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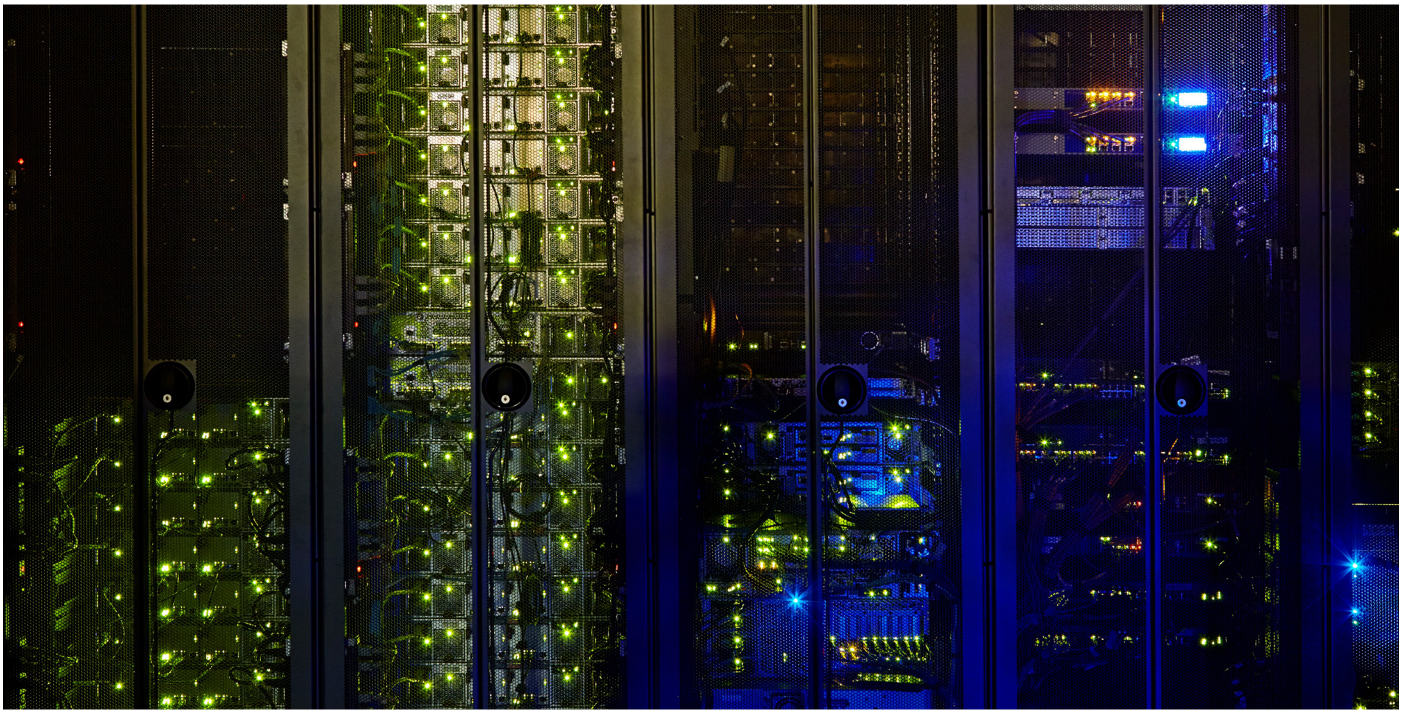
HPE SUPERDOME FLEX SERVER ARCHITECTURE AND RAS

Unmatched combination of flexibility, performance, and reliability for critical environments of any size



CONTENTS

INTRODUCTION

The HPE Superdome Flex Server is a compute breakthrough that can power critical applications, accelerate data analytics and tackle AI and HPC workloads holistically. It delivers an unmatched combination of flexibility, performance, and reliability for critical environments of any size. A unique modular architecture and unparalleled scale allow customers to start small and grow at their own pace. Leveraging its in-memory design and groundbreaking performance, businesses can process and analyze growing quantities of data at extraordinary speed. HPE Superdome Flex safeguards these vital workloads with superior RAS and end-to-end security, while HPE Pointnext Services portfolio, broad partner ecosystem, and mission-critical expertise complement the capabilities and value of the platform to ensure moving to HPE Superdome Flex is a success.

Some noteworthy characteristics of the platform include:

- Modular architecture that scales seamlessly from 4- to 32-sockets in 4-socket increments in a single system
- Shared memory capacity from 768 GB up to 48 TB
- Features Intel® Xeon® Scalable processors 1st or 2nd generation
- Proven RAS capabilities not available on other standard platforms
- Best-in-class predictive fault-handling Analysis Engine, predicts hardware faults and initiates self-repair without operator assistance
- Firmware First approach to log analysis ensures error containment at the firmware level, including memory errors, before any interruption can occur at the OS layer
- Mission-critical resiliency from end-to-end implementation of processor RAS features, to redundancy of key system components to advanced system software

This document describes the HPE Superdome Flex architecture and explains its significant benefits in performance, manageability, and reliability for your mission-critical environment.

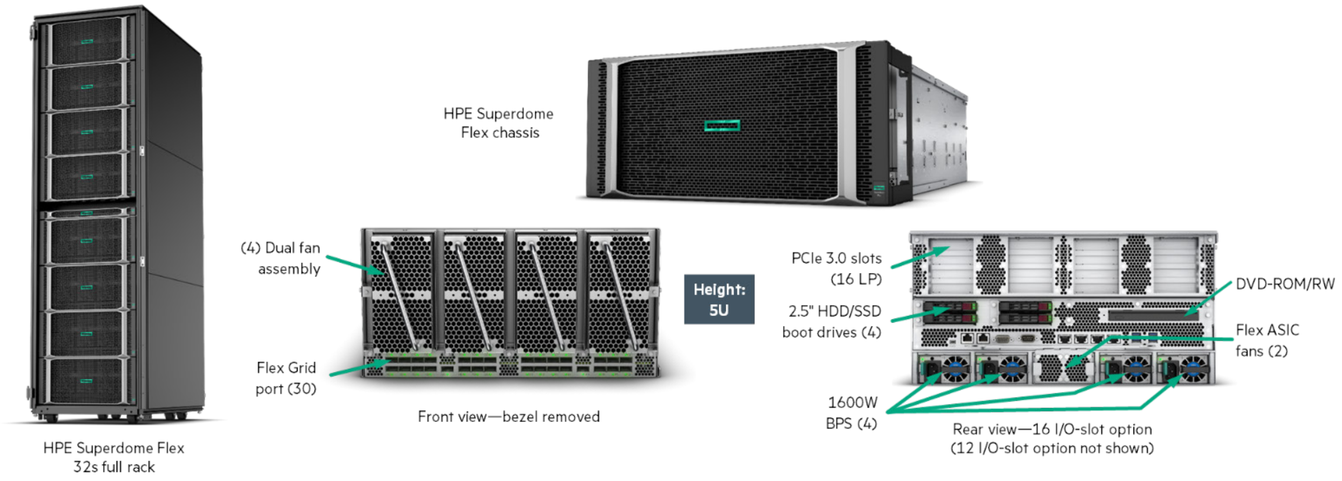

HPE Superdome Flex chassis
(4) Dual fan assembly
Flex Grid port (30)
Height: 5U
Front view—bezel removed
PCIe 3.0 slots (16 LP)
2.5" HDD/SSD boot drives (4)
1600W BPS (4)
DVD-ROM/RW
Flex ASIC fans (2)
Rear view—16 I/O-slot option (12 I/O-slot option not shown)
HPE Superdome Flex 32s full rack

FIGURE 1. HPE Superdome Flex system

As shown in Figure 1, HPE Superdome Flex is designed around a 5U modular building block that can scale from 4-socket up to 32-sockets in 4-socket increments through a cabled crossbar interconnection fabric called the HPE Superdome Flex Grid. With this modular design flexibility, HPE Superdome Flex customers don’t pay for infrastructure costs (that is, power capacity, Flex Grid cables, and more) above and beyond the system scale they require, but can easily add capacity in the future as their application needs change. Service access for the system is limited to the front or rear of the enclosure by way of forward and rearward sliding rails, and components like Bulk Power Supplies (BPS), fan assemblies, boot drives can all be serviced while the mission-critical workloads and operating environments continue to run. HPE Superdome Flex Grid provides adaptive routing features designed specifically to enhance performance by routing traffic through the optimal latency path available, and provide superior uptime by automatically routing traffic around failed components.

Reliability, availability, serviceability

Reliability, availability, and serviceability, collectively known as “RAS,” are top reasons customers deploy mission-critical workloads on HPE Superdome Flex. The server provides capabilities that keep systems up and running despite component failures or recovering quickly and automatically from failures, so those mission-critical workloads can resume rapidly without waiting for a service person to effect repairs. Robust RAS has always been a designed-in philosophy for HPE Superdome servers, and HPE Superdome Flex builds on that strategy with such RAS strengths as:

- A selective and extended implementation of Intel Xeon Scalable RAS capabilities through custom reference code modifications
  - For example, HPE Superdome Flex implementation of Adaptive DDDC utilizes more error correction regions and has a finer granularity than provided in Intel® standard reference code. This results in better annual service and replacement rates for memory than other vendors’ platforms can provide.
- Cabled HPE Superdome Flex Grid with adaptive routing:
  - Automatically chooses the optimum latency path through the crossbar fabric for best performance and even detects and routes traffic around failures without requiring a reboot.
  - HPE nPar support provides complete workload isolation and independent serviceability if cabled properly.
- Rack Management Controller (RMC) or embedded RMC (eRMC) provides the server management command-line interface and includes an HPE Superdome Flex Analysis Engine to provide error handling/correction, self-healing, and system health monitoring.
- Hot-swappable power and cooling components.

