Thunderbolt™ 5
The Next Generation
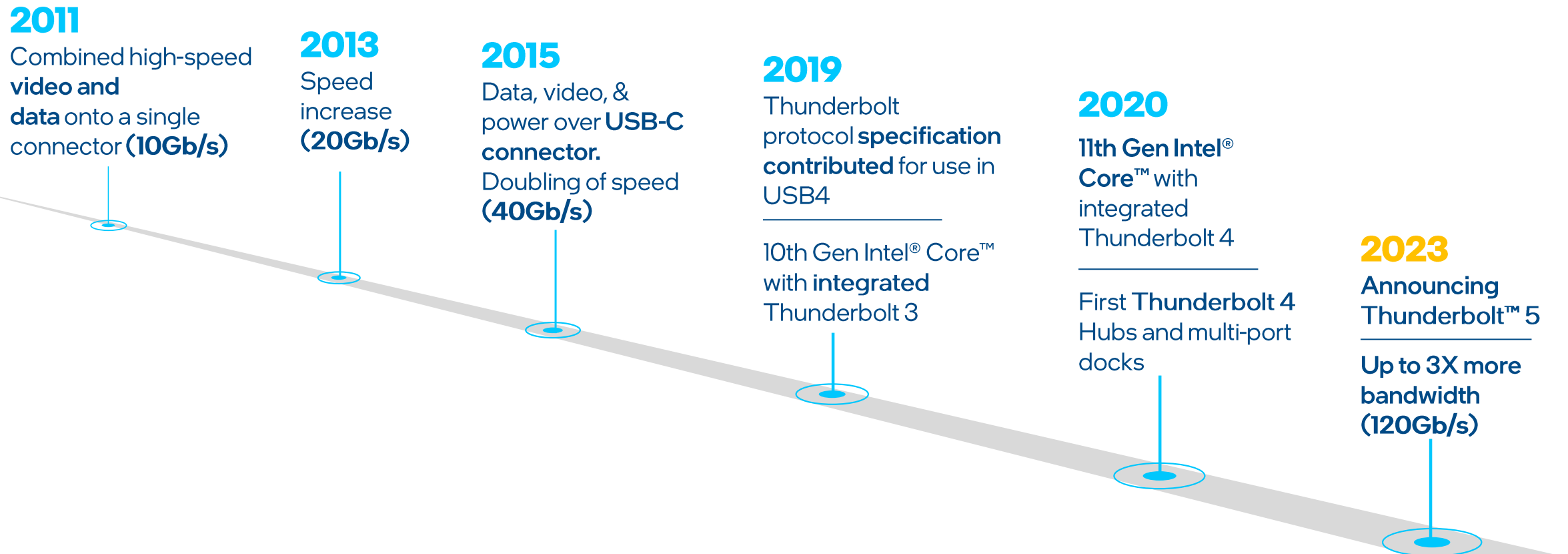
The best solution for creators and gamers
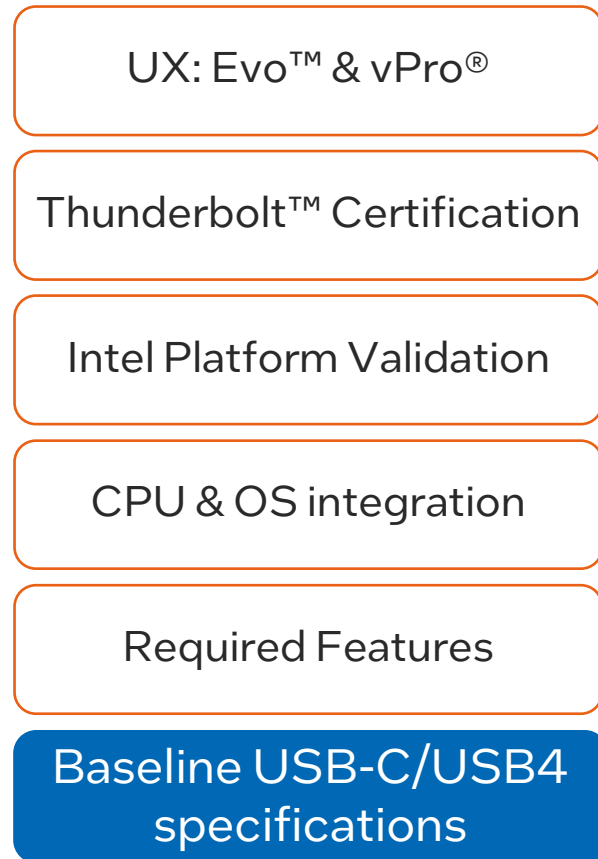
Thunderbolt™

