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TECH NOTE

Nutanix Physical Memory Configuration

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Contents

1. Executive Summary

This document addresses the following frequently asked questions about physical memory on Nutanix appliances or nodes:

- When should I use a given number of memory modules per Nutanix node?
- How should I populate my Nutanix node with memory modules to get the best possible performance, prepare for future expansion, or achieve optimal total cost of ownership (TCO)?
- When is a Nutanix node's memory mode balanced, nearly balanced, or unbalanced?

We also discuss each of these questions in relation to the significant differences between Intel CPU families.

2. Introduction

Audience

This tech note is part of the Nutanix Solutions Library. We wrote it for anyone who wants to understand the memory performance, scalability, and speed characteristics of different Intel CPU architectures. This knowledge is important when making design decisions and recommendations for the Nutanix solution. Readers of this document should already be familiar with Nutanix NX appliances (also called nodes), physical memory, and Intel CPUs.

Purpose

In this document, we cover the following topics:

- Introduction to Nutanix physical memory configuration.
- Intel Ice Lake architecture.
- Intel Skylake and Cascade Lake architecture.
- Intel Broadwell architecture.
- Configuration examples.
- Considerations and recommendations.

Document Version History

Version Number	Published	Notes
1.0	August 2019	Original publication.
1.1	September 2020	Updated Nutanix overview.

Version Number	Published	Notes
2.0	October 2021	Updated with Ice Lake processors. Added Memory Interleaving and Ice Lake sections, updated the Configuration Example with Skylake or Cascade Lake and the Considerations and Recommendations sections, and updated the Skylake and Cascade Lake Components and the Skylake and Cascade Lake Configuration Example tables.
2.1	November 2022	Updated the Considerations and Recommendations section.

3. Nutanix Physical Memory Configuration

This document covers what you need to consider when you configure physical memory for NX appliances, also called Nutanix nodes.

Maximum memory frequency or speed and the number of available memory slots depend on the exact CPU model within the different CPU families, the kind of memory used, and type of motherboard. Here, we discuss the maximum values that NX nodes can currently support. OEM-supported platforms can have different maximum values. Check with the hardware vendor for the maximum values for your specific system.

> Note: Maximum physical memory capacity varies between the different Nutanix node types because of form factor differences and the number of Nutanix nodes per Nutanix block.

This document considers CPU configuration and performance at a very high level. For more details, refer to Intel processor documentation.

Interleaved Memory

Interleaved memory increases the memory bandwidth available for applications and lets the CPU spread memory access across DIMMs instead of limiting it to one DIMM at a time. Interleaved memory enables processes, transactions, and applications to access contiguous memory more quickly because the system doesn't need to finish one memory transaction before it starts the next.

An interleave set is the logical construct that holds the DIMMs. A balanced memory configuration only has one interleave set per CPU, and nearly balanced and unbalanced memory configurations have at least two interleave sets per CPU.

Ice Lake

The NX G8 series of Nutanix nodes uses Intel Ice Lake processors. The following figure outlines one CPU socket in the Ice Lake CPU architecture. It includes the relevant components discussed in this document.

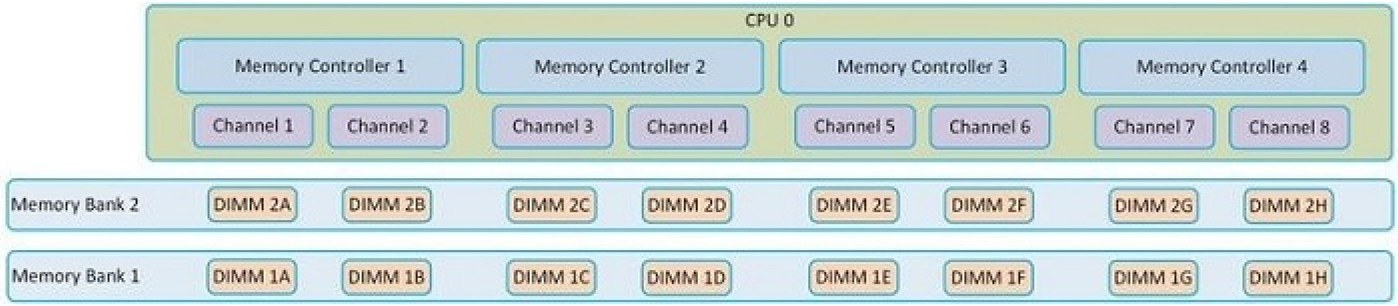

Figure 1: Ice Lake CPU Architecture

The following table provides memory information for both a single-CPU socket system and a dual-CPU socket system. The dual-CPU socket system is the most common configuration for Nutanix nodes, but specific models come with a single CPU socket.

