CLOUD COMPUTING SECURITY

HP Labs G-Cloud
A Secure Cloud Infrastructure

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Covering…

- A few words about HP Labs
- An outline of Cloud Computing
  - Business drivers, Goals, etc.
- Cloud Security
  - Stakeholders and their issues
  - Routes of attack
  - Properties required
- Secure services
  - Control over security properties
- Infrastructure design
  - Virtual machines, networks and storage
  - Sensors and monitoring

HP LABS AROUND THE WORLD

– Global talent, local innovation

AMERICAS
- 46 university collaborations in the Americas
- Guadalajara Advanced Prototyping Center $1M
- 29 projects with HP Brazil R&D
- DARPA, DOE, US Army, MPO external funding
- NSF Post-Docs support $1M
- UC Discovery awards

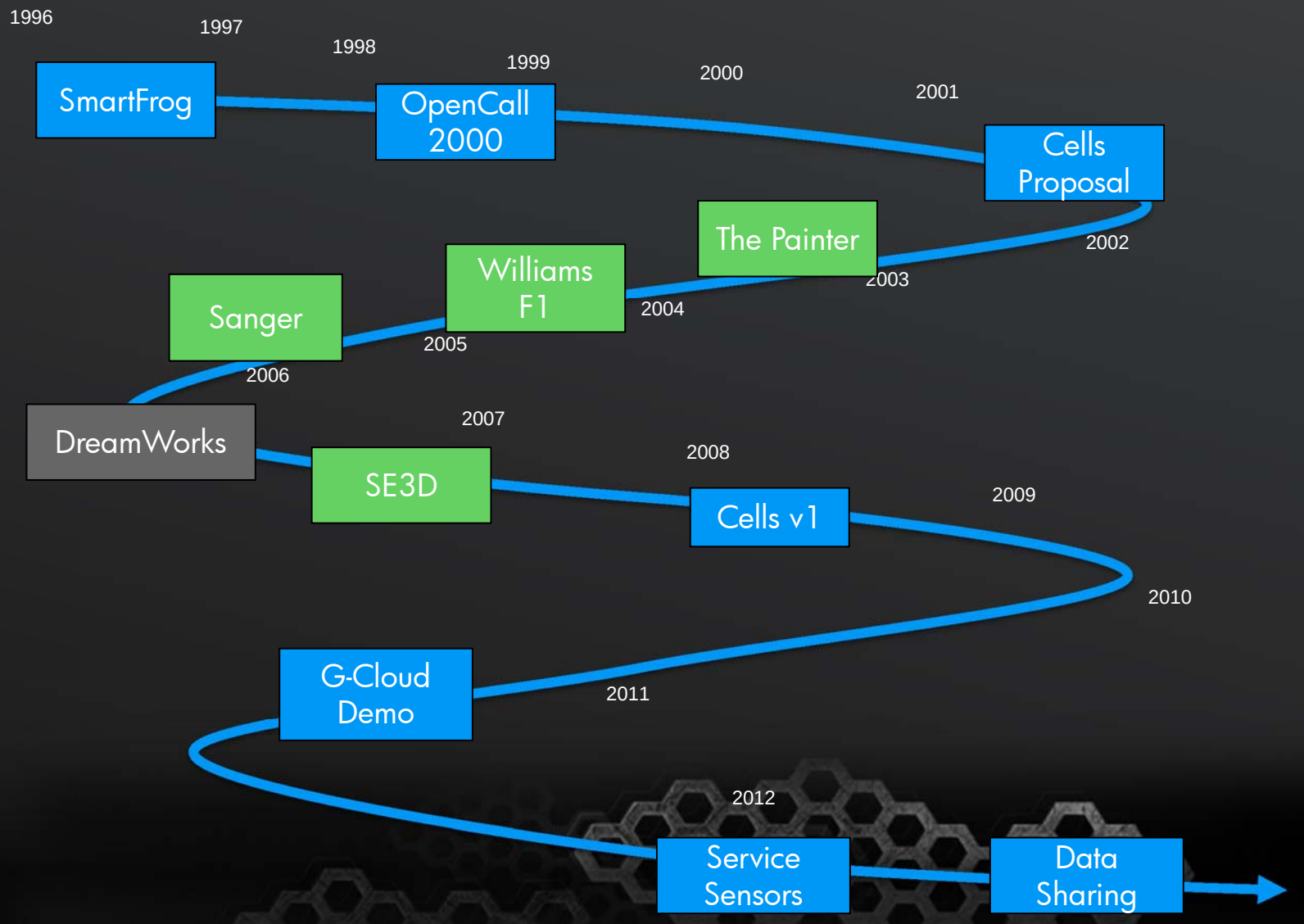
EMEA
- 10 university collaborations in EMEA
- 4 EU FP7 consortia, UK Tech Strategy Board awards
- UK CASE PhD support

APJ
- 7 university collaborations in the Asia-Pacific Region
- A*STAR and EDB support, Singapore

HP LABS RESEARCH AREAS

– Innovation at every touchpoint of information

A long history



Cloud Services

IT delivered as a logical service, available on demand, charged by usage

Logical Service: details of delivery hidden

On Demand: scales up and down immediately and seamlessly

Charged by Usage: metering and billing of services, pay for what you use

Cloud computing is **computation** offered as a service

Cloud computing Concepts

- Multi-tenancy
  - Shared service infrastructure, running simultaneous collocated workloads, for multiple customers
  - Dynamic sharing for flexibility and utilisation efficiency
- Cloud-scale infrastructure
  - Commodity scale-out hardware
  - Targeting extreme economies of scale
- Ubiquitous access
  - Using portable client devices
  - Any where, any time

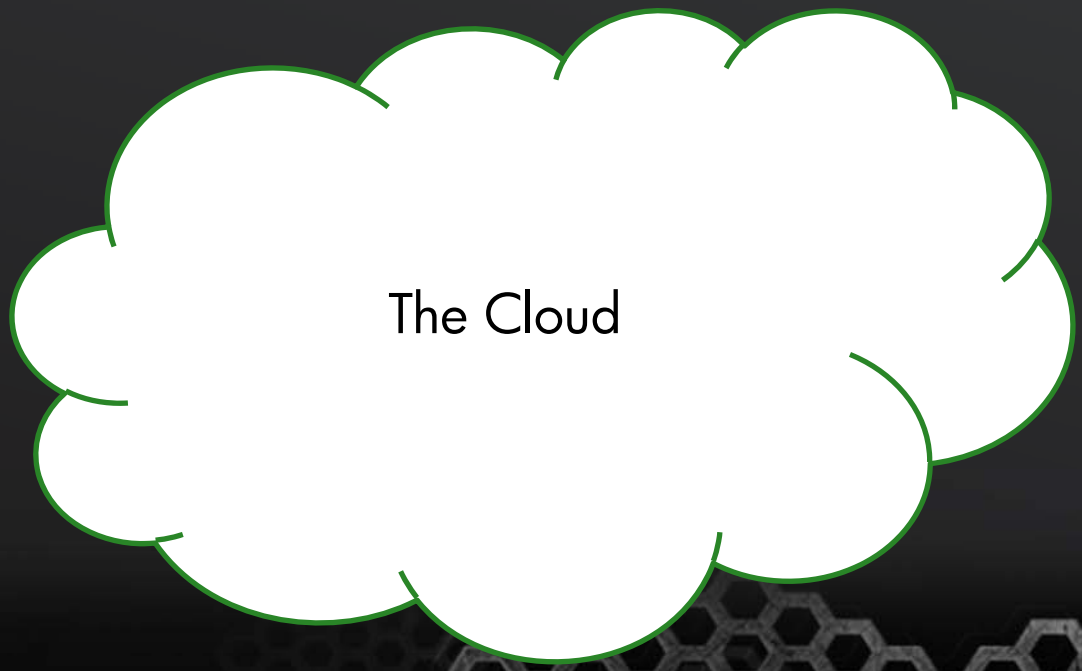
Cloud Computing benefits

- **Cost management**
  - Benefit from economies of scale
  - Avoids cost of over-provisioning
  - Reduction in up-front capital investment, switch to expense more in line with business needs
- **Risk reduction**
  - Someone else worries about running the data-centre, protecting your data, and providing disaster recovery
  - Reduces risk of under-provisioning
- **Flexibility**
  - Add/remove services on demand
  - Scale up and down as needed – rapidly
- **Ubiquity**
  - Access from any place, any device, any time

Barriers to adoption

- **Security, Regulatory, Data locality concerns**
- Concerns about lock-in, lack of multi-vendor options
- Challenge of migrating from in-house (or outsourced) apps
- Trust in the service vendors
  - Service levels
  - Stability
  - Geographic presence
- Vested Interests

Roles in the Cloud



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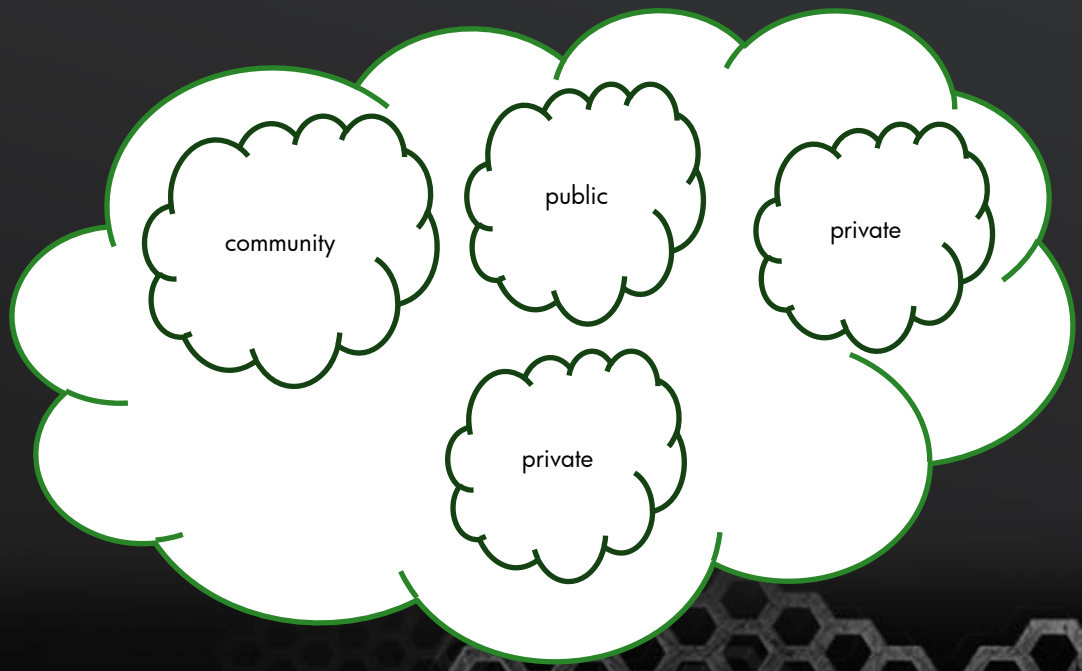

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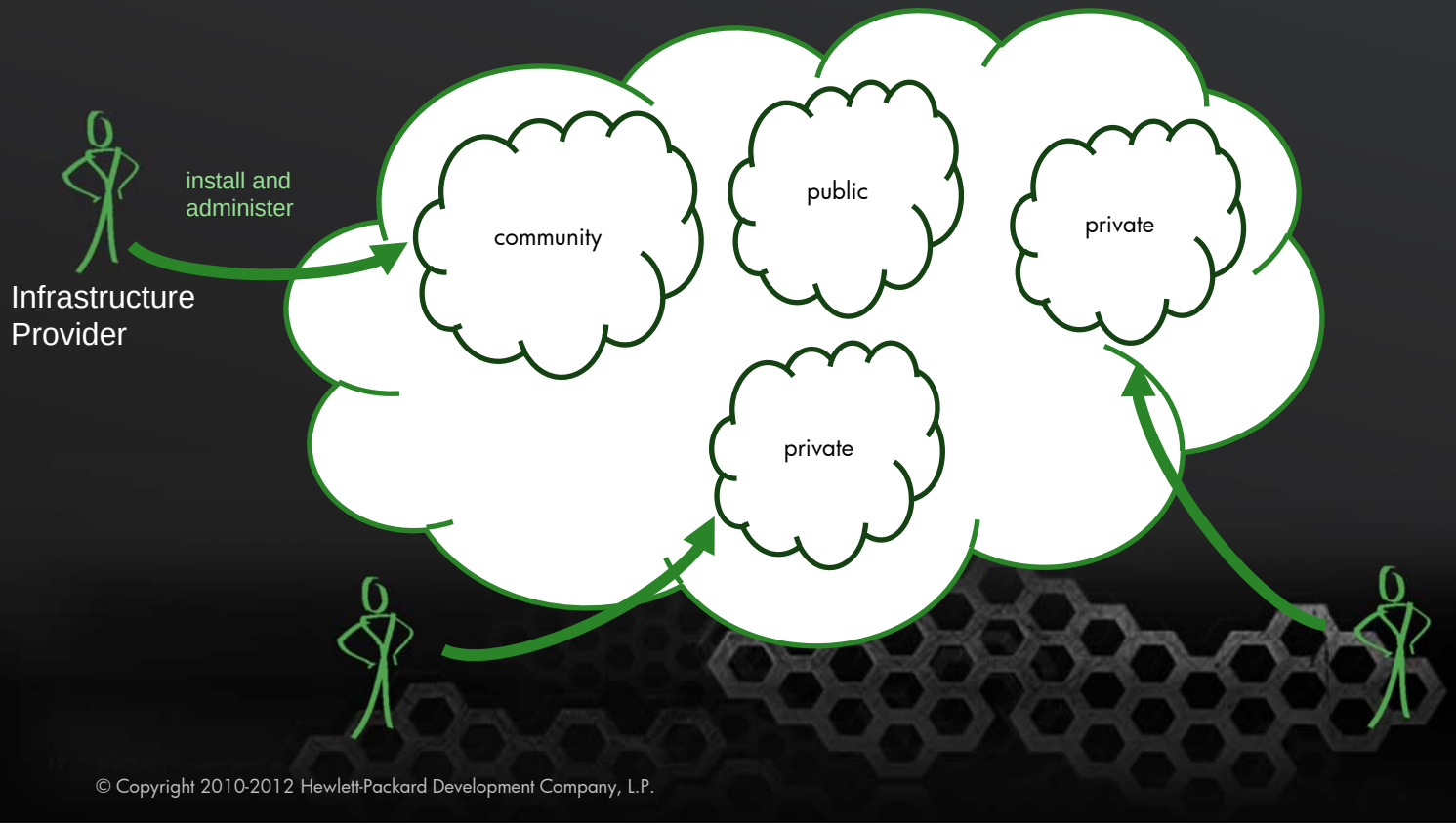

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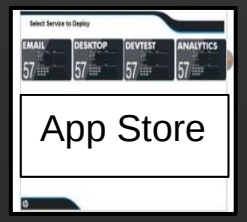
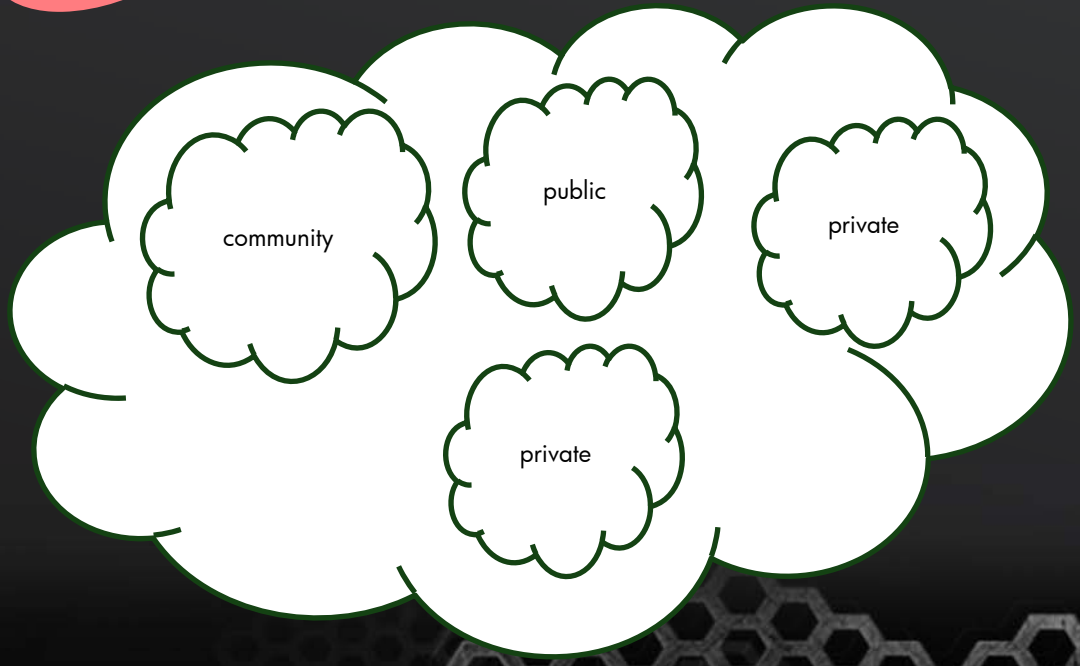


Service Developer

Infrastructure Provider



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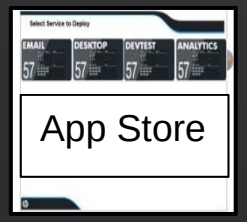

