Architectural Attacks
and their
Mitigation by Binary Transformation

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Joint work with

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(attacks)

and

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Austin Chu

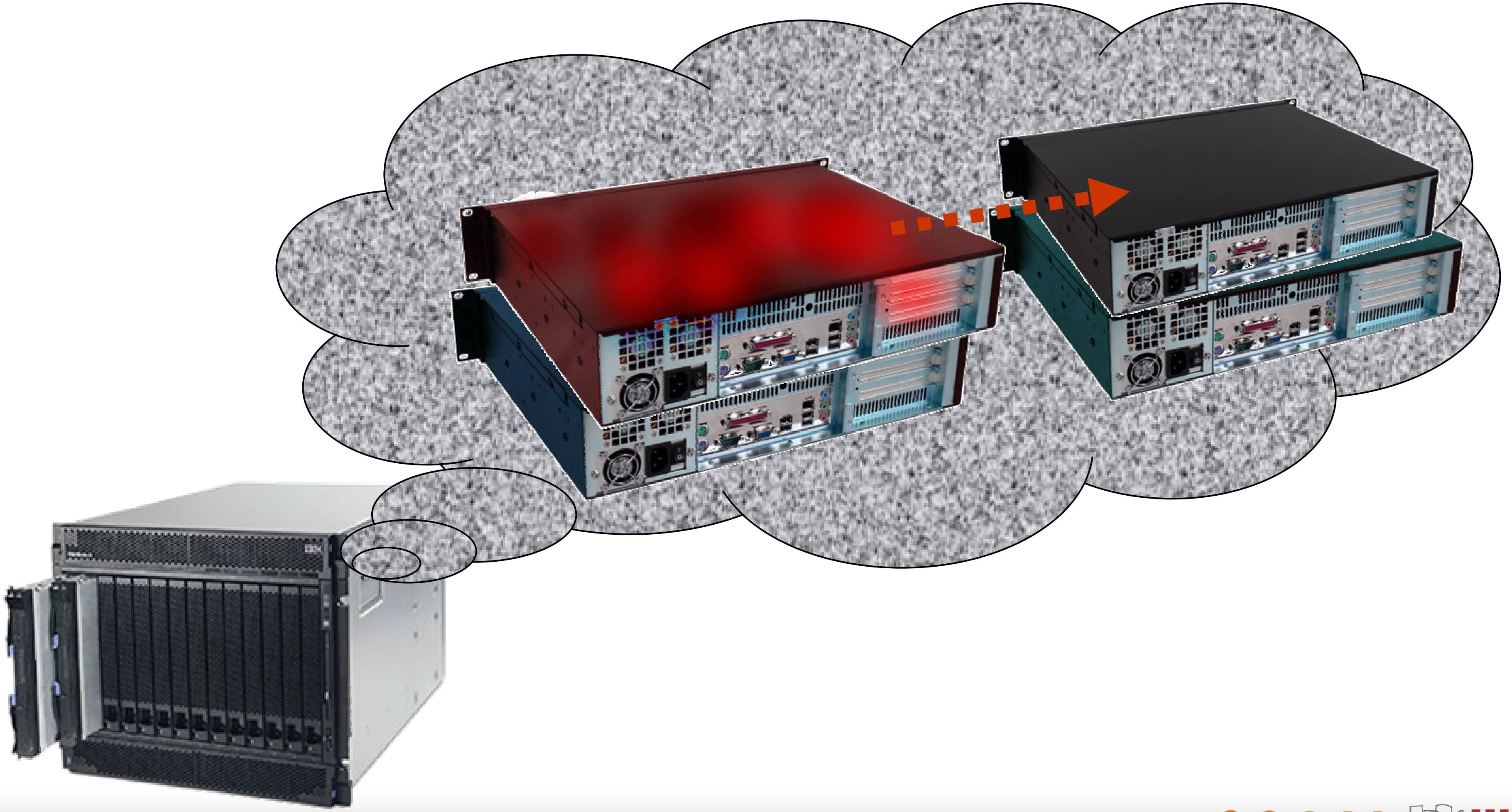
Ronald Rivest

Qin Zhao

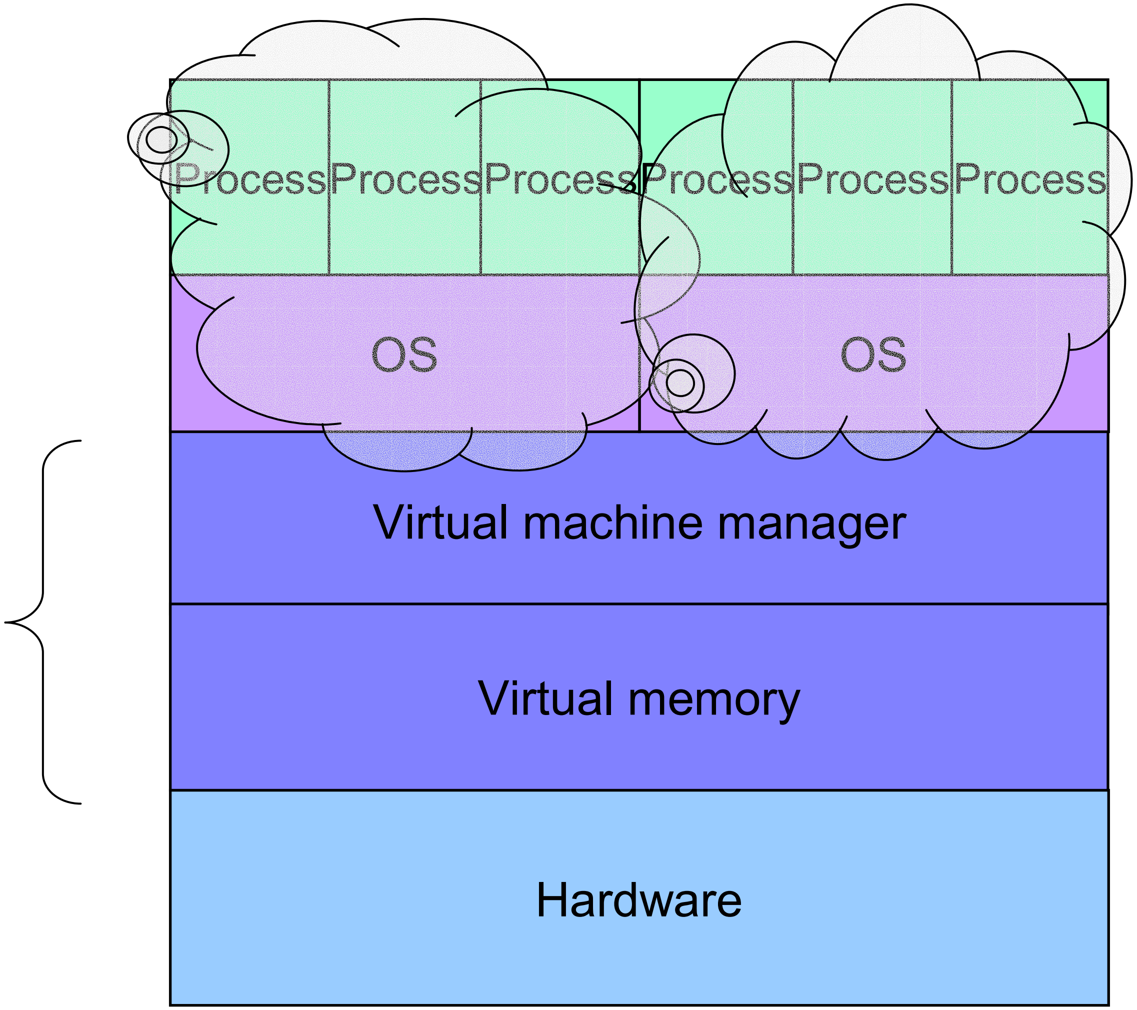
(mitigation)

Security of virtualization in cloud computing

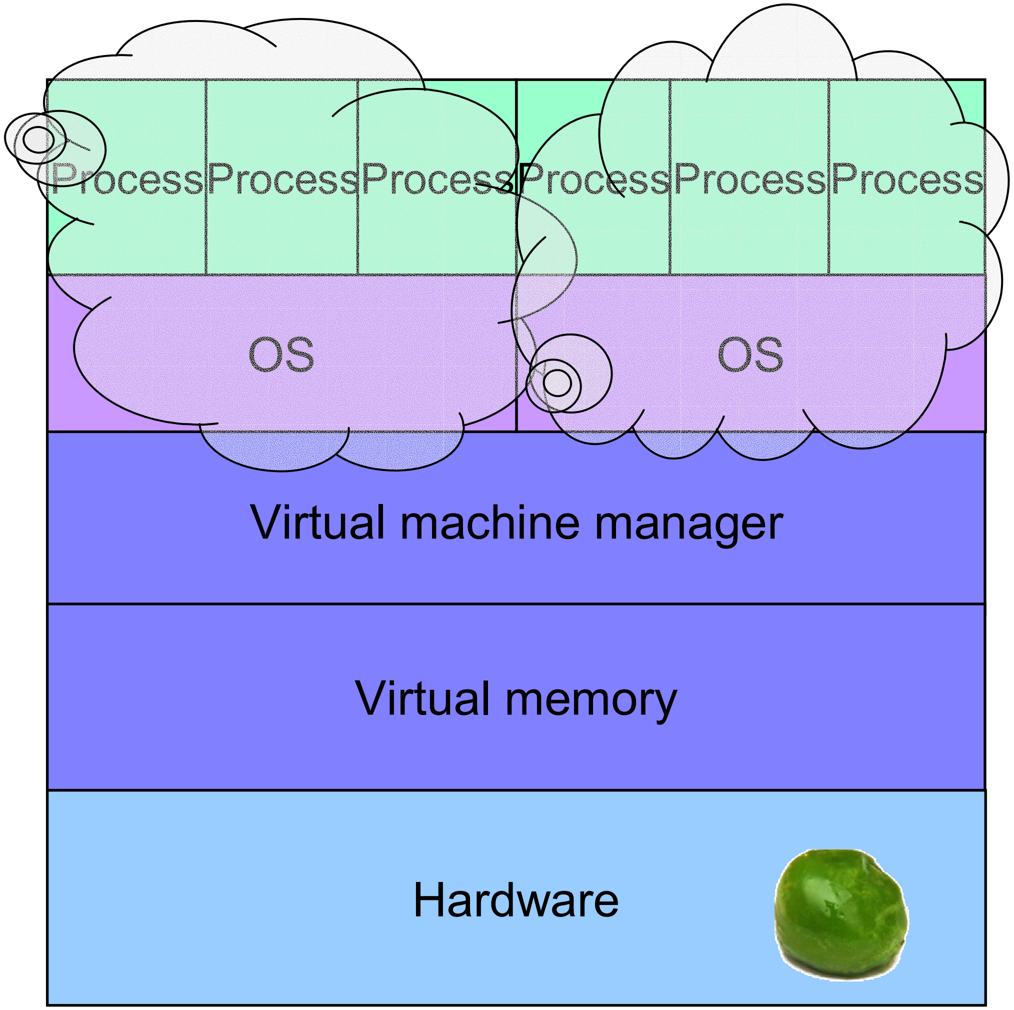
What if someone running on the shared hardware is malicious?