A detailed discussion of RAS is provided in the RAS section of this document.

Manageability

HPE Superdome Flex has an advanced manageability system that is always on, constantly monitoring and managing the system components, fabric, and infrastructure for mission-critical high availability. The design team has focused on management as a major development area in the system. It is designed to integrate seamlessly into both industry standard and the HPE suite of management products using industry-standard Redfish® APIs. In addition, the HPE Superdome Flex Analysis Engine provides enhanced self-diagnosis and automated recovery features. A comprehensive SSH command-line interface is available for administrators to get to the most detailed features in a repeatable (and scriptable) manner as well.

Major management components and resources include:

- HPE Superdome Flex Rack Management Controller (RMC)
- HPE OneView, including HPE OneView Remote Support (OVRS)
- HPE Insight Remote Support
- HPE Smart Update Manager

HPE Superdome Flex management subsystem integrates into data center solution management components using the industry-standard Redfish API. This enables standard solutions such as OpenStack®, as well as simple scripting to be used to get information and control the system.

A detailed discussion of HPE Superdome Flex management capabilities is provided in the Management section of this document.

SYSTEM ARCHITECTURE

HPE Superdome Flex combines the best of Intel Xeon architecture and the new HPE Superdome Flex ASIC chipset to provide the most flexible x86-server solution available. The system is capable of delivering performance and scalability from 4-sockets to 32-sockets, in 4-socket increments, and is imbued with the necessary RAS features to operate in mission-critical environments where application availability is of paramount importance. Figure 2 shows the architecture of HPE Superdome Flex Base Chassis, which comprises the basic modular building block for the server solution. Each HPE Superdome Flex system consists of at least one Base Chassis plus as many as seven additional Expansion Chassis to provide the ability to scale up to 32-sockets or divide the system into hard partitions (HPE nPars) to isolate workloads and/or consolidate multiple workloads onto a single managed complex. HPE Superdome Flex ASIC provides the ability to connect Base and/or Expansion Chassis together via HPE Superdome Flex Grid cables, which provides many key benefits as listed here:

- **Adaptive routing:** Routes fabric traffic around any failed resources, and load balances the fabric for optimal performance by utilizing the available path with the lowest possible latency.
- **Configuration flexibility:** Cabling can be quickly reconfigured in the field to maximize performance whenever application needs change.
- **Signal integrity advantages:** Cables have higher signal propagation velocity, which means less delay and lower latency, and they provide better isolation between channels with lower crosstalk and a higher signal-to-noise ratio than can be achieved in copper traces across a printed circuit board.
- **Future-proof:** External copper cables provide an infrastructure that can be easily adapted to optical cabling technology in the future. When data transfer speeds exceed the capability of copper cables, and the cost to implement optical cabling becomes affordable, something as easy as plugging in a new version of HPE Superdome Flex ASIC assembly could convert HPE Flex Grid to optical fibers instead.
- **Lower entry costs:** With a modular chassis connected by cables, it is only necessary to buy the hardware, including power and cooling infrastructure, to fit the need, and not spend more securing expandability until that is needed, avoiding unnecessary and costly over-overprovisioning of infrastructure.

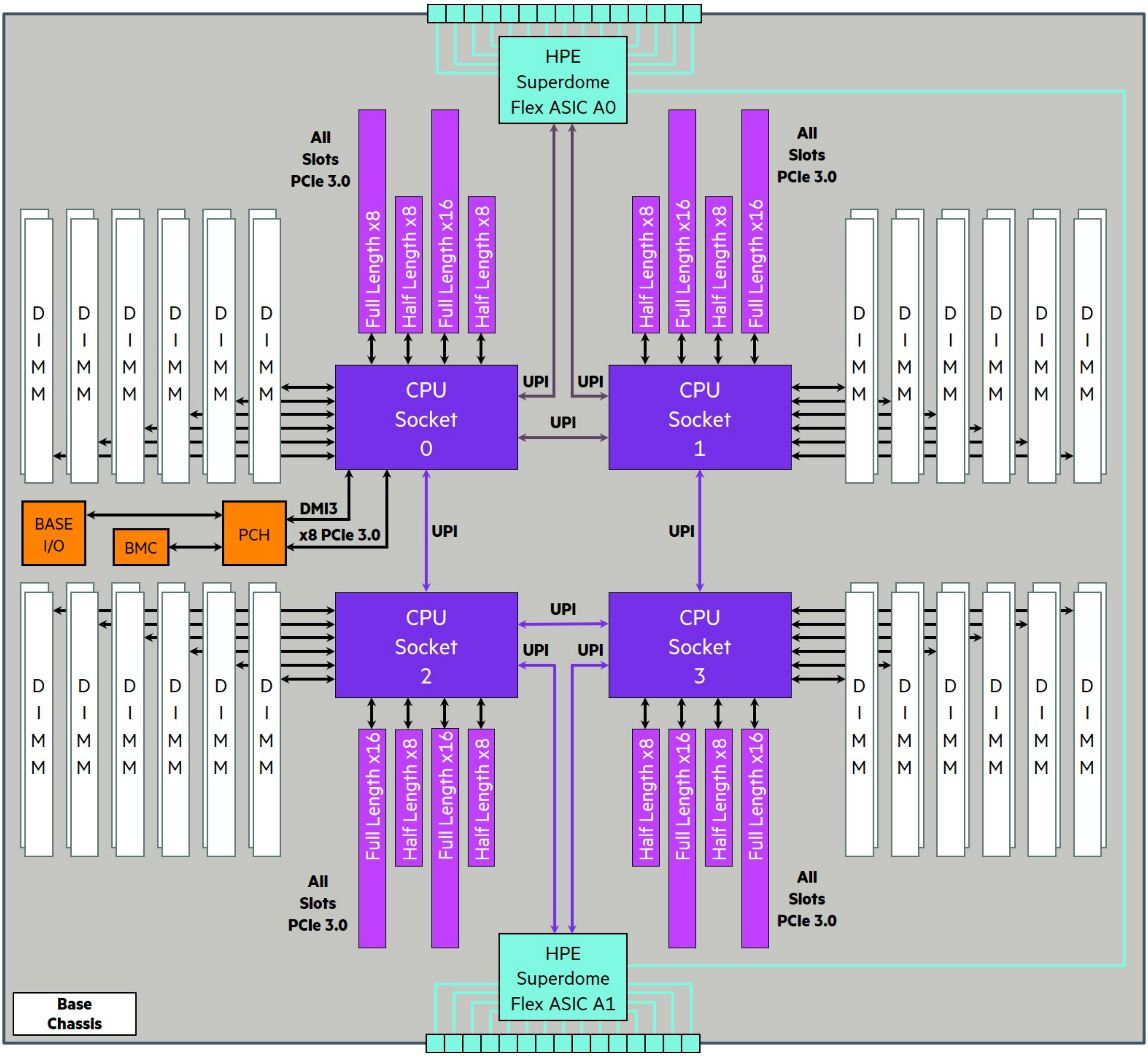


FIGURE 2. HPE Superdome Flex modular chassis architecture

HPE Superdome Flex chassis—the modular building block

Each HPE Superdome Flex chassis accommodates four Intel Xeon Scalable 82xx, 81xx, 62xx, or 61xx series processors, which can provide as many as 28 cores per processor socket. With hyper-threading enabled, a 112-core HPE Superdome Flex chassis provides 224 logical processors. The four processors are connected together in a ring fashion via 10.4 GT/s Intel Ultra Path Interconnect (UPI) links. Each processor is also connected to one of two custom-designed HPE Superdome Flex ASICs via Intel UPI links to send remote targeted cache-coherent data traffic to external chassis in 8-socket or larger HPE nPars. HPE Superdome Flex architecture provides each processor with direct connections to 12 HPE DDR4 DIMM slots, which can accommodate 32 GB, 64 GB, and 128 GB DDR4 DIMMs, and provides direct connections to PCIe 3.0 x8 and x16 stand-up card slots. The 82xx and 62xx series processors support Intel® Optane™ Persistent Memory 100 series for HPE (in 128 GB, 256 GB, and 512 GB sizes) in addition to DDR4 memory.

Also, the two HPE Superdome Flex ASICs are cross-connected to provide the system with the unique ability to support both 82xx and 81xx Platinum and 62xx and 61xx Gold series processors while still providing scalability from 4-sockets up to 32-sockets. The second-generation Intel Xeon Scalable processors (82xx and 62xx processors) offer the following advantages over previous generation.

- Faster core frequencies for most SKUs, of up to 300 MHz faster per core
- Higher core count for select SKUs, 2 or 4 more cores available
- ~10% faster memory bus at 2933 MT/s, available with all DIMM configurations; new DIMMs are required
- Hardware fixes for security, notably Spectre and Meltdown fixes
- Support for Intel Optane Persistent Memory 100 series for HPE
- Increased memory capacity and new “L” option for highest capacity DIMMs + persistent memory
- New Vector Neural Network Instructions (VNNI) to enhance AI/machine learning workloads
- Minimal to no per-socket power increase

HPE Superdome Flex ASIC

HPE Superdome Flex ASIC is an HPE custom-designed ASIC that interfaces directly to Intel Xeon Scalable processors and provides the system with the ability to connect up to eight HPE Superdome Flex chassis together in a cache-coherent fabric called HPE Superdome Flex Grid. HPE Superdome Flex ASIC provides two UPI links to interface with two Intel Xeon Scalable processors on one side, and provides sixteen Grid ports on the other side to interface with HPE Superdome Flex ASICs within the same chassis, and to external chassis via HPE Superdome Flex Grid cables. The HPE Superdome Flex ASIC maintains coherency by tracking cache line state and ownership across all the processor sockets within a system (or within an HPE nPar partition) inside a directory cache built into the ASIC itself. This coherency scheme is a critical factor in the ability of HPE Superdome Flex to perform at near linear scaling from 4-sockets all the way up to 32-sockets, whereas, typical glueless architecture designs already see more limited performance scaling to as low as 4- to 8-sockets due to broadcast snooping.

