Emerging Systems for Operating Data Centers

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GI FG Betriebssysteme Herbsttreffen
TU Dresden, Dec 16, 2004

Outline

- New domain for OS: Enterprise IT environments
- Research Prototype from HP Labs
  - Formal Basis: Layered Information Model
  - Resource Grounding
  - Resource Allocation
- Summarizing remarks

6TH SYMPOSIUM ON OPERATING SYSTEMS DESIGN & IMPLEMENTATION

'04

Sponsored by USENIX
in cooperation with ACM SIGOPS

11:00 a.m.–12:30 p.m.

AUTOMATED MANAGEMENT I

Automated Worm Fingerprinting
Sumeet Singh, Cristian Estan, George Varghese, and Stefan Savage, *University of California, San Diego*

Understanding and Dealing with Operator Mistakes in Internet Services
Kiran Nagaraja, Fabio Oliveira, Ricardo Bianchini, Richard P. Martin, and Thu D. Nguyen, *Rutgers University*

System Administration as Search: Finding the Needle in the Haystack
Andrew Whitaker, Richard S. Cox, and Steven D. Gribble, *University of Washington*

Microreboot—A Technique for Cheap Recovery
George Candea, Shinichi Kawamoto, Yuichi Fujiki, Greg Fr
Armando Fox, *Stanford University*

11:00 a.m.–12:30 p.m.

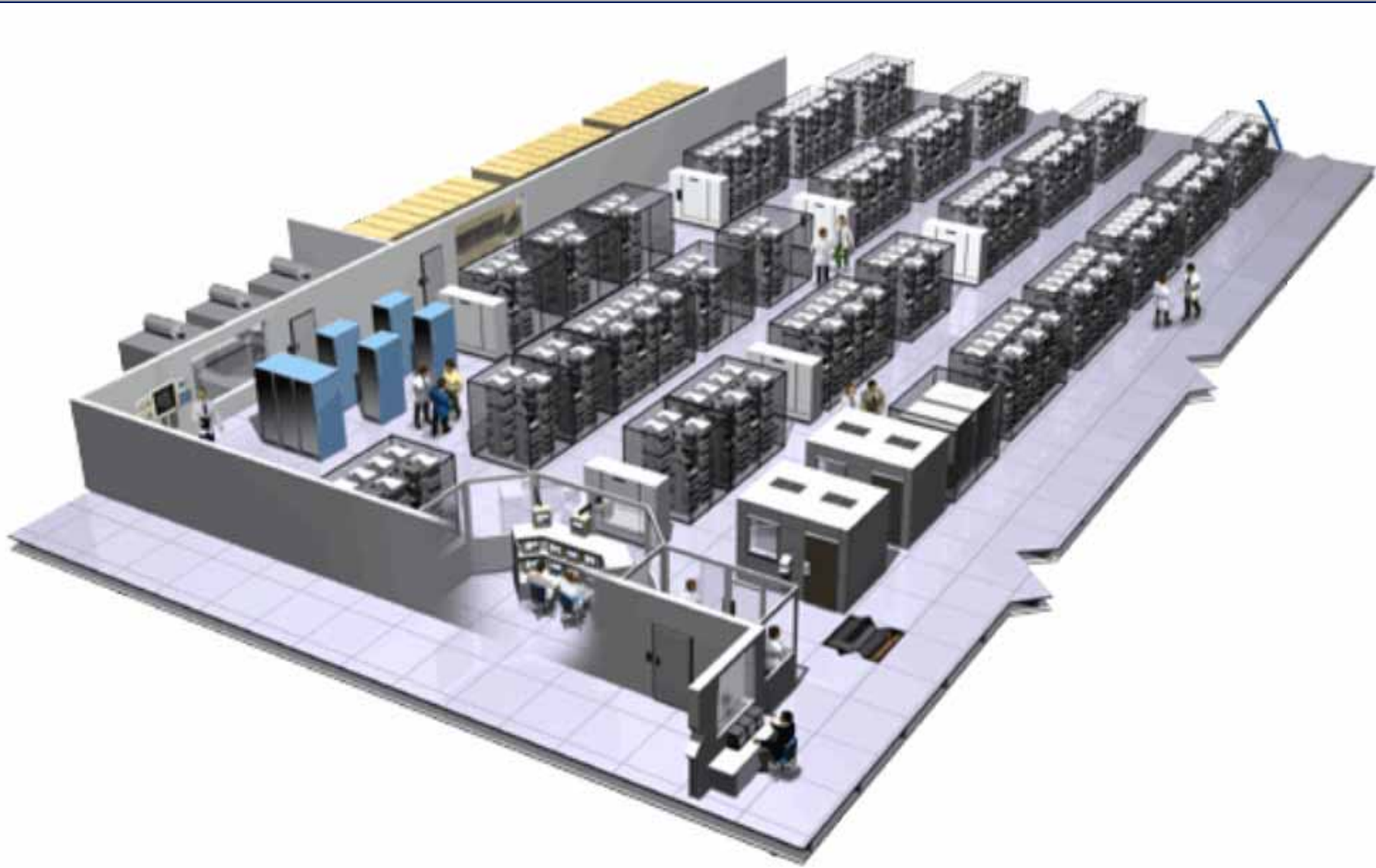
AUTOMATED MANAGEMENT II

Correlating Instrumentation Data to System States: A Building Block for Automated Diagnosis and Control
Ira Cohen, *Hewlett-Packard Laboratories;* Jeff Chase, *Duke University;* Moises Goldszmidt, Terence Kelly, and Julie Symons, *Hewlett-Packard Laboratories*

Automatic Misconfiguration Troubleshooting with *PeerPressure*
Helen J. Wang, John Platt, Yu Chen, Ruyun Zhang, and Yi-min Wang, *Microsoft Research*

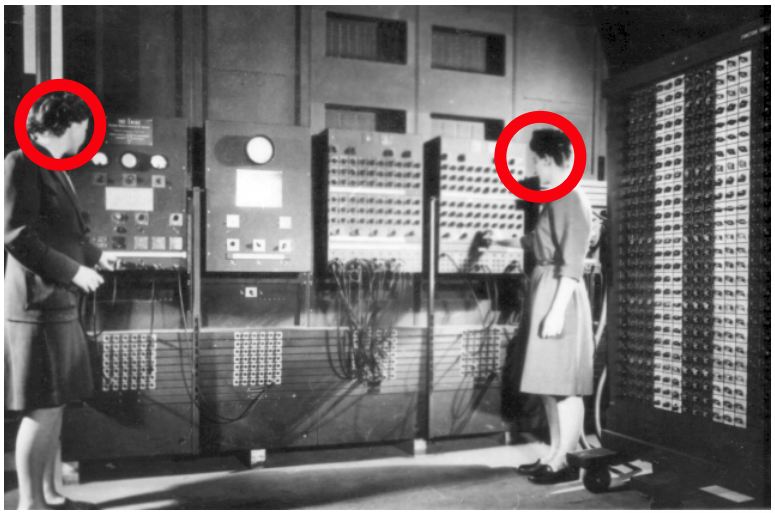
Using Magpie for Request Extraction and Workload Modelling
Paul Barham, Austin Donnelly, Rebecca Isaacs, and Richard Mortier, *Microsoft Research, Cambridge, UK*

Enterprise Data Center



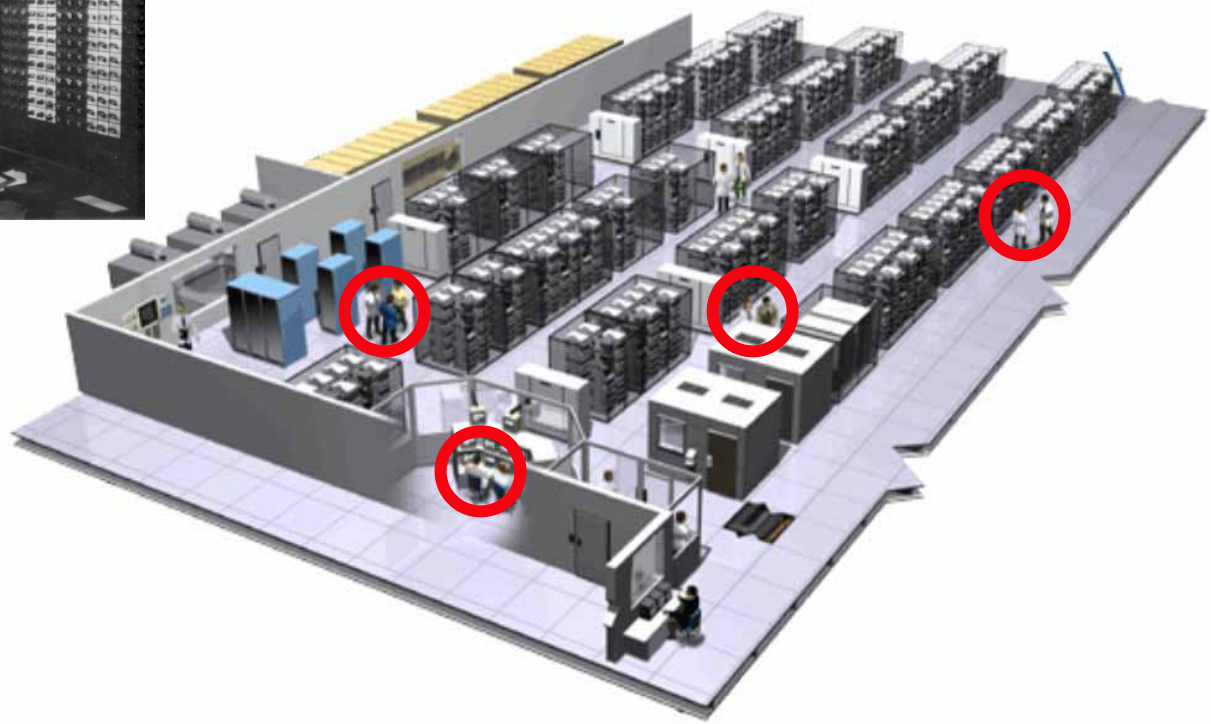
Ratio: Operators / Machines

1954: **20-to-1**…



…50 years later: **1-to-20** avg.

(Google: 1-to-500)



Single Computer Environment

- has pool of local resources shared among applications:
  - CPUs, Memory, Disks, Busses
  - IO devices
- purpose: host data and perform applications.
  - editor, compiler, browser
  - text processor

- **Operating System:** resource management, application control, monitoring and accounting, access control.
  - Linux, HP-UX, Windows

Data Center Environment

- has pool of local resources shared among applications:
  - Servers, Storage Arrays, Networks
  - Devices (LB, FW)
- purpose: host data and perform applications.
  - SAP, CRM, ERP
  - Oracle

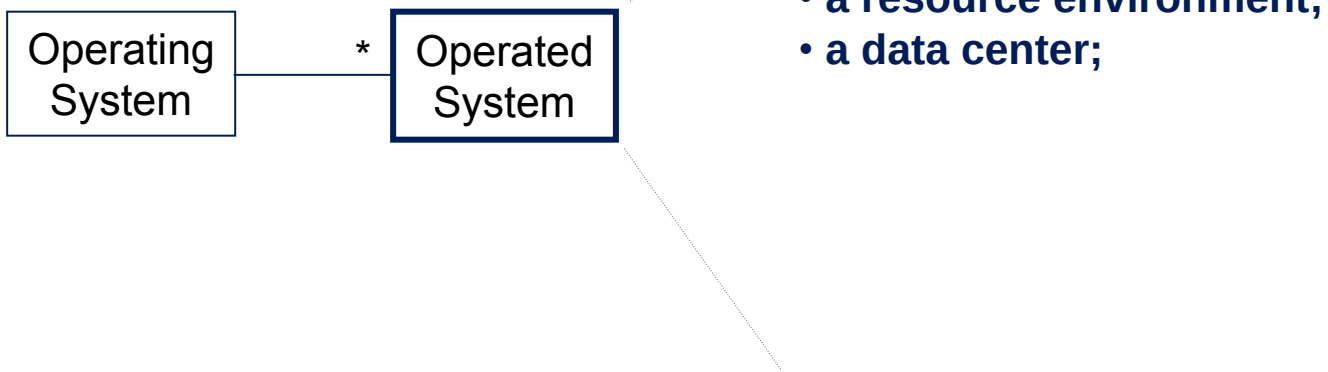
- **OperatingSystem:** resource management, application control, monitoring and accounting, access control.
  - HP OpenView, Tivoli: monitoring assistance

Globally Networked Enterprise IT

- distributed enterprise IT systems (e.g. supply-chain, procurement),
- global scale, e.g. HP 140 data centers world wide, 7,000 applications
- Enterprise Grid (leverage Grid technology)

Definition

- An **Operating System** is a **System** that **operates Systems.**



Definition

- An **Operating System** is a **System** that **operates Systems.**

- a device, a machine;
- a resource environment;
- a data center;

also:

- **an application;**
- **an IT solution;**

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- **local to**
- **large-scale, distributed.**

Definition

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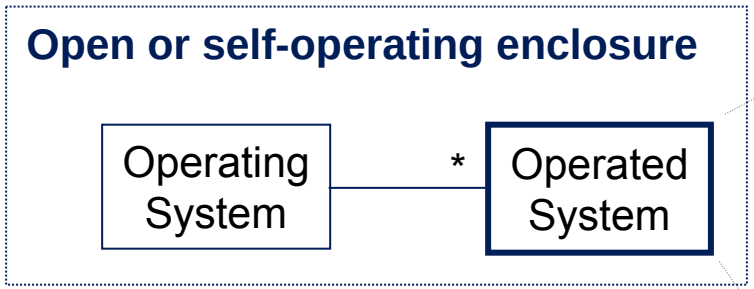


- a device, a machine;
- a resource environment;
- a data center;

- an application;
- an IT solution;

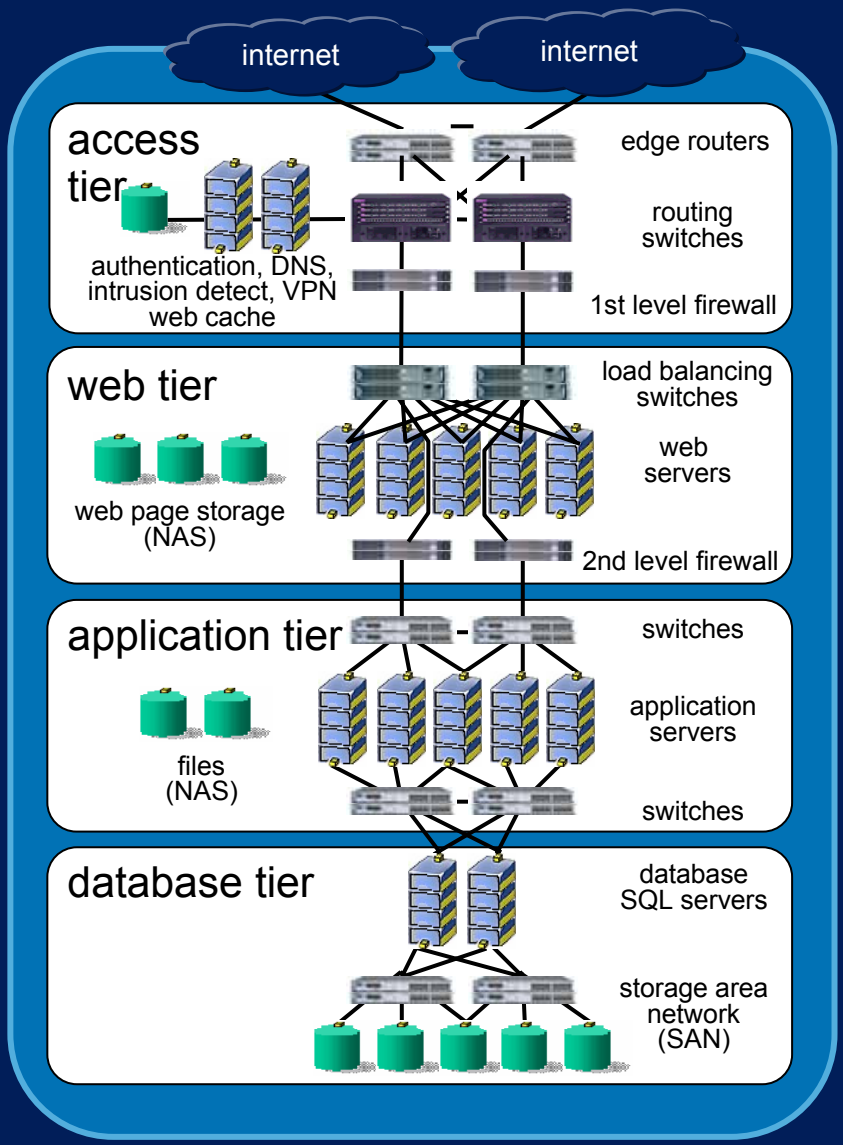
- local to
- large-scale, distributed.

