In the emerging data center, building blocks of industry-standard components scale to support the largest enterprise applications. This industry trend presents many challenges as IT architects chart the future of advanced data centers. This paper presents a standard framework—the Dell Scalable Enterprise reference architecture—as a tool to help guide this process. The paper includes an architectural model that is standards-based, flexible, and pragmatic. This model serves as a taxonomy that IT technologists can use to model current and emerging data center environments.

Understanding Dell's Direction

Standardization is the key to the data center evolution and the basis for this approach. It enables multiple suppliers for a data center function and provides opportunities to evolve features in a way that benefits the entire industry. Standardization also encourages rapid price reductions in data center solutions as multiple suppliers compete for business. By participating broadly in the promotion of standardization, Dell is in an excellent position to assess the practical effectiveness and relevance of each area. As a result, Dell can provide simple, pragmatic steps toward the future data center as they become practicable.

Dell Scalable Enterprise Architecture

The model depicted in Figure 1 is the inevitable open standards-based data center model, which is valid for current and emerging data centers. At the highest level, it functions as a closed-loop management system. The flow of Information and associated actions are shown by arrows in the diagram.

In this model, a standardized mapping layer provides what will become the foundation of the future data center. This layer maps the relationships of the following software and hardware resources in the data center to a target end service:

- Standard servers, fabrics, and storage subsystems
- Applications and operating systems
- Systems management software, depicted in Figure 1 as the Managed Node Architecture¹ (or Element Management)
- Application management software

These resources may be physical or logical. Additional software layers provide the monitoring, operational policies, controls, and services required for the highly automated environment envisioned in the future data center. The following section describes how these automated processes can address a common issue in the data center.

---

¹ For more information, see “Toward the Systems Management Architecture of the Future: Standardizing the Managed Node,” at www1.us.dell.com/content/topics/global.aspx/innovation/en/cto_systems_management?c=us&l=en&s=corp.
Example: Provisioning Additional Servers in the Scalable Enterprise

A real-world problem that occurs in data centers is the periodic performance challenges associated with enterprise applications such as e-mail or database applications. In this example, an enterprise application is performing below a minimum-acceptable performance threshold. Operational policies determine that an additional server with associated storage must be configured and brought online to meet demand. This process can take days if performed manually, but the automated processes in the emerging data center can dramatically reduce the time.

As part of its routine role, the monitoring software gathers performance data, which it passes to the orchestration software. The orchestration software compares the performance data to policies provided by the Enterprise Management Framework that specify expected performance levels. If the orchestration software detects a variance and determines that more processing capability is required, it instructs a resource manager to deploy additional server, storage, and network resources, configured with appropriate software, as specified in the “response tasks” configured in the policy.

Under the direction of the orchestration software, server, storage, and application resource managers work through the support systems to deploy the required resources. The server resource manager assigns a server from the standby pool to an execution environment, then instructs an imaging application in the support systems to apply the appropriate disk image or workload to the server. Meanwhile, the storage resource manager configures the required logical unit numbers (LUNs), which are attached to the server. When these processes are complete, the server is added to network domains, virtual local area networks (VLANs), and put into service.

Integrity checks are performed along the way and the mapping layer is updated to reflect the newly configured resources, and the relationships between them. Finally, monitoring software verifies that the application performance data is now in line with expected performance based on policies.

While not completely automated today, this scenario illustrates a fundamental characteristic of the emerging data center: the reprovisioning process. As standardization matures, this process will become highly automated and governed by a variety of predefined operational policies.

Key Data Center Activities

The advanced data center environment modeled here is architected to address standard data center activities. These activities are best described by the Information Technology Infrastructure Library (ITIL) Service Delivery and Support model and the Microsoft Operations Framework (MOF).

The ITIL has been widely adopted by IT organizations as an organized method to manage physical assets and services. It provides a cohesive set of best practices drawn from the public and private sectors worldwide. Figure 2 shows the areas addressed by ITIL, which fall into two main categories. “IT Service Delivery” encompasses best practices associated with managing the IT infrastructure. “IT Service Support” encompasses the best practices associated with the business policies that control IT services.

