Best Practices for Liquid & Air Cooling of a 51.2Tbps Switch for High-Density AI Clusters

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Networking

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Best Practices for Liquid & Air Cooling of a 51.2Tbps Switch for High-Density AI Clusters

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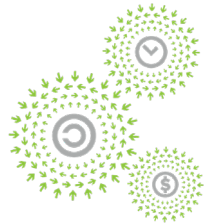

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Agenda

- AI power challenges
- Responses at silicon level
- Responses at system level
- Alibaba 51.2T AI switch & deployment
- Call to Actions

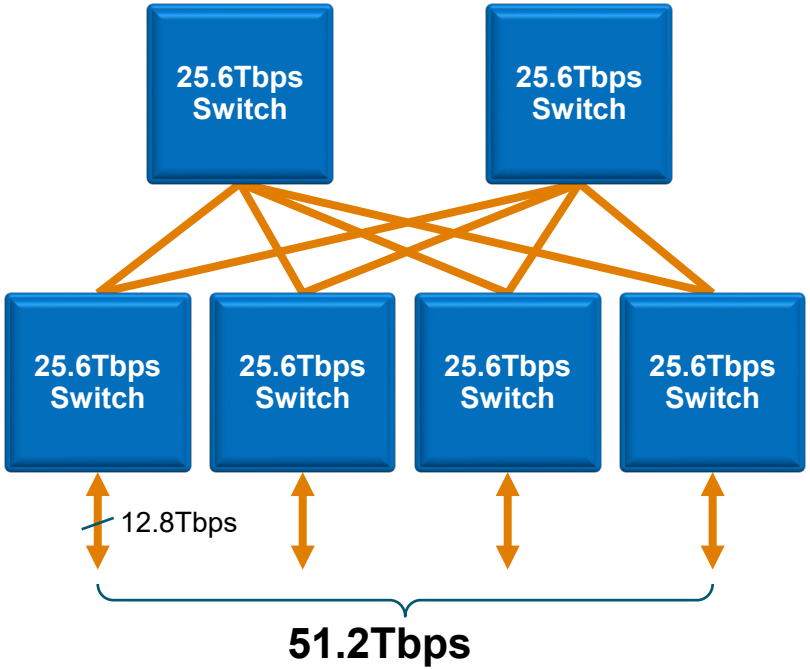
Surging Thermal & Power Density for AI

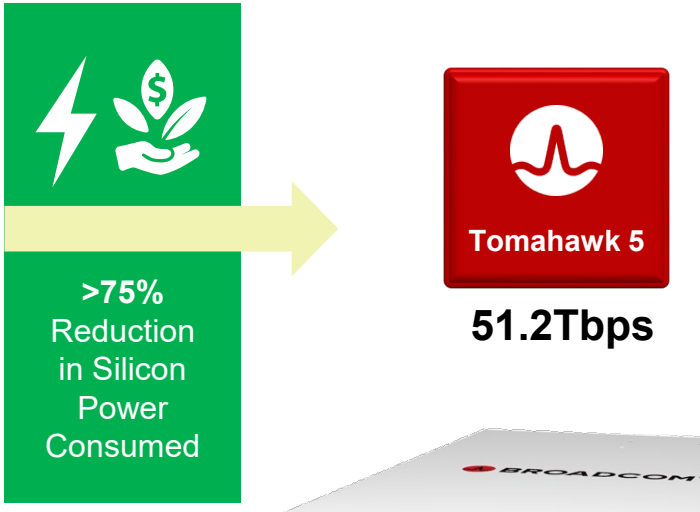
- ~10x Power and thermal density per OU in 5 years!
  - ~2017, ORv2, ~12kW/rack
  - ~2021, ORv3, ~18kW to 36kW/rack
  - ~2022, ORv3 HPR (High power rack), ~92kW to 140kW/rack

- Driven by explosive AI computation demand
  - > 2x TFLOPS (in example of FP16) per XPU generation
  - ~2x bandwidth per switch generation
  - ~30% power efficiency improvement with process advancement