Table: Ice Lake Components

Component	Single CPU Quantity or Speed	Dual CPU Quantity or Speed
Memory controllers	4	8
Memory channels	8	16
Memory slots per channel	2	2
Total memory slots	16	32
Memory banks	2	2
Maximum memory speed using memory bank 1*	3,200 MHz	3,200 MHz
Maximum memory speed using memory banks 1 and 2*	2,933 MHz	2,933 MHz

**Intel processor type and number of memory banks populated determine the maximum memory speed, which can be one of the following: 3,200 MHz, 2,933 MHz, or 2,667 MHz.*

Configuration Example with Ice Lake

As an example, consider a dual-CPU socket system where the customer needs 2,048 GB of memory.

For memory performance and scalability, use 16 × 128 GB memory modules, as this design populates all 16 memory slots in memory bank 1.

Based on memory module price per gigabyte, the TCO is potentially lower (and therefore optimal) when you use both memory banks—32 memory slots total—than when you use one memory bank, or 16 memory slots. Use 32 × 64 GB memory modules if you need the system to be optimized for performance and TCO.

If budget or a specific memory capacity are more important than performance, you can also achieve a nearly balanced configuration for a dual-CPU socket system with 4, 8, 12, and 24 DIMM slots populated.

The following table provides examples of memory configurations and their relation to scalability, TCO, and performance. The figures in the Number of Memory Slots Used column apply to a dual-CPU socket system.

Table: Ice Lake Configuration Example

Memory Capacity	DIMM / Memory Size	Number of Memory Slots	Scalable	TCO Optimal	Performance Optimal
1,024 GB	32 GB	32	No	Yes	Yes
1,024 GB	64 GB	16	Yes	No	Yes
1,024 GB	128 GB	8	Yes	No	No
2,048 GB	64 GB	32	No	Yes	Yes
2,048 GB	128 GB	16	Yes	No	Yes
4,096 GB	128 GB	32	No	Yes	Yes

Skylake and Cascade Lake

Nutanix uses Intel Skylake and Cascade Lake CPUs in the following node series:

- NX G6 Nutanix nodes: Skylake
- NX G7 Nutanix nodes: Cascade Lake

The following figure outlines one CPU socket in the Skylake and Cascade Lake CPU architecture. It includes the relevant components discussed in this document.

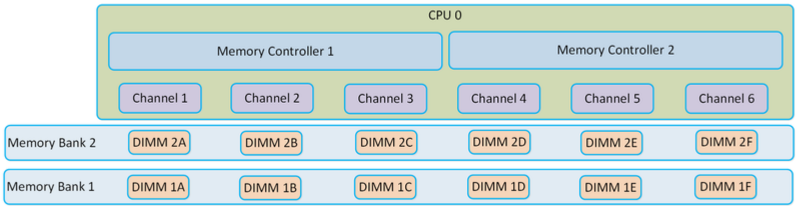

Figure 2: Skylake and Cascade Lake CPU Architecture

The following table provides memory information for both a single-CPU socket system and a dual-CPU socket system. The dual-CPU socket system is the most common configuration for Nutanix nodes, but specific models come with a single CPU socket.

