THE CHINESE UNIVERSITY OF HONG KONG
Faculty of Engineering

Application Form for Overseas Research Attachment Programme (ORAP)
for PhD Students
Summer Term, 2024-25

Note:
Students interested in the attachment programme should submit the completed application form and the following documents to Faculty Office, at Room 606, Ho Sin Hang Engineering Building or by email submission to wwcheung@cuhk.edu.hk or carmanfung@cuhk.edu.hk on or before **12 noon, 3 March 2025**:
- an up-to-date CV, and
- the letter from the overseas mentor confirming the support to be made, including financial support, if any and related research support facilities

SECTION 1 - PERSONAL PARTICULARS

Name: (English)	**Junliang Hu**	(Chinese)	胡俊良
CU Student ID:	**1155167045**	Year of study:	**4th-year**
Programme:	**PhD Computer Sci & Erg**	Cumulative GPA:	**3.633**
Name of Supervisor:	**Ming-Chang Yang**		
Mobile:	**+852 66704983**	Email:	**jlhu@cse.cuhk.edu.hk**
Office address:	**Room 921, Ho Sin Hang Engineering Building (SHB)**		
Applicant Signature:			

SECTION 2 – LIST OF PUBLICATIONS
Please state below your publications in chronological order.

Title of publication	Type of publication (e.g. journal article, conference paper)	Publication venue (title of journal/ conference)	Publication date (Day/Month/Year)
Aceso: Achieving Efficient Fault Tolerance in Memory-Disaggregated Key-Value Stores	Conference Paper	ACM SIGOPS 30th Symposium on Operating Systems Principles (SOSP '24)	04/11/2024
SEPH: Scalable, Efficient, and Predictable Hashing on Persistent Memory	Conference Paper	17th USENIX Symposium on Operating Systems Design and Implementation (OSDI '23)	10/07/2023

SECTION 3 – PROPOSED RESEARCH PLAN

Host University / Institution: **Virginia Tech**

Country: USA Period: From 01/06/2025 (DD/MM/YYYY) to 31/12/2025 (DD/MM/YYYY)

Name of Mentor(s): **Huaicheng Li**

Research Area(s) Operating Systems; Cloud Computing; Serverless Systems;

Research Plan *(Please use the space provided)*

Guest-Empowered Tiered Memory Management in Virtualized Cloud Environments

1. Introduction and Background

Cloud computing has increasingly adopted tiered memory architectures to expand memory capacity while maintaining cost-effectiveness. However, traditional tiered memory management in virtualized environments faces challenges in isolation, elasticity, and efficiency. Existing hypervisor-based solutions lack guest involvement, leading to suboptimal memory allocation and significant CPU overhead.

This research aims to explore an alternative approach where guest operating systems actively manage tiered memory placement while the hypervisor ensures elastic and isolated memory provisioning. Our proposal, HyperTier, integrates guest-driven tiered memory management with virtualization-aware optimizations to improve scalability and reduce overhead.

2. Research Objectives

- Develop a virtualization-compatible tiered memory management system that balances performance, isolation, and elasticity.
- Design a novel elastic tiered memory provisioning mechanism (HyperFlex) to dynamically allocate fast and slow memory tiers.
- Optimize guest-side tiered memory management (HyperPlace) to minimize CPU overhead while ensuring efficient memory placement.
- Evaluate the proposed system on real-world cloud workloads, including databases, scientific computing, graph processing, and machine learning.

3. Literature Review

Several research efforts have explored tiered memory management in cloud environments:

- OS-Level Approaches: Systems like Thermostat [1] and Memtis [2] optimize tiered memory within a single OS but lack virtualization support.
- Hypervisor-Based Approaches: Solutions like HeteroVisor [3] and RAMinate [4] manage tiered memory at the hypervisor level, but they impose high CPU overhead and compromise guest autonomy.
- Performance Monitoring Unit (PMU) Sampling [5]: Recent advances in PMU-based memory access sampling provide opportunities for low-overhead hot data classification in virtualized environments.

Our research extends these approaches by integrating hypervisor-assisted tiered memory provisioning with guest-optimized memory placement.

4. Methodology and Approach

- HyperFlex: Tiered Memory Provisioning
  - Implements a fine-grained, elastic memory allocation mechanism.
  - Uses NUMA-aware virtualization techniques to expose memory tiers to guests.
  - Supports dynamic inflation and deflation of memory tiers via a virtualized ballooning mechanism.
- HyperPlace: Guest-Side Hot Data Management
  - Utilizes PMU-based sampling to classify frequently accessed memory pages.
  - Employs a segment-tree-based classification algorithm to rank memory hotness.
  - Implements a symmetric exchange mechanism to migrate hot and cold data efficiently.
- Evaluation and Benchmarking
- Compare HyperTier against existing tiered memory solutions.

Research Plan (cont'd)

- Test performance on workloads such as:
  - Databases: B-tree index operations, OLTP transactions (Silo).
  - Scientific Computing: Blast wave simulation, nuclear reactor modeling.
  - Graph Processing: Graph500, PageRank.
  - Machine Learning: Large-scale linear classification.

5. Expected Outcomes

- Improved performance: Reduction in CPU overhead compared to existing hypervisor-centric approaches.
- Enhanced scalability: Support for multiple virtual machines with minimal performance degradation.
- Better resource utilization: More efficient use of fast and slow memory tiers, reducing total cost of ownership (TCO).
- Open-source implementation: Release of HyperTier's codebase for reproducibility and further research.