A Timeline of Thunderbolt™ Innovation

Wired Connectivity
Vision

Simplify the connectivity experience to one connector & cable that can do it all with Thunderbolt & USB-C

2011
Combined high-speed **video and data** onto a single connector **(10Gb/s)**

2013
Speed increase **(20Gb/s)**

2015
Data, video, & power over **USB-C connector.** Doubling of speed **(40Gb/s)**

2019
Thunderbolt protocol **specification contributed** for use in USB4

10th Gen Intel® Core™ with **integrated** Thunderbolt 3

2020
11th Gen Intel® Core™ with integrated Thunderbolt 4

First **Thunderbolt 4** Hubs and multi-port docks

2023
Announcing Thunderbolt™ 5

Up to 3X more bandwidth **(120Gb/s)**

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Thunderbolt™ Delivering on USB-C Vision

One connector that does it all

UX: Evo™ & vPro®

Thunderbolt™ Certification

Intel Platform Validation

CPU & OS integration

Required Features

Baseline USB-C/USB4 specifications

	Thunderbolt™ 4	USB4*
USB Type-C	✔	✔
40 Gbps bandwidth	✔	Optional
15W power to run accessories	✔	Optional
Mandatory testing and certification	✔	Optional
2 x 4K/60Hz monitors	✔	Optional
Required PC charging on at least one computer port	✔	Optional
Universal 40 Gbps cables up to 2m	✔	Optional
Up to 4 Thunderbolt™ ports on accessories	✔	Optional
System wake from sleep	✔	Optional
Intel® VT-d based DMA protection	✔	Optional

Thunderbolt™ is the best-in-class end-to-end solution

Thunderbolt™

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Thunderbolt™ Momentum Continues

Broad adoption, support, and availability

OS support

- Broad OS support

Platform alignment

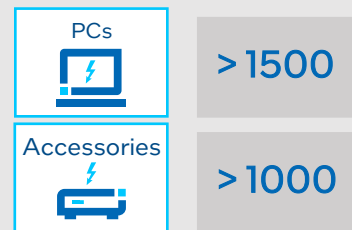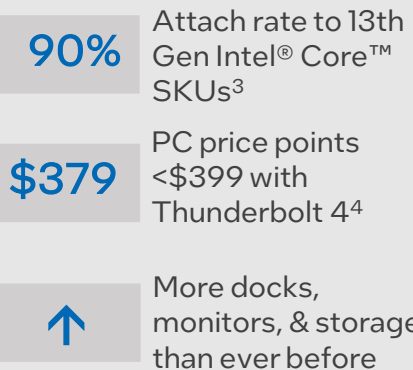- Thunderbolt 4 is required in all Intel® Evo™ and Intel® vPro® Enterprise based laptops

intel **evo** EDITION

intel **vPRO** ENTERPRISE

Rapid Growth

- Thunderbolt designs on PCs and accessories are accelerating[1,2]

Thunderbolt 3 & Thunderbolt 4

| PCs | > 1500 |
| Accessories | > 1000 |

Broadly Available

- Thunderbolt 4 based PCs & accessories are widely available

90% Attach rate to 13th Gen Intel® Core™ SKUs[3]

$379 PC price points <$399 with Thunderbolt 4[4]