Figure 2. IT Infrastructure Library (ITIL)

The processes promoted in the ITIL specification are governed by the Standard for IT Service Management (BS15000) of the British Standards Institution. There are multiple implementations of the ITIL, including the Microsoft Operations Framework (MOF). The MOF implementation of ITIL extends ITIL with best practices derived from Microsoft operations groups, partners, and customers.
The ITIL and MOF models describe fundamental operations, summarized in Table 1, that must be considered when architecting the data center. The scalable enterprise architecture presented in this paper is designed to address these operations.

**A Closer Look at Dell's Scalable Enterprise Architecture**

The following sections briefly describe each functional block in the model shown in Figure 1.

### Standard Servers, Storage, and Fabrics

These standard platforms are the hardware components—server, storage, and fabrics—that are available as resources to be applied to a data center problem or service. The Dell scalable enterprise model is based on hardware components that are accepted by the industry as nonproprietary.

#### Servers

In this model, standard servers are defined as x86 instruction set machines because most of the development in the industry today occurs on these platforms. For this reason, it is important to carefully consider whether alternative proprietary platforms are the best long-term choice as smooth integration becomes increasingly difficult. In this model, standard servers are also assumed to have 1-4 CPU “sockets” that can accommodate single- or multicore CPUs. These servers are expected to comprise the overwhelming majority of server deployments. (See sidebar.)

![Servers](image-url)

**Why are 1- to 4-socket servers expected to dominate?**

Larger servers with more than 4 sockets are expensive, require nonstandard infrastructure components, and have extremely long development cycles. Furthermore, the introduction of dual-core CPUs with two CPU cores in a single processor allows the rough equivalent of two CPUs to be installed in each socket of an industry-standard 1- to 4-socket server. Thus, 2- or 4-socket, industry-standard servers can become the rough equivalent of today’s 4- and 8-CPU servers. In the future, multicore CPUs with more than two CPU cores per processor will allow even-higher processor densities on 1- to 4-socket servers. This trend is expected to limit the need for larger servers with more than 4 CPU sockets.

<table>
<thead>
<tr>
<th>Data Center Operations</th>
<th>IT Service Support</th>
<th>IT Service Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource installation and registration: unpack and install equipment and present as available resource.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Resource discovery: detect presence of equipment and update available resource inventory.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Setup and configuration: set up resource and configure it for normal operation.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Infrastructure provisioning: install operating system and agents or other base infrastructure on equipment or virtual platform.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Resource inventory update: create physical resource object in scalable enterprise resource directory (SERD)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Virtualization deployment: create virtual machine or target platform.</td>
<td>optional</td>
<td>optional</td>
</tr>
<tr>
<td>Application and service provisioning: install application and other support agents on target platform.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Integrity verification: audit and verify machine contents.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Groupings and bindings: create membership in groups of domains, including connection with service-level agreement.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>In-service operation and monitoring: compare operational behavior to service level “object” in SERD.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Update deployment: deploy firmware, operating system, agents, or application patches, and update SERD.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Event notification: alert or “abnormality modification” to EMF and orchestration layers.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Charge-back and billing: meter and measure for billing.</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 1. Standard Data Center Operations Described by the ITIL
Storage

In Dell’s Scalable Enterprise architecture, standard storage is “sharable”—either network-attached storage (NAS) or storage-area networks (SANs). Internal or direct-attached storage subsystems are minimized. This approach allows the storage environment to be abstracted more effectively, and removes physical dependencies between applications and data.

Storage is perhaps the most mature of subsystems in the scalable enterprise model because key concepts such as RAID, LUNs, and LUN remapping are well-established. Going forward, the industry should focus on standardizing currently proprietary management packages to enable more flexible and interoperable storage solutions.

Standard Servers: Characteristics and Applicable Standards

The main characteristics of standard servers are:
- One, two, or four CPU sockets
- Rack or blade systems
- Intel instruction set architecture. Extended Memory 64 Technology (EM64T) preferred

Standard servers should support the following industry standards:
- PCI Express I/O subsystem (4x and 8x transport widths)
- Intelligent Platform Management Interface (IPMI), version 1.5 or later
- Systems Management BIOS (SM BIOS)
- Distributed Management Task Force (DMTF): Systems Management Architecture for Server Hardware (SMASH) and the Common Information Model (CIM)
- UL Power Supply Ad Hoc -US TAG TC108
- NCITS T10 - SCSI standards
- Server System Infrastructure (SSI)*

*Optional or emerging standard

Standard Storage: Characteristics and Applicable Standards

The main characteristics of standard storage are:
- NAS or SAN
- Block storage, with optional file storage.

