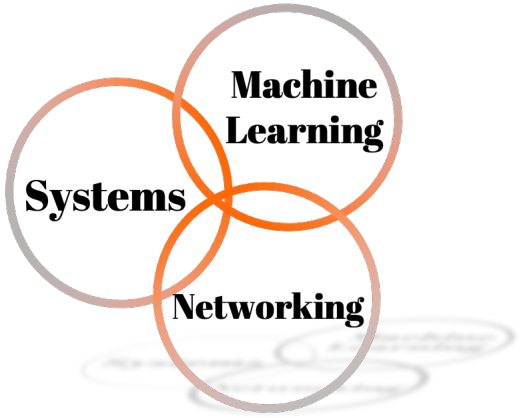
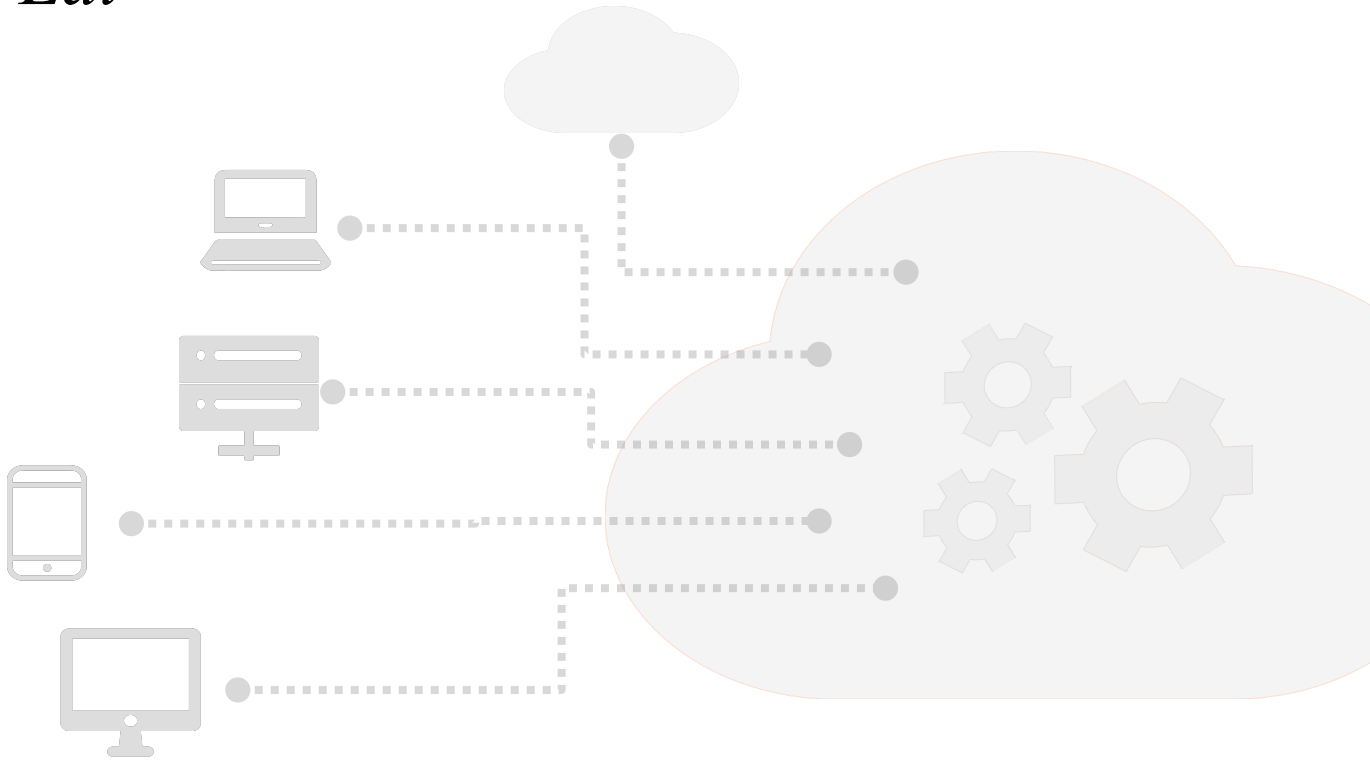


CS 598: Systems for GenAI

Instructor: Fan Lai



ILLINOIS

About Fan

- **Assistant Professor in CS**
  - PhD'23: "Minimalist Systems for Pervasive Machine Learning''
- **Research interest**
  - Cloud ML (LLMs, Image/Video Gen)
  - Collaborative ML (on-device AI), ML4Sys

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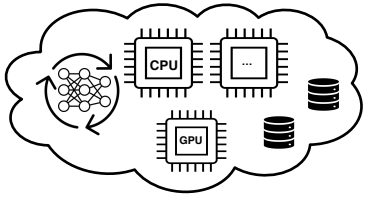

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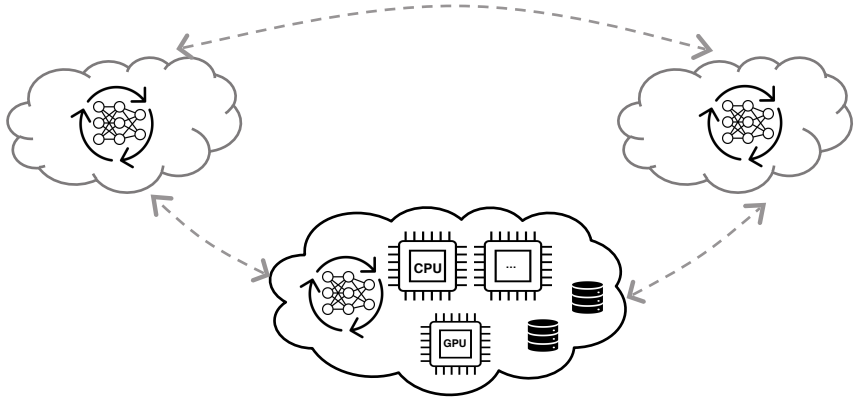

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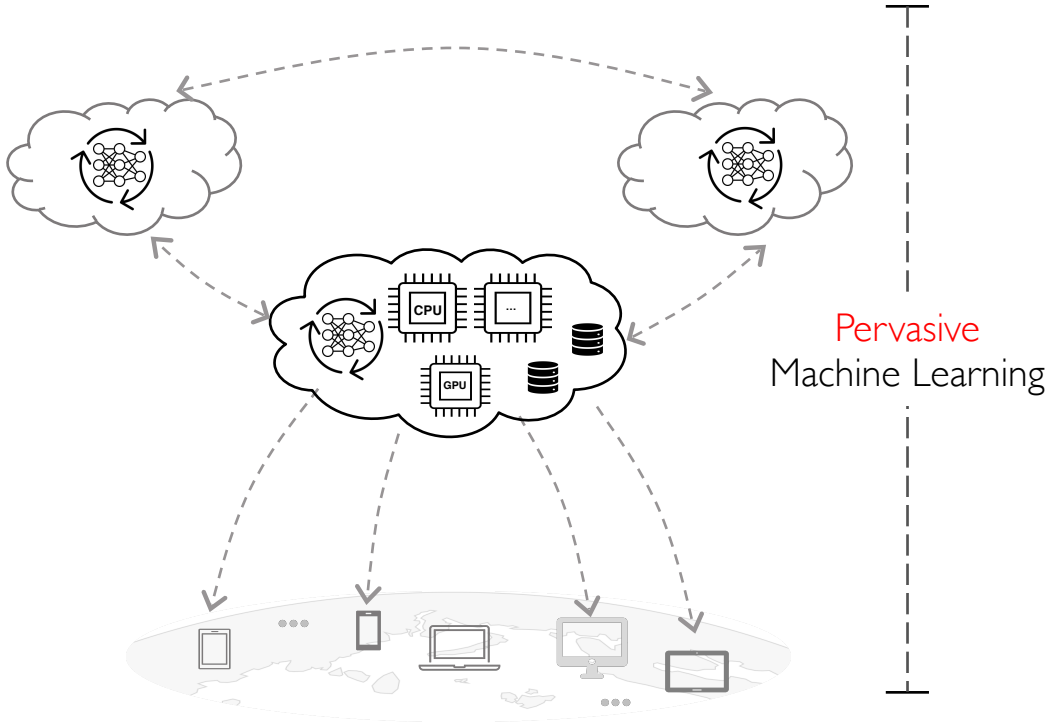

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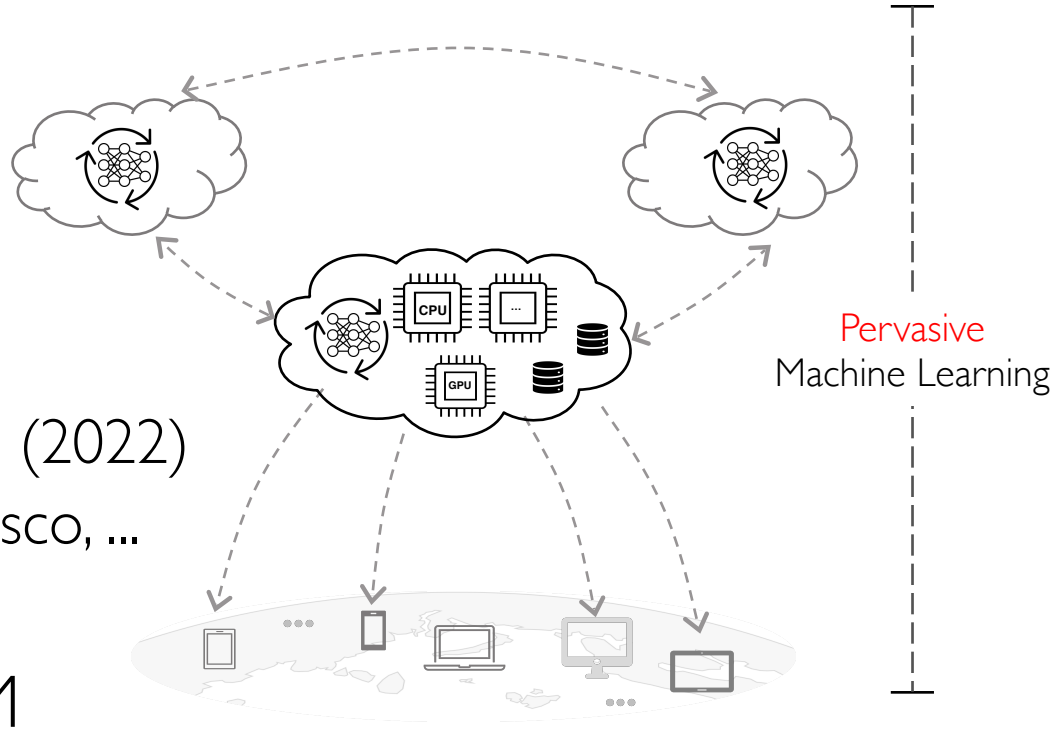
- **Research interest**
  - Cloud ML (LLMs, Image/Video Gen)
  - Collaborative ML (on-device AI), ML4Sys
- **Industry**
  - Visiting Faculty@Google (2023-2024), Meta AI (2022)
  - MLSys adoptions at Google, Meta, LinkedIn, Cisco, ...
- **Office hours:** SC 3128, Friday 2 PM – 3 PM



About Chengsong Zhang (TA #1)

- **Research on image generation**
- **Created several Stable Diffusion WebUI Extensions**
  - Segment Anything (Github 3.3k stars)
  - AnimateDIFF extension (Github 3k stars)
- **Office hours from next week**
  - Zoom, Wednesday 7 PM - 8 PM

About Jimmy Shong (TA #2)

- **Research on hyper-scale model training**
- **Worked on On-Device LLM Chatbot at MIT**
  - TinyVoiceChat (Github ~800 stars)
- **Office hours from next week**
  - Zoom, Wednesday 7 PM - 8 PM

Status and Prerequisites

- **As of today: ~92 registered**
  - If you are not planning to take the class, please drop ASAP

Status and Prerequisites

- **As of today: ~92 registered**
  - If you are not planning to take the class, please drop ASAP
- **Systems Courses: OS/databases/distributed systems/networking**
  - Equivalent courses are acceptable as well
- **ML/AI course is helpful but not required**
- **Good programming skills** (e.g., PyTorch, TensorFlow, ...)
  - Build systems for course project

Course Schedule

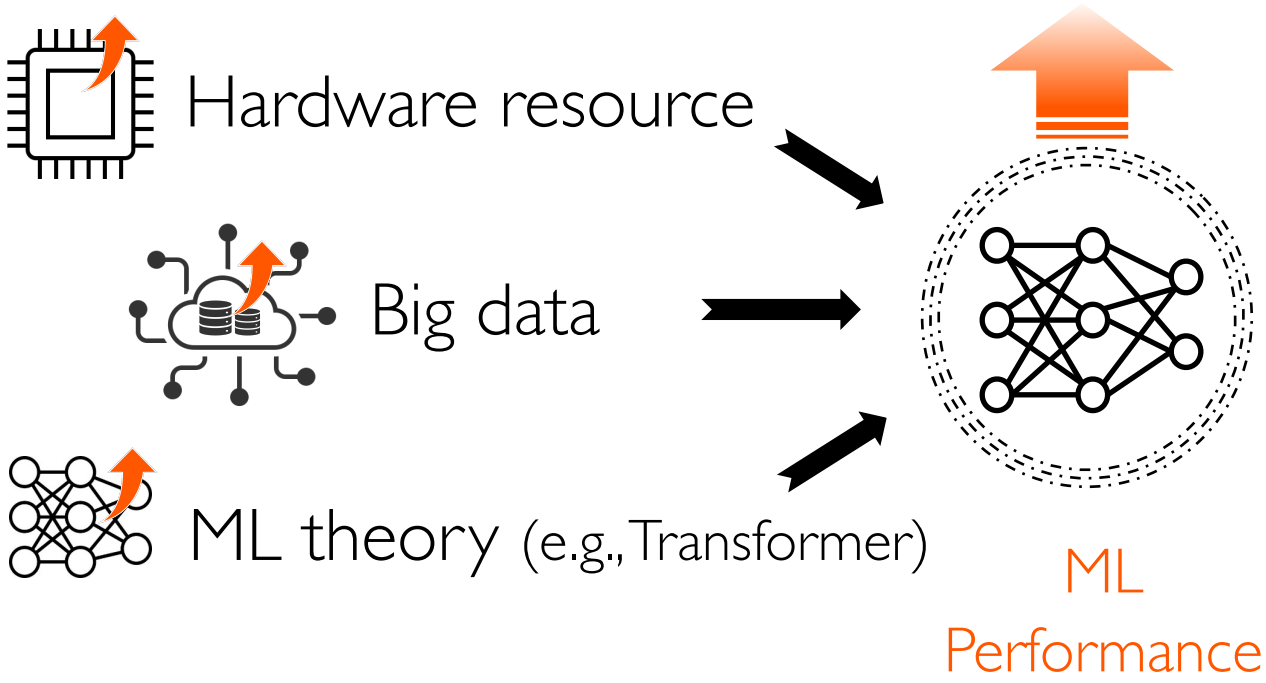
- Webpage: https://github.com/fanlai0990/cs598
- Discussion, Questions: Please Use Piazza
- In-person lectures, discussion
- Feel free to drop us email too :)

Agenda

- What will you learn in this course?
  - GenAI, systems, networks, ...
- What will you do in this course?
  - Participation, presentation, research project, ...