Virtualization

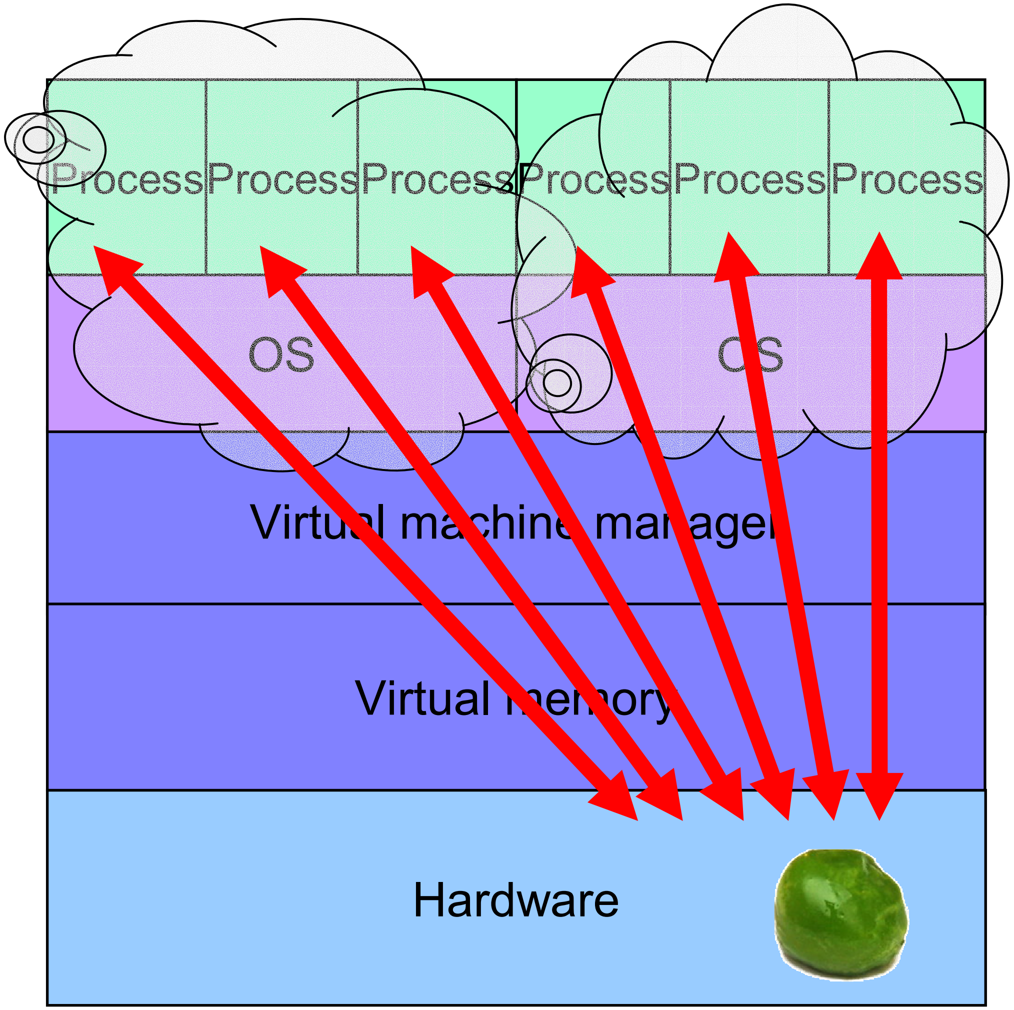


Cross-talk through architectural channels



Cross-talk through architectural channels

- Contention for shared hardware resources



