Cornell University
Computer Systems Laboratory

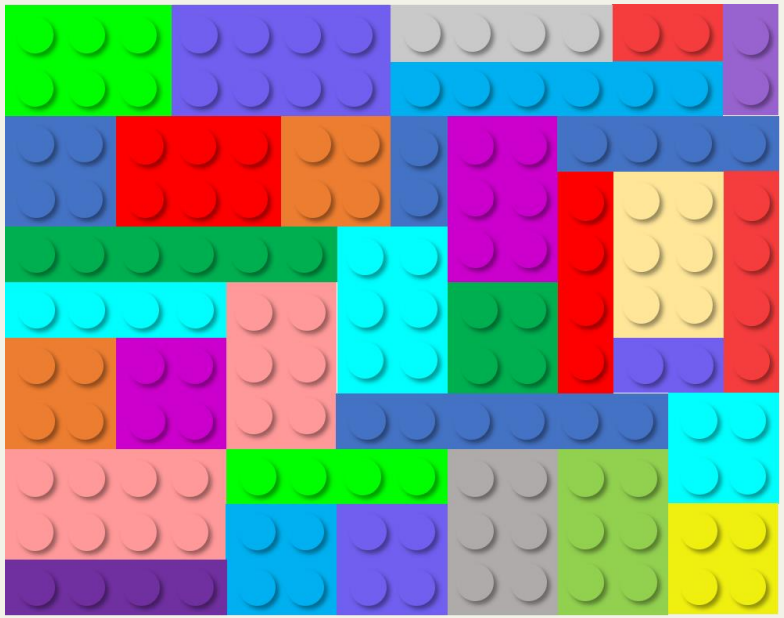
CSL

μQSim: Enabling Accurate and Scalable Simulation for Interactive Microservices

Yanqi Zhang, *Yu Gan, Christina Delimitrou*
Cornell University

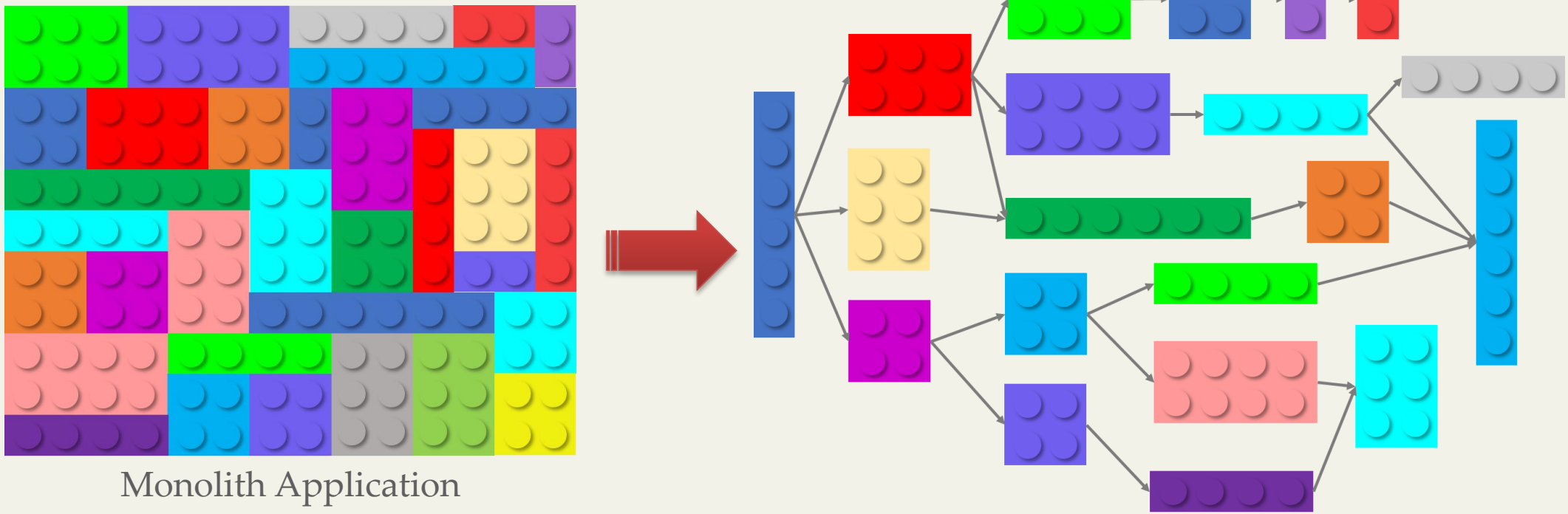
Session: Datacenters and Cloud Computing, March 26th

Marching to Microservices



Monolith Application

Marching to Microservices



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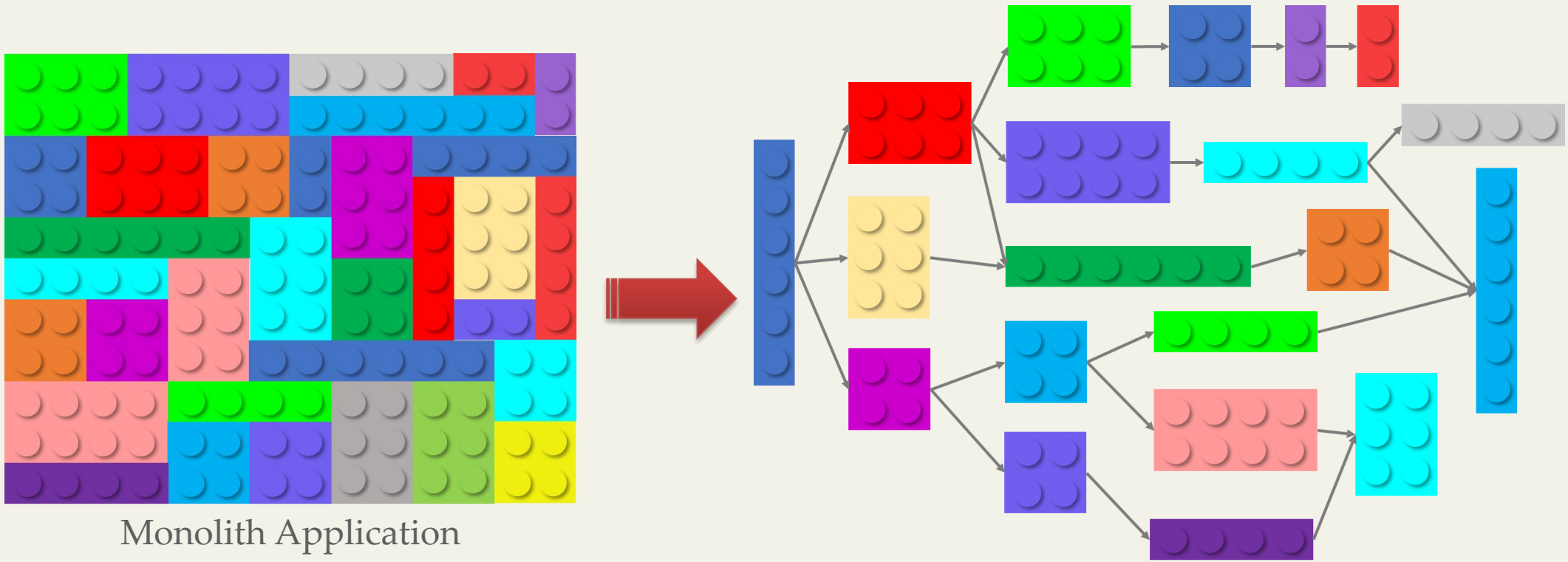

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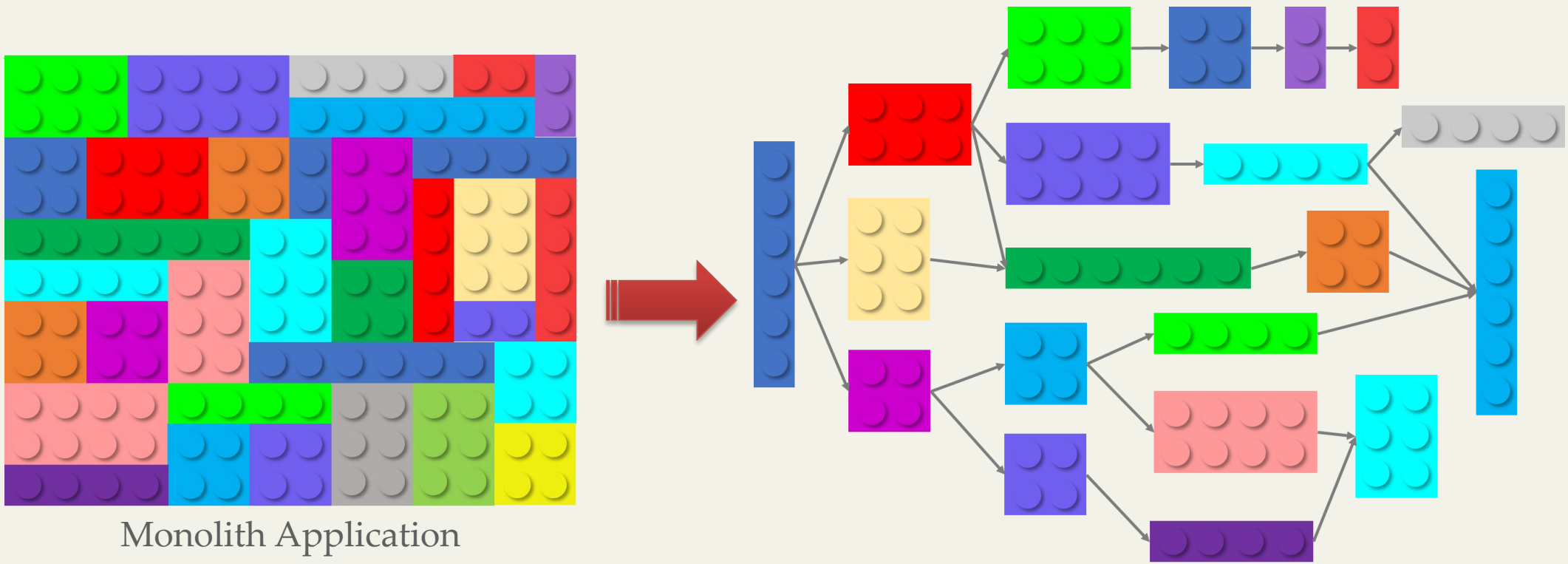

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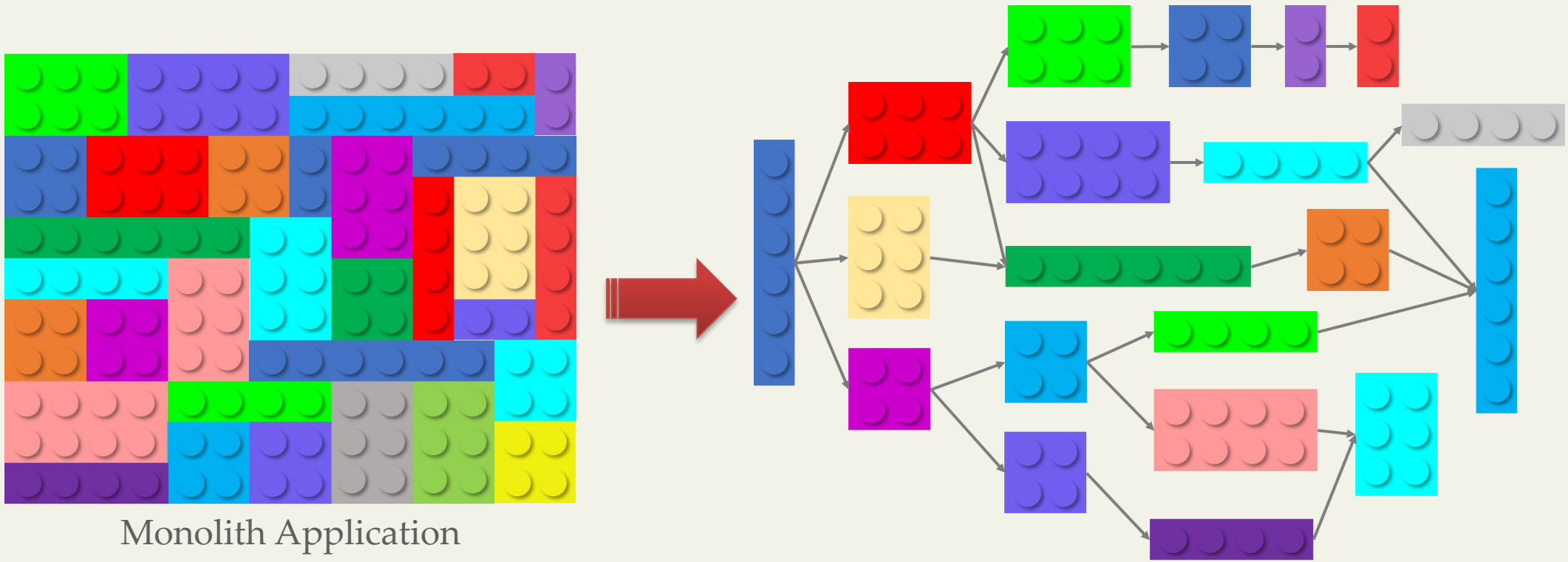

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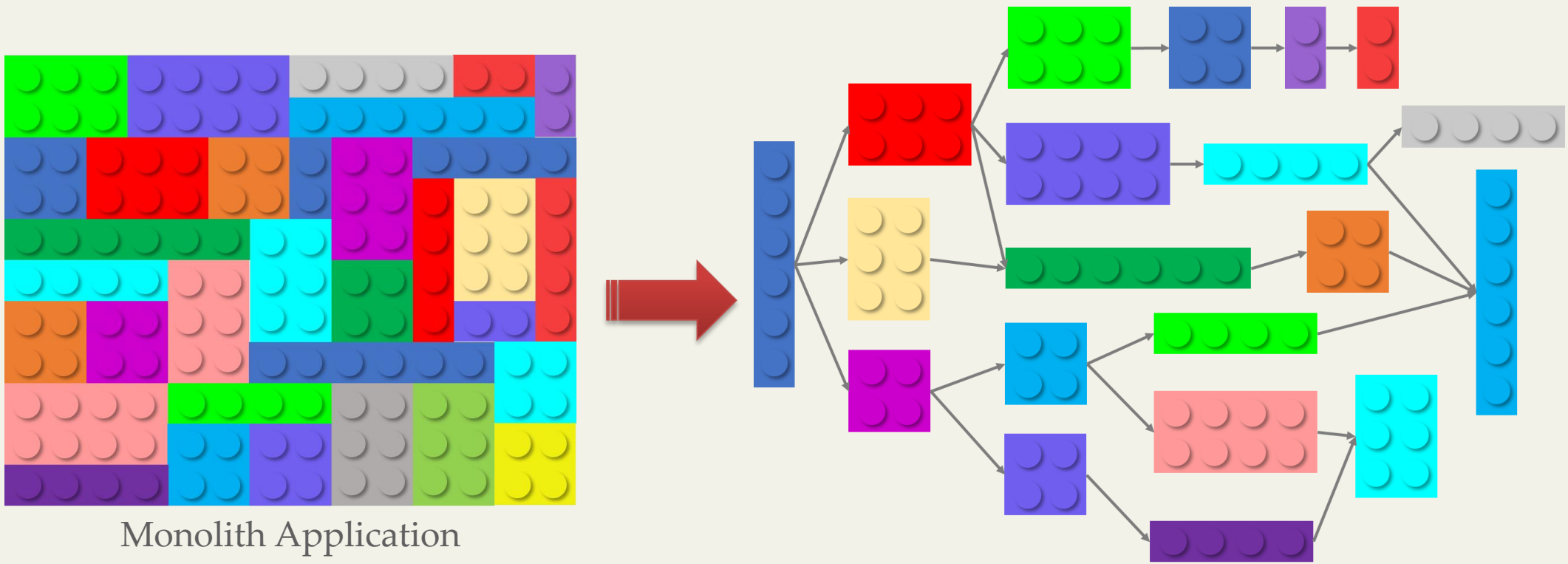

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- PL/framework heterogeneity

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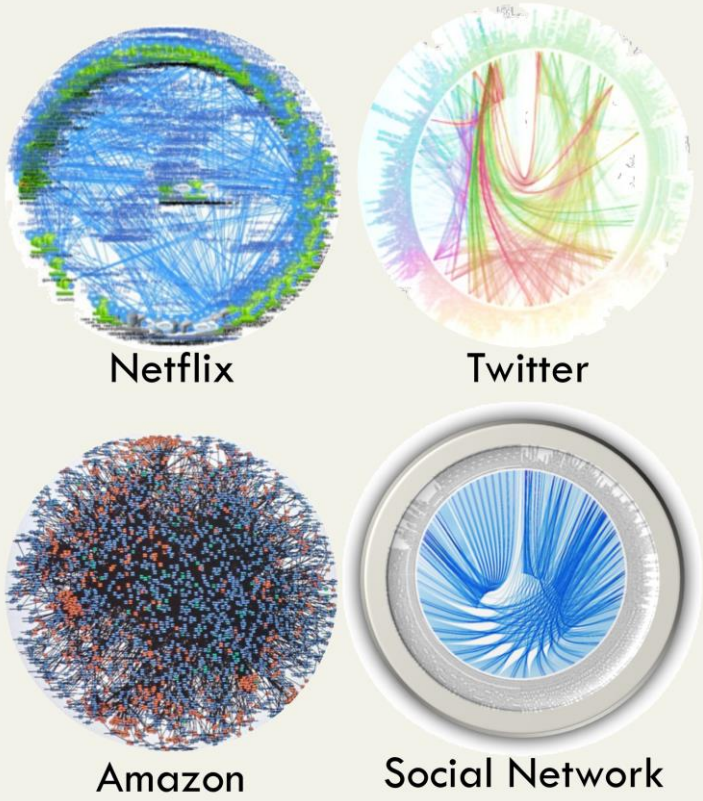

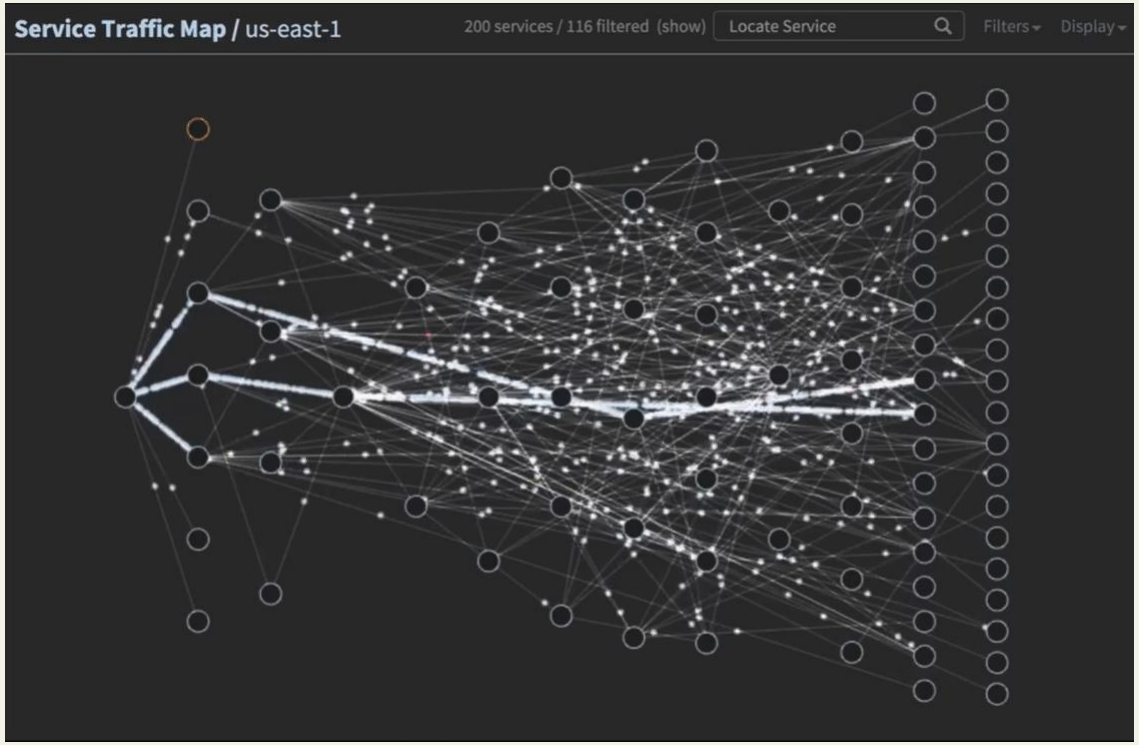

Real time traffic of Social Network Microservices

Visualization tool: https://github.com/netflix/vizceral.git

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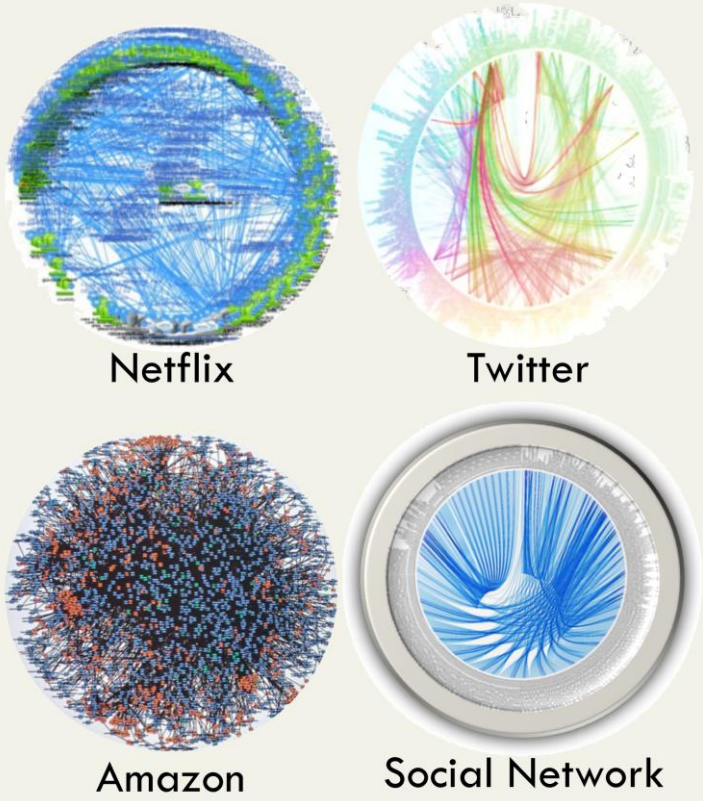

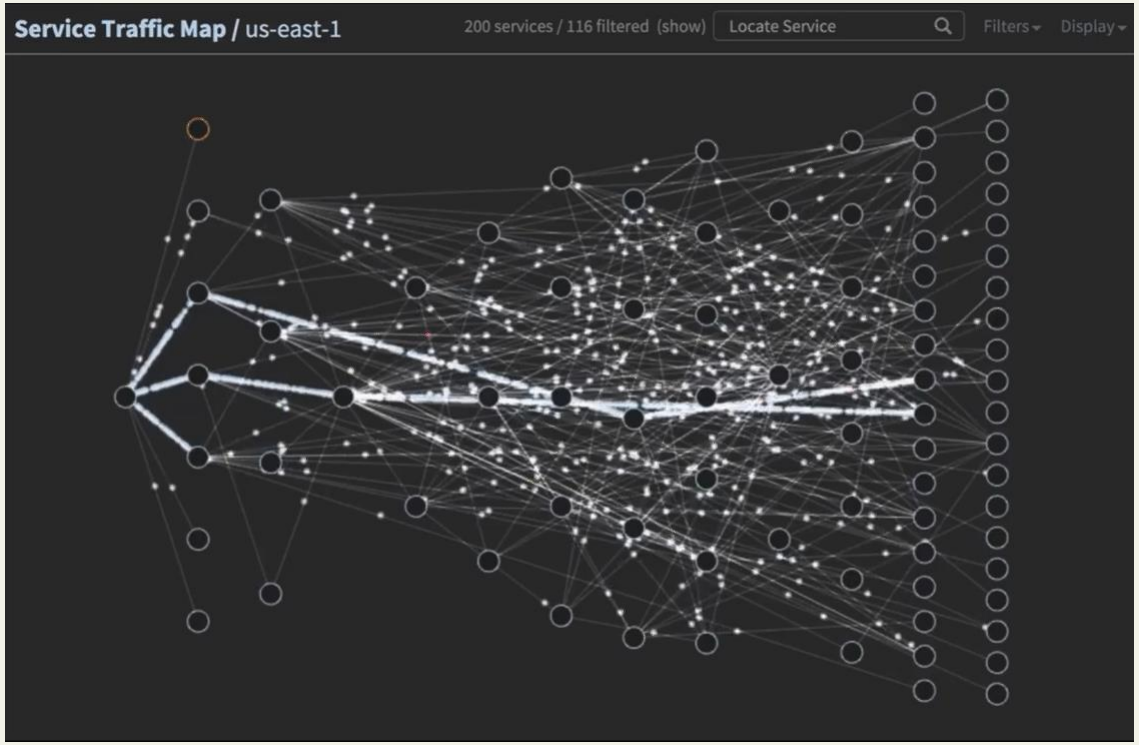

Real time traffic of Social Network Microservices

- Complicate cluster management due to microservice dependencies

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μQSim Design

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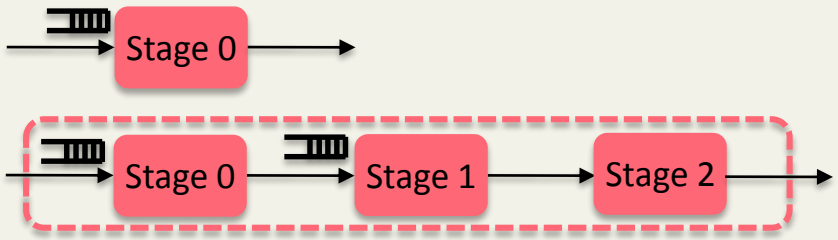

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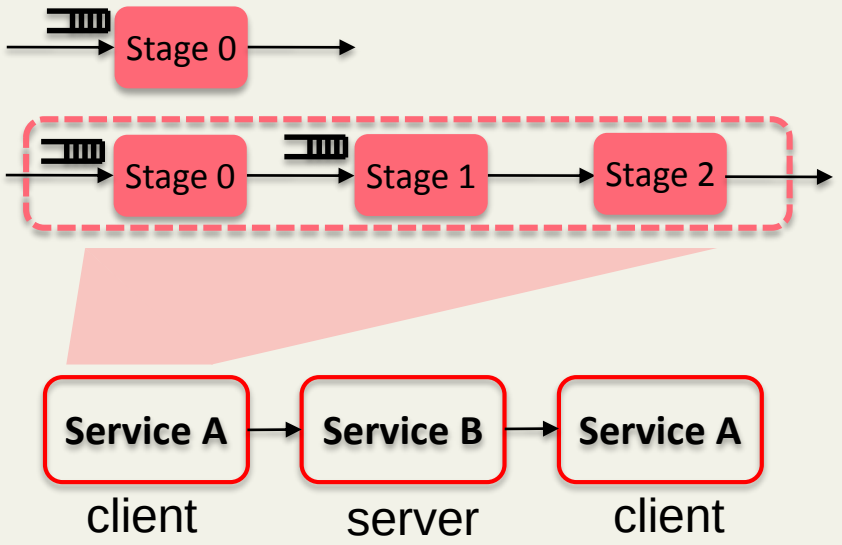

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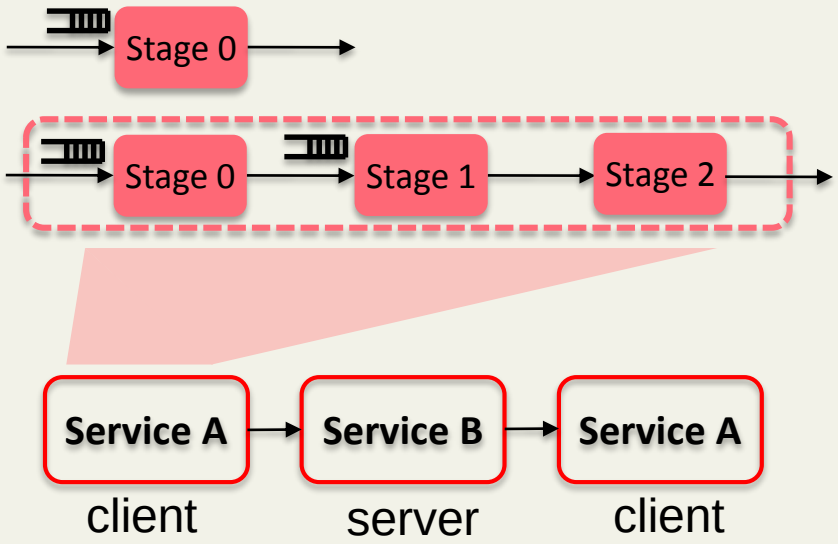

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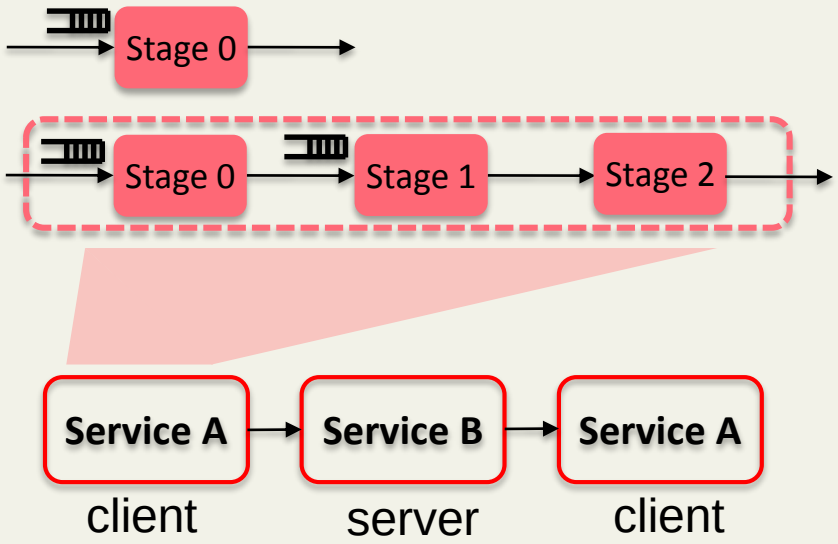

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  - Model sources of blocking: network connections, threads blocked by I/O accesses

Modeling Individual Microservices

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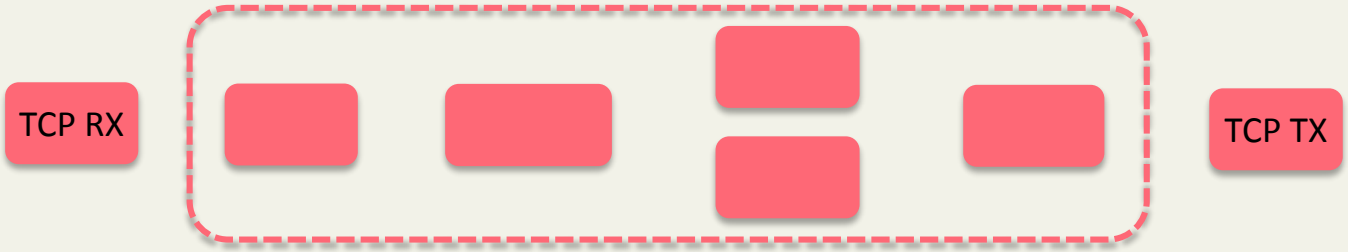

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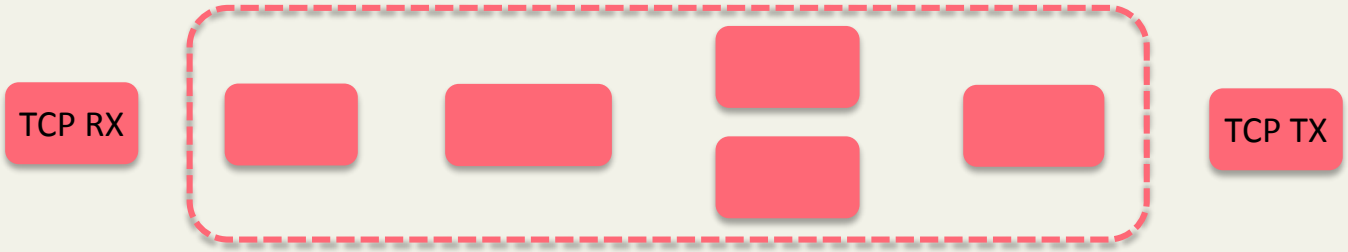

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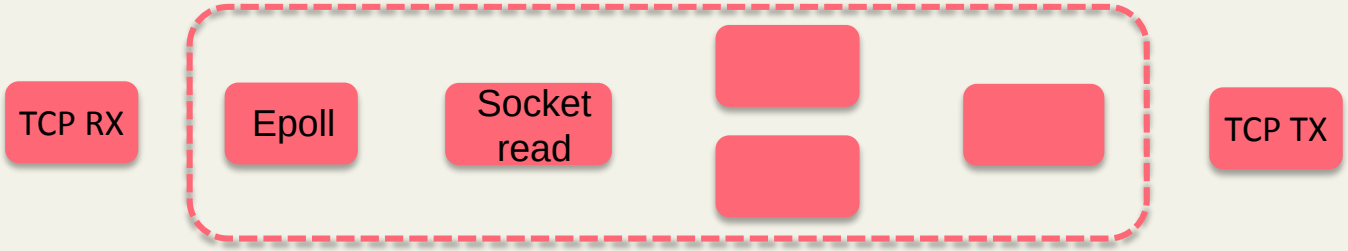

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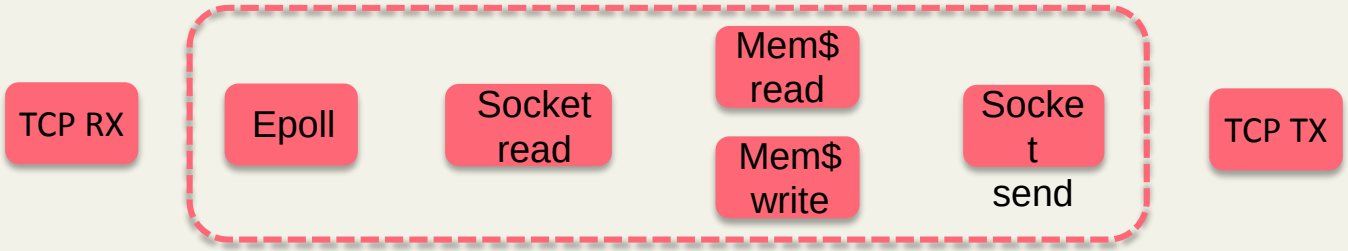

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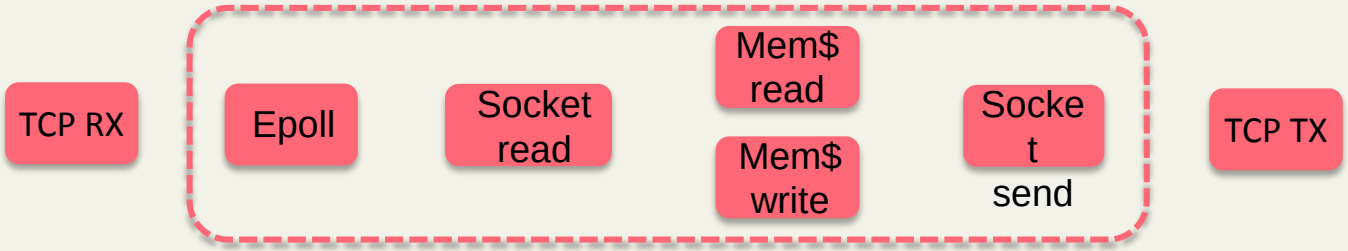

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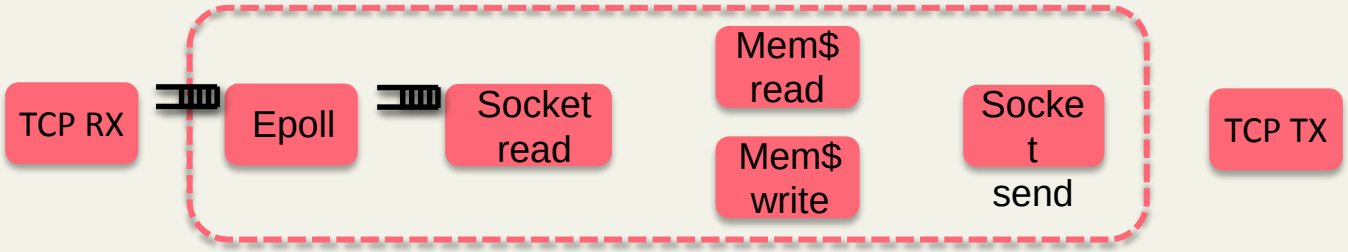

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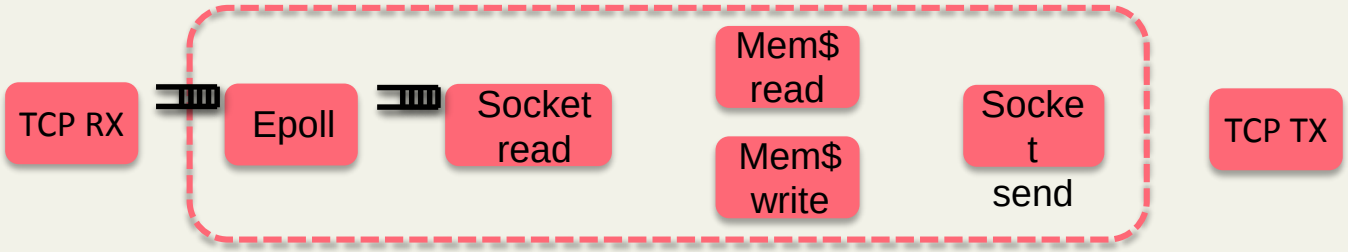

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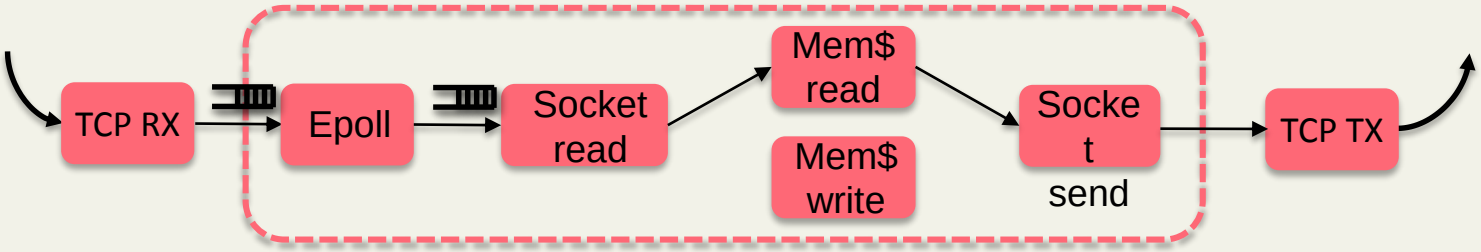

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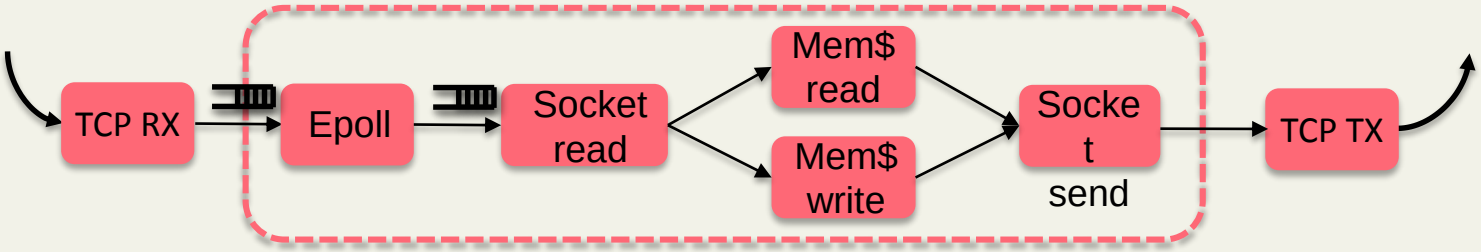

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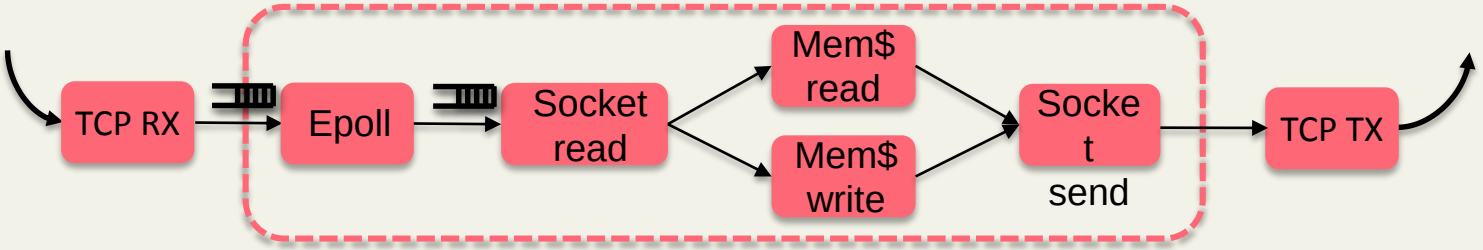

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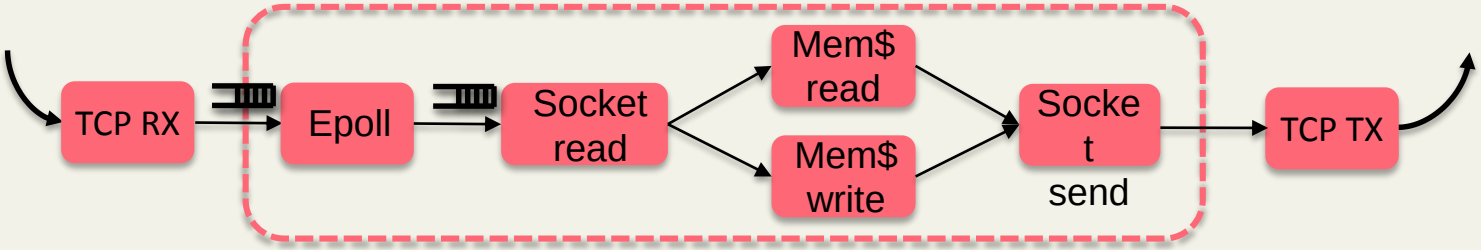

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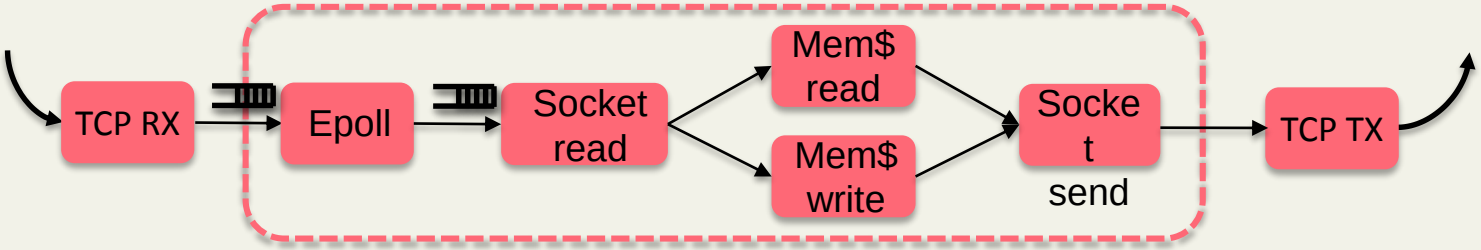

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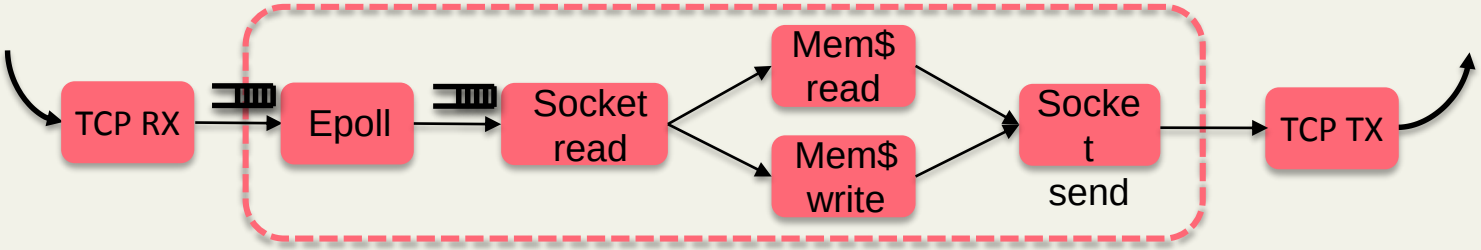

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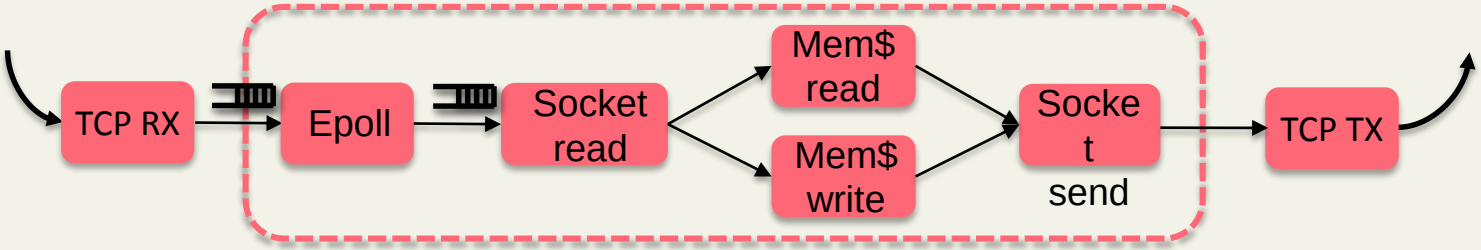

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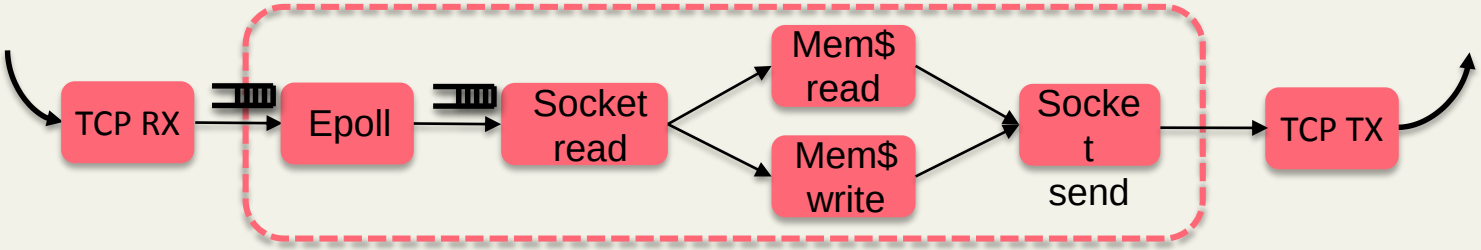

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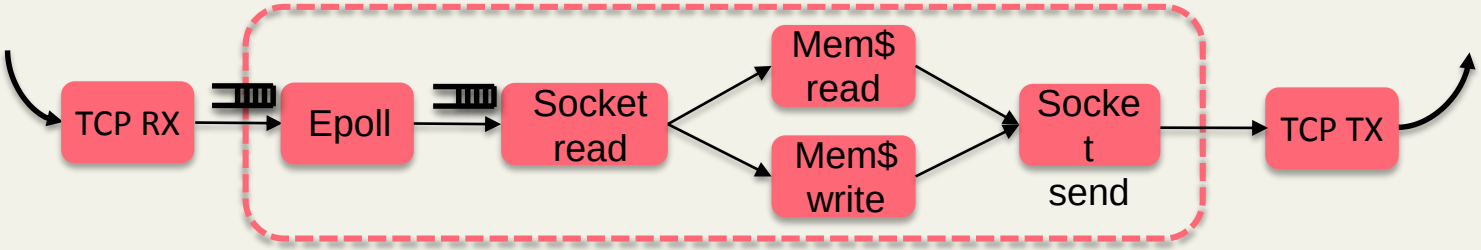

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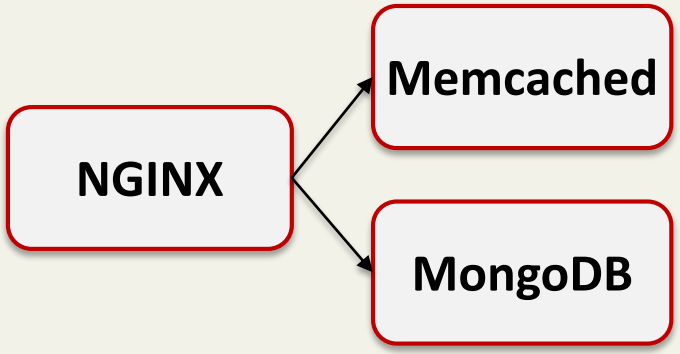

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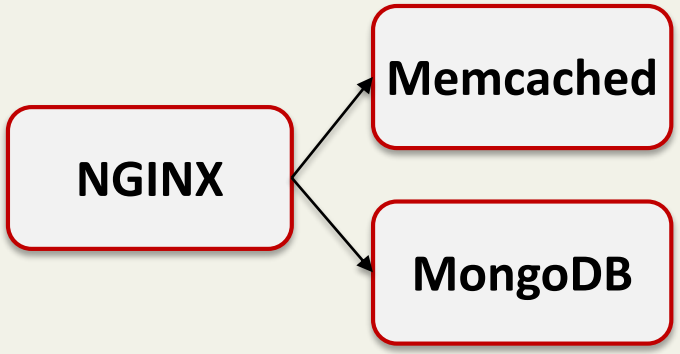

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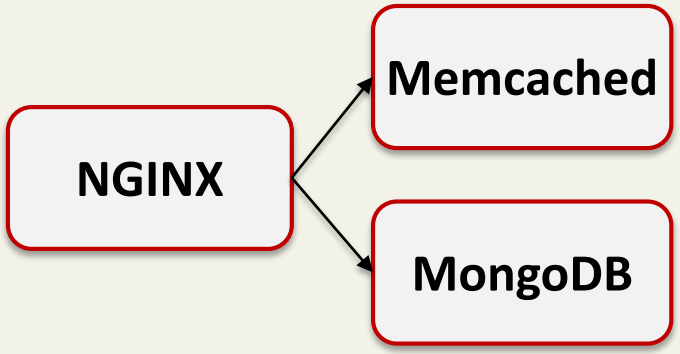

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- **Deployment**
  - Available servers and hardware resources
  - Service to server mapping
  - Services on the same server share network stack & disk I/O

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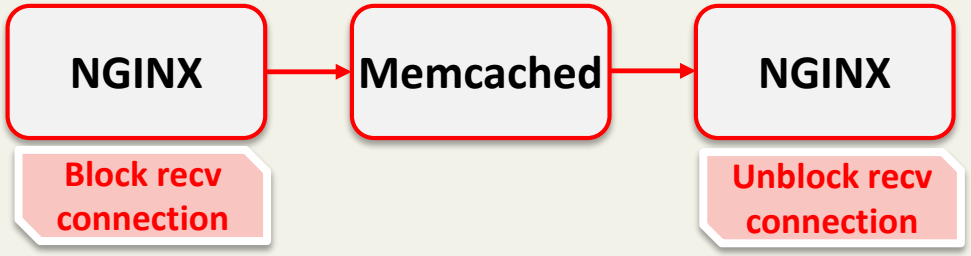

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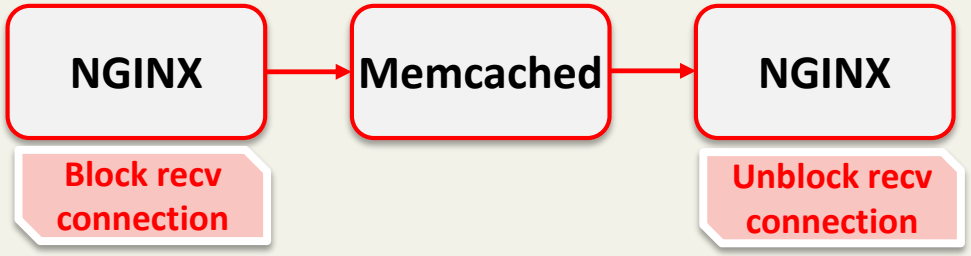

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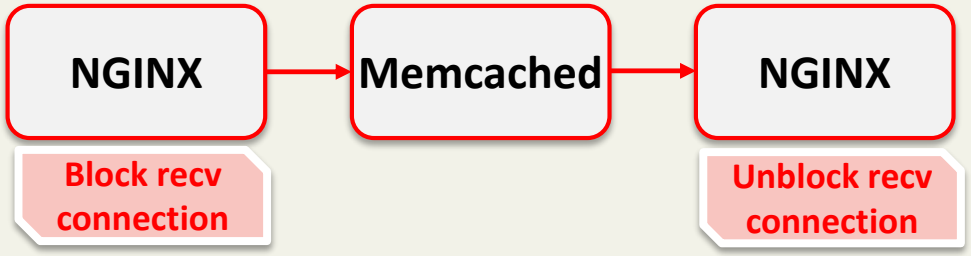

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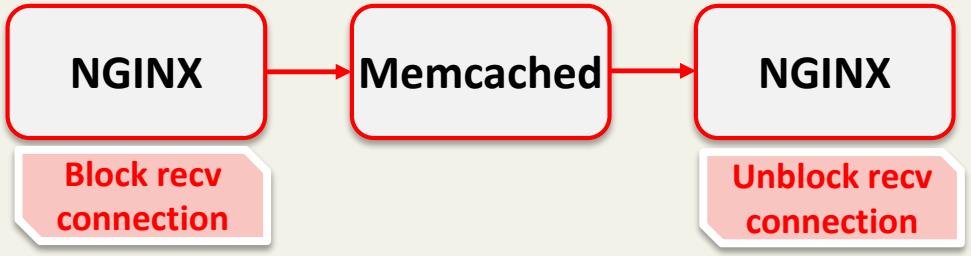

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