What Do We Talk About When We Talk About "Systems for GenAI"

Cloud Enabled Last Leap in Machine Learning (ML)



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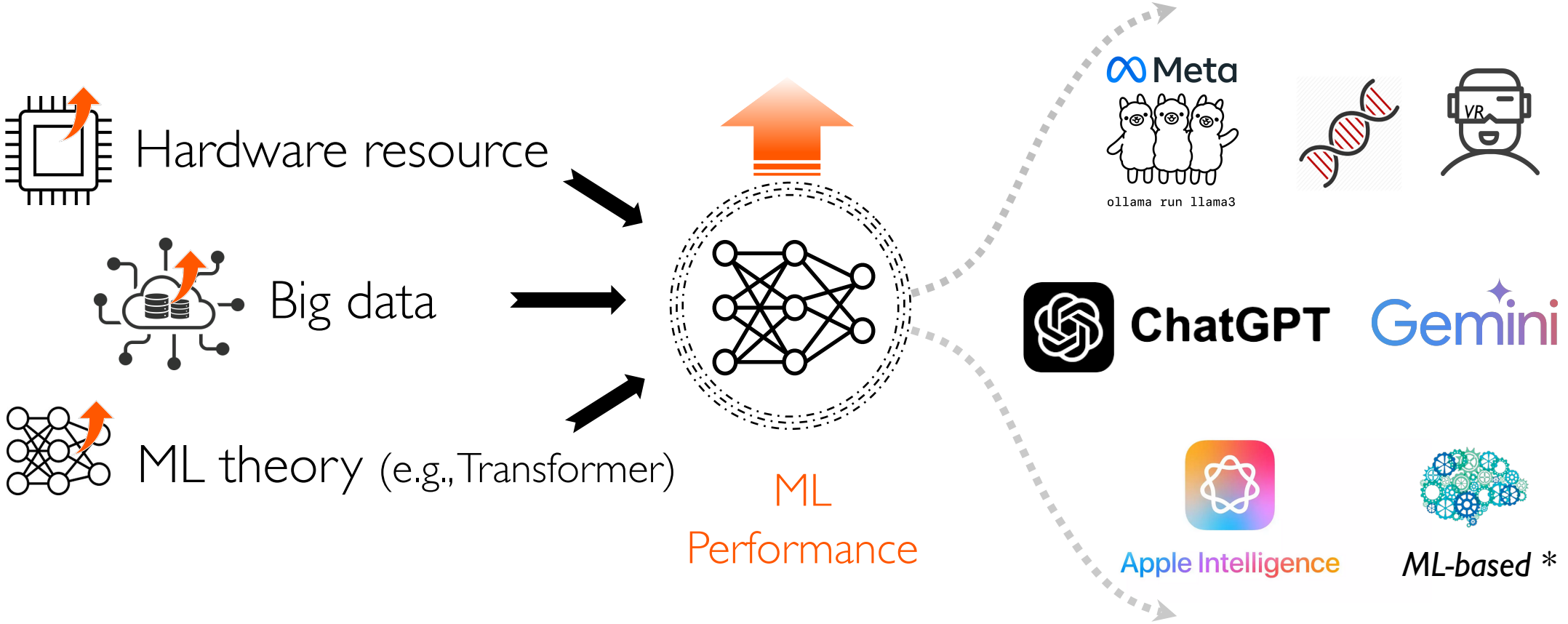
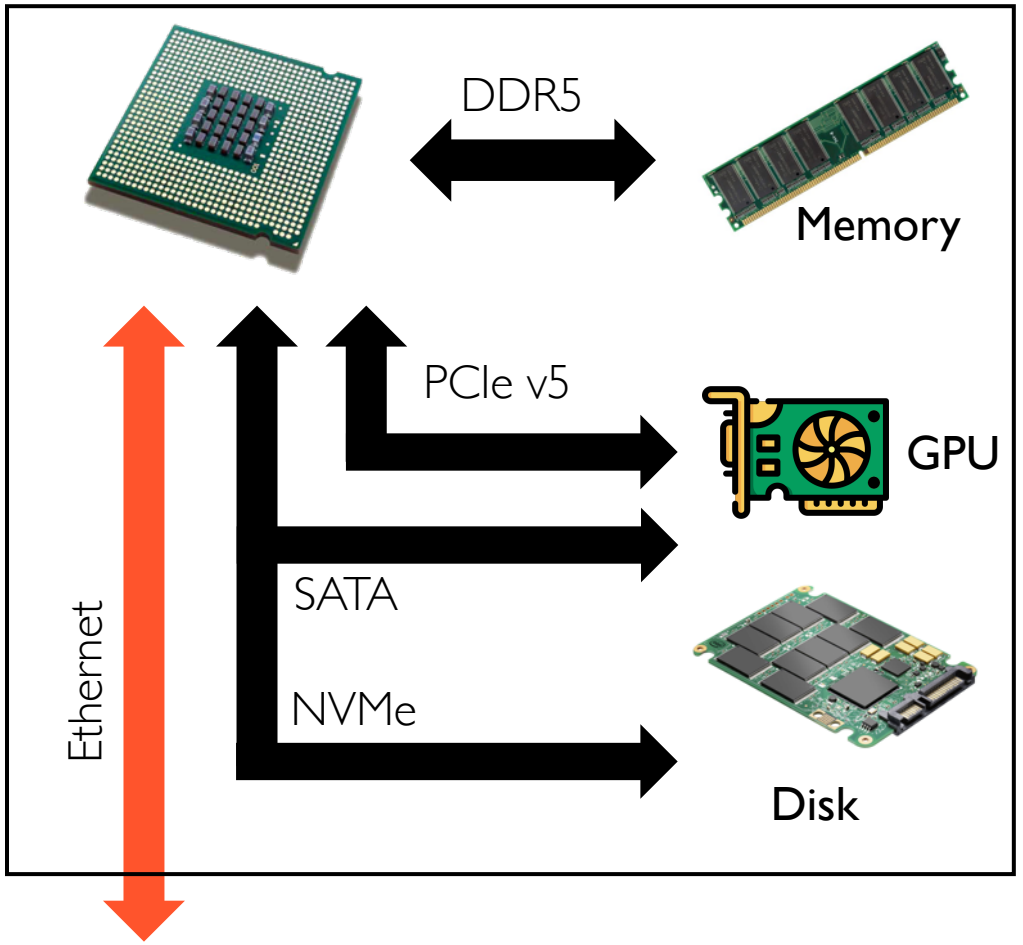


What's in a (Simplified) AI Server?

- **Interconnected compute and storage resources**



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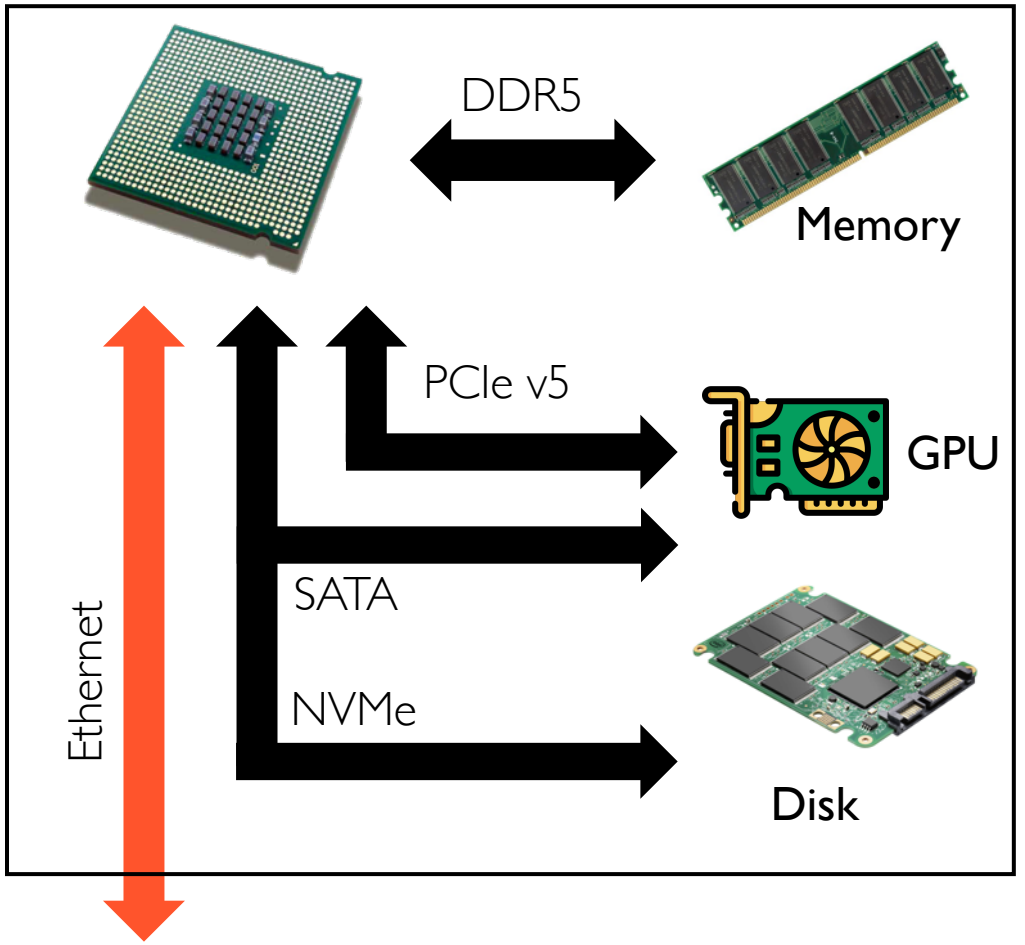

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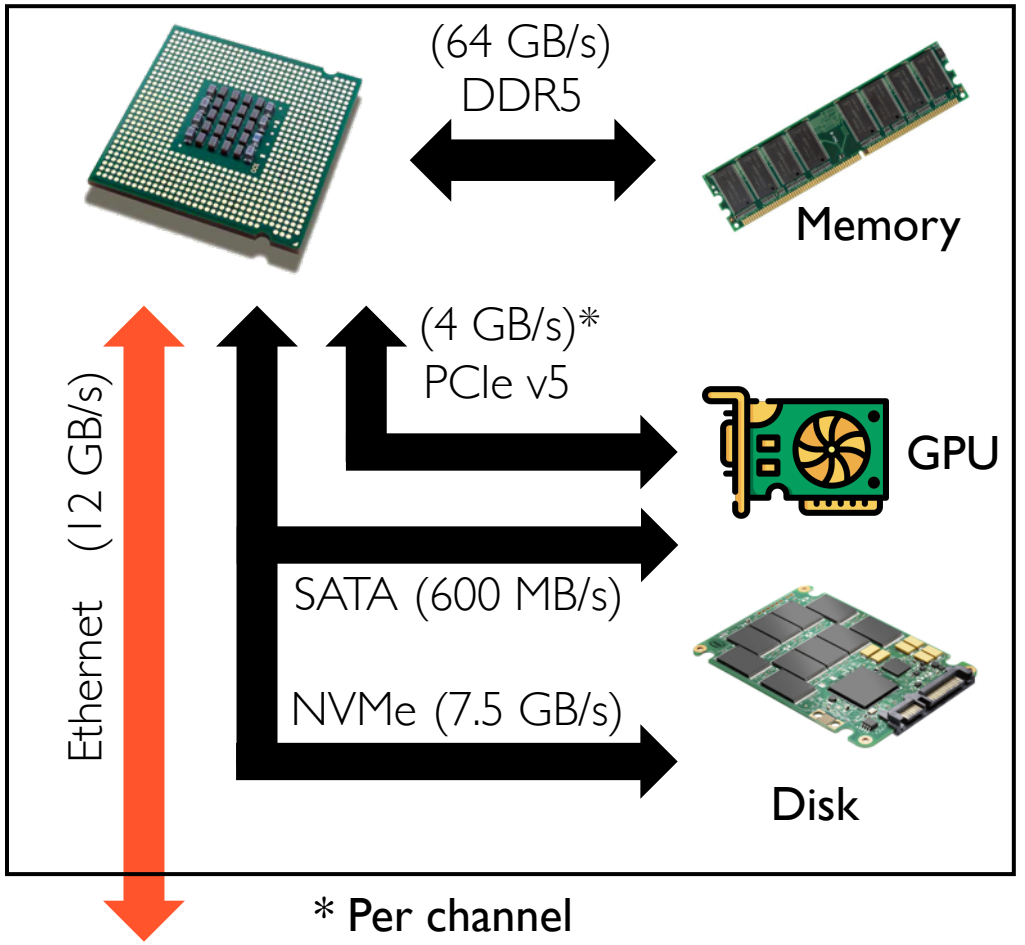
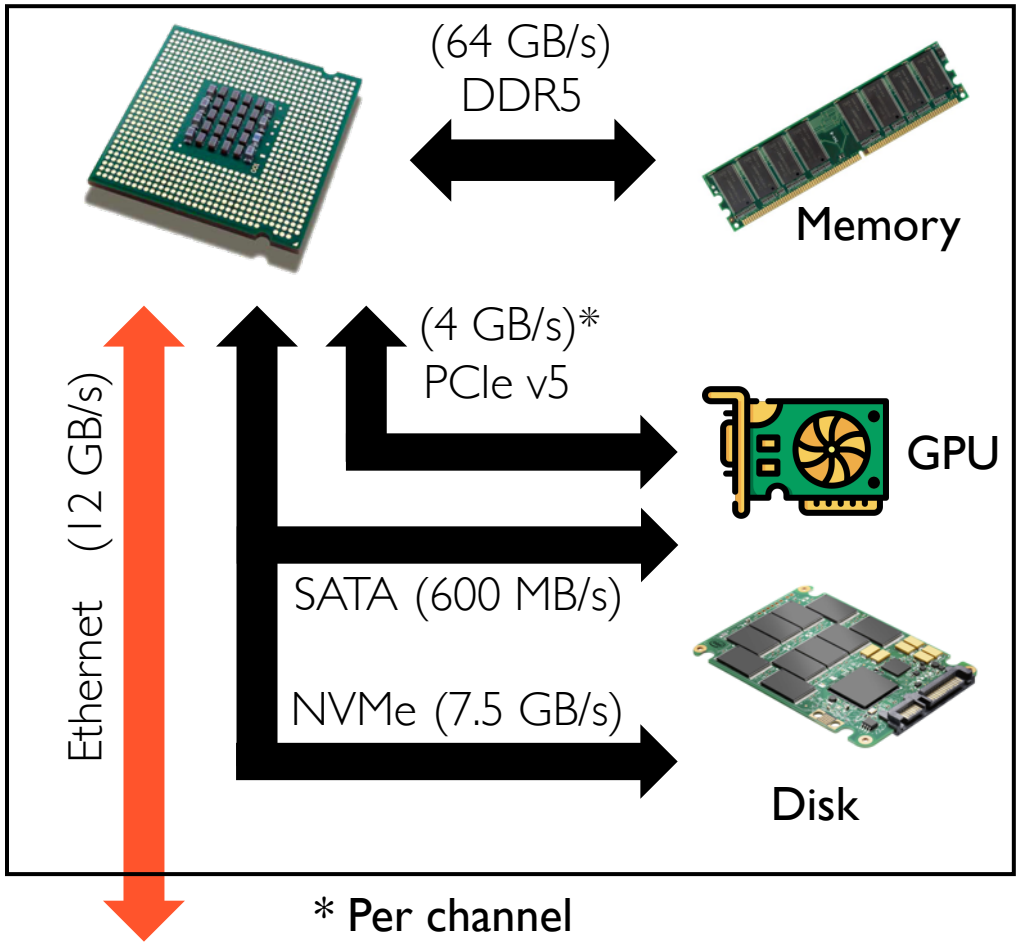
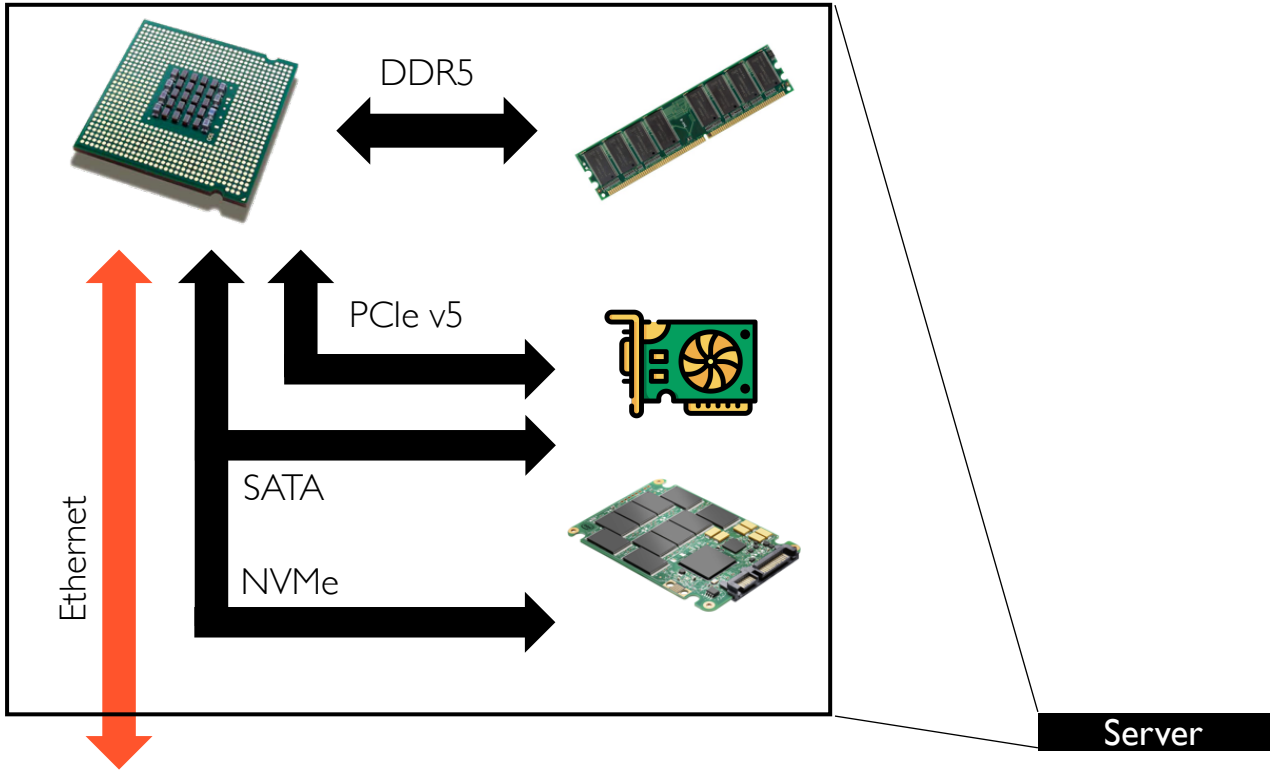