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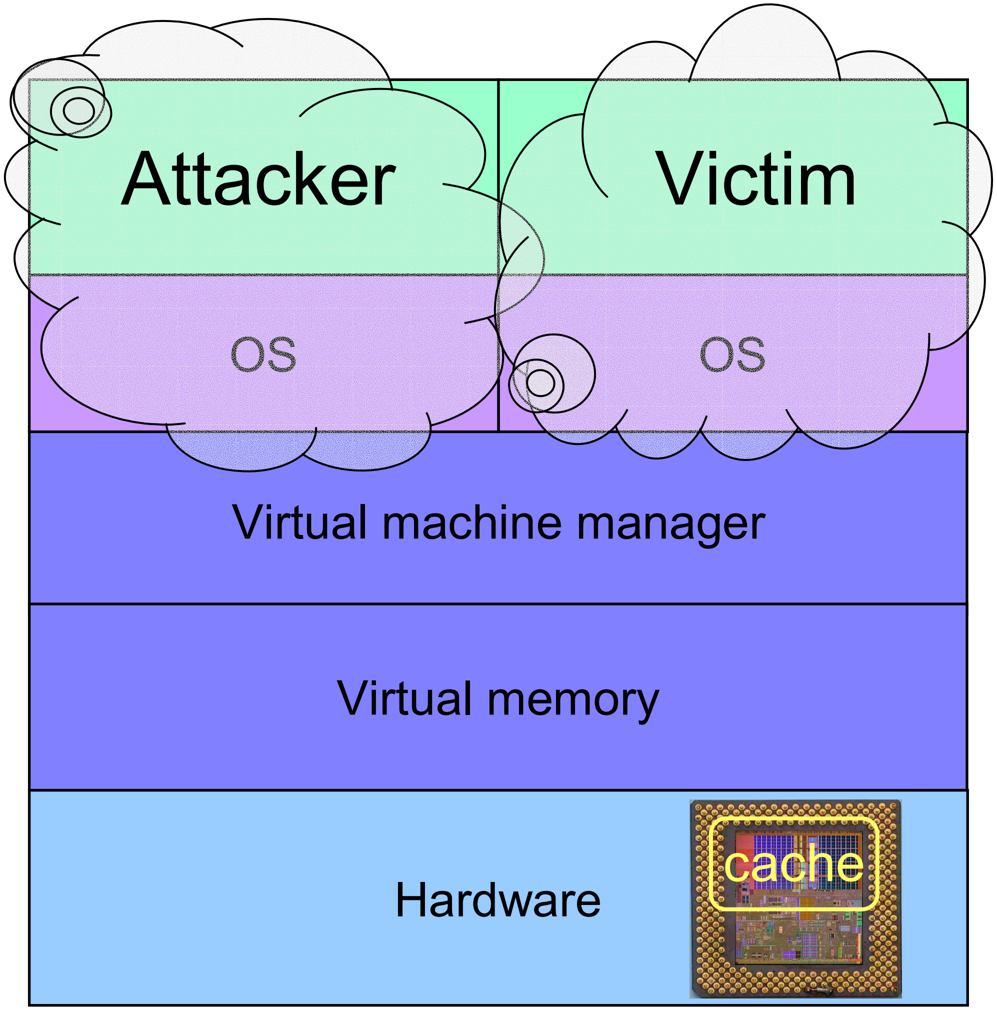
- Example: contention for CPU data cache



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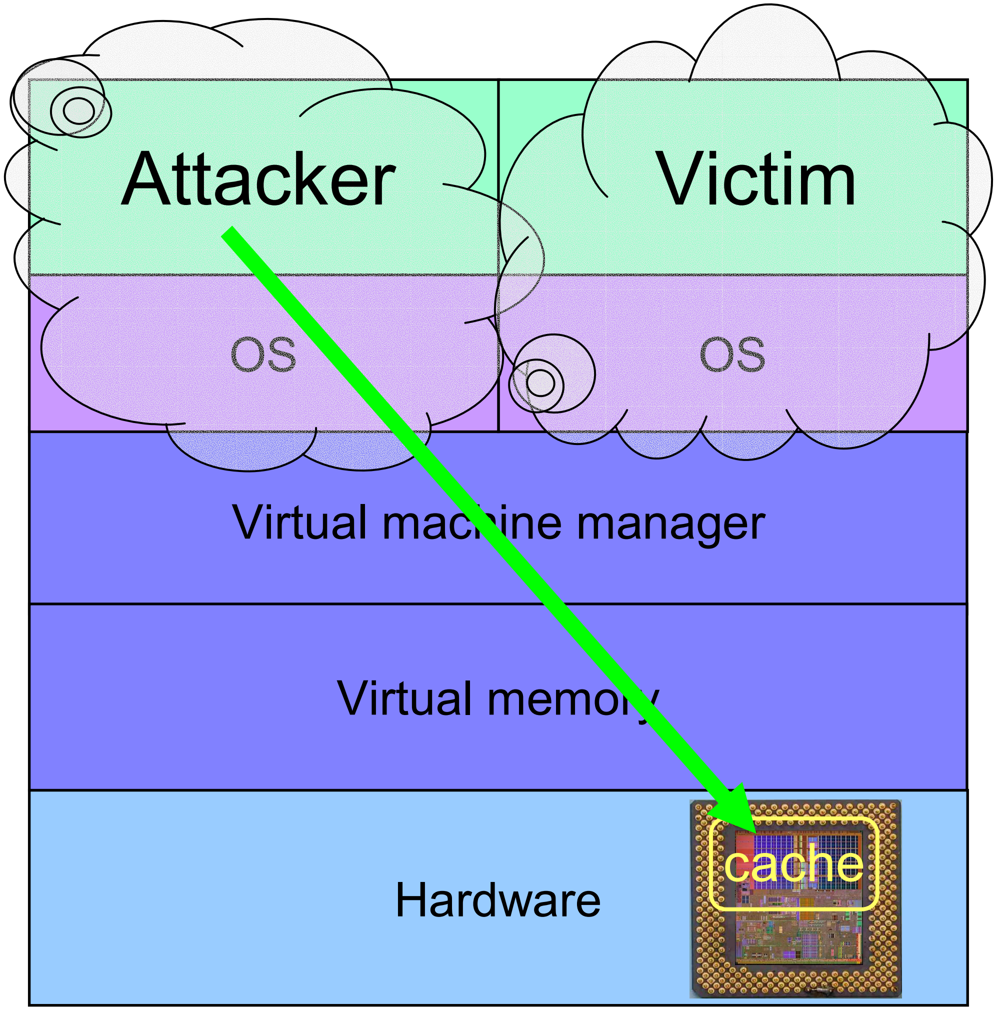