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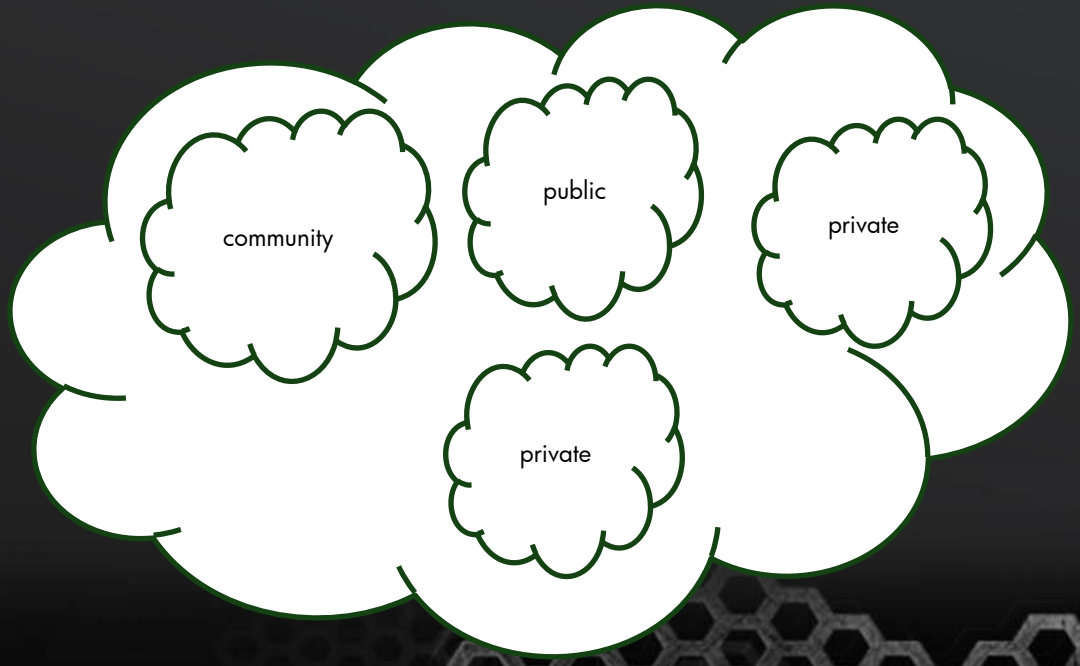

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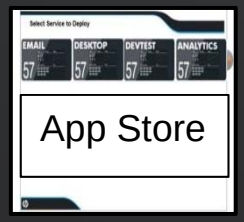

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Service Provider

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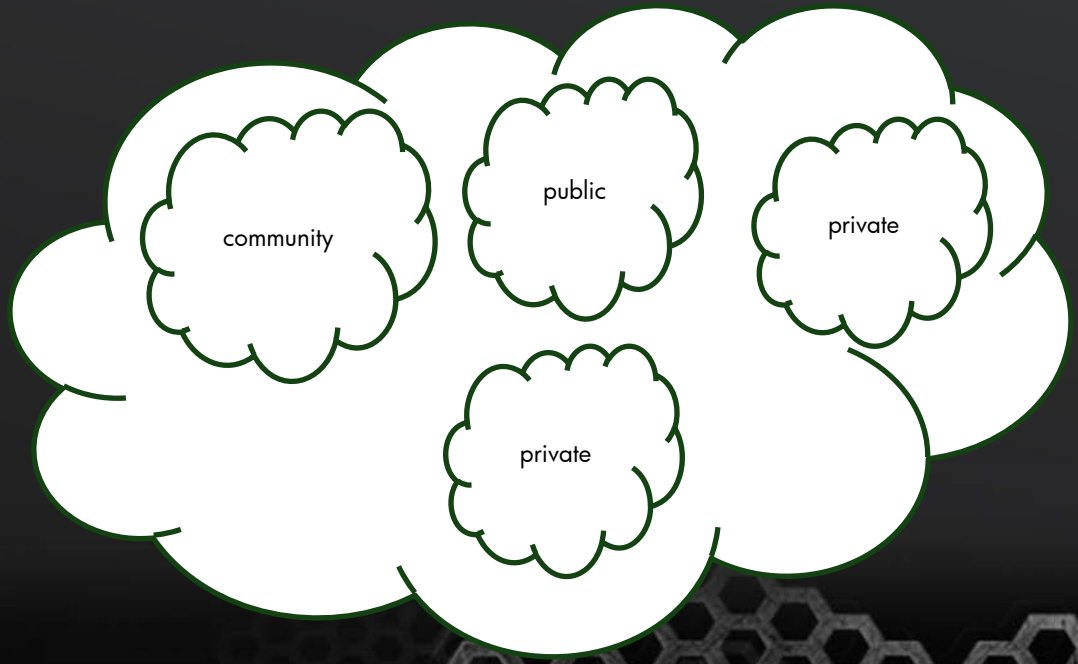

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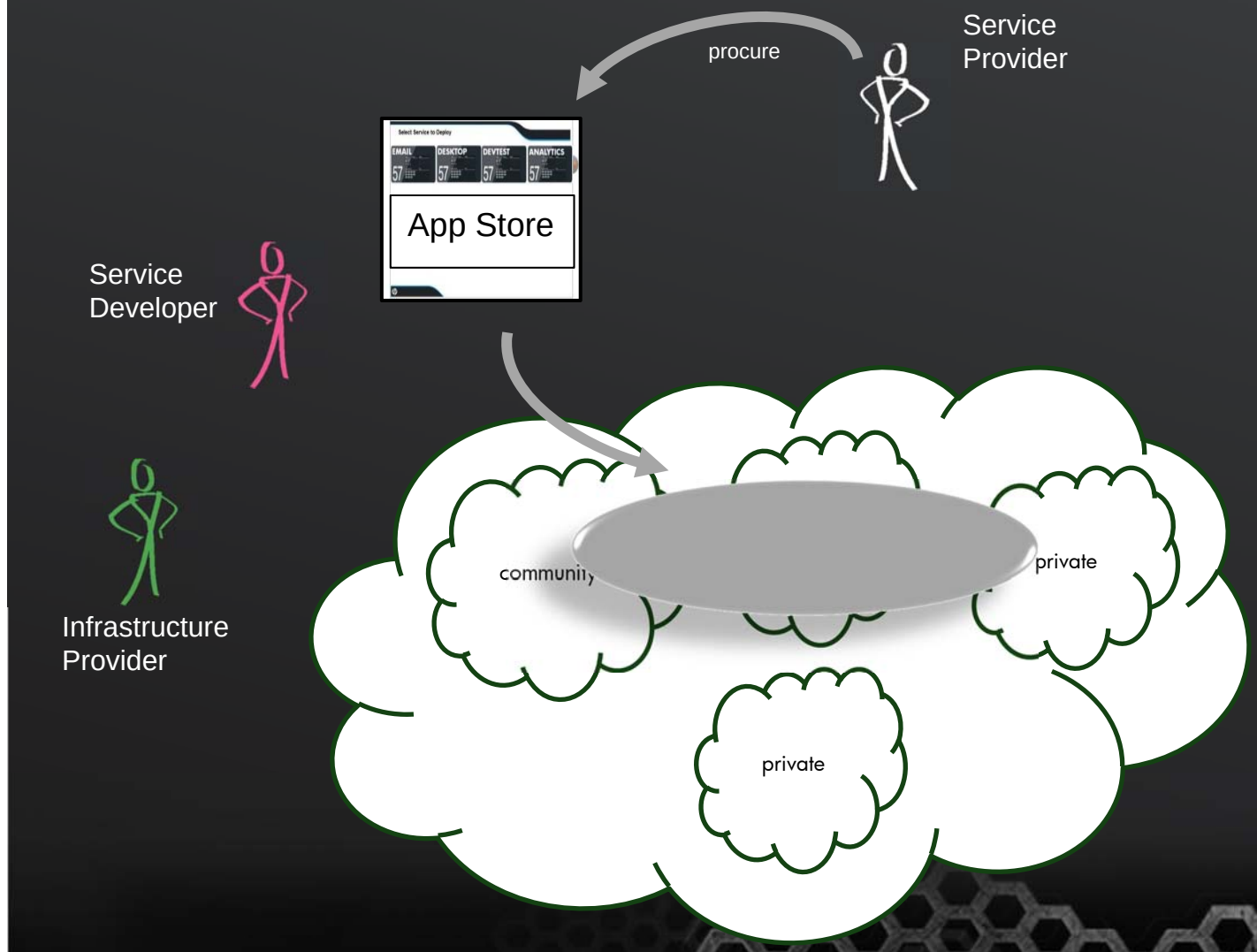

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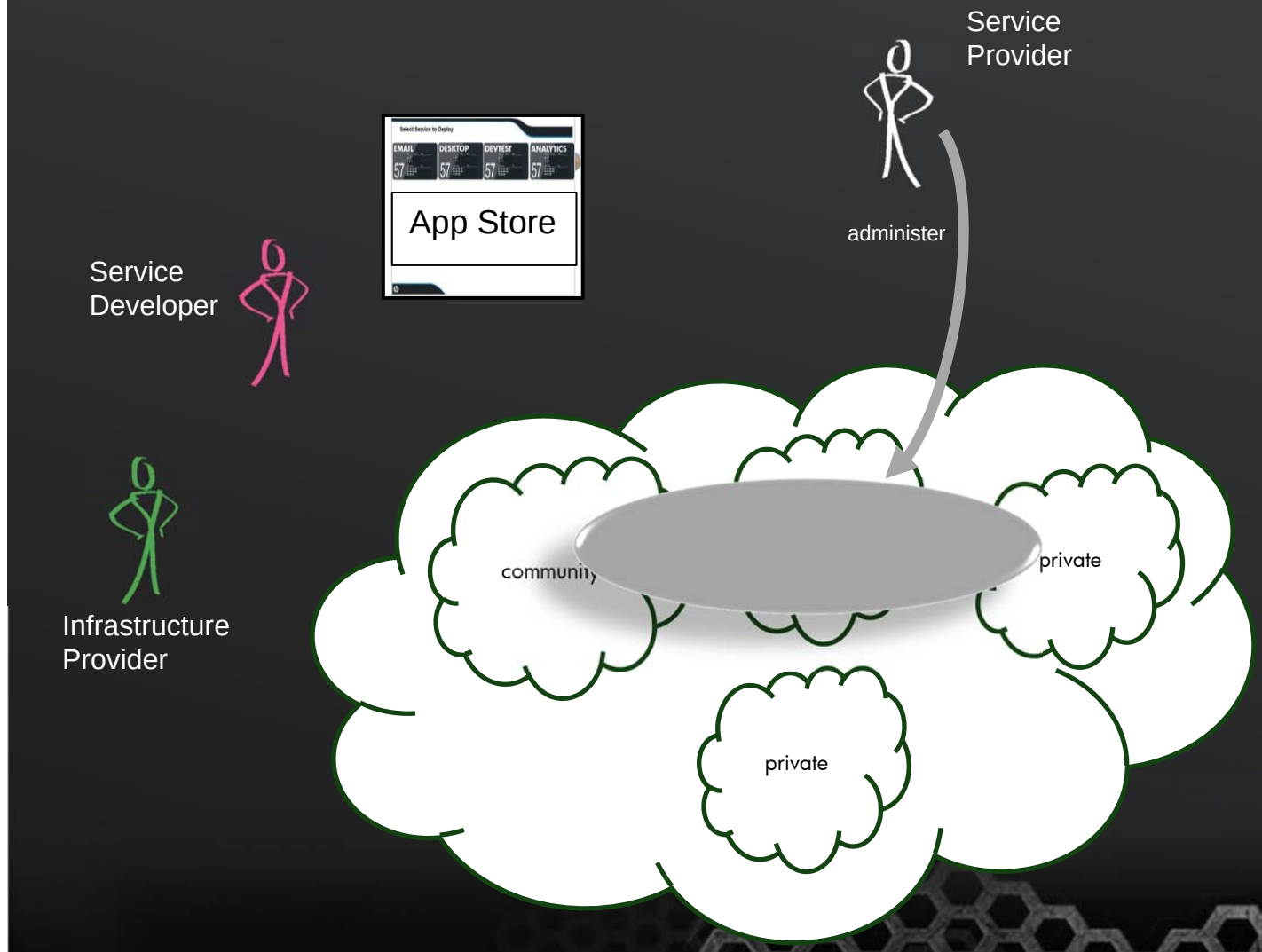

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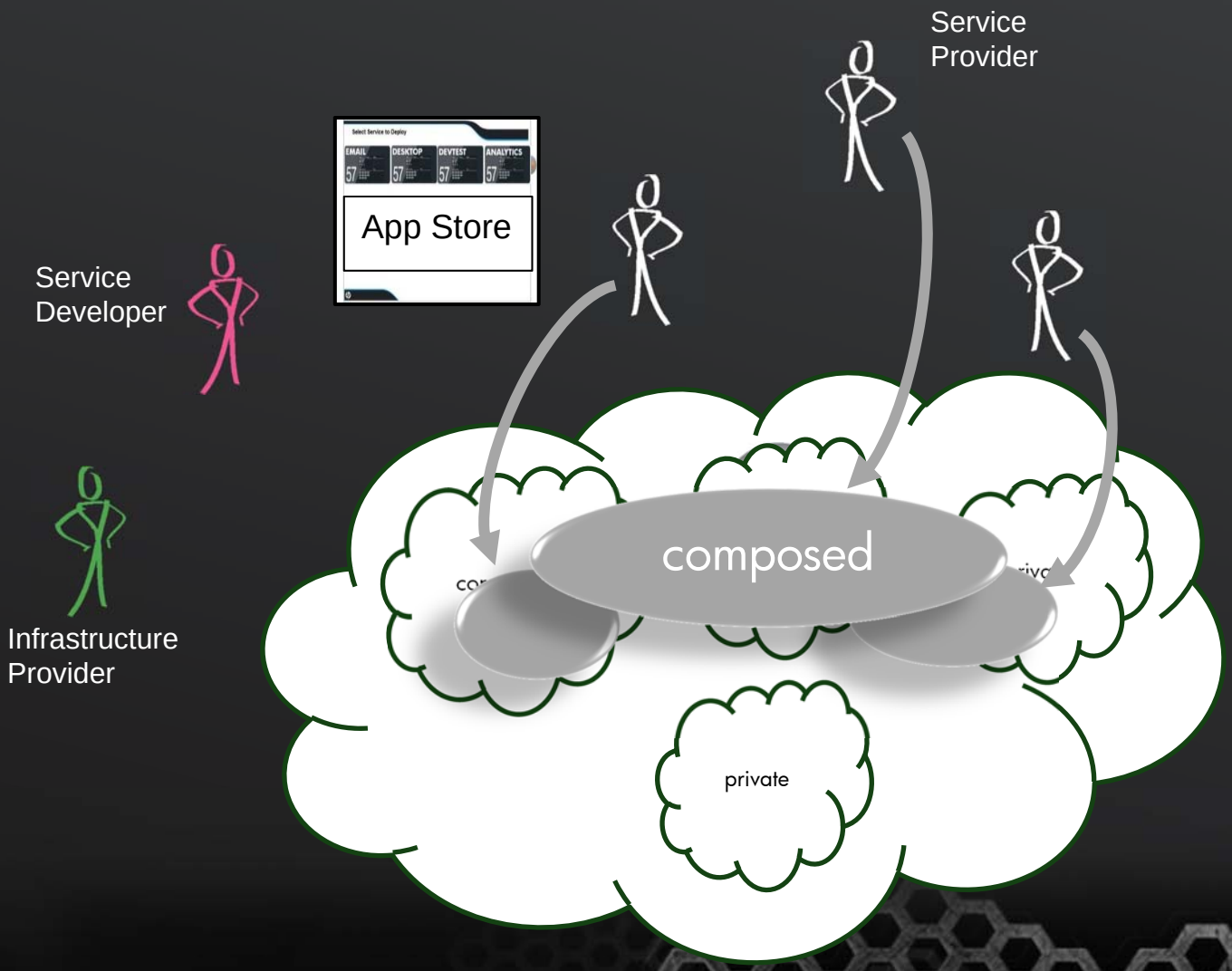

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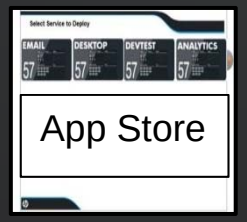

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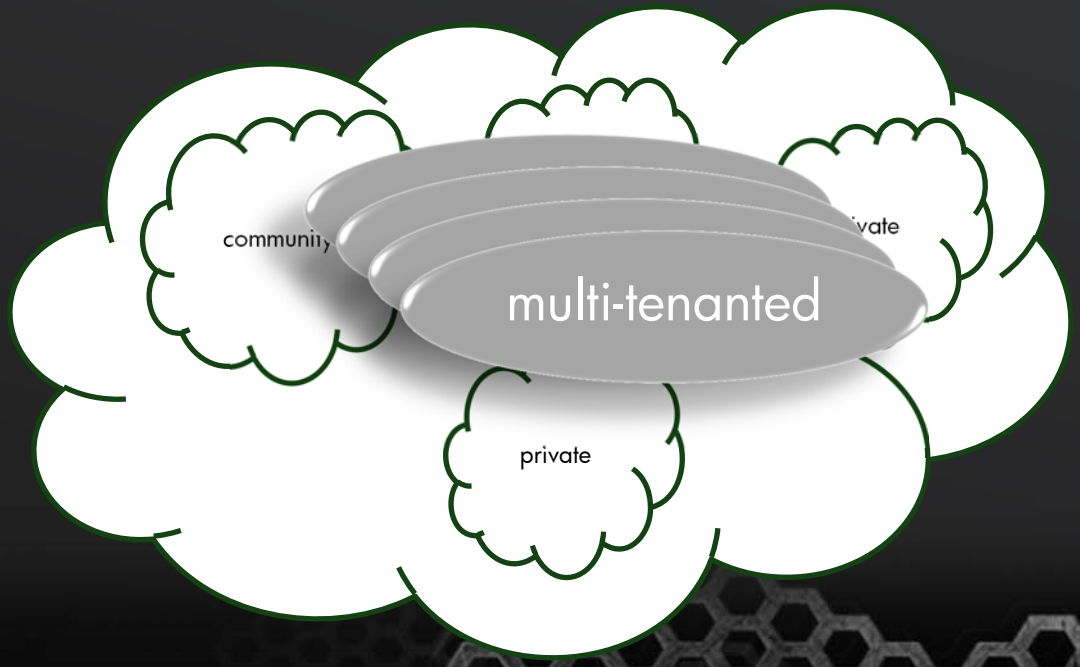

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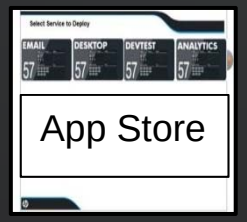