Hypothesis

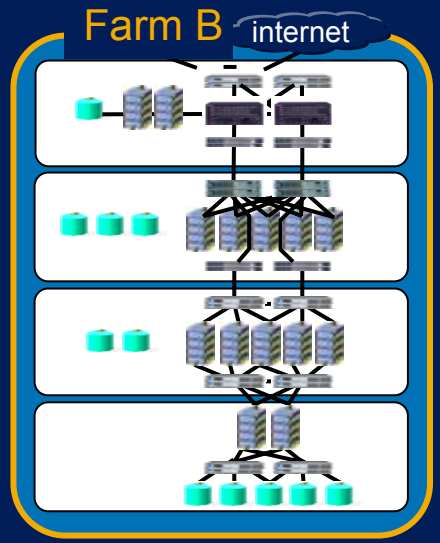
New OS Technologies will:

- largely automate the operation of data centers and IT solutions
  - Resource management, configuration management, application deployment, HW&SW life cycle management, monitoring, accounting;
- merge into commercial IT software and solutions for automating their operation (“self-”)
  - HP’s Adaptive and IBM’s Autonomic Computing, SAP’s Utility Initiative, Oracle’s 10g;
- fundamentally change the way IT solutions are planned, designed, implemented, operated
  - using more formal methods and models that also enable computer-assistance and design tools;

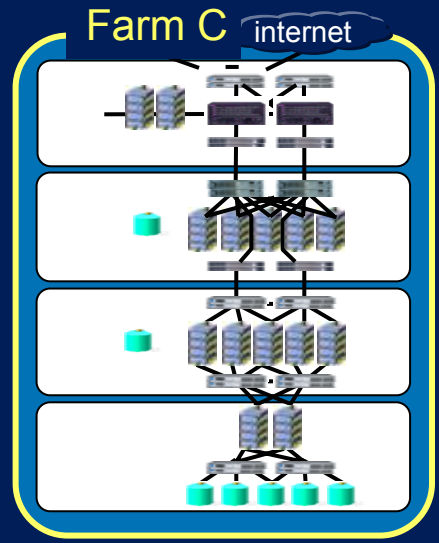
Enterprise Applications



Application Container: “Farm”

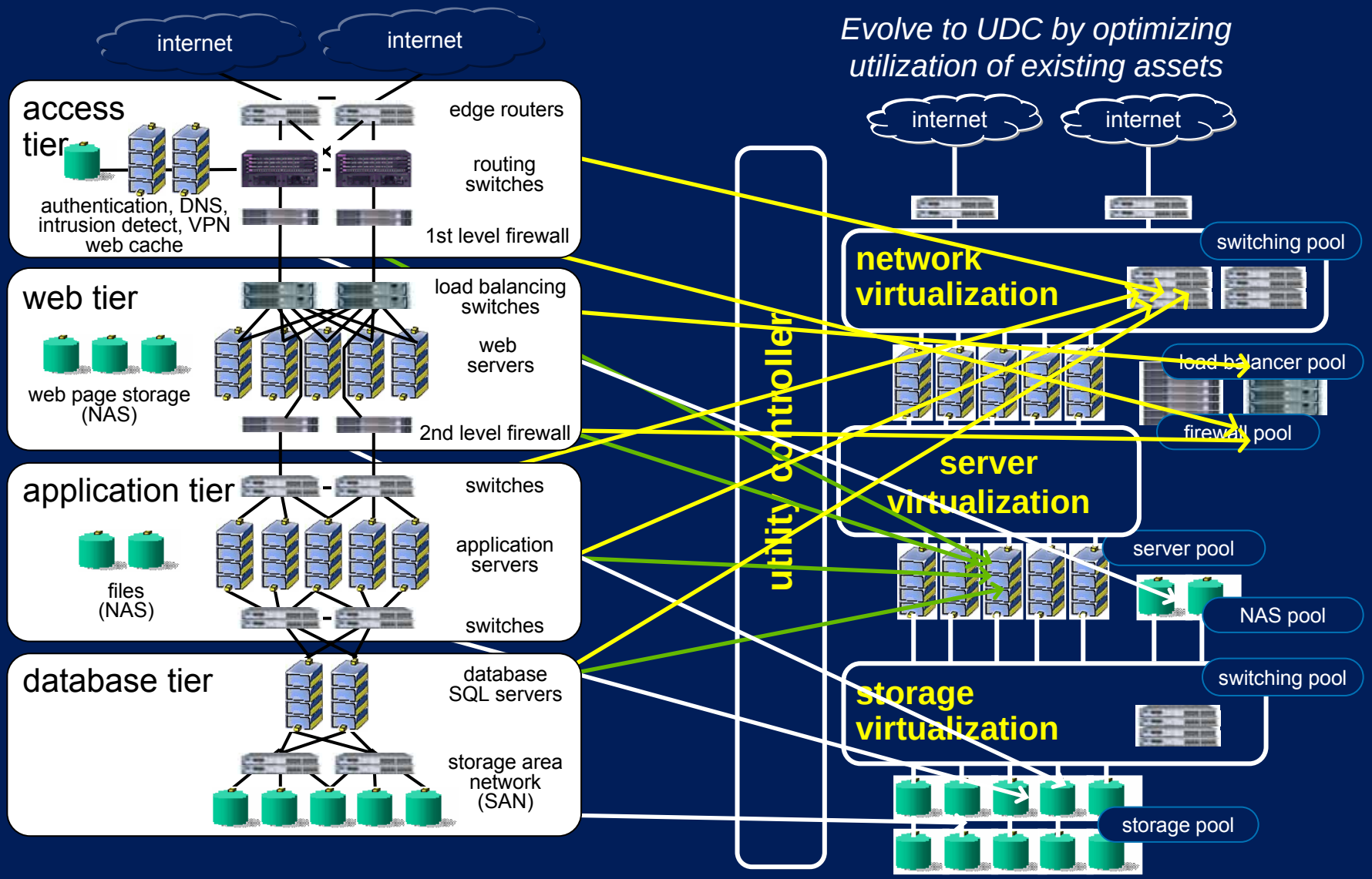


Customer “B”



Customer “C”

Programmable Resource Infrastructure

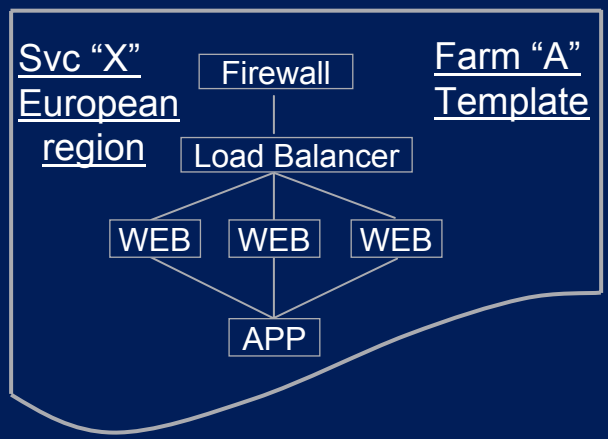


Creating an Application

1. Architect application:

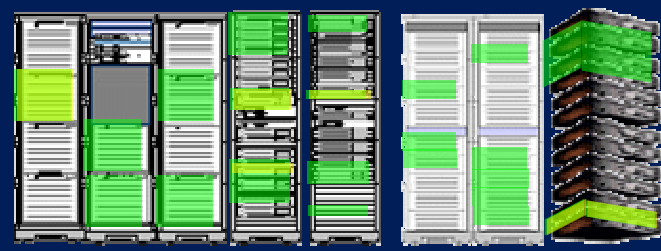
- business case
- service growth projection
- SLO requirement
- availability
- security needs
- time to implement

2. Design a resource topology :



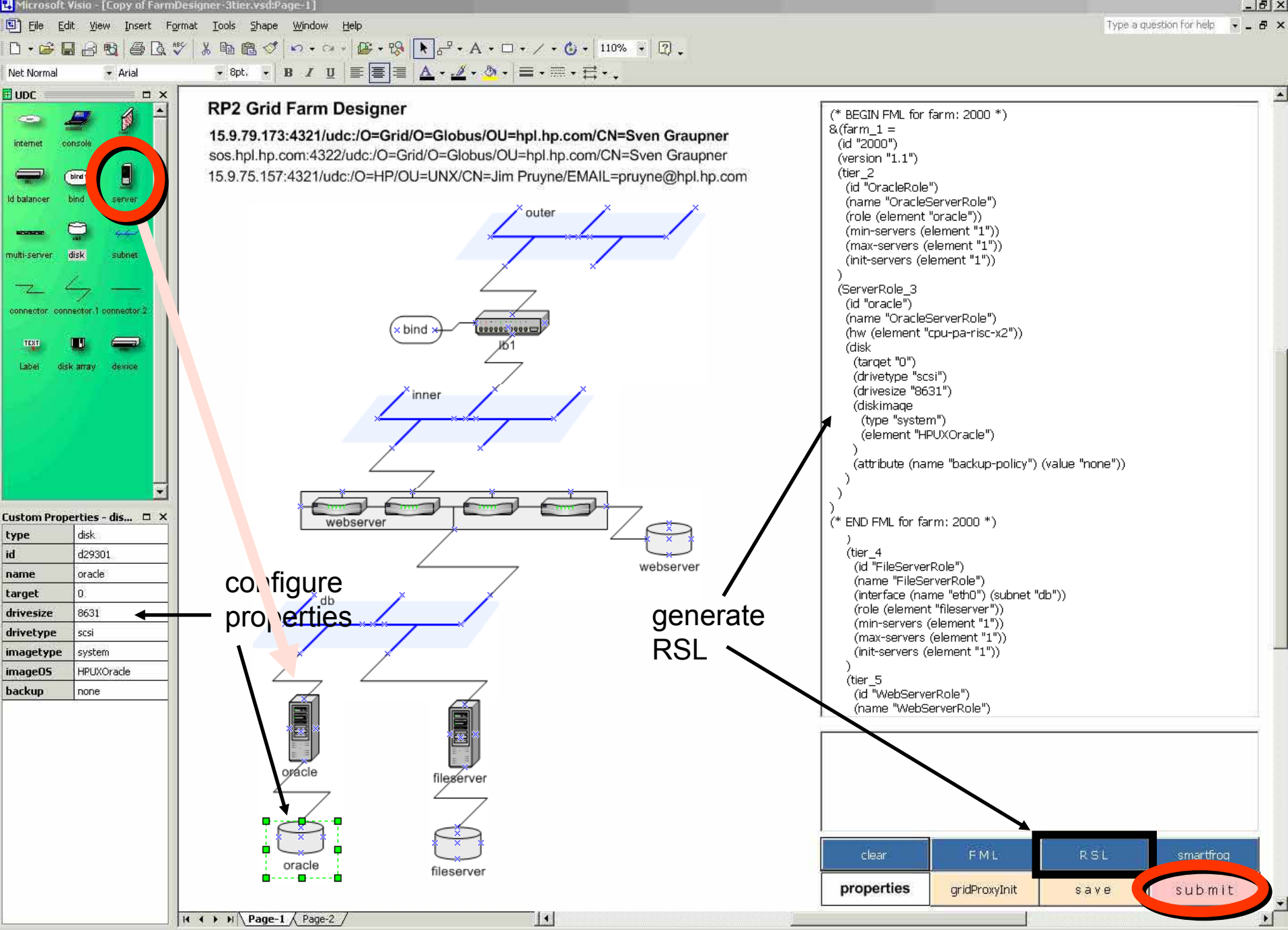
3. Activate the Application

- automatically locate and allocate resources
- auto-configure network and storage
- auto-configure firewall & load balancers
- auto-configure & boot servers

