MOOR INSIGHTS & STRATEGY

# IBM Announces POWER8 with OpenPOWER Partners

***IBM Steals a Page from ARM's Playbook, but Has a Long Road Ahead to Challenge Intel's Leadership***

## Executive Summary

IBM is reinforcing its newfound open processor strategy with a POWER8 processor and servers that target cloud and big data solutions. IBM typically claims that new POWER chips offer superior performance than Intel Xeon, the industry leader, and this chip is no exception. POWER8 will be well received by IBM's traditional scale-up AIX installed base.

However, IBM historically has been unable to translate their supposed speeds-and feeds-advantage into additional market share in the vital Linux internet-scale market. IBM now is pinning its hopes on adopting an ARM-like open development model with partners to foster more innovation, competition, and adoption. IBM hopes to save the POWER processor from the fate suffered by SPARC, Itanium, DEC Alpha, MIPS, and other proprietary architectures. IBM also recently announced new members for the not-for-profit consortium, launched last August, and more detail about their plans for the OpenPOWER Foundation.

This paper examines how IBM got here, what they announced in April 2014, what they need to accomplish, and the challenges they face in realizing their goals. In summary, we find the following:

**POWER8 and OpenPOWER Assessment**

1. POWER8 looks to be very fast when running IBM software ("Blue on Blue"). Additional data are required to assess its merits relative to Intel E7v2 (Ivy Bridge) running identical scale-out software stacks.
2. IBM's new coherent interface, CAPI, provides a compelling heterogeneous solution for GPUs, FPGAs, and flash memory.
3. OpenPOWER success will be critical if IBM is to transition from Big Unix Iron to the Big Linux Datacenter. We applaud IBM's strategy and efforts, but it will take significant investments and time to approach the level ARM enjoys today as an open architecture.

**IBM Challenges**

1. Evolve to a new business model of providing silicon technology to new partners, and even to competitors, while running a multi-billion dollar vertically integrated business model.
2. Convince hyperscale datacenters of the value of POWER over Intel <u>and</u> ARM.
3. Win large RFPs with ODMs to obtain a route to hyperscale markets.

4. Attract serious SOC partners to reduce costs and establish credibility as an open architecture.

**MI&S Recommendations**

1. IBM POWER7 customers not planning to migrate to Intel Xeon should plan to transition to the new POWER8 servers as they come to market.
2. Linux customers should evaluate the new technology for applications that benefit from POWER's large thread count, massive amount of flash memory, and/or accelerators such as GPUs or FPGAs.
3. Take a wait-and-see approach to the OpenPOWER ecosystem which may materialize if Google and other hyperscale customers adopt it and take it into production.

## The POWER8 Processor, Now with CAPI

The POWER8 chip delivers what the industry has come to expect from IBM: a large, fast chip with more cores, more threads, more cache, more I/O, higher frequency, more RAS, cool new features, *etc*. But it also has a new open peripheral interconnect called the Coherent Accelerator Processor Interface (CAPI) which provides cache-coherent access to DRAM for heterogeneous processors. Similar in some ways to AMD's Hybrid System Architecture (HSA), IBM partners can use CAPI to attach accelerators and I/O resources with impressive results. NVIDIA, Mellanox, Texas Memory Systems, and Altera demonstrated early examples of this technology. Coherent access to lots of DRAM and flash could enable significant advantages for IBM and its partners in big data applications.