↑ More docks, monitors, & storage than ever before

[1] Based on sales of Thunderbolt controllers to computer and accessory vendors.
[2] Based on number of accessories to complete Thunderbolt certification.
[3] Estimates and Projection based on Intel internal data.
[4] Based on Asus TP470EA-AS34T listed at $379.99 on Amazon.com 8.29.23
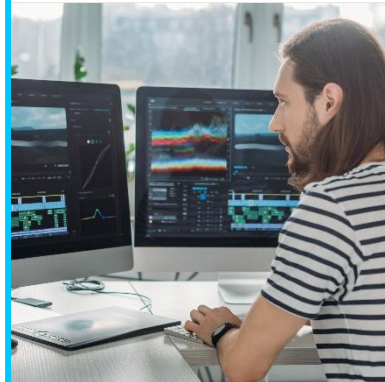
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Thunderbolt™ 5

Satisfies the increasing needs of creators and gamers

Up to 3x today's best bandwidth to keep pace with the needs of creators and gamers

Less time waiting, more time creating

- ✓ 8K HDR monitors to see every detail
- ✓ Quickly backup and archive projects
- ✓ Accelerate workflows and collaboration

Connect with community without friction

- ✓ The fastest refresh rate monitors
- ✓ Next-level SSDs for portable gaming
- ✓ Studio quality capture & streaming

New Capabilities Powered by Thunderbolt™ 5

|	Today	Tomorrow
Video	▪ Two 4K monitors ▪ Resolution vs. refresh rate tradeoffs ▪ Two 4K limited to 60Hz	▪ Multiple 8K for Creators ▪ Up to 540Hz for Gamers ▪ Three 4K @ 144Hz
Data	▪ 32Gb/s of data bandwidth ▪ Dual 4K video limits bandwidth for data	▪ 2x more bandwidth for external SSDs, eGFX, Creator tools, and more ▪ Bandwidth flexibility for better use
PC connection	▪ Second cable for charging gamer, creator PCs and workstations	▪ A single cable for more notebooks

⚡ **Thunderbolt**™

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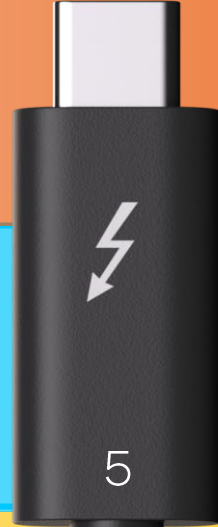
Thunderbolt™ 5 Provides Industry Leading Experience

Simplicity, reliability, and maximum performance

More accessories

THUNDERBOLT

DisplayPort → v2.1

CERTIFIED USB 80 Gbps → USB4* v2
USB3 20G

PCI EXPRESS → PCIe 4.0

Standards Based, Royalty Free

More speed

80G Bi-directional
120G Transmit

Up to 3x faster connection

More video

120G Transmit

Bandwidth Boost: the best display experience

More power

240W PC charging

15W device

Up to 2x more PC charging

*Other names and brands may be claimed as the property of others

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True-to-Life Creation, Ultra-Fast Gaming

- Ultimate display experience
- The fastest data connection
- Outstanding docking solutions