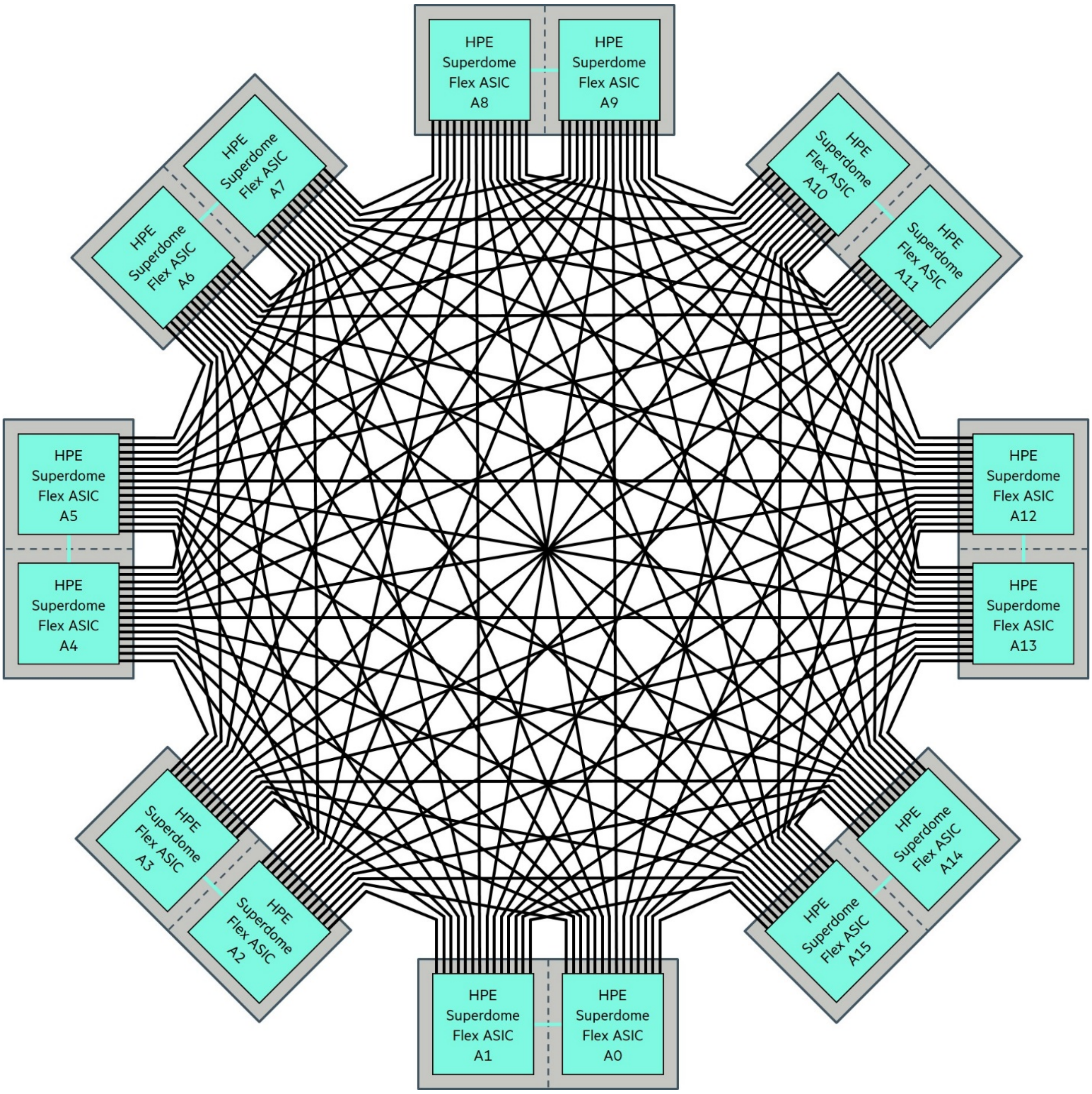
HPE Superdome Flex ASIC provides the following features:

- Physical address support for up to 64 TB of main memory per cache coherence domain
- Very large directory cache to track cache line state and maintain coherency across all attached processor sockets
- Adaptive routing features provide fault resiliency and load balance the fabric
  - Performance gets optimized by choosing the optimal latency datapaths
  - Failed components get detected and routed around automatically
- Provides 16 Flex Grid ports, each capable of 13.3 GB/s data rates for maximum Flex Grid bandwidth
  - More than 210 GB/s of bi-sectioned crossbar Grid bandwidth at 8-sockets with 4 Flex Grid link connections between each ASIC
  - More than 425 GB/s of bi-sectioned crossbar Grid bandwidth at 16-sockets with 2 Flex Grid link connections between each ASIC
  - More than 850 GB/s of bi-sectioned crossbar Grid bandwidth at 32-sockets with 1 Flex Grid link connection between each ASIC

HPE Superdome Flex Grid—the crossbar fabric

HPE Superdome Flex Grid is the fundamental differentiator for HPE scalable system design. This capability, enabled by the custom HPE Superdome Flex ASIC, is what allows HPE to offer a system with greater scalability than the 8-socket limit provided by the standard Intel reference architecture. The custom HPE Superdome Flex ASIC and HPE Superdome Flex Grid cabling provides the low latency and high-bandwidth cache-coherent path between all the processors defined within each HPE nPar. And it is important to differentiate true hard partitioning (complete workload isolation) through the complete disablement of any cabled HPE Superdome Flex Grid links between HPE nPars, so no data traffic from one HPE nPar can impact another. Each HPE nPar can be serviced independently and without interruption to other HPE nPars residing within the same complex, and cabling from the nPar being serviced can be disconnected without impact to the other nPars.

By providing system scaling of up to 32-sockets, HPE Superdome Flex stands alone in providing the largest possible cache-coherent solution available today, thereby allowing customers to tackle workloads they couldn’t imagine doing before. An example of HPE Flex Grid interconnect scheme for a 32-socket HPE nPar is shown in Figure 3.


HPE Superdome Flex ASIC A8
HPE Superdome Flex ASIC A9
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HPE Superdome Flex ASIC A13
HPE Superdome Flex ASIC A3
HPE Superdome Flex ASIC A14
HPE Superdome Flex ASIC A2
HPE Superdome Flex ASIC A15
HPE Superdome Flex ASIC A1
HPE Superdome Flex ASIC A0

FIGURE 3. 32-socket HPE Superdome Flex Grid interconnect

As Figure 3 shows, HPE Superdome Flex Grid links provide single-hop, direct interconnection between every ASIC to keep latency to a minimum and maximize performance. The cabled HPE Superdome Flex Grid is so flexible, that even above the 32-socket scale, where HPE Superdome Flex ASIC can no longer provide single-hop, direct interconnect, it is still conceivable to scale higher (64-sockets or even more) by allowing for multi-hop links. Such flexibility means that even special need customers may discover that a true cache-coherent system solution at a previously unimaginable scale can solve computing problems never before attempted.

Memory subsystem

Each HPE Superdome Flex chassis has 48 DDR4 DIMM slots that can accommodate 32 GB RDIMMs, 64 GB LRDIMMs, or 128 GB TSV RDIMMs for a maximum per-chassis capacity of 6 TB. This gives a fully scaled 32-socket HPE Superdome Flex a total memory capacity of 48 TB of main memory to support the most intensive in-memory applications. For systems utilizing the second-generation Intel Xeon Scalable processors (82xx and 62xx processors) the DIMM slots can also accommodate 128 GB, 256 GB, and 512 GB persistent memory modules, in addition to DDR4 memory. Half of the DIMM slots must always be populated with DDR4 memory. The other half can have either DDR4, or a ratio of 6:1, 6:2, or 6:6 with persistent memory. Persistent memory configurations are supported in the App Direct mode, as supported by the operating system. A diagram of the memory subsystem architecture is shown in Figure 4.