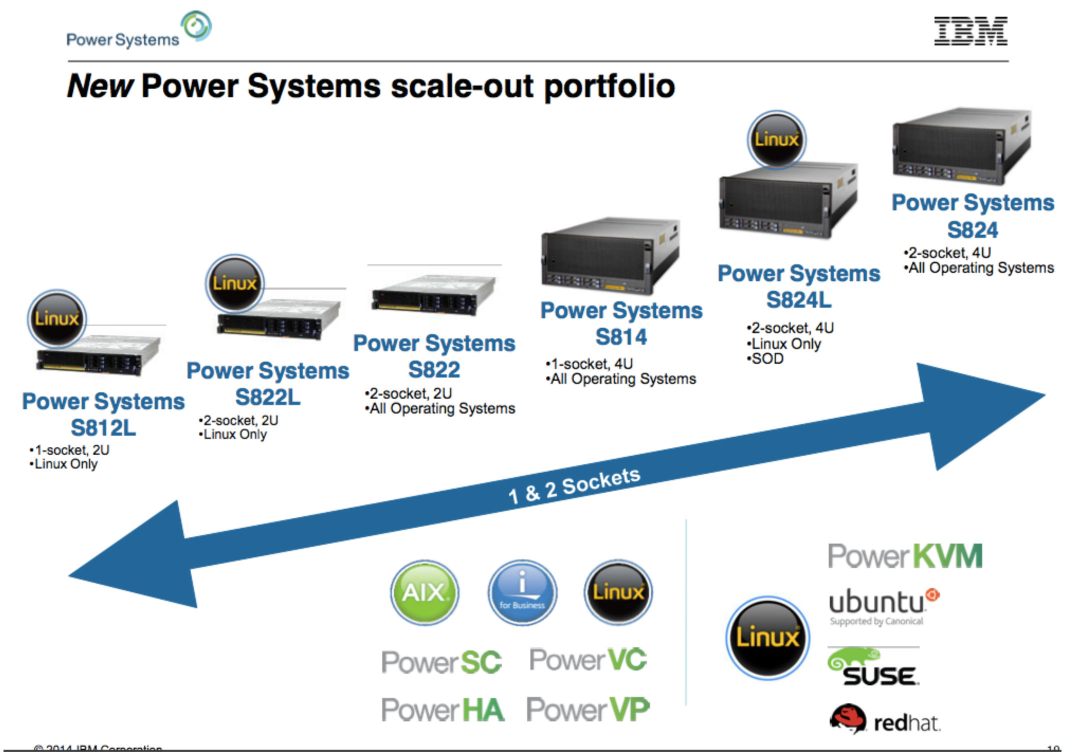
IBM's new POWER8 is a big chip with 12 cores per die and 8 threads per core for a total of 96 threads per socket. IBM claims the chip delivers four times the memory bandwidth, five times the I/O bandwidth, and three times the on-die cache, of an Intel Xeon. The processor has 4.2 billion transistors and is 650mm$^2$ in IBM's 22nm SOI process with 15 metal layers. In another move aimed at big data, IBM designed a "Dynamic Balanced Memory Architecture" which they claim delivers 2.6X the internal data rate, 4X the bandwidth, and 3.2X the cache of x86, plus a 96MB L4 cache located with the DRAM buffers on the memory DIMMs. In comparison, Intel 's top-of-the line 15-core E7 V2 processor has 4.31 billion transistors and is 541mm$^2$ in 22nm using 9 layers of metal. Each E7 core has two threads, so it has 30 hardware threads *vs.* 96 for POWER8.

Thread count is interesting, but only in the context of memory and I/O subsystems' ability to support each thread. We await additional benchmarks to conclude whether the new IBM memory architecture can feed all those threads effectively. But on the surface, the math seems to work.

## New POWER8 Systems

IBM introduced new 1- and 2-socket servers in 2U and 4U chassis—three of which support Linux only, not AIX or "i". Also, IBM announced their intent to introduce new enterprise (rack-scale) systems later this year and an aggressive upgrade program to entice customers to buy POWER7+ big iron now then upgrade later.

