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Policy-Sealed Data:
A New Abstraction for Building Trusted Cloud Services

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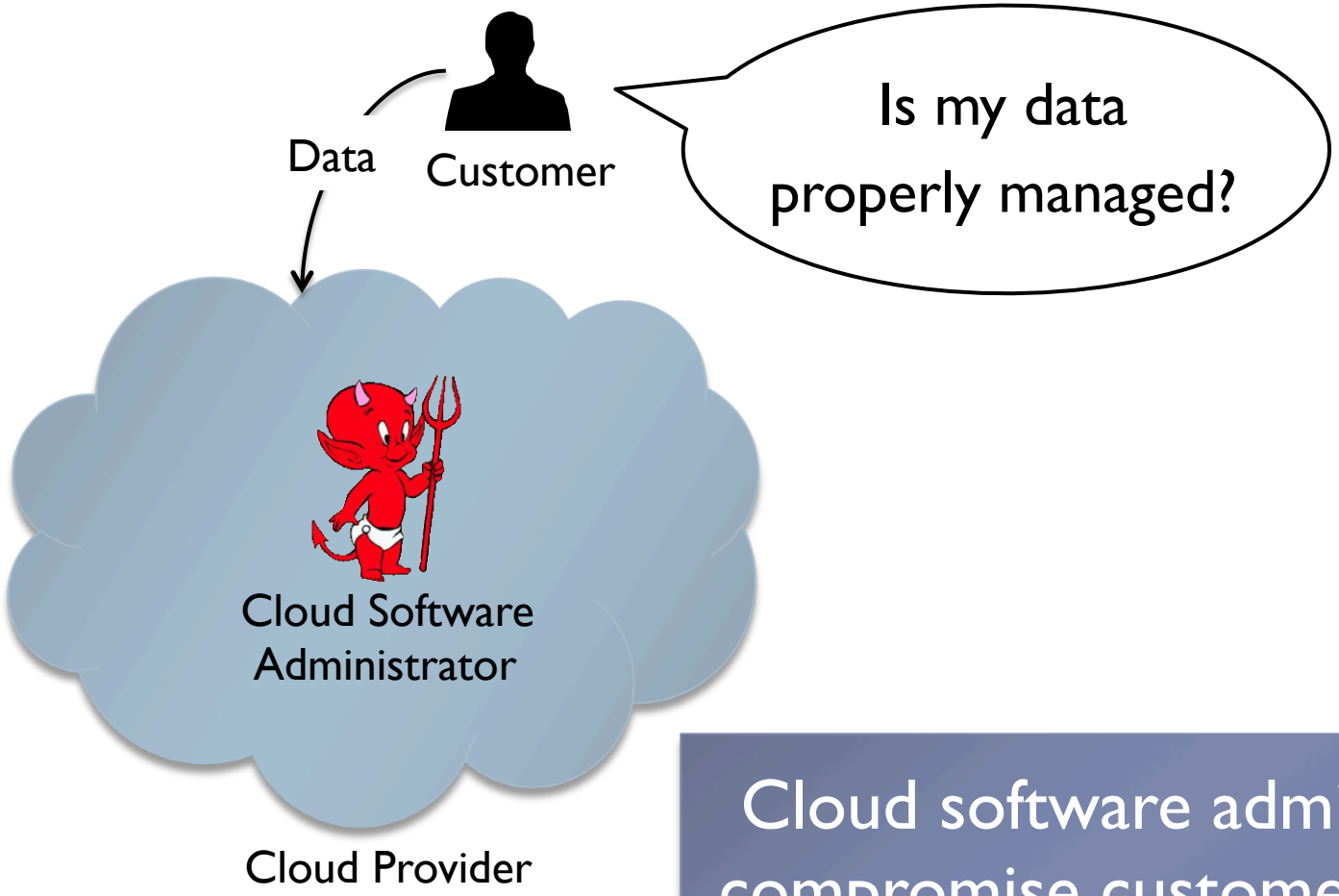
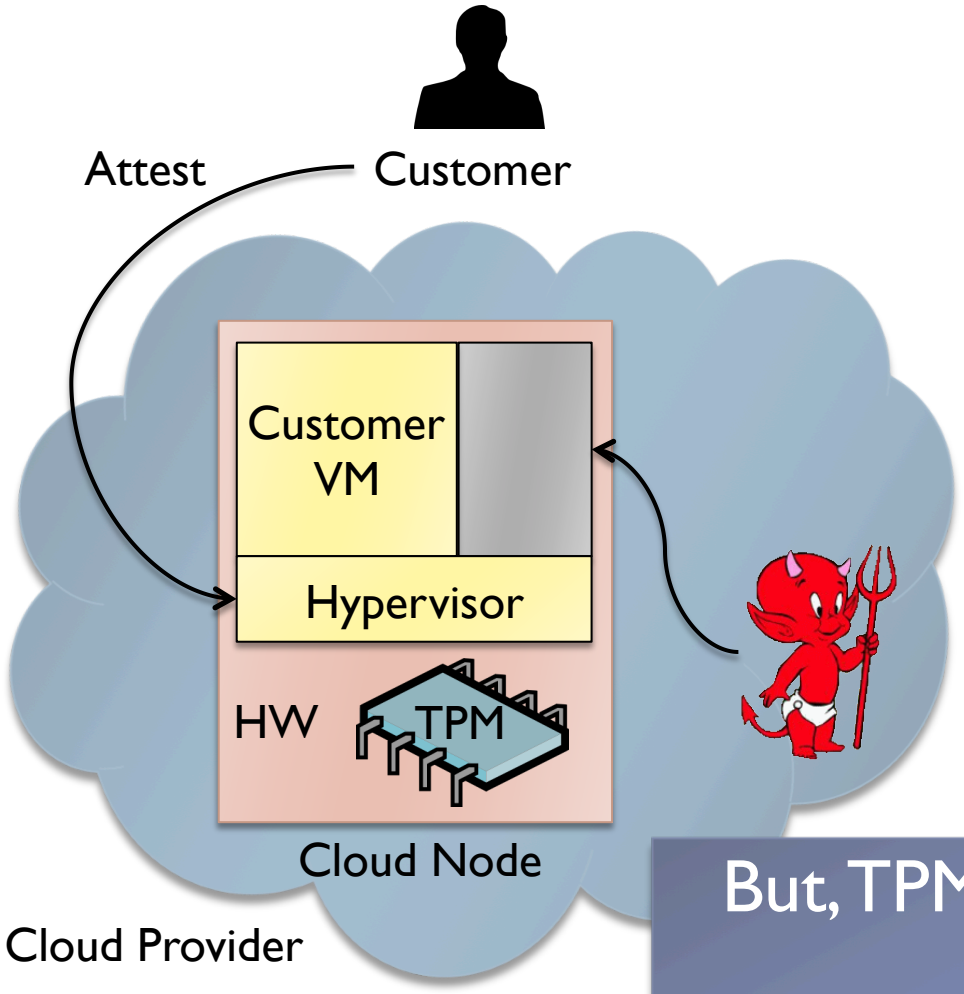
Managing the Cloud is Complex & Error-Prone