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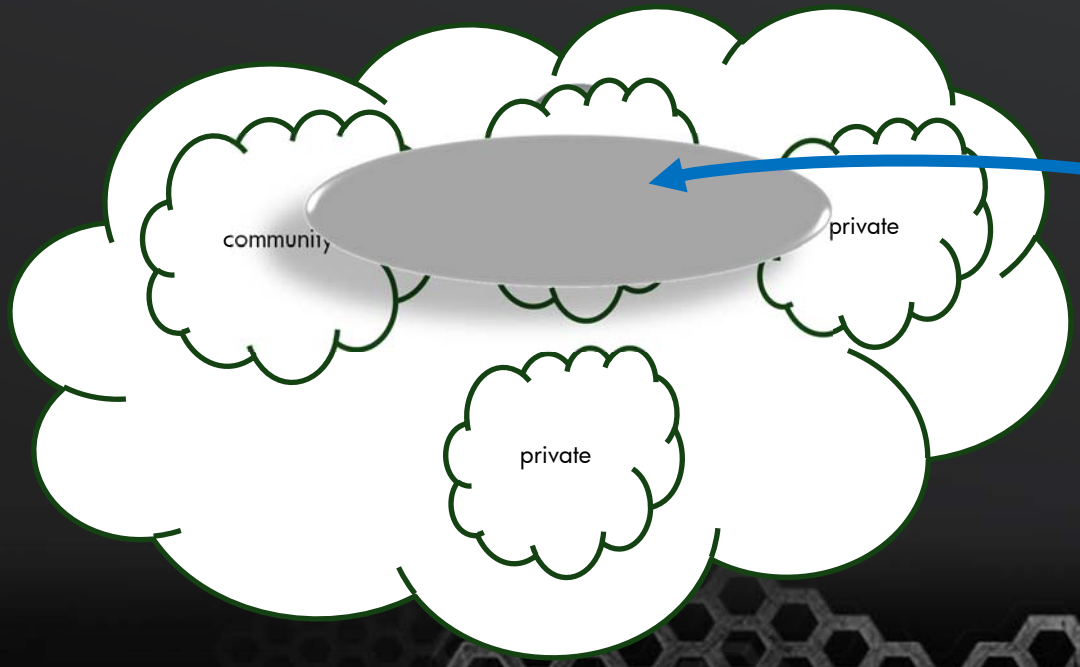
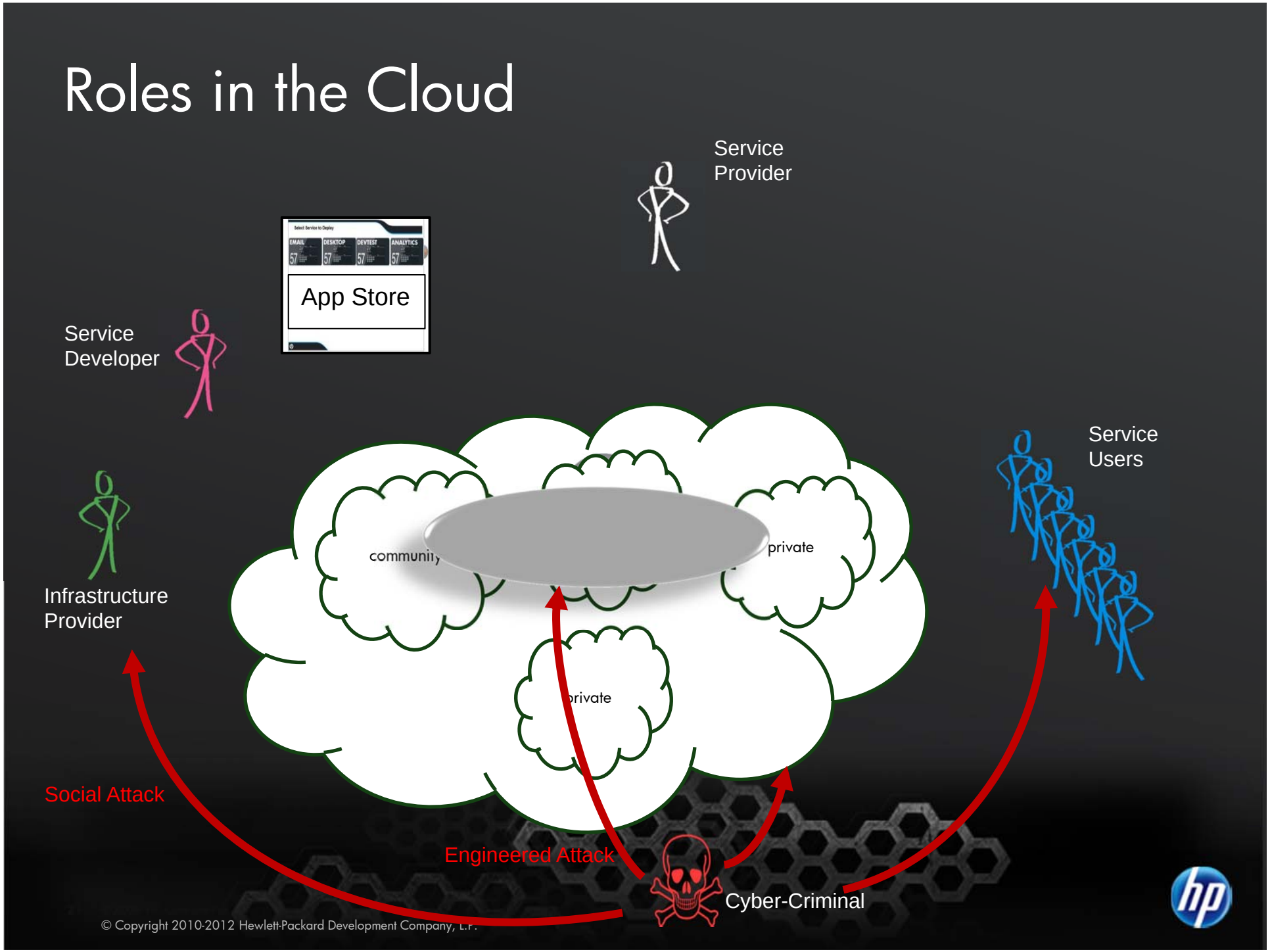
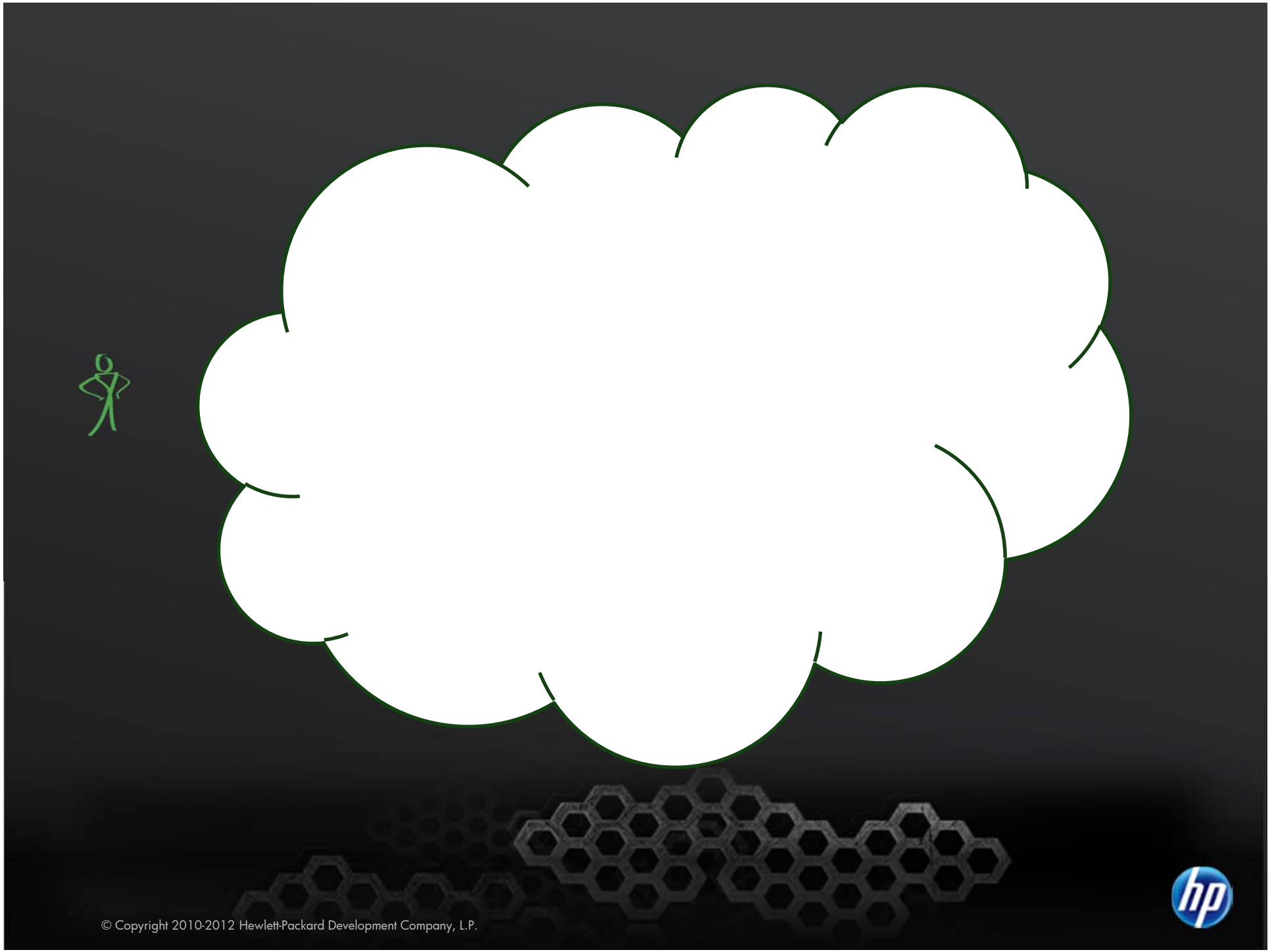
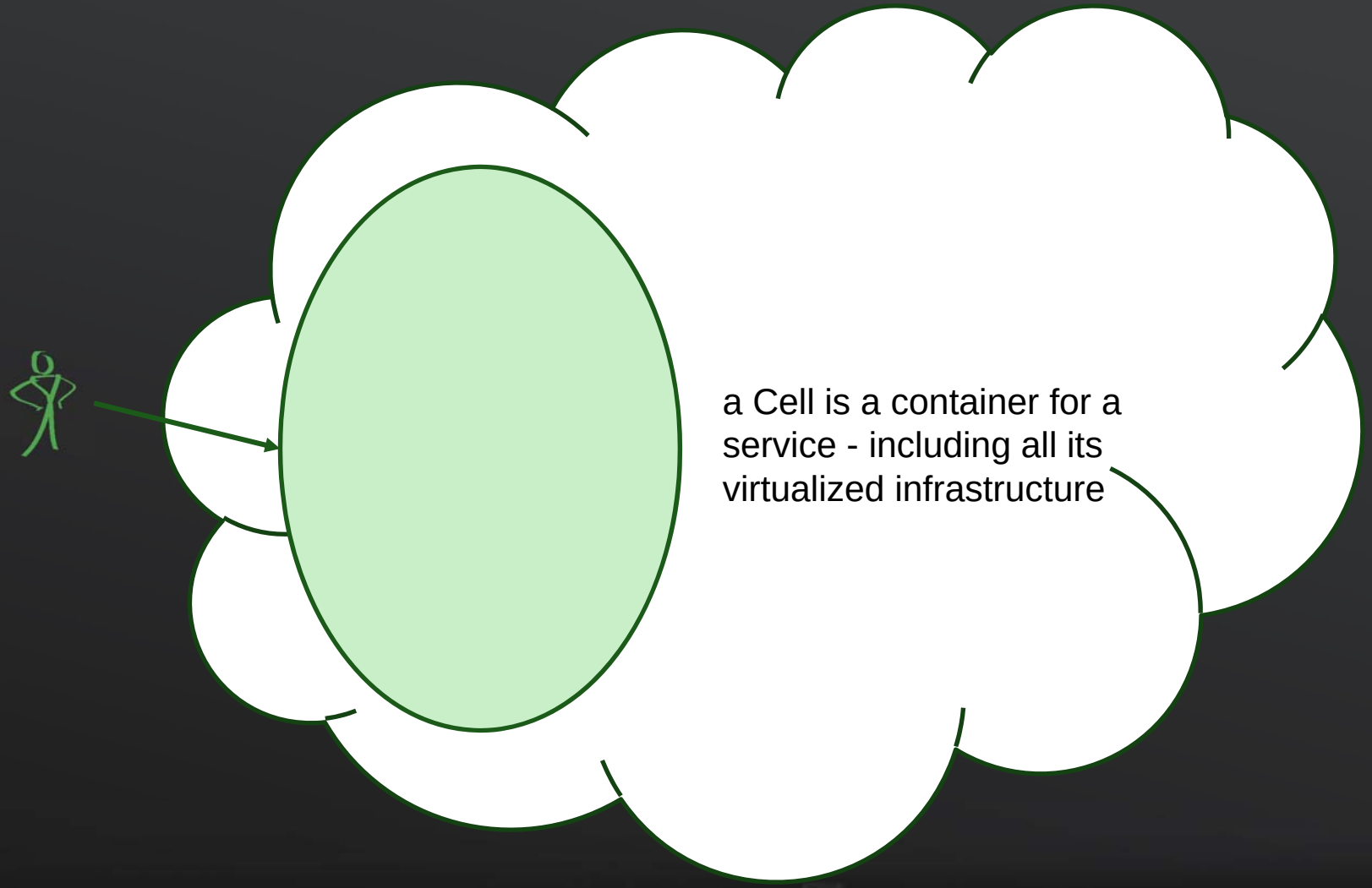