What's in a (Simplified) AI Server?

- **Interconnected compute and storage resources**
  - Different bandwidth and latency constraints
- **Simplified diagram**
  - Doesn't include faster networks such as RDMA, dedicated GPU interconnects such as NVLink



Cloud Datacenter: Scale-Out Servers



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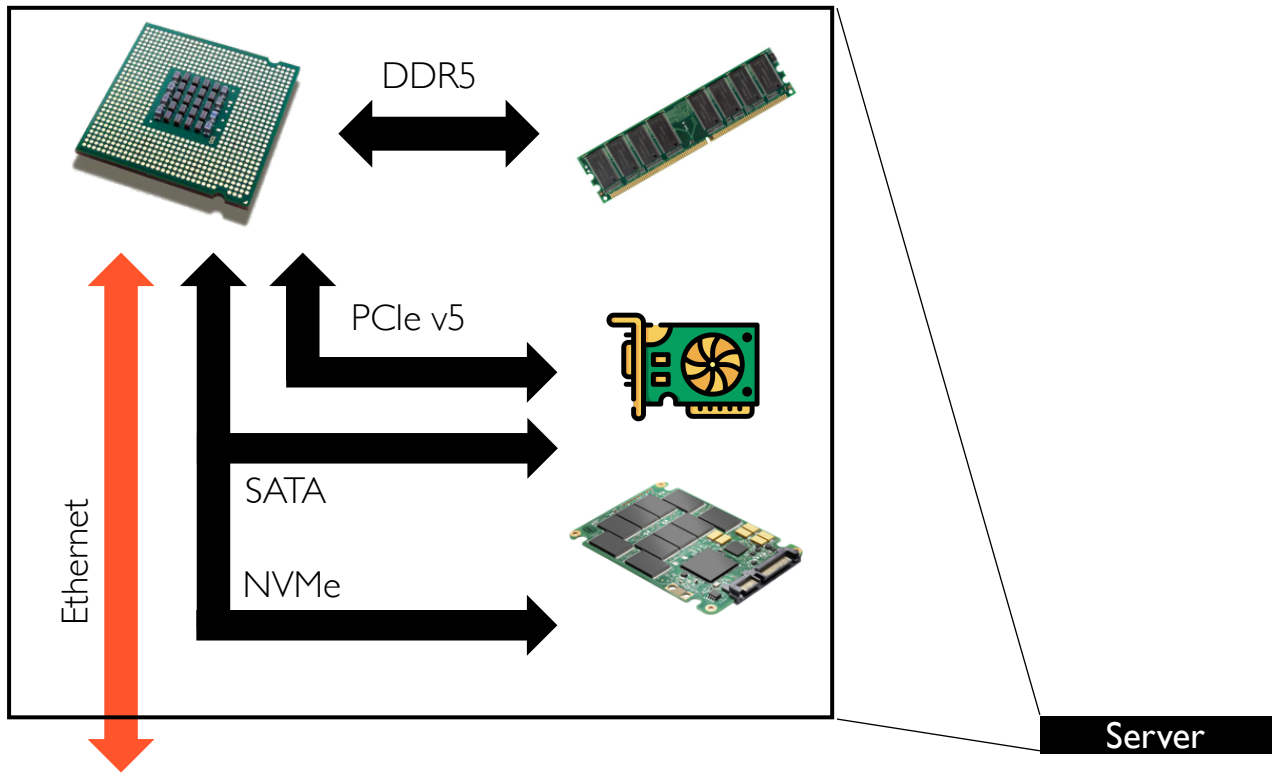
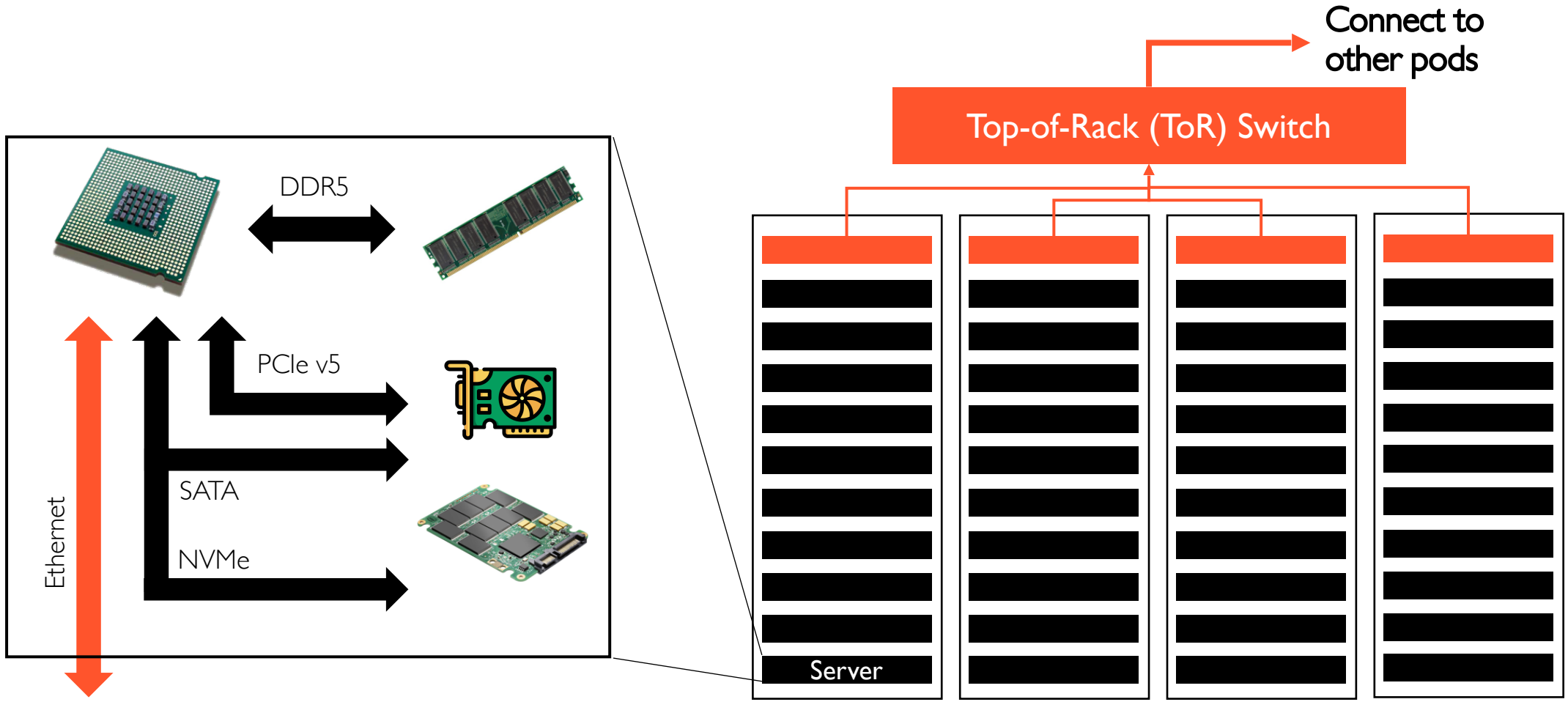


Meta's AI datacenter houses 16K of its 24K GPUs for training the latest Llama 3 model

Cloud Datacenter: Scale-Out Servers



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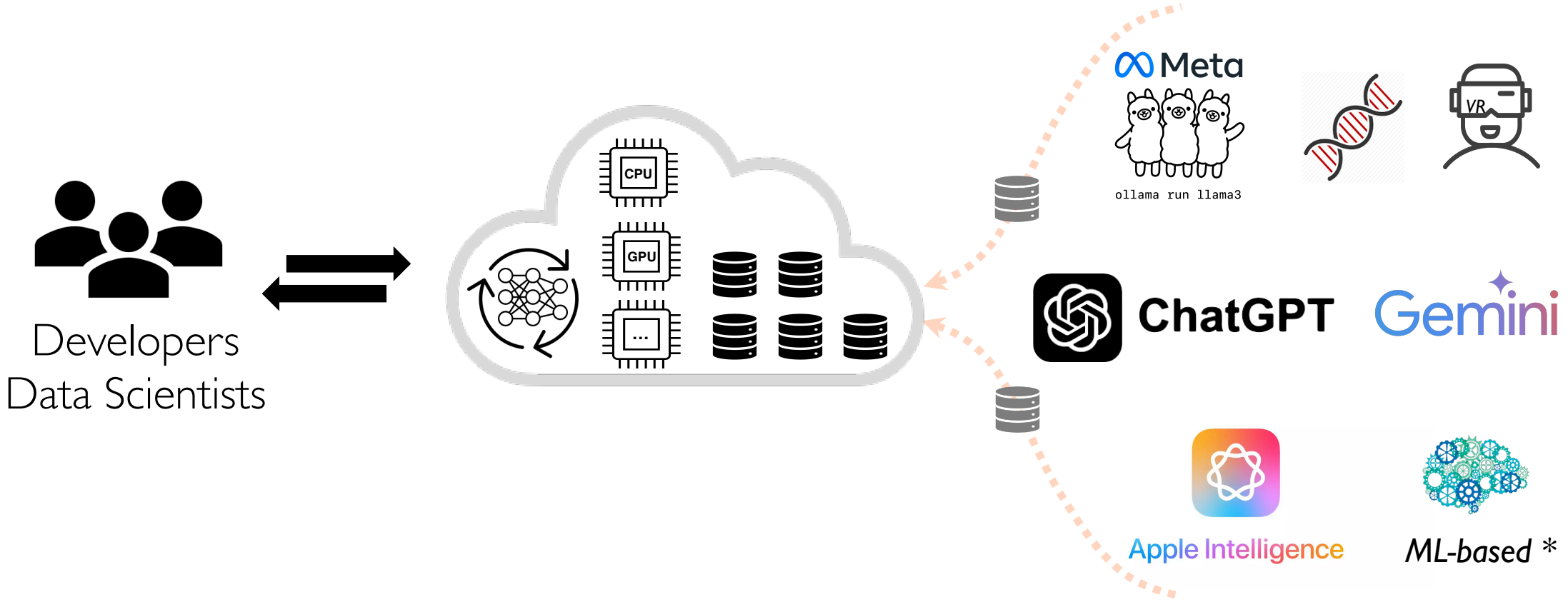
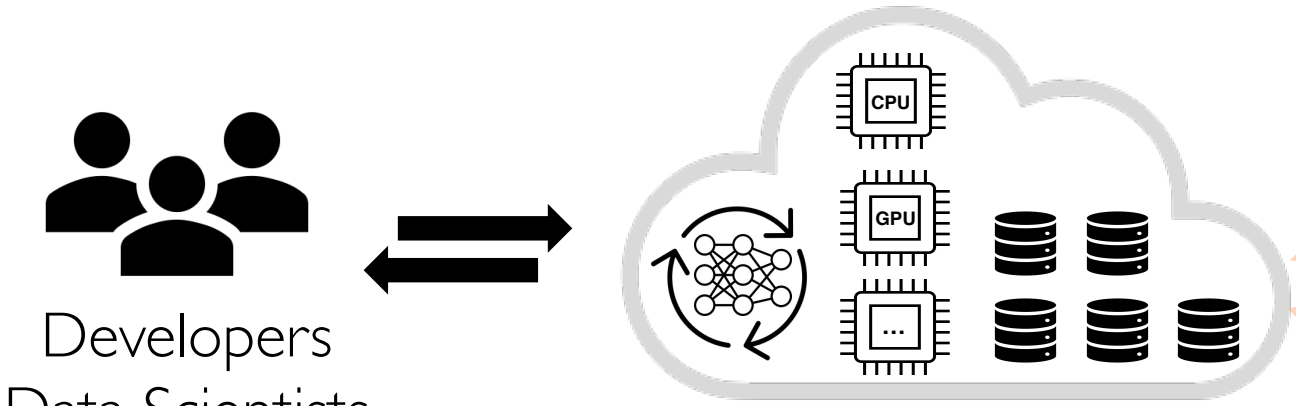
Cloud Faces Skyrocketing GenAI Workloads



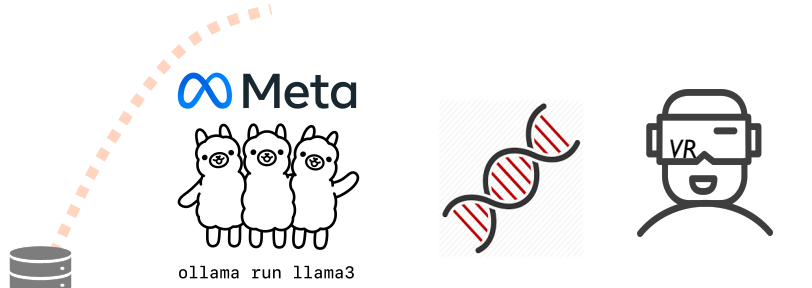
Cloud Faces Skyrocketing GenAI Workloads