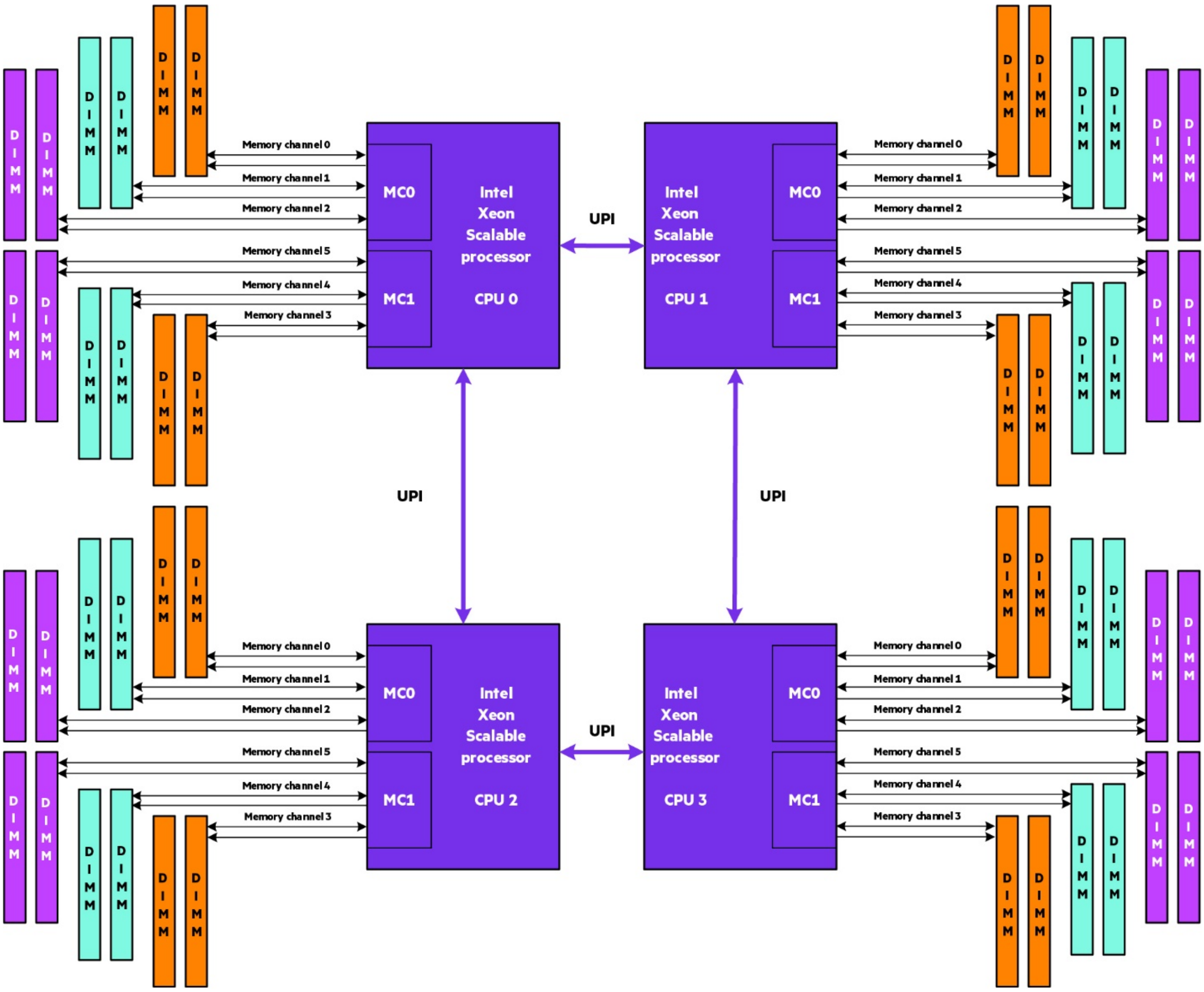


FIGURE 4. HPE Superdome Flex chassis memory subsystem

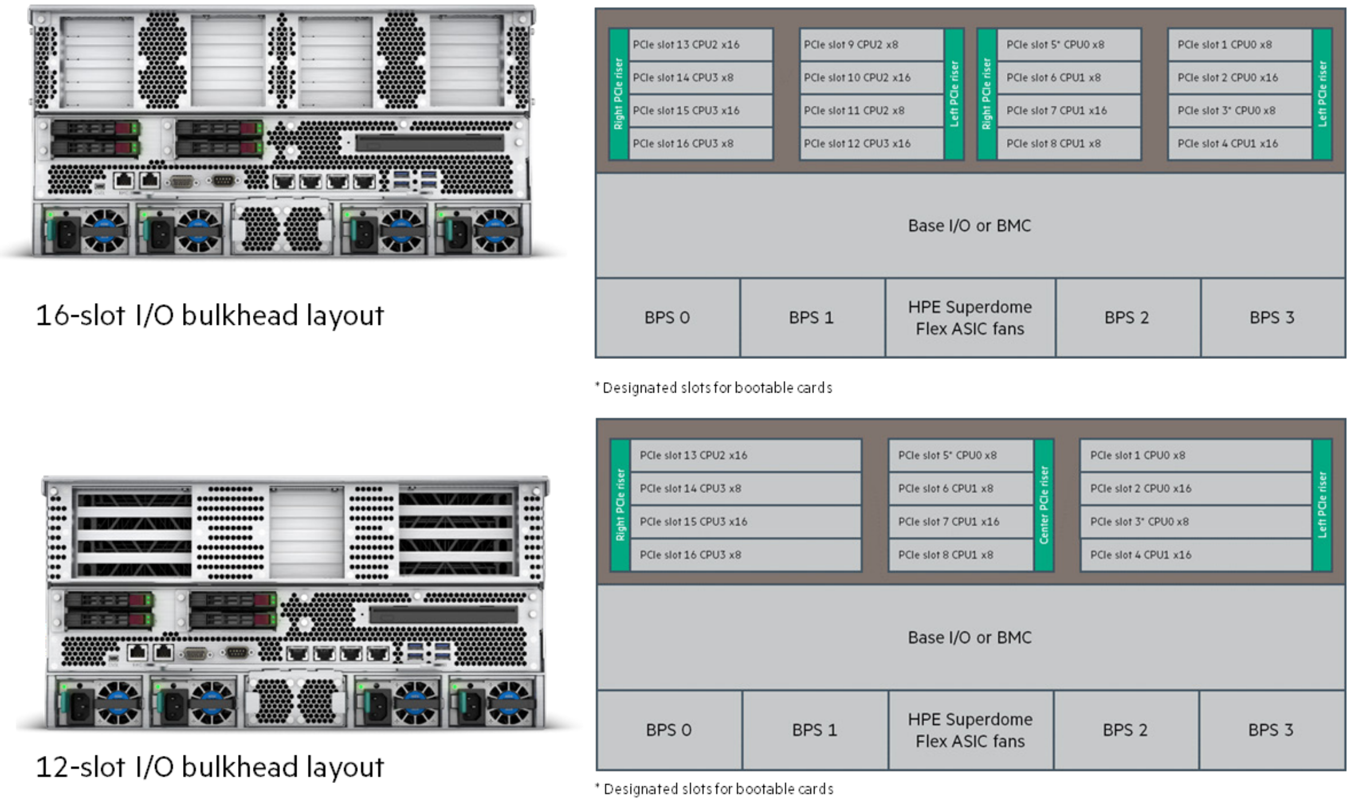
As illustrated in Figure 4, the memory subsystem includes the following features:

- Each Intel Xeon Scalable processor provides two fully independent integrated memory controllers (MCs), and the processors are connected together in a cache-coherent ring architecture providing three latency levels per chassis (local, direct attach, indirect attach).
- Each memory controller provides three fully independent memory channels.
- Each memory channel connects directly to two DDR4 DIMM slots, or supported configuration of DDR4 and persistent memory.
- External chassis connections provided through (not shown).

Since these memory channels are fully independent, they can all run simultaneously at DRAM data transfer rates up to 2933 MT/s to provide each 4-socket HPE Superdome Flex chassis with >360 GB/s of local memory bandwidth (STREAM TRIAD). What's more, with HPE Superdome Flex you are only at half capacity at 16-sockets, and you can count on that same linear memory bandwidth scaling all the way to 32-sockets where such incredible memory capacity and performance levels will be needed to keep as many as 896 cores of Intel Xeon Scalable processing power running the most demanding workloads.

I/O subsystem

As has long been a hallmark of HPE mission-critical server design, achieving breakthrough system performance means that maintaining balance between processing power, memory capacity/performance, crossbar interconnectivity, and system I/O capabilities is of paramount importance. Each HPE Superdome Flex chassis can be equipped with either a 16-slot or 12-slot I/O bulkhead to provide innumerable stand-up PCIe 3.0 card options and flexibility to maintain that vitally important system balance for any workload imaginable. The 16-slot I/O bulkhead provides nine low profile x8 and seven low profile x16 PCIe 3.0 card slots. The I/O bulkhead utilizes the available 48 PCIe lanes per processor to the maximum degree possible with as much as 110 GB/s per chassis of I/O bandwidth available. The 12-slot I/O bulkhead provides four full-height x8, four full-height x16, three low profile x8, and one low profile x16 PCIe 3.0 card slots. The I/O bulkhead provides sufficient extra power capacity to support ~ 300W full-height, double-width GPU cards for those high-demand HPC/HPTC workloads or for machine learning as the ultimate neural net training engine. With either I/O bulkhead selection, the I/O design provides direct connections between the processors and the card slots without need for bus repeaters or retimers that could add latency or reduce bandwidth. Hence, HPE Superdome Flex customers can rest assured they will get the best per card performance possible. Figure 5 shows the layouts for both the 16-slot and 12-slot I/O bulkhead options.



16-slot I/O bulkhead layout

* Designated slots for bootable cards

12-slot I/O bulkhead layout

* Designated slots for bootable cards

FIGURE 5. HPE Superdome Flex I/O bulkhead options

In addition to having the choice to pick the best I/O bulkhead option to fit any application's needs, the I/O subsystem design of HPE Superdome Flex system also provides Base I/O functionality. It also provides built-in, hot-swappable boot drives to ease deployment and minimize costs. Of course, a customer may also choose to boot from SAN, as is often recommend for SAP HANA®, or may even choose network boot options via PXE.