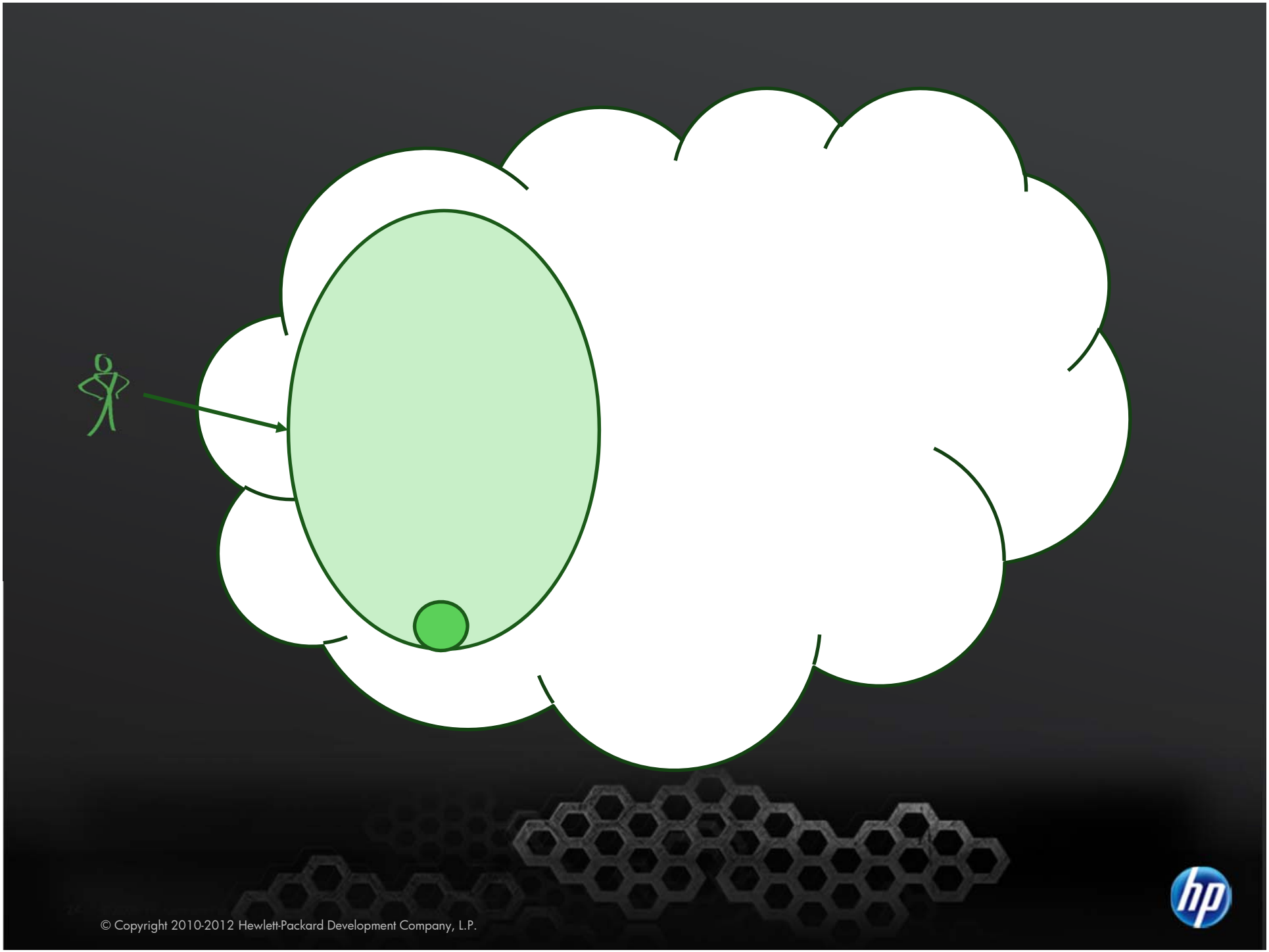
Service Users

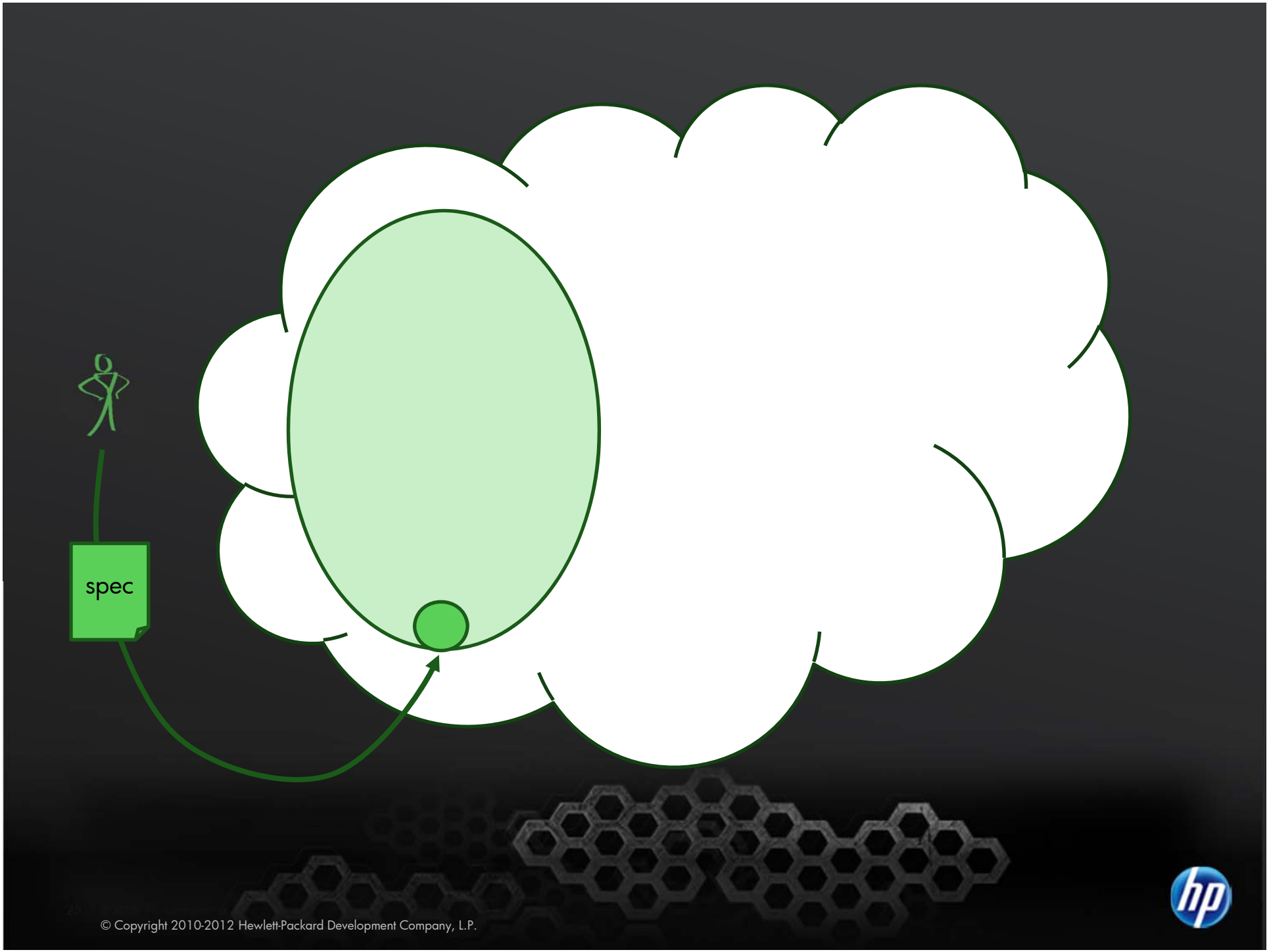
Roles in the Cloud

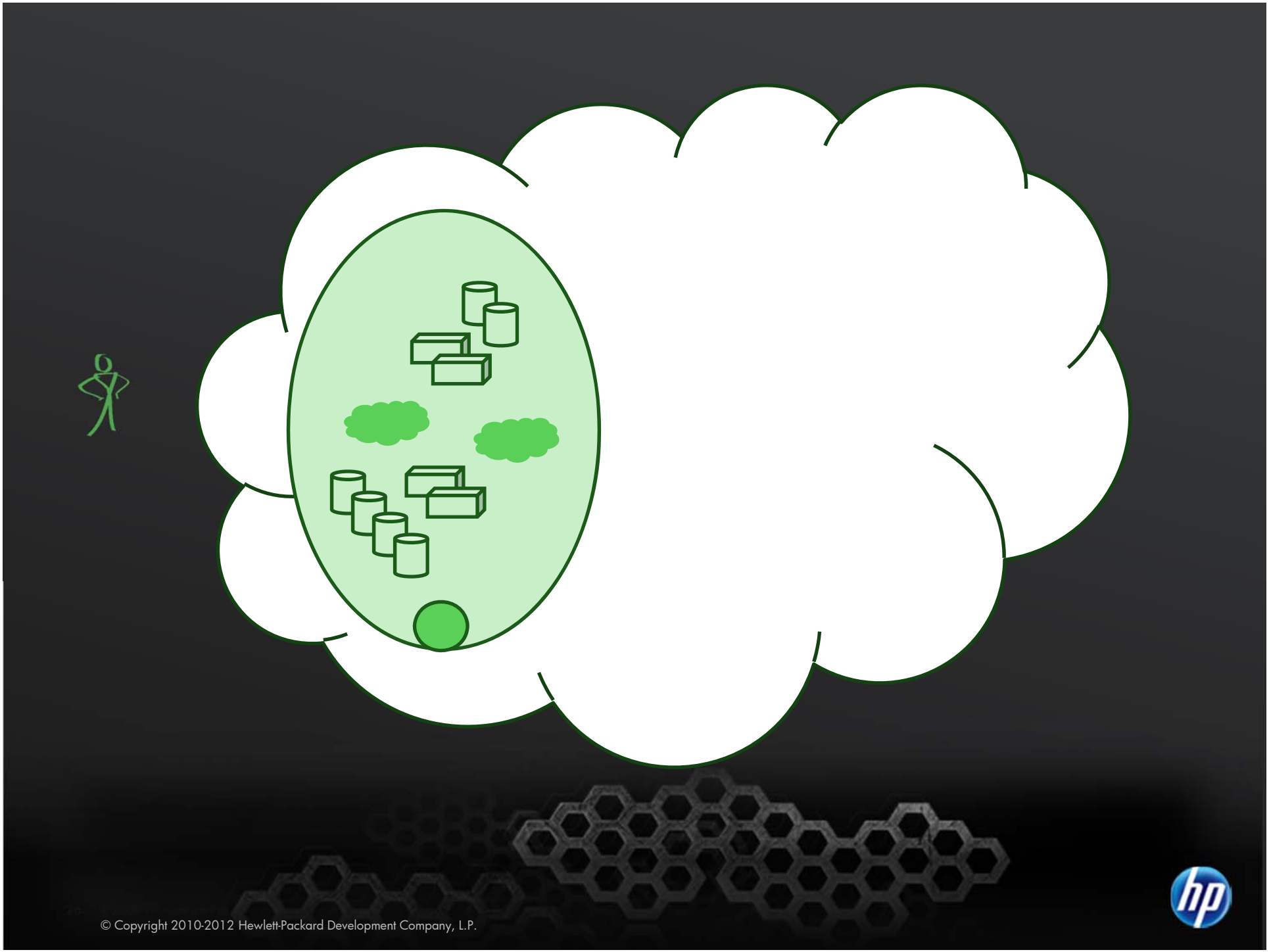


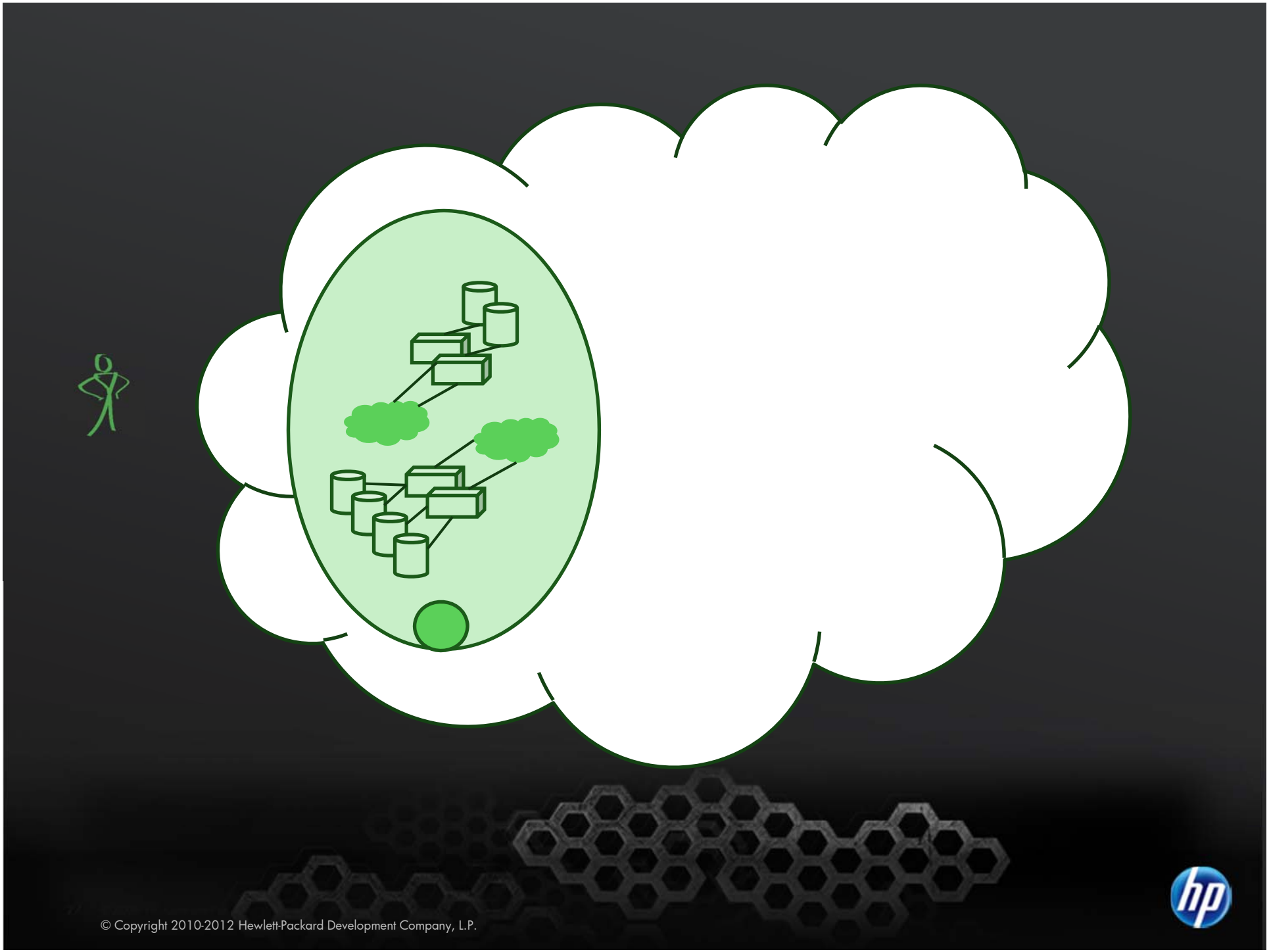


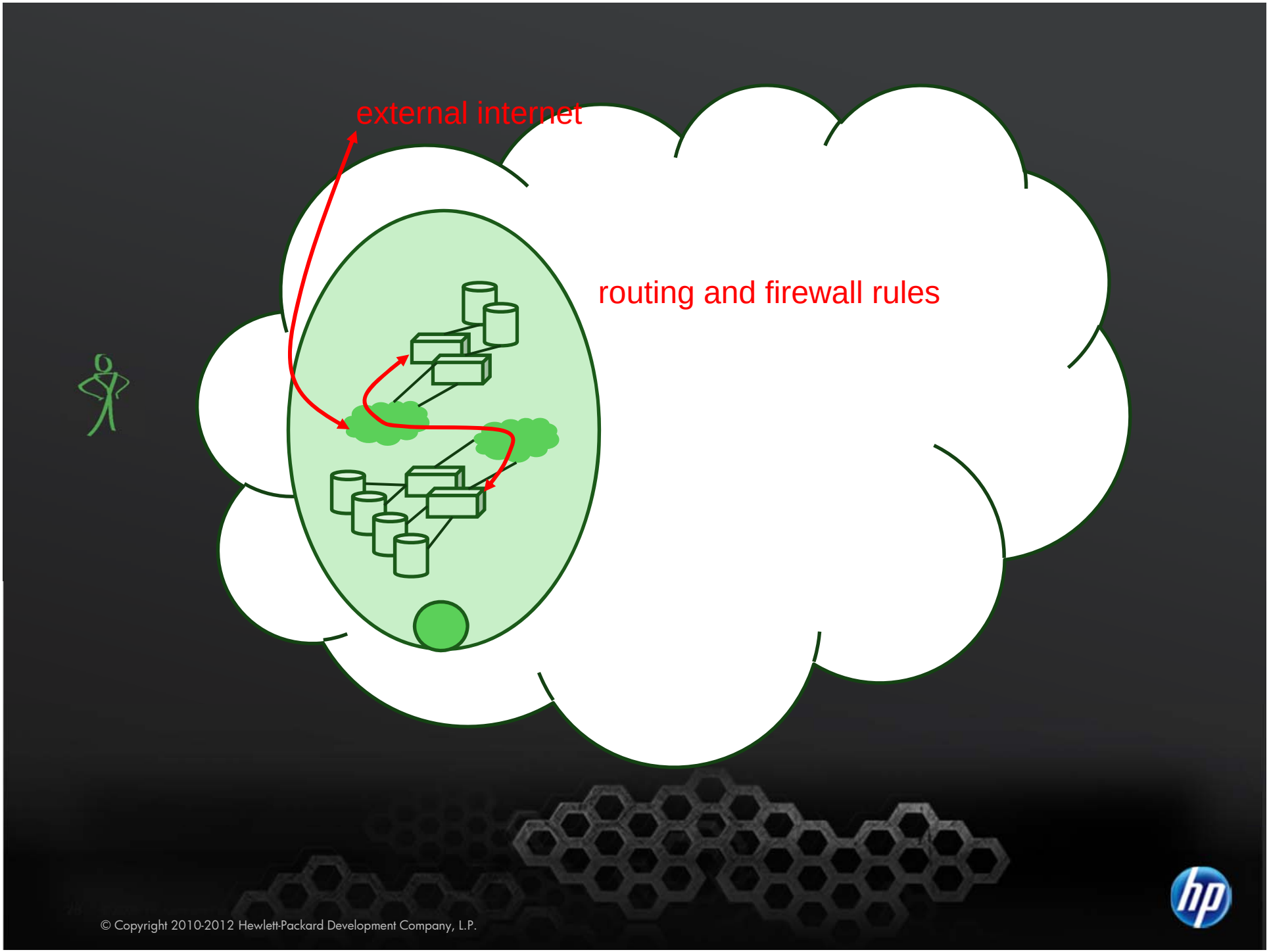


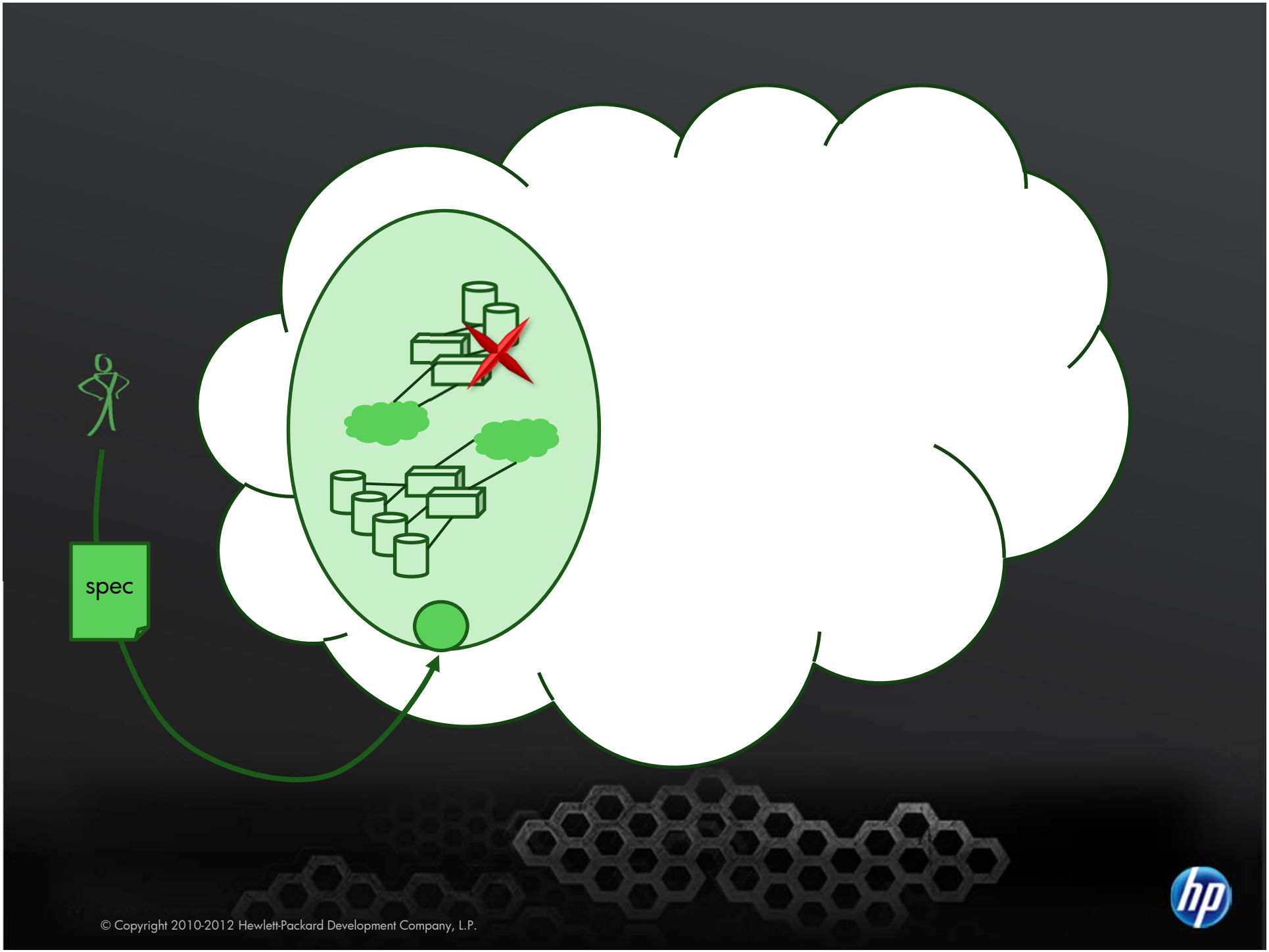


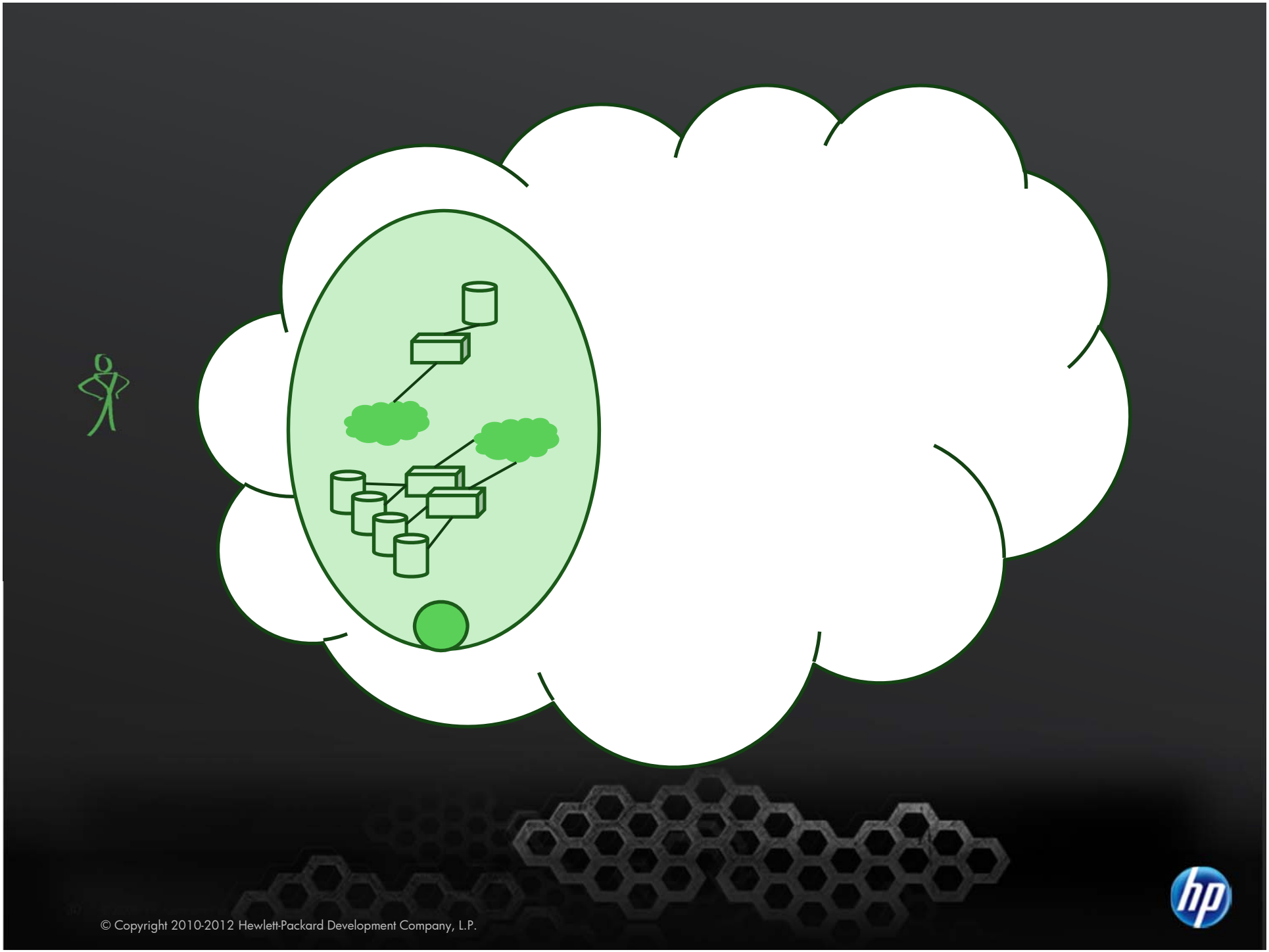


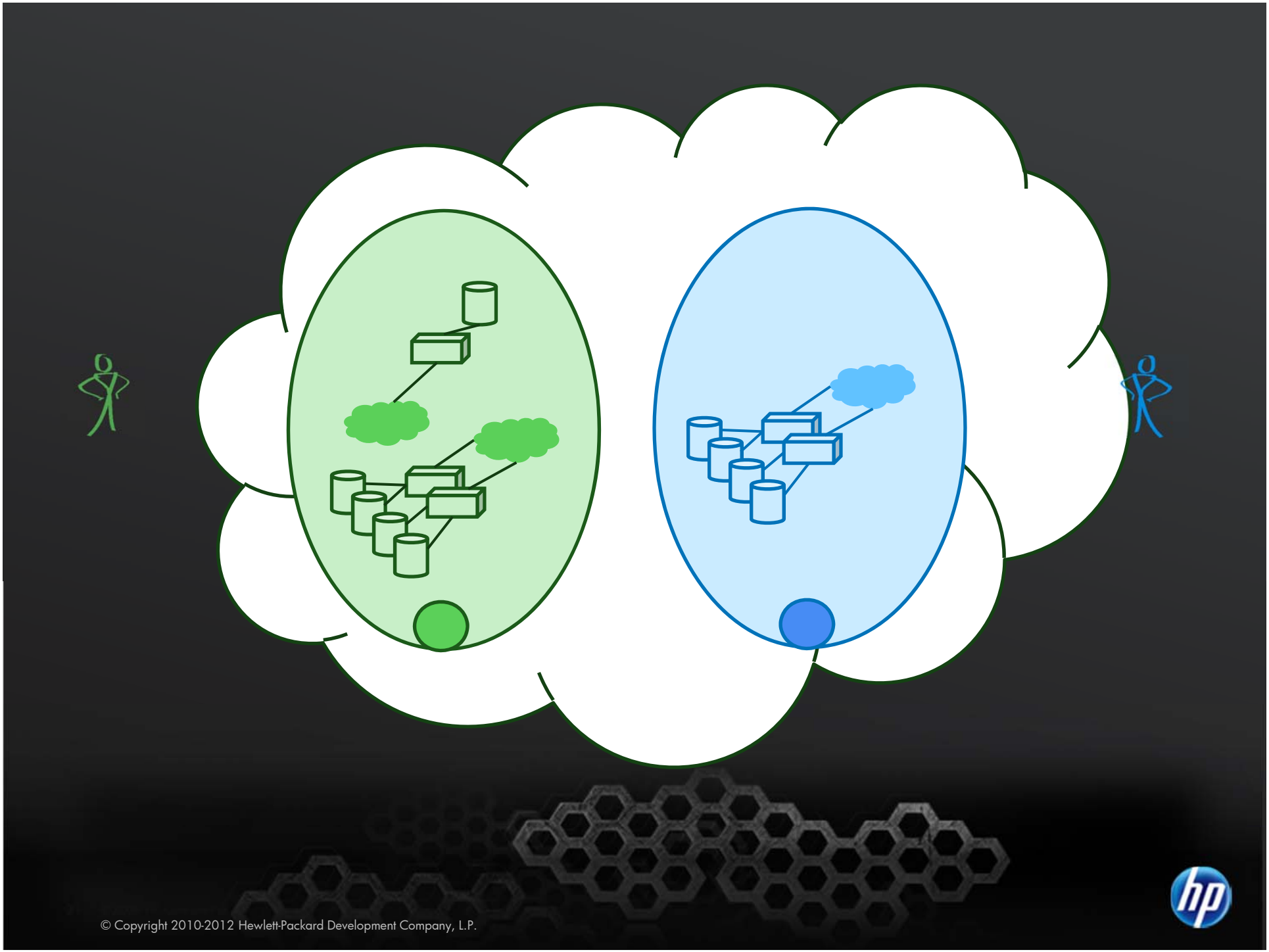


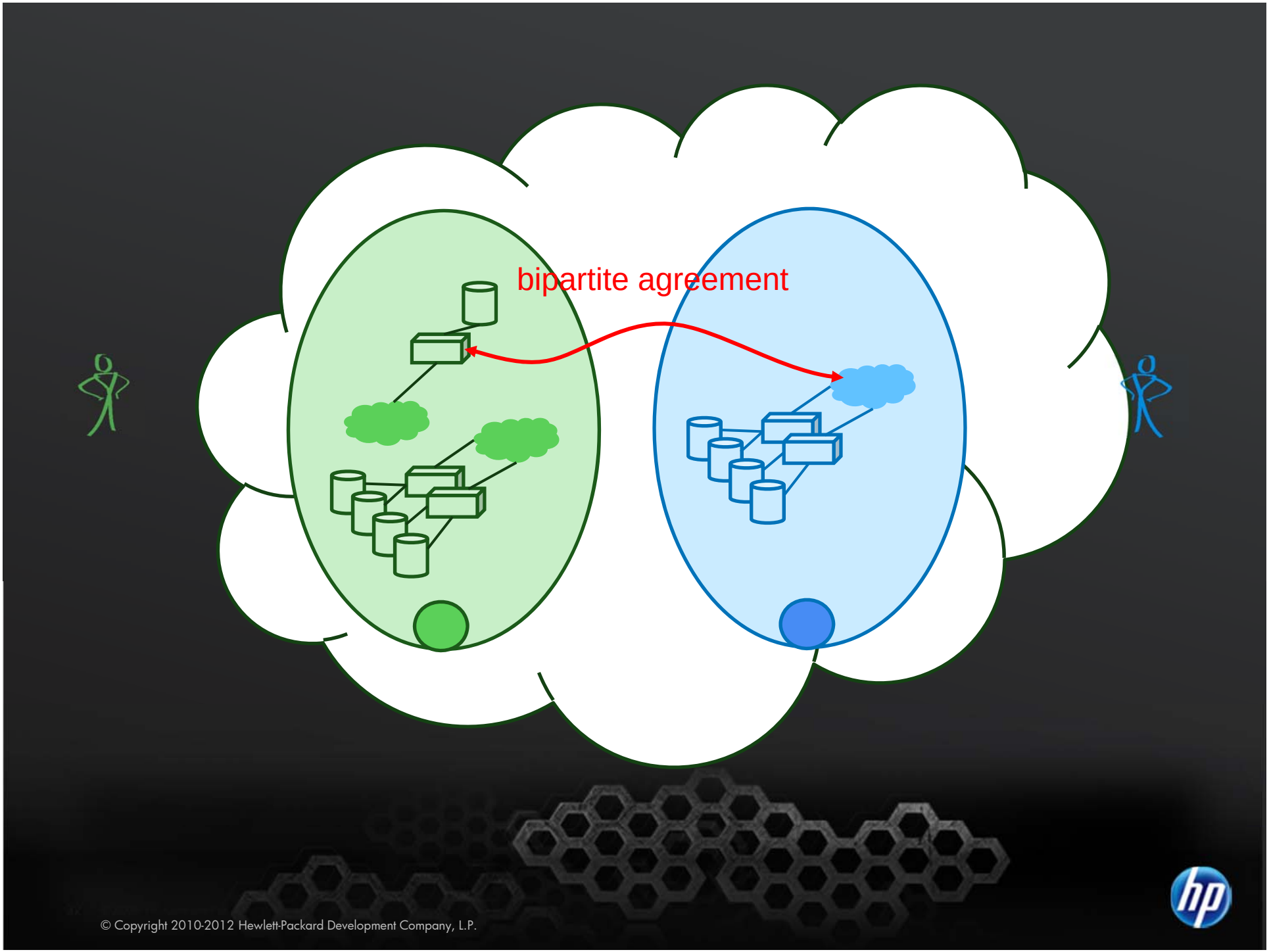






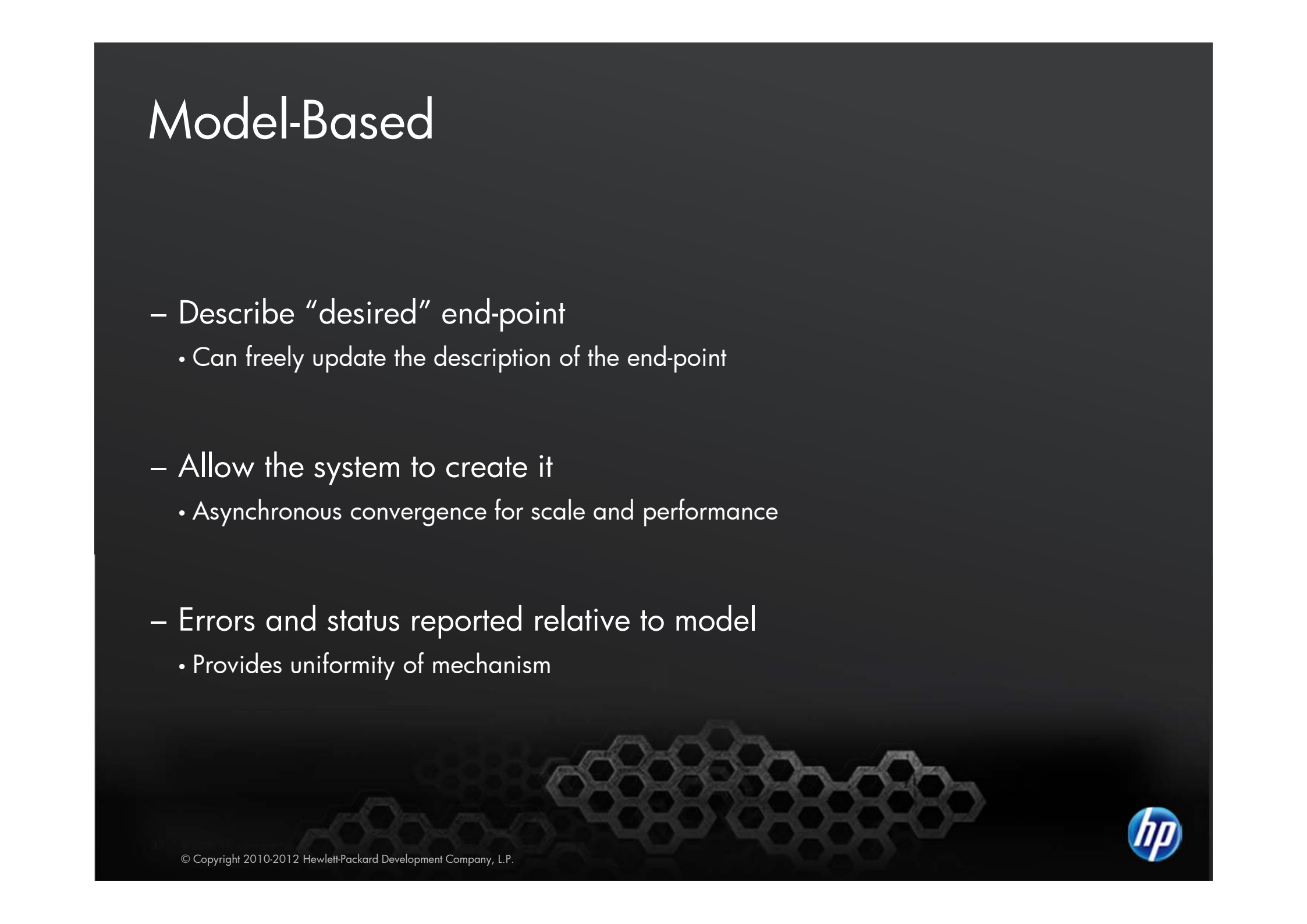






Model-Based

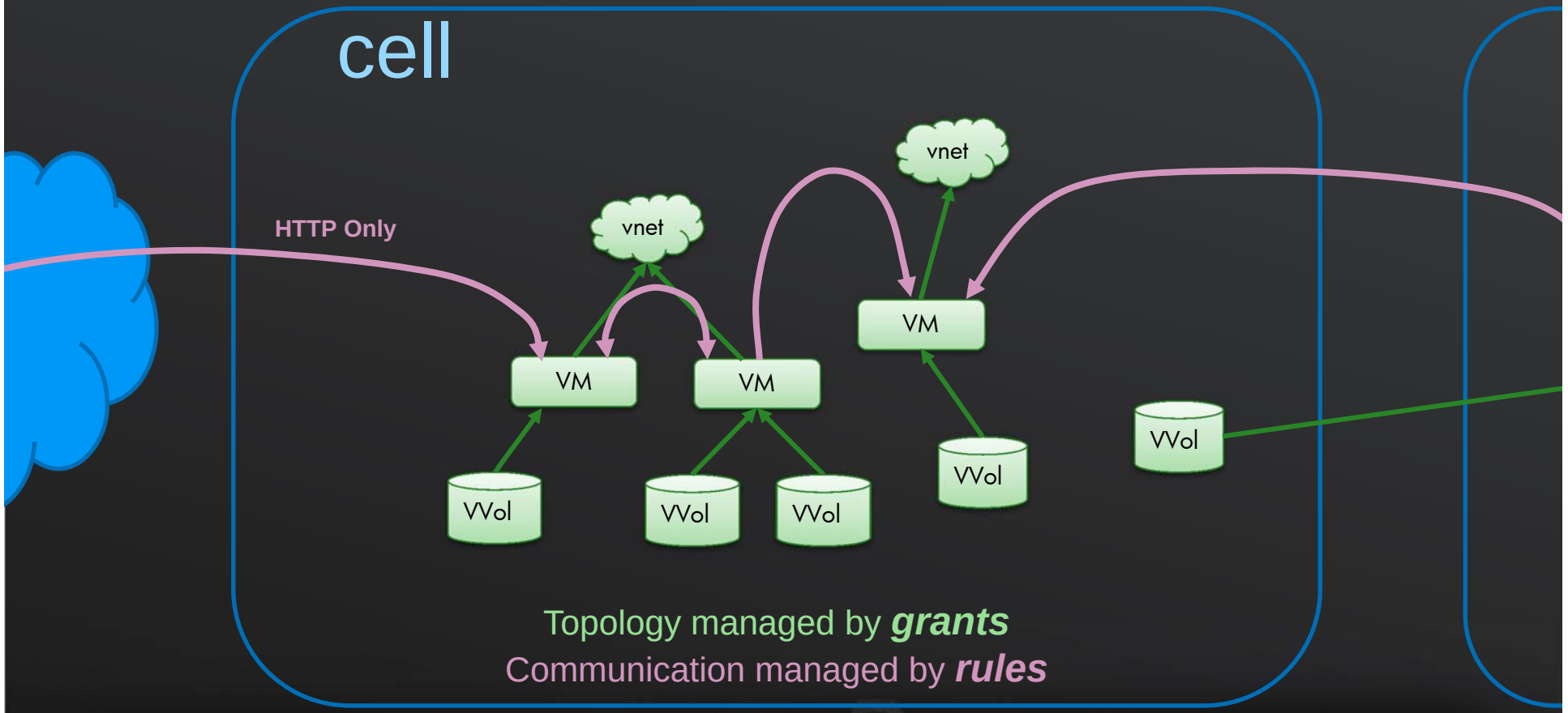
- Describe "desired" end-point
  - Can freely update the description of the end-point
- Allow the system to create it
  - Asynchronous convergence for scale and performance
- Errors and status reported relative to model
  - Provides uniformity of mechanism



Model-Based: Why

- Declarative
  - Enables analysis and tool support
  - Cross-model properties and policies
  - Basis for compliance and transparent management
  - Enables different principals to sign different parts of the model, independent of right of model submission, and mapping into enterprise IT roles
  - Enables IT best practice
- Inherently idempotent
  - Hugely simplifies interaction model, improves security
- Enables back-end asynchrony and parallelism for scale and performance
- Template descriptions of services
  - Simplifies service packaging
  - Ease of integration with a Cloud Marketplace
- Easy to map transactional interfaces to model-based; hard to do the other way around and maintain the advantages