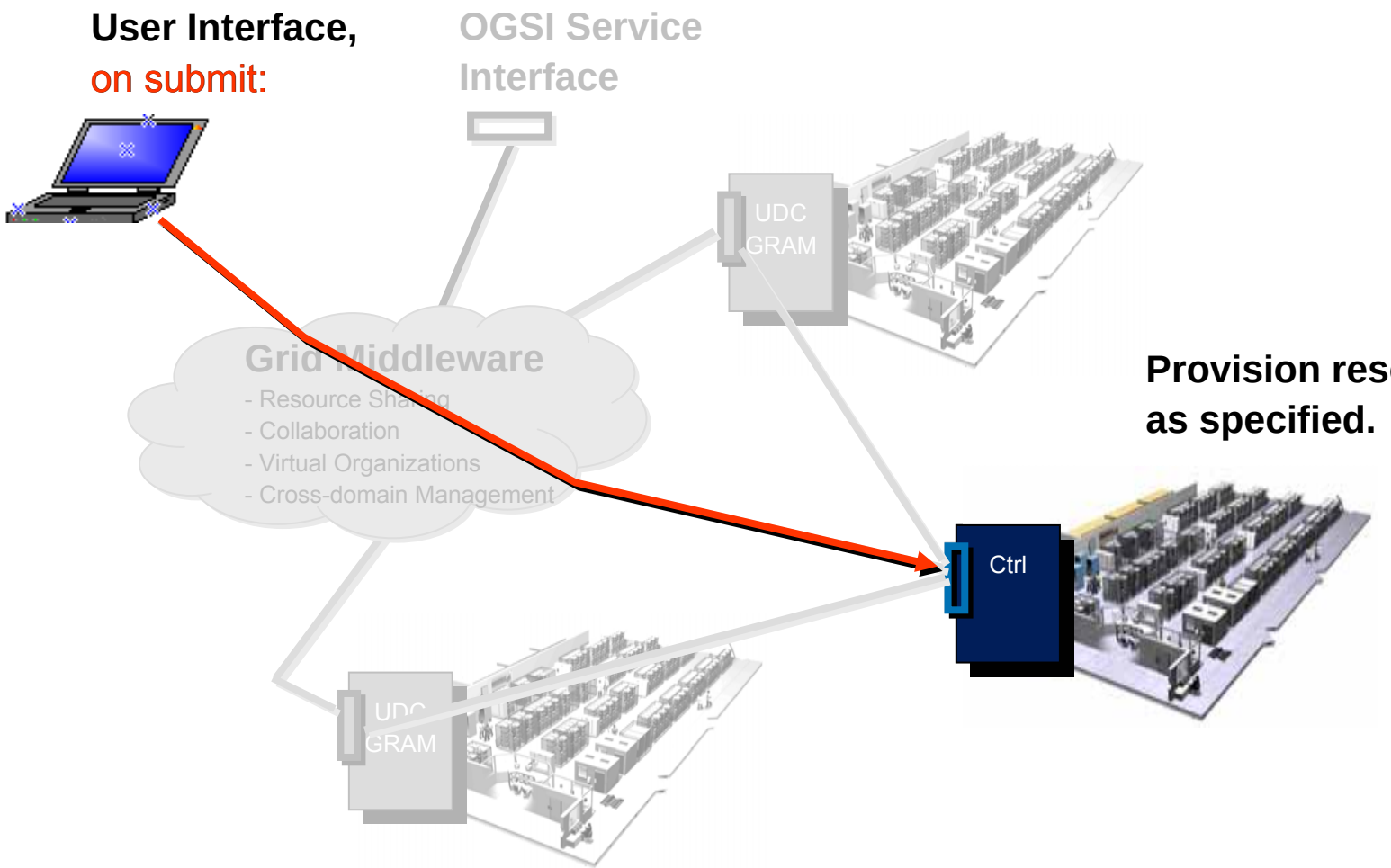


available

new service added

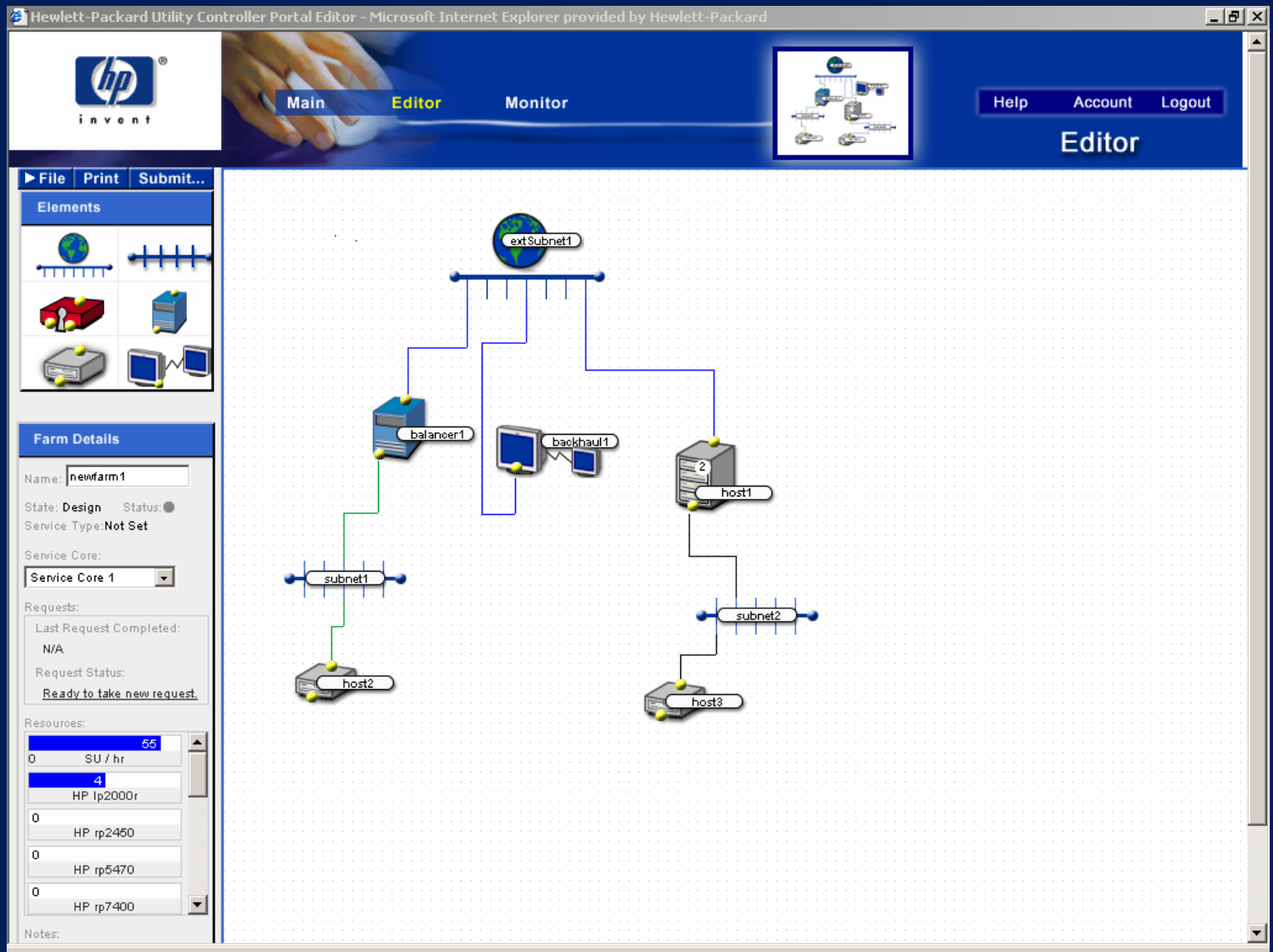

Microsoft Visio - [Copy of FarmDesigner-3tier.vsd:Page-1]
File Edit View Insert Format Tools Shape Window Help
UDC
internet
console
ld balancer
bind
server
multi-server
disk
subnet
connector
connector.1
connector.2
Label
disk array
device
Custom Properties - dis...
type disk
id d29301
name oracle
target 0
drivesize 8631
drivetype scsi
imagetype system
imageOS HPUXOracle
backup none
RP2 Grid Farm Designer
15.9.79.173:4321/udc:/O=Grid/O=Globus/OU=hpl.hp.com/CN=Sven Graupner
sos.hpl.hp.com:4322/udc:/O=Grid/O=Globus/OU=hpl.hp.com/CN=Sven Graupner
15.9.75.157:4321/udc:/O=HP/OU=UNX/CN=Jim Pruyne/EMAIL=pruyne@hpl.hp.com
outer
bind
lb1
inner
webserver
webserver
db
oracle
fileserver
oracle
fileserver
configure properties
generate RSL
(* BEGIN FML for farm: 2000 *)
&(farm_1 =
(id "2000")
(version "1.1")
(tier_2
(id "OracleRole")
(name "OracleServerRole")
(role (element "oracle"))
(min-servers (element "1"))
(max-servers (element "1"))
(init-servers (element "1"))
)
(ServerRole_3
(id "oracle")
(name "OracleServerRole")
(hw (element "cpu-pa-risc-x2"))
(disk
(target "0")
(drivetype "scsi")
(drivesize "8631")
(diskimage
(type "system")
(element "HPUXOracle")
)
(attribute (name "backup-policy") (value "none"))
)
)
)
(* END FML for farm: 2000 *)
)
(tier_4
(id "FileServerRole")
(name "FileServerRole")
(interface (name "eth0") (subnet "db"))
(role (element "fileserver"))
(min-servers (element "1"))
(max-servers (element "1"))
(init-servers (element "1"))
)
(tier_5
(id "WebServerRole")
(name "WebServerRole")
clear
FML
RSL
smartfrog
properties
gridProxyInit
save
submit
Page-1
Page-2

Submit Design for Deployment



GRAM = Grid Resource Allocation Manager

Farm Editor


Hewlett-Packard Utility Controller Portal Editor - Microsoft Internet Explorer provided by Hewlett-Packard
Main
Editor
Monitor
Help
Account
Logout
Editor
File
Print
Submit...
Elements
Farm Details
Name: newfarm1
State: Design
Status:
Service Type: Not Set
Service Core:
Service Core 1
Requests:
Last Request Completed:
N/A
Request Status:
Ready to take new request.
Resources:
55
0 SU / hr
4
HP lp2000r
0
HP rp2450
0
HP rp5470
0
HP rp7400
Notes:
extSubnet1
balancer1
backhaul1
2
host1
subnet1
subnet2
host2
host3

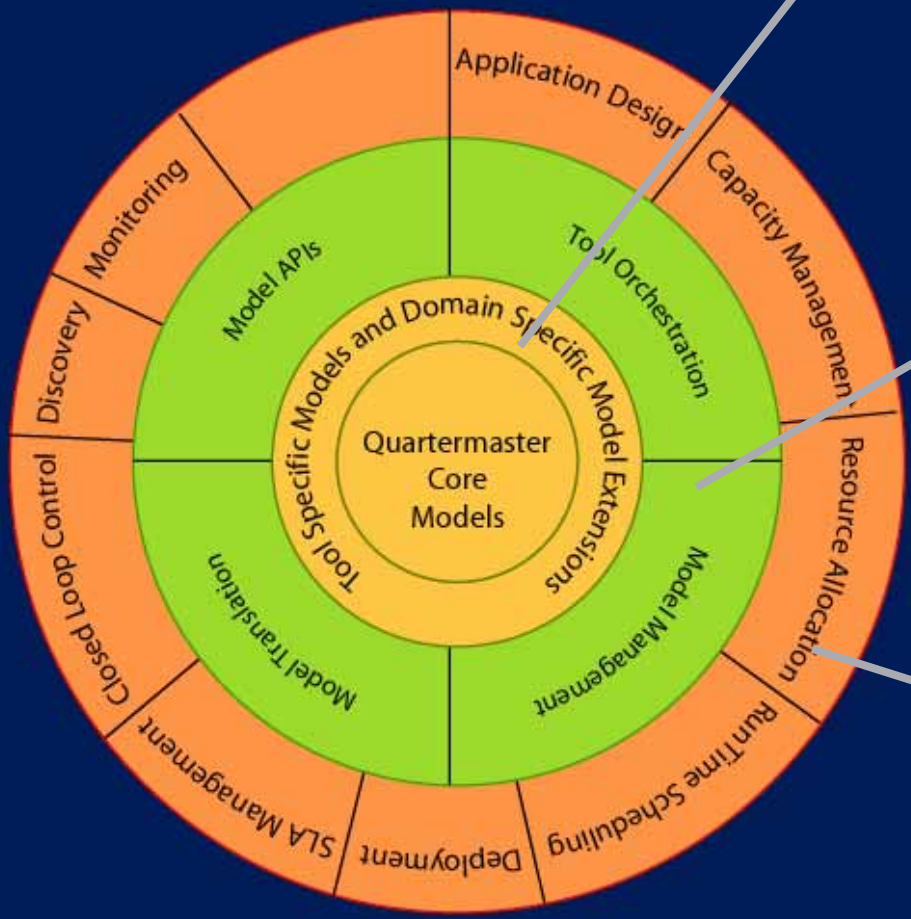
Outline

- New domain for OS: Enterprise IT environments
- Research Prototype from HP Labs
  - Formal Basis: Layered Information Model
  - Resource Grounding
  - Resource Allocation
- Summarizing remarks

QM Contributions

- *Design of Resource Topologies* for enterprise applications,
- *Grounding* resource topologies from application specifications into allocatable resources in a data center,
- requesting and making *Allocation* decisions for resource topologies including a complex *Resource Request Format*,
- ability to deal with *Resource Constructions*,
- *Assignment* of allocated resource capacity to resource instances in a data center,
- *Deployment* of resources (creation, configuration of resources) using actuators,
- *Run-time Control* functions in form of dynamic adjustment of resource use, which is also referred to as *Flexing*.

QM Research Prototype

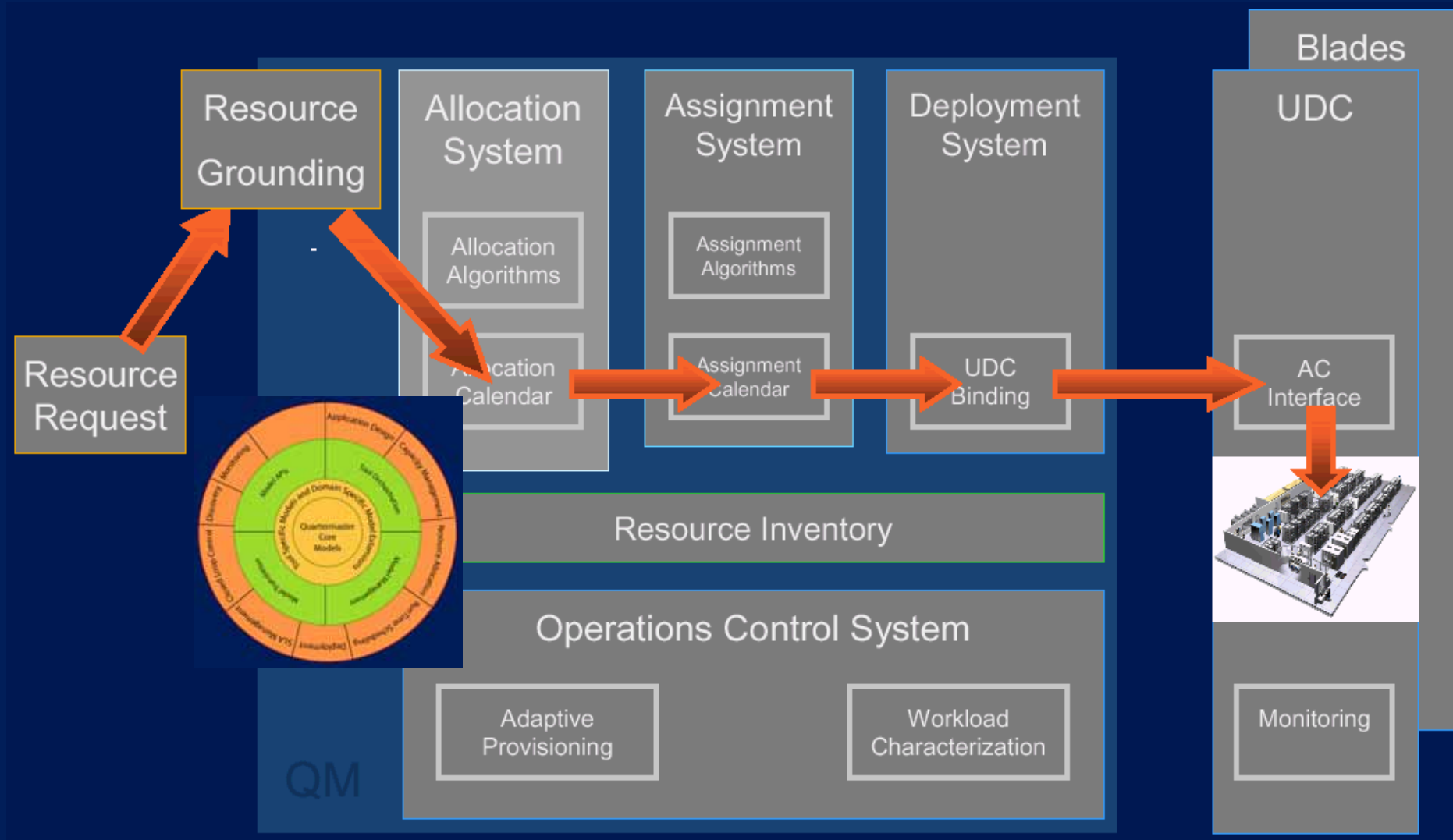


Quartermaster Core
- Model and instance repository
  - •core models
  - •tool specific models
  - •domain-specific models
  - •instance data

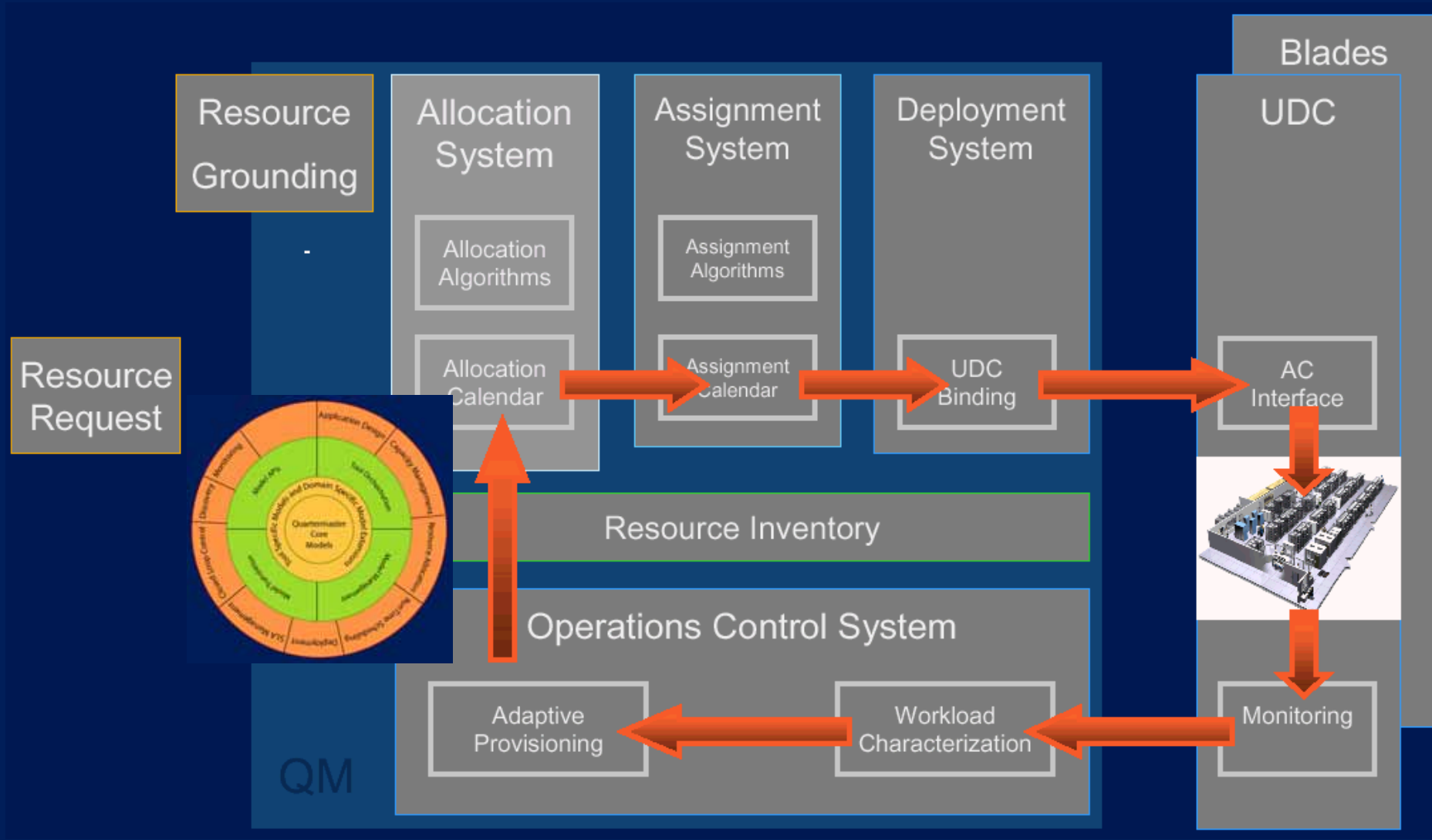
Quartermaster Model Management
- Model creation and management
- Model translation
- Object APIs for tools
- Tool orchestration

Quartermaster Tools
- System composition
- Capacity management
- Resource Allocation
- Reservation/Scheduling
- …

Resource Request Flow



Run-time Resource Adjustment



Core: Layered Information Model

Apply same abstractions to each layer.

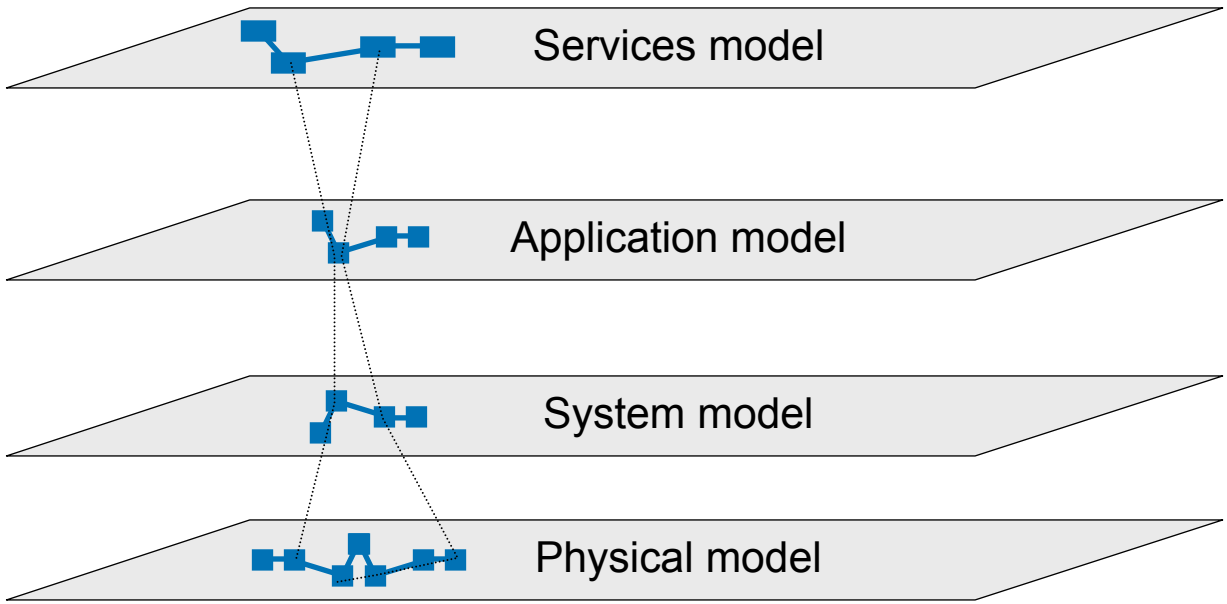
Maintain relationships within and across layers.