ORv3 rack

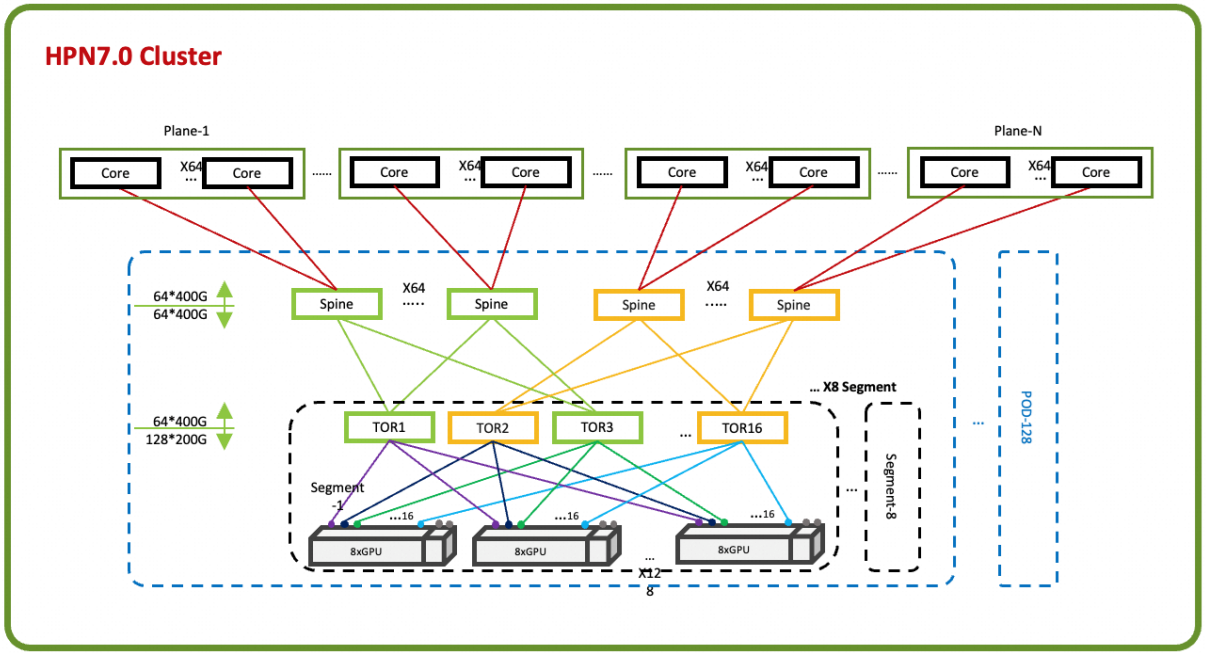
Higher Integration Enables Flatter Network & Power Reduction





Alibaba AI Cluster with 51.2T Tomahawk5

- ~35% system power (with optics) saving compared with 25.6T TH4 in same cluster size
- Develop independent liquid network cooling, not reliant on GPU server liquid cooling



Air Cooling
(Demo show in 2023 APSARA)