The best display experience

Up to 120 Gbps Tx bandwidth
- 3x more than Thunderbolt™ 4
- 50% more than DP 2.1

Thunderbolt™ 5 → Thunderbolt 5 →
Thunderbolt 4 → DP 2.1 →

- Dynamic display bandwidth management
- Up to three display streams

The most data bandwidth

- 2x more than today's solutions

SSD | GPU

More power

Up to 240W

Outstanding docking solutions

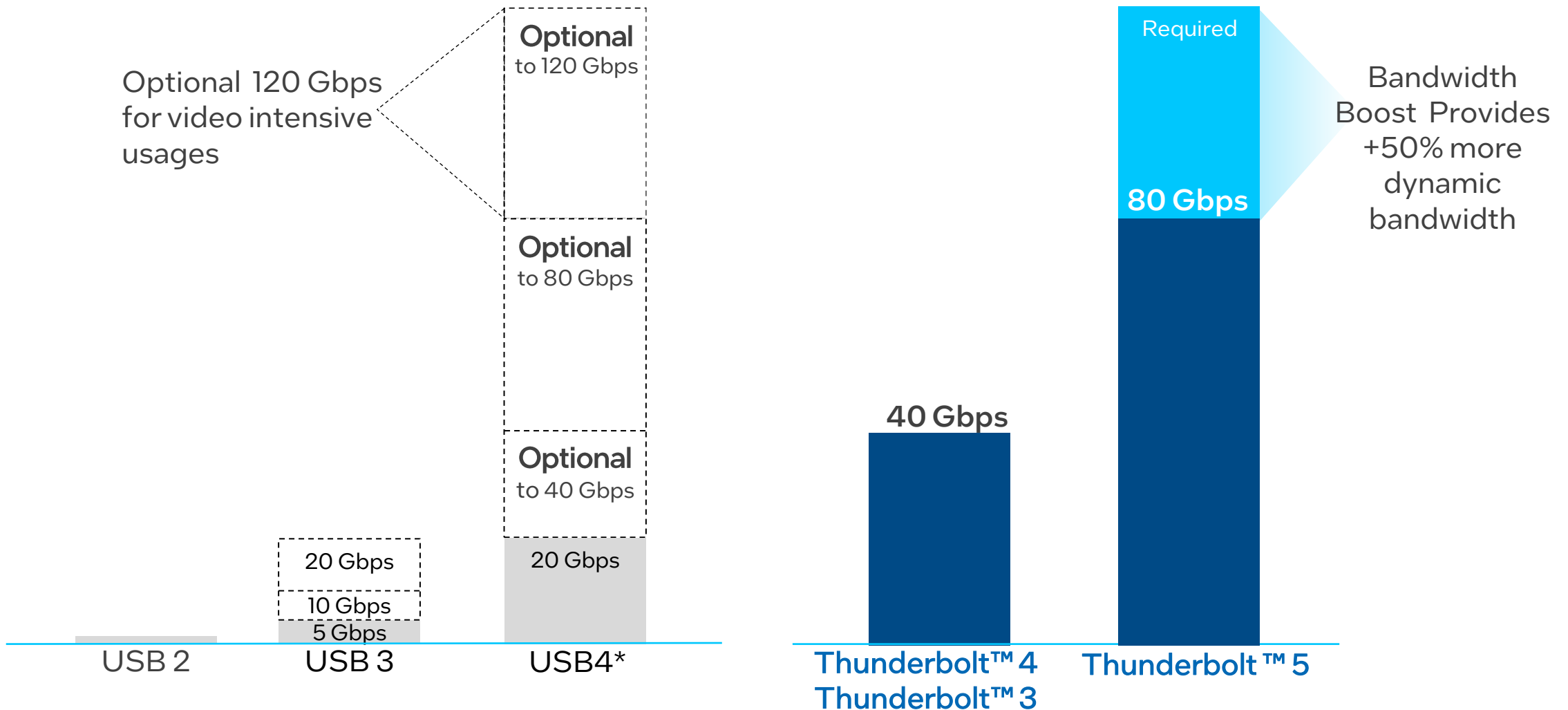| Thunderbolt™ 5 | DP 2.1 MF | 3x more bandwidth for video |
| Thunderbolt 5 | DP2.1 MF | 6x more bandwidth for data |
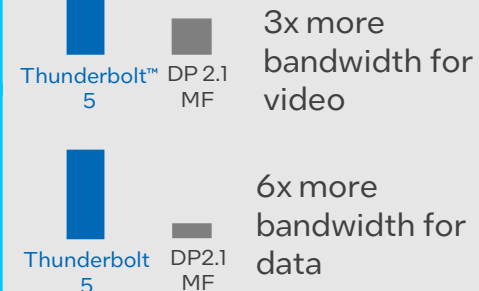
Thunderbolt™ Networking

2x the speed of Thunderbolt 4
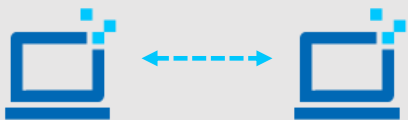
Thunderbolt™ 5 Delivers Up to 120 Gbps