Service topology:
External access points, API, capacity.

Application topology:
Application components, web/app servers, DB.

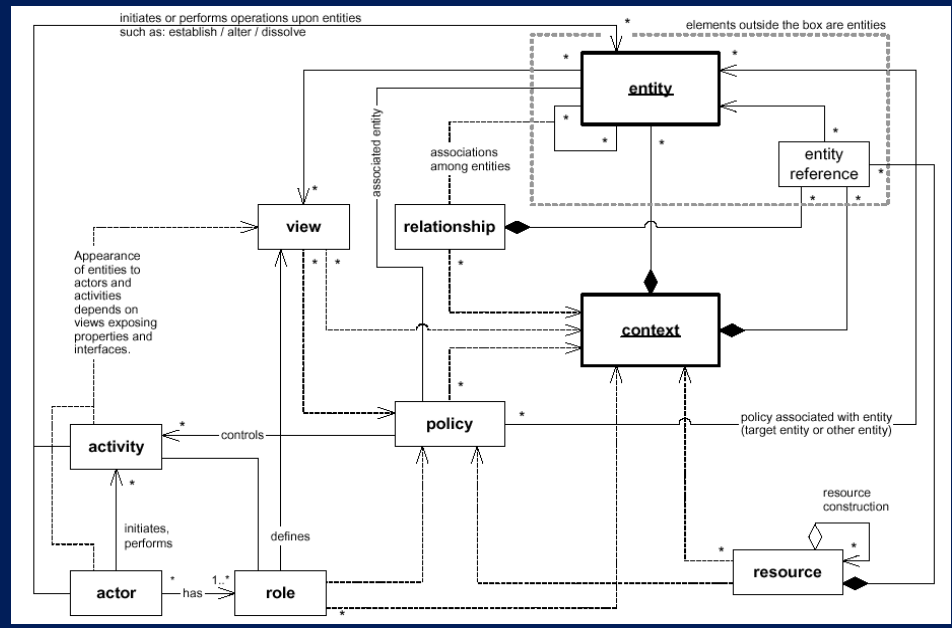
System topology:
Servers, disks, subnets, IP domains, DNS.

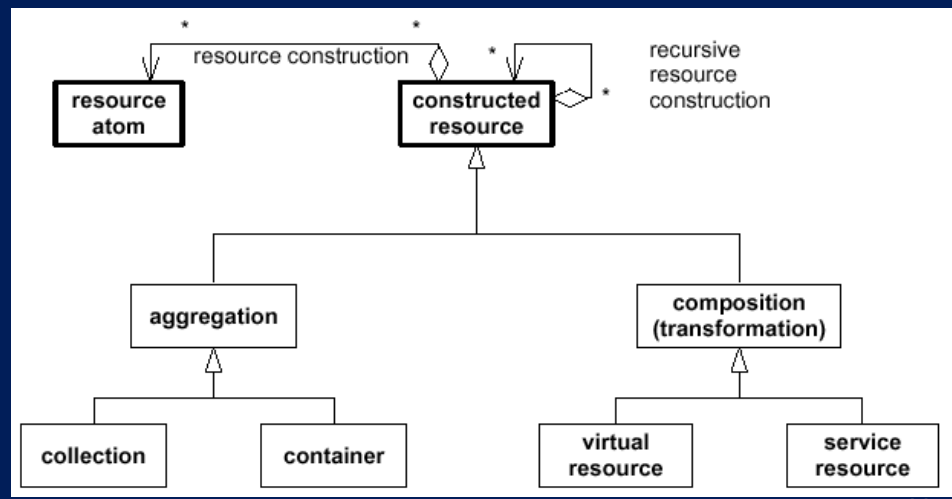
Physical topology:
Switches, connections, racks, devices.



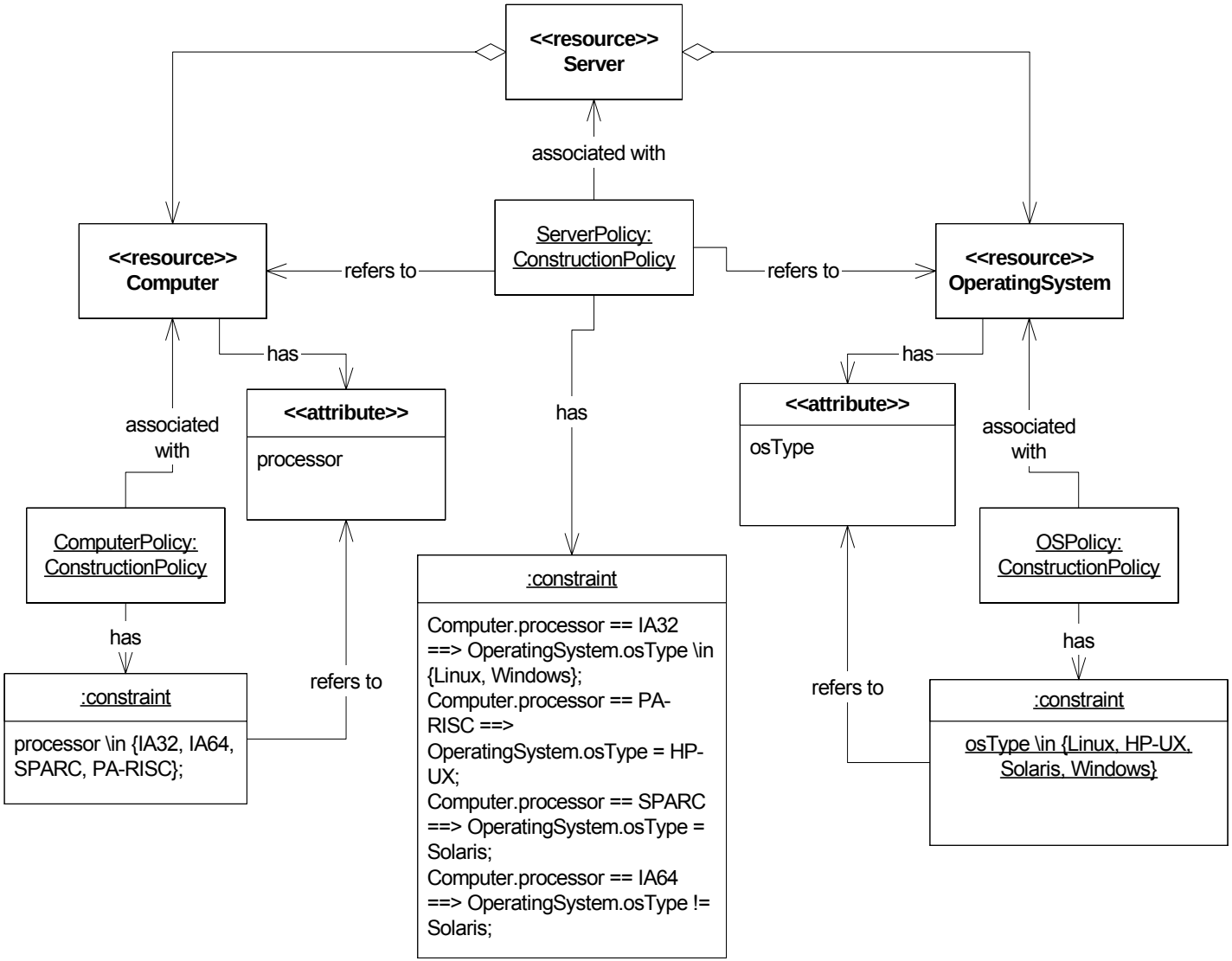
QM Core Model Entities

- Purpose:
  - Identify and structure all information maintained in QM according to a uniform model.
- First-class Entities:
  - Actor,
  - Role,
  - Activity,
  - Resource (atom, construction),
  - Relationship,
  - Context,
  - View,
  - Policy.



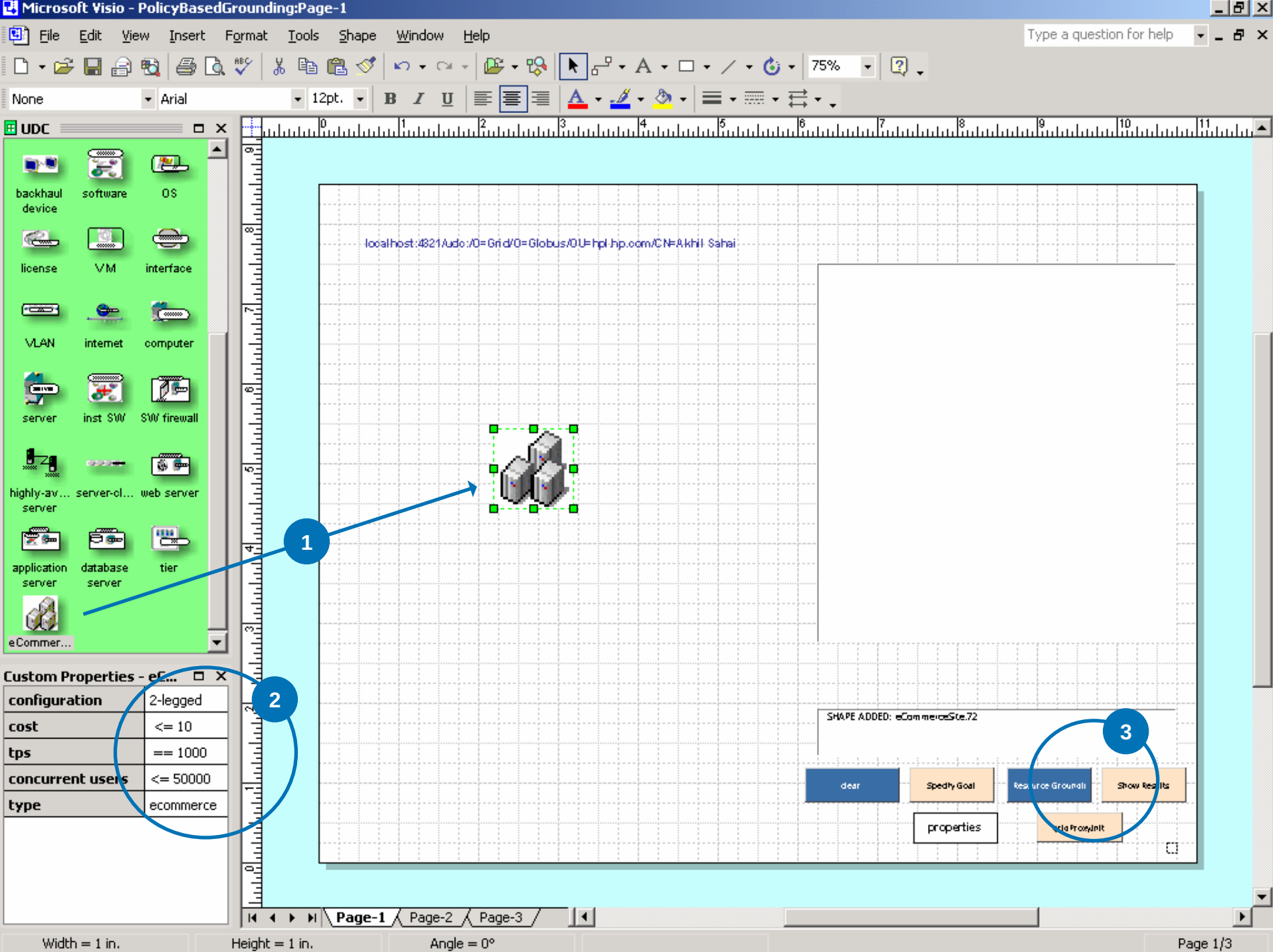


Model Representation in CIM



Example: Resource Grounding

- Purpose:
  - Describe resource needs in higher terms such as *"e-commerce site that can handle up to 300,000 queries per minute"*.
  - Many ways exist to construct this solution. Resource grounding finds a solution that meets all specified criteria and, recursively, and obeys all constraints.
- Definition:
  - A "grounded" resource is a resource that can be allocated.
  - Resource grounding is the process of resolving non-grounded resource specifications into grounded, allocatable resource specifications.
  - Resource grounding is based on pre-configured templates using a constraint satisfaction engine to recursively identify matching templates and binding all parameters.
- OS Analogy:
  - None.


