Architectural Principles for Secure Multi-Tenancy

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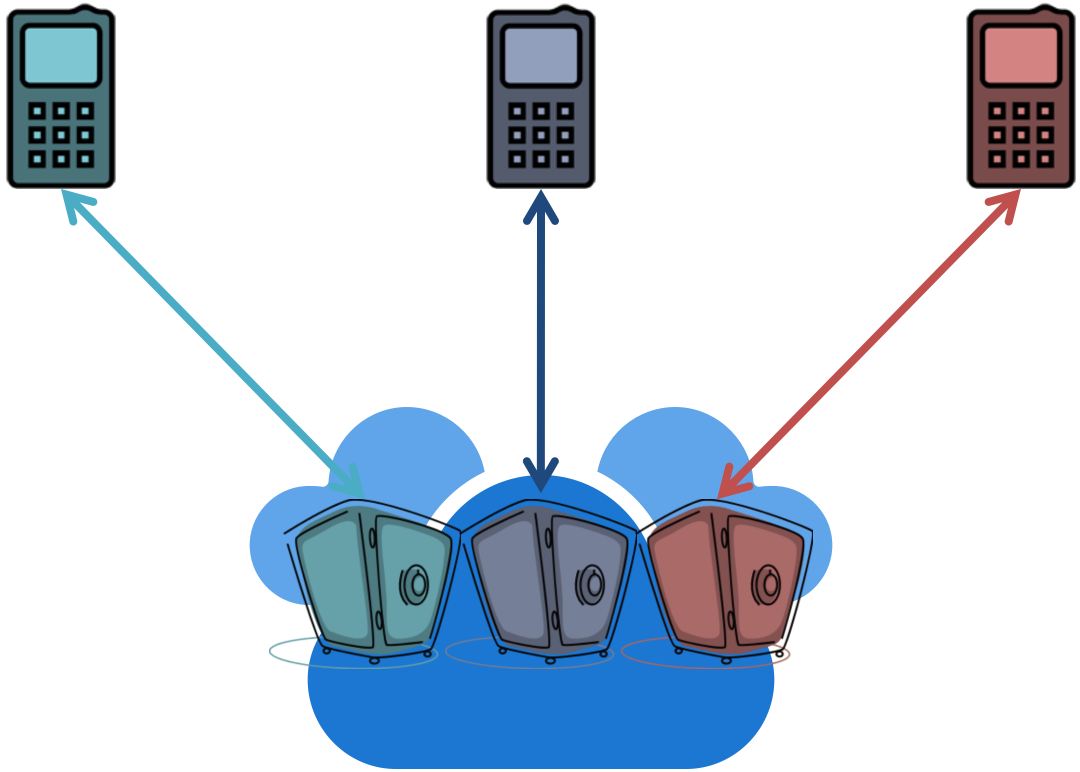


multi-tenancy

hosting by a provider of **more than one tenant at the same time**

Essential to effective cloud computing, by enabling resources to be shared in a secure and cost-effective fashion