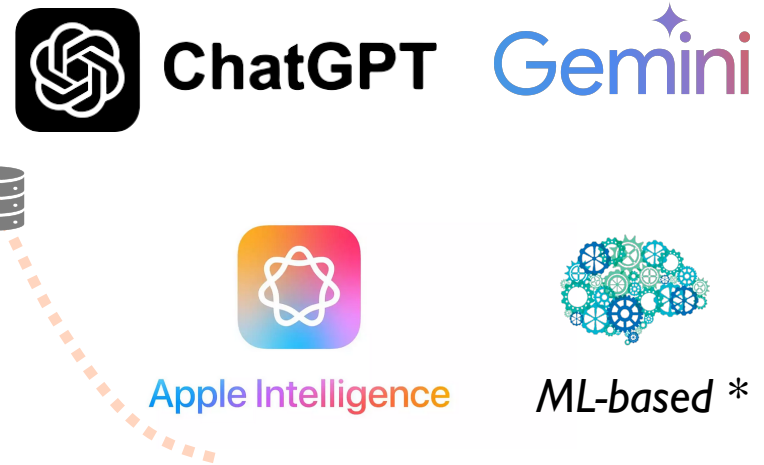
Model size **doubled** every two years [1]



Developers
Data Scientists

Petabytes of data ingestion every day [1]





[1] "Sustainable AI: Environment Implications, Challenges and Opportunities", Meta, MLSys'22

GenAI Lifecycle Demands Great Systems Support

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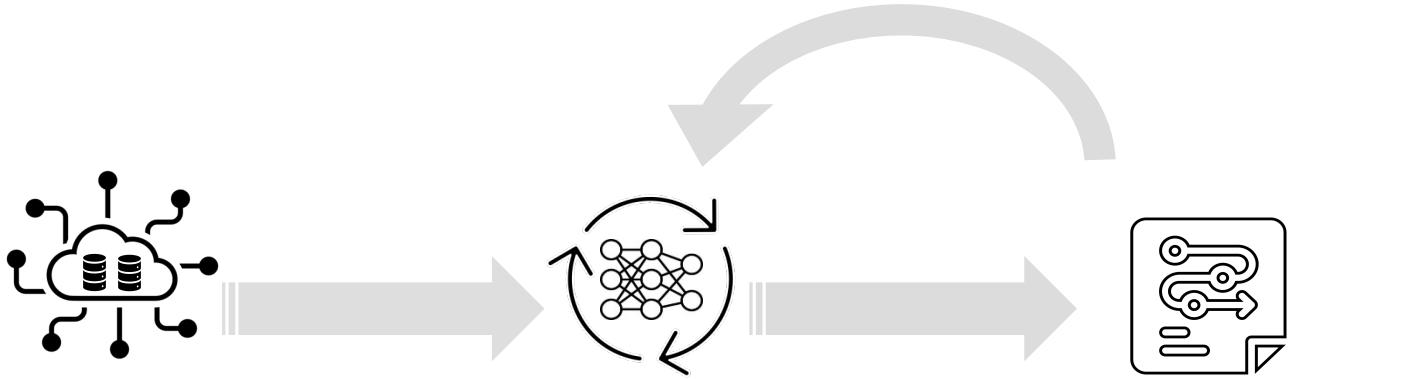
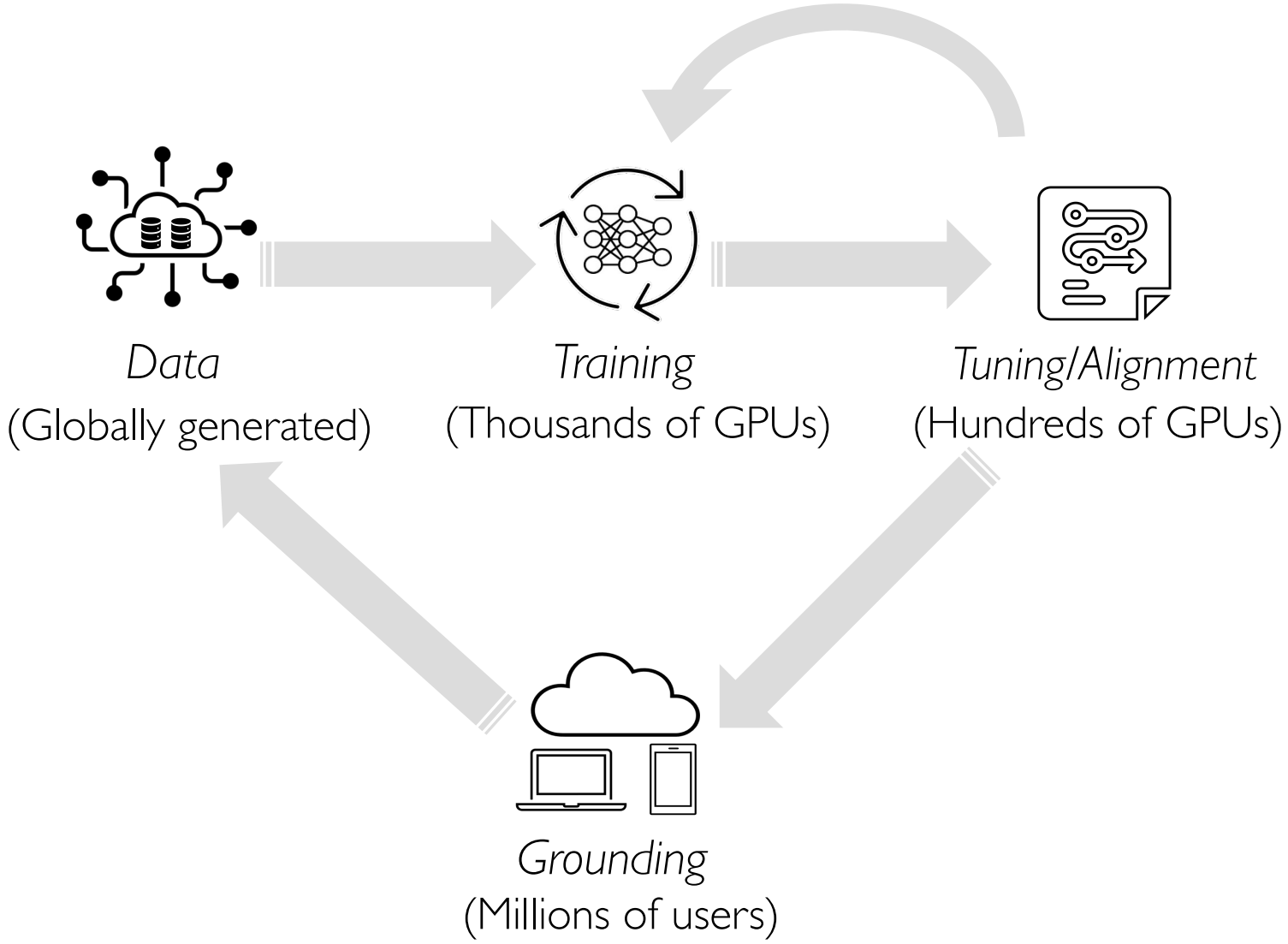


Data
(Globally generated)

Training
(Thousands of GPUs)

Tuning/Alignment
(Hundreds of GPUs)

GenAI Lifecycle Demands Great Systems Support



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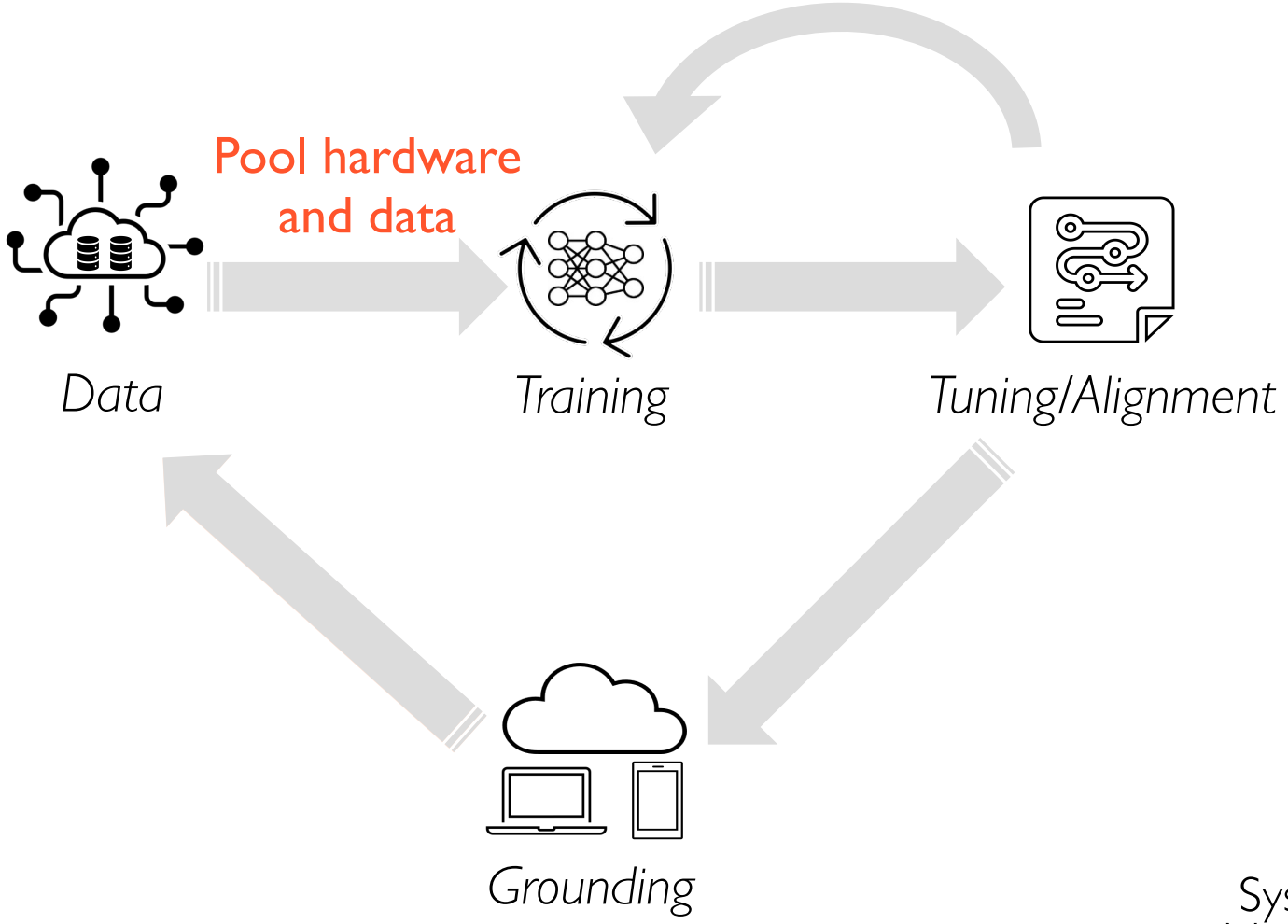
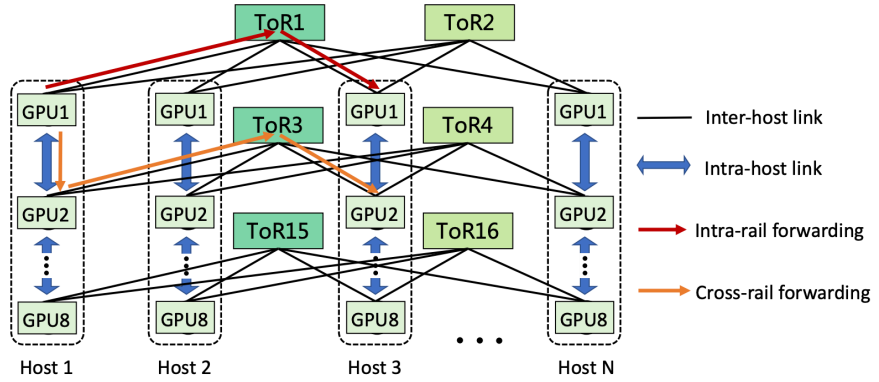


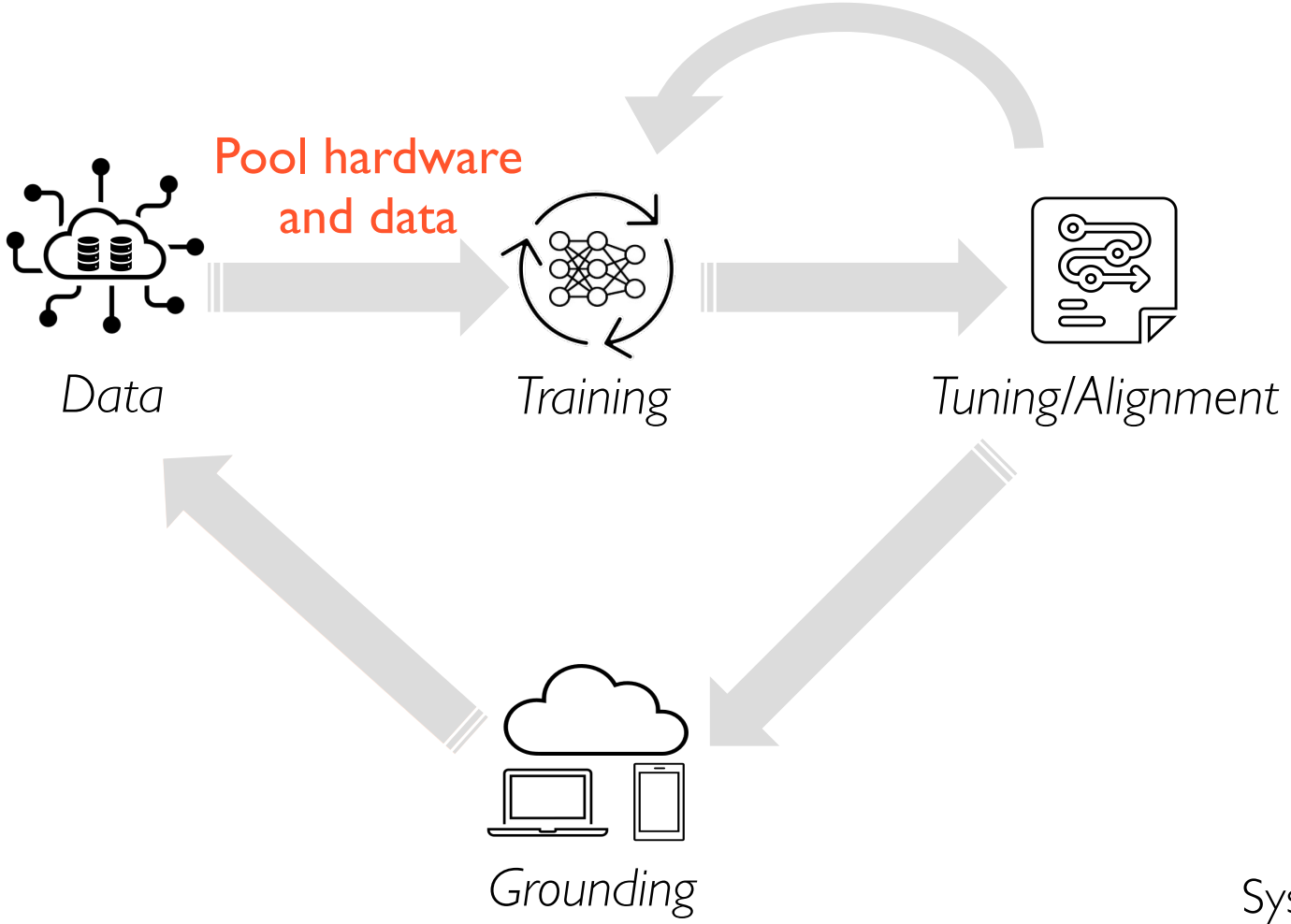
ML



HyperScale Training Infra
(e.g., compute, communication, memory)

