Memory + Interfaces

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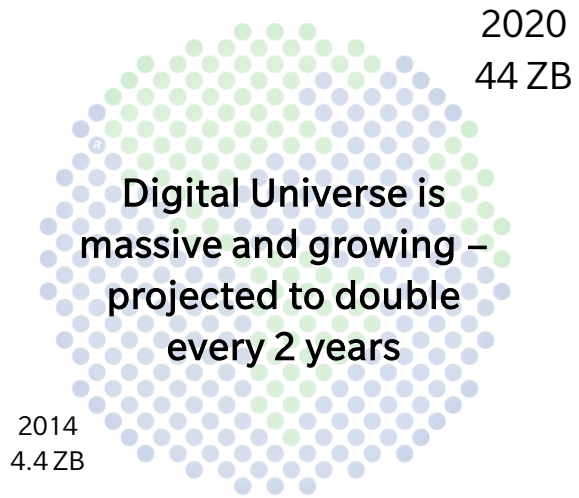
Senior Vice President and General Manager

The World's Data. Delivered.

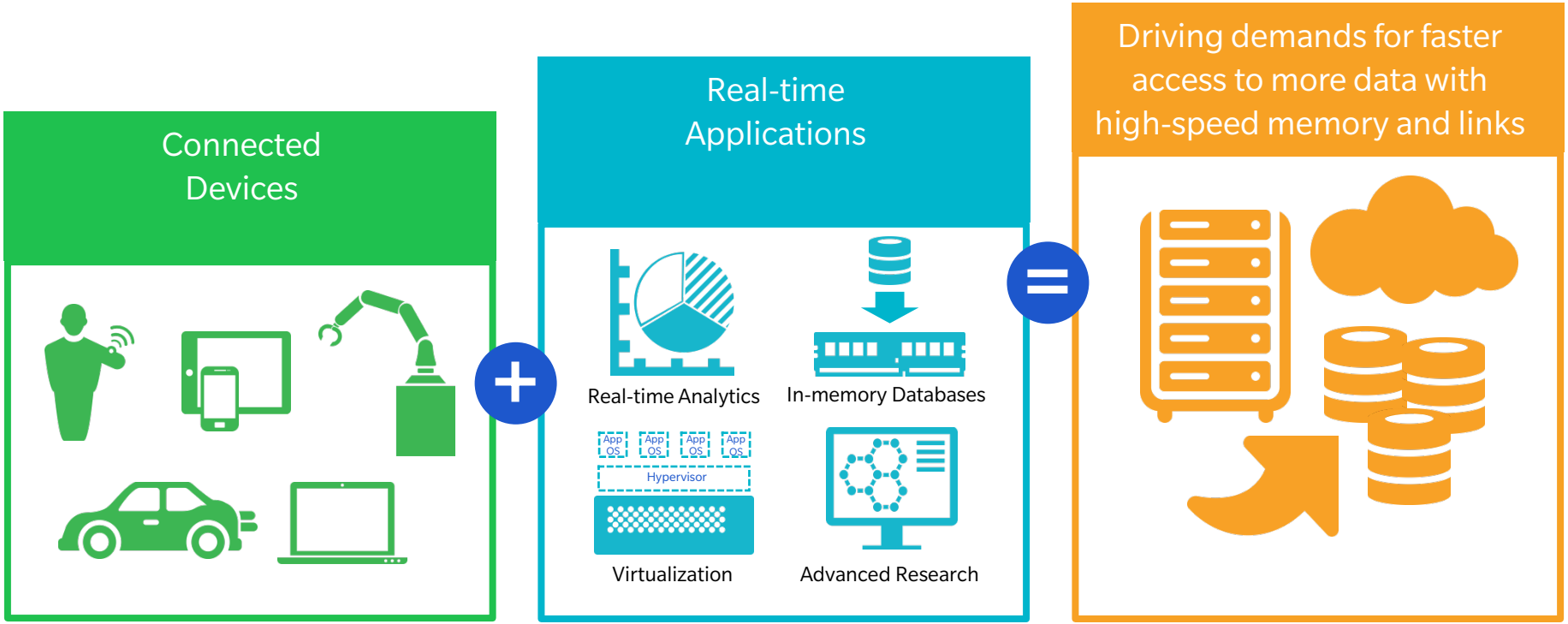


Source: IDC 2014

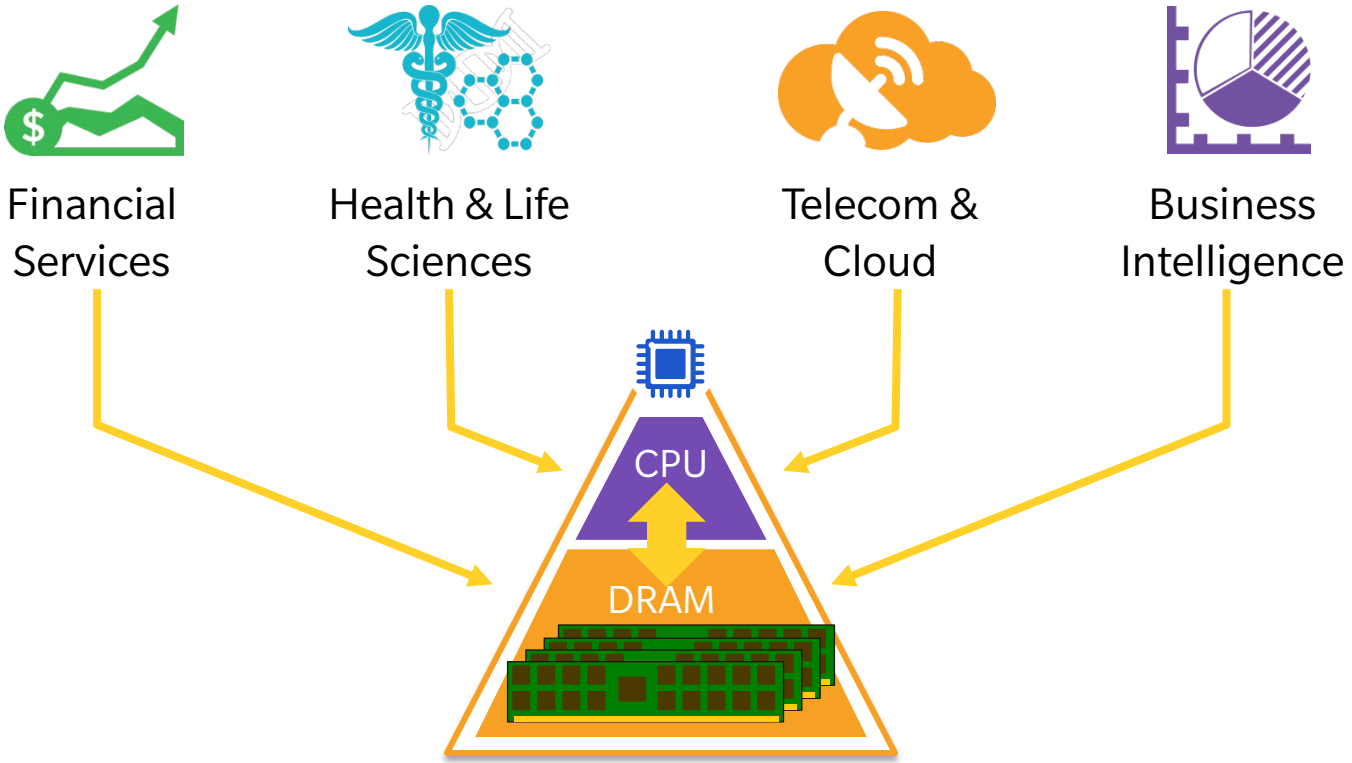
More. Faster. Better.

- Chips to enable more capacity at high-performance for enterprise and data center servers
- Interfaces to deliver data faster to chips and memory
- Innovations to make systems with better power efficiency, reliability and usability