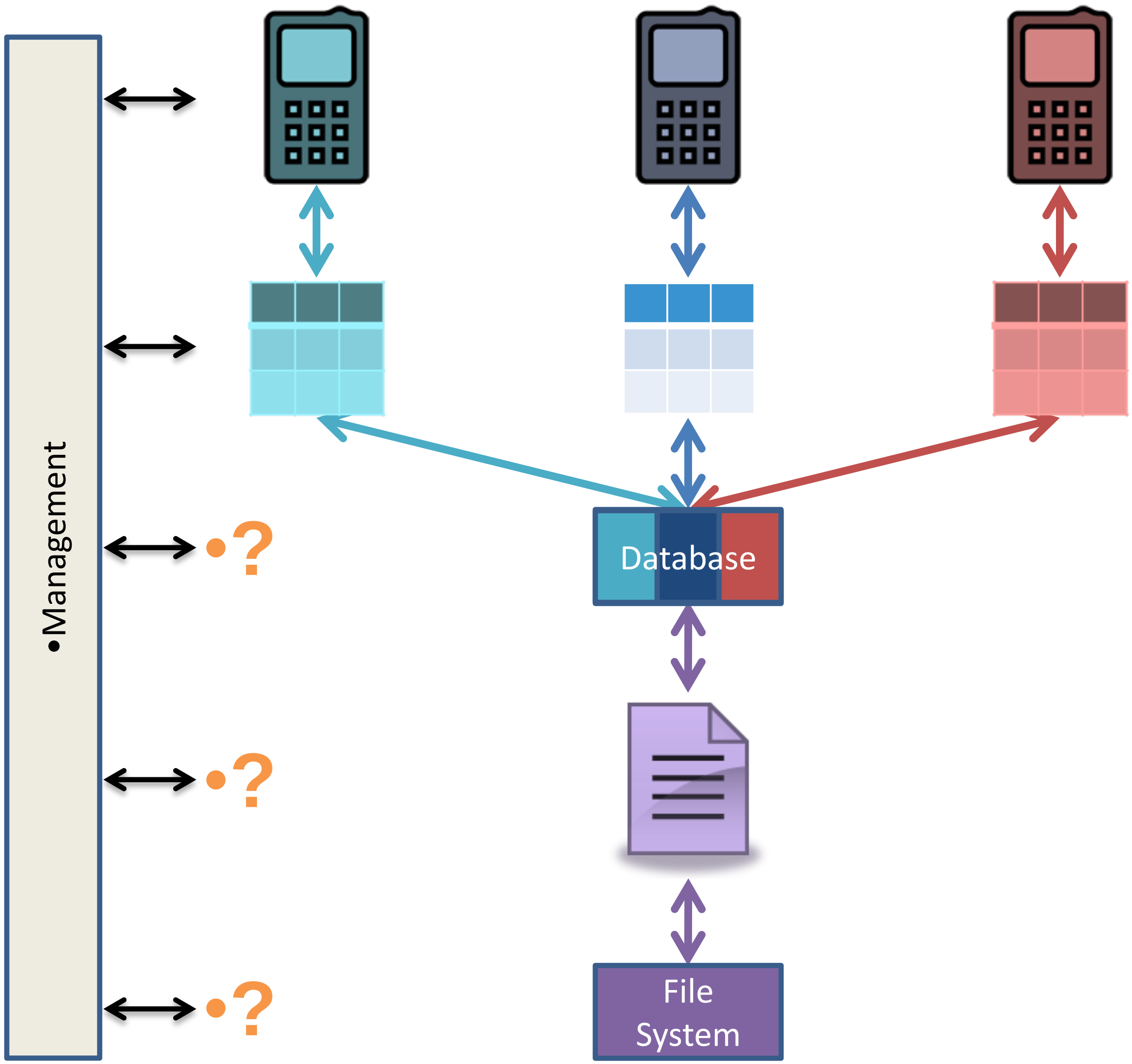
Objectives and Principles

- Layered approach, applicable to alternate cloud models
  - Individual components comprising the infrastructure on which clouds are built
  - Provider cloud-level infrastructures, layered on interconnected sets of components
  - Tenant clouds, layered on infrastructure elements operated by the provider and tenant
- Providers manage the first two layers, allowing tenants to implement the third
  - This talk examines both provider and tenant perspectives
- Subscribers must place trust in providers per Service Level Agreements (SLAs), but the trust level shouldn't be (or need to be) unlimited

Constructing Multi-Tenant Infrastructures

- A secure multi-tenant (MT) infrastructure can combine two types of components
  - MT-capable: components that provide explicit multi-tenancy support and are trusted to process and segregate information belonging to multiple tenants
  - Non-MT: components unable to enforce such segregation, that must not receive multiple tenants' information in a form that could enable leakage across tenant boundaries
- Can segregate non-MT components and across tenant boundaries via physical, network-based, and/or crypto methods
- Generally, we expect MT-capable components to evolve upward from platforms, hypervisors, and selectively into the application stack
  - Trustworthy components require trustworthy supporting layers
  - Trusted MT-capable hypervisors are fundamental components for cloud architectures