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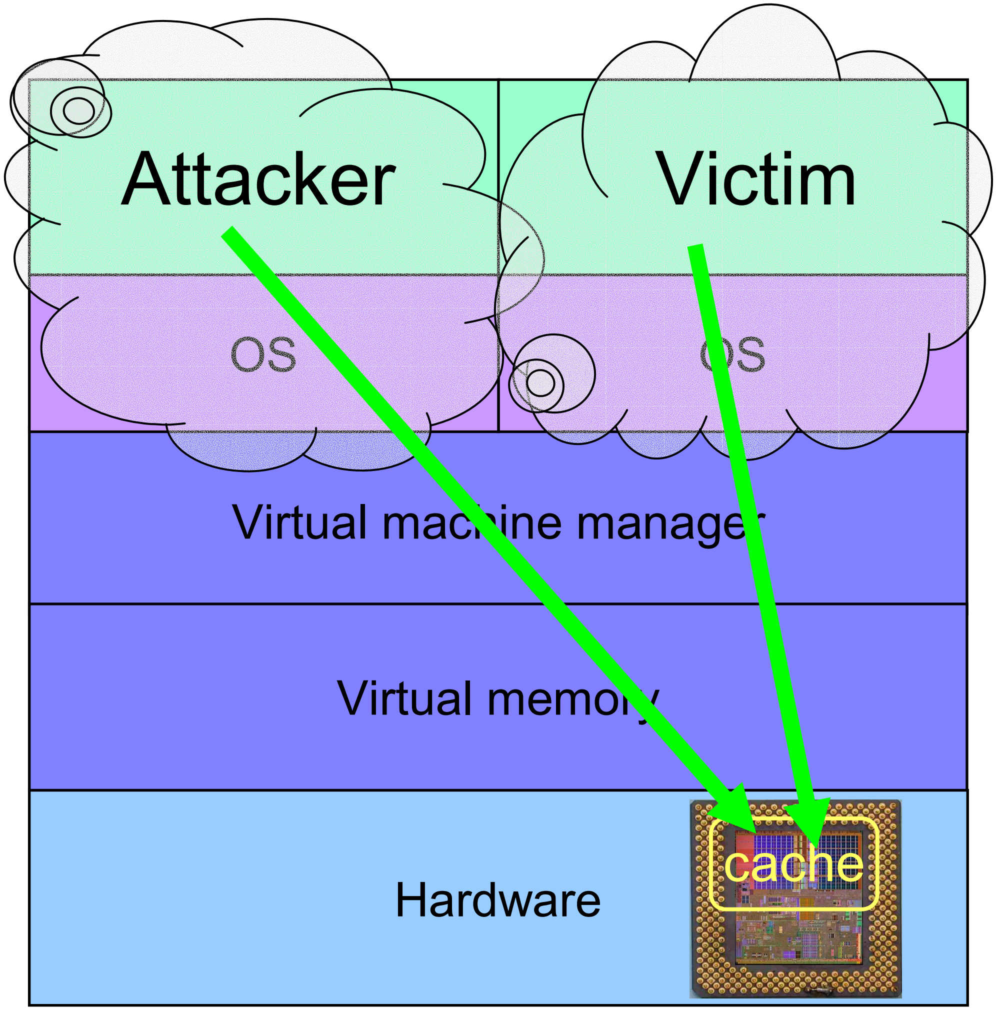