**Figure 1: Systems Portfolio**

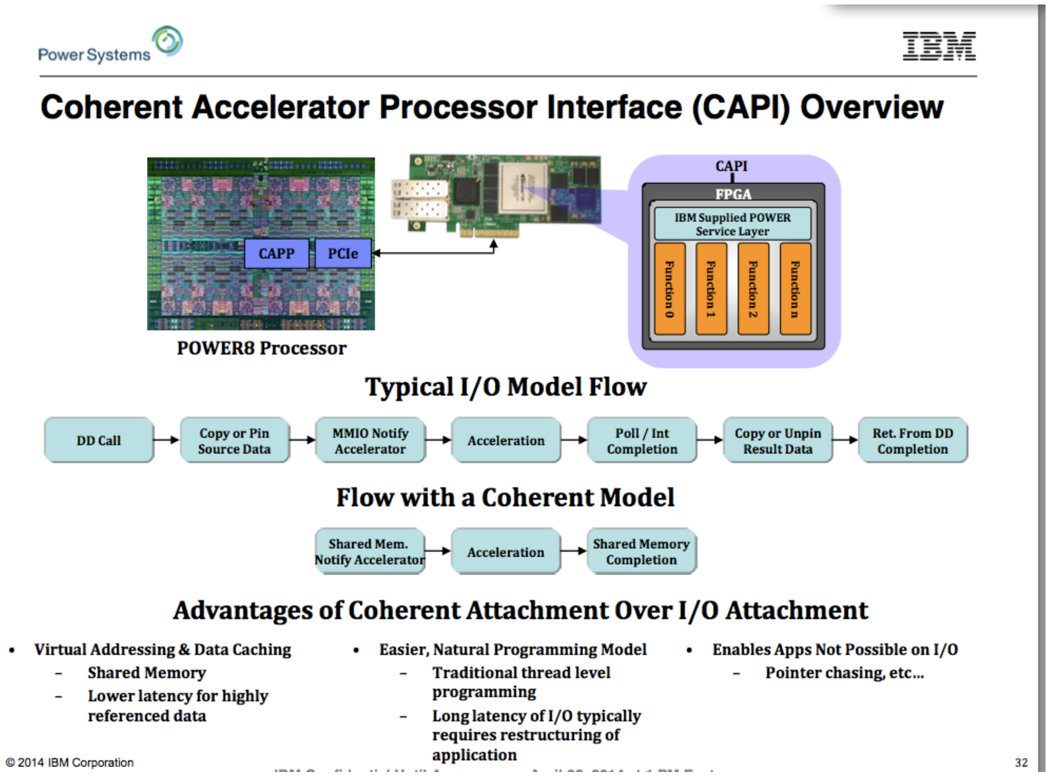



IBM provided internally-run benchmarks, claiming such things as 2X the performance of x86, and 50-80% lower Total Cost of Acquisition. Unfortunately, many of these claims were "Blue on Blue" (IBM software on IBM hardware) compared to "another database" on x86-based Intel Xeon E5 (Ivy Bridge) servers. Therefore, we are not able to determine how much of the advantage is due to the chip, the software, or the combination of the two. Additionally, Intel's upcoming Ivy Bridge version of its E7 high end server chips was not referenced by IBM's materials and executives.

## CAPI: Coherent Acceleration Processor Interface

IBM's CAPI enables direct attach to DRAM with full cache coherency. It is implemented on standard PCI-3 physical layer hardware; it significantly reduces the amount of processing time needed to set up an operation and the amount of DRAM needed to hold copies of data in OS memory space. While the NVIDIA solution is not taking advantage of CAPI in this release, the FPGA and flash examples that IBM touted are enabled by CAPI with impressive results. IBM claimed a 10X throughput advantage, with one-seventh the latency, while accessing 80TB of flash for in-memory databases with Cognos.

**Figure 2: CAPI Overview**




Synthetic chip benchmarks are fairly useless. So an IBM claim that did catch our attention was a benchmark of a no-SQL database on CAPI-attached flash which delivered the same performance as a standard-memory implementation at one-fifth the cost. This innovative system design, enabled by software and a new interface, delivers dramatically superior value beyond that which any chip-level innovation could possibly enable. It is unclear whether similar results could be obtained by attaching a flash array to an x86 processor, although the low latency of CAPI would be difficult to replicate on an x86 server.

## OpenPOWER

### The Motivation for OpenPOWER

In January 2005, IBM POWER5 was stealing share from SUN and HP, and it was on its way to garnering over 50% of the then-robust UNIX server market. However, to become relevant to Linux buyers, IBM needed a way to offer lower-priced systems while protecting the margin of its higher-priced AIX servers. So IBM launched a Linux-only server product line, branded as IBM OpenPOWER, to compete in what would become a fast-growing and price-sensitive Linux server market.