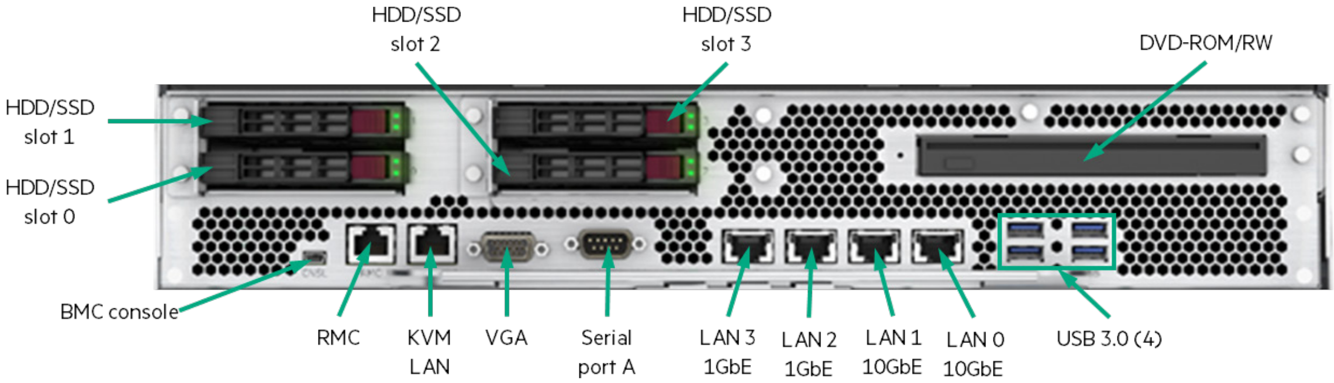


FIGURE 6. HPE Superdome Flex Base I/O

HPE Superdome Flex Base I/O, as illustrated in Figure 6, provides the Base Chassis of HPE Superdome Flex complex the following features:

- Built-in boot storage provided via four hot-swappable 2.5" HDD/SSDs
- One DVD-ROM/RW drive for OS/driver installation
- Two general-purpose 10GbE LAN ports
- Two general-purpose 1GbE LAN ports
- Four USB 3.0 ports
- OS Console serial, VGA, and KVM LAN ports
- One Rack Management Controller (RMC) LAN port for connection to the management LAN
- One Board Management Controller (BMC) console port for initial system setup, password recovery, and debug

Each HPE Superdome Flex system will have at least one Base or Partitionable Chassis to act as HPE nPar monarch, and may contain up to seven Expansion Chassis depending on customer configuration. If the system is to be carved up into multiple HPE nPars, then each HPE nPar will need at least one Base or Partitionable Chassis. However, selecting two to provide for fail-over purposes will increase overall system availability by allowing for automatic reconfiguration and reboot in the unlikely event of a chassis deconfiguration event.

HPE Superdome Flex chassis management

Each HPE Superdome Flex chassis includes a Platform Controller Hub (PCH) chip and Baseboard Management Controller (BMC) to provide all the features required to tie the chassis into the HPE Superdome Flex server management's primary component, the Rack Management Controller (RMC). The PCH chip provides initial reset functionality and real-time clock functionality. The BMC provides the bulk of hard partitioning capabilities and error handling. The BMC hardware and firmware also provide remote server management capabilities over an Ethernet management network. The BMC of each chassis interface directly with the RMC to provide the processing power needed to manage a large and flexible system like HPE Superdome Flex.

HPE Superdome Flex Rack Management Controller

HPE Superdome Flex is managed through HPE Superdome Flex Rack Management Controller (RMC). It provides the ability to manage the partitioning of the system and component inventory and health. While each chassis has its own Baseboard Management Controller (BMC), HPE Superdome Flex RMC collectively manages all chassis and the system fabric with the aid of each chassis BMC, avoiding the need to drill down when managing individual nodes.

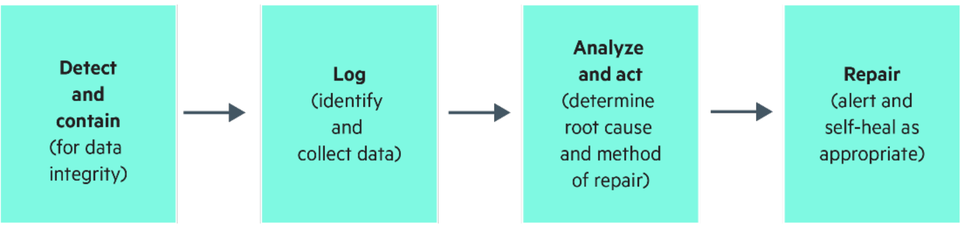
HPE Superdome Flex RMC's built-in Analysis Engine is constantly analyzing all hardware to detect faults, predict failures, and initiate automatic recovery actions as well as notifications to administrators and HPE Insight Remote Support and HPE OneView.

RAS

HPE Superdome Flex servers offer RAS features in key hardware subsystems—processor, memory, and I/O—and provide the ideal foundation for mission-critical Linux®, Microsoft Windows, and VMware® operating environments. Mission-critical HPE Superdome Flex addresses the growing emphasis on availability and provides it through a layered approach that offers application, file system, and operating system protection. Mission-critical HPE Superdome Flex infrastructure and the x86 operating environments provide a comprehensive RAS strategy that covers all layers—from application to hardware.

Fault management strategy

HPE Superdome Flex servers fully realize HPE's design strategy for systems handling mission-critical workloads, which is to implement, when applicable, a four-stage RAS strategy of detection, logging, analyzing, and repair (Figure 7).



Detect and contain (for data integrity) → **Log** (identify and collect data) → **Analyze and act** (determine root cause and method of repair) → **Repair** (alert and self-heal as appropriate)

FIGURE 7. HPE hardware RAS strategy

This strategy keeps customer workloads up and their data available even in the presence of faults. In the rare event of an unrecoverable fault, the strategy still provides detection and containment to protect corrupt data from reaching the network and permanent storage.

When faults do occur that require support action, accurate diagnosis of the fault is critical to determine what is wrong and how to fix it right the first time. The following are some of the design keys for diagnostic abilities that are built-in to every HPE Superdome Flex server:

- Minimize time to repair
- Capture enough data to diagnose failures the first time
- Allow system to run after failure for complete error logging
- Ability to diagnose all system components (software, firmware, and hardware) via complete error logging
- Field-replaceable-unit (FRU)-level granularity for repair
- Component-level granularity for self-healing

Firmware First

Part of HPE Superdome Flex's comprehensive strategy for fault management includes Firmware First problem diagnosis. With Firmware First, firmware with detailed knowledge of HPE Superdome Flex system is first on the scene of problems to quickly and accurately determine what's wrong and how to fix it. Intel Xeon Scalable processors Enhanced Machine Check Architecture Gen 2 (EMCA2) allows firmware a first look at error logs so that firmware can diagnose problems and take appropriate actions for the platform before OS and higher-level software involvement. Firmware First covers correctable errors, uncorrectable errors, and gives firmware the ability to collect error data and diagnose faults even when the system processors have limited functionality. Firmware First enables many platform specific actions for faults including predictive fault analysis for system memory, CPU, I/O, and interconnect.

RAS differentiators

While features such as hot-swap N+1 power supplies and single-/multi-bit memory error correction have become common in the industry, a number of RAS differentiators set HPE Superdome Flex servers apart from other industry-standard servers. HPE Superdome Flex servers offer several types of RAS differentiators:

- Self-healing capabilities
- Processor RAS
- Memory RAS
- Platform RAS
- Application RAS
- OS RAS

Self-healing

When faults do occur, HPE Superdome Flex provides several mechanisms to react so that unplanned downtime is avoided. Primary means of downtime avoidance include disabling failed or failing components during boot and attempting recovery on failed or failing components during run time. Taking failed or failing hardware offline allows the system to remain running with healthy hardware until the system can be serviced. Such self-healing capabilities avoid unplanned system downtime.

Deconfiguration of failed or failing components

HPE Superdome Flex provides the ability to deconfigure components so that any single hardware fault can be tolerated.

- Memory DIMM, I/O slot, and CPU core deconfiguration: Reactive and predictive fault analysis allows for deconfiguration of failed or failing memory DIMMs, I/O slots, and CPU cores so that the system can remain available with only healthy memory DIMMs and CPU cores in use.
- On a reboot, failed memory may be repaired using spare cells in the DRAM. This Post package repair technology is supported on HPE Superdome Flex.

Run-time deactivation of components before failure

Faults in many areas of HPE Superdome Flex servers result in run-time deactivation of resources to avoid continued usage of failing components. This level of self-healing provides zero system downtime and allows for repair actions at the next planned downtime event. System interconnects and the memory subsystem provide self-healing capabilities with deactivation of failing resources when needed:

- HPE Superdome Flex Grid link self-healing with link width reduction, online port deactivation, and alternate routing for fabric connections
- Adaptive double device data correction (ADDDC) to tolerate two failed devices on a DIMM
- MEMlog™ memory capability for high-performance applications

Processor RAS

HPE Superdome Flex servers use the Intel Xeon Scalable processors. These processors include extensive capabilities for detecting, correcting, and reporting hard and soft errors. Since these RAS capabilities require firmware support from the platform, they are often not supported in other industry-standard servers. HPE Superdome Flex implements RAS functionality provided in Xeon Scalable series processors including:

- Corrupt data containment
- PCIe Live Error Recovery containment
- Poison error containment
- Processor interconnect fault resiliency
- Advanced MCA recovery
- Socket disable and deconfiguration
- Enhanced UPI error reporting
- HPE Address Range Scrub

Corrupt data containment

HPE Superdome Flex servers with Intel Xeon Scalable processors enable corrupt data containment mode that provides the detection and possible recovery of uncorrectable errors. When corrupt data containment mode is enabled, the producer of the uncorrected data will not signal a Machine Check Exception. Instead, the corrupted data is flagged with an error containment bit. Once the consumer of the data receives the data with the error containment bit set, the error is signaled and handled by firmware and the operating system. Several recovery flows are possible including uncorrected no action (UCNA), software recovery action optional (SRAO), and software recovery action required (SRAR). The mission-critical HPE Superdome Flex infrastructure and the x86 operating environment support all of these Corrupt Data error flows and provide end-to-end hardware, firmware, or software error recovery where possible.