Cross-talk through architectural channels

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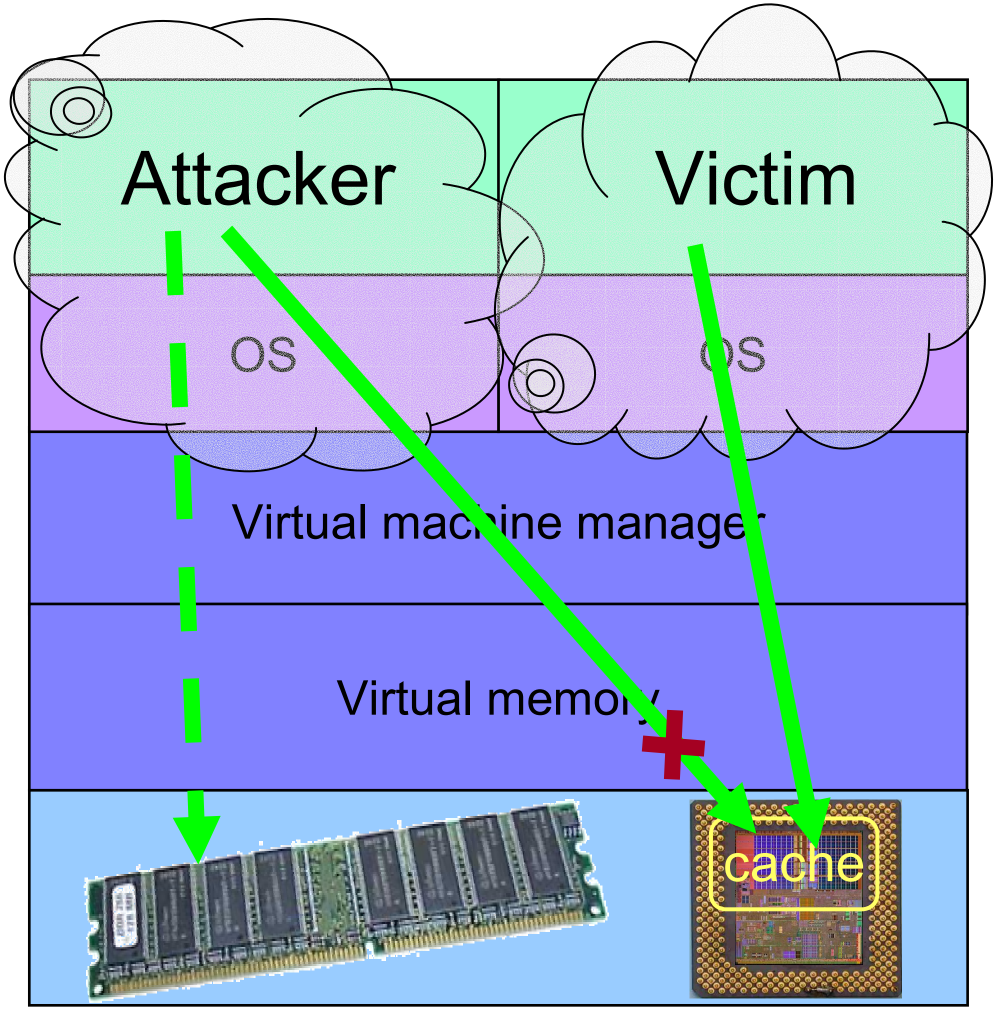
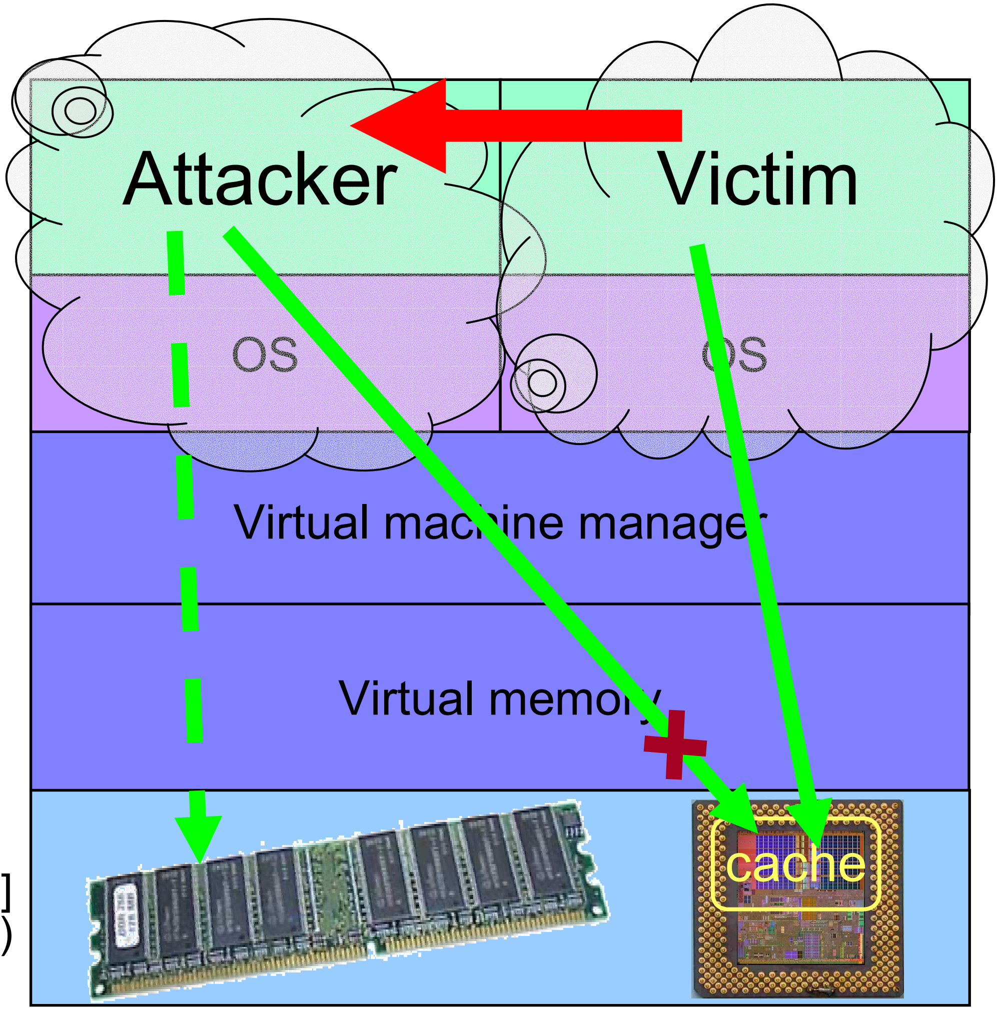
- Example: contention for CPU data cache leaks memory access patterns (timing + address)



Cross-talk through architectural channels

- Contention for shared hardware resources
- Example: contention for CPU data cache leaks memory access patterns (timing + address)
- This is sensitive information!
- Example:
  Steal encryption keys in 65ms from OS kernel