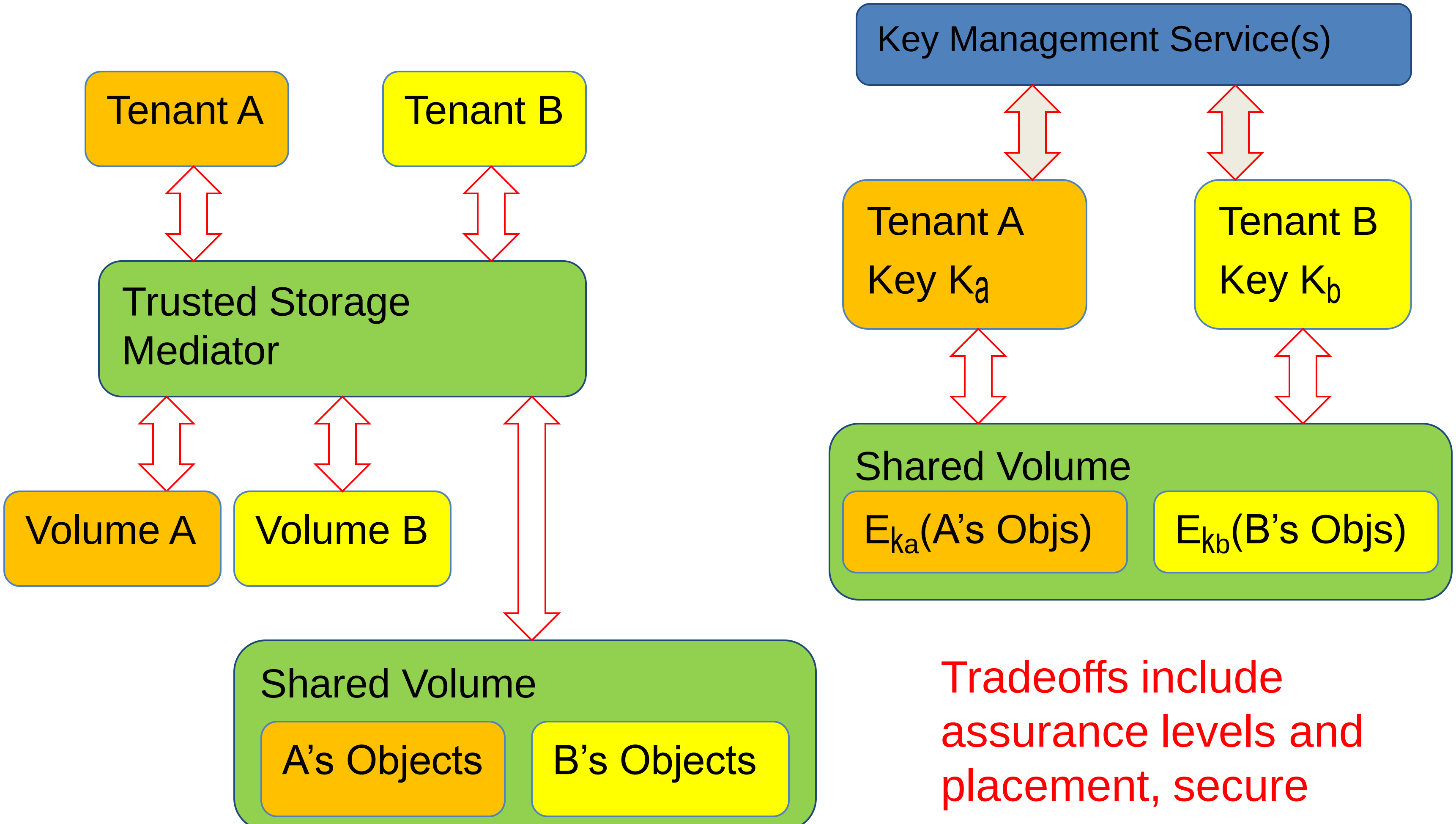
Multi-Tenancy: Consolidated Database Example



Securing Storage Elements

- Storage resources must be restricted to appropriate tenants
  - Explicitly by MT-capable mediators
  - Implicitly by configuration, so that non-MT components can access only devices and volumes corresponding to their tenants
- Need controls on access to containers and their information objects
  - Container-level access typically mediated by cloud provider
  - Object-level access mediated by provider and/or by tenant
- Resources must be clean when provided, persistent and protected while in use, securely cleaned when no longer needed
  - Challenges: ensuring confidentiality, ongoing integrity, guaranteed erasure