PCIe Live Error Recovery containment

Uncorrectable errors in a server's PCIe subsystem can potentially propagate to other components, resulting in a crash of the partition—if not the entire server. To minimize this risk in HPE Superdome Flex servers, HPE implemented specific firmware features leveraging Intel's Live Error Recovery (LER) mechanism that provides a means of trapping errors at a root port to prevent error propagation. LER containment allows the platform to detect a subset of Advanced Error Reporting (AER) and proprietary-based PCIe errors in the inbound and outbound PCIe path. When a PCIe error occurs, LER is able to contain the error by stopping I/O transfers to avoid corrupted data from reaching the network and/or permanent storage. LER containment also avoids the propagation of the error and an immediate crash of the machine. In parallel of this error containment, HPE firmware is informed and in turn, the OS and upper layer device drivers are made aware of the error. HPE contribution to the enhancement of the Advanced Error Reporting PCIe implementation allows Linux to better report the details of such errors in the Linux syslog files as well as cooperating with device drivers to resume from recoverable PCIe errors. This innovative solution for Live Error Recovery on HPE Superdome Flex is not available on typical Xeon processor-based systems.

Poison error containment

HPE Superdome Flex servers further expand protection of customer data from corruption by tagging poison data in the processor and scalable server chipset. Poison data is prevented from going to or from I/O. Poison data can be read speculatively, but never consumed. Poison data will never be used by the processor or I/O.

Processor interconnect fault resiliency

All processor interconnects, including UPI, Memory Interconnect, and PCIe, have extensive cyclic redundancy checks (CRCs) to correct data communication errors on the respective busses. They also have self-healing mechanisms that allow for continued operation through a hard failure such as a failed link.

PCIe links also support width reduction and bandwidth reduction when full width or full speed operation is not possible.

Advanced MCA recovery

Advanced MCA recovery is a technology that is a combination of processor, firmware, and operating system features. The technology allows for errors that can't be corrected within the hardware alone to be optionally recovered by the operating system. Without MCA recovery, the system would be forced into a crash. With MCA recovery, the operating system examines the error, determines if it is contained to an application, a thread, or an OS instance. The OS then determines how it wants to react to that error.

Intel Xeon Scalable processors expand upon previous Xeon E7 processor capabilities for advanced error recovery. Intel Xeon Scalable processors provide the ability to recover from uncorrectable memory errors in the instruction and data execution path (software recovery action required [SRAR]) in addition to handling nonexecution path uncorrectable memory errors (software recovery action optional [SRAO]). In expanding E7 processor memory error recovery including SAP HANA application recovery (Intel, 2011), HPE has done extensive development and testing of execution path recovery.

When certain uncorrectable errors are detected, the processor interrupts the OS or virtual machine and passes the address of the error to it. The OS resets the error condition and marks the defective location as bad, so it will not be used again and continues operation.

Socket disable and deconfiguration

During run time, if there is a CPU socket failure, the partition will log errors and crash. The Analysis Engine detects a socket error indication, a service notification will be sent to Insight Remote Support along with the CPU physical location. The system should reboot and come back up after system logs are collected.

If a CPU fails during boot time, BIOS will call it out, and a service notification gets sent to IRS. BIOS disables the CPU group containing the faulty socket. A CPU group can be two sockets or four sockets depending on the CPU type. The rest of the chassis in the partition will continue booting up and be part of the partition.

Memory RAS

Main memory failures have been a significant cause of hardware downtime. HPE Superdome Flex servers use several technologies for enhancing the reliability of memory such as proactive memory scrubbing and adaptive double device data correction (ADDDC).
HPE Superdome Flex adds support for Post Package Repair to spare and replace defective portions of DRAMs. Additionally, HPE Memory DIMMs are qualified to provide both performance and quality. HPC applications may take advantage of the MEMlog memory RAS handling.

Proactive memory scrubbing

To better protect memory, HPE Superdome Flex implements a memory patrol scrubber. The memory scrubber actively scans through memory looking for errors. When an error is discovered, the scrubber rewrites the correct data back into memory. This scrubbing, combined with ECC, prevents multi-bit, transient errors from accumulating. However, if the error is persistent, then the memory is still at risk for multi-bit errors. Accumulated memory DIMM errors can result in multi-bit errors that cannot be corrected and can result in data corruption. Proactive memory scrubbing is a hardware function included in HPE Superdome Flex servers that finds memory errors before they accumulate.

Data correction

The industry standard for memory protection is single error correction and double error detection (SECDED) of data errors. Additionally, many servers on the market provide single device data correction also known as chip sparing or chipkill. Adaptive double device data correction (ADDDC) in HPE Superdome Flex servers further improves memory protection, above and beyond the protection offered by these standard methods.

ADDDC technology determines when the first DRAM in a rank has failed, corrects the data, and maps that DRAM out of use by moving its data to spare bits in the rank. Once this is done, Single device data correction is still available for the corrected rank. Thus, a total of two entire DRAMs in a rank of dual in-line memory modules (DIMMs) can fail and the memory is still protected with ECC. This amounts to the system essentially being tolerant of a DRAM failure on every DIMM. After two DRAMs have failed, the memory contents are at risk. The firmware will initiate an OS shutdown to prevent data corruption.

ADDDC drastically improves system uptime, as fewer failed DIMMs need to be replaced. This technology delivers up to a 17x improvement in the number of DIMM replacements versus those systems that use only Single-chip sparing technologies. Furthermore, ADDDC significantly reduces the chances of memory-related crashes compared to systems that only have Single-chip sparing capabilities.

Although ADDDC is based upon an Intel Xeon processor E7 processor feature, HPE Superdome Flex has enhanced the feature with specific firmware and hardware algorithms. ADDDC provides a memory RAS improvement over Intel base code and reduces memory outage rates by 33% to 95% over standard x86 offerings.

New memory RAS introduced with Intel Xeon Scalable processors

Intel Xeon Scalable processors and their DDR4 memory subsystem provide a new memory RAS feature and retain two memory RAS features not available in previous E7 versions. These features are:

- **Multiple Rank Sparing**

  Failures may span DRAM ranks. This feature provides the ability to move data from a faulty rank. This is a new feature for ADDDC over DDDC.

- **DRAM Bank Sparing**

  To better target the most likely memory failure modes at the DRAM level, DRAM Bank Sparing provides the ability to move data away from a faulty bank. DRAM Bank Sparing is automatically enabled as part of ADDDC and provides up to 33% more error resiliency compared to E7 v2 enhanced DDDC.

- **DDR4 Command/Address Parity Error Retry**

  DDR4 Command/Address bus is parity protected and the E7 v4 and v3 integrated memory controller and memory buffer provide detection and logging of parity errors. In previous E7 platforms, all Command/Address bus parity errors were fatal events, which caused an OS crash. Command/Address Parity Error Retry, ADDDC provides resiliency to errors across all memory interfaces and components.

Persistent memory RAS

HPE Superdome Flex supports Intel Optane Persistent Memory 100 series for HPE, available in 128, 256, and 512 GB capacities in the App Direct mode. HPE extends the system RAS capability with Analysis Engine support for reporting of controller failures, data failures, thermal conditions, and unsafe shutdown support.

HPE has enhanced the Address Range Scrub reporting capabilities of HPE Superdome Flex with persistent memory[1] to reduce boot and system delays. The HPE Superdome Flex system keeps track of bad address locations and reports them to the operating system instead of requesting them from the persistent memory. This is an enhancement over system calls to the persistent memory DIMMs.

The persistent memory modules implement the patrol scrubber and ADDDC using the microcontroller on the DIMM. This maintains the integrity of the data much longer than processor-based patrol scrubbers. HPE provides health indications when the persistent memory modules begin to show signs of wear. The Analysis Engine monitors media failures on the persistent memory modules and a warning is sent out by the Analysis Engine before an end-of-life persistent memory module failure, so that it can be proactively replaced.

Data can be queued in the persistent memory module when a power failure occurs. The system provides a mechanism to attempt to write all of the data prior by signaling the problem and maintaining power to the persistent memory module long enough for the write. The Analysis Engine reports power fluctuations or unsafe shutdowns that can occur in the system.

In the event of the persistent memory microcontroller failure, whether on boot, on power-up, complete failure, communication failures or over temperature conditions, the Analysis Engine logs and reports all of these errors for a fix, firmware upgrade or replacement.

Finally, thermal events can lead to persistent memory module failure or loss of data. The Analysis Engine monitors thermal events and reports those so that appropriate action can be taken.

Platform RAS

HPE Superdome Flex offers built-in RAS features, including System Fabric RAS and Fault-Tolerant RAS.

System Fabric RAS

HPE Superdome Flex Grid is a new and improved interconnect scheme, providing a flexible solution with adaptive routing capabilities. The system not only routes traffic down the optimal latency path for performance reasons, but also provides the ability to route traffic around failed component in the Grid and continue running in the event of most fabric failures. HPE's innovative scalable enterprise system chipset includes extensive self-healing, error-detection, and error correction capabilities.

Designed with the goal of achieving a fault-tolerant fabric

HPE Superdome Flex Grid has been designed to achieve fault-tolerant fabric resiliency. The basics of the fabric are high-bandwidth links providing multiple paths and a packet-based transport layer that guarantees delivery of packets through the fabric. The physical links contain adaptive routing features to dynamically route traffic around failed components without requiring downtime. Strong CRCs are used to guarantee data integrity. The cabled fabric interconnect itself has no active components to fail, and it is conceivable that cables themselves may be serviceable in the future, including replacement and link re-activation without an HPE nPar reboot.