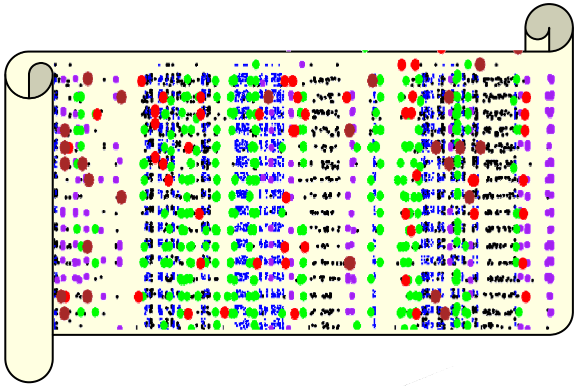
[Osvik Shamir Tromer 05]
(non-virtualized process vs. kernel)



Hey, You, Get Off of My Cloud! Exploring Information Leakage in Third-Party Compute Clouds

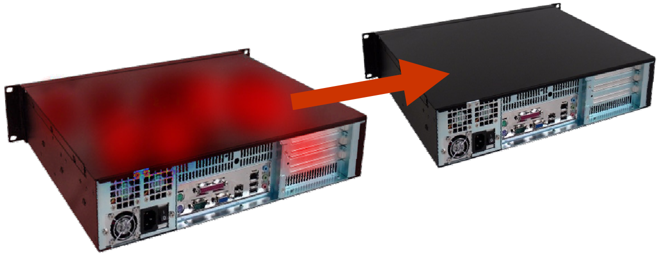
[Ristenpart Tromer Shacham Savage 09]

Demonstrated, using Amazon EC2 as a study case:



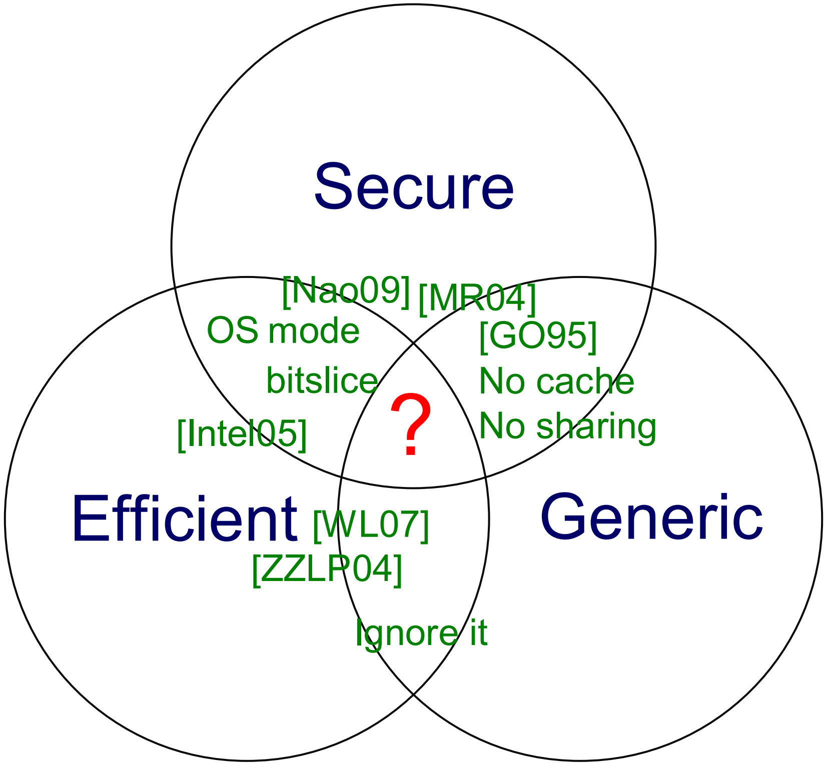
- Cloud cartography
  Mapping the structure of the “cloud” and locating a target on the map.
- Placement vulnerabilities
  An attacker can place his VM on the same physical machine as a target VM (40% success for a few dollars).

- Cross-VM exfiltration
  Once VMs are co-resident, information can be exfiltrated across VM boundary.
  → covert channels
  → keystroke timing eavesdropping
  → password theft [Song Wagner Tian 01]



All via standard customer capabilities, using our own VMs to simulate targets.
We believe these vulnerabilities are general and apply to most vendors.

Countermeasures?



DynamoREA

[Amarasinghe Chu Rivest Tromer]