Microsoft Visio - PolicyBasedGrounding:Page-1
File Edit View Insert Format Tools Shape Window Help
Type a question for help
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None Arial 12pt.
UDC
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VM
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VLAN
internet
computer
server
inst SW
SW firewall
highly-av... server
server-cl...
web server
application server
database server
tier
eCommer...
Custom Properties - eC...
configuration 2-legged
cost <= 10
tps == 1000
concurrent users <= 50000
type ecommerce
localhost:4821/uddi:/O=Grid/O=Globus/OU=hpl.hp.com/CN=Akhil Sahai
SHAPE ADDED: eCommerceSite.72
clear
Specify Goal
Resource Grounding
Show Results
properties
Grid Proxy Init
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2
3
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Page-3
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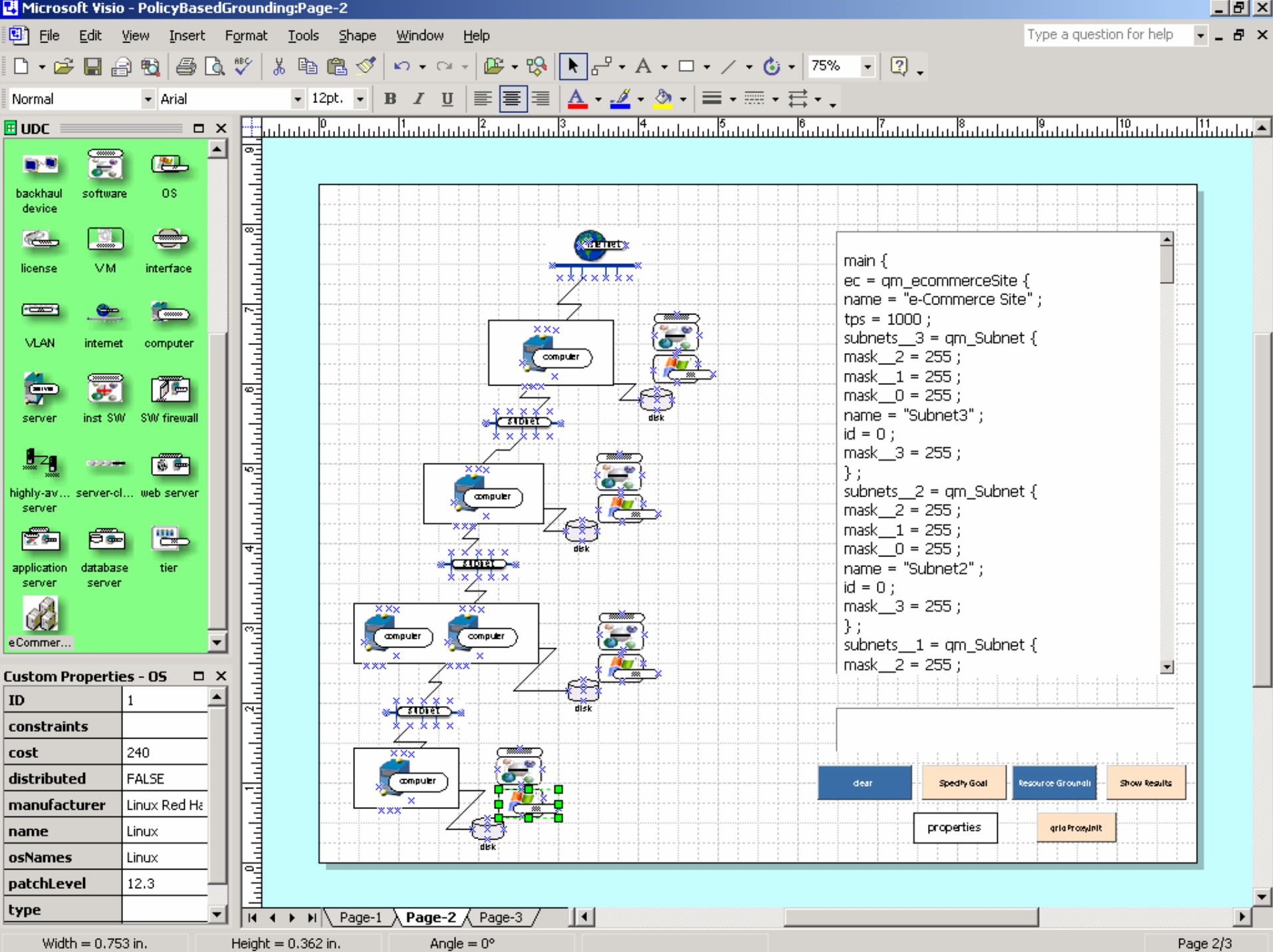
Page 1/3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Normal Arial 12pt.
UDC
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SW firewall
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server-cl...
web server
application server
database server
tier
eCommer...
Custom Properties - OS
ID 1
constraints
cost 240
distributed FALSE
manufacturer Linux Red Ha
name Linux
osNames Linux
patchLevel 12.3
type
internet
computer
disk
main {
ec = qm_ecommerceSite {
name = "e-Commerce Site" ;
tps = 1000 ;
subnets__3 = qm_Subnet {
mask__2 = 255 ;
mask__1 = 255 ;
mask__0 = 255 ;
name = "Subnet3" ;
id = 0 ;
mask__3 = 255 ;
} ;
subnets__2 = qm_Subnet {
mask__2 = 255 ;
mask__1 = 255 ;
mask__0 = 255 ;
name = "Subnet2" ;
id = 0 ;
mask__3 = 255 ;
} ;
subnets__1 = qm_Subnet {
mask__2 = 255 ;
clear
Specify Goal
Resource Grounding
Show Results
properties
qria ProxyInit
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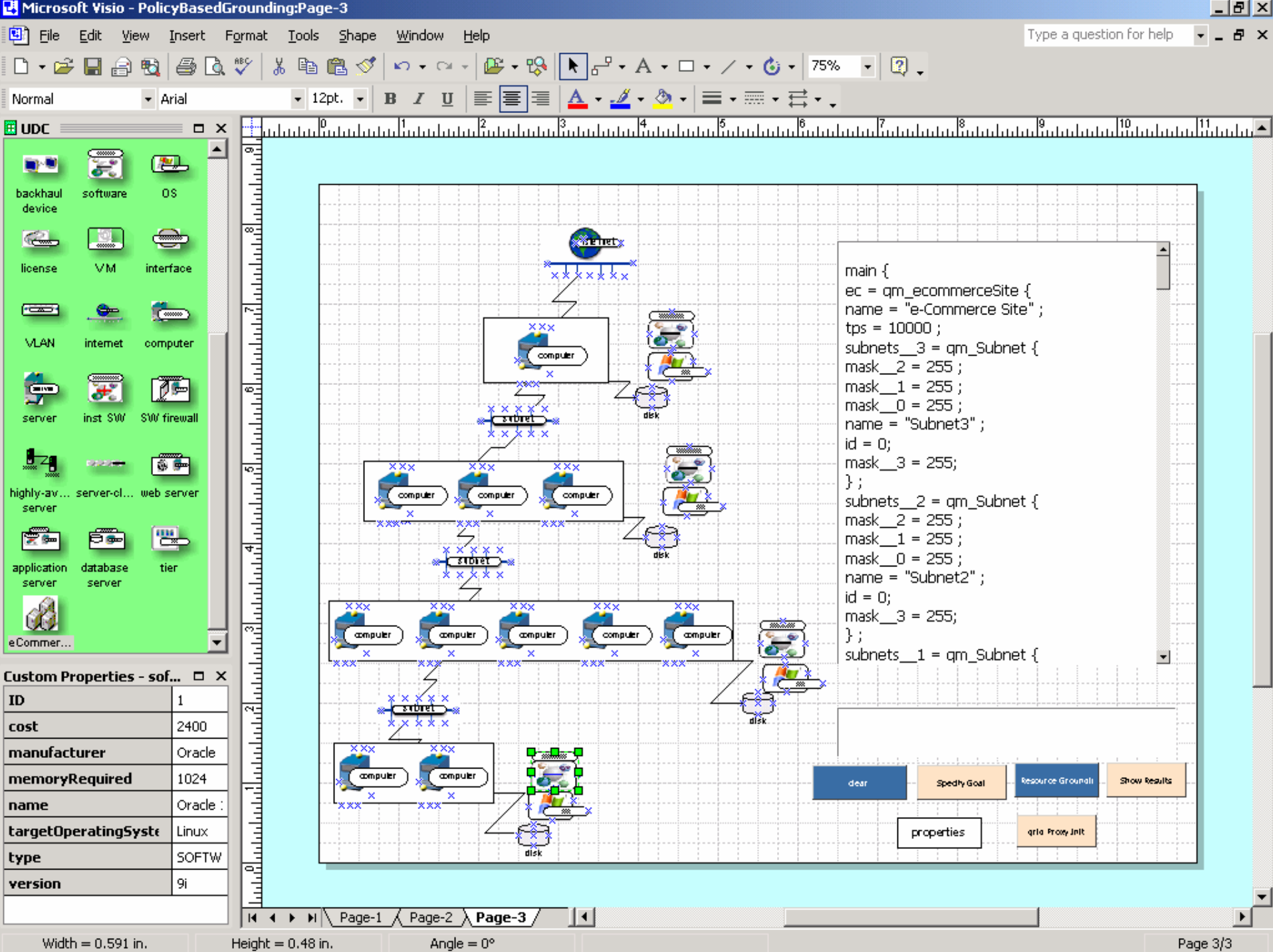
Page 2/3


Microsoft Visio - PolicyBasedGrounding:Page-3
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UDC
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VLAN
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inst SW
SW firewall
highly-av... server
server-cl...
web server
application server
database server
tier
eCommer...
Custom Properties - sof...
ID 1
cost 2400
manufacturer Oracle
memoryRequired 1024
name Oracle :
targetOperatingSyste Linux
type SOFTW
version 9i
internet
computer
disk
subnet
main {
ec = qm_ecommerceSite {
name = "e-Commerce Site" ;
tps = 10000 ;
subnets__3 = qm_Subnet {
mask__2 = 255 ;
mask__1 = 255 ;
mask__0 = 255 ;
name = "Subnet3" ;
id = 0;
mask__3 = 255;
} ;
subnets__2 = qm_Subnet {
mask__2 = 255 ;
mask__1 = 255 ;
mask__0 = 255 ;
name = "Subnet2" ;
id = 0;
mask__3 = 255;
} ;
subnets__1 = qm_Subnet {
clear
Speedy Goal
Resource Grounding
Show Results
properties
qria Proxy Init
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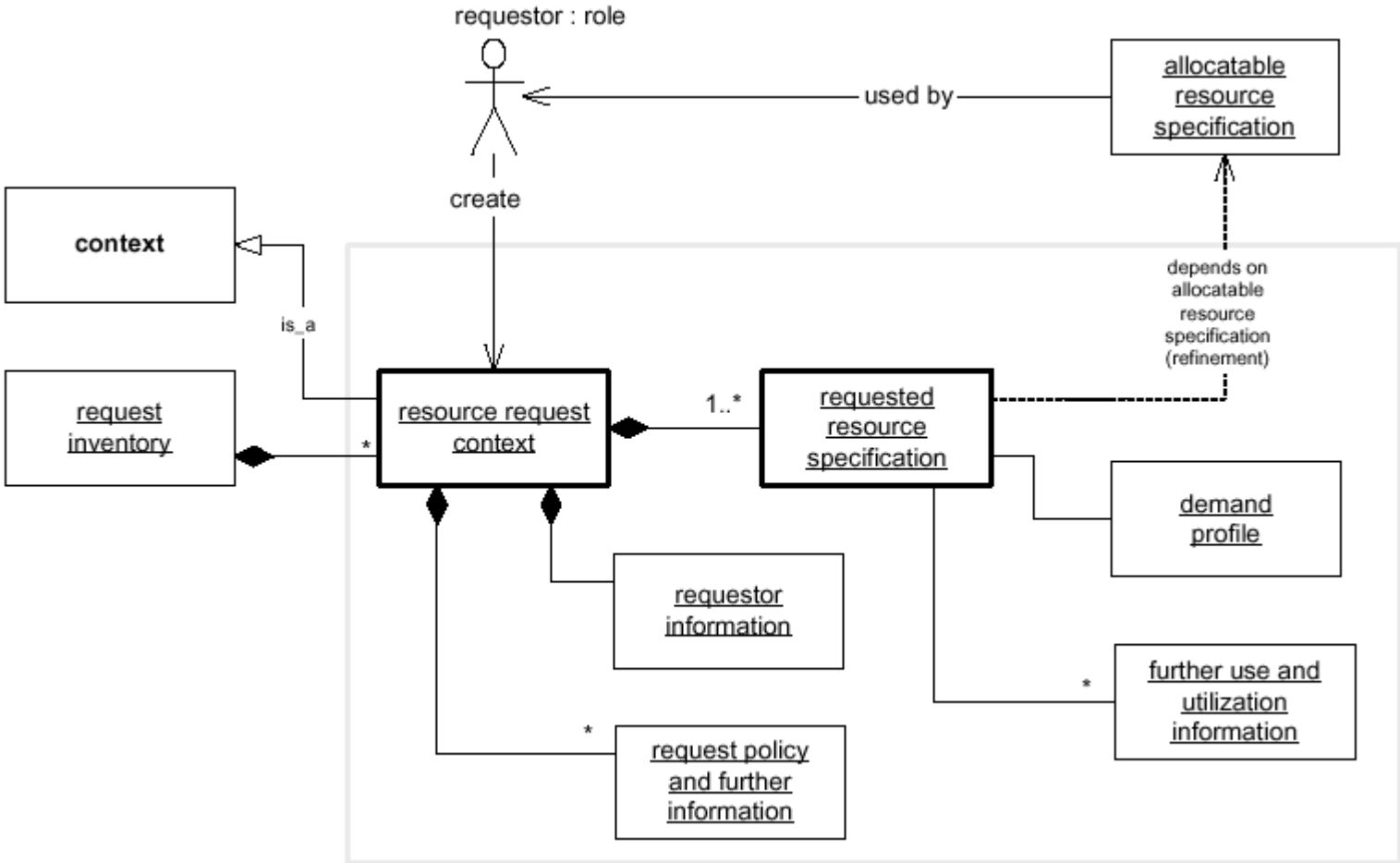
Height = 0.48 in.
Angle = 0°
Page 3/3

Example: Resource Allocation

= Commitment to provide specified *quantities* of requested resource types for the specified *times*.

- Purpose:
  - Specifies resource need for complex resource arrangement:
    - Multiple resource types (atoms or constructions),
    - Per resource type: Demand Profile (quantity over time),
    - Topology information.
    - Policy information.
    - Requestor information.
- OS Analogy:
  - malloc(int nbytes);
  - sbrk(int n);
  - OS syscalls do not incorporate demand over time ("profile").

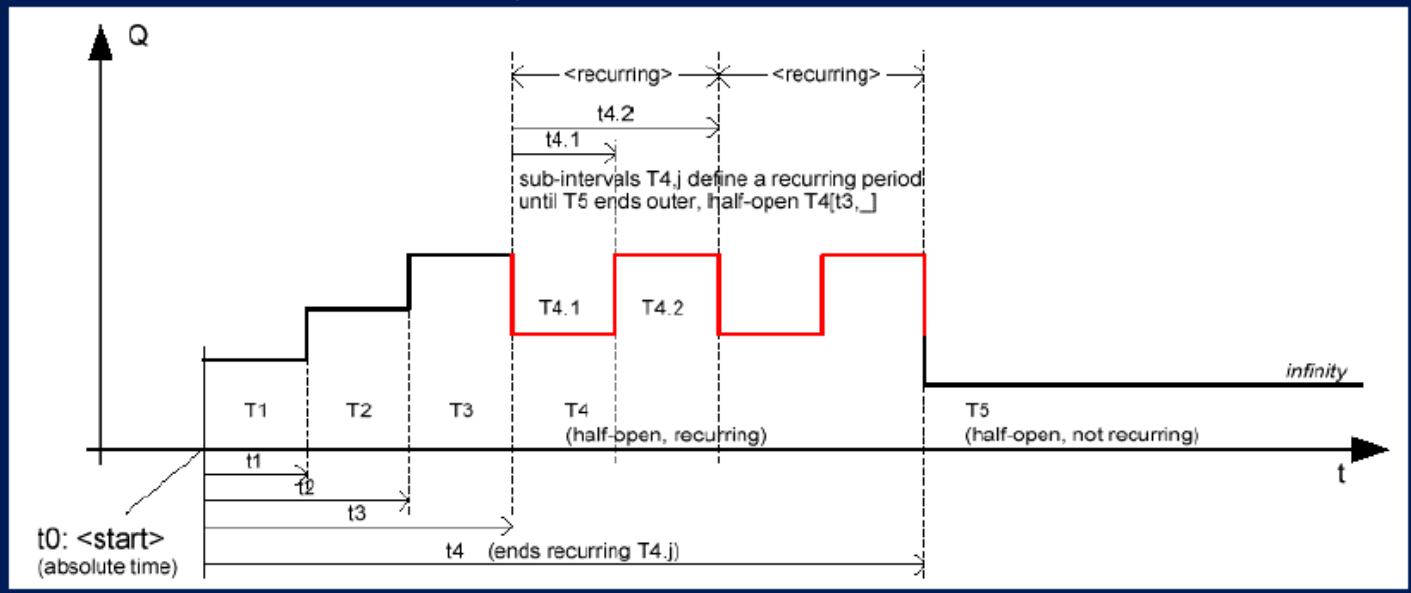
Resource Request Format



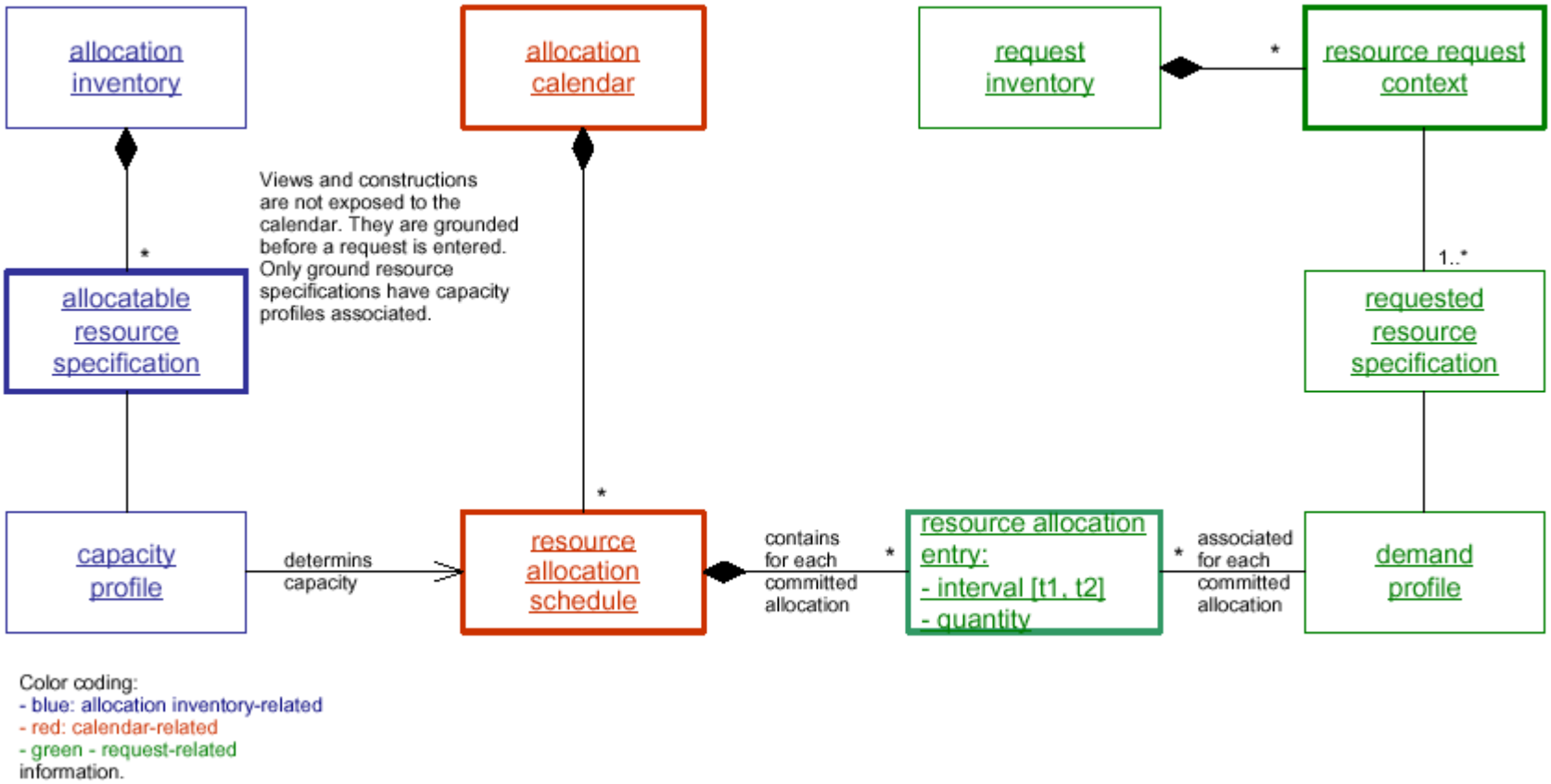
Resource Profile

- Purpose:
  - Specifies resource quantity over time.
  - Used for both, demand and capacity.

