A New Edge Micro Data Center and its Passive Thermosyphon Cooling System at TUe

A NEW EDGE MICRO DATA CENTER AND ITS PASSIVE THERMOSYPHON COOLING SYSTEM AT TUe: COOLING SYSTEM THERMAL PERFORMANCE TESTS

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Extended Abstract

SUMMARY

A new innovative Edge Micro Data Centre and its new passive two-phase cooling system are presented here. EMDC's are hyperconverged heterogenous hardware capacities ranging from 1.8kW up to 500kW. HIRO, providing Powerfull Edge as a Service (PEaaS) is seeking very high cooling energy efficiency (PUE approaching 1.0) and solutions to re-use waste heat from their locally installed EMDC's and edge services that are supporting the big data processing and AI of their customers (smart hospitals, Industry 4.0, 5G/6G MEC, smart cities, smart energy grids). The smallest EMDC with 11 nodes (8 processing and acceleration, 1 ethernet switch, 1 PCIe switch and DC power) is used in the test set-up. The gravity-driven loop thermosyphon cooling system is composed of a compact monoblock for insertion and cooling of 11 EDMC nodes, a riser and downcomer and a compact air-coil condenser cooled by several fans (or by natural convection). The heat of the EDMC nodes is removed by 11 thermal bridges in the monoblock evaporator. In demonstration "stress" tests run at TUe in The Netherlands, monitoring all individual node temperatures and energy consumptions, the cooling system achieved very high cooling performance during all the tests. Defining the PUE here to be equal to the total energy consumption including fans divided by that of only the computer itself, at maximum heat load the PUE was only 1.034 while at medium heat loads using lower fan speeds values as low as 1.007 were recorded and at heat loads of 186 W and below, the fans could be turned off for *completely passive cooling operation*. The IP of this thermosyphon cooling for EMDC's is property of JJ Cooling and HIRO and is subject to further research. HIRO market launch of their first product line of EMDC's is planned for Q3 2024.

1. INTRODUCTION

A new innovative Edge Micro Data Centre together with its new passive two-phase cooling system is presented here. Then, the bench test results for its 11 EDMC node computer are presented. The computer system is described (in only necessary detail) while the focus is on the new thermosyphon cooling system. After describing its features, thermal tests are presented illustrating its cooling performance and low energy consumption (or no fan power at all) during some stress tests done at TU Eindhoven, one of the BRAINE project members, where the entire system (actually two complete systems) were installed for the Case Studies of other project members to be run.

2. DESCRIPTION OF EDGE COMPUTER AND THERMOSYHON COOLING SYSTEM

The EMDC is based on Industry standard (Com Express) and modular so that it can have any combination and number of CPU's, FPGA's, GPU's and NVMe storage connected via a dual fabric (Ethernet and PCIe) in a passive backplane. This allows the EMDC to be configured for any type of application and sized in any capacity from 1.8kW up to 500kW (container size). A monolithic machined aluminum monoblock cooling system, is mounted on the backplane and provides the mechanical positioning and thermal interface for the nodes. A node can carry a CPU, FPGA, GPU, Switch or nVMe, see Figure 1 (left). EMDC's capacity scales with 8 nodes, from 8, 16,24 nodes in mobile enclosures to 48, 96, etc. in rack mounted containerised EMDC's. The modular design allows for a very compact, robust and easily maintainable configuration, capable of dissipating all generated heat. The modular design allows for a very compact, robust and easily replaceable configuration, capable of dissipating all generated heat. The thermal design and simulations of the thermosyphon, see Figure 1 (right), were done using JJ Cooling Innovation's internal thermosyphon, micro-evaporator coldplate and compact air-coil codes. These have been described elsewhere ([1] and [2]).

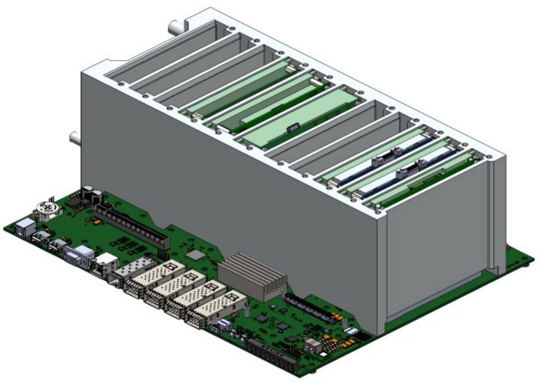
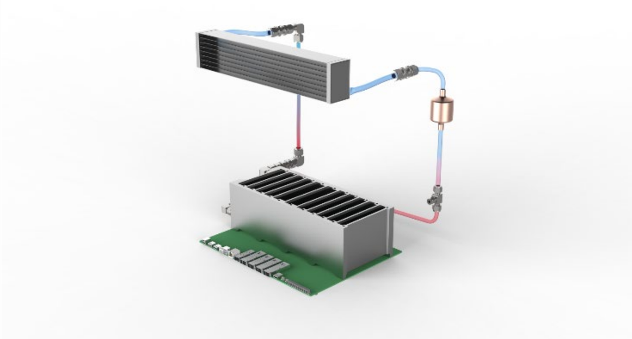

Figure 1. Left: Edge computer, backplane and monoblock. Right: Image of layout of thermosyphon cooling.