Basically, these OpenPOWER servers were the same as their AIX siblings, but they were priced to compete with x86 2-socket servers. IBM invested heavily in porting the traditional enterprise software stack, including Oracle, SAP, and of course, IBM DB2/WebSphere software. While it was a valiant attempt to penetrate the Linux market, it never took off. The big Linux buyers were happy with Intel Xeon and showed no interest in buying a different architecture. It is important to note that these systems still used the proprietary POWER/VM hypervisor, instead of Xen or KVM, and did not support industry-standard low-level management such as IPMI—essential in cloud datacenters. IBM hopes to address these technical hurdles with its new announcements of support for KVM and IPMI.

**The Demise of UNIX: a Big Deal for Big Blue**

Between 2002 and 2012, IBM UNIX market share rose from 14% to over 55% share on the back of the speedy POWER architecture in the scale-up datacenter. Once the heart of the enterprise datacenter, the market for UNIX based servers is now declining precipitously. IDC sees UNIX server revenue sliding from $10.2 billion in 2012 to $8.7 billion in 2017, and according to public Gartner reports, they see UNIX share crashing from 16% of server revenue in 2012 to 9% in 2017. Recently this market decline began accelerating: IDC reported a 31.3% decline in the UNIX market in the critical 4th quarter of 2013. The rich vein of gold that IBM has been mining for 10 years appears to be playing out.