2x Switch density

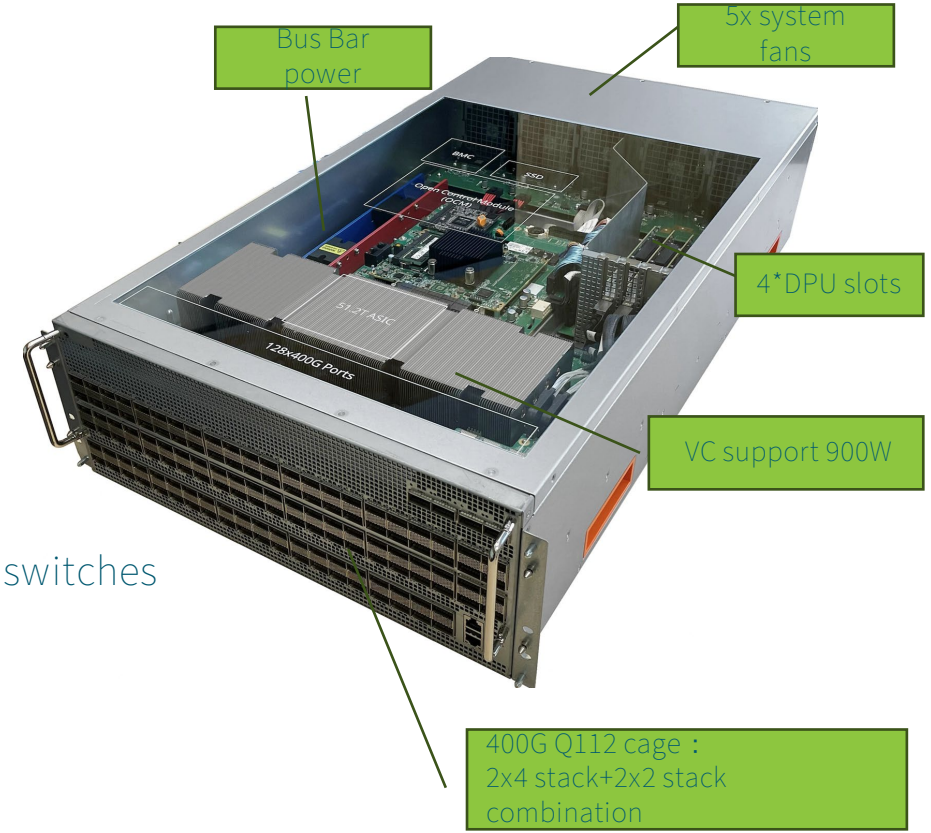
Liquid Cooling

Air Cooling Solution

High Performance & Cost Efficient design

- 4RU design support ***max 35C ambient temp.***
- Two PCB stack design with 128x400G Q112
  - 1*Switch board+1*Line card
- 4+1 Redundancy：80*80*86mm Fans
- Smaller Heat Sink：285*112mm Vapor chamber
- Most design shared between different generation switches

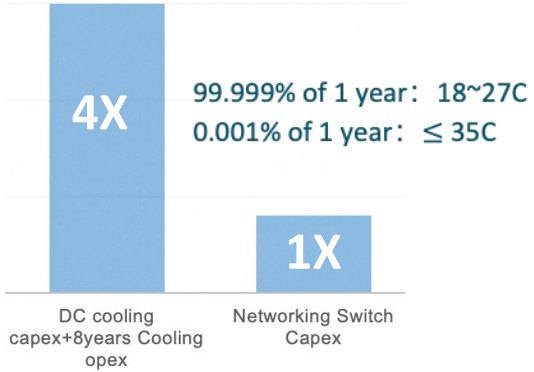
TH4-Migaloo II TH5-Tigatron



Air Cooling Design Practices

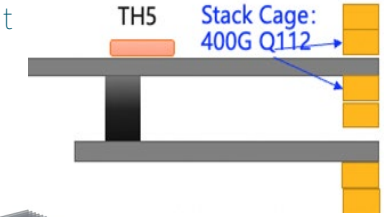
- Practice 1: Reasonable ambient target, no over design

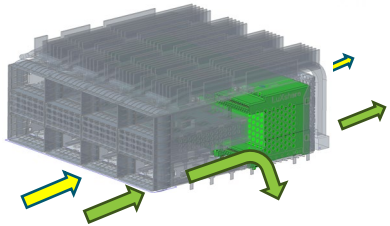
	ASHARE class4	GR-63 core Shelf level	ETSI 300 019 Class 3.1	IEC 60721 Class 3K3
Ambient	5~40C	5~45C	5~40	5~40



- Alibaba Defined Standard based on years of know-how

35C ambient design



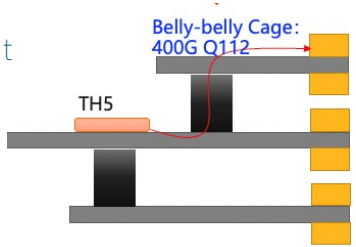


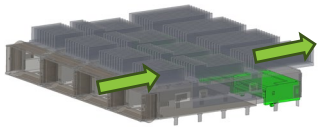
V.S.

< 35C ambient enables

- Millions dollars of saving!
- 4 years successful operating

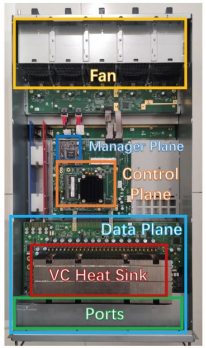
40C ambient design



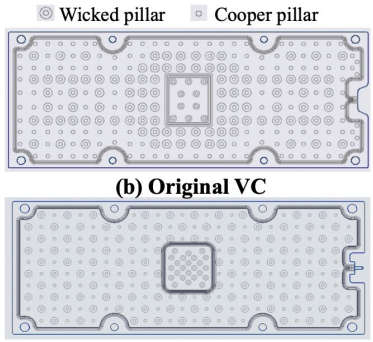


Air Cooling Design Practices

- Practice 2: further optimization beyond simulation under high power density application