Infrastructure Models

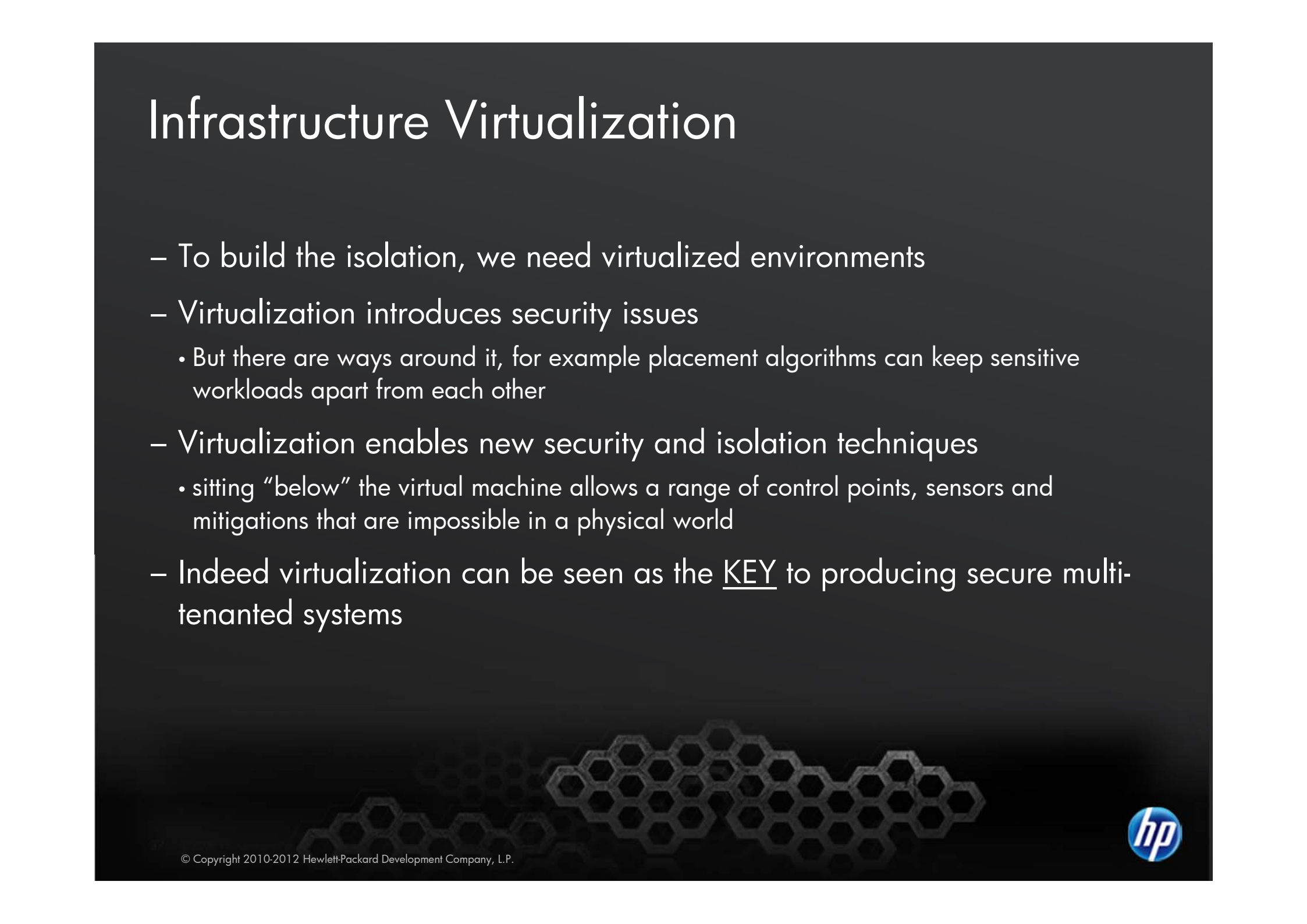


Future Modelling

- Currently we provide explicit description of topology and some security properties
- However, this is but the start….
  - Support for loose models and constraints
    - Models that are configured according to user or business-level concepts
  - Order-dependencies
    - Declarative description of state transitions and dependencies on the state
  - Specification of QoS policies
    - linked through sensor framework, constraints and dependencies, to create auto-flexing models
  - Specification of service high-availability policies
    - Automatically mapped into placement and recovery decisions
    - Federation properties
  - Specification of additional security policies
    - Guiding placement and other aspects such as providing “security probes”
    - Semantic controls over data sharing

Infrastructure Virtualization

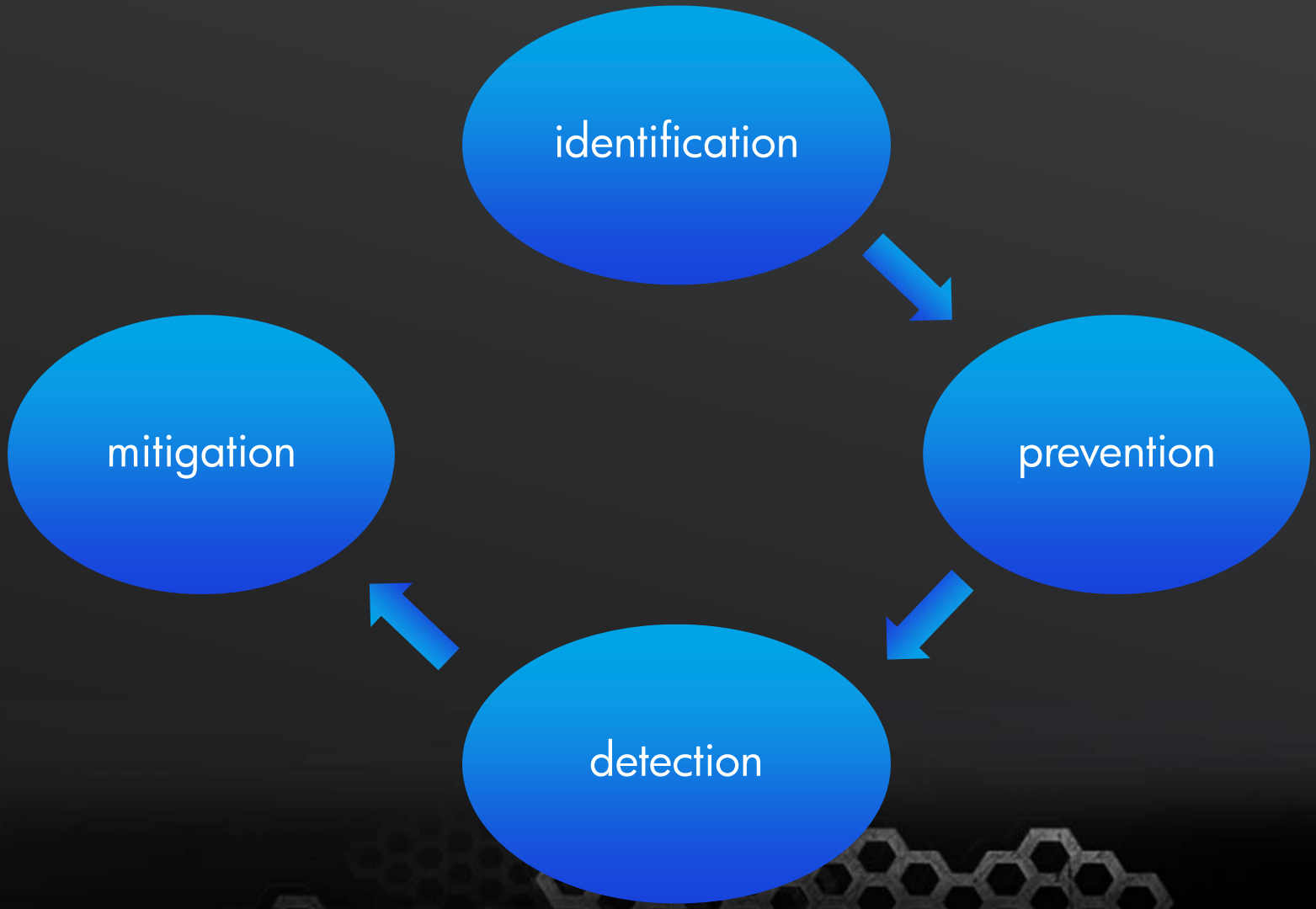
- To build the isolation, we need virtualized environments
- Virtualization introduces security issues
  - But there are ways around it, for example placement algorithms can keep sensitive workloads apart from each other
- Virtualization enables new security and isolation techniques
  - sitting "below" the virtual machine allows a range of control points, sensors and mitigations that are impossible in a physical world
- Indeed virtualization can be seen as the KEY to producing secure multi-tenanted systems

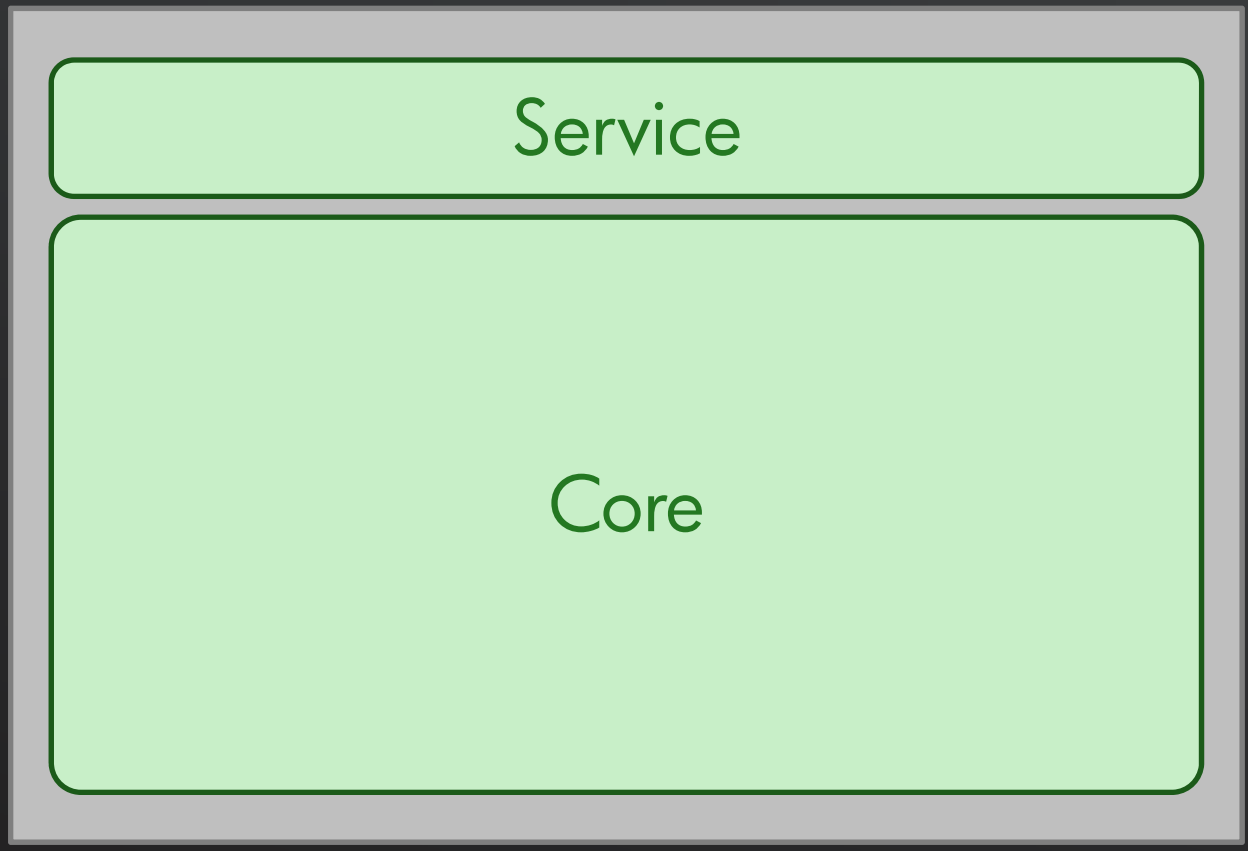


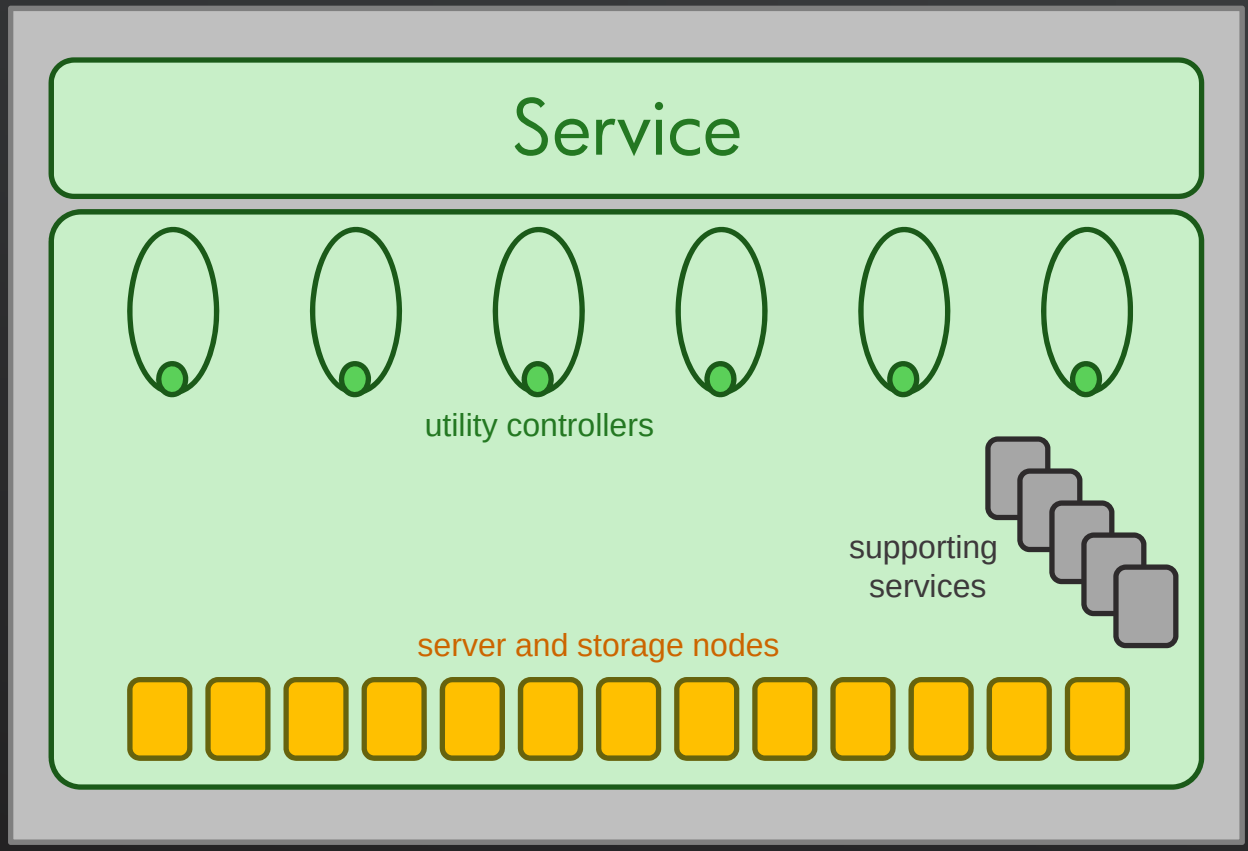
Infrastructure Integrity

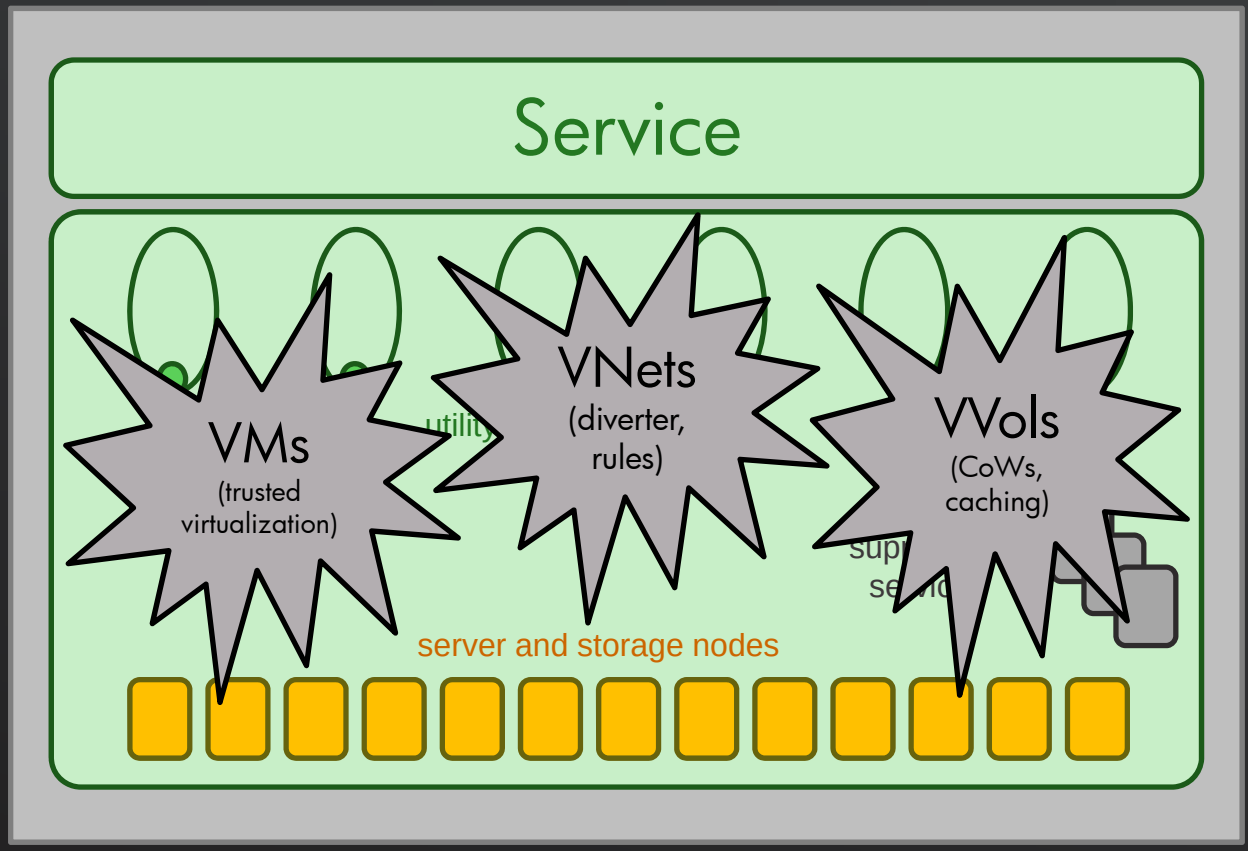
- We must protect the cloud at all costs
- Threats come from
  - Services run upon it
  - Direct attacks from outside
  - Internal administrators
- We must understand these threats, and the paths that they may use to undermine the cloud
- We must provide a number of engineering solutions to deal with the threats
  - Minimize attack surface, defence in depth
  - Provide a framework for countermeasures
  - Sensors to detect attacks, both attempts and successes
  - Mitigations to remove attempted and successful attacks
  - Diagnosing attacks by turning sensor data into diagnoses