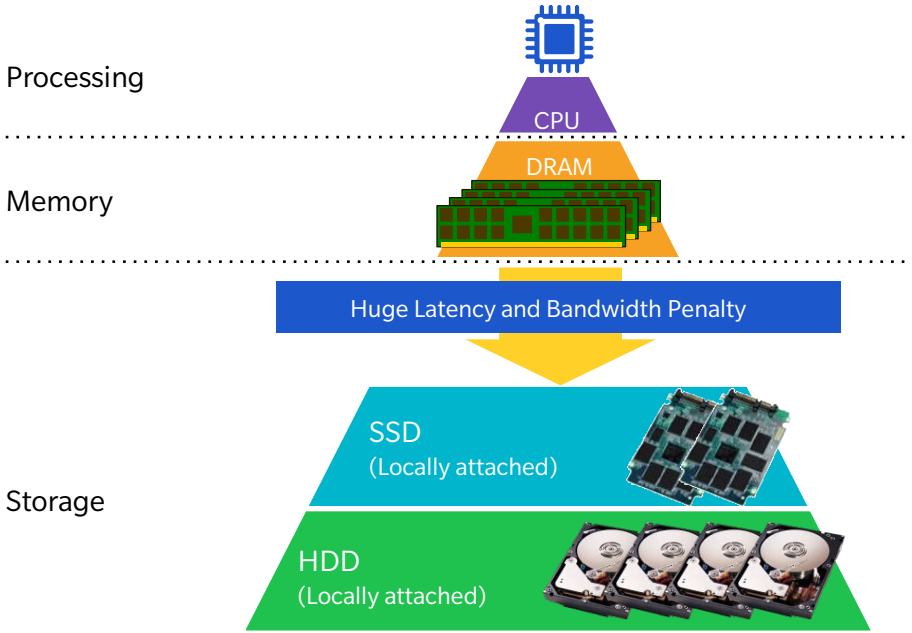
Big Data Drives Server Growth



Real-time Applications Demand More Memory



Benefits of Keeping Large Data Sets In Memory

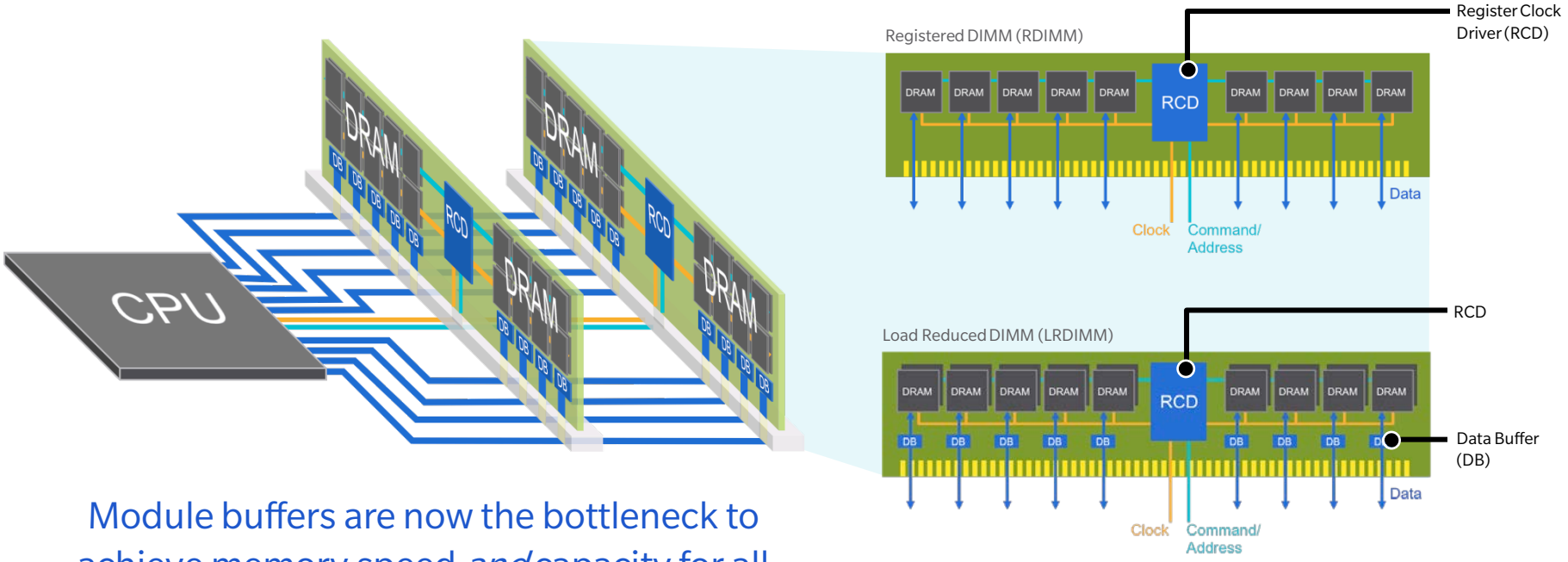


Modern Server Memory Hierarchy

Latency	Bandwidth
0.1us	100-150GB/s
~1000x	~200x
150us (New) 300+us (Conditioned)	500MB/s
10,000us	500MB/s