Standard storage should support the following industry standards:
- NCITS T10 - SCSI I/O standards
- Serial ATA II
- Serial-Attached SCSI (SAS)
- SNIA: Storage Management Interface Specification (SMI-S)
- IETF RFC 3270 - iSCSI
- NCITS T11 - TWG on Fibre Channel
- NCITS T13 - all interface standards
- Storage Networking Industry Association (SNIA): Common RAID Disk Data format (DDF)*

*Optional or emerging standard

Fabrics

Standard fabric technologies are driven by three parameters: bandwidth, latency, and cost. Today, different fabric technologies are preferred for compute, storage, and control functions in the data center. Two technologies are prime candidates for fabrics: Infiniband and the emerging 10-gigabit (Gb) Ethernet over copper with additional capabilities such as TCP offload engine (TOE) and Remote Direct Memory Access (RDMA). Fibre Channel and Infiniband will continue to be used in the data center, but Dell believes that Ethernet will eventually emerge as the long-term unifying fabric technology for the data center.

Managed Node Architecture

The Managed Node Architecture (or Element Management) layer consists of all the software required to operate and configure specific server, storage subsystems, and fabrics. This includes every aspect of platform management, from powering up and configuration through provisioning and execution. The Managed Node layer operates under the guidance of the Orchestration layer discussed later in this paper.

Currently, servers, storage, and fabrics each require specific management tools. However, the scalable enterprise architecture expects all managed nodes to eventually support the management operations defined by the SMASH standard, which standardizes command line interface scripts. Under this approach, a common set of systems management operations apply to all managed nodes. Only the operations that help manage specific features that are unique to servers, storage, or fabrics will differ.

Mapping and Control

The Mapping and Control function is a pivotal part of the scalable enterprise architecture. It exists to manage the
relationships of all components in the architecture and, thus, contains the state of each relationship.

Mapping and Control is tied tightly to the physical processes presented in Table 1. Figure 3 presents the major components of the Mapping and Control layer:

- **Scalable Enterprise Resource Directory (SERD)** — The SERD contains the details of each relationship. Today, the SERD is largely undeveloped, but there are emerging configuration and management databases that address some of the basic physical information required in the SERD.

- **Raw Resource Pool** — This is a collection of objects that describes the resources available throughout the architecture. An object can represent a single item such as an application or a collection of objects that are bound together by virtue of their physical relationship such as a server with a CPU, memory, and host bus adapter (HBA). Additional objects can be added to this pool as needed.

- **Logical Resource Pool** — This pool is a collection of “logical” objects that are available, but are not bound to anything except, in some cases, other logical objects. The pool may include virtual devices as part of the environment.

- **Physical and Logical Groups** — These optional groupings exist at the physical and logical level and define like members that are grouped together, and dependencies that may be significant to a group. For example, two physical servers that are the members of a high-availability computing cluster might be grouped together. Or, a several virtual machines that are members of a virtual cluster might be grouped together. An example of a dependency is a physical cluster that is dependent on a specific uninterruptible power supply.

- **Dynamic Bindings** — The dynamic bindings represent the highest set of relationships that exist in the architecture. The previously discussed relationships have been relatively static. In contrast, Dynamic Bindings describe relationships that can be removed or modified as needed to best serve operational policy. For example, a virtual application object that is made up of a virtual machine with guest operating system, all necessary agents, and an application may be bound to an object representing a physical server. As a result of data collected during normal operations, a predefined utilization threshold may be reached. Policy in the orchestration layer detects the exception to the service-level agreement that governs the application. The orchestration layer instructs the virtual machine resource manager to move the virtual application from the existing server (by “breaking” the binding) to a new server (by creating a new binding).

Perhaps the most important function that directly impacts the Mapping and Control layer is provisioning or reprovisioning. It occurs under the direction of the orchestration block with the appropriate resource managers and is responsible for creating an application or service. Provisioning employs packages from the support system that perform tasks such as installing software and beginning operation.

**Monitoring (Listening/Verifying)**

The monitoring layer of the scalable enterprise architecture has a dual role: the listening function and verifying function. For the listening function, monitoring software gathers operational data describing current behavior of the hardware and software resources. This data includes a variety of parameters that can be analyzed to determine if operations are aligned with current poli-
cies. The data is provided by a set of authoritative agents from each virtual and physical resource. Agentless monitoring can be implemented where appropriate. This data is analyzed by orchestration software within the framework of specific operational and business policies that are likely to be provided by the Enterprise Management Framework in the future. For the verifying function, the monitoring software verifies that the mappings in the SERD matches what was expected.