Example MT Storage Alternatives



Tradeoffs include assurance levels and placement, secure erasure

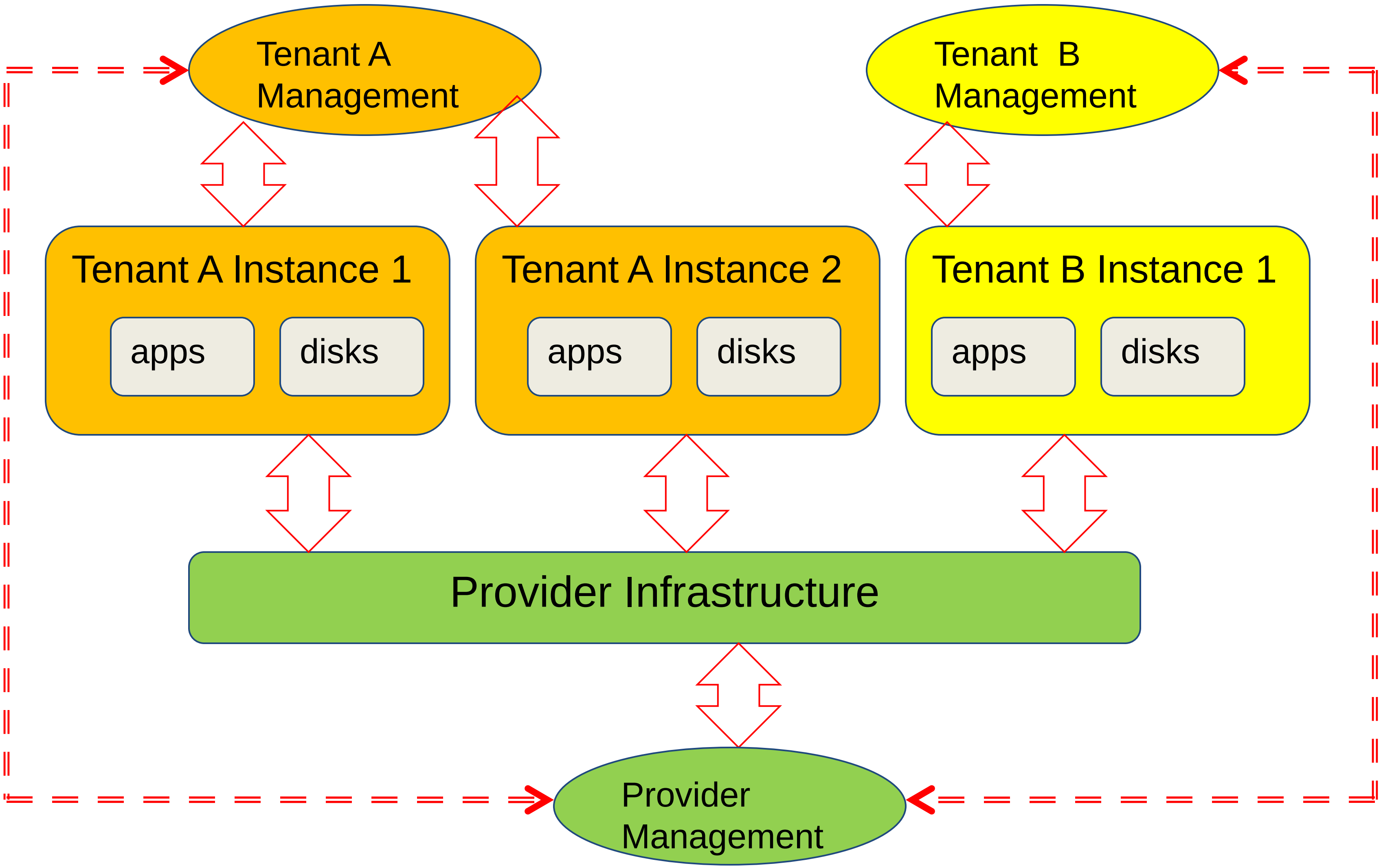
Securing Provider Clouds: Isolation and Integrity

