

## TrustVisor: Efficient TCB Reduction and Attestation

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## Motivating Example

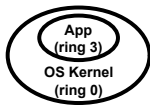
- Conscientious web server admin / dev
- Wants to protect most critical data
  - SSL private key, password file, ACL, ...
- Evaluates low-cost options
- Her best efforts rest on a house of cards...



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## Challenge: Reducing the Trusted Computing Base

- Today's OSES have too much power
- Total access to application data



- App may require little OS support
  - Self-contained computation 'S'
- Trusted computing base for S includes majority of: OS, drivers, and privileged applications!!!

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## What is S?

- Self-contained code in an application
- Data secrecy and integrity requirements
- General-purpose computing
- Some examples
  - Manages a private key for web server or CA
  - Manages Access Control List (ACL)
  - Is a compute client in distributed setting
  - Is similar to a Flickr session [McPaPeReIs2008]

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## Outline

- Motivation (done)
- **High-Level Overview**
- Detailed Description
- Prototype: Apache + SSL
- Limitations
- Summary & Conclusions

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## Meet TrustVisor

- Tiny hypervisor for isolation of code S
  - No scheduling or Inter-Process Communication
- Efficient transitions between OS and S
- External verification of Output = S(Input)
- Protected storage for S



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### External Verification: Attestation

Verifier → What code are you running? → Target

$$\text{Sign} \left( \underset{\text{TrustVisor}}{S}, \text{Inputs}, \text{Outputs}, K^{-1} \right)$$

- Trust in attestation rooted in hardware TPM (Trusted Platform Module)
- SSL-enabled web server scenario:
  - Client can evaluate server before sending data
  - Enables more meaningful SSL server validation

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### Protected Storage

- Initially, S is “red” (untrusted)
- App can register S → “blue” (attestable)
- TV enables “blue” code to protect data...

- Access-controlled by **identity** of S (hash)
- Enabled by TPM-like Sealed Storage
- “Micro-TPM” in software

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### Alternative Approaches

Approach	Metric	TCB Size (LoC)	Protection granularity	Performance
Monolithic kernel		millions	–	best
Virtualization		millions	VM	good
Virtual TPM (vTPM)		millions	consistent code	good
Overshadow etc.		millions	process	good
Security / μ kernel		~100K	process	moderate
Flicker		<1K	fine	poor
<b>TrustVisor</b>		<10K	fine	good

TrustVisor runtime TCB in lines of code:

- ~6500 C/ASM + ~2800 Headers
- Hypervisor + crypto

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### TrustVisor ↔ OS Architecture

TrustVisor:

- Virtualizes RAM, CPU
- Restricts DMA
- Restricts TPM to Locality 1

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### TrustVisor ↔ S Architecture

TrustVisor API

- Registration
- Invocation
- Micro-TPM

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## Identifying S to TrustVisor

- Applications identify S via **registration**
  - Page-level protection granularity
- Applications make “normal” function calls
  - TrustVisor detects switch to S via traps
- S runs with no access to legacy OS
  - One set of Inputs and Outputs per **invocation**

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## Sensitive Code Timeline

Multiple **invocations** during a single **registration** cycle

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## Micro-TPM Design

- Small subset of hardware TPM operations for:
  - Protected Storage + External Verification
- TPMs are optimized for cost, not speed
- TrustVisor implements critical-path TPM operations in software on main CPU
  - Extend, Seal, Unseal, Quote, GetRand
  - Reduces latency by **orders of magnitude**
- Trust in Micro-TPM still rooted in hardware TPM
- Infrequent TPM operations do not require virtualization

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## Example App: Apache + SSL

- Goal: Protect long-term private key  $K_{SSL}^{-1}$ 
  - Cert revocation is abysmal in practice
- Desired properties
  - Malware, malicious admin unable to learn  $K_{SSL}^{-1}$
  - Externally verifiable configuration
- Two sensitive code modules (S)
  - S1: Generate and seal the long-term key (**rare**)
  - S2: Unseal and use the key during SSL session establishment (**frequent**)



**Apache**  
HTTP SERVER PROJECT

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## Apache + SSL Performance

- ‘ab’ with 10,000 txns / trial, avg 10 trials

200 Concurrent Transactions

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## Outline

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- High-Level Overview (done)
- Detailed Description (done)
- Prototype: Apache + SSL (done)
- **Limitations**
- **Summary & Conclusions**

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## Limitations

- Design-level
  - Does not currently provide trusted path to user
  - Requires application awareness
- Prototype-level
  - No SMP support (currently single CPU)
  - Only protects  $K_{SSL}^{-1}$
  - Executable code for S must be proactively paged into memory before registration
  - AMD-only

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## Summary & Conclusions

- Tiny hypervisor to support isolation
- Externally verifiable via attestation
- Frequent TPM operations in software
- Compelling performance argument
- Requires no OS changes
- Conclusions
  - Interesting point in the design space
  - Foundation for future trustworthy systems

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## Q & A

- Thank you!
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