**Enterprise Management Framework (EMF)**

The EMF provides a unified operational management view. Today's EMFs are typically higher-order management packages such as those offered by BMC or CA. Although these EMFs do not include an overall policy mechanism, they provide tools that consolidate the systems management information data, and help to interpret monitoring information and manage workflow across a variety of managed nodes. Therefore, the EMF is a good mechanism to track availability and response time measurements associated with managing service-level agreements.

**Orchestration**

Orchestration is a control level introduced by the Gartner Group as part of the emerging modern IT infrastructure. Orchestration combines operational data from the monitoring function and policy information from the EMF to describe how resources should be connected for optimal operation. Currently, the best examples of orchestration are custom scripts designed to correct specific operational problems. These custom scripts have drawbacks. They are developed manually, are inflexible and nonadaptive, and are not based on industry standards.

**Resource Managers**

Resource managers establish relationships that govern how resources are used. Ideally, resource managers are the source of the mapping information stored in the SERD. A resource manager allocates and manages server, network, storage, operating system, and applications resources. Examples of current resource manager software applications are EMC® Visual Storage Resource Manager (VisualSRM®) and Dell's network resource manager, Dell OpenManage™ Switch Administrator.

**Support Systems**

Support systems can be thought of as “helpers” or “isolatable functions.” They are self-contained utilities that help the orchestration and resource managers to control system-wide behavior. An example is the Altiris imaging function, which can be dispatched to place an image on a server in a reasonably independent fashion. If the target and source can be described and the completion of the operation characterized, there is little need for additional involvement from other blocks during the process.

**Applications and Operating Systems**

These are the software applications, services, and operating systems required to successfully complete end-user tasks. The operating system provides access to resources and is the interface between applications and the rest of the system. As the data center architecture evolves, operating systems will most likely evolve into two branches: application-facing operating systems that are closely aligned with applications, and infrastructure-facing operating systems that focus on internal operations. Even greater distinctions between the two branches will emerge as server virtualization matures.

**Standardization is the Key**

The key to the continued evolution of the data center is the pervasive standardization seen throughout this architecture. Standardization is especially important in the SERD, the information store that contains the mapping information describing the relationships between hardware resources, and, in turn, their connection to applications and user-requested services. The standardized SERD must include a configuration management data base (CMDB) and a common globally addressable infrastructure.

Standardization of the SERD will also contribute toward standardizing another difficult area: the application program interfaces (APIs) and calling interfaces between software packages. The most enduring interface today is the command line interface (CLI), in which the calling software mimics a systems management console and
issues commands to the target software. This approach amounts to custom “shim” layers between packages. The data center will require a standards-based alternative. The SERD is part of the solution. By standardizing the catalog, data, and format describing the relationships that can be mapped, the data becomes the interface. If the common set of objects in the SERD is based on defined standards such as the Distributed Management Task Force (DMTF) CIM and XML standards, virtually any software package can be called to perform necessary operations.

**Conclusion**

The Dell vision of the scalable enterprise is embodied in the model presented in this paper. Its highly automated processes will enable IT managers to quickly, automatically, and cost effectively deploy and redeploy IT assets to accommodate changes in their business environments. Its greatest strength lies in its reliance on standards-based hardware and software components, rather than proprietary solutions that lock a data center into a single vendor’s hardware and professional services.

Standardization will help to drive a competitive market with multiple vendors providing interoperable software tools. The competition will tend to increase innovation and lower prices. Standardization will also help to ensure that future software tools are backward-compatible with today’s tools. Standards-based software, combined with standardized servers, storage systems, and switched fabrics, will enable the flexible and scalable architecture required for the future data center.

Dell is committed to driving key enterprise standards that will provide the underpinnings for the scalable enterprise. Dell is focused on accelerating the adoption of these standards with key partners in the industry. In this way, Dell will help to fundamentally shift the way the data center is architected, deployed, and managed.

*Additional contributors to this white paper were Frank Molsberry, Suri Brahmaroutu, Lano Cox, Jon Hass, Brent Schroeder, Drue Reeves, and Matt Brisse.*

**For More Information**

- ITIL: www.itil.co.uk.