Dynamic Runtime Enforcement of Abstraction

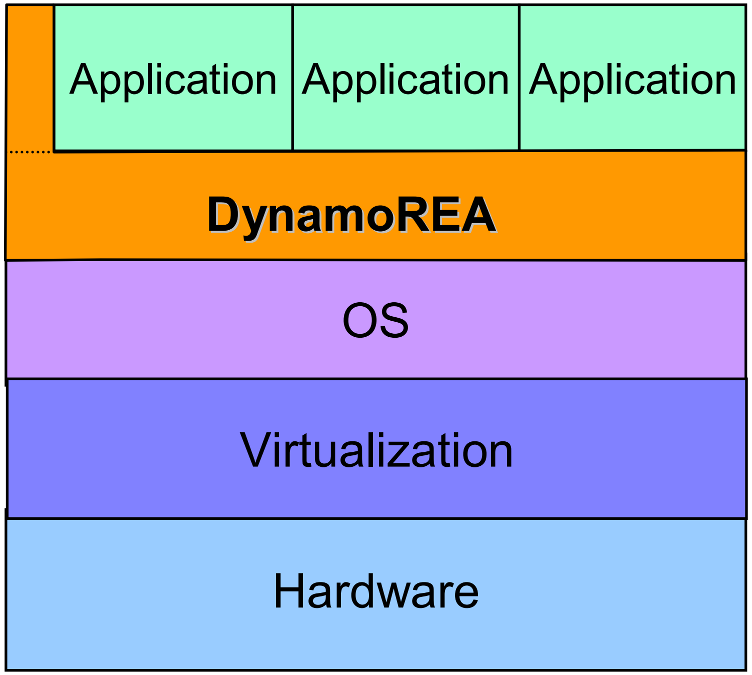
Approach:
Dynamic binary rewriting

Transform x86 instructions on-the-fly to eliminate information flow through architectural effects.

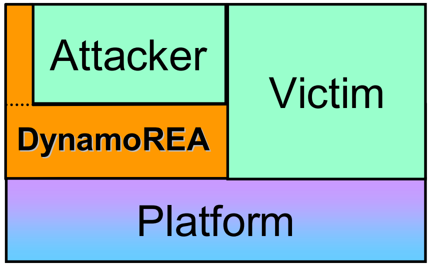
Supports common apps on COTS platforms (Linux x86).

Tool: VMware's DynamoRIO.
Observe and modify:

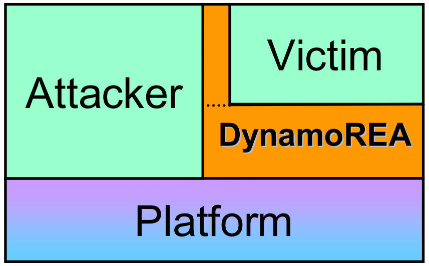
- instructions
- memory management
- I/O
- system calls



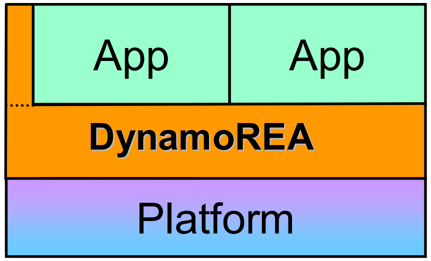
DynamoREA transformations



Example:
Degrade observation of timing



Example:
Inject noise/delays to hide leakage signal



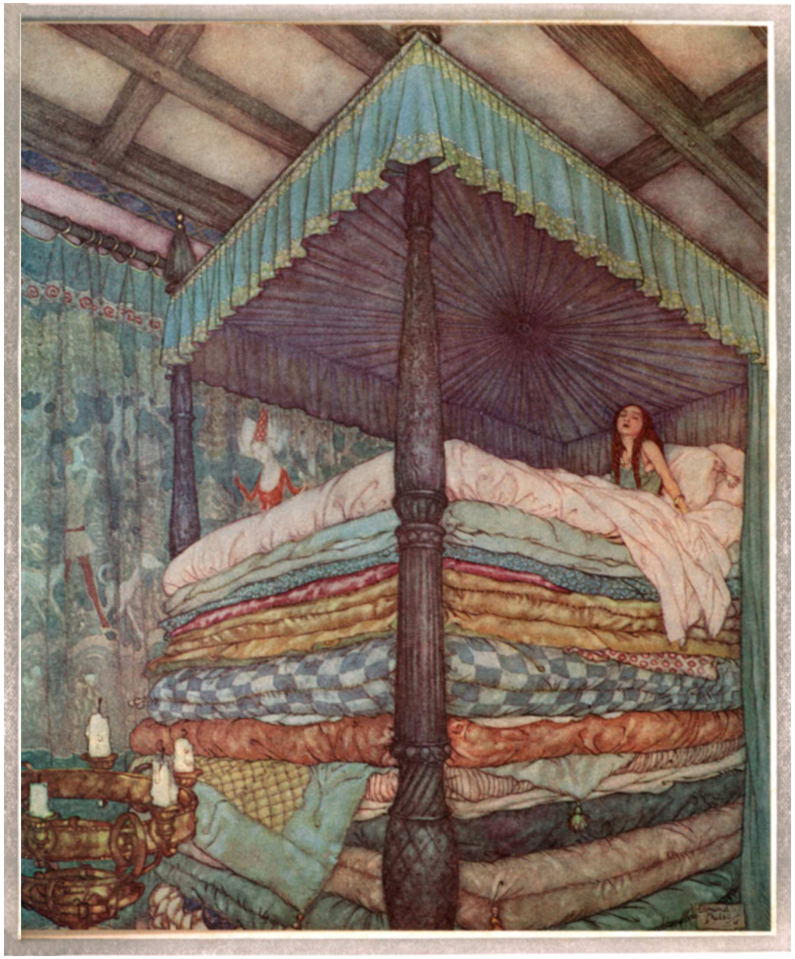
General:
Make execution a deterministic function of what the process knows anyway
→ indistinguishable from a **leak-free system**
→ attacker learns nothing

DynamoREA

- Goal:
  Securely run existing apps
  on leaky platforms.

- Methodology:
  - **Secure by default.**
  - Optimize handling of common cases for efficiency.

- Currently:
  Proof-of-concept prototype.
  Keep posted!



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