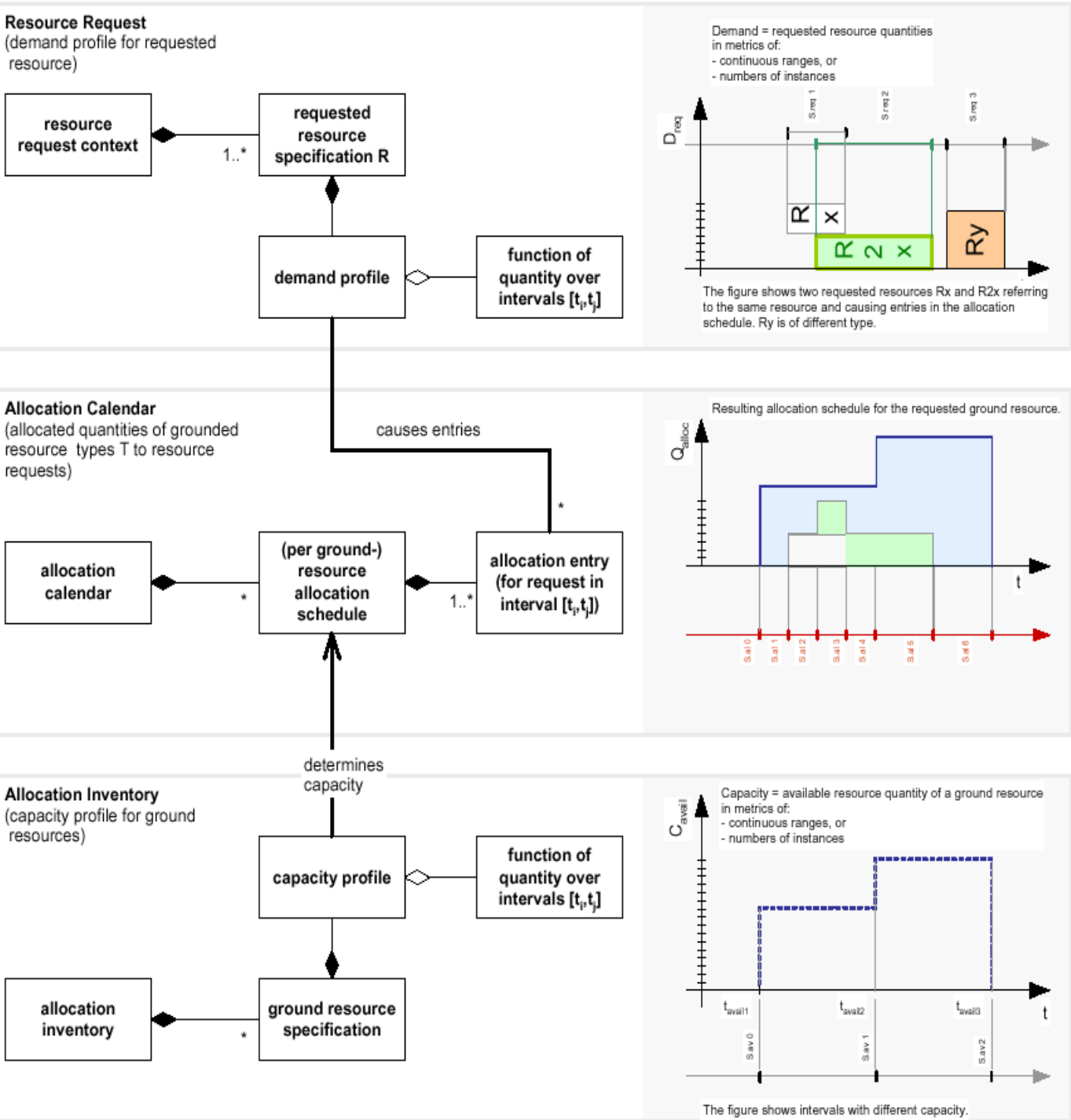
Quantity Specification Q[3]	Example
Constant value: *n*	5 machines
Range flexing: *[n,m]* initially *k*, $n \le k \le m$	5 - 10 machines, initially 8
Discrete statistical distribution of *n* resources as tuples: *[n,p(n)]*, $n=0,1,2...N$, $\Sigma p(n)=1$	1 machine requested with probability 0.3, 2 machines with probability 0.6, 3 machines with probability 0.1
Statistical distribution as probability function	Gaussian normal distribution with expectancy and standard deviation of a demand



Allocation Subsystem Components



Matching Profiles



Summary

- New domain for OS Technology is emerging: systems for operating enterprise IT environments.
- Highly relevant area for the coming decade. Change will affect HW+SW vendors as well as system integrators and service providers in how IT systems are built and operated, significantly more based on formalisms and tools supporting design and validation of designs.
- CS graduates will need skills in architecture, design, specification and operation of complex IT environments.


hp
invent

More detail…

Automating the Operation of Enterprise IT Environments

Habilitation Thesis

(Preliminary Draft)

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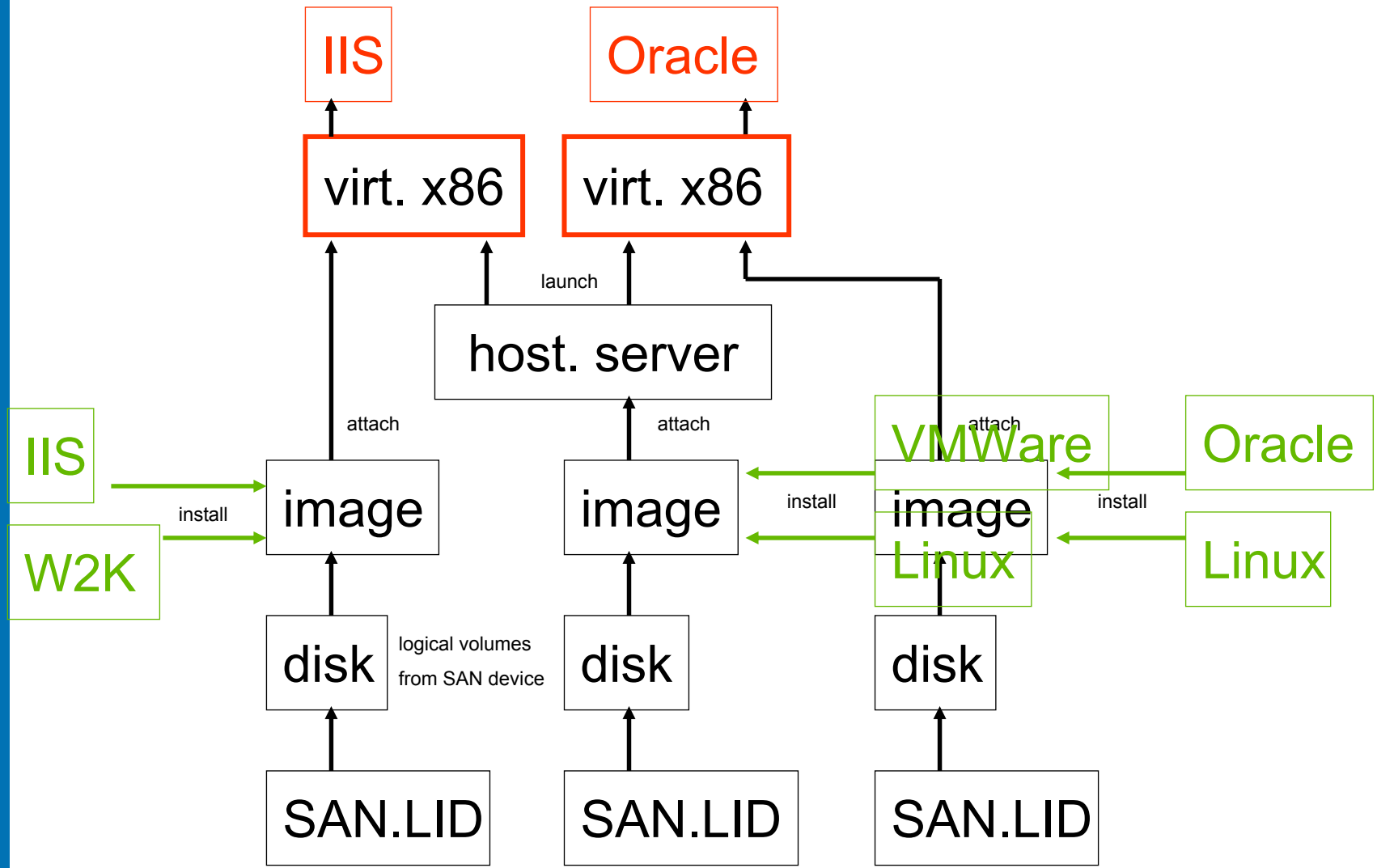
USA

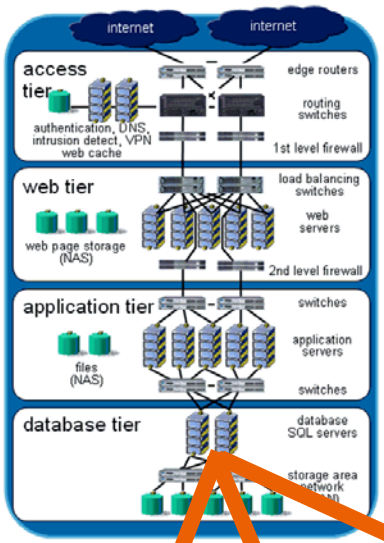
to be submitted to the
Faculty of Computer Science
Chemnitz University of Technology
Germany

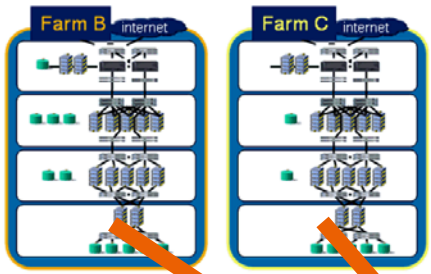
Palo Alto, November 12, 2004.

Example: Resource Construction



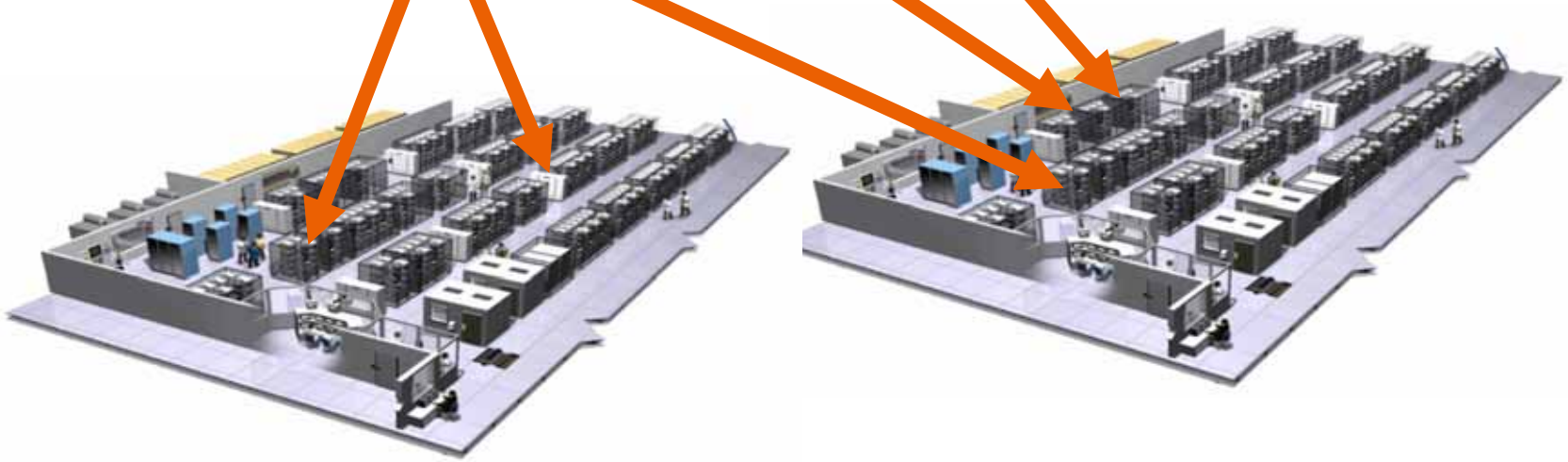
Resource Allocation for Topologies





Enterprise applications have diverse resource needs.

Enterprise data center have diverse resource inventories.



Comparing with

- *Distributed OS* → different granularity of resources, ability to deal with resource constructions.
- *Management Systems* → fully integrated, operates autonomously, operator role only sets policy.
- *Compute Grids* → heterogeneous resource topologies targeted for enterprise applications, longer life time, transactional, resource planning, aimed at by Enterprise Grid.
- *Autonomous Systems* – implies self-operation and (operating) systems for this purpose.

Aspects of Operating Systems

System Structure	Releasing Resources
External Interface	Process / Application Management
Underlying Control Points	Protection and Isolation
Base Abstractions	Self-Operation and Impact of Failure
Resources and Resource Management	Virtualization and Working Set
Requesting Resources	Interrupt Handling and Signaling
Grounding Resource Requests	Middleware and Interconnect Layer
Resource Scheduling	Information Base and Model

Web Services in the Enterprise
Concepts, Standards, Solutions and Management
Reihe: Network and Systems Management,
Sahai, Akhil, **Graupner**, Sven
2004, Approx. 310 p., Geb.
ISBN: 0-387-23374-1

Erscheinungstermin: Dezember 2004

Druckversion
Diesen Titel empfehlen

Alle Bücher dieser Autoren
Sahai, Akhil
Graupner, Sven

Verwandte Fachbereiche
Database Management & Info Retrieval
Programming, SWE & Operating Systems
Wirtschaftsinformatik

Über dieses Buch | Inhaltsverzeichnis

Über dieses Buch

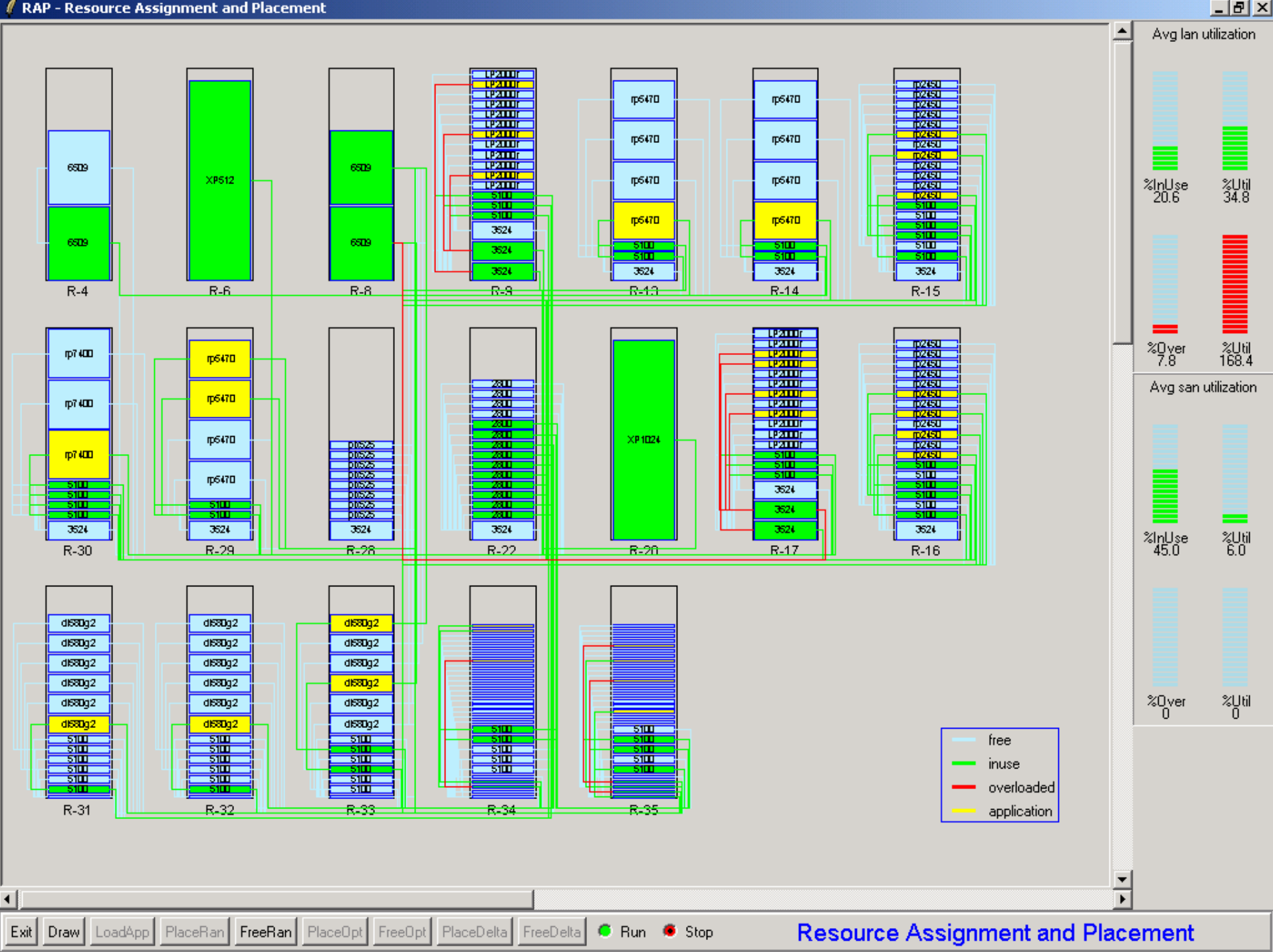
The emergence of web services is transforming traditional enterprises. However, the industry hype surrounding these technologies obscures the understanding of their impact and implications to enterprises. Here the authors take the "big picture" perspective, helping software architects, developers and IT managers understand the concepts behind web service technologies: the challenges and opportunities they present, how they fit into the enterprise stack, how they relate to the business and IT layers of the enterprise, as well as the existing and emerging standards and their relevance. This professional reference is a guide for business managers and analysts on both how to manage web services, and how to use them in management.