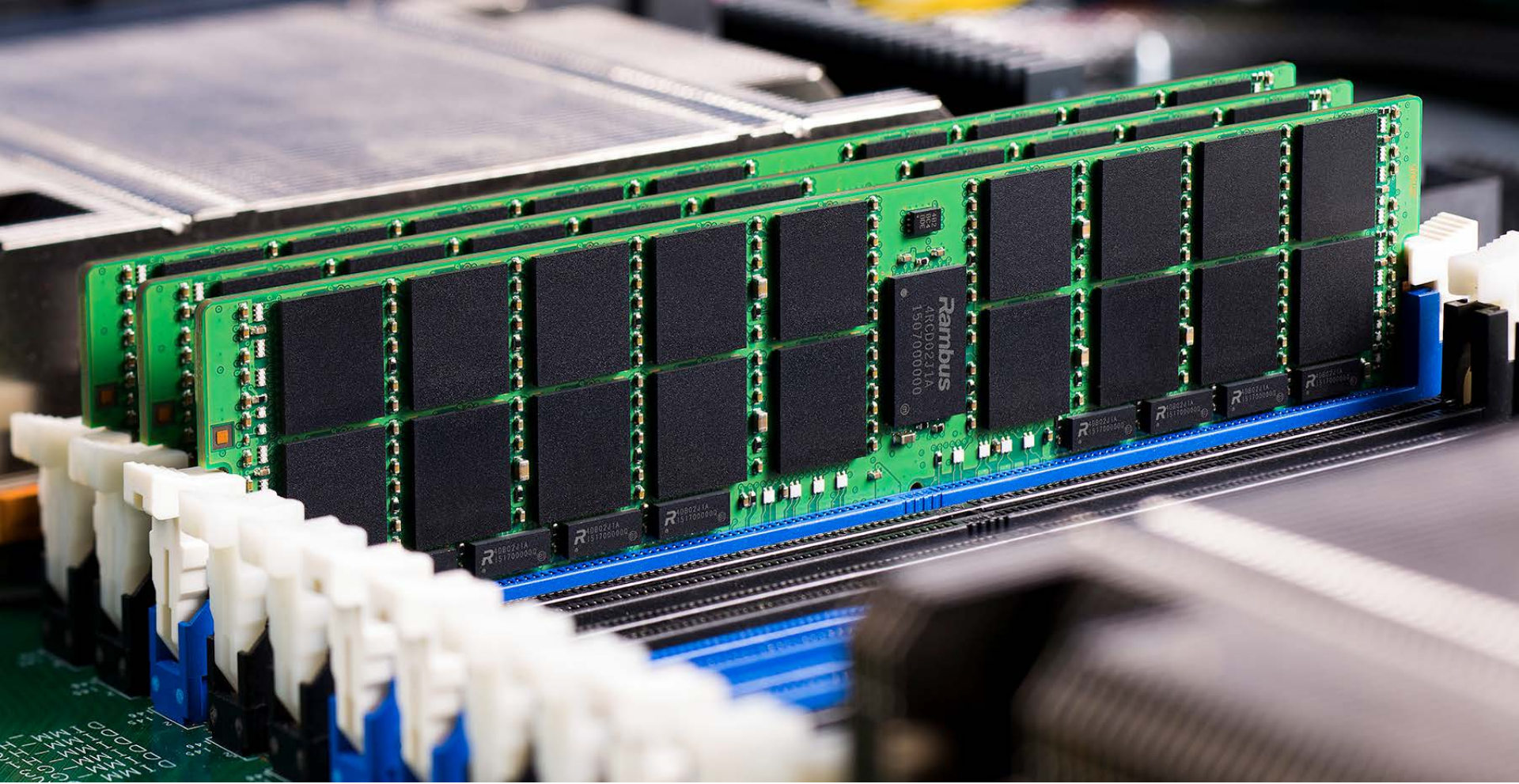
Large performance penalty for insufficient memory capacity due to latency and bandwidth gap between memory and storage

Boost Capacity and Bandwidth with DDR4 DIMMs



Module buffers are now the bottleneck to achieve memory speed *and* capacity for all server CPUs using DDR4

Server DIMM Chipset = RCD + DB


Rambus
4RCD0221A
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The Market Responds …

THE WALL STREET JOURNAL.

The company is announcing plans to sell chips under its own brand for the first time in its 25-year history. **The latest move builds on Rambus's expertise in communications technology associated with memory**. Rambus won't actually manufacture its new chips. Like most semiconductor companies founded since the 1980s, it will hire manufacturing specialists to make them.

VentureBeat

Rambus is making an advanced server memory interface chipset, dubbed the RB26 for R+DDR4 memory modules. **The chips are like the wheels on Ferraris. They enable memory to keep up with high-speed data processors in enterprise and data center server markets**. This new family of chips will enable applications such as data-intensive processing, real-time analytics, virtualization, and in-memory computing with increased speed, reliability, and power efficiency.

EE Times

Rambus, which started its business 25 years ago as a developer of RDRAM technology, is returning to its roots in memory technology innovation. **Seizing the opportunity in a growing market of enterprise servers and datacenters that is screaming for dramatic performance improvements both in bandwidth and capacity**, Rambus is rolling out a server memory interface chipset.