Systems & Networking

GenAI Lifecycle Demands Great Systems Support



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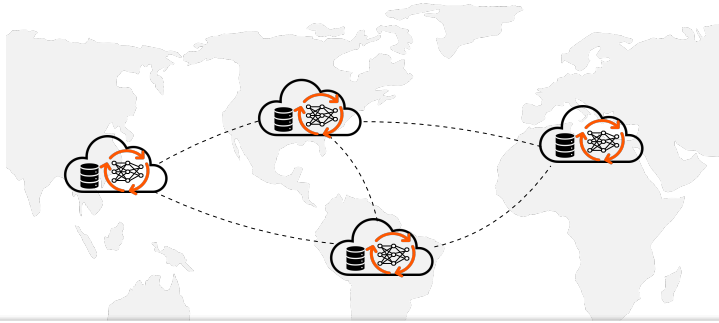

Distributed model training across massive servers and even datacenters

Model Auto-Sharding

HyperScale Training Infra
(e.g., compute, communication, memory)

Systems & Networking

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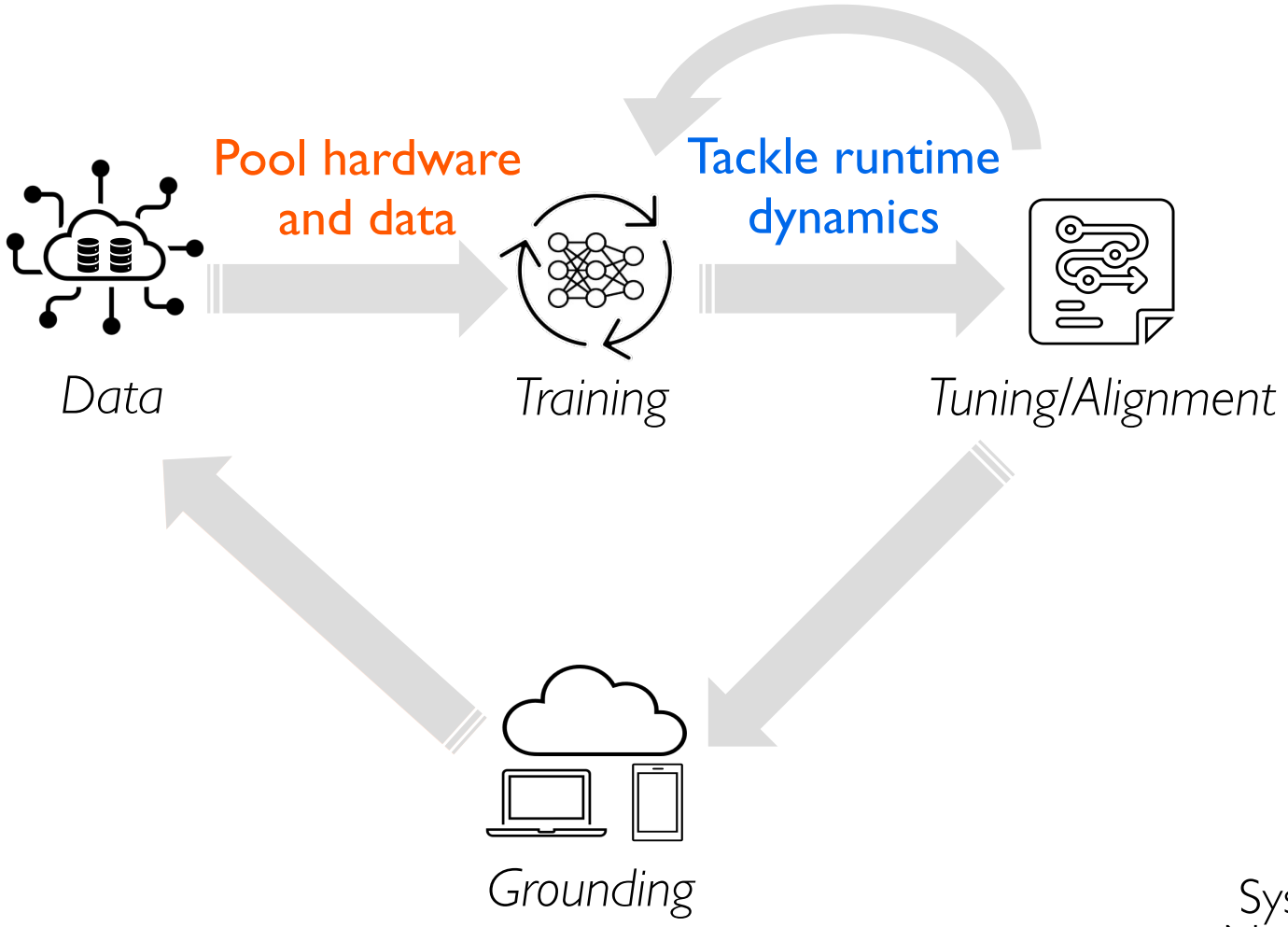

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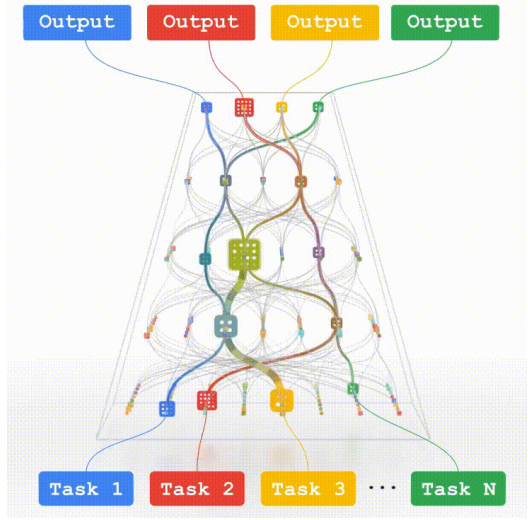

Model Auto-Sharding

Adaptive Runtime

Training can dynamically activate model components (e.g., MoE, sparsity)

Systems & Networking

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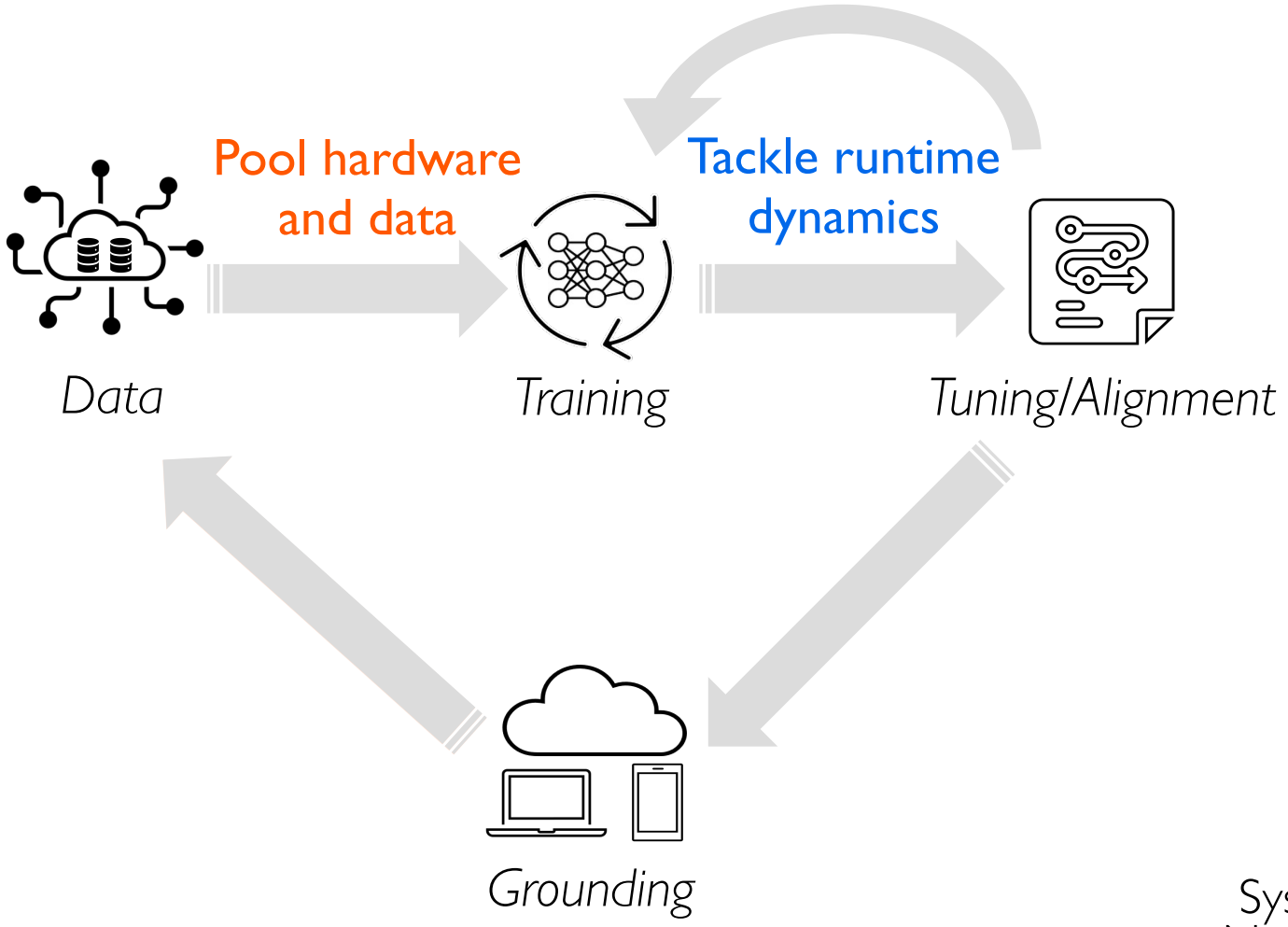

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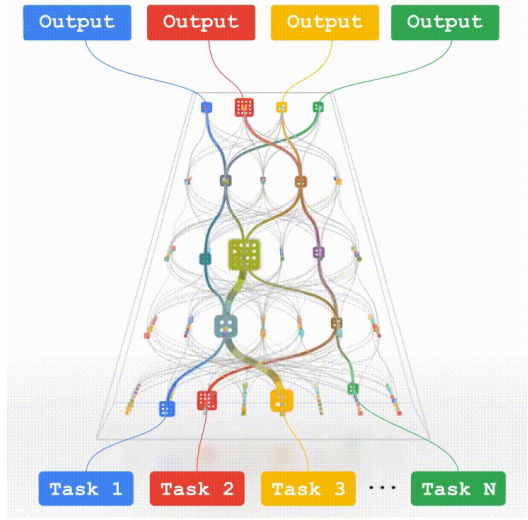

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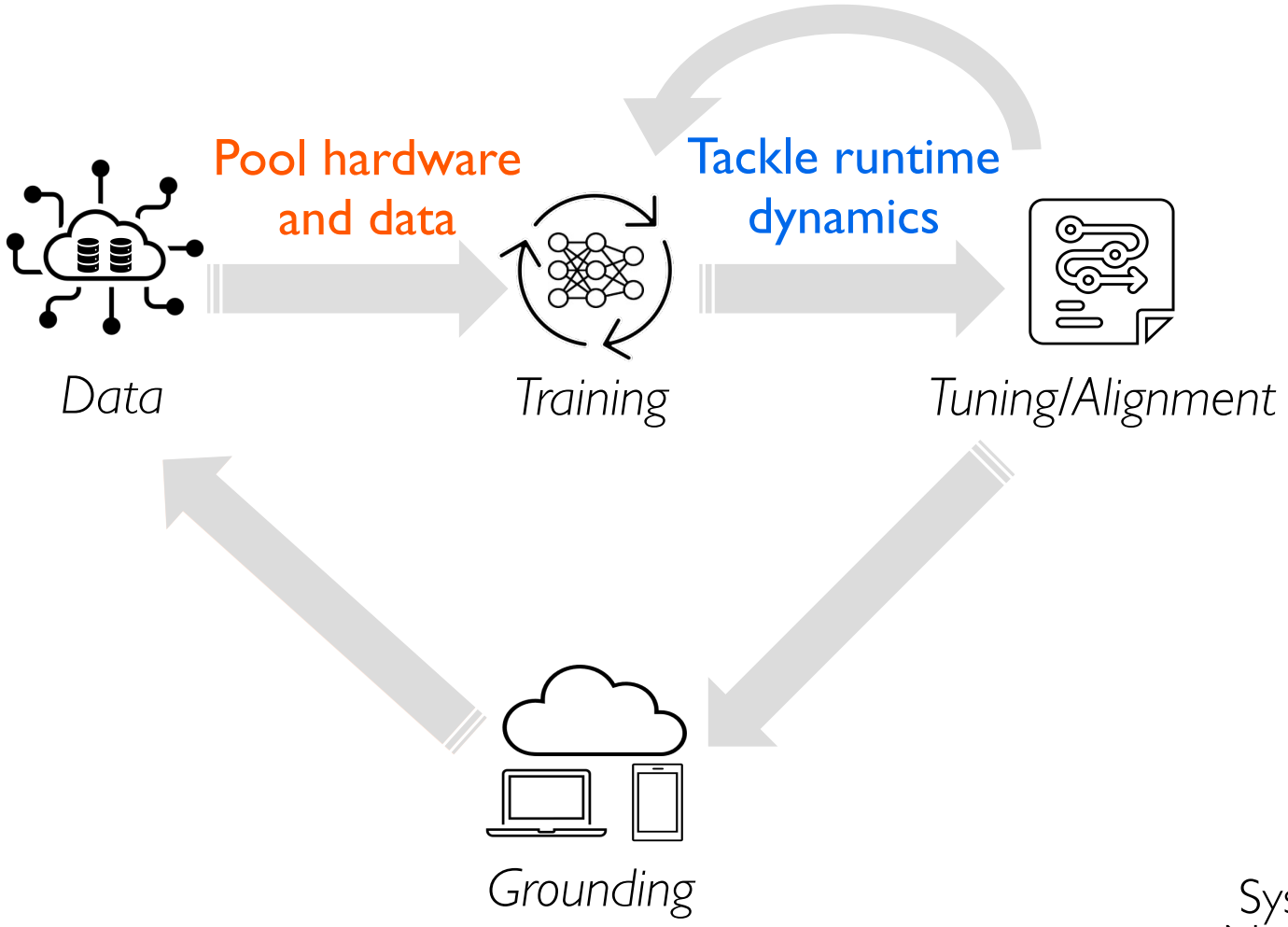

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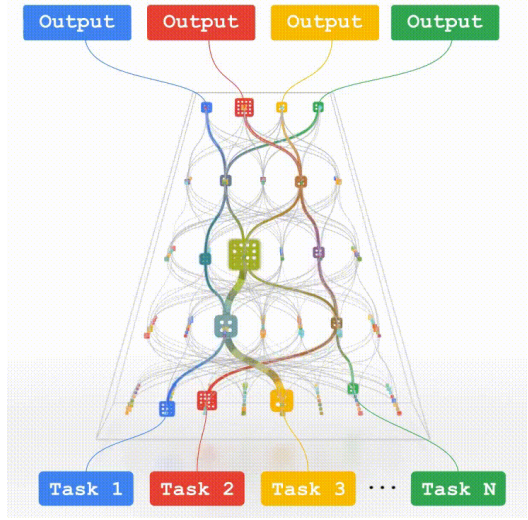