Cloud software admins. can compromise customers' data

Trusted Computing Can Help Mitigate Threats



1. Newer hypervisors can offer protection from SW admins.
   - e.g., nested virtualization: CloudVisor [SOSP'11], Credo [MSR-TR]

2. Trusted computing can attest cloud node runs "correct" hypervisor
   - Trusted Platform Module (TPM)

But, TPMs alone ill-suited for the cloud

TPMs Alone Are Ill-Suited for the Cloud

1. Stifle VM and data migration across cloud nodes
   - TPMs root-of-trust not transferable from one node to another

2. Cloud providers hesitant to reveal low-level cloud details
   - TPMs abstractions can reveal node's identity and details of the node's entire software stack

3. Commodity TPMs can hinder the cloud's ability to scale
   - TPMs' poor performance may introduce bottlenecks

Our Contributions

1. Policy-sealed data abstraction
   - Data is handled only by nodes satisfying customer-chosen policy
   - Examples:
     - Handle data only by nodes running CloudVisor
     - Handle data only by nodes located in the EU

2. Use attribute-based encryption (CP-ABE) to implement abstraction efficiently
   - Binds policies and node attributes to node configurations
   - Ciphertext-Policy Attribute-Based Encryption [Bethencourt07]

Excalibur incorporates both contributions

Excalibur Addresses TPM Limitations in Cloud

Policy-sealed data

- Enables flexible data migration across cloud nodes
  - Customer data accessible to any node that satisfies the customer policy
- Hides node's identities and low-level details of the software
  - Only high-level attributes are revealed

Attribute-based encryption

- Masks TPMs' poor performance
  - Enforcing policies does not require direct calls to TPMs

Outline

- ~~Introduction~~
- Threat model
- Policy-sealed data
- Design
  - Monitor
  - CP-ABE
- Evaluation

Threat Model

The attacker can…

- configure nodes remotely
  - reboot nodes
  - install software platform
  - access disk
  - eavesdrop network

The attacker cannot…

- perform physical attacks
  - e.g., scrape TPMs to learn its secrets
- compromise system's TCB
  - monitor
  - secure hypervisor
- compromise CP-ABE

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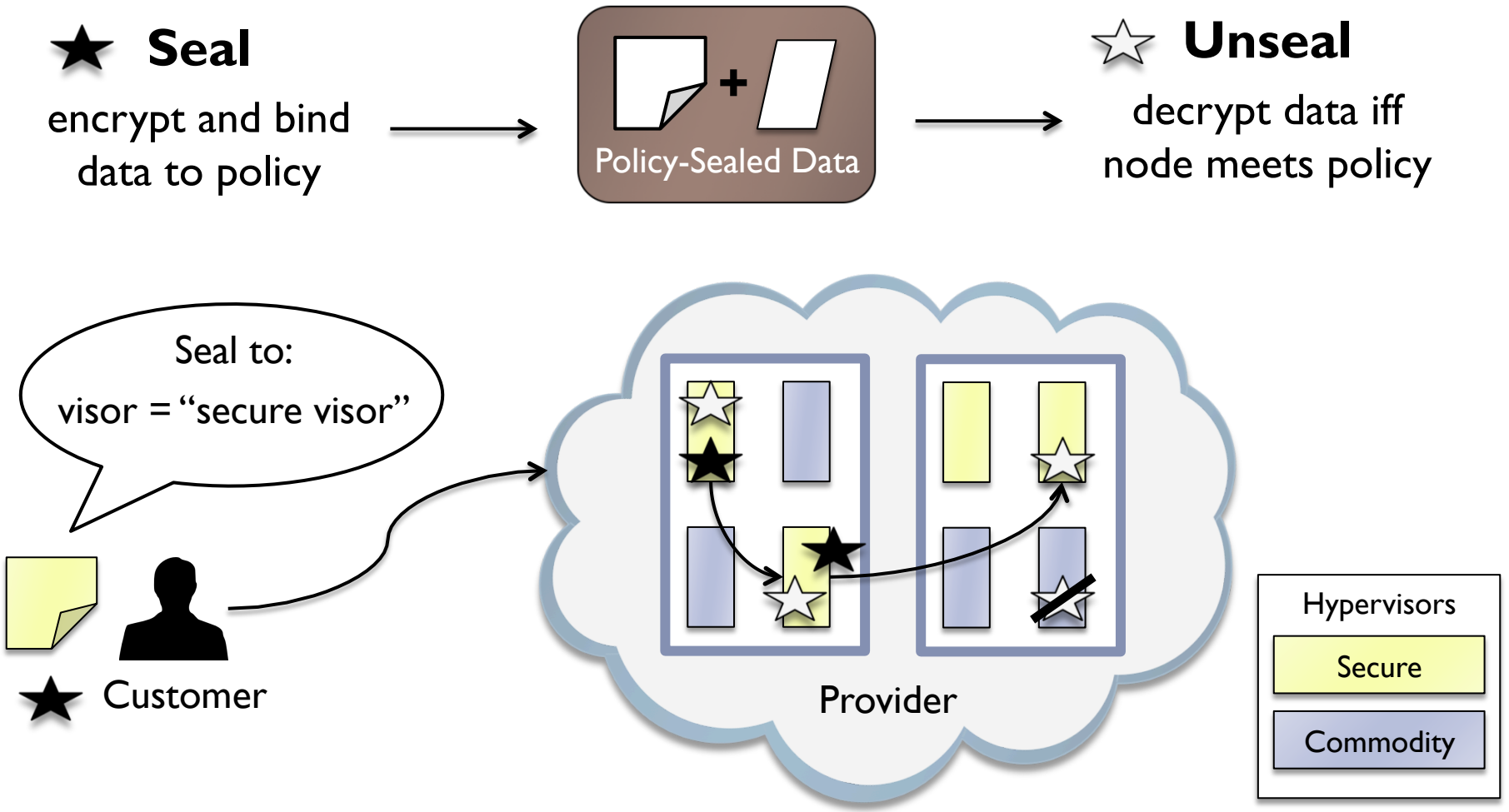
Policy-Sealed Data