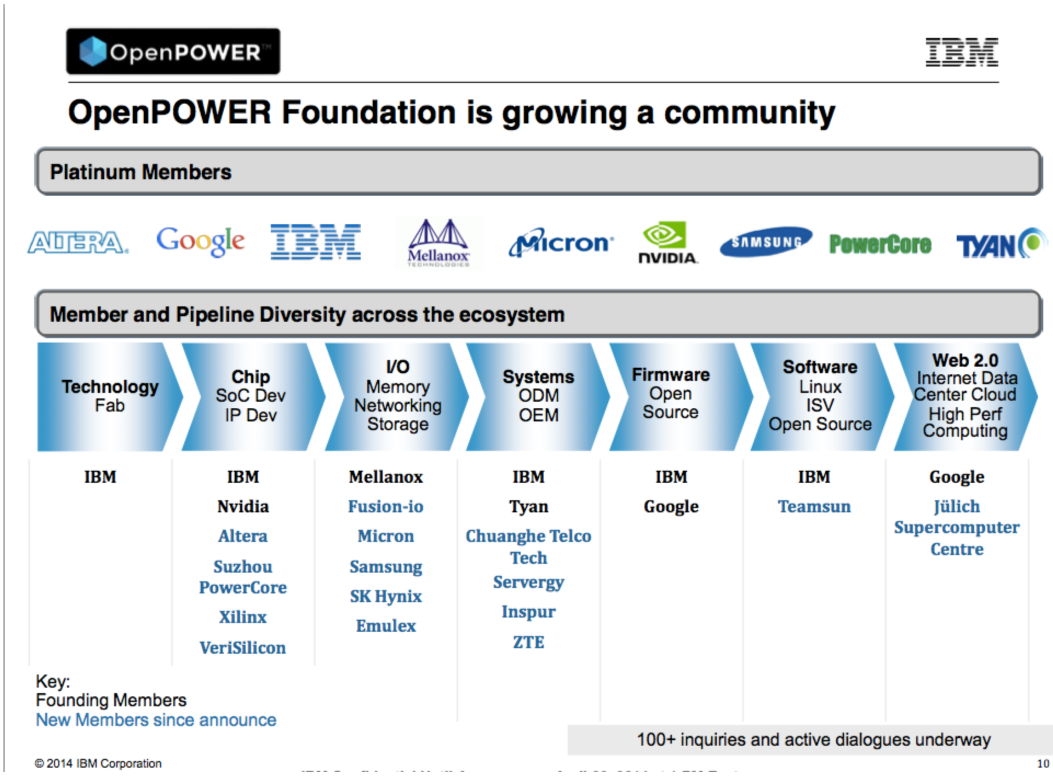
**Enter OpenPOWER**

Given these dynamics, IBM decided last year to reboot OpenPOWER by actually “opening” (aka “licensing”) the POWER architecture to enable partners to collaborate for specific Linux scale-out workloads. In August 2013, IBM established an OpenPOWER consortium—now formalized as the OpenPOWER Foundation—and promised to spend yet another billion dollars to build an ecosystem for Linux on POWER. While the new POWER8 products are very interesting, especially the cache-coherent CAPI interface, IBM must find additional revenue sources through new markets and partners, or they will struggle to fund the substantial development costs needed to design future POWER processors.

Looking at the problem more strategically this time around, IBM intends to license the IBM silicon “crown jewels” for customized server SOC development, thus mimicking the successful innovation and business model of ARM. IBM hopes this strategy will spur innovation and create a software ecosystem that can compete with Intel as well as with the emerging cadre of ARM-based servers.

As of IBM’s April 2014 announcement, OpenPOWER has some notable partners, including GPUs, RDMA I/O, memory subsystems, FPGAs, as well as one silicon partner, two platform partners, and perhaps most importantly, the largest datacenter operator in the world: Google.

**Figure 3: Foundation Members**




### *End-Users*

The most impressive member of the group is Google, a company known for placing bets in a wide array of experimental and research technology. If Google deploys a significant number of POWER-based servers, it would be a major milestone and would indicate potential for OpenPOWER. The second end-user, Jülich, is a long-time IBM HPC customer who probably is interested in the computational power of POWER8 coupled with GPUs and/or FPGA's. IBM will need to attract at least three or four more internet-scale datacenters to demonstrate the viability of POWER in the Linux market, and that will be no easy feat. Based on their list of system and silicon partners, IBM likely is targeting the large Chinese datacenters such as TenCent, Alibaba, Baidu, China Telecom, *etc*. Note that these firms are all rumored to be investigating ARM-based servers, and they also have deep collaborative relationships with Intel through projects such as the Rack Scale Architecture initiative Project.

### *Silicon Partners*

At this early date, IBM was able to speak publicly about only one SOC partner: "Suzhou PowerCore Technology Co." Recently created as part of an information technology ecosystem development initiative by Jiangsu Province, Suzhou PowerCore is working with the Research Institute of Jiangsu Industrial Technology to develop a POWER8-based custom chip for the Chinese datacenter market.

The lack of a significant SOC vendor committing to OpenPOWER servers is not surprising at this early point along the IBM journey to an ARM-like ecosystem. Most of these SOC players already possess ARM 64-bit V8 licenses. IBM must demonstrate quickly that they can attract these companies, or the window of opportunity may close. Meanwhile IBM's initial focus, by necessity, will be to collaborate with providers of acceleration technology and select system partners.

### *System Partners*

Big Blue was unable to attract other system suppliers to use their chips in building Linux servers during the first OpenPOWER incarnation. This dynamic still presents an important challenge to the new OpenPOWER program. After all, Dell and HP are not interested in using an IBM chip to compete with IBM's own servers and sales channel. Luckily for IBM, the channel serving the hyperscale market is also undergoing changes, as board-level companies like Quanta step in between their traditional OEM customers and sell directly to datacenters like Facebook. And of course Google, a member of the OpenPOWER Foundation, designs and builds their own servers.

Looking at IBM's announcement on the system side, IBM has enlisted the support of two Chinese firms and one boutique US firm. Inspur is a leading domestic Chinese IT provider and could help POWER penetrate that fast-growing market. ZTE is a telecommunications and IT provider based in Hong Kong and is also well positioned in the Chinese infrastructure industry. Servergy is a boutique server company based in Dallas, Texas that focuses on energy-efficient PowerPC-based servers.