Partitioning and error isolation

Resiliency is a prerequisite for true hard partitions. HPE nPars are hard partition technology providing complete workload isolation, enabling you to configure a multichassis server complex as one large server or as multiple, smaller, independent servers. Each HPE nPar has its own independent processors, memory, and I/O resources of the chassis that make up the partition. If the HPE Superdome Flex Grid is cabled appropriately, resources may be removed from one partition and added to another by using commands that are part of the system management interface, without having to manipulate the hardware physically. HPE nPars offer optimal performance with a recabling for up to 16 socket nPars.

Many systems use a shared backplane, where all blades are competing for the same electrical resources, and this raises the potential for a number of shared failure modes. For example, high queuing delays and saturation of shared crossbar resources may limit performance scaling, or enclosure power failures in systems with shared power may cause multiple partitions to fail at the same time. On HPE Superdome Flex system, subsystems are directly connected via cables, and each chassis provides its own bulk power conversion for a more flexible, reliable, and scalable system.

Application-level RAS

HPE Serviceguard for Linux (SGLX) monitors the availability and accessibility of your critical IT services including databases, standard applications, and custom applications. Those applications—and everything they rely upon to do their job—are meticulously monitored for any fault in hardware, software, operating system, virtualization, storage, or network. When a failure or threshold violation is detected, HPE SGLX automatically and transparently resumes your normal operations in mere seconds by restarting the service in the right way and in the right place to enable improved performance.

[1] Further references to "persistent memory" in this white paper refer to Intel Optane Persistent Memory 100 series for HPE

Furthermore, you can extend the comprehensive protection of HPE Serviceguard for Linux beyond the walls of your data center. HPE Serviceguard Metrocluster for Linux and HPE Serviceguard Continental clusters for Linux offer robust recovery mechanisms for geographically dispersed clusters and enable your business to remain online even after a catastrophic event with disaster recovery solutions.

For more details on HPE Serviceguard for Linux high-availability and disaster recovery clustering solution, visit this hpe.com/us/en/product-catalog/detail/pip.hpe-serviceguard-for-linux.376220.html.

OS-level RAS

Mission-critical HPE Superdome Flex environment provides an unparalleled set of features to detect and recover from faults. Many years of collaboration between the processor, firmware, OS, and application design teams has led to the delivery of several advanced error-recovery capabilities. Specifics of OS error recovery for memory and PCIe faults are described in the RAS differentiators section.

RAS feature summary

Chassis-level features

- Firmware First error handling
- Redundant, hot-swappable power supplies (N+N or N+1) and fans
- HPE Superdome Flex Grid link failover, link-level retry, dynamic link tuning, and bandwidth negotiation
- Adaptive routing finds bad fabric links and routes traffic around failures
- Cyclic redundancy check (CRC) protection per micro-packet and fast retry for transient errors
- Systemic transient errors, triggering retry or recovery attempt
- HPE Superdome Flex Grid link failover
- Racking error reporting
- Socket disable at boot subject to limitations
- Chassis deconfigure at boot
- HPE nPars

Processor coverage

- EMCA2 architecture and recovery
- Integer pipeline or instruction pipeline retry capability
- Error-correcting code (ECC) coverage on all internal caches and cache tags
- Register or TLB parity protection
- Improved error (viral) containment, aiding system survivability
- UPI link-level retry, restart, or recalibrate
- UPI rolling CRC check for transient errors
- Core disable, indictment and deconfiguration at boot time and core-level corrupt data containment
- Data containment (Poison)

Memory features

- Proactive memory (patrol and demand) scrubbing
- Adaptive DDDC for mission-critical and HPC needs
- Address or Command parity error resiliency
- DIMM indictment and deconfiguration
- Memory error logging or history in management firmware
- OS-level page deallocation with MEMlog
- Memory error storm response
- DRAM post package repair
- Rank and bank sparing

I/O capabilities

- PCIe Live Error Recovery (LER); PCIe root port containment and card error recovery
- PCIe Stop and Scream; PCIe root port corrupt data containment
- PCIe end-to-end CRC checking
- PCIe corrupt data containment (data poisoning)
- PCIe link CRC error check and retry
- PCIe link retraining and recovery
- Root port and card-level deconfigure

Management

- Analysis Engine
- Onboard analyzer
- Virtual KVM
- IRS and HPE Proactive Care support
- HPE SUM
- HPE OneView
- Onboard error logging services

HPE Superdome Flex: key areas of RAS superiority over standard x86

- Firmware First
- Automatic error logging
- Auto self-healing (Analysis Engine)
- Disabling and deconfiguration of failed FRUs
- Onboard fault analyzer
- Automatic restart
- Advanced processor error handling (EMCA2)
- Advanced memory resiliency (ADDDC)
- Memory error storm response
- Enhanced fabric resiliency (Flex Grid adaptive routing)
- Advanced PCIe error recovery (LER)
- Hard partitions (HPE nPars)

MANAGEMENT

HPE Superdome Flex offers extensive management capabilities through both built-in management capabilities and additional management resources.

Built-in management capabilities

HPE Superdome Flex management offers the following built-in management components:

- HPE Superdome Flex Rack Management Controller
- HPE Superdome Flex BMC

HPE Superdome Flex Rack Management Controller (RMC or eRMC)

The main component in the management subsystem is the Rack Management Controller (RMC), which connects to all the system chassis via a physically secure private LAN (see Figure 8, for N chassis system). Also, each chassis is managed by a Baseboard Management Controller (BMC), which configures and manages the hardware in that chassis as well as providing vMedia and vKVM features.

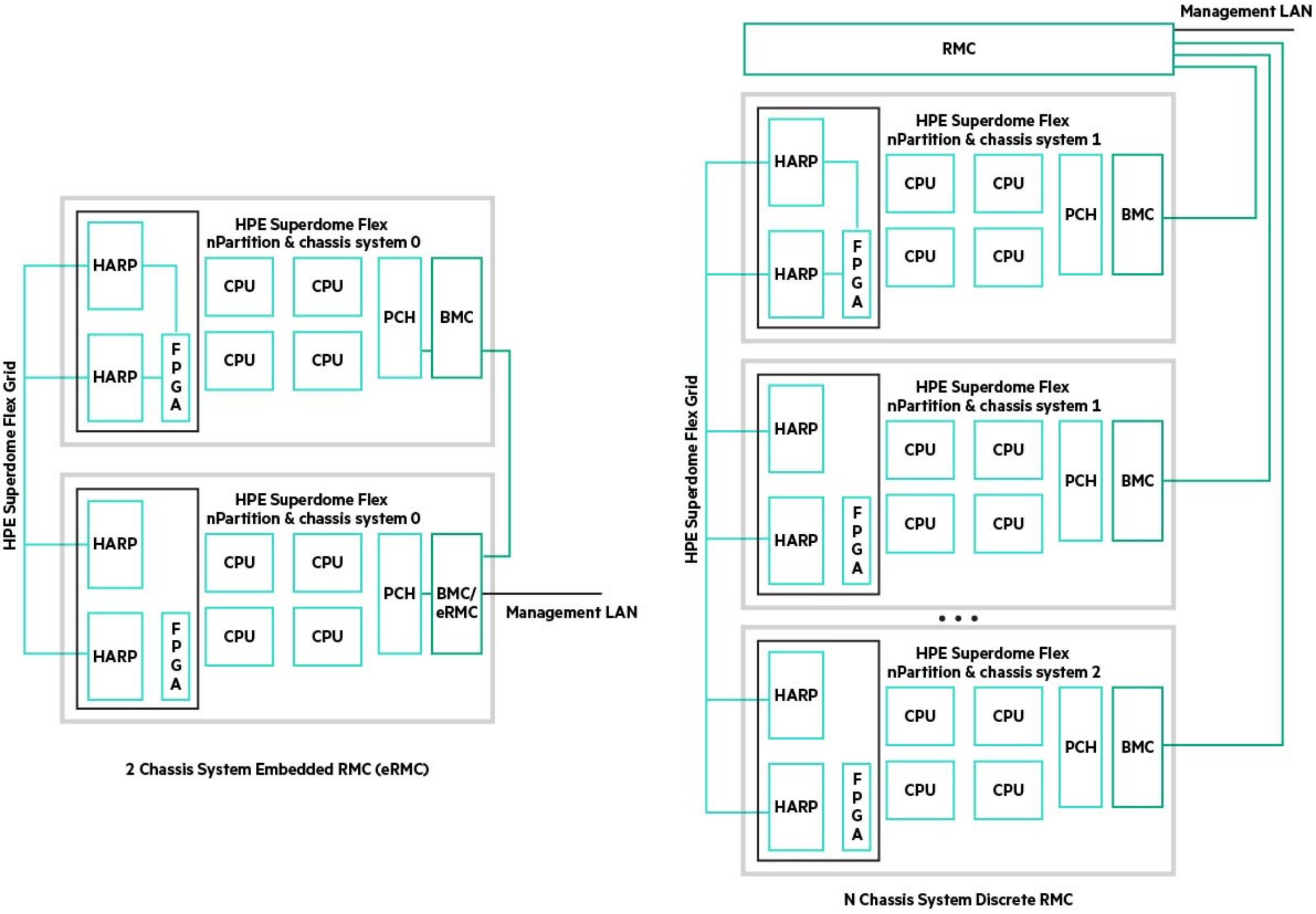

Management LAN
RMC
HPE Superdome Flex Grid
HPE Superdome Flex nPartition & chassis system 0
HARP
HARP
FPGA
CPU
CPU
CPU
CPU
PCH
BMC
BMC/ eRMC
Management LAN
2 Chassis System Embedded RMC (eRMC)
HPE Superdome Flex nPartition & chassis system 1
HPE Superdome Flex nPartition & chassis system 2
• • •
N Chassis System Discrete RMC

FIGURE 8. Rack Management Controller (RMC) options

There is an option for one and two chassis configurations of HPE Superdome Flex to run the RMC functionality on one of the BMC management processors, connecting the two chassis together. This is called the embedded RMC or eRMC configuration. Functionality is identical to the larger configuration, but the extra 1U RMC appliance is not needed. For three or more chassis, or if there are plans to grow to that scale, use the RMC appliance.