Policy-Sealed Data: Attributes & Policies

- Node configurations expressed as set of attributes
- Attributes mapped to nodes' identities and software config
  - node id → hardware attributes
  - software config → software attributes
- Customers select trusted node configurations in policies
  - Logic expressions over attributes

Node Attributes

```
service : "EC2"
hypervz : "CloudVisor"
version : "1"
country : "Germany"
zone    : "z1"
```

Data Policy

```
service = "EC2"
  and
hypervz = "CloudVisor"
  and
version >= "1"
  and
(country = "Germany"
   or
 country = "UK")
```

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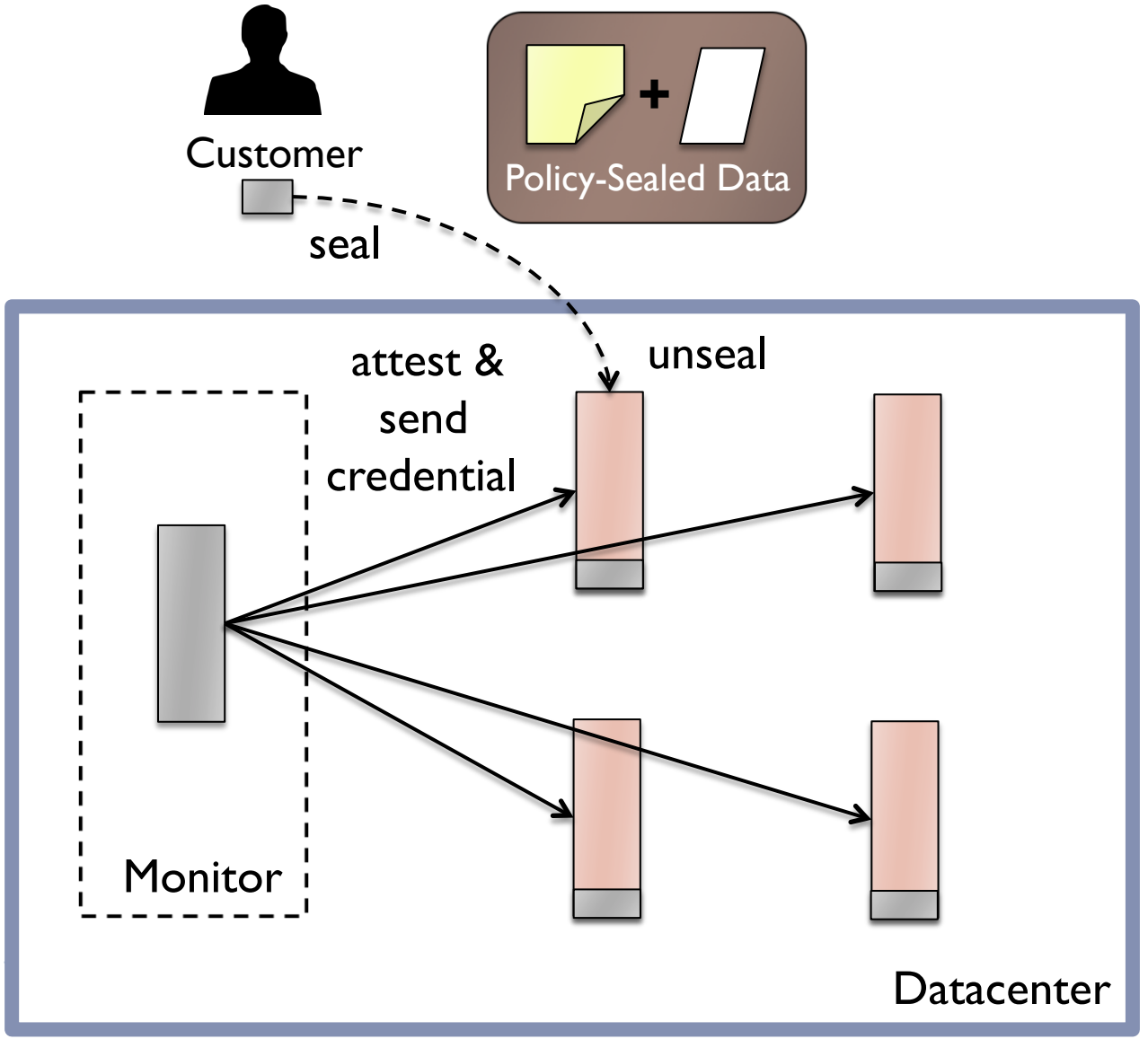
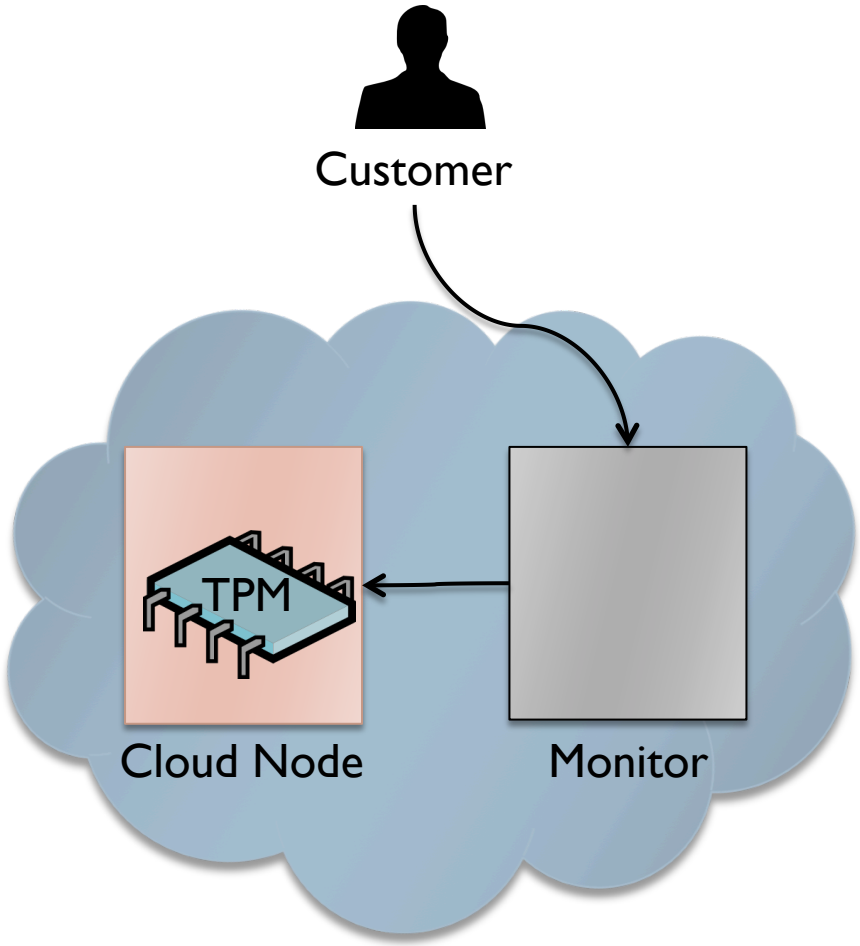
Excalibur Architecture