IBM now must forge relationships with the ODMs and partners that hyperscale datacenters contract to build their custom and semi-custom servers including Quanta, Wiwynn, ZT Systems, and Hyve. These companies do not build systems speculatively; they only build what customers specify and order at significant scale. To attract these ODMs, IBM must build relationships and credibility with hyperscale end users who are willing to deploy a lot of POWER servers.

### *I/O, Memory, Networking, and Storage Partners*

IBM has made the most progress in enlisting partners who can add value to their new POWER8 servers through acceleration technology and memory subsystems. One of the most interesting IBM demonstrations was with NVIDIA using GPUs to accelerate Java by 8-fold. IBM also has an RDMA solution with Infiniband leader Mellanox, and they demonstrated both flash- and FPGA-attached processors sitting directly on the CAPI bus, avoiding the I/O overhead typically associated with co-processors and flash. This approach, which provides shared access to main memory and cache, will allow IBM to build workload-accelerators with their partners without requiring modifications to the standard POWER8 silicon and motherboards.

## The Road Ahead for OpenPOWER

It likely will take two to three years for IBM to enable an ARM-like level of SOC customization and get usefully close to ARM's business model sophistication. IBM must build a silicon development ecosystem. They need IP from companies like Cadence and Synopsys; manufacturing partners such as Global Foundries, TSMC, or perhaps Samsung (also an OpenPOWER alliance member); and the tools required to build, validate, and test custom SOCs.

IBM understands the magnitude of the challenge and has outlined three phases of OpenPOWER as they ramp investments and develop their fledgling hardware and software ecosystem:

1. **Phase 1: Crawl** The first phase rolls out this year using existing POWER8 chipsets, third-party system implementations, and CAPI exploitation with partners and IBM software. This could produce some very interesting workload-specific solutions and accelerators, while IBM recruits major datacenter buyers and SOC partners to enter the second phase.
2. **Phase 2: Walk** The first POWER8 derivatives produced by partners likely will have only minor changes, if any, to the POWER8 or POWER8+ design. With Suzhou PowerCore, IBM plans to enable a Chinese processor manufacturer to produce an SOC with verifiable silicon integrity and security (critical in the post-Snowden era). If IBM is able to enlist more SOC partners, development will follow the ARM technology licensing model: partners build custom SOCs around IBM core technology (combination of hard macros and RTL) then innovate and add value in the non-core IP blocks such as I/O, accelerators, and networking. This phase will be two to three years in the making and will likely be based on POWER8+ and POWER9 technology.
3. **Phase 3: Run** Full custom processor development using architecture and technology IP licenses from IBM likely will take at least three years to develop and may be the preferred approach for very large customers. While Phase 2 (Walk) SOCs can be built for tens-of-millions of dollars, a full custom implementation could cost hundreds-of-millions of dollars and take three to four years.

## Conclusions and Recommendations

POWER8 looks like a very fast and capable server chip, especially for IBM workloads, and the CAPI feature could enable higher performance and lower costs. IBM's current scale-up customers desiring to stay with POWER architecture should be delighted by the new capacity and the new acceleration opportunities. It remains to be seen how well POWER8 will perform against the next generation Intel Xeon E7 v2 family when it becomes available later this year.

The most important question is whether the internet-scale datacenters want another alternative to Xeon. Upcoming ARM SOCs are just around the corner with an array of competitive choices and standard software in development.

Table 1 explores how IBM might stack up against ARM and Intel in the highly anticipated battle for the new generations of internet-scale datacenters.