Model Auto-Sharding

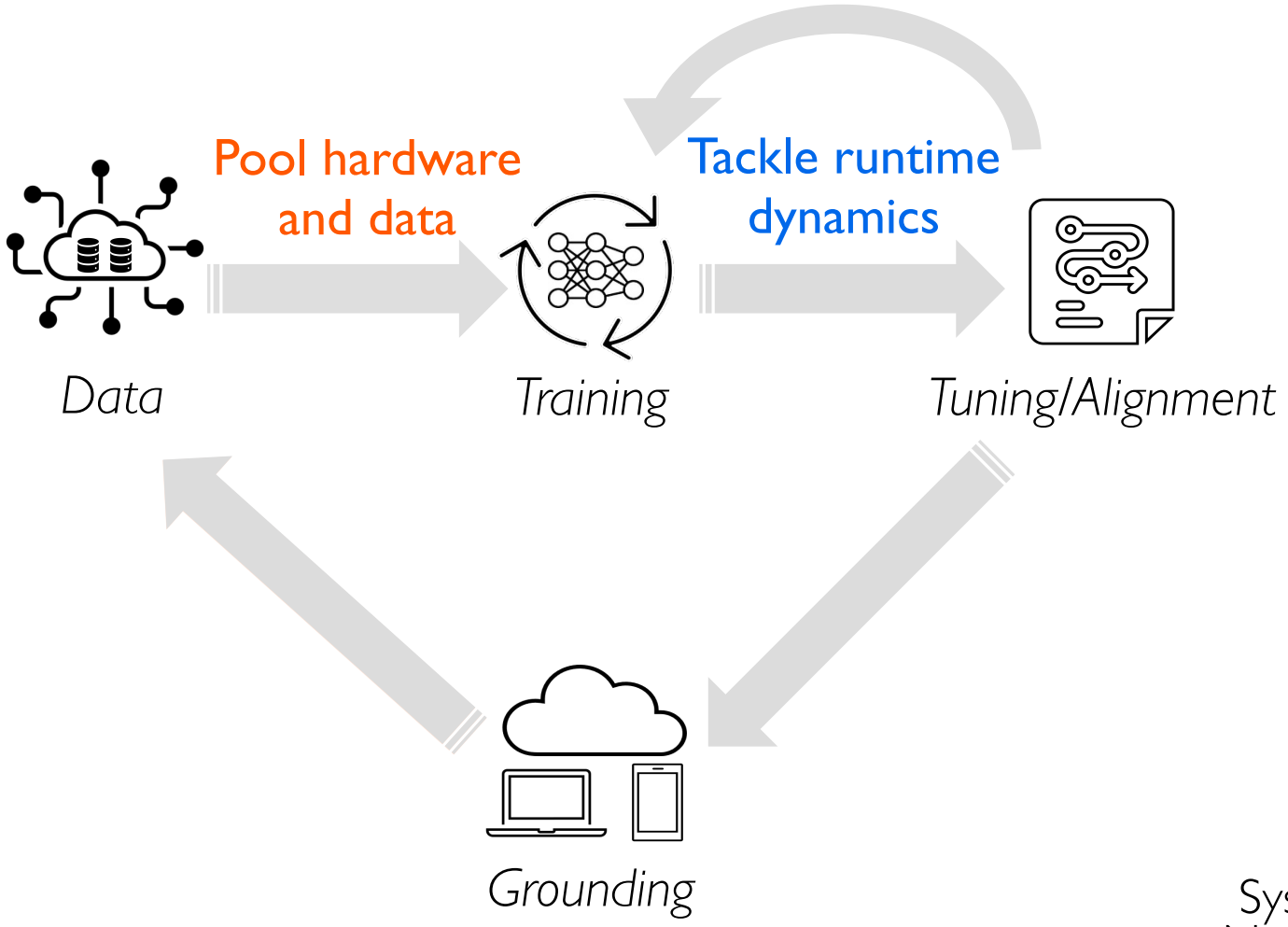
Adaptive Runtime

Multi-job Scheduling

Jobs can compete for the shared resources

Systems & Networking

GenAI Lifecycle Demands Great Systems Support



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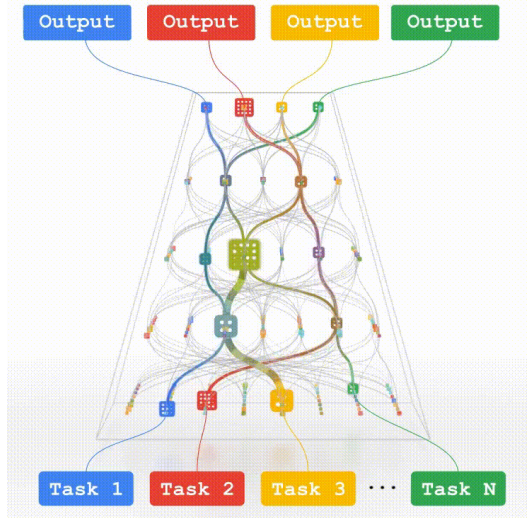

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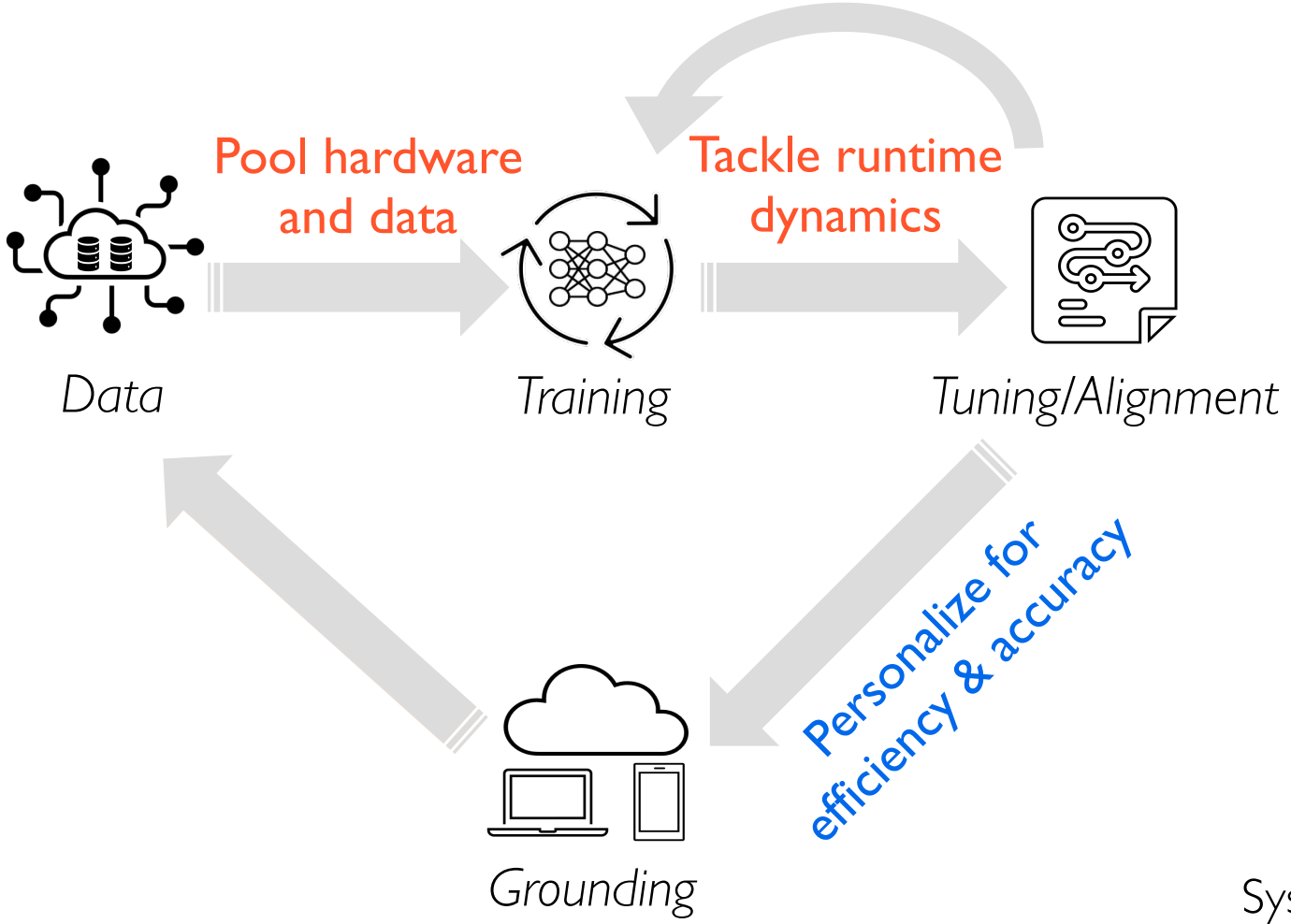

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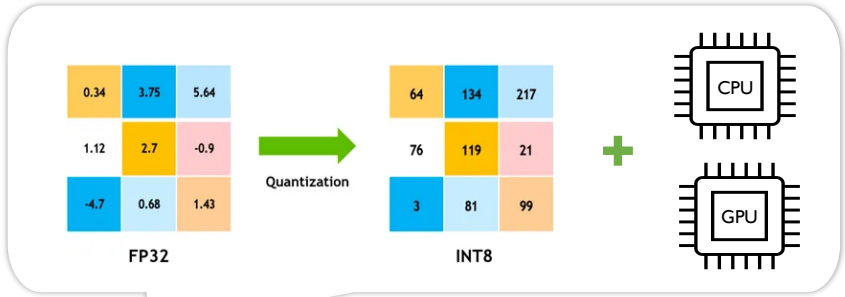


Model Quantization

Model Auto-Sharding

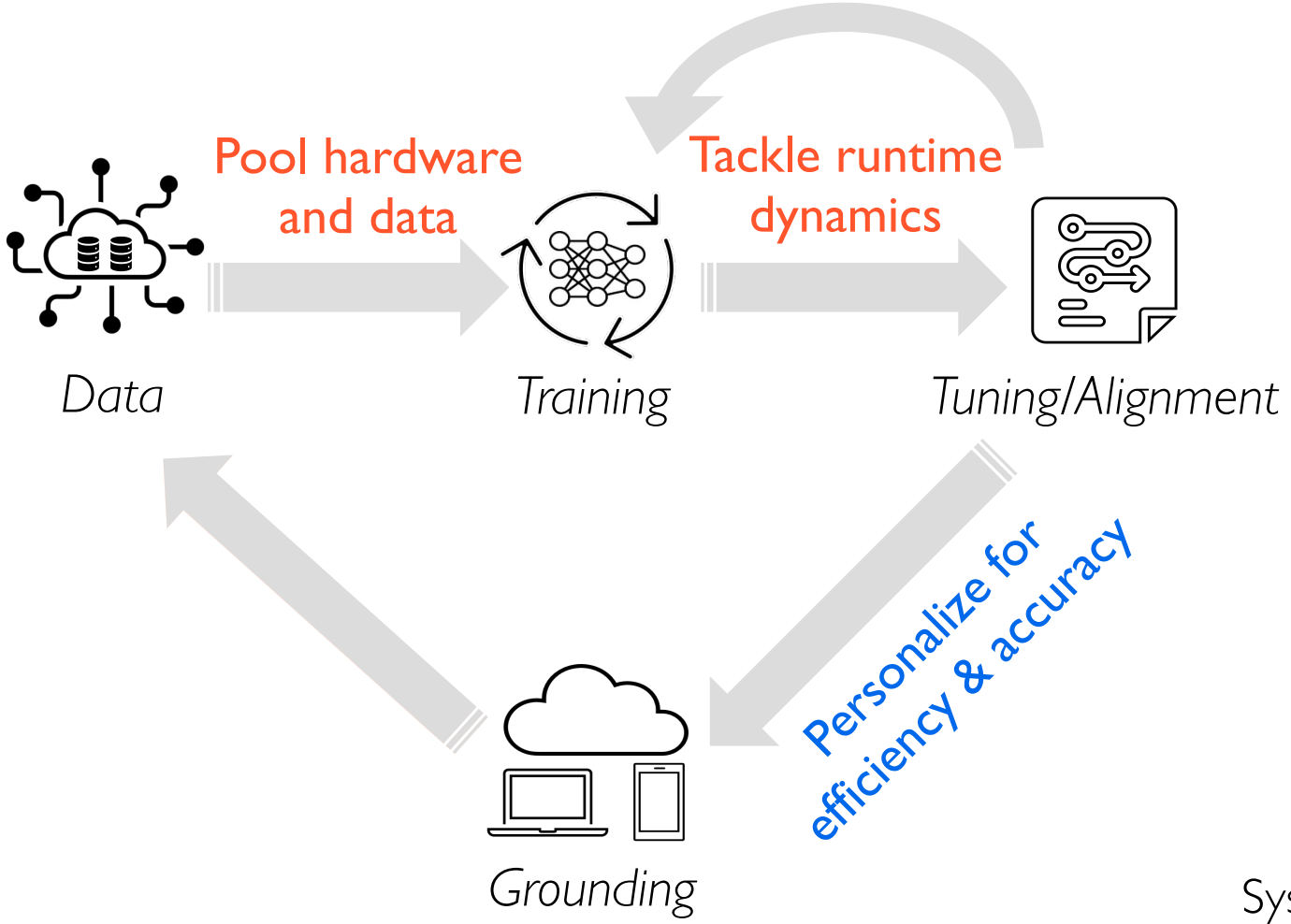
Adaptive Runtime

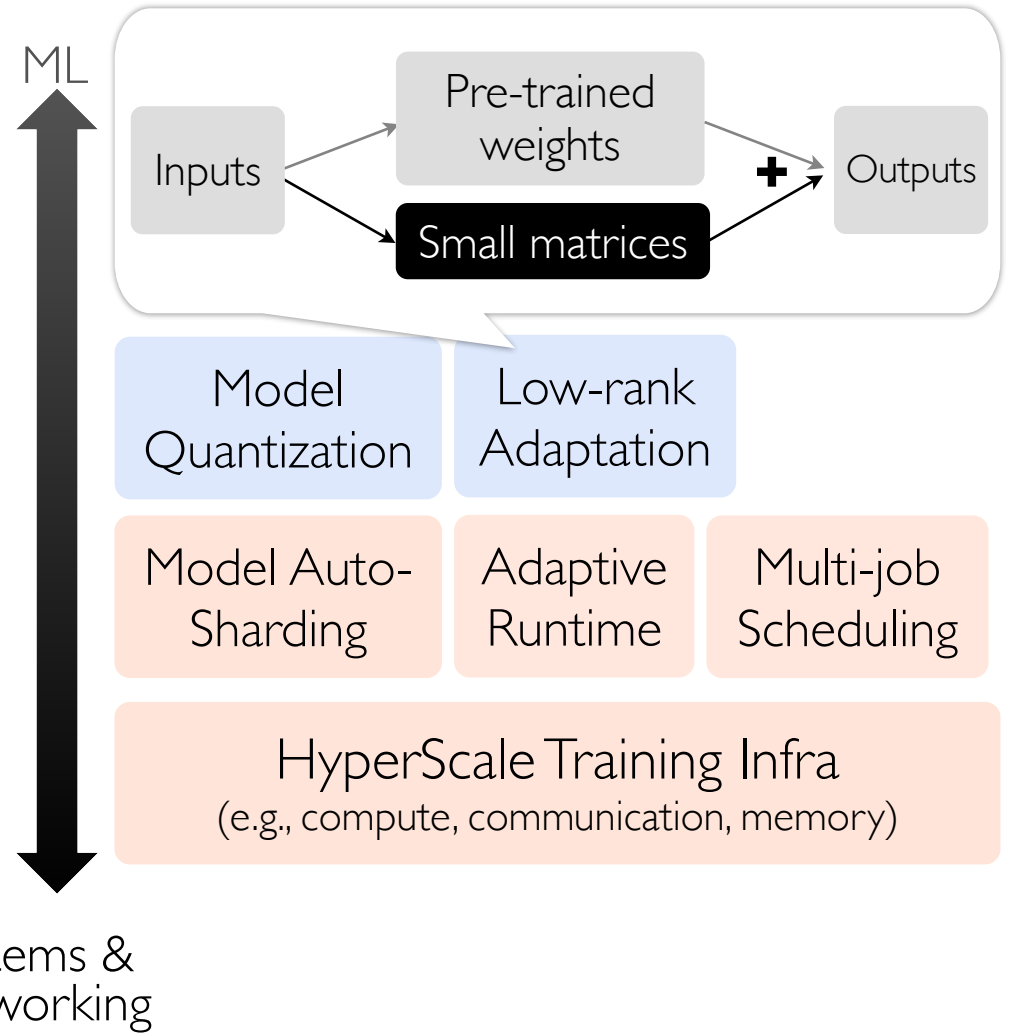
Multi-job Scheduling

HyperScale Training Infra
(e.g., compute, communication, memory)