- Check node configurations
  - Monitor attests nodes in background
- Scalable policy enforcement
  - CP-ABE operations at client-side lib



Excalibur Mediates TPM Access w/ Monitor



Monitor goals:

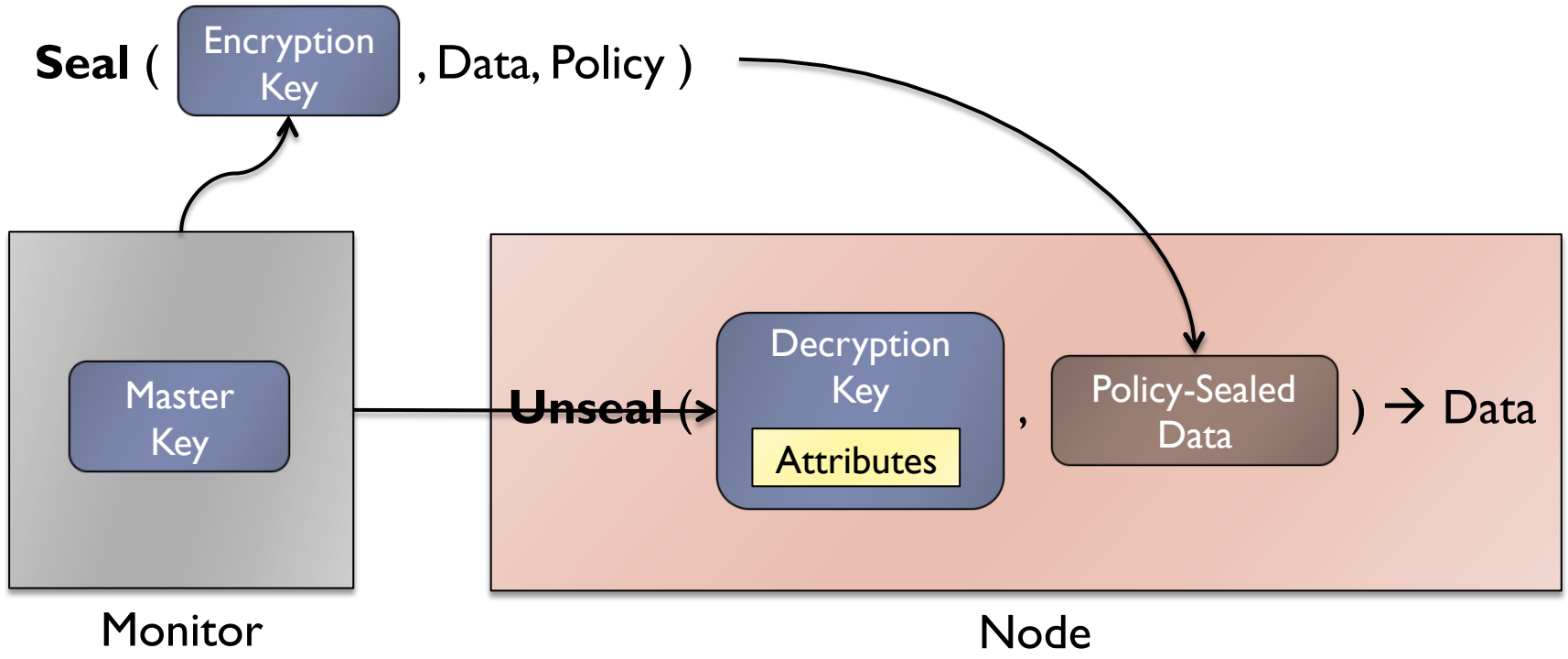
- Track node ids + TPM-based attestations
  - Hides low-level details from users
- Track nodes' attributes that cannot be attested via today's TPMs
  - e.g., nodes' locations (EU vs. US)
- Form the cloud's root of trust
  - Customers only need to attest the monitor's software configuration

Attribute-based Encryption Is Key to Scalability

Customers seal data to a policy with a CP-ABE encryption key

Once each node attests its configuration, monitor hands CP-ABE decryption key

- Ciphertext-Policy Attribute-Based Encryption [Bethencourt07]