**Table 1: IBM OpenPOWER SWOT Analysis**

| Strengths | Weaknesses |
|---|---|
| • Excellent performance with IBM software<br>• Innovative technologies (CAPI)<br>• Highly-tuned IBM software stack<br>• IBM sales & support | • No credible SOC partners<br>• Large die size drives high costs<br>• IBM is the only major vendor<br>• Lack of experience in hyperscale<br>• Lack of optimized Linux software |
| **Opportunities** | **Threats** |
| • CAPI for RDMA & application accelerator support (increases performance and lowers costs)<br>• Whitebox POWER8 servers<br>• Chinese internet market | • Intel E7 performance, features, & compatibility<br>• Intel ecosystem & marketing<br>• ARM has at least a 3-year head start<br>• IBM competitive threat prevents major players to adopt |

On the positive side for OpenPOWER, one could argue that POWER is a superior alternative to ARM to compete with Intel for server applications. POWER has generations of server DNA. It delivers the performance, RAS, and advanced features such as RDMA that are valuable in large server applications. ARM, on the other hand, is a relatively "wimpy" processor. It has fewer threads, lower frequencies, fewer instructions per cycle, and comes with virtually no server DNA in its gene pool.

On the positive side for ARM and Intel Atom, many applications in a scale-out datacenter simply do not require the performance of a "brawny" core…neither POWER nor Xeon. Most hyperscale customers do not deploy vast numbers of Intel's high-end Xeon processors, but instead they select lower-priced and lower-frequency models that are adequate for their needs. After all, driving a Ferrari wastes a lot of money and fuel if a Volkswagen will get you to the corner store just fine. This is why Intel itself developed an entire family of low-power Atom server SOCs. And this is why ARM boasts over a dozen design wins for ARM V8 server SOC development with established semiconductor companies such as AMD, Applied Micro, Broadcom, Cavium, and others.

One can debate what it means for a processor to be open, but if one views the question from an end-user's standpoint, it means:

1. I can buy a compatible processor from more than one source (which requires SOC Partners, available IP, and manufacturing sources)
2. The architecture is relevant to my needs (is competitive as a server-class uP)
3. Software is readily available and tuned for the architecture
4. I can work with a variety of system vendors to get the best product at the best price.

*Based on this viewpoint, the strong hand is held by neither IBM nor ARM, but by Intel.*

Intel commands over 95% share of the server market in unit volume, and that gives them a massive edge in the ecosystem and economies of scale, as well as a lead in manufacturing costs and technologies. ARM comes in ahead of POWER, since it already has many vendors developing SOCs for the server market, as well as manufacturers such as TSMC, Global Foundries, and Samsung. And the ARM LENARO and LEG groups have made considerable progress providing standardized Linux software, tools, drivers, and firmware.

IBM has a start on system-level collaboration on CAPI, but sorely lacks SOC adopters, manufacturing partners, OEM/ODM system design partners, and most importantly a relevant Linux ecosystem. The fact that IBM intends to spend $1B to build this ecosystem demonstrates that they understand both the magnitude of the challenge, and the criticality of being successful. If they fail, the POWER architecture will be the final nail in the RISC coffin, with only ARM managing to survive to present a credible challenge to Intel's massive market leadership.

As a consequence, ARM has discussed its expectation to secure about 20% of the server market by 2018-19. How much market could that leave for POWER? The POWER business today is modest from a revenue perspective, but tiny from a volume standpoint. That is where Google might come in.

If IBM is able to establish a beachhead, meaning full production-level workloads at Google, then IBM with OpenPOWER could lay claim as the high-performance alternative to Xeon and let ARM-based SoCs have the low-end (performance and margin) business. IBM and OpenPOWER would have to invest heavily in POWER architecture and the Linux ecosystem to compete with Intel for Linux business. IBM would have to:

1. Manage their ability to shift the business model,
2. Win new end-users,
3. Win new SOC vendors, and
4. Win new ODMs and system vendor partners willing to compete with IBM.

That is a lot of winning to do, especially when the "run" stage is five years off and we have not yet seen an Intel response. Can IBM pull it off? Most industry watchers thought IBM POWER was down-for-the-count in the late 1990s as SUN, DEC, and HP's chips garnered some 85% of the UNIX market. Then IBM did what they do best: they made a clear decision and then they executed flawlessly. As a result, IBM won the prize (UNIX)…only to have the prize wither away to Linux. Now IBM must decide what they want their hardware business to look like in five years, and they need to execute quickly before the window of opportunity closes permanently.

The stakes could not be higher.

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