The performance creators and gamers need

Optional 120 Gbps for video intensive usages

Optional to 120 Gbps

Optional to 80 Gbps

Optional to 40 Gbps

20 Gbps

20 Gbps

10 Gbps

5 Gbps

USB 2

USB 3

USB4*

120 Gbps

Required

80 Gbps

Bandwidth Boost Provides +50% more dynamic bandwidth

40 Gbps

Thunderbolt™ 4 Thunderbolt™ 3

Thunderbolt ™ 5

Thunderbolt™

Thunderbolt™ 5 Delivers Up to 120 Gbps

Bandwidth Boost for the best display experience

Bandwidth flexibility based on usage

#### Evenly distributed

80 Gbps of bandwidth in each direction

40G	→
40G	→
40G	←
40G	←

Connection provides:
- Transmit: Up to **80 Gbps**
- Receive: Up to **80 Gbps**

High speed transmitter →

High speed receiver ←

Bandwidth Boost

120 Gbps for higher display bandwidth needs

40G	→
40G	→
40G	→
40G	←

Connection provides:
- Transmit: Up to **120 Gbps**
- Receive: Up to **40 Gbps**

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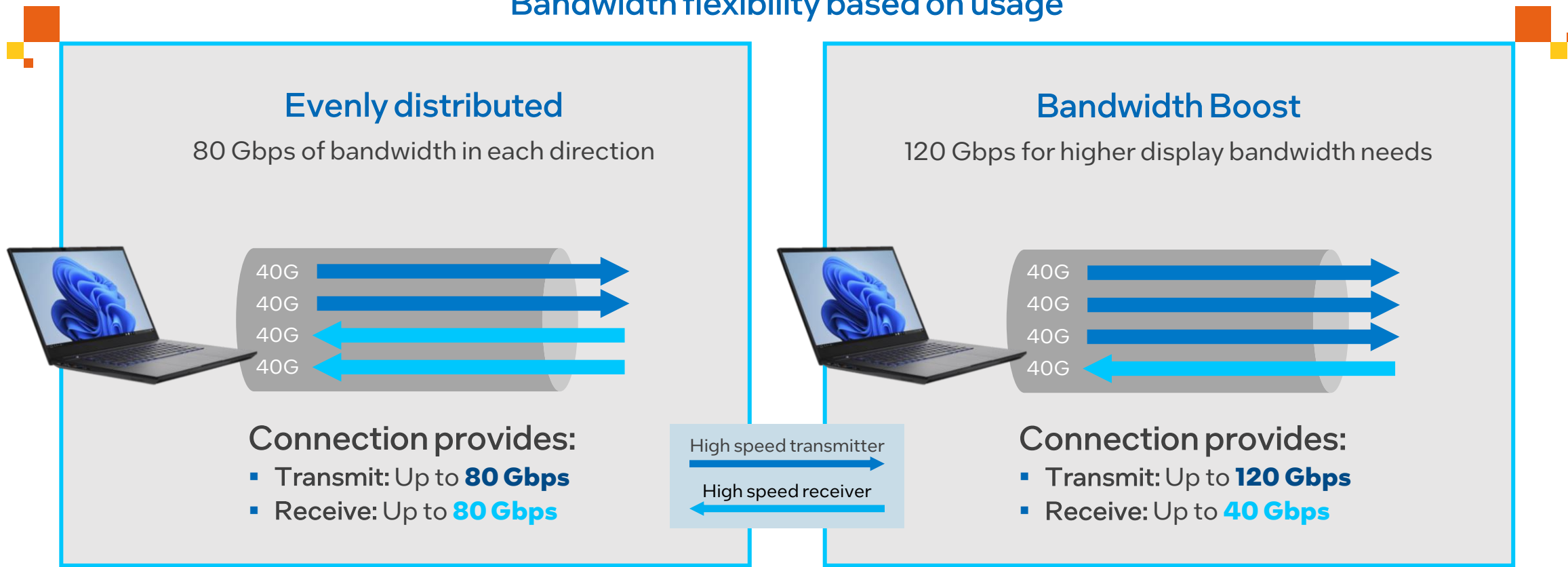
New Signaling Technology

## Delivers more speed with today's PCBs, connectors, & cables

Thunderbolt™ 5 & USB4* v2 incorporates advanced signaling technology: Pulse Amplitude Modulation with 3 Levels (PAM-3)

- Key Benefits:

  - Significant performance benefits through enabling more data per clock cycle

  - Utilize existing PCB technology, connectors, & passive cables up to 1m

PAM2
Baud-Rate: 1
Noise Margin: 1

PAM3
Baud-Rate: 0.63
Noise Margin: 0.5
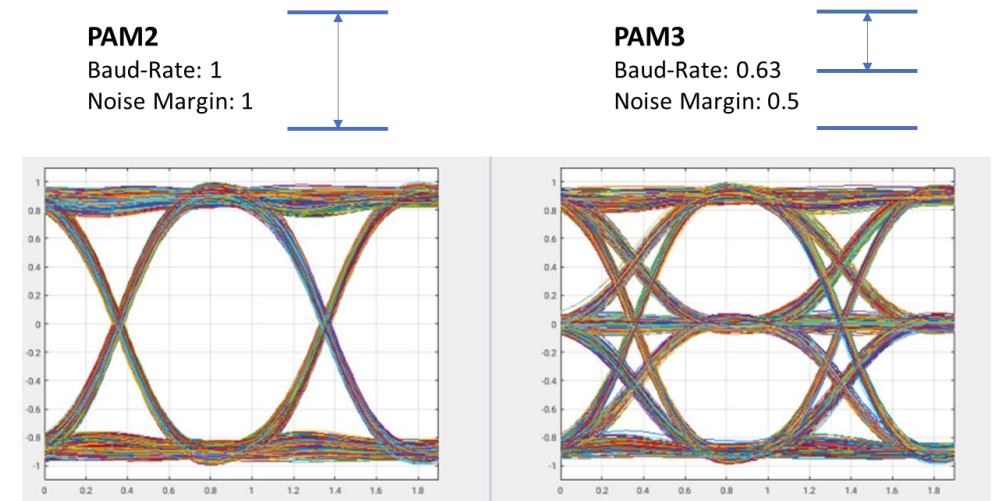
*Other names and brands may be claimed as the property of others

Thunderbolt™ 5 Will Be Broadly Compatible

Compatibility

Thunderbolt™ 5

✓ Thunderbolt 4

✓ Thunderbolt 3
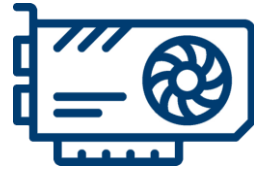
✓ USB4*

✓ USB 3

✓ DisplayPort* 2.1
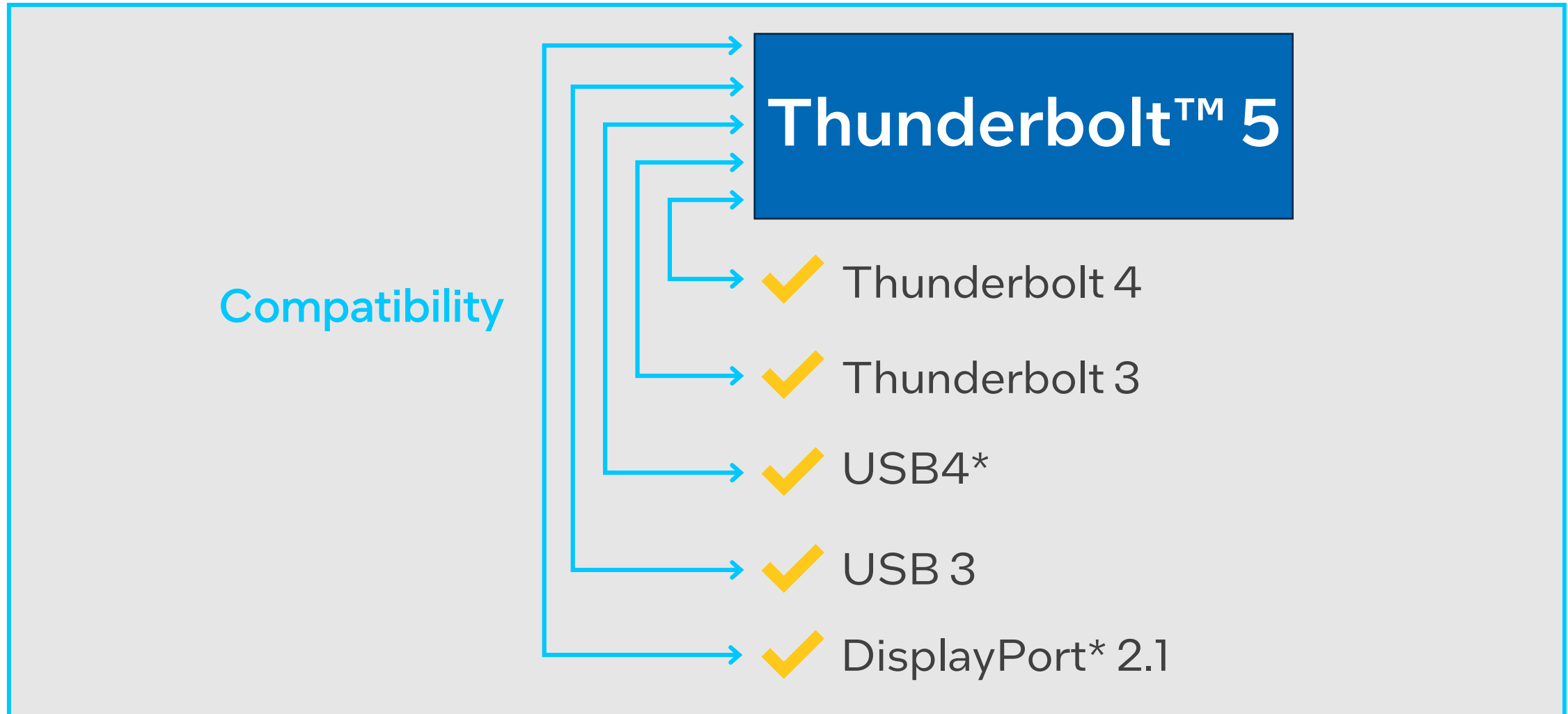
*Other names and brands may be claimed as the property of others