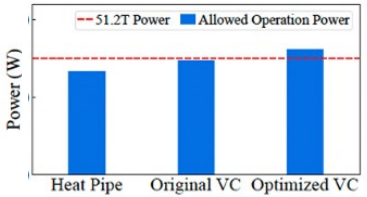
(a) 51.2Tbps single-chip switch



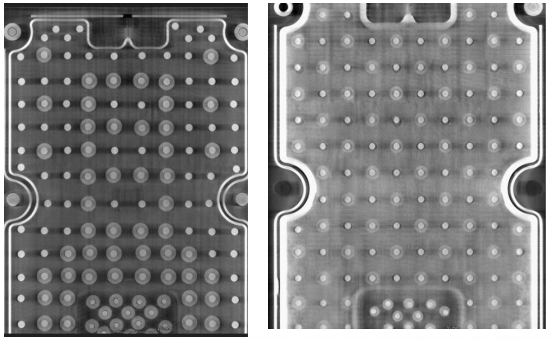
(b) Original VC

(c) Optimized VC

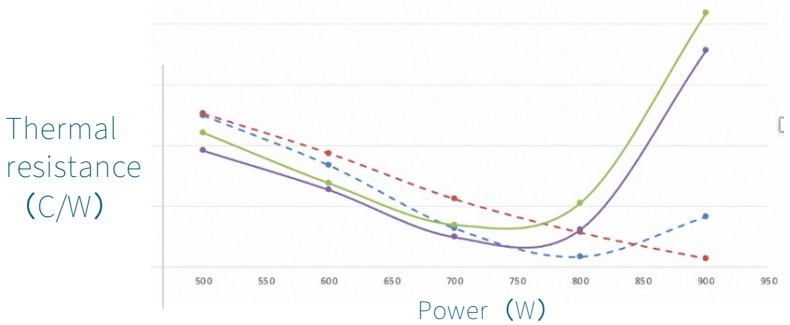
Source: Sigcomm'24 《Alibaba HPN: A Data Center Network for Large Language Model Training》



(b) Cooling efficiency.



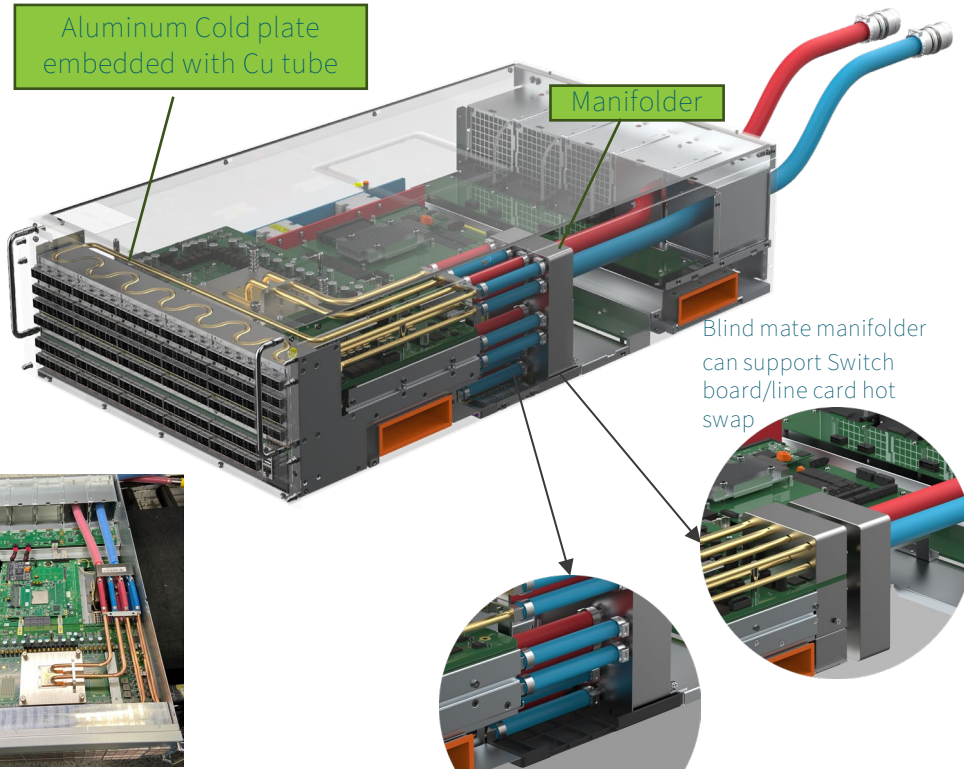
Wick structure optimization and water volume control are critical for air cooling thermal performance improvement