- Normally, a tenant’s instance should be enclosed in a virtual perimeter, with elements and communications paths disjoint from other tenants and instances
  - Underlying physical resources can usually be shared
  - Selective external connectivity (default deny) is usually needed; providers can offer monitoring and filtering services
- VMs should be identified uniquely and associated with their instances; cryptographic credentials are attractive
- Security SLAs can specify assurance levels and/or methods to be applied
  - Verifiability by tenant and/or third party is important
  - Providers can offer scanning services to subscribers
- Challenge: effective integrity verification of dynamic objects

Securing Provider Clouds: Audit and Compliance Support

- Effective cloud monitoring requires data from multiple components and layers; both providers and subscribers have monitoring needs
  - Cloud-level attacks are relevant to subscribers, and tenant-level activity is relevant to a cloud's overall security posture
- Flow of monitoring information should be constrained by authorization and privacy policies
- Cloud infrastructure should allow for discovery, measurement, and recording of proper, secure resource configuration
- Conflict: providers prefer opacity, subscribers seek transparency
  - Possible rendezvous point: neutral independent parties

Tenant-Provider Relationships



Provider-side Conclusions

- Layered architecture is fundamental
  - Monitoring and management must span layers coherently, while satisfying authorization and privacy policy
- Should allocate MT segregation functions to appropriate trusted components, building up from platforms and hypervisors
  - May also need higher-level MT, particularly to achieve application-level or user-level protection granularity
- Successful cloud providers will be attractive attack targets, and need to protect themselves and their subscribers
  - Providers must protect themselves and tenants against collateral damage
  - Cloud provider security challenges and responsibilities may exceed those of conventional data center operators
- Overall challenge: enable providers to construct efficient operational environments, where their tenants' trust in those providers can be constrained

The Tenant View

- Architectural considerations for the tenant:
  - Service Level Compliance
  - Self-service Considerations
  - Integrated Monitoring
  - Limiting Trust

Tenant View: Service Level Compliance

- Providers and tenants are assumed to be mutually untrusting.
- Contract between the provider and the tenant is embodied in a Service Level Agreement (SLA).
- Verifying compliance with SLA requires the provider to surface specific evidences.
  - However, provider will not disclose infrastructure configuration details.
- Verification requires agreement on how to validate the “what” represented by the SLA.
- Challenge: What evidence constitutes sufficient proof of the SLA?

Tenant View: Self-Service Administration

- Tenants require autonomous control of the tenancy, with minimal dependency on the provider.
  - Not just a matter of convenience; also ensures tenant privacy.
- Desire consistent management model across all resource types
  - Compute, Network, Storage.
- Tenants must also anticipate the need to perform self-service across multiple Tenancies.
  - Consistency improves efficiency, and reduces risk.
- Challenge: Federated and delegated authentication, satisfying provider and tenant assurance requirements.

Tenant View: Self-Service Resources

- All tenant-visible units of resource management must be logical, not physical.
- Enable those objects to be scoped to (nested in) a container abstraction.
- Enable recursive delegated administration capabilities at the container layer.
- Implement out-of-band monitoring of management activities
  - Verify actual state of the system remains in compliance across management state changes, across tenancies.

Tenant View: Integrated Monitoring

- Monitoring information from providers must be integrated with tenant systems.
  - Lack of integration increases costs, and introduces delays in detection, response, and remediation.
- Providers should offer tenants appropriate visibility into provider infrastructure operations.
  - Service State Information Model
  - Automation in incident response
- Challenges: service modeling, and protocols for automation of incident response.

Limiting Trust In Providers

- Tenants may deter and/or mitigate the risks in trusting the provider through compensating controls
  - Strong authentication of all actors, appropriate separation of duties, comprehensive auditing, and integration with Tenant's security monitoring.
- Provider environments should enable tenant-controlled confidentiality and integrity.
  - Tenants may choose not to share encryption keys with provider.
- Trust in availability is necessary: provider is a potential single point of failure for a tenancy.
- Challenges: Ensuring availability, requisite trust properties, and providing corresponding controls.

Research Challenges and Conclusions

- Need enhanced techniques and assurance for trustworthy computing
  - When other tenants aren't trusted
  - When a platform isn't fully trusted
  - When the platform's operator isn't fully trusted
- Need effective means to validate integrity of items that are intended to change
- Want effective means to process data without exposing its information
- Modeling and verifying service relationships.