THE FUTURE OF ENTERPRISE SSD

Jihyo Lee, FADU CEO and Co-Founder
Flash Memory Summit 2019
THE CONSENSUS IS THAT SSD/ENTERPRISE IS EXPLODING

Price is not an Issue

SSD is Exploding

NAND Price/GB

Capacity (EB)

2015 2017 2019 2021(F)
THE ERA OF SSD (NAND) IS COMING

Past

DRAM

HDD

Future

DRAM

SCM / NVDIMM

Performance SSD

Capacity SSD

HDD
MUCH MORE EFFICIENCY IS REQUIRED

Bandwidth
8GB/s

>10X

4GB/s

SATA
500MB/s

PCle 3.0

PCle 4.0

7GB/s

>6X

175mm

107mm

110mm

22mm

F A D U
BUT, AS AN INDUSTRY, WE HAVE BEEN SLOW TO INNOVATE

<table>
<thead>
<tr>
<th></th>
<th>SATA SSD</th>
<th>Traditional Enterprise NVMe SSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput (read)</td>
<td>750MB/s</td>
<td>~3GB/s</td>
</tr>
<tr>
<td>IOPS (read)</td>
<td>80K</td>
<td>~600K</td>
</tr>
<tr>
<td>Active Power (read)</td>
<td>3W</td>
<td>~20W</td>
</tr>
<tr>
<td>Idle Power</td>
<td>1W</td>
<td>~4W</td>
</tr>
<tr>
<td>KIOPS / Watt</td>
<td>27K / W</td>
<td>25K / W</td>
</tr>
</tbody>
</table>

- 4x Better
- 7x Better
- 7x Worse
- 4x Worse
- Basically No Change
NOW IT'S TIME TO FACE REALITY
LEGACY ARCHITECTURES HAVE NOT DELIVERED ON THEIR SPECS

<table>
<thead>
<tr>
<th></th>
<th>U.2 7mm</th>
<th>M.2 22110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td>3.3 GB/s</td>
<td>3.0 GB/s</td>
</tr>
<tr>
<td>Write</td>
<td>2.0 GB/s</td>
<td>1.4 GB/s</td>
</tr>
<tr>
<td>Active Power</td>
<td>12 W</td>
<td>8 W</td>
</tr>
</tbody>
</table>

1.4 GB/S Read

> 60% DEGRADATION DUE TO THERMAL MGMT.
POWER AND THERMAL ARE SERIOUS ISSUES GOING FORWARD

PCIe Gen3
Bandwidth: 3.5GB/s
M.2: 8.5W
U.2 / E1.S: 12W
U.2 15mm: 25W
E1.L: 45W

PCIe Gen4
PCIe Gen5
Bandwidth: 7GB/s
14GB/s

Are we certain that future SSDs can deliver?
ALSO CUSTOMERS ARE ASKING FOR NEW FEATURES

Append Only Stream
Zoned Name Space
QLC
I/O Determinism
Computational Storage
Controller Memory Buffer
Open Channel

EDSFF
Multi-stream
SR-IOV
Open Channel
Persistent Memory Region

3D Xpoint
NVMe Over Fabric
Multiple Name Space

BUT WHICH ARE REALLY BEING ADOPTED FOR MAINSTREAM?
CUSTOMERS ARE FRUSTRATED 
BY THE UNCERTAINTY

Can I secure 
the 
performance?

Can I get the 
required feature?

Can I make my 
system 
competitive?
SO THEY ARE TURNING TO SELF-BUILD MODEL

It’s been tiring to wait to get the proper SSD from supplier.

We found there is no way to get the SSD we look for other than self-build.

Consigning NAND is challenging, but is better way to secure price and cost competitive SSD.
WE NEED TO EXECUTE THE BASIC THINGS RIGHT

1. Fully utilize PCIe bandwidth

2. Keep power budget and deliver the real performance

3. And deliver real innovation for customers
WE UTILIZE THE FULL PCIe 3.0 BANDWIDTH EVEN IN M.2

<table>
<thead>
<tr>
<th></th>
<th>FADU Bravo</th>
<th>Current Leader</th>
<th>Current Follower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential Read (GB/s)</td>
<td>3,500</td>
<td>3,000</td>
<td>1,900</td>
</tr>
<tr>
<td>Sequential Write (GB/s)</td>
<td>2,850</td>
<td>1,400</td>
<td>1,430</td>
</tr>
<tr>
<td>Random Read (KIOPS)</td>
<td>820</td>
<td>480</td>
<td>295</td>
</tr>
<tr>
<td>Random Write (KIOPS)</td>
<td>100</td>
<td>47</td>
<td>36</td>
</tr>
<tr>
<td>Active R/W Power (W)</td>
<td>5 / 8</td>
<td>7 / 8</td>
<td>8.25</td>
</tr>
<tr>
<td>KIOPS/W (Read)</td>
<td>164</td>
<td>68</td>
<td>&lt;40</td>
</tr>
</tbody>
</table>
EVEN AT BEST PERFORMANCE, WE ELIMINATE HEAT ISSUE