Forbes

DDR4 is really hard to get right at high capacities and high speeds in a reliable way. In a world of Big Data server applications, these high capacities and reliability are paramount, and memory will just keep getting faster in a very technologically-challenging. Quite frankly, server OEMs and ODMs needed a new producer of DDR4 server memory chips, **and that new provider is Rambus.**

EEFOCUS 与非网

Rambus: Moving up from IP licensing to making chips

Micro-Electronics 新電子

Targeting server memory business , Rambus joins chip product market

日経産業新聞

Rambus shifts over their business from licensing semiconductor for server

전자신문 etnews

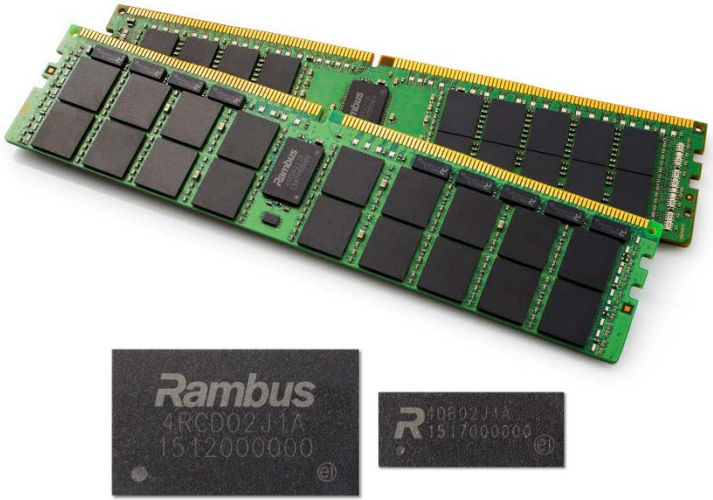
Rambus turns into fabless chipmaker

반도체네트워크 SEMICONDUCTOR NETWORK

Rambus introduces new server memory interface chipset for advanced enterprise and data center systems

Standard Made Better

RB26 DDR4 Server DIMM Chipset



Sampling today

Industry-leading Performance and Margin

- Compliant with latest JEDEC spec @ 2666 Mbps; built-in support for 2933Mbps
- Wide margin IO design with advanced programmability
- Exceeds JEDEC reliability requirements

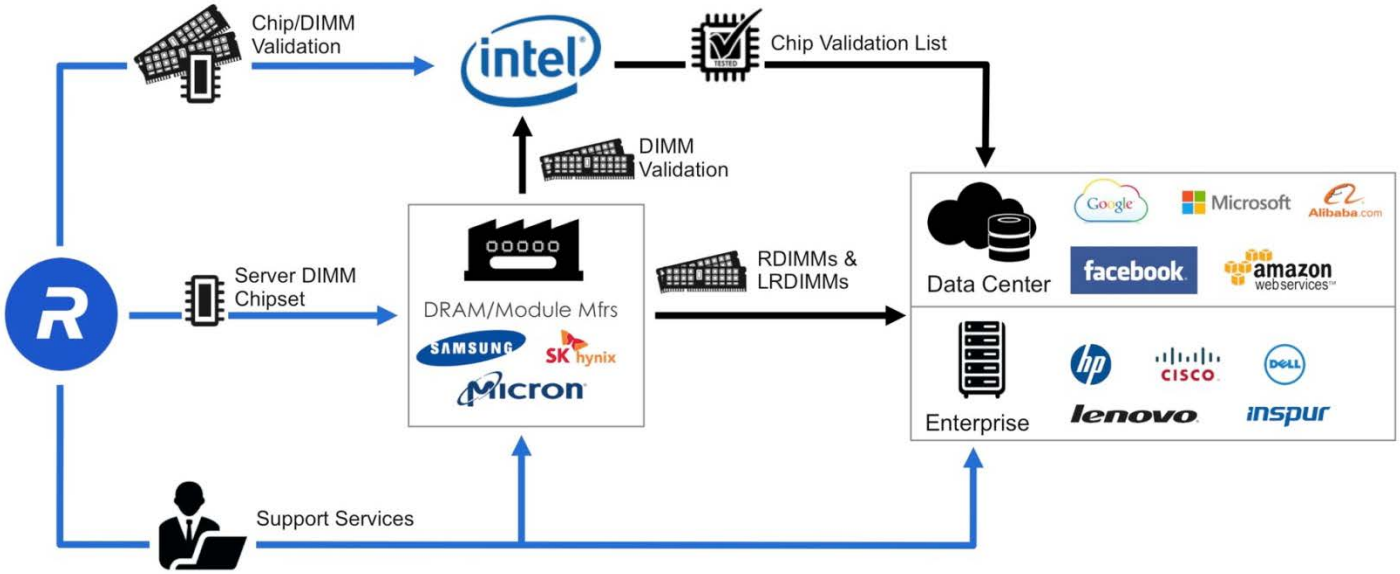
Optimized Power

- Frequency-based power optimization

Best-in-class Debug and Serviceability

- Integrated tools for bring-up and debug
- Works out of the box with default system BIOS