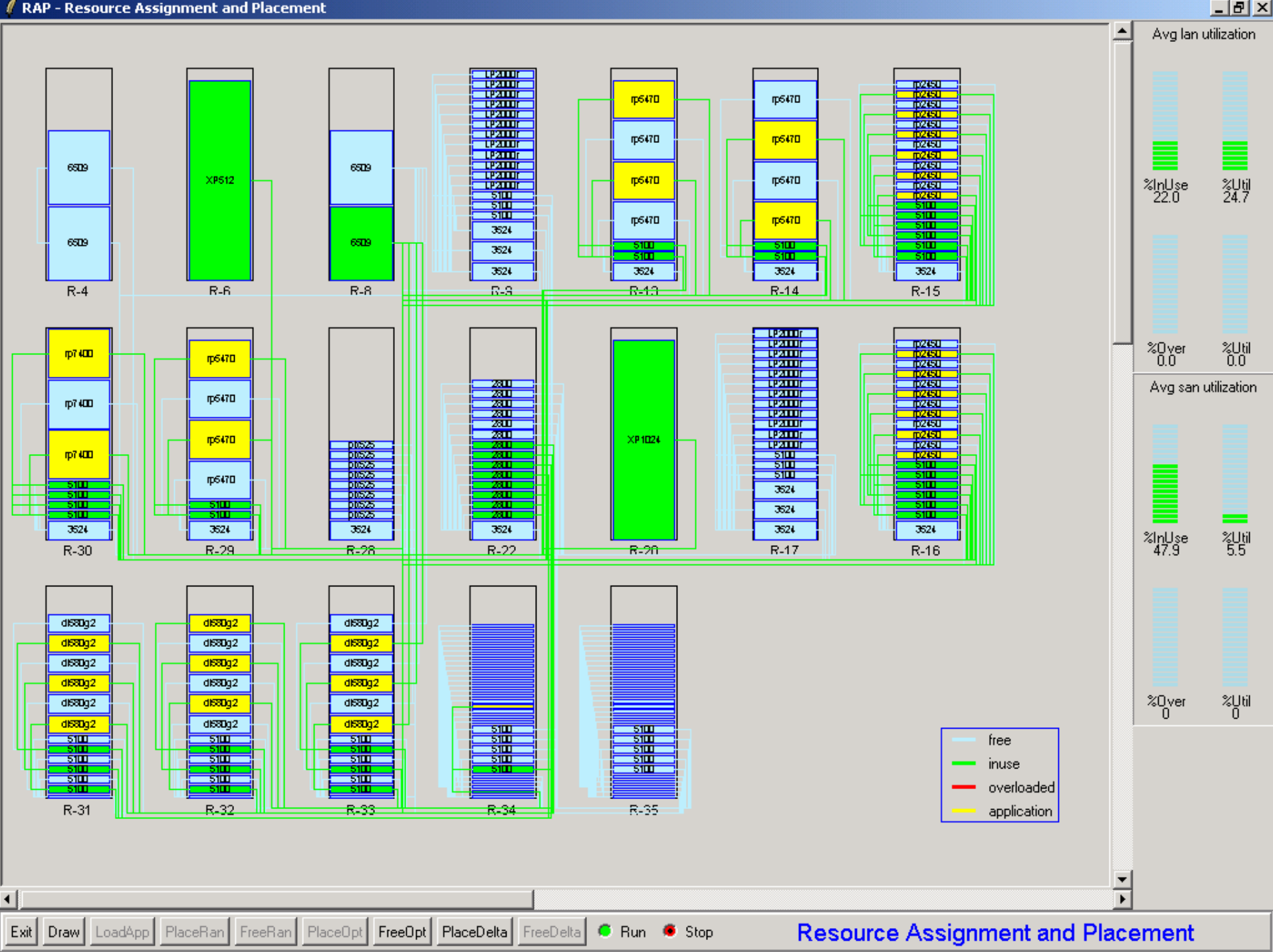
Geschrieben für:

Students and Academics, Software Architects, Developers and IT Managers who develop and maintain enterprise applications and web services.

Example: Resource Assignment

- Automate dynamic resource assignment
  - Quickly solves complex assignment problems that are beyond the scope of a human operator
  - Creates optimal assignments to avoid bottlenecks
  - Responds to changes in user requirement in “real-time”
- Core Innovation
  - Solved a very complex combinatorial non-linear NP-hard problem by transforming it into a linear one that can be handled efficiently by commercial solvers
  - Advantage of approach: Clearly indicates if a feasible optimal solution exists and if not, why not.


RAP - Resource Assignment and Placement
Avg lan utilization
%InUse 20.6
%Util 34.8
%Over 7.8
%Util 168.4
Avg san utilization
%InUse 45.0
%Util 6.0
%Over 0
%Util 0
R-4
R-6
R-8
R-9
R-13
R-14
R-15
R-30
R-29
R-28
R-22
R-20
R-17
R-16
R-31
R-32
R-33
R-34
R-35
free
inuse
overloaded
application
Exit
Draw
LoadApp
PlaceRan
FreeRan
PlaceOpt
FreeOpt
PlaceDelta
FreeDelta
Run
Stop
Resource Assignment and Placement

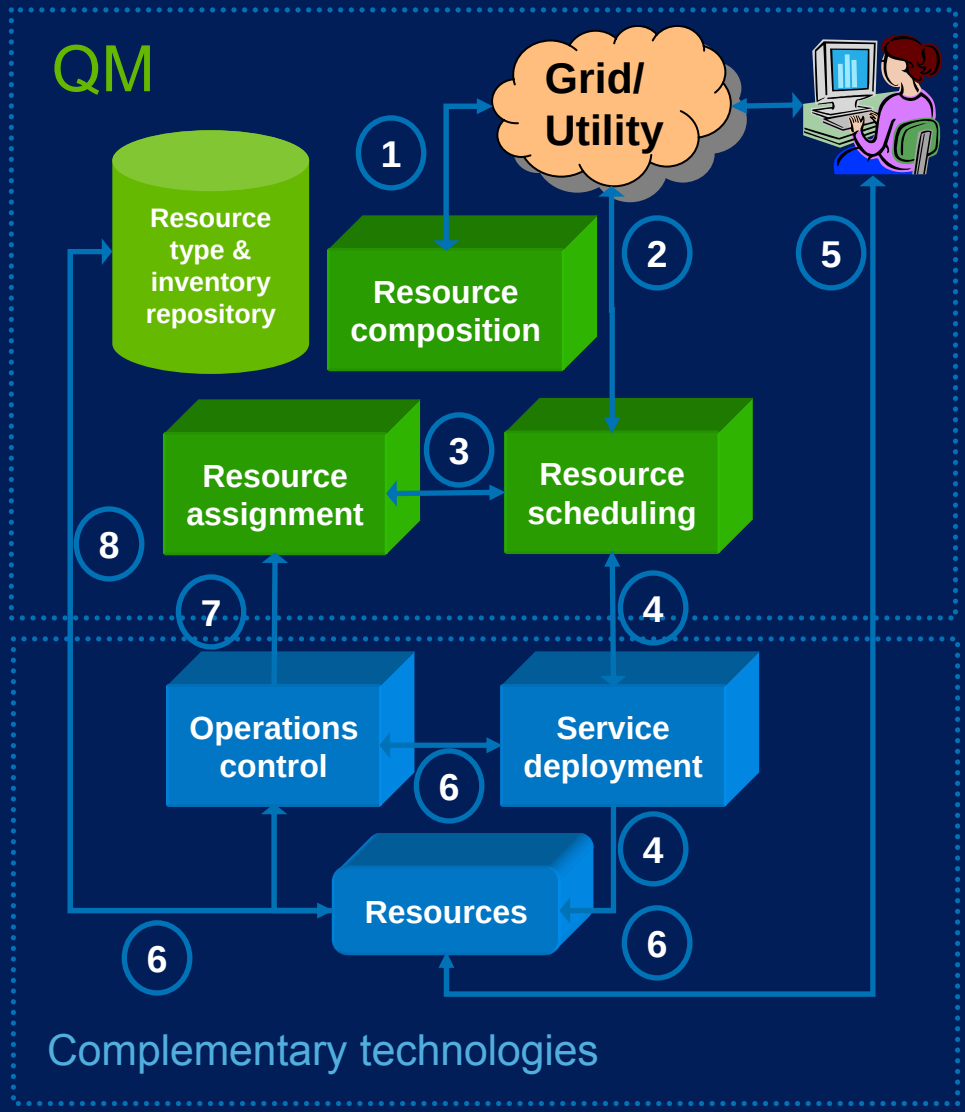

RAP - Resource Assignment and Placement
Avg lan utilization
%InUse 22.0
%Util 24.7
%Over 0.0
%Util 0.0
Avg san utilization
%InUse 47.9
%Util 5.5
%Over 0
%Util 0
R-4
R-6
R-8
R-9
R-13
R-14
R-15
R-30
R-29
R-28
R-22
R-20
R-17
R-16
R-31
R-32
R-33
R-34
R-35
free
inuse
overloaded
application
Exit
Draw
LoadApp
PlaceRan
FreeRan
PlaceOpt
FreeOpt
PlaceDelta
FreeDelta
Run
Stop
Resource Assignment and Placement

Some Related Work

- Grid standards for Grid/utility computing
- Imaging / provisioning systems: Altiris, Rembo, Novadigm (+ many others)
- MS Dynamic Systems Initiative, MS Provisioning System
- Adaptive systems: ThinkDynamics, Corosoft
- IBM eLiza, autonomic computing

- Proprietary (product-specific) solutions in place today for installation / configuration / activation

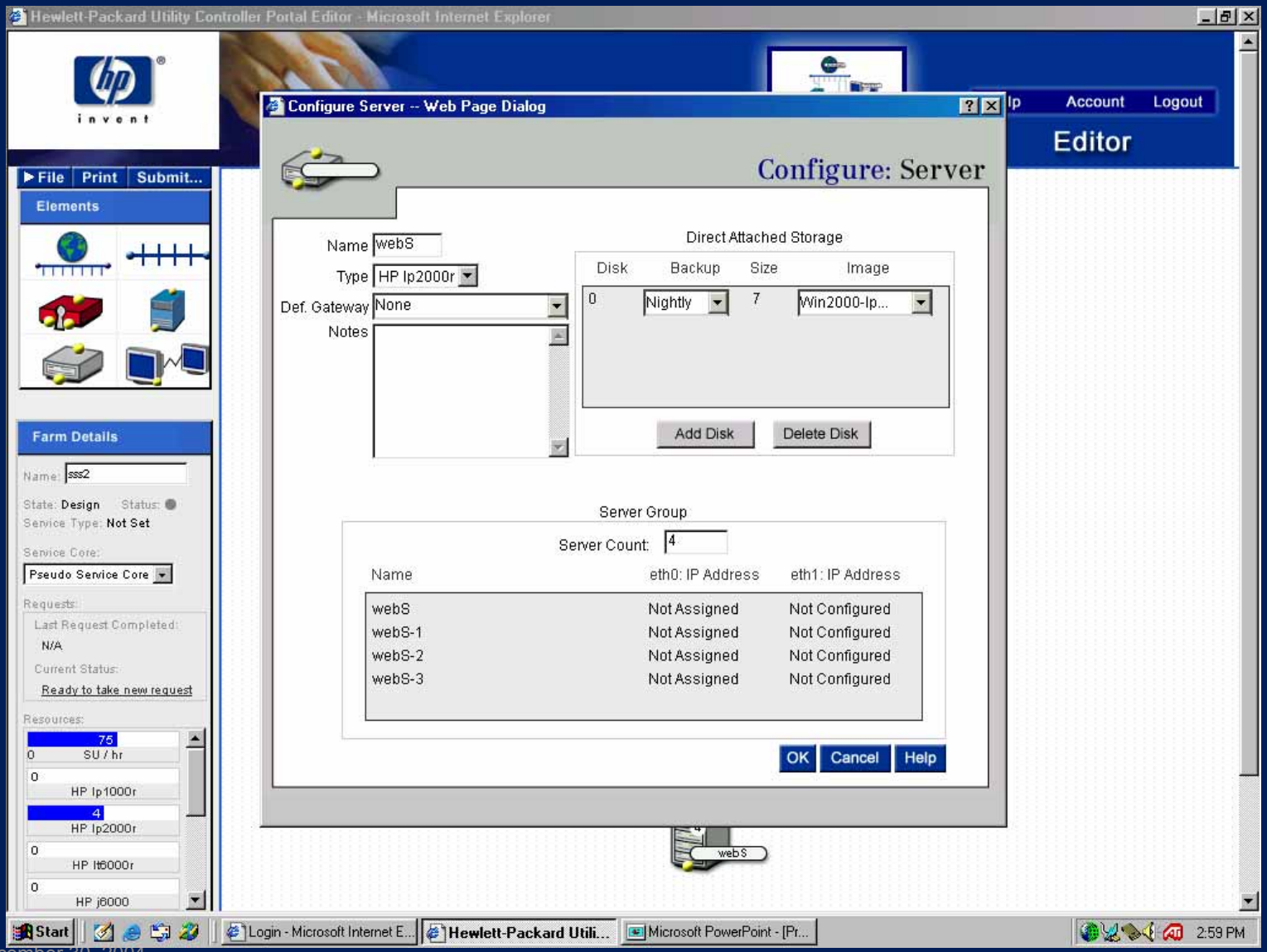
QM Research Prototype



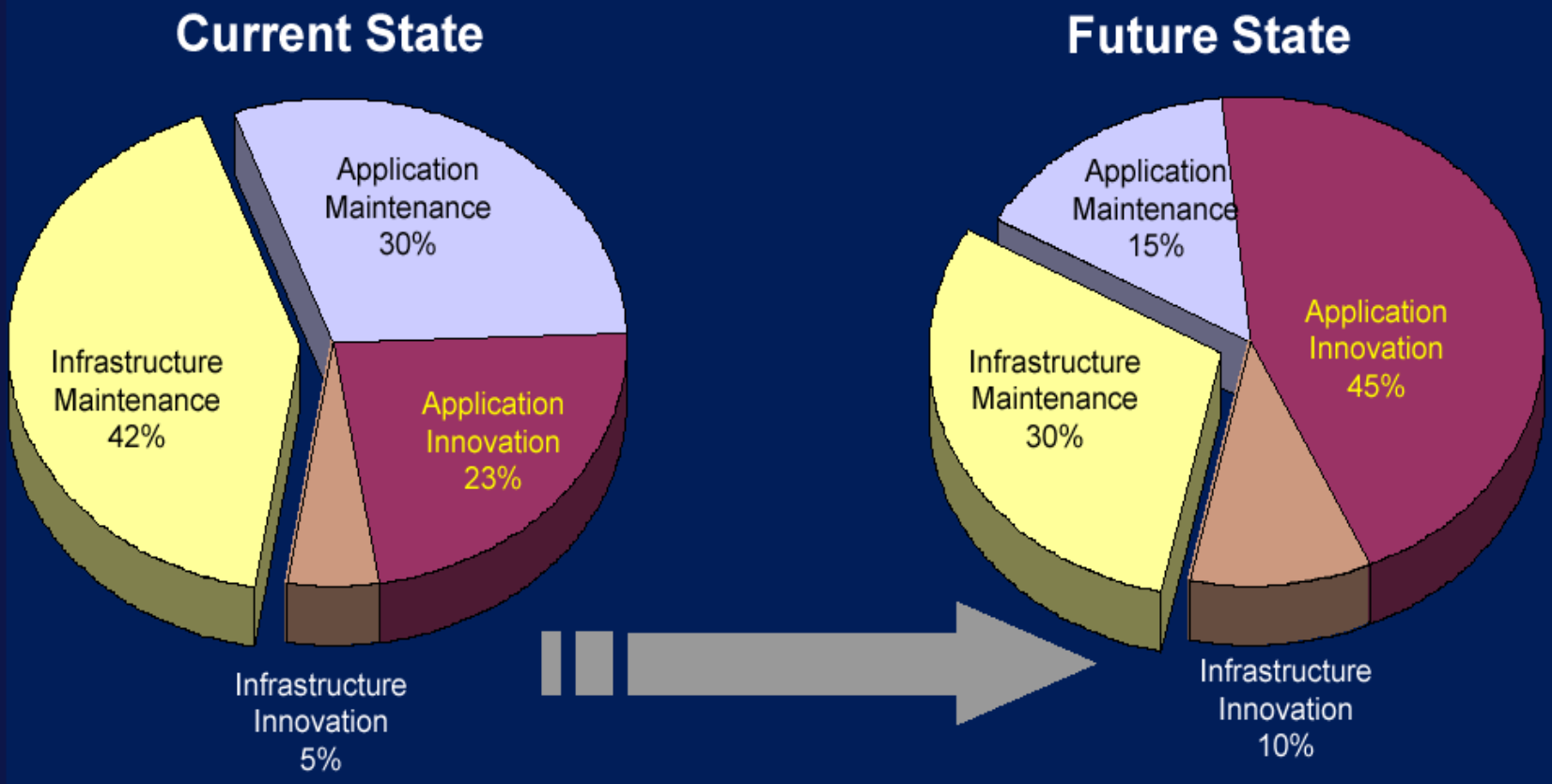
1. User uses a resource composition service to design a custom environment (or selects a pre-configured template).
2. User schedules deployment of application.
3. Resources needed for the deployment are assigned.
4. Service is deployed, and
5. Resources are made available to user.
6. On-line monitoring is used to adjust resources as necessary.
7. Resource availability & utilization is used to improve future decisions.
8. The type/inventory repository tracks any changes in resources.