HPE Superdome Flex RMC provides the following key features:

- Analysis Engine
- Firmware manager
- Partition management
- SSH-based command-line interface
- A console for each HPE nPar
- Redfish interface

The Analysis Engine is constantly analyzing all hardware for faults. Based on detected errors and events, the Analysis Engine can predict failures and initiate automatic recovery actions as well as notifications to administrators and to HPE OneView Remote Support or to HPE Insight Remote Support.

Onboard Firmware Manager can scan a partition and report components with incompatible firmware versions. Mismatched firmware (due to parts replacements or system upgrades) of a single HPE nPars or an entire HPE Superdome Flex can have firmware updated to a consistent level with just a click of a button. Partitions with consistent firmware levels are fully validated for the most reliable operation by the system developers. HPE Superdome Flex firmware is managed as one version of **complex firmware**, which includes a version of HPE nPar firmware, similar to server BIOS. The complex firmware is all the infrastructure components of the enclosure including the RMC, the BMCs, FPGAs, and CPLDs in the hardware, and BIOS images for the system. Having a single installation and version that is upgradable greatly simplifies firmware management and enhances platform reliability.

Partition management is implemented entirely in firmware. There are no dependencies on additional software tools and no need for an external management station or special hypervisor to build your desired partition configuration. The result is faster and easier partition configuration and partition start or stop. HPE nPars are fully electrically isolated from each other and run independently. All are controlled and monitored from the RMC.

The RMC SSH-based command-line interface provides access to all capabilities of the RMC, Analysis Engine logs, system control, as well as access to the console for each HPE nPar in the system.

The Redfish interface from the RMC enables the system to be managed by both HPE tools as well as being easy to script for using simple Python, curl, or other methods, in a secure, modern RESTful interface over https. Because HPE has been working with the industry on the Redfish standard from its inception, the standard already supports large, partitionable systems managed by a single aggregated controller like HPE Superdome Flex RMC. Therefore, the ability to present and control a system with many chassis, multiple HPE nPars, and more, is all comprehended by the standard, making it easier to integrate with software such as OpenStack.

HPE Superdome Flex BMC

Each chassis is managed by a Baseboard Management Controller (BMC), which configures and manages the hardware in that chassis as well as providing virtual media and virtual keyboard, video, or mouse (KVM) features. System control and inventory remains with the RMC in order to ensure coordination across HPE nPars and the entire system. The BMCs carry out instructions from the RMC and monitor each chassis independently, reporting any problems to the RMC. The virtual media (vMedia) and vKVM functions are served directly by one BMC for an HPE nPar, from the chassis that has the active Base I/O.

Additional management resources

Additional management resources such as HPE Insight Remote Support, HPE Insight Online, HPE OneView, and HPE Smart Update Manager offer efficient and comprehensive monitoring and control of the HPE Superdome Flex from virtually anywhere.

HPE Insight Remote Support

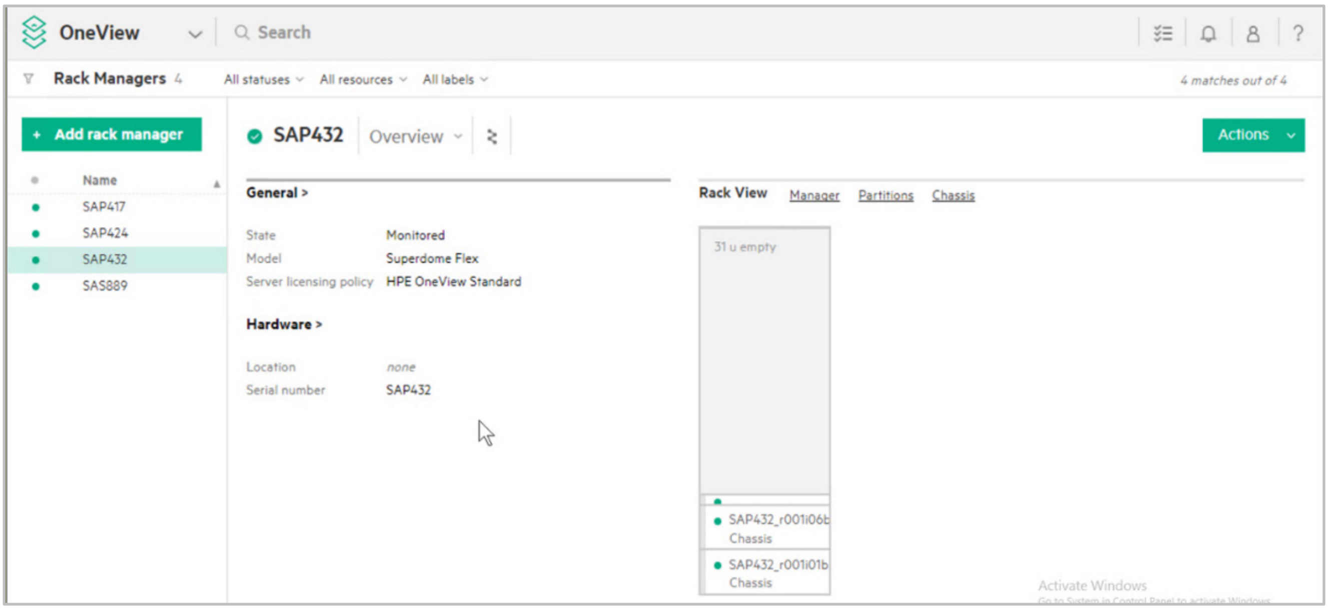
HPE Superdome Flex Analysis Engine has been upgraded to work directly with HPE Insight Remote Support. No connection to the OS LAN is required on HPE Superdome Flex for monitoring or inventory collection by Remote Support (RS). Monitoring and troubleshooting are performed entirely through the RMC, as well as inventory collection. A software package in HPE Superdome Flex Foundation Software called DCD supplements the analysis and inventory coverage of the RMC by monitoring for a few errors, such on I/O and disks that the firmware cannot detect as easily. DCD only communicates inside the system to the RMC; it does not require any configuration or connection out of the OS. The Analysis Engine utilizes all the information from DCD, the BMCs, UEFI, and other sensors throughout the system to determine if a problem has occurred or is about to occur on the system. It will send service events and periodic assessment reports to HPE Insight Remote Support, which can connect to HPE back end for automatic notification to HPE Pointnext Services of any problem with the system. Various support contract levels are available for HPE Superdome Flex. For more information, go to hpe.com/services/getconnected.

HPE Insight Online

HPE Insight Online provides one stop, secure access to the information you need to support HPE Superdome Flex with standard warranty and contract services. Through HPE Pointnext Services, HPE Insight Online can automatically display devices remotely monitored by HPE. It provides the ability to easily track service events and support cases, view device configurations and proactively monitor your HPE contracts and warranties. This allows your staff or HPE authorized services partner to be more efficient in supporting your HPE environment. What's more, they have the ability to do all this from anywhere and at any time. HPE Insight Online also provides online access to reports provided by HPE Proactive Care services. The embedded management capabilities built into HPE Superdome Flex server have been designed to seamlessly integrate with HPE Insight Online and HPE Insight Remote Support.

HPE OneView

Integration with HPE OneView provides a GUI look and feel to the HPE Superdome Flex system, including detailed inventory of its components, and the ability to receive alerts and health information for up-to-date status. HPE OneView fully monitors the HPE Superdome Flex server, including now HPE OneView Remote Support (OVRS) featuring One Click activation, pre-failure alerts, and automated case creation.



State	Monitored
Model	Superdome Flex
Server licensing policy	HPE OneView Standard
Location	none
Serial number	SAP432

FIGURE 9. HPE OneView screenshot

HPE Smart Update Manager

HPE Smart Update Manager (SUM) is HPE's firmware management and update tool for enterprise environments. It can remotely update all HPE firmware as well as firmware from other HPE products. SUM gives recommendations for firmware that needs updating and has an easy-to-use web user interface providing reporting capabilities, dependency checking, and installing updates in the correct order through CLI and/or GUI.

CONCLUSION

Through our very close association with Intel during processor development, we have been able to have HPE Superdome Flex fully exploit the performance and RAS functionality built into the CPU. Our Platinum membership of the Linux Foundation yields a high degree of kernel enablement to ensure scalability, reliability, and performance at the OS level. This results in the groundbreaking performance, robust RAS, and flexible manageability that sets HPE Superdome Flex apart as the x86 scale-up solution for mission-critical environments.

Resources

HPE Superdome Flex information
hpe.com/servers/superdomeflex

HPE Insight Remote Support
hpe.com/services/getconnected

Smart Update Manager
hpe.com/info/hpsum

LEARN MORE AT

hpe.com/superdome

**Make the right purchase decision.
Contact our presales specialists.**

Chat **Email** **Call**

Get updates

Hewlett Packard
Enterprise

a00036491ENW, May 2021, Rev. 6