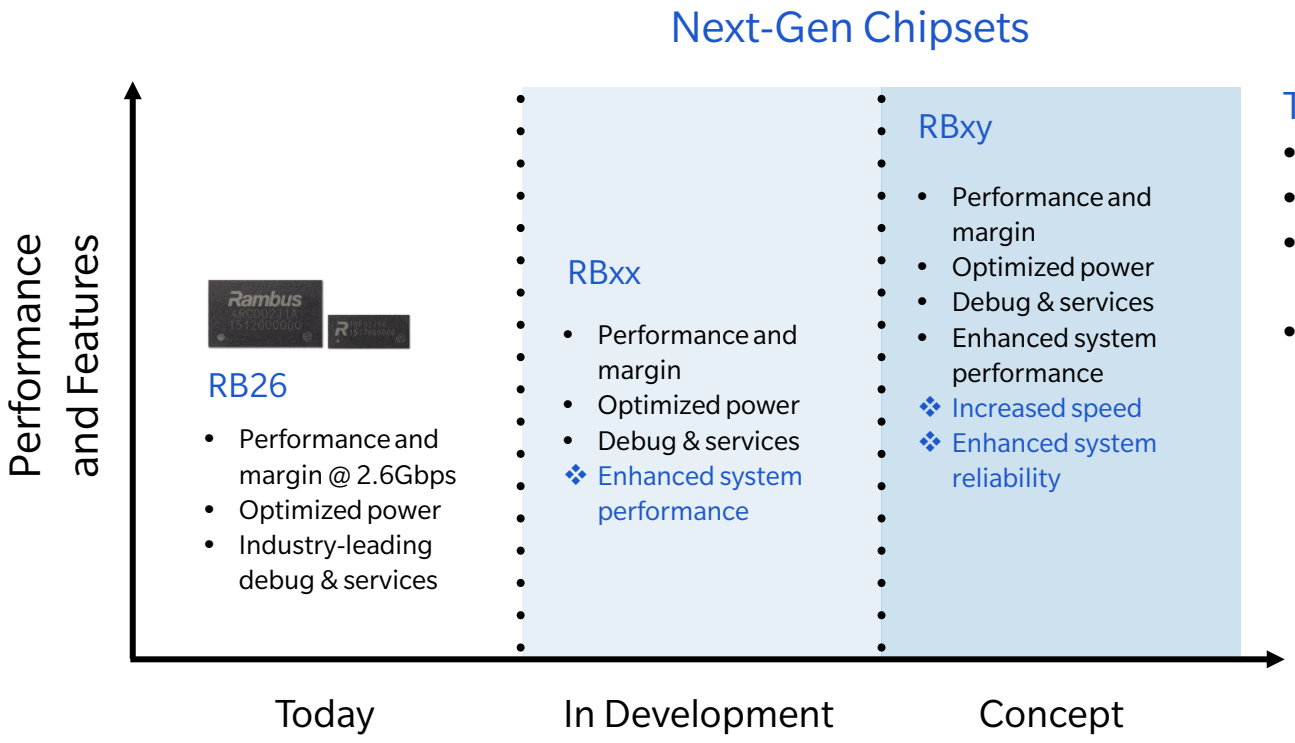
Who Needs the Server DIMM Chipset



- Server DRAM capacity expected to more than double in next 3 years
- DDR4 server penetration projected to reach more than 80% in 2017 and 100% in 2019*

*Source: IDC, June 2015

Server DIMM Chipset Roadmap



Technology Considerations:

- Speeds beyond DDR4
- DRAM scaling limits
- Buffer support for different memory types
- Further power reduction

R+ Memory Interfaces for Data Center and Mobile

High-performance, low power memory interfaces with improved system margin and flexibility

- R+ LPDDR3
  - Supports 2133Mbps, 30% lower power than LPDDR3
  - SoC PHYs compatible with LPDDR4, LPDDR3
- R+ DDR4
  - Supports 3200Mbps
  - Designed for high-capacity servers and consumer applications

Partnering for success:

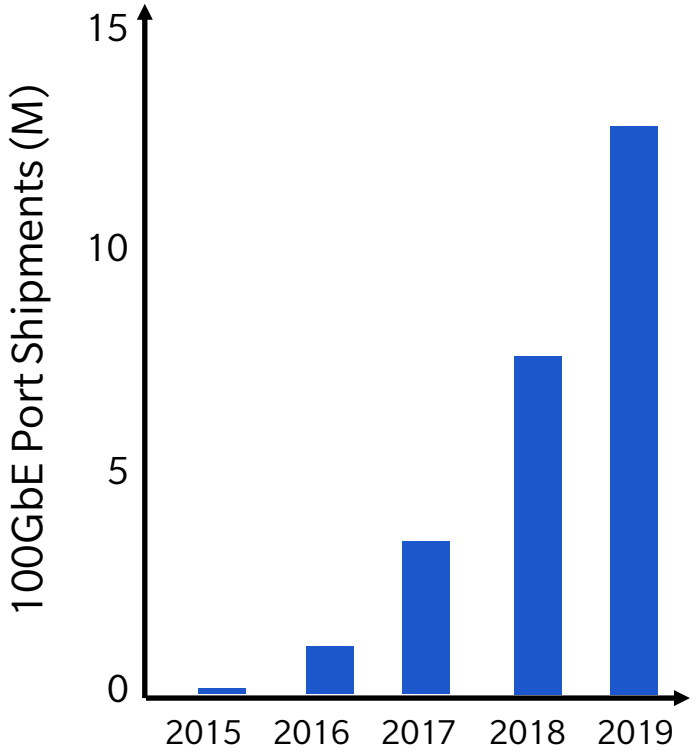
Rambus Leadership in Memory Solutions

● – Rambus Leadership Product
● – Industry Standard Compliant Product

	Interface Type	RDRAM	SDRAM	DDR	XDR	DDR2	GDDR3	XDR2	DDR3	GDDR5	LPDDR2	Mobile XDR	LPDDR3	R+ LPDDR3	DDR4	LPDDR4
	Year Introduced	1994	1996	1999	2001	2003	2003	2005	2007	2009	2010	2010	2012	2013	2013	2014
	Max Data Rate	500Mb/s	133Mb/s	400Mb/s	3200Mb/s	800Mb/s	1200Mb/s	12800Mb/s	1600 Mb/s	7000 Mb/s	1066Mb/s	4300Mb/s	1600Mb/s	2400Mb/s	3200Mb/s	4300Mb/s
Features	Programmable Read Latency	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Variable Block Size	●	●	●	●	●	●	●	●		●		●	●	●	●
	Core Prefetch	●		●	●	●	●	●	●	●	●	●	●	●	●	●
	Dual Edge Clocking	●		●	●	●	●	●	●	●	●	●	●	●	●	●
	DLL or PLL on a DRAM	●		●	●	●	●	●	●	●					●	
	Advanced Power States	●			●	●	●	●	●	●	●	●	●	●	●	●
	Programmable Write Delay	●			●	●	●	●	●	●	●	●	●	●	●	●
	Double Bus Rate Control	●			●			●		●	●	●	●	●		
	Driver Impedance/On Die Termination Calibration using Precision Resistor	●			●		●	●	●	●	●	●	●	●	●	●
	Fly-By Command/Address				●			●	●	●					●	
	Timing Deskew/Flexphase				●			●	●	●		●	●	●	●	●
	Bank Grouping/Microthreading							●		●		●			●	
	Channel Equalization Tech.							●							●	
	Near ground signaling (NGS)											●		●		●
	Multi Channel Die											●				●
	On Die Termination of CA signals											●				●
	Encoded Data Mask											●				●
	Encoded DBI											●				●

Note: This list is not exhaustive. Many of the generically labeled innovations listed in the far left hand column are patented or patent pending. Dates shown refer to when innovations were included in the standard when promulgated (some features may no longer be required to conform to such standard), a commercial product or referenced in a datasheet.

Links are Increasingly Important in Data Centers

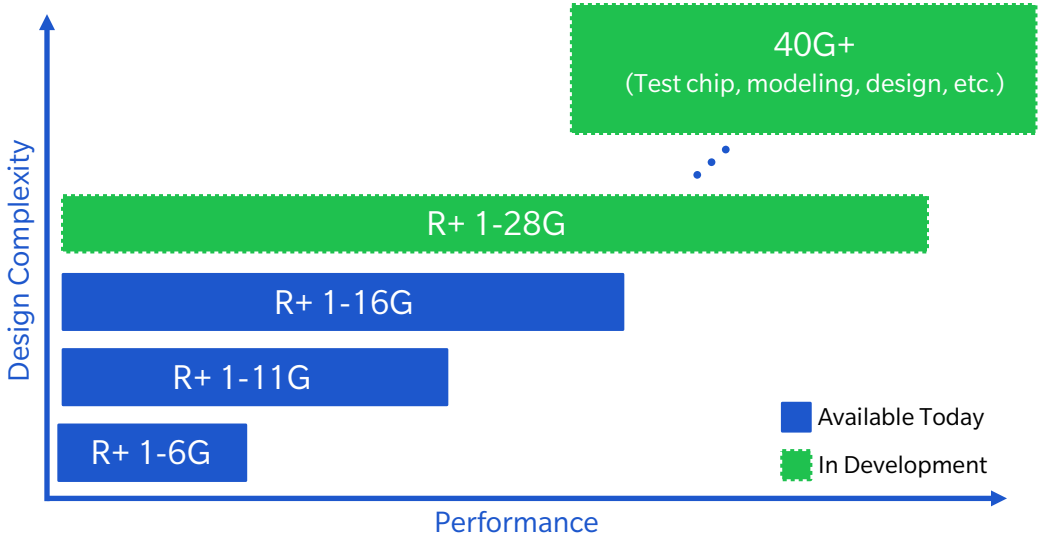


- Big Data driving increasing need for high-speed serial links, the backbone of the cloud
- Pervasive across all high-end routers, switches and networking systems
- 100GbE switch ports are growing from current annual run-rate of tens of thousands to handily exceed 10 million by 2019 – Crehan Research

Source: Crehan Research Inc.

