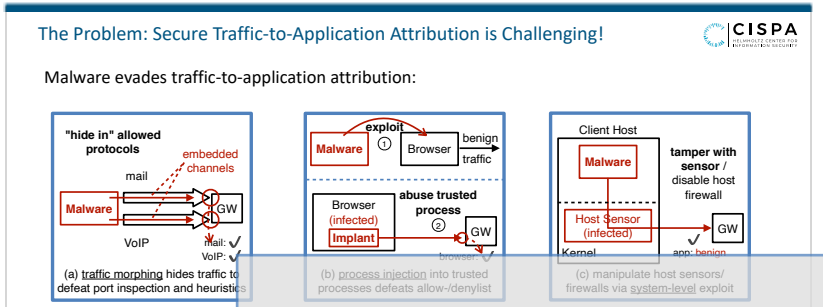
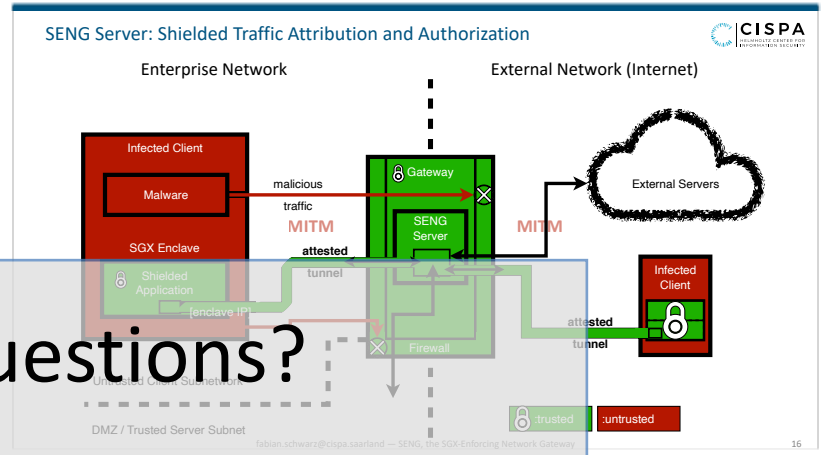


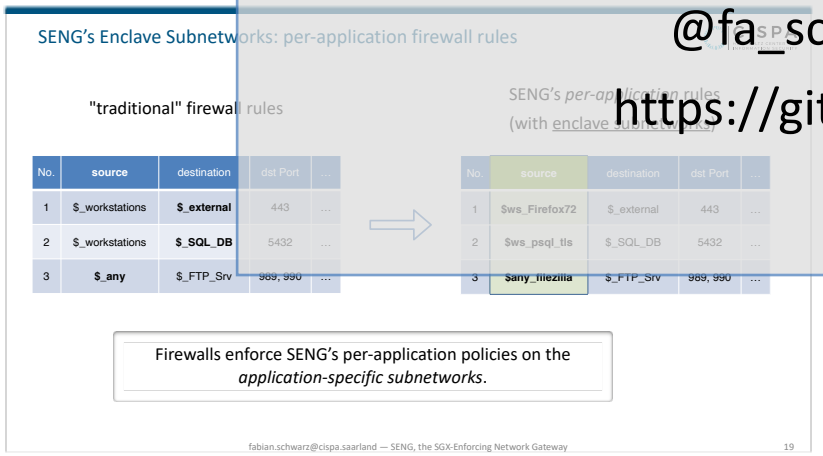
SENG SDK ("SENG-sdk"):

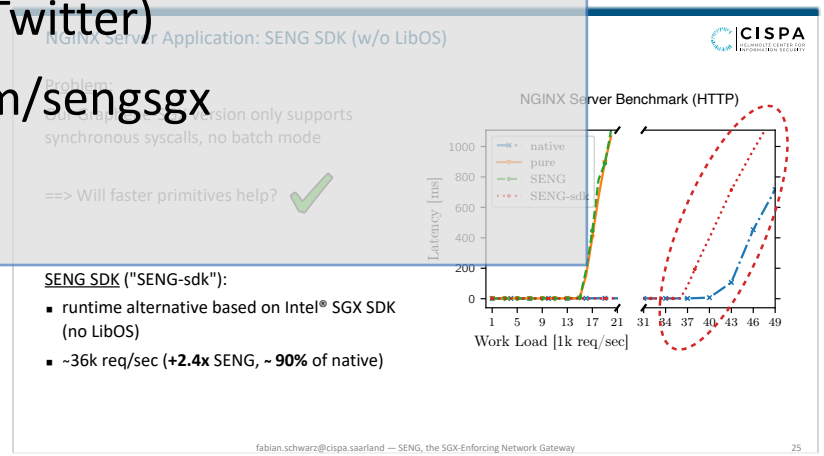
- runtime alternative based on Intel® SGX SDK (no LibOS)
- ~36k req/sec (**+2.4x** SENG, **~ 90%** of native)

Summary: SENG, the SGX-Enforcing Network Gateway









Thank you! Questions?

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@fa_schwarz (Twitter)

https://github.com/sengsgx