Read : Write = 7:3 (4KB, TC1, QD64)

Performance

FADU Bravo 247 K IOPs
Current Leader 100 K IOPs

NAND temperature

Current Leader 74°C
FADU Bravo 62°C
WE GUARANTEE MAXIMUM PERFORMANCE

Seq. Read @ Real Data Center Environment

3,500

3,000

2,500

FADU
Bravo

Current Leader
## FADU Everest: PCIe 4.0 Without Power Issue

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Power</td>
<td>7.5 W</td>
<td>13 W</td>
</tr>
<tr>
<td>Sequential Read</td>
<td>7 GB/s</td>
<td>7 GB/s</td>
</tr>
<tr>
<td>Sequential Write</td>
<td>3 GB/s</td>
<td>6.5 GB/s</td>
</tr>
<tr>
<td>Random Read</td>
<td>1,650 KIOPS</td>
<td>1,650 KIOPS</td>
</tr>
<tr>
<td>Random Write</td>
<td>170 KIOPS (7% OP)</td>
<td>540 KIOPS (28% OP)</td>
</tr>
<tr>
<td>KIOPS (Read)</td>
<td>212 KIOPS/W</td>
<td>201 KIOPS/W</td>
</tr>
</tbody>
</table>
WE KNOW LATENCY AND QOS IS CRITICAL

QOS 4K Read Latency
Synthetic Workload, 5% Seq. Write Injection

QOS 8K Read Latency
Synthetic Workload, 10% Seq. Write Injection

Latency in μs

Current Leader
FADU BRAVO

Latency in μs

Current Leader
FADU BRAVO
INTRODUCING THE FADU BRAVO XL SSD

Sequential Read: 3,500 MB/s
Sequential Write: 2,870 MB/s
Random Read: 830 KIOPS
Random Write: 370 KIOPS
Active power (R/W): 5W / 6.3W
QD1 Avg. Latency: 19 µs
QD1 QoS (99.9%): 30 µs

Live demo in our booth
WE DELIVER WHATEVER OUR CUSTOMERS REQUEST

IOD actual result (Read in NS 1~3, Write in NS4)

Throughput (MiB/s) 99.9999% Latency (µs)

<table>
<thead>
<tr>
<th></th>
<th>NS1/NS4</th>
<th>NS1/NS2/NS4</th>
<th>NS1/NS2/NS3/NS4</th>
<th>NS1/NS4</th>
<th>NS1/NS2/NS4</th>
<th>NS1/NS2/NS3/NS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput (MiB/s)</td>
<td>325</td>
<td>411</td>
<td>411</td>
<td>324</td>
<td>324</td>
<td>324</td>
</tr>
<tr>
<td>99.9999% Latency (µs)</td>
<td>845</td>
<td>5364</td>
<td>4992</td>
<td>837</td>
<td>848</td>
<td>840</td>
</tr>
</tbody>
</table>

Supporting Features in FADU Bravo

- SR-IOV
- Multistream
- CMB
- PMR
- Dual-Port
- Multiple Namespace
- IOD
- Open Channel
WE’RE ALSO INNOVATING THE WAY AN SSD IS MADE

You Choose/Supply your NAND

We Deliver What You Need

- SOC
- Firmware
- Hardware Design
- Testing / Validation
- End SSD Product

Controller + Firmware

Full Turnkey Solution

Fully Consigned SSD

TOSHIBA

Micron

SK hynix

FADU
THE SSD INDUSTRY NEEDS TO MOVE IN THE RIGHT DIRECTION

1. Fully utilize bandwidth
2. Keep power budget
3. Deliver real innovation

- **DRAM**
- **SCM / NVDIMM**
  - NVDIMM-P
  - XL-SSD
- **Performance SSD**
  - Performance SSD (eTLC)
- **Capacity SSD**
  - Capacity SSD (QLC)
- **HDD**

- XLDIMM ('21)
- Bravo XL (Now)
- Everest XL ('20)
- Bravo (Now)
- Everest ('20)
- Everest Q ('20)
For more information visit our booth #940 and www.fadu.io