Table: Skylake and Cascade Lake Components

Component	Single CPU Quantity or Speed	Dual CPU Quantity or Speed
Memory controllers	2	4
Memory channels	6	12
Memory slots per channel	2	2
Total memory slots	12	24
Memory banks	2	2
Maximum memory speed using memory bank 1*	2,933 MHz / 2,667 MHz	2,933 MHz / 2,667 MHz
Maximum memory speed using memory banks 1 and 2*	2,933 MHz / 2,666 MHz	2,933 MHz / 2,667 MHz

**Intel processor type and number of memory banks populated determine the maximum memory speed. Cascade Lake maximum memory speed is 2,933 MHz. Skylake maximum memory speed is 2,666 MHz.*

Configuration Example with Skylake or Cascade Lake

As an example, consider a dual-CPU socket system where the customer needs 512 GB of memory. You can use only 8 × 64 GB memory modules (which provide 512 GB of memory), but this configuration doesn't deliver optimal performance.

For better memory performance and future scalability, use 12 × 64 GB memory modules, as this design populates all 12 memory slots in memory bank 1 and offers 768 GB of memory.

Based on memory module price per gigabyte, the TCO is potentially lower (and therefore optimal) when you use both memory banks—24 memory slots total—than when you use one memory bank, or 12 memory slots. In addition to potentially better TCO, we've seen a slightly better performance predictability during testing when we use all memory slots. In this example the configuration is 24 × 32 GB memory modules.

If budget or a specific memory capacity are more important than performance, you can also achieve a nearly balanced configuration for a dual-CPU socket system with 6, 8, and 16 DIMM slots populated.

The following table provides examples of memory configurations and their relation to scalability, TCO, and performance. The figures in the Number of Memory Slots Used column apply to a dual-CPU socket system.

Table: Skylake and Cascade Lake Configuration Example

Memory Capacity	DIMM / Memory Size	Number of Memory Slots	Scalable	TCO Optimal	Performance Optimal
512 GB	64 GB	8	Yes	No	No
768 GB	32 GB	24	No	Yes	Yes
768 GB	64 GB	12	Yes	No	Yes
1,024 GB	64 GB	16	Yes	No	No

Memory Capacity	DIMM / Memory Size	Number of Memory Slots	Scalable	TCO Optimal	Performance Optimal
1,536 GB	64 GB	24	No	Yes	Yes
1,536 GB	128 GB	12	Yes	No	Yes

Broadwell

The NX G5 series of Nutanix nodes uses Intel Broadwell processors. The following figure outlines the Broadwell CPU architecture, representing one CPU socket. It includes the relevant components discussed in this document.

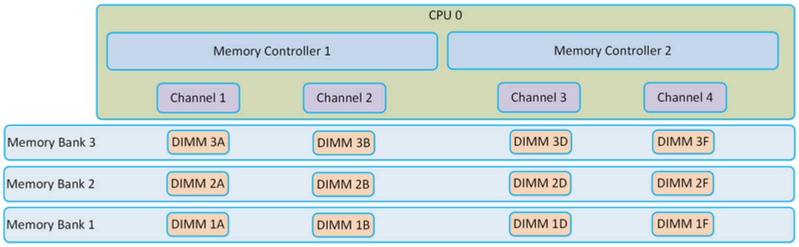

Figure 3: Broadwell CPU Architecture

The following table provides figures for both a single-CPU socket system and a dual-CPU socket system. The dual-CPU socket system is the most common configuration for Nutanix nodes, but specific models come with a single CPU socket.

Table: Broadwell Components

Component	Single CPU Quantity or Speed	Dual CPU Quantity or Speed
Memory controllers	2	4
Memory channels	4	8
Memory slots per channel	3	3
Total memory slots	12	24
Memory banks	3	3
Maximum memory speed using memory bank 1	2,400 MHz	2,400 MHz

Component	Single CPU Quantity or Speed	Dual CPU Quantity or Speed
Maximum memory speed using memory banks 1 and 2	2,400 MHz	2,400 MHz
Maximum memory speed using memory banks 1, 2, and 3	1,866 MHz	1,866 MHz

Configuration Example with Broadwell

As an example, consider a dual-CPU socket system where the customer needs 512 GB of memory.

For better memory performance and scalability, use 8 × 64 GB memory modules, as this design populates all eight memory slots in memory bank 1. You can add eight more 64 GB memory modules while keeping the same memory speed.

Based on memory module price per gigabyte, the TCO is potentially lower (and therefore optimal) when you use both memory banks—16 memory slots total—than when you use one memory bank, or 8 memory slots. Using all three memory banks—24 memory slots—provides the lowest TCO but decreases performance. The memory modules operate at 1,866 MHz in this configuration, compared to the 2,400 MHz they can achieve when memory bank 3 isn't used.