6. Timeline

- Month 1: Literature review, finalizing research plan.
- Month 2: Develop HyperFlex provisioning module.
- Month 3: Implement HyperPlace optimization.
- Month 4: Integration and performance testing.
- Month 5: Benchmarking and evaluation on real workloads
- Month 6: Paper writing and final submission

7. Resources and Collaborations

Host Institution Facilities:

- Access to cloud computing testbeds with tiered memory configurations.
- Virtualized environments supporting PMEM and CXL.mem.
- Performance monitoring and profiling tools.

Collaboration Opportunities:

- Engage with researchers specializing in virtualization and memory management.
- Work with cloud providers to validate the feasibility of deployment at scale.

8. References

[1] Neha Agarwal and Thomas F. Wenisch. 2017. Thermostat: Application-transparent Page Management for Two-tiered Main Memory. In Proceedings of the TwentySecond International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS '17), 2017. Association for Computing Machinery, New York, NY, USA, 631–644. https://doi.org/10.1145/3037697.3037706

[2] Taehyung Lee, Sumit Kumar Monga, Changwoo Min, and Young Ik Eom. 2023. MEMTIS: Efficient Memory Tiering with Dynamic Page Classification and Page Size Determination. In Proceedings of the 29th Symposium on Operating Systems Principles (SOSP '23), 2023. Associ- ation for Computing Machinery, New York, NY, USA, 17–34. https:// doi.org/10.1145/3600006.3613167

[3] Vishal Gupta, Min Lee, and Karsten Schwan. 2015. HeteroVisor: Exploiting Resource Heterogeneity to Enhance the Elasticity of Cloud Platforms. In Proceedings of the 11th ACM SIGPLAN/SIGOPS Interna tional Conference on Virtual Execution Environments (VEE '15), 2015. Association for Computing Machinery, New York, NY, USA, 79–92. https://doi.org/10.1145/2731186.2731191

[4] Takahiro Hirofuchi and Ryousei Takano. 2016. RAMinate: Hyper- visor-based Virtualization for Hybrid Main Memory Systems. In Proceedings of the Seventh ACM Symposium on Cloud Computing (SoCC '16), 2016. Association for Computing Machinery, New York, NY, USA, 112–125. https://doi.org/10.1145/2987550.2987570

[5] Amanda Raybuck, Tim Stamler, Wei Zhang, Mattan Erez, and Simon Peter. 2021. HeMem: Scalable Tiered Memory Management for Big Data Applications and Real NVM. In Proceedings of the ACM SIGOPS 28th Symposium on Operating Systems Principles (SOSP '21), 2021. Association for Computing Machinery, New York, NY, USA, 392–407. https://doi.org/10.1145/3477132.3483550

SECTION 4 – RECOMMENDATION OF THE SUPERVISOR

RECOMMENDATION (Please use the space provided)

To the ORAP Selection Committee,

I am pleased to write this recommendation in strong support of Junliang Hu's application for the Overseas Research Attachment Programme (ORAP) for the 2024-25 academic year.

Junliang is an exceptionally talented and passionate researcher in the field of operating systems (OS). He has demonstrated an outstanding commitment to OS research, beginning with his undergraduate studies, where he engaged in multiple experimental OS kernel development projects. During his PhD at CUHK, he has continued to excel, publishing two research papers in OSDI and SOSP, the most prestigious conferences in the OS field. His achievements place him among the top young researchers in this highly competitive domain.

Virginia Tech, where Junliang will conduct his research attachment, ranks in the top tier for the area of OS according to CSRankings. Under the mentorship of Prof. Huaicheng Li—a rising star researcher in the broad field of computer systems—Junliang will have the opportunity to work in a top-tier research environment. His expertise in systems-level optimizations for storage and memory technologies aligns closely with Junliang's research interests, making this attachment an excellent match.

Additionally, this research visit will not only be highly beneficial for Junliang's academic and professional development but will also strengthen CUHK's global collaborations and visibility in the OS community. By engaging in high-impact research at Virginia Tech, Junliang will bring back valuable knowledge, foster further collaborations, and enhance CUHK's standing in the field. Given his proven research excellence and dedication, I am confident that this attachment will be highly productive and yield meaningful outcomes, including publications in top conferences.

Thus, I strongly endorse Junliang Hu's application and believe that his research attachment at Virginia Tech will be an invaluable experience for both him and CUHK.

Signature of Supervisor: Ming Chang Yang Date: 2 March 2025

Name of Supervisor: Ming-Chang Yang

The data collected will be kept confidential and used by the Engineering Panel to process the selection.

Overseas Research Attachment Programme (ORAP) 2024-25

SECTION 5 – ENDORSEMENT OF THE GRADUATE DIVISION HEAD

Graduate Division is expected to continue the Postgraduate Studentship (PGS) support to the applicant and make proper arrangements for teaching and other divisional duties during the attachment period of the applicant.

To be completed by Graduate Division

Our Graduate Division confirms to support HU Junliang *(name of applicant)* *(Student ID:* 1155167045 *)* for his/her application for the Overseas Research Attachment Programme. We shall continue to provide the Postgraduate Studentship during the proposed attachment period from 06/2025 *(mm/yyyy)* to 12/2025 *(mm/yyyy)*.

Signature of Graduate Division Head: 

Name of Graduate Division Head: Professor TAO Yufei

Date: 03 MAY 2025