Thunderbolt™ Family of Accessories
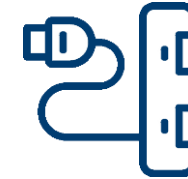## Thunderbolt™ accessories to meet your needs
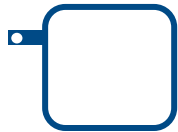
Consumer and Commercial Docks

External Graphics

Portable Storage, Enclosures

Adapters

Portable Docks

External AI Accelerator

Desktop Storage

Docking Monitors

Hubs & Compact Docks

Video Interfaces

Audio Interfaces

Monitor Stand Docks

Thunderbolt enables powerful solutions for all your productivity, creation, and gaming needs

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Extending System Architecture with Thunderbolt™

Plug and Play connection for performance boost

External Graphics

- Graphics performance boost
- Faster frame rates for Gamers
- Reduced encode, export time for Creators

External AI Accelerators

- Elevated video collaboration & audio effects
- Creator/Gaming effects
- Local AI Inferencing reduces need to reach into the cloud

More Creative, Superior Gaming, Higher Productivity, Personalized Experience

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Thunderbolt™ 5 Will Be Easy To Find
Thunderbolt brand continues to be simple

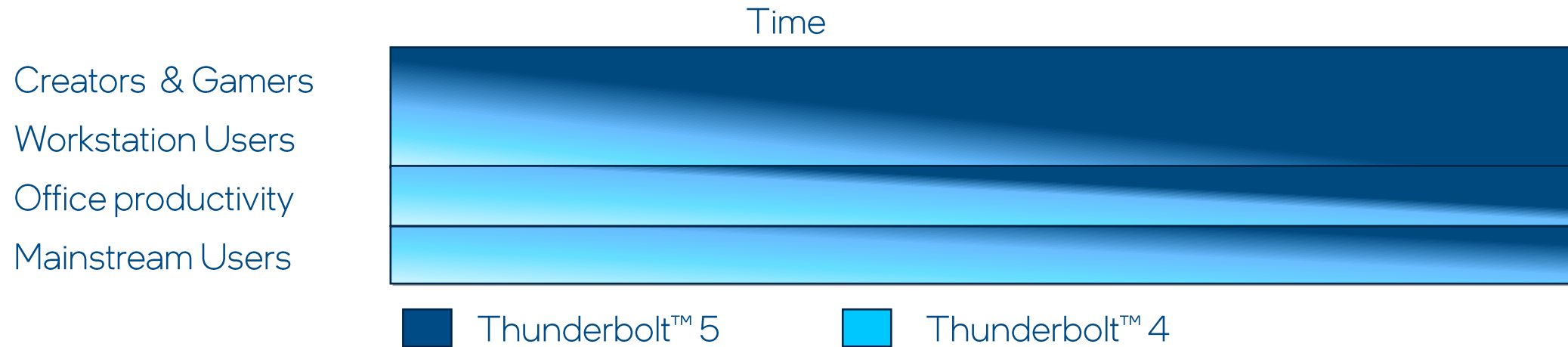| Name	Logo	Icon	Port	Cable
Thunderbolt™ 5	Thunderbolt™			