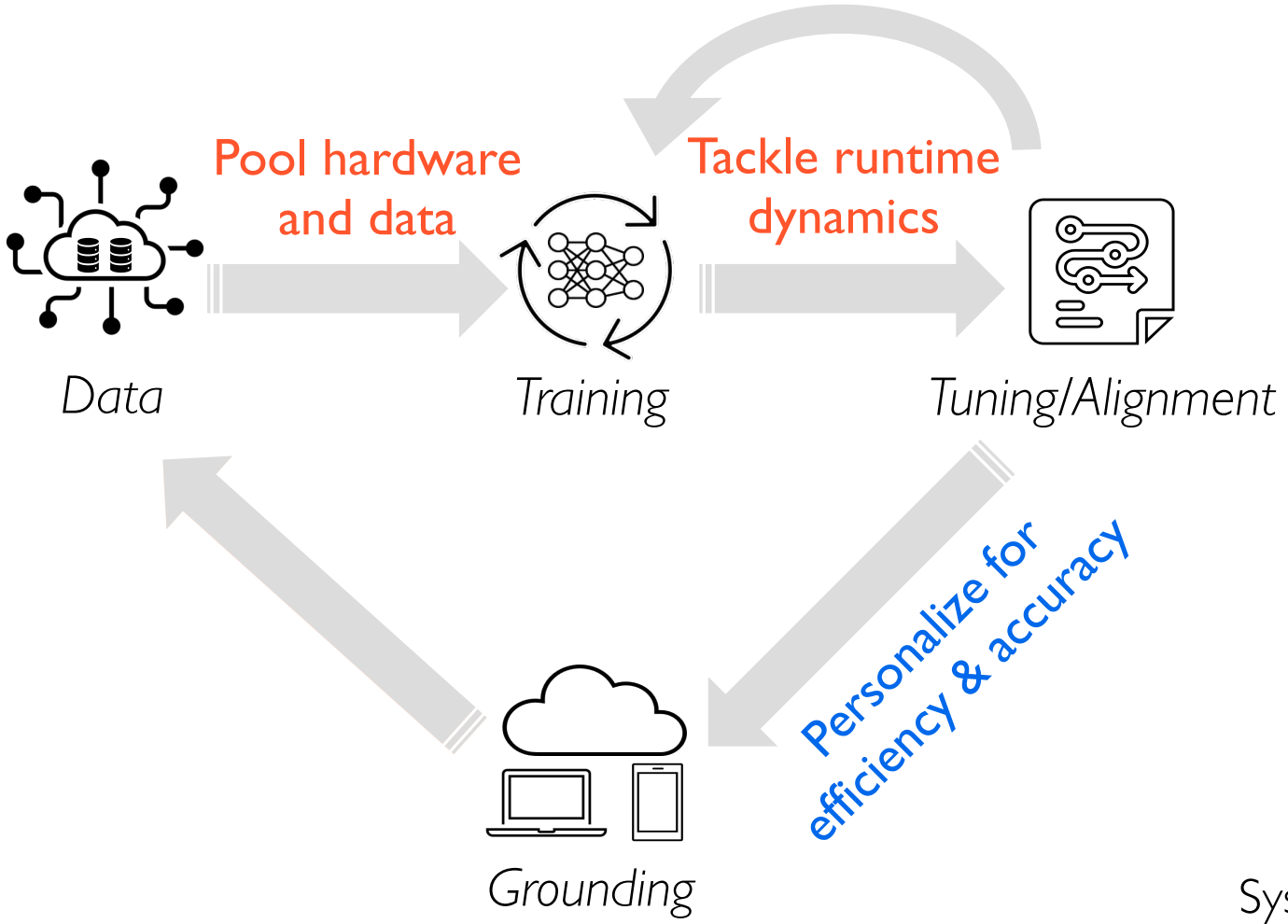
Systems & Networking

GenAI Lifecycle Demands Great Systems Support





GenAI Lifecycle Demands Great Systems Support



ML

Systems & Networking

Overloaded

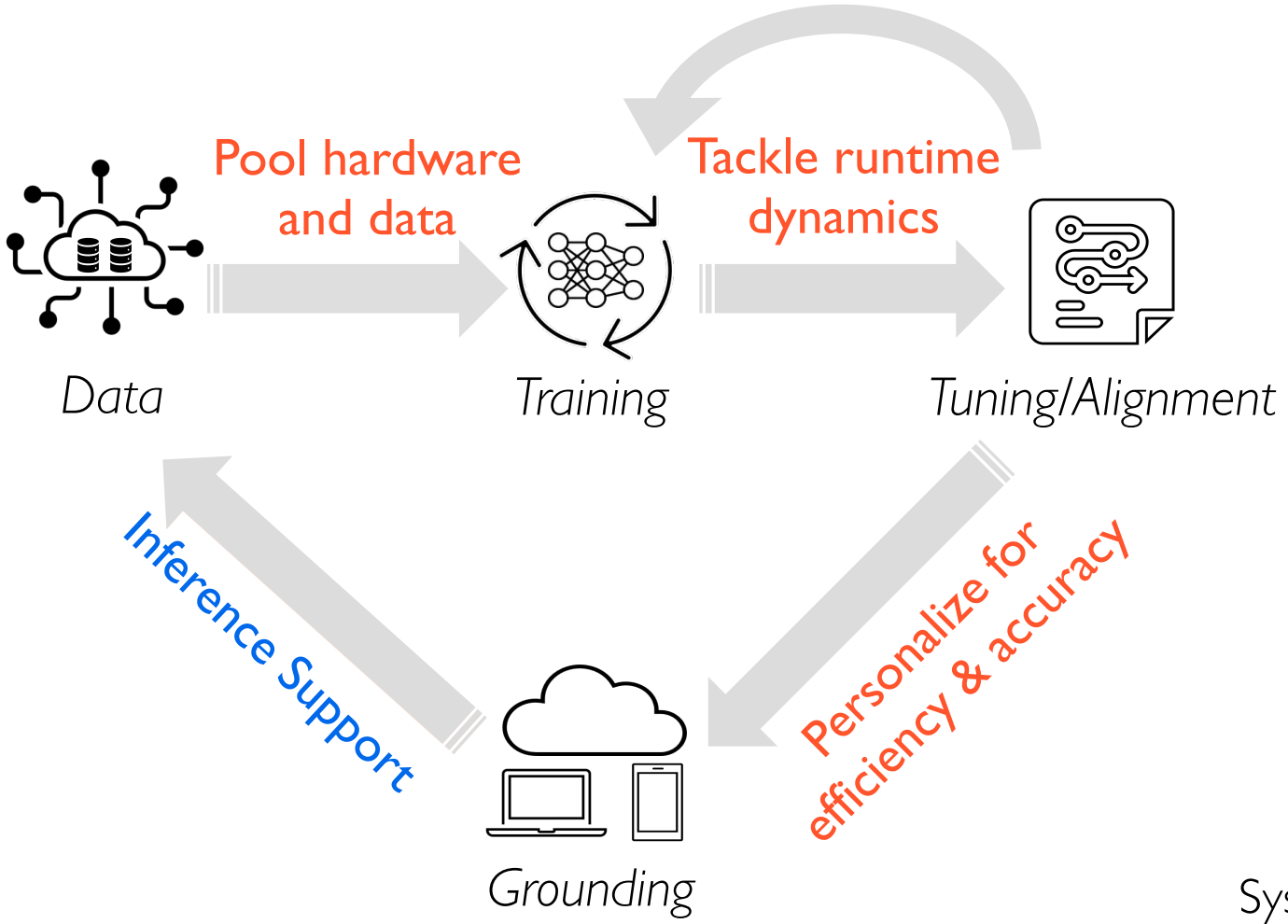
O(1M) requests → Request Scheduler → Model 1 ✗ *404*

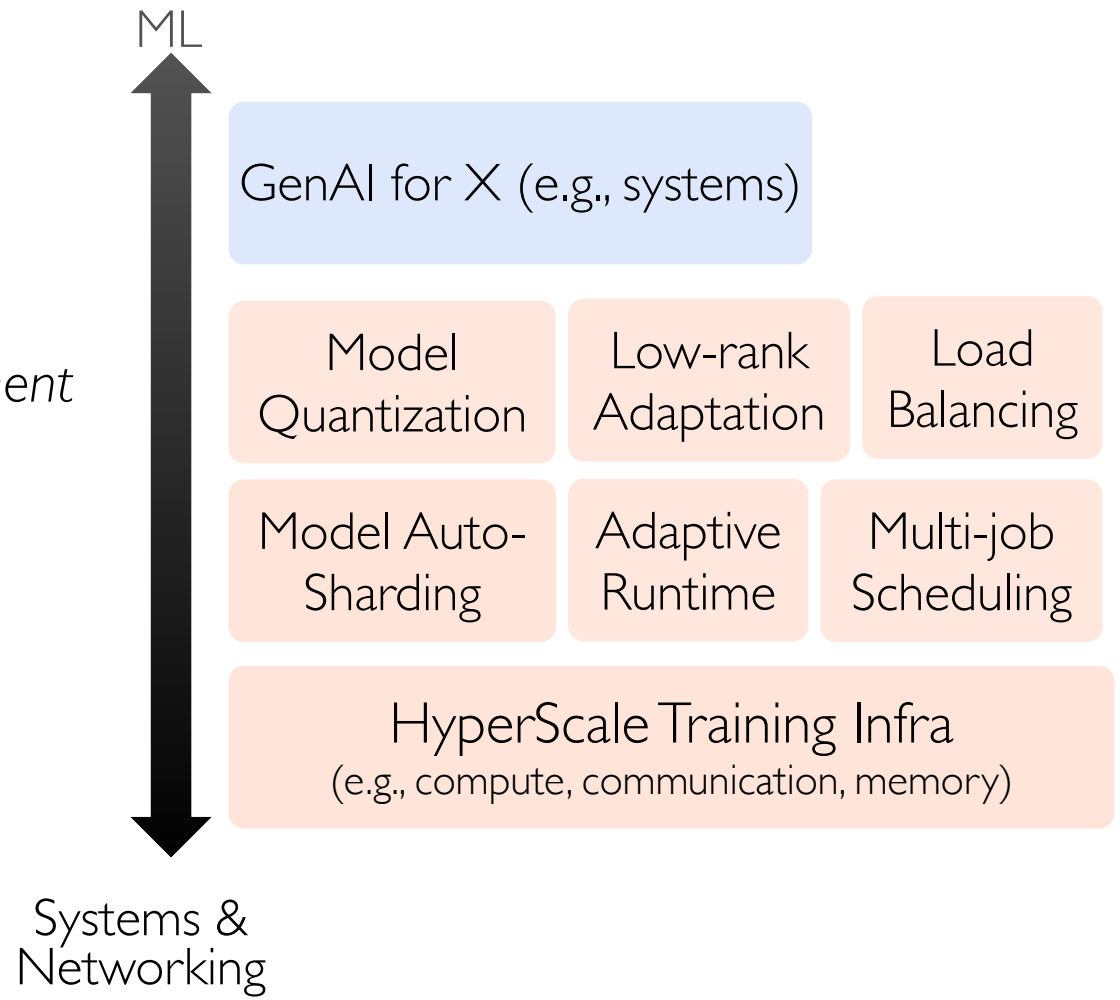
Request Scheduler → Model N

Model Quantization	Low-rank Adaptation	Load Balancing
Model Auto-Sharding	Adaptive Runtime	Multi-job Scheduling

HyperScale Training Infra
(e.g., compute, communication, memory)

GenAI Lifecycle Demands Great Systems Support





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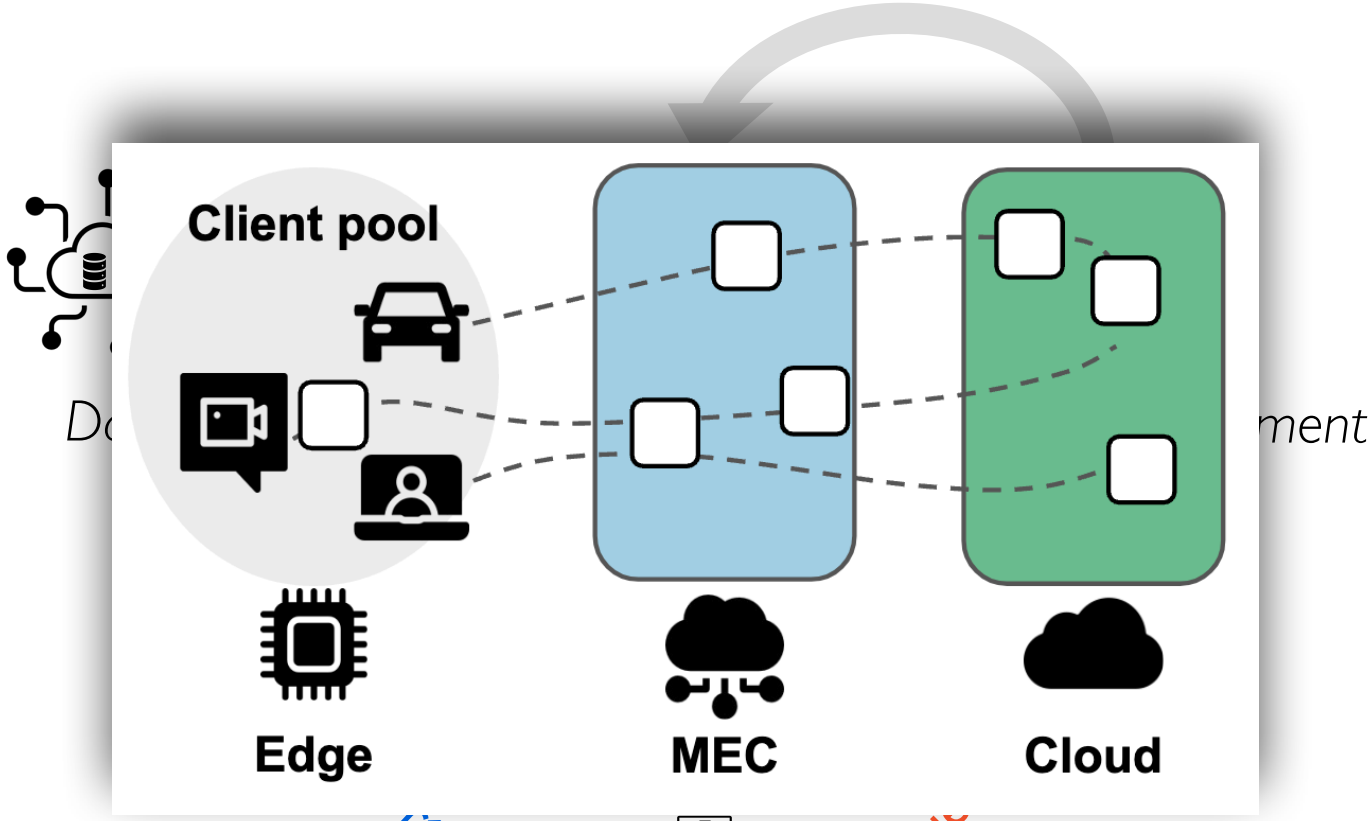


ML

Systems & Networking

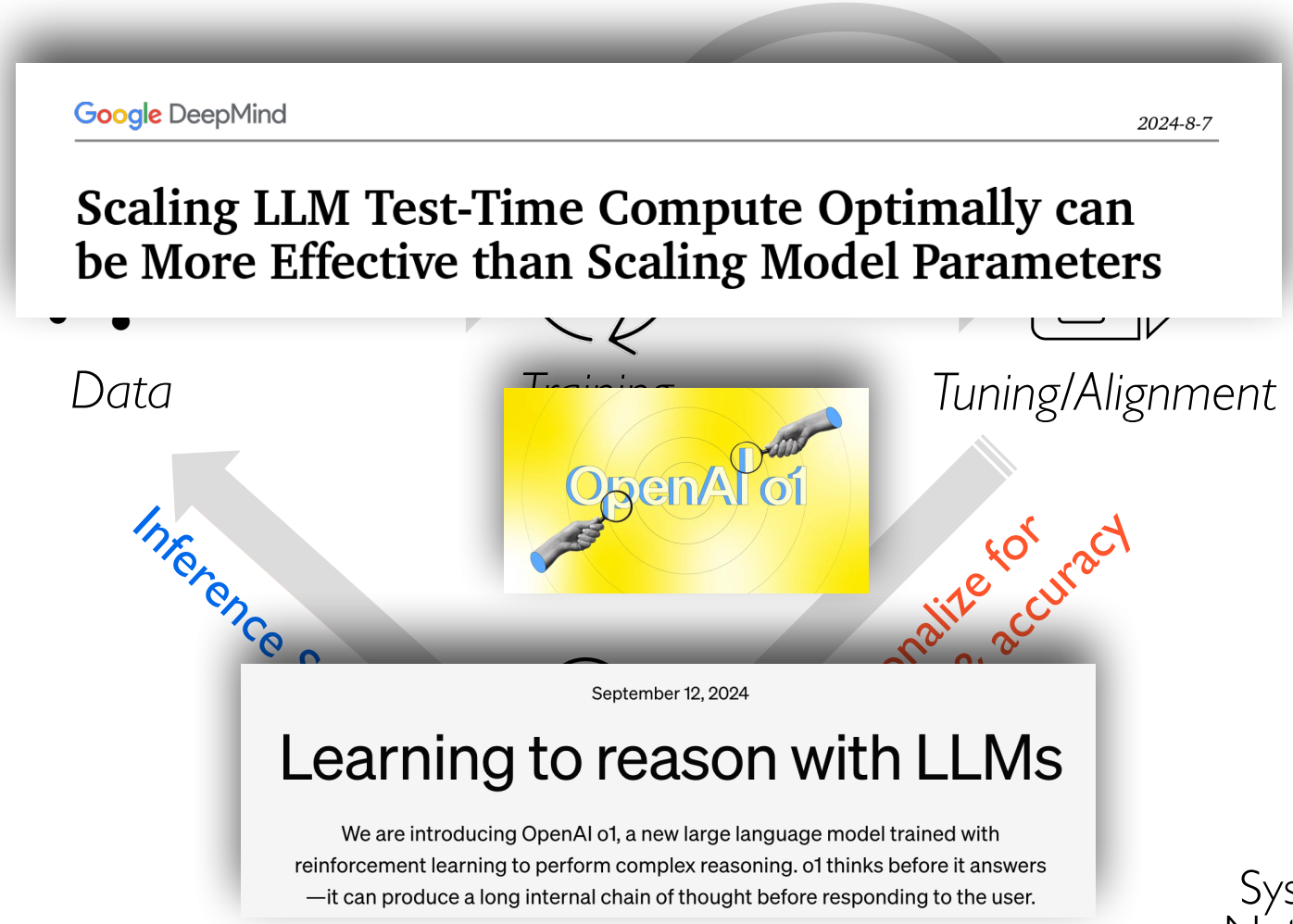
GenAI for X (e.g., systems)

Model Quantization | Low-rank Adaptation | Load Balancing

Model Auto-Sharding | Adaptive Runtime | Multi-job Scheduling

HyperScale Training Infra
(e.g., compute, communication, memory)

GenAI Lifecycle Demands Great Systems Support



ML

GenAI for X (e.g., systems)

Scaling Reasoning

Model Quantization

Low-rank Adaptation

Load Balancing

Model Auto-Sharding

Adaptive Runtime

Multi-job Scheduling

HyperScale Training Infra
(e.g., compute, communication, memory)

Systems & Networking

What will you learn in this course?

-- How to Support Practical GenAI

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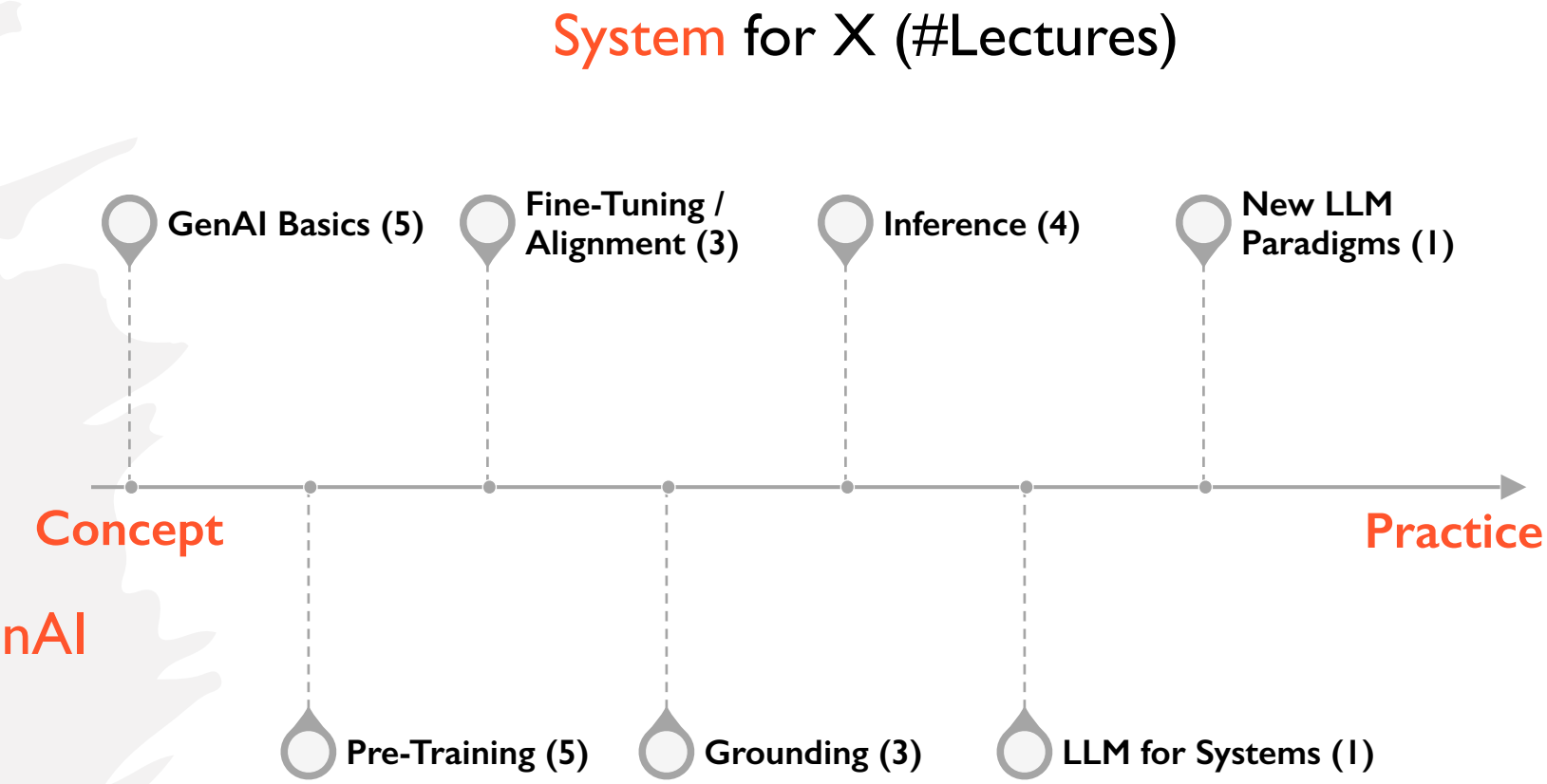

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Learning Outcomes

After completing this course you should be able to

- Articulate and critique latest GenAI Sys
- Be prepared to perform new research
- Communicate your research findings

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This is a Research Seminar Course.
The more active the better.

Agenda

- What will you learn in this course?
  - GenAI, systems, networks, ...
- **What will you do in this course?**
  - Participation, presentation, research project, ...

Course Expectations (Grading)

Participation	15%	Paper reading; Up to two absences

ALL activities will be done in groups except for your own participation

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Paper Summary	10%	Two summaries
Paper Presentation & Discussion	15%	One Presentation
Project Proposal	5%	2-page Proposal
Project Presentations	20%	Mid-term + Final Presentation
Project Report	35%	One Final Report

ALL activities will be done in groups except for your own participation

Form Groups ASAP

- Use Piazza to find potential group members
- Group size should be 4-5
  - May allow a few smaller groups if/when students drop out
- Submit at https://forms.gle/h8W3VrkN5ViZkg5G8
  - By Jan 31st the latest, but **right now** is better

Participation

- **Reading: 43 papers/articles across**
  - Primarily from systems venues like SOSP, OSDI, NSDI, EuroSys, and MLSys
  - Some from traditional AI/ML venues but still with systems flavor

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Before Each Lecture

- Read 1-2 required reading
- Submit one insightful question per required reading (link)

Feb 14 (Training Infra)	The Llama 3 Herd of Models (Sec 1-4.2, Required) DeepSeek-V3 Technical Report (Sec 3.1-3.2, 3.4, Required) Gemini: A Family of Highly Capable Multimodal Models

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During Lecture

- Please be interactive!
- Up to 2 absences with legitimate reasons

After Lecture

- Feel free to discuss on Piazza

Paper Presentation

- **This is a seminar-style course**
  - Each group presents one lecture covering required papers
  - (Optional) Include a few slides to skim through companion papers

- **The entire class will be dedicated to the assigned paper(s)**
  - Aim for 40-min presentation w/o interruption, but there will be intermittent discussions
  - No more than 55 minutes in total (w/ interruption)

- **Lead the discussion** (details)
  - Go through the required paper in details, along with its strengths and weaknesses

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Share slides (in *.ppt format) to cs598-aisys-staff@lists.cs.illinois.edu 24 hrs before the class

Paper Summaries

- **Two summaries per-group, covering required and companion papers**
- **Each summary must follow the template and address the following**
  - What is the problem and why is it important?
  - What is the hypothesis of the work?
  - What is the proposed solution, and what key insight guides their solution?
  - What is one (or more) drawback/limitation, and how will you improve it?
- **Summary (template) should include the gist of class discussion**

Share summary (in *.pdf) to cs598-aisys-staff@lists.cs.illinois.edu within 24 hrs of presentation

Panel Discussion (right after presentation)

- **The Authors (assigned)**
  - 'Companion' group that writes summary and answer questions from 'Reviewers'
- **The Reviewers (assigned)**
  - 'Reviewer' group that writes summary and poses challenging **research** questions
- **Rest of the Class & Presenters**
  - Ask questions directly too

Each group will be assigned to these slots at least once; 1 presentation & 2 summaries (only! 😊)

Summary of Your Role

Presenter Group

- Share slides 24 hrs before class
- Maximum 55-minute presentation
- Respond to questions on Piazza
- Share you final slides after class

Authors (Companion) Group

- Share summary within 24 hrs after class presentation
- Respond to Reviewers' questions

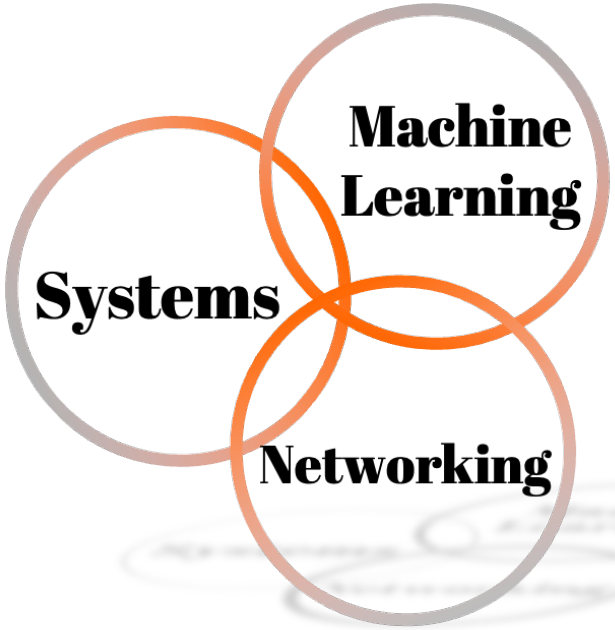
Reviewers Group

- Share summary within 24 hrs after class presentation
- Pose challenging research questions

Audience Group

- Read required papers
- Submit one insightful question per required reading before each lecture

Systems for GenAI Projects



Research-Oriented Course!

- **The final project accounts for 60% of total grades**

- **What can and cannot be a project?**
  - Just surveys are not allowed
  - Measurements of new environments or of existing solutions in new environments are acceptable
  - Proposing new research problems or addressing existing ones is highly preferred!

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  - Proposing new research problems or addressing existing ones is highly preferred!
- **An ideal project should answer the questions you asked during paper reviews and points you cared about for presentations**

How to Approach it?

1. **Find a problem and motivate why this is worth solving**
2. **Quickly survey background and related work**
   - Might require you to go back to the first step
3. **Form/update your hypothesis**
4. **Test your hypothesis**
   - Go back to 3 until you are happy
5. **Present your findings on poster and in writing**
   - Discuss known limitations

Draft Proposal (Feb 26)

- **Two pages (template), plus references, must include**
  - ***Problem:*** What is the problem?
  - ***Motivation****:* Why is it important?
  - ***Solution overview:*** Any initial thoughts?
  - ***Evaluation plan:*** How would you evaluate it?

- **Submit as a group, including your group information** *(form a group ASAP)*

- **Approved by the instructor and agreed upon by you**
  - Forms the basis of expectation

Mid-Semester Checkpoint (Apr 2, 4)

- **In-class short presentation over two lectures**
  - This is to make sure you are receiving feedback and making progress

- **Must include**
  - What is the problem?
  - Why is it important? (Motivating experiments)
  - What are the most related work?
  - What's your hypothesis so far?
  - How are/will you evaluate it?

Poster & Paper (Apr 30, May 2, 7)

- **Final Presentation/Poster (Apr 30, May 2, 7)**

- **Final report (7-8 pages excluding references by May 15):**
  - Should be written like the papers you've read
  - As if you'd submit it to a workshop with ~3 more months of work or to a conference after ~6 more months of work
  - How to Write a Great Research Paper by Simon Peyton Jones

Project Ideas

- **Some potential project ideas (will share more on Piazza soon)**
  - Multi-tier memory, including CXL and RDMA, for long-context LLMs
  - Energy-efficient GenAI serving on end-user devices
  - Systems support for reinforcement learning from human feedback
  - Making chatbots real by allowing them to cut in
  - Repurposing spatiotemporal redundancy in video generation
  - …
- **Any of your crazy ideas!**

Any Questions?

Date	Milestone	Details
01/31/25	Form Group	Find 4-5 like-minded teammates
02/26/25	Submit Proposal	Send your proposal by email to receive feedback either via email or in-person or both
04/02/25 04/04/25	Mid-Semester Presentations	Define and motivate a problem, overview, related work, and form initial hypothesis/idea
04/30/25 05/02/25 05/07/25	In-Class or Poster Presentations	Present your research findings
05/15/25	Research paper	Submit a report like the papers you read

NO extensions! Delayed submission will receive NO CREDIT

Thank you!

Audience Group

- Read required papers
- Submit short questions

Presenter Group

- Present one lecture
- 55-minute presentation

Form Groups of 4-5; submit by *Jan 31st*

Reviewers Group

- Write one paper summary
- Participate in panel discuss.

Authors (Companion) Group

- Write one paper summary
- Participate in panel discuss.