HP Utility Data Center (UDC)

Configuring Resource Topology

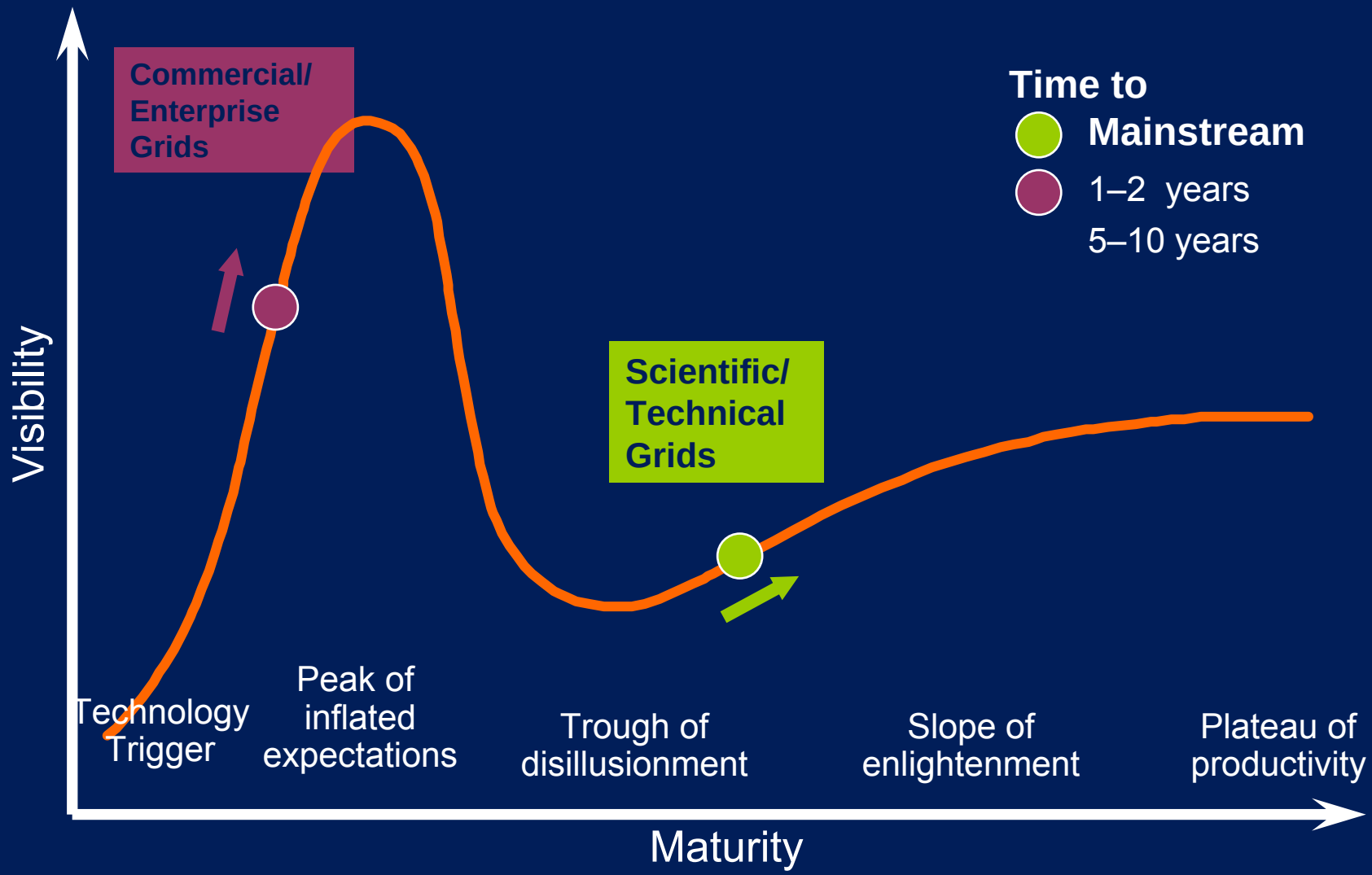


Addressing the Pain Points in the Enterprise.



Source: HP

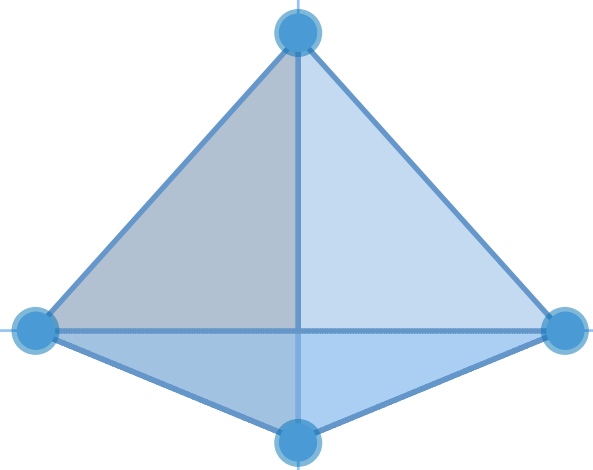
Hype cycle


Commercial/ Enterprise Grids
Time to
Mainstream
1–2 years
5–10 years
Scientific/ Technical Grids
Visibility
Technology Trigger
Peak of inflated expectations
Trough of disillusionment
Slope of enlightenment
Plateau of productivity
Maturity

The Opportunity: Increased Agility

Improve agility:

- Enable the IT environment to adapt to changing business needs



Manage costs:

- Lower operations and acquisition costs
- Manage fixed costs
- Optimize fixed vs. variable costs
- Manage cost of change

Mitigate risk:

- Ensure security and continuity of business operations
- Risk of innovation
- Impact of technology implementation

Increase quality:

- Improve levels of availability and response time
- Extend service levels across the enterprise
- Ability to change the service as well as deliver it
- Agility as service level

Enterprise Grids are different Grids

	Scientific Grid	***Enterprise Grid***
Workload	compute jobs	mostly transactional
Lifetime	duration of job, range of hours, sometimes days	duration of application deployment, range of months and years
Resources	homogeneous, parallel machines or clusters	diverse resource, environment including servers, storage, networks (LAN, SAN), devices
Schedulable Unit	job	Resource Topology

Service-Oriented Architecture

What kinds of features does an SOA have?

Feature	Principles
Security – Three level security mechanism (transport, message and authentication/authorization) utilizing standards (http/s, WS-Security, etc) and security integration (Select Access, Netegrity SiteMinder).	Standards-based, Architecturally Layered, Identifiable Participants
Discovery – Ability for discovering and addressing all services available in the SOA.	Identifiable Participants, Discoverable Participants
Registry – Ability to register all services discovered in the SOA with a standard UDDI registries. Registry stays synchronized with discovery mechanism.	Standards-based, Discoverable Participants, Model Oriented
Metrics – Measure various statistics about service interactions (response time, errors, etc.) and aggregate them.	Architecturally Durable, Model Oriented
SLO – Define service level objectives for metrics at different aggregation levels with breach transition notification.	Architecturally Durable, Model Oriented
Audit – Archive any service interaction. Can define the criteria for audit and interaction context to archive.	Architecturally Layered, Identifiable Participants
Routing – Can be deployed to have the ability to control the flow of interactions. QoS and customer routing available.	Architecturally Durable, Architecturally Adaptive, Flexibly Deployed
Management Integration – SOA itself is built from set of interacting services and described as a model that forms the core for integration and adaptive change.	Extensible Platform, Model Oriented, Architecturally Adaptive

QM: Capacity Profile

▶ **Capacity** – Capacity is the current or anticipated quantitative availability of a resource (type or instance). Capacity may be expressed in metrics of continuous ranges or numbers of instances.

Examples of capacity expressed in terms of numbers of instances are: 100 machines of type A or 20 devices of type B. Examples of capacity expressed in terms if continuous ranges are: 1GB/s bandwidth or 10 TB storage.

▶ **Capacity Profile** – Capacity profile of a ground resource is a function of anticipated capacity of a resource over time.

Only ground resources have capacity provisioned. Capacity of a resource is a function over time about what quantity of a resource type is available (or are expected to be available) over a time period. Capacity profile is provided by the inventory maintainer role.

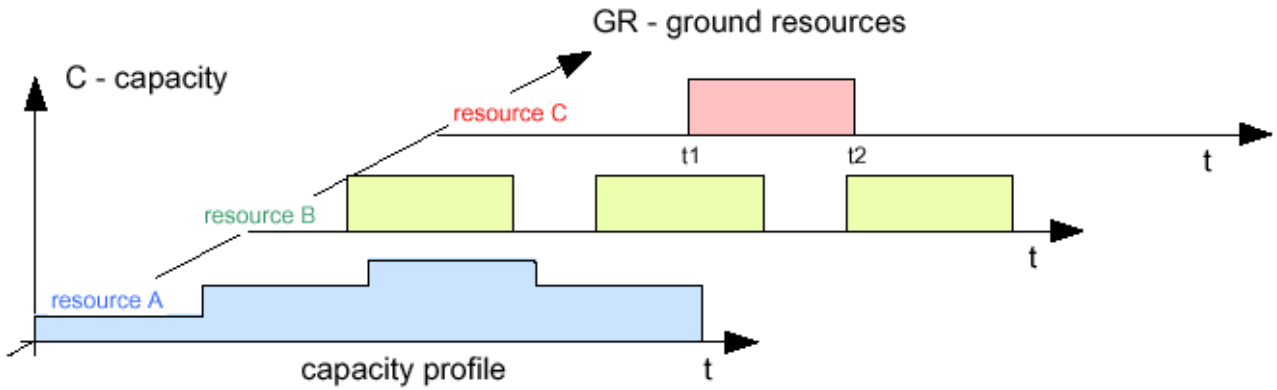


Figure 4: Capacity profiles of ground resources (are part of ground resource specification).

QM: Demand Profile

▶ **Demand** – Demand is the current or anticipated quantitative use of a resource. Demand may be expressed in metrics of continuous ranges or numbers of instances.

Examples of demand expressed in terms of numbers of instances are: 87 machines of type A or 12 devices of type B. Examples of demand expressed in terms if continuous ranges are: 0.86 GB/s bandwidth or 8.4 TB storage.

▶ **Demand Profile** – Demand profile of a requested resource is a function of anticipated demand of a resource over time.

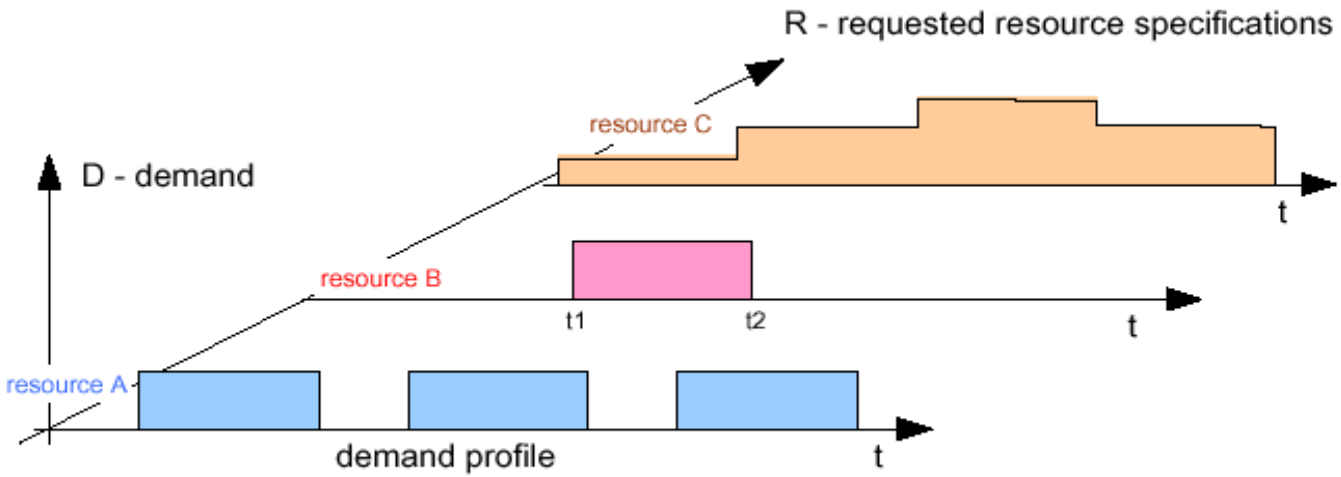
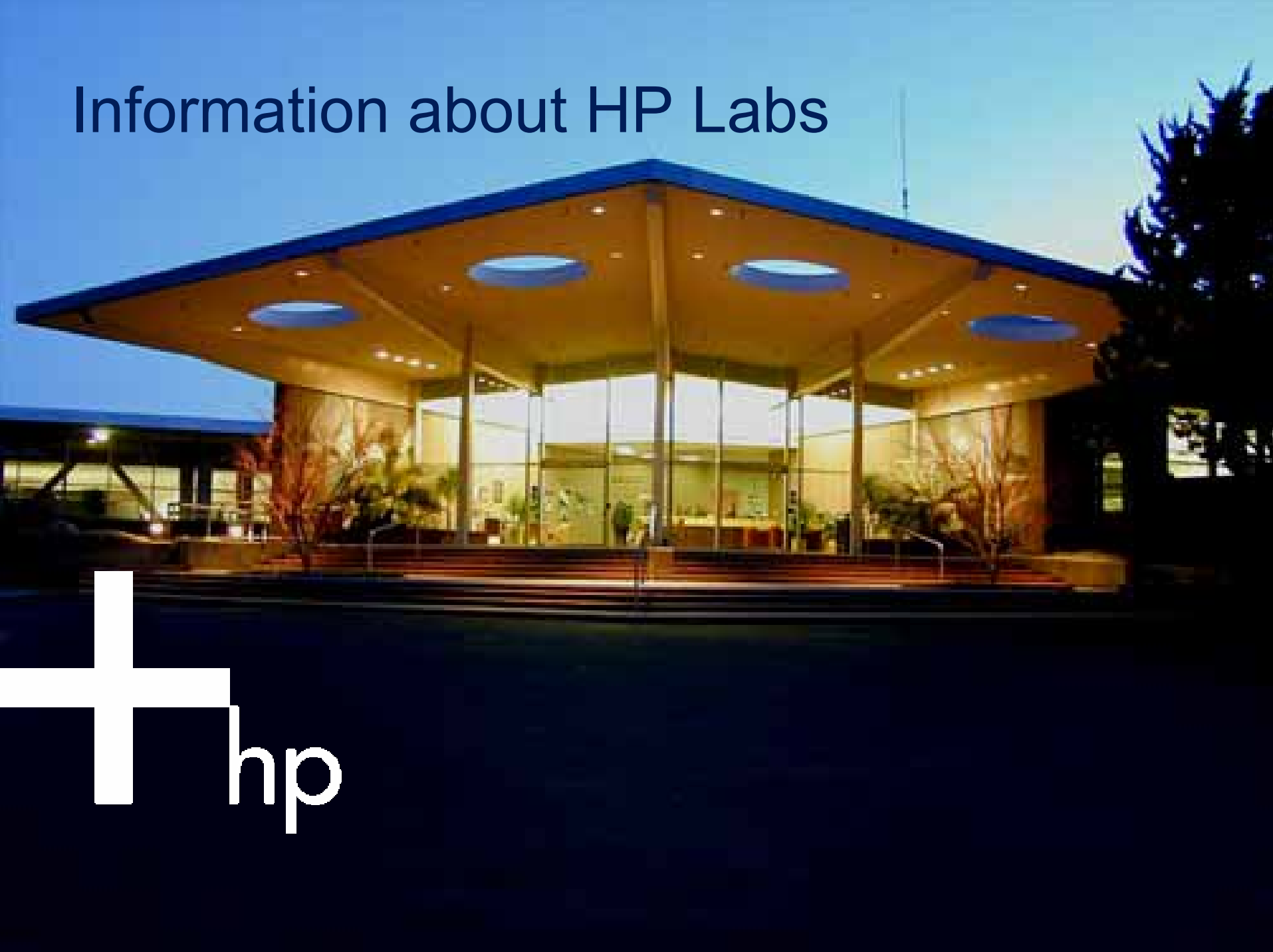


Figure 5: Resource demand profiles as part of a resource request.

Information about HP Labs



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  - U.K.
  - Israel
  - Japan
  - India

HP Labs web site

http://www.hpl.hp.com

Research Centers in HP Labs