Thunderbolt™

Thunderbolt™ 5 Product Update

- Thunderbolt™ 5 will be brought to market through Intel's upcoming discrete silicon
  - Code-named "Barlow Ridge"
  - Includes controllers for computers and accessories
- Thunderbolt 5 Computers and accessories are expected to launch starting in '24
  - Prototype dock and laptop demonstrated today
- Technical collateral and development resources will be released to the Thunderbolt developers worldwide in Q4 '23

Thunderbolt™ 5 & Thunderbolt™ 4

Deliver a scalable roadmap for all users

Time

Creators & Gamers

Workstation Users

Office productivity

Mainstream Users

■ Thunderbolt™ 5   ■ Thunderbolt™ 4

- Thunderbolt™ 5 provides the industry's highest performance wired connectivity solution

- Thunderbolt™ 4 delivers the simplicity, reliability, and performance that mainstream consumer & business users require

⚡ Thunderbolt™   intel®   17

Thunderbolt™ 5 Leaps Ahead

		Thunderbolt™ 5	Thunderbolt™ 4	USB4*	USB 3/DP
Unrivaled Simplicity	One universal computer port	●	●	-	-
	Required speed for Universal cables up to 2 meters in length	120 Gbps	40 Gbps	20 Gbps	-
	Accessories with four Thunderbolt ports	●	●	-	-
Exceptional Performance	PC speed requirements	80Gbps & 120 Gbps	40 Gbps	20 Gbps	10 Gbps
	PC video requirements	Dual 6K	Dual 4K	One monitor (No Minimum BW)	One monitor (No Minimum BW)
	PC data requirements[1]	PCIe 64 Gbps USB3 – 10 Gbps	PCIe 32 Gbps USB3 –10 Gbps	- USB3 –10 Gbps	- USB3 –5 Gbps
	Required PC charging on at least one computer port	Required up to 140W available up to 240W	Required up to 100W available up to 140W	-	-
	Required PC wake from sleep when computer is connected to a Thunderbolt dock	●	●	-	-
	Minimum PC port power for accessories	15W	15W	7.5W	4.5W
	Thunderbolt Networking[1]	64 Gbps	32 Gbps	-	-
Reliable Connectivity	Mandatory certification for all shipping computers, accessories and cables	●	●	-	-
	Cable testing and cable quality audits for Thunderbolt cable manufacturers	●	●	-	-
	Required Intel® VT-d-based DMA protection	●	●	-	-
	USB4 specification	Compliant	Compliant	Compliant	Compatible

[1] Maximum theoretical bandwidth, realized performance dependent on specific HW and SW configuration
[2] Available with support for up to 20Gbps   *Other names and brands may be claimed as the property of others

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Thunderbolt™ 5 delivers 3x the speed to meet the growing needs of Content Creators and Gamers

- Intel continues to lead the industry in wired connectivity with Thunderbolt™ 5 based solutions launching in '24

- Thunderbolt™ 5 delivers 80Gbps of bi-directional bandwidth, and with Bandwidth Boost provides up to 120Gbps, 3x the capability of today's fastest solutions, for the best display and data experiences

- Built on the USB4 v2, DisplayPort 2.1, & PCI Express Gen 4 specifications, Thunderbolt™ 5 provides a standards-based solution compatible with previous versions

- Thunderbolt™ the best-in-class end-to-end solution, has achieved wide adoption in the industry

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