The following table provides examples of memory configurations that perform best, keeping memory speed at 2,400 MHz. The Scalable column indicates whether you can increase the memory footprint without changing memory module size. The figures in the Number of Memory Slots column apply to a dual-CPU socket system.

Table: Broadwell Configuration Example

Memory Capacity	DIMM / Memory Size	Number of Memory Slots	Scalable	TCO Optimal
256 GB	16 GB	16	No	Yes
256 GB	32 GB	8	Yes	No
512 GB	32 GB	16	No	Yes

Memory Capacity	DIMM / Memory Size	Number of Memory Slots	Scalable	TCO Optimal
512 GB	64 GB	8	Yes	No
1,024 GB	64 GB	16	No	Yes
1,024 GB	128 GB	8	Yes	No

4. Considerations and Recommendations

- Nutanix recommends balanced memory configurations:
  - Use identical CPUs.
  - Keep the memory configuration identical across CPUs.
  - Keep memory channel configuration identical.
  - Use identical DIMMs.
- The following table explains the relationship between number of DIMM slots populated, predictable performance, and maximum memory bandwidth or throughput capability for these definitions:
  - P-1.0: balanced configuration; predictable performance and maximum throughput for the given CPU.
  - P-0.n: nearly balanced configuration; predictable performance with nearly n percent throughput possible for the given CPU.
  - U: unbalanced configuration.

Table: Populated DIMM Slots, Performance, and Bandwidth or Throughput

Number of DIMMs	2	4	6	8	12	16	18	24	32
ICX*	P-0.125	P-0.25	P-0.33	P-0.50	P-0.75	P-1.0	U	P-0.66	P-1.0
SKX / CLX**	P-0.167	P-0.33	P-0.5	P-0.66	P-1.0	P-0.66	U	P-1.0	NA
BDX***	P-0.25	P-0.50	U	P-1.0	U	P-1.0	U	P-1.0^	NA

** Ice Lake*

*** Sky Lake / Cascade Lake*

**** Broadwell*

^ Reduces performance if you populate all the memory slots

- Use the following formulas to determine the number of memory modules required for different balanced memory configurations:
    - Ice Lake, optimal performance and scalability: Amount of memory required / 16. For example: 2,048 GB / 16 = 128 GB memory modules.
    - Ice Lake, optimal performance and TCO: Amount of memory required / 32. For example: 2,048 GB / 32 = 64 GB memory modules.
    - Skylake and Cascade Lake, optimal performance and scalability: Amount of memory required / 12. For example: 768 GB / 12 = 64 GB memory modules.
    - Skylake and Cascade Lake, optimal performance and TCO: Amount of memory required / 24. For example: 768 GB / 24 = 32 GB memory modules.
    - Broadwell, optimal performance and scalability: Amount of memory required / 8. For example: 512 GB / 8 = 64 GB memory modules.
    - Broadwell, optimal performance and TCO: Amount of memory required / 16. For example: 512 GB / 16 = 32 GB memory modules.
- When you populate all available memory banks, memory speed drops for all CPUs:
    - Ice Lake from 3,200 MHz to 2,933 MHz.
    - Skylake and Cascade Lake from 2,933 to 2,666 MHz.
    - Broadwell from 2,400 MHz to 1,866 MHz.
- The memory speed drop described doesn't necessarily mean lower performance for Ice Lake, Cascade Lake, or Skylake processors because using all memory slots in these CPUs provides higher bandwidth. Application characteristics and memory type factor in here.
- When you need larger memory module sizes (for example, 128 GB memory modules or support for up to 4.5 TB of memory per socket), choose a model with a compatible CPU suffix (M, L) during your selection process.

About Nutanix

Nutanix is a global leader in cloud software and a pioneer in hyperconverged infrastructure solutions, making clouds invisible and freeing customers to focus on their business outcomes. Organizations around the world use Nutanix software to leverage a single platform to manage any app at any location for their hybrid multicloud environments. Learn more at www.nutanix.com or follow us on Twitter @nutanix.

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