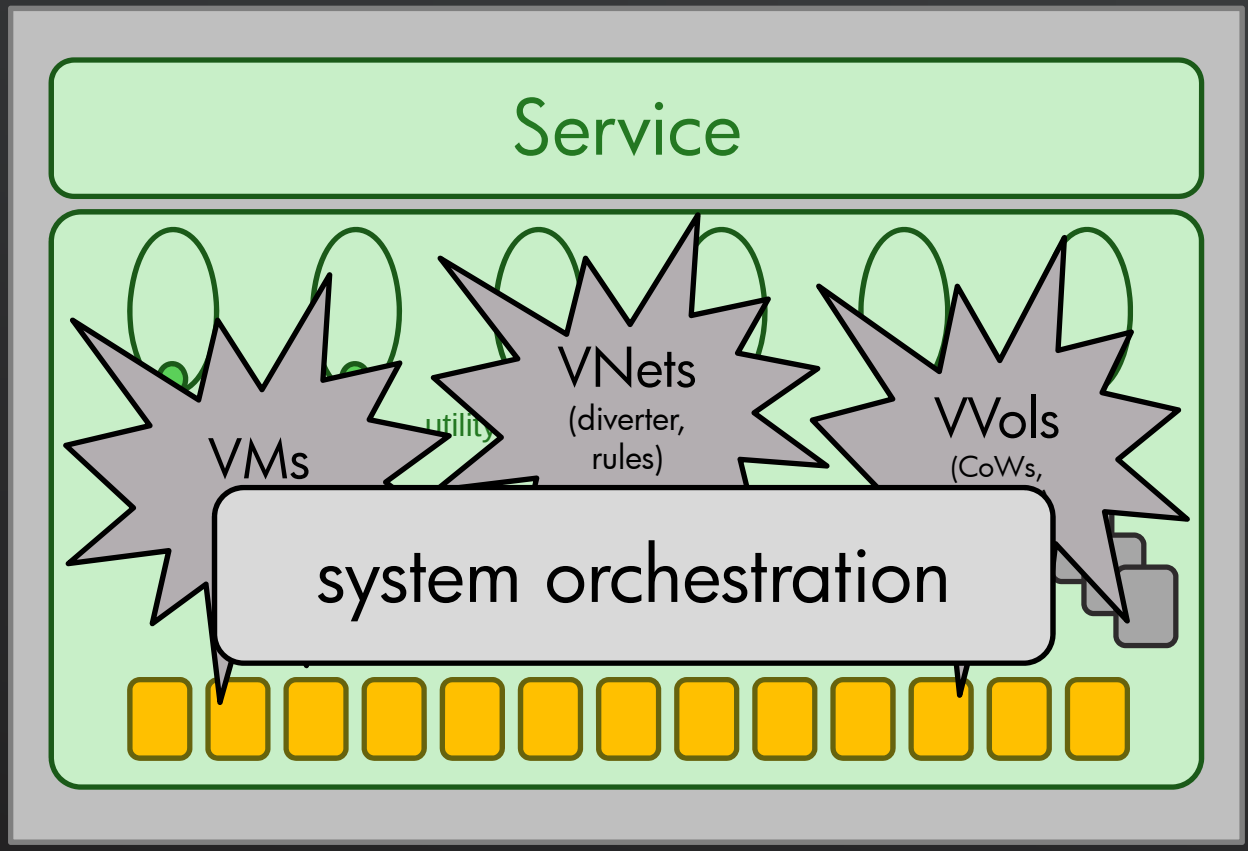
Threats





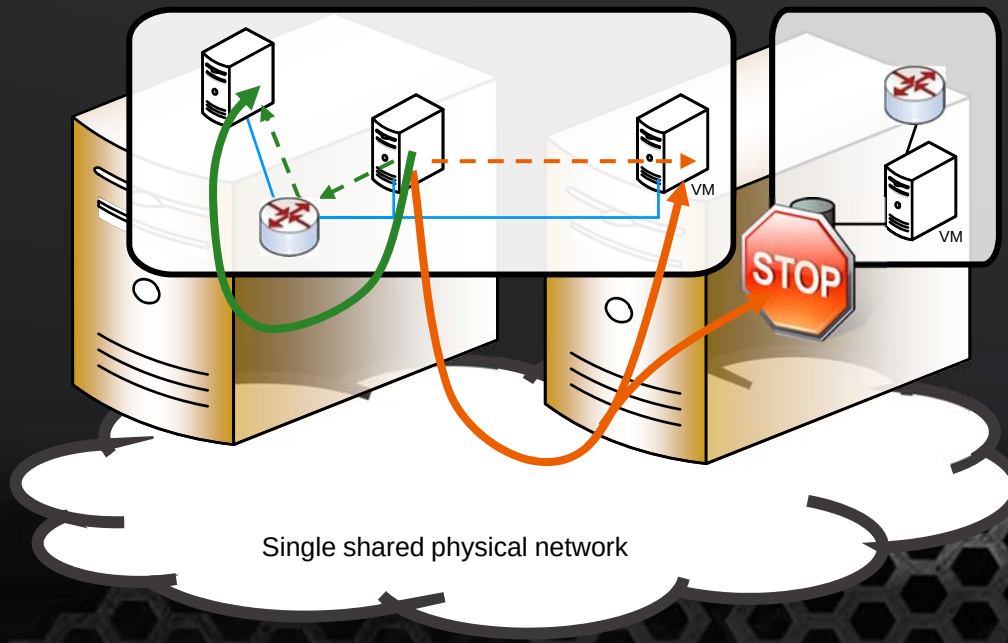




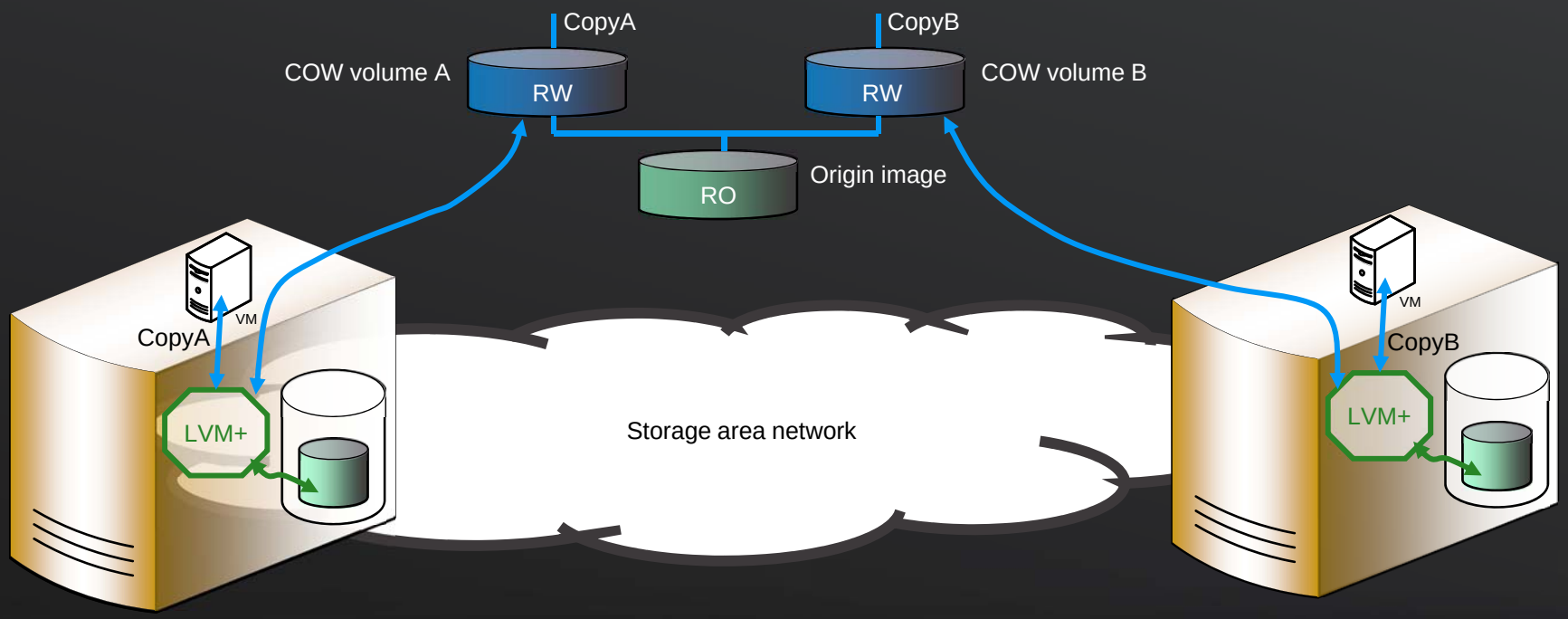


Virtual Networking

- Goals
  - Support full layer-3 unicast, multicast and broadcast packets
  - Create the illusion of subnets and routing
  - Provide all the inter-VM and subnet routing policies
  - Strong and secure separation

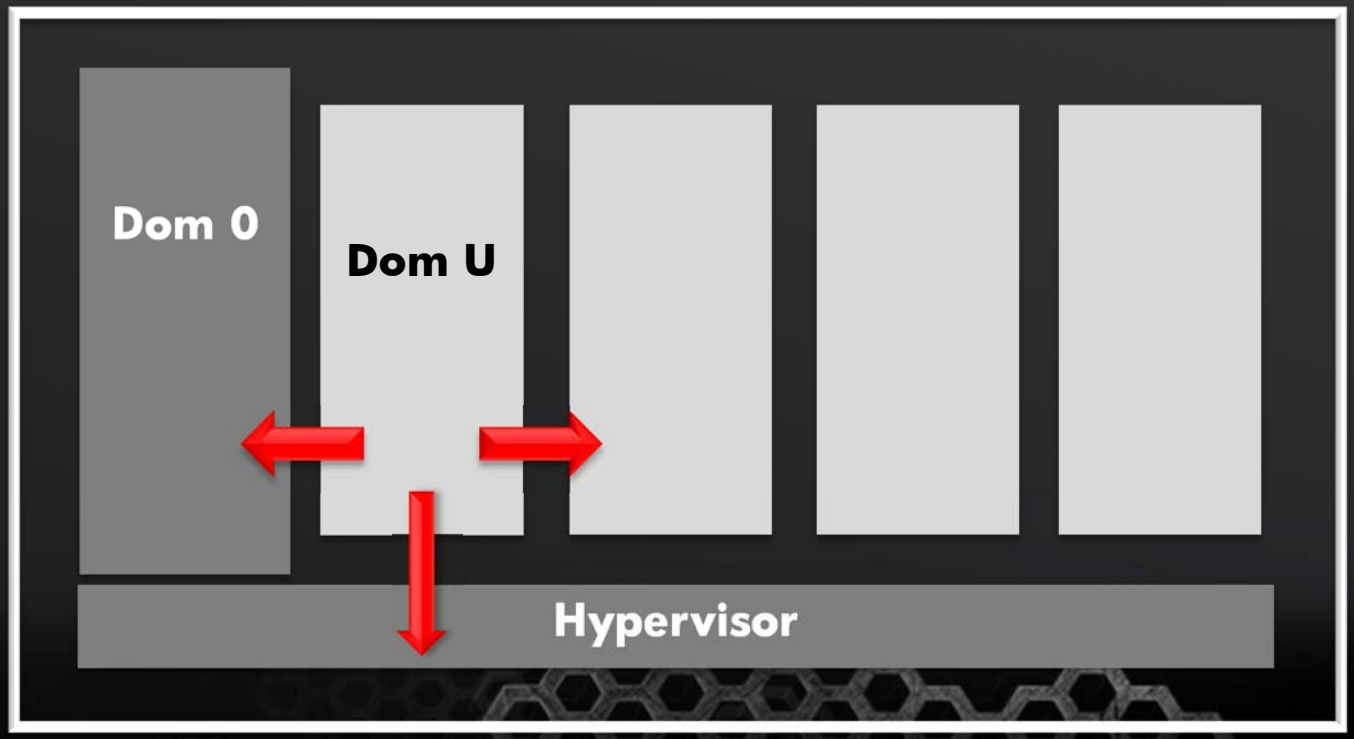


Virtual Storage



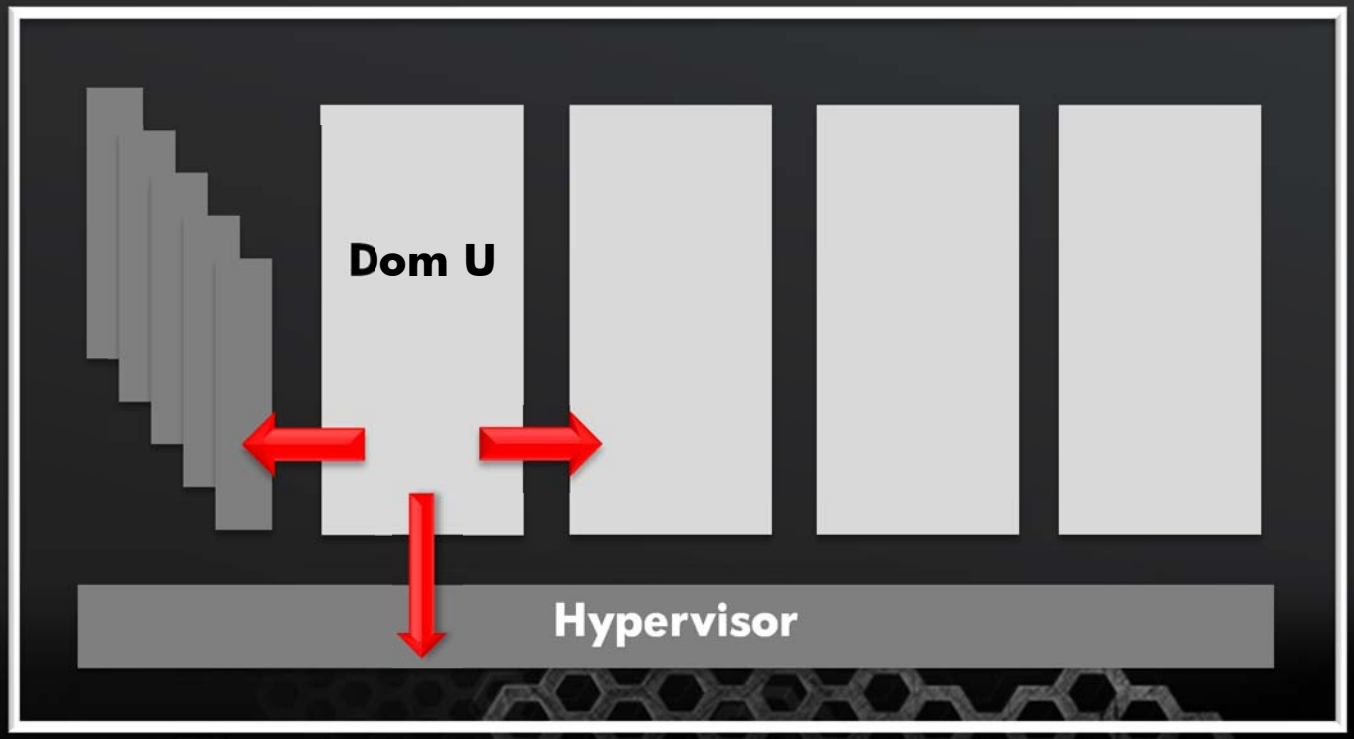
Virtualization Security: Threat

- The main requirement is that the core virtualization technology is secure
- What happens if a VM successfully breaks out of its container and takes over the host?