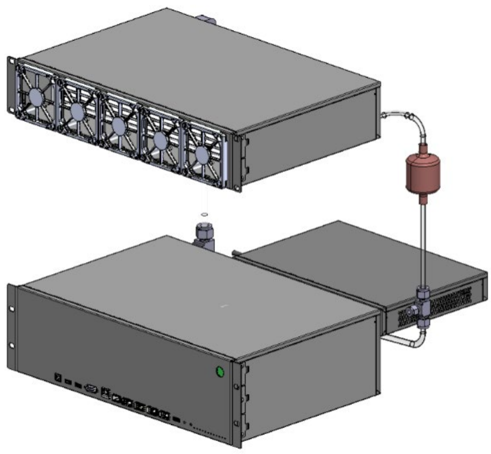


Figure 2. Left: Drawing showing how the Edge computer and its cooling system can be installed in a rack; Right: Photo of the installed micro data center.

Because the enormous density of the EMDC processing power, AI acceleration and system memory, an exceptional amount of heat must be dissipated from a limited volume. Proper cooling of EMDC nodes is an essential part of the EMDC, and lowers hardware failure rates by a factor 10, lowers risk of overheating and keeps the cXU's in their optimal performance temperature range. The solution shown in Figure 2 (left) also needs to minimize the expansion and contraction due to temperature fluctuations that can cause intolerable stresses on the PCB's and connectors. Therefore, controlling tolerances has formed an important focus to make this work. To handle this and find a very efficient, compact cooling solution, an innovative thermosyphon cooling system (Figure 2, right) has been developed based on a monoblock plus an external condenser in which the coolant circulates by gravity without the aid of moving parts. The heat is absorbed by the evaporating coolant in the thermal "bridges" of the monoblock, and then it is exhausted to the environment with (or without) fans in the overhead air-coil condenser. Each individual PCBs covered with a custom heat spreader (not shown), and is firmly pressed to the thermal bridge of the monoblock by means of industry standard wedge locks.

The EDMC and its thermosyphon cooling system consists of the 11-EDMC nodes and the separate external condenser. Figure 2 (right) illustrates how it can be installed, if wished, into an electronics or computer rack. In the present case, this is a 19-inch rack where the EMDC fits into the height of a 3U 19-inch rack and the condenser fits into the height of a 2U 19-inch rack. The FPGA module has been developed as an external 1U size unit and connects to the backplane with a PCI-e connector. As depicted in Figure 3, the EDMC electronics are enclosed in a versatile housing (no fans and thus no noise or vibration) that can be installed in a variety of ways, such as with a separate heat exchanger module that can be positioned the wall above it internally inside the building or externally on the outside wall of the building. Notably, the system can be expanded to handle double or triple the number of nodes shown here. Alternatively, the system can be housed in a computer rack.

Figure 3. System versatility. Left: The image shows the system being wall-mounted with its air-coil installed on inside or outside of the building wall depending on where the heat is to be dissipated. Right: The image shows the system mounted in a rack.

3. RESULTS

The entire system was installed at the Technical University of Eindhoven (TUe) in The Netherlands. Algorithms and instrumentation we set up to monitor the temperature of each node using its internal thermometer and the energy consumption of each mode and that of the controller/fans. Then, a series of operational "stress" tests were run to validate the entire system and the cooling system. The tests were run across four days in the laboratory at room air temperatures measured to vary from 20.4°C to 21.6°C. Figures 4 and 5 show the thermal test results at several representative operating conditions.

Figure 4. Left: Test results with fan set at 40% of PWM to operate all nodes without any throttling for PUE = 1.034; Right: Test results with ARM off and fans off…completely passive cooling.

Figure 5. Left: Test results for Standard (PWM Default) with ARM node throttling at PUE = 1.016; Right: Fan power as % of PWM, temperatures and energy consumptions measured over time.

The cooling system achieved very good cooling performance during all the tests, with the controls on the fans running the fans only at the speed necessary to keep the maximum temperature below that of the maximum allowable of the hottest node. Furthermore, during the cold startup, it can be seen there is no overshoot of the nodes' temperatures and that steady-state is quickly reached.

Addressing energy-efficient cooling, defining the PUE here to be equal to the total energy consumption including fans divided by that of only the computer itself, at maximum heat load the PUE was only 1.034 while at medium heat loads using lower fan speeds values as low as 1.007 were recorded and at heat loads of 186 W and below, the fans could be turned off for *completely passive cooling operation*.

CONCLUSIONS

The description of a new Edge computer and its passive thermosyphon cooling system are presented. The thermal test results from several "stress" tests are presented, showing that all nodes remain safely (significantly below) their maximum operating temperature limits. The test results also demonstrated very efficient cooling using the thermosyphon and the external air-cool cooled by fans. Very low PUE's were obtained and COMPLETELY PASSIVE COOLING was achieved at partial loading using only natural convection on the air-coil.

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4. REFERENCES

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[2] Minazzo, Enzo M., Rouaze, Gautier, Marcinichen, Jackson B., Thome, John R. and Buining, Fred. "Thermal-hydraulic Characterization of Thermosyphon Cooling System for Highly Compact Edge Microdatacenter. Part II: Solver Validation", INTERPACK 2023, October 24-26, 2023, San Diego