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Methodology

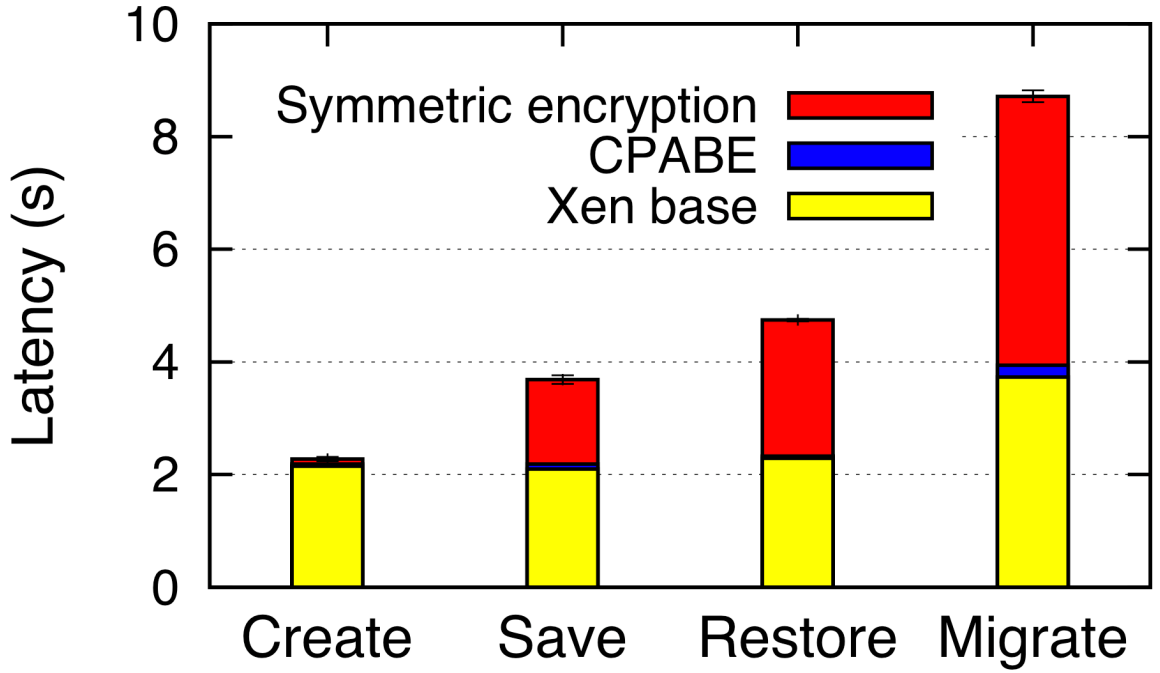
- Two questions:
  - What is the overhead of policy-sealed data?
  - Is the monitor a scalability bottleneck?

- Implemented cloud service akin to EC2
  - Based on Eucalyptus / Xen cloud platform
  - Supports location attribute
  - Interposed seal / unseal in VM management operations

- Testbed: single monitor and five nodes
  - Intel Xeon, 2.83Ghz 8-core CPU, 1.6 GB RAM, TPM v1.2

What Is the Overhead of Seal / Unseal?

Overhead of CP-ABE in Eucalyptus / Xen platform



CP-ABE's overhead could be significant

However, VM operations are infrequent

Is the Monitor a Scalability Bottleneck?

- Monitor can attest a large number of nodes
  - Max throughput: 630 attestation-verifications/sec
  - E.g., 10K node cluster attests in ~15 seconds

- Monitor can serve many attestation requests from customers
  - Max throughput: 4800 attestation-requests/sec
  - Increases throughput of standard TPM attestation
    - Batches multiple attestation requests into single TPM call
  - Speedup orders of magnitude over standard TPM attestation

Conclusions

- **Excalibur** overcomes TPM's limitations in the cloud
- **Policy-sealed data**: new trusted computing primitive
  - Flexible sealed storage
  - Reduce overexposure
- CP-ABE makes Excalibur scale
  - Masks low performance of TPMs
- Evaluation indicates that the system is practical