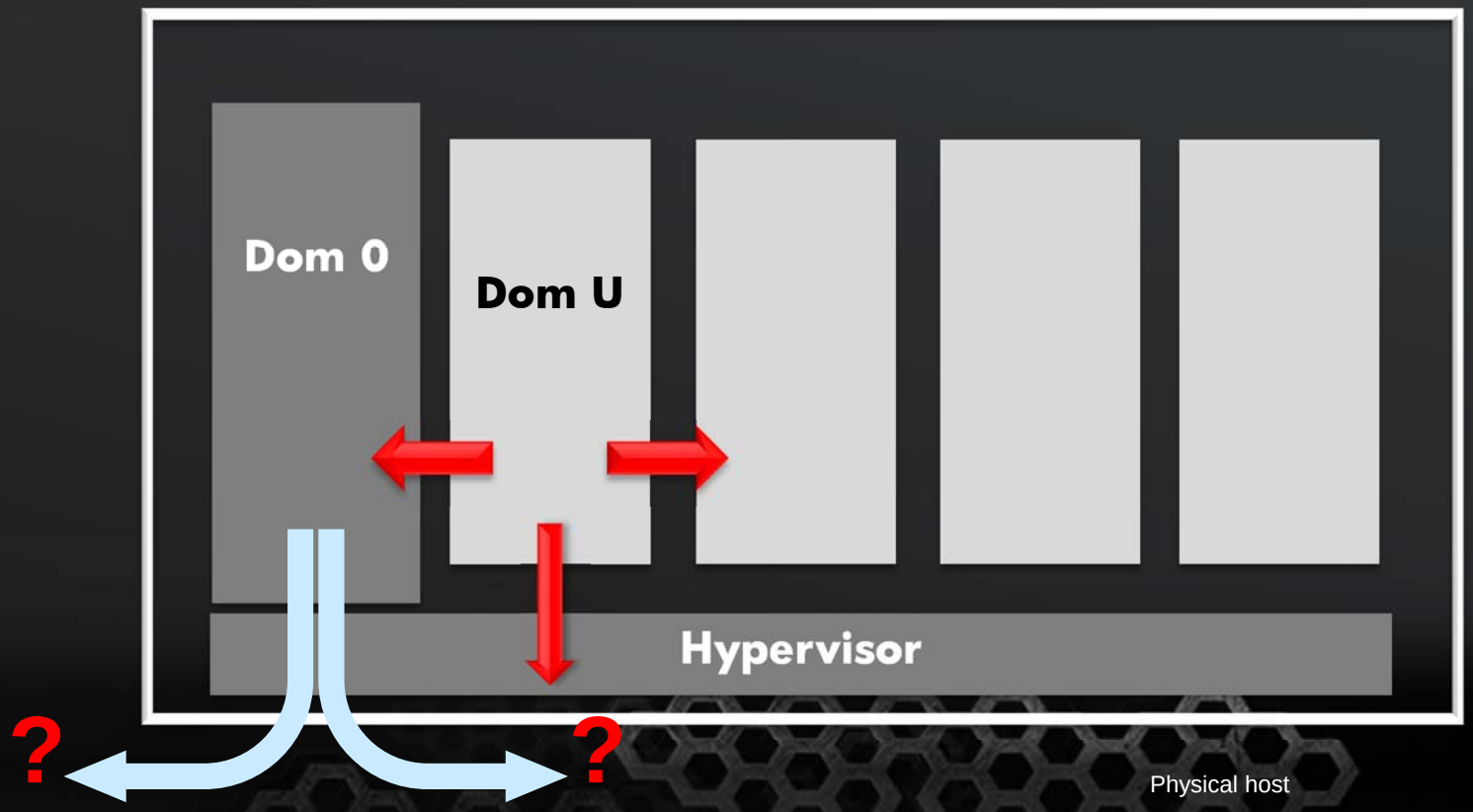
Virtualization Security: Prevention

- Use trusted virtualization technologies to minimize risk of attack and reduce impact
- Subdivide the Hypervisor and DOM0 into smaller, simpler, more secure parts and limiting the impact of success



Virtualization Security: Host Compromise

– Provide host peer-peer detection of dom0 “misbehaviour”



Sensors

Aim to detect:

– Illegal Actions

- System components detecting or initiating abnormal activity with other system components: this is either a bug or a successful attack and needs immediate attention
- Attempts of user VMs to communicate with disallowed targets

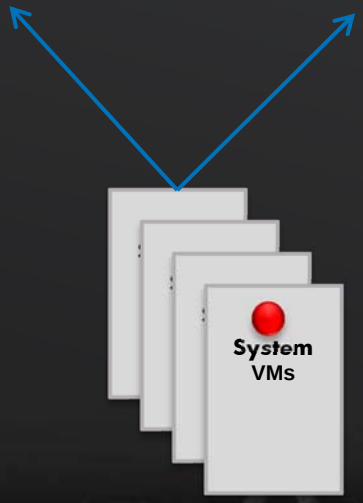
– Abnormal behaviour

- Sudden changes in profiles of IO or CPU usage
- Requests for VMs or other resources beyond reasonable or specified limits
- Excessive churn in topology
- Sudden widening of network rules

Sensors are implemented everywhere

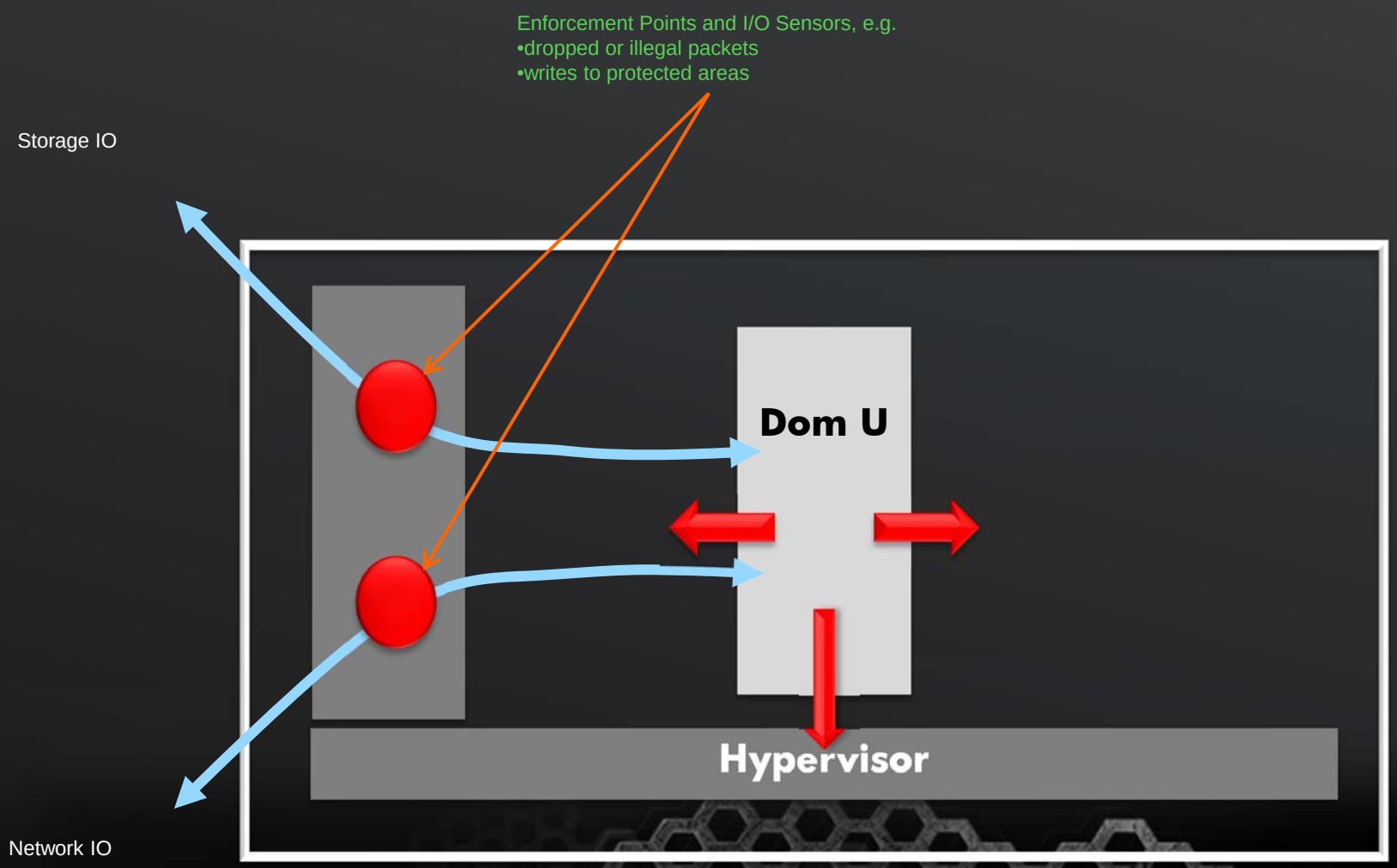
Sensors: System

System components inter-communicate in limited ways



System components can verify requests for "reasonableness"

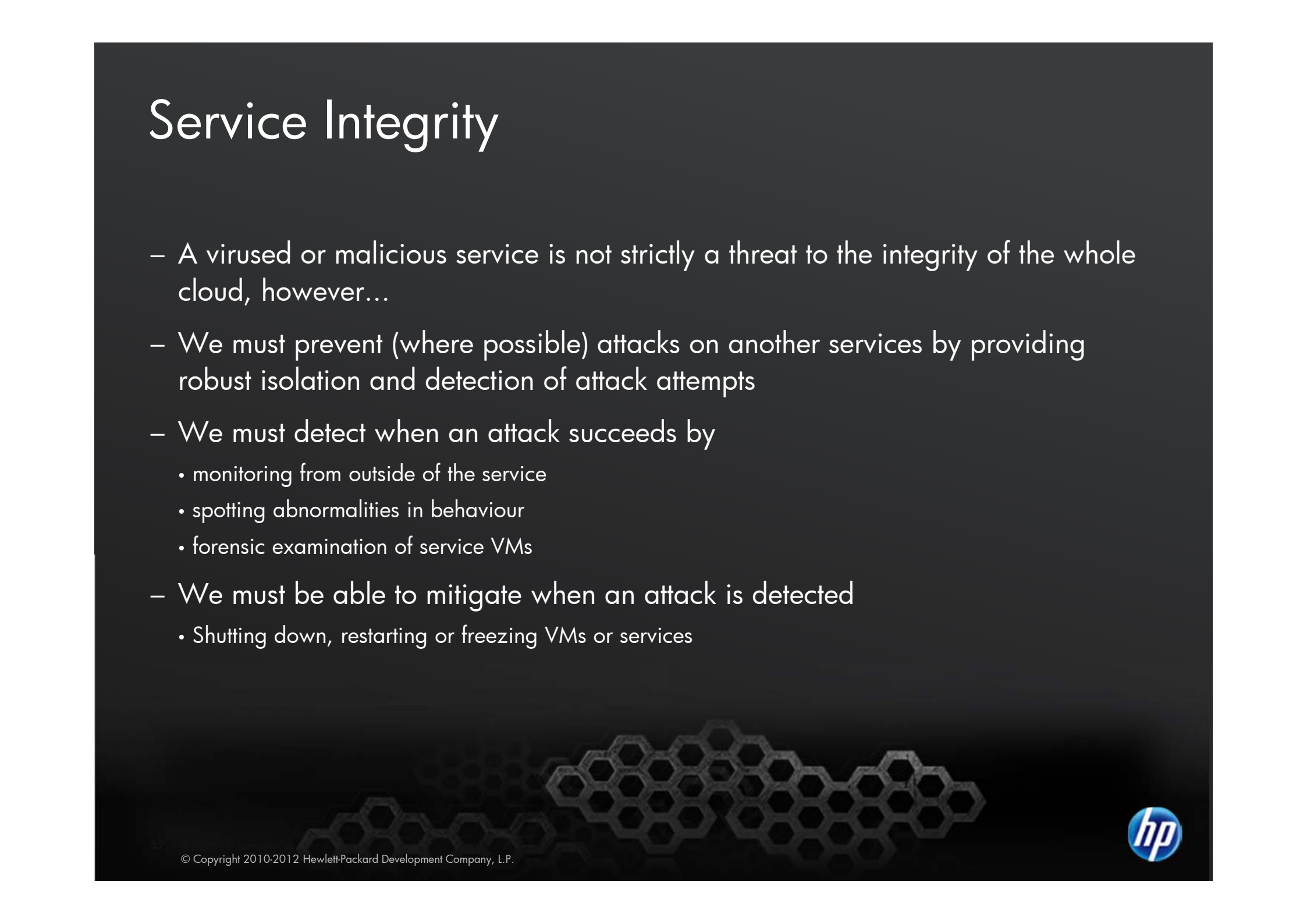
Enforcing and Sensing: IO



Includes checks on System VMs

Service Integrity

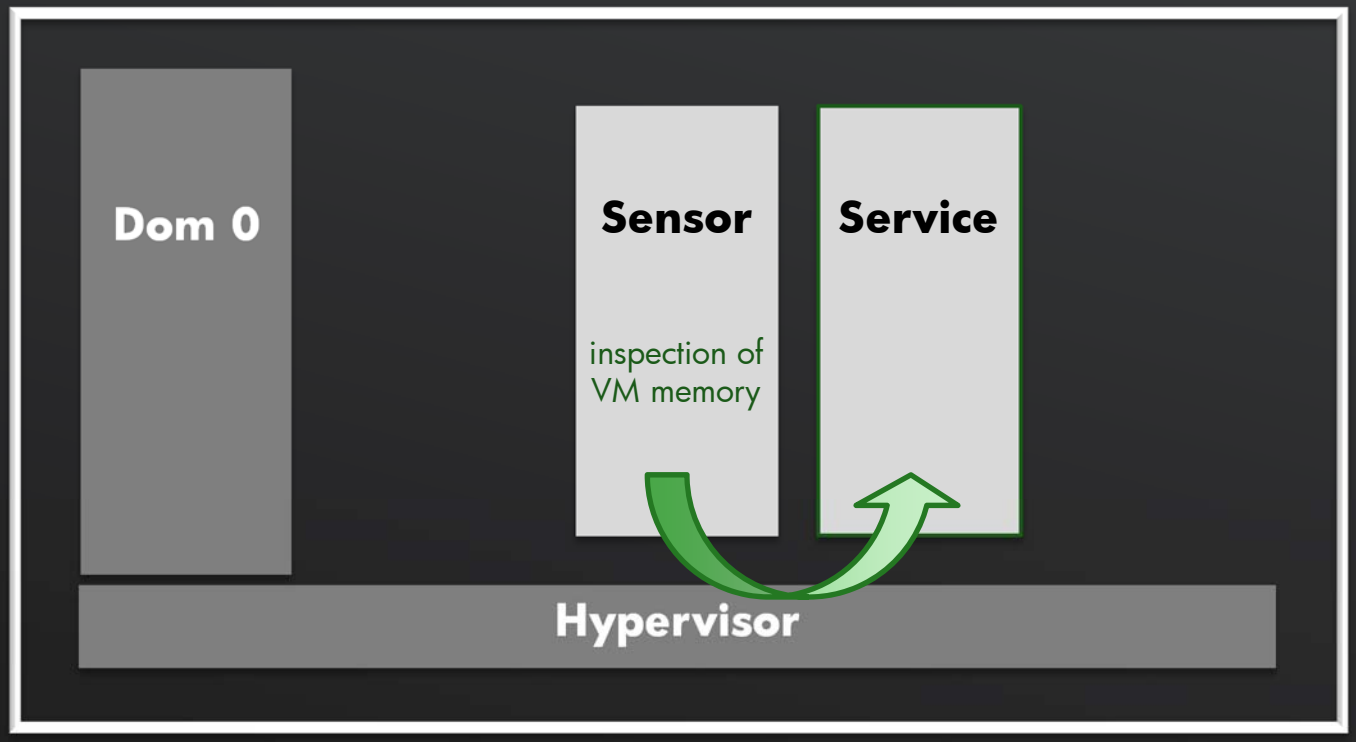
- A virused or malicious service is not strictly a threat to the integrity of the whole cloud, however…
- We must prevent (where possible) attacks on another services by providing robust isolation and detection of attack attempts
- We must detect when an attack succeeds by
  - monitoring from outside of the service
  - spotting abnormalities in behaviour
  - forensic examination of service VMs
- We must be able to mitigate when an attack is detected
  - Shutting down, restarting or freezing VMs or services



Service Sensors

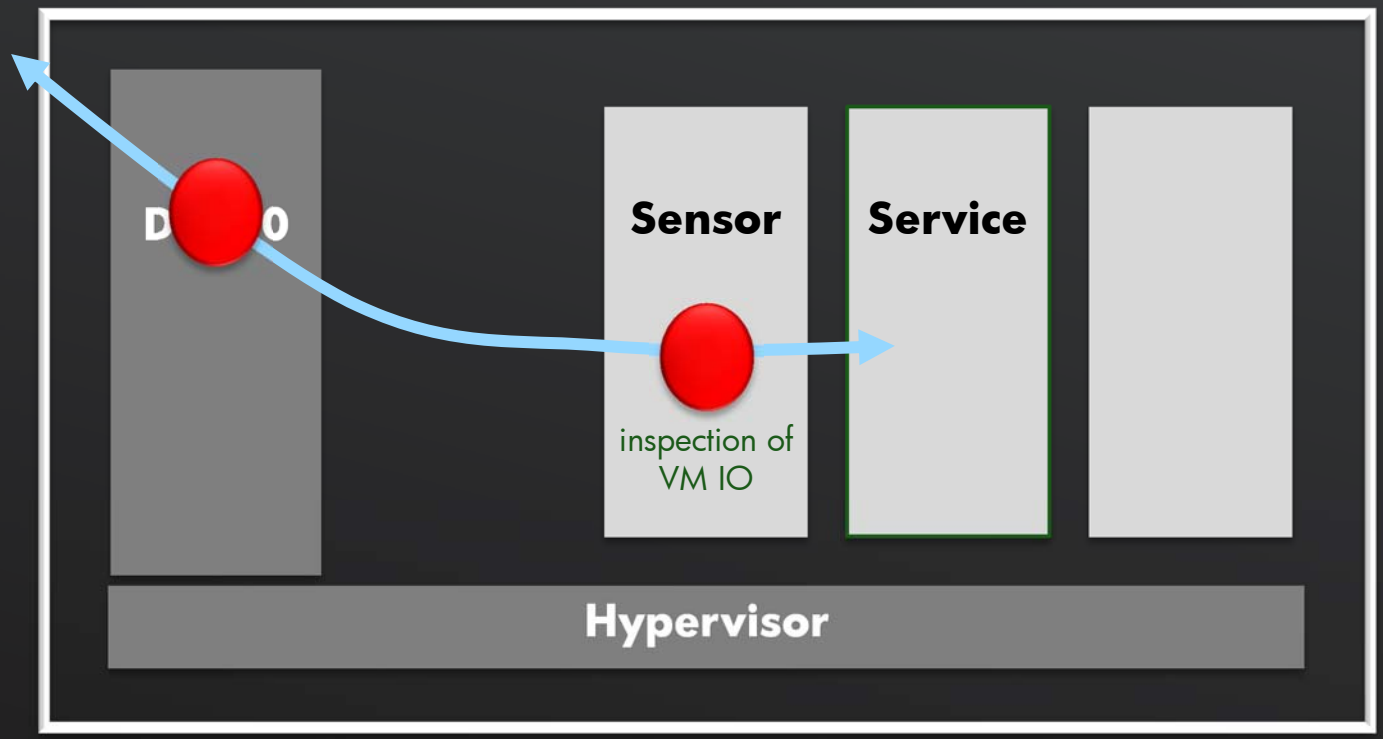
- We want to allow service writers to be able to create sensors that monitor their own services
  - run outside of the service, looking in, and undetectable to it
  - service owners have a better view of the service semantics
  - can be offered by 3rd party monitoring specialists (NSA for USG)
  - that do not have any privileged access to core system capability
- Virtualization gives control over what one compartment can do or see with another compartment.
- We can use the fact that one virtual machine can (given permission)
  - look into the memory space of another.
  - Interpose itself into an IO path of another.

Sensor VMs



- Invisible to the service VM
- Viruses and root-kits cannot hide by altering OS or disabling virus checkers
- Enabled by an API in the hypervisor
- Needs care to ensure that it doesn't become another vector for attack!

Sensor VMs



– Deployable by the service provider, infrastructure provider or trusted 3rd party

Sensor VM properties

- It's hard to detect the presence of the sensors.
- It's impossible to hide the code or IO from the sensors
- We can see if the OS tables have been manipulated
- We can see into disc and network buffers
- We can sit in the IO path and carry out specific deep inspection
- We can look for evidence of the use of different "virus components"
- We do not look only for specific attacks
- We gain evidence to suggest the existence of malware.

Our Demonstrator