R+ Serial Links for Data Centers

High-speed, multi-protocol serial link interfaces optimized for challenging enterprise systems



Demonstrated Excellence

- 15+ years of high-speed SerDes design
- Silicon demonstrated up to 40Gbps(NRZ) SerDes
- Simulation, modeling and design of 56G interfaces, interconnects and systems
- State-of-the-art signal and power integrity internal tool methodology

Rambus Leadership in High-Speed Signaling

● – Rambus Leadership Product
● – Industry Standard Compliant Product

	Interface Type	Quad Serdes	RaserV SerDes	PCIe 1.0	RaserX SerDes	Raser SerDes	PCIe 2.0	10GBASE-KR	R+ MP SerDes	USB 3.0	PCIE 3.0	USB 3.1 SSIC	R+ MP SerDes
	Year Introduced	2000	2002	2002	2005	2005	2006	2007	2008	2008	2010	2013	2013
	Max Data Rate	3.125 Gb/s	6.4 Gb/s	2.5 Gb/s	10 Gb/s	4 Gb/s	5 Gb/s	10 Gb/s	6.4 Gb/s	5 Gb/s	8 Gb/s	10 Gb/s	11.2 Gb/s
Features	PAM-4 Signaling		●		●								
	Transmitter Pre-Emphasis		●		●	●		●	●		●	●	●
	Multi-Tap Transmit Equalization		●		●	●		●	●		●	●	●
	Transmit Compliance Pattern	●	●	●	●	●	●	●	●	●	●	●	●
	Adaptive Transmit Equalization	●	●		●	●	●	●	●		●	●	●
	Adaptive Receive Equalization				●	●	●		●	●	●	●	●
	Partial Response Decision Feedback Equalization				●								
	Selectable Tap Decision Feedback				●								
	Receiver with Eye Diagram		●		●				●				●
	Receiver with Adaptive Sampling Phase				●								
	Fast lock CDR – extra edge samplers					●							
	2nd order CDR					●			●				●

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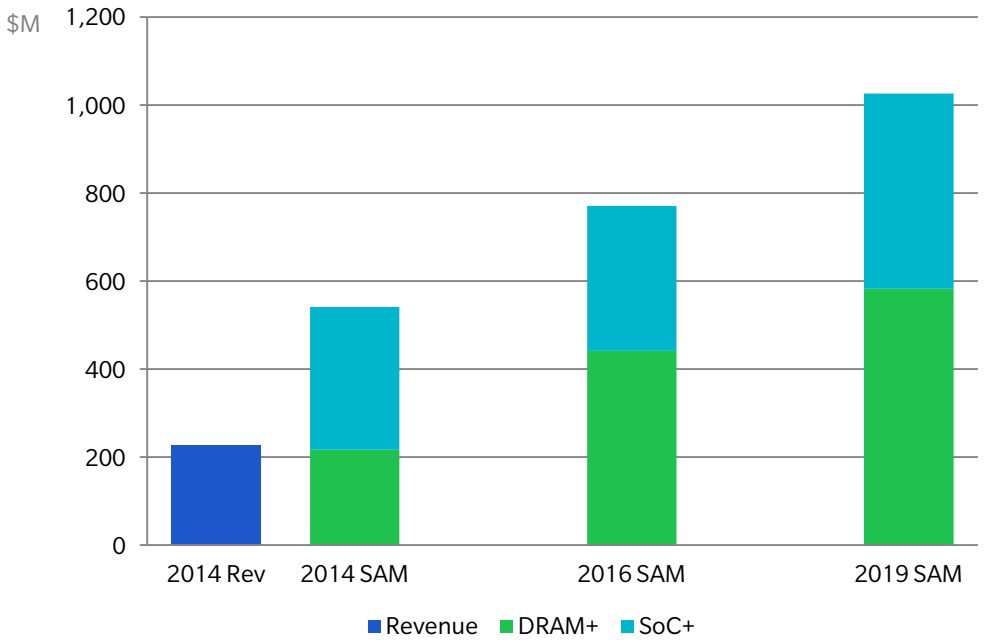
Growth Opportunity for Memory & Interfaces



- Significant opportunities from datacenters growth
- DRAM revenue will grow as we continue to license technology and begin to sell buffer chips to DRAM companies
- SoC revenue will grow as we license our patent portfolio as well as memory and serial link SIP