The lower the data on the Y-axis, the better

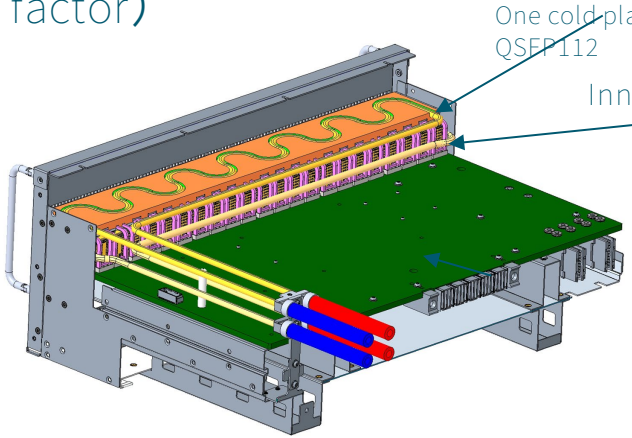
Liquid Cooling Solution

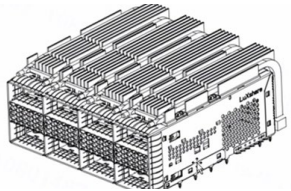
- Driven by Power and Cost Efficiency
- 80% heat carried out by liquid, 20% by air
- Separate high leakage risk area from circuit
- Liquid cooling enables lower grade fan and PSU
  - Liquid fluid: PG25
  - System operation pressure ≤ 2Bar
  - System pressure loss ≤ 55Kpa(including QD)

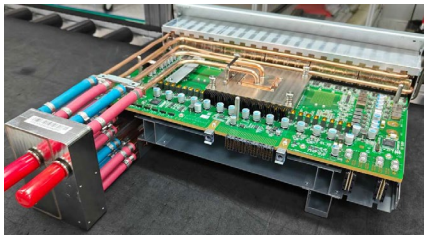


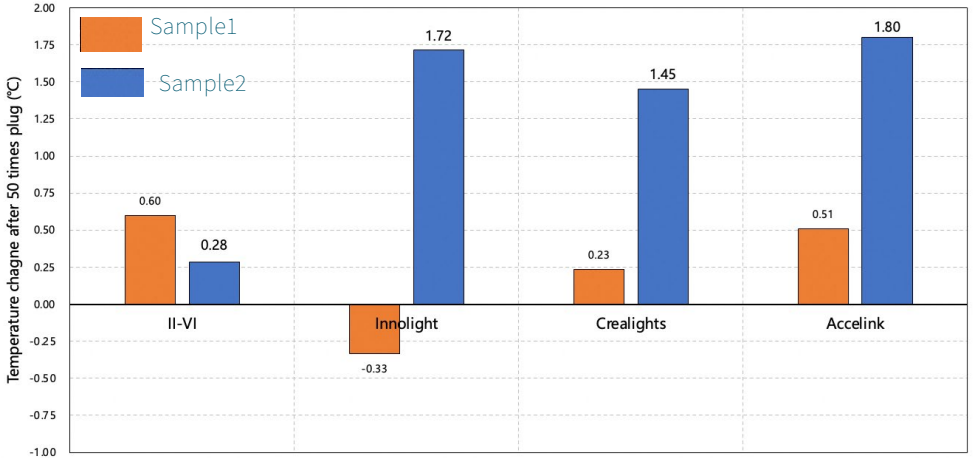
Liquid Cooling Design Practices

- Practice 1: lower cost liquid cooling for stack QSFP112 cage （2x4 and 2x2 form factor）









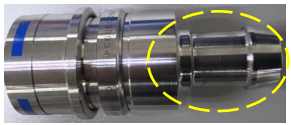
No obvious performance degradation after～50 plug in/out cycles in accordance with SFF and MSA

Liquid Cooling Design Practices

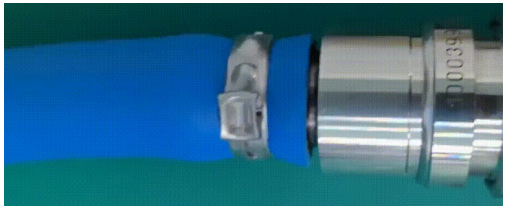
- Practice 2: uncommon but crucial Quick Disconnector test

3 step hose barb

1 step hose barb

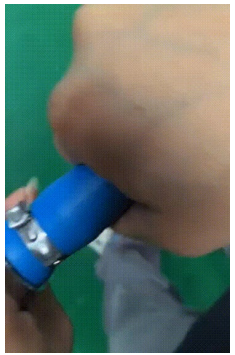


High pressure test

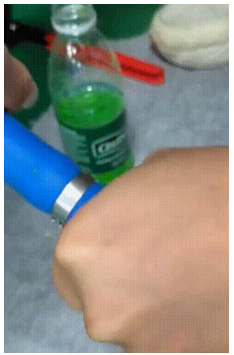


- Uncommon failure: EPDM hose is moving on its own under test condition of 6Mpa which doesn't happen under 4Mpa

Passed under dry contact



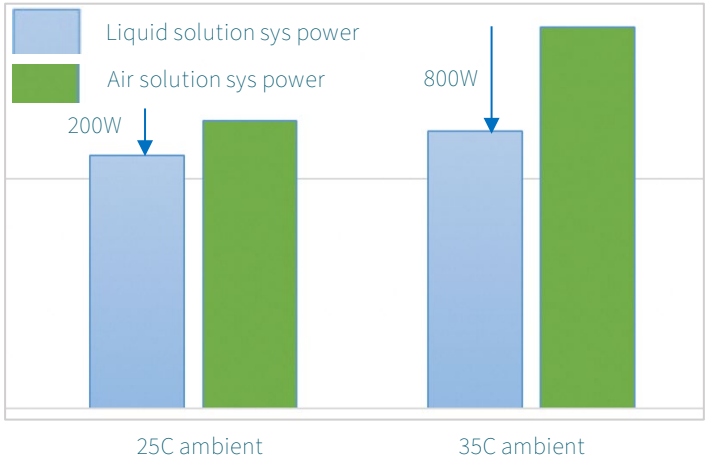
failed under wet contact



- Uncommon failure: EPDM hose is moving with pulled and twisted force when QD connecting is wet.

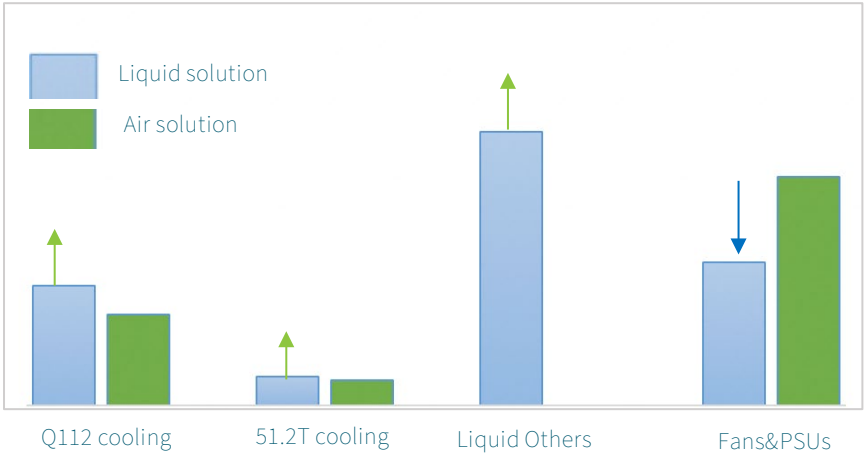
Liquid Cooling is ready for volume ramping

Power



Power saving with liquid cooling enables an additional GPU card

Cost



System wise, liquid cooling cost premium over air cooling is within high single digit %

Call to Action

- Air and liquid cooling are both crucial for high density AI cluster and evolve in parallel
- Require holistic design from silicon, optics, components to system level
- Problem to solve:
    - aim to create a new MSA spec to support 1.6T/3.2T OSFP liquid cooling
- Invite contributions to SONiC, UNP and OCP networking project
    - SONIC : https://lists.sonicfoundation.dev/g/main
    - S^{3}IP UNP : Contact fangbo.zfb@alibaba-inc.com
    - OCP networking : https://www.opencompute.org/projects/networking
- Plan to contribute following spec to OCP before 2025 Q1
    - QSFP112 MSA : http://qsfp112.com/
    - ODCC S^{3}IP Spec : https://www.odcc.org.cn/download/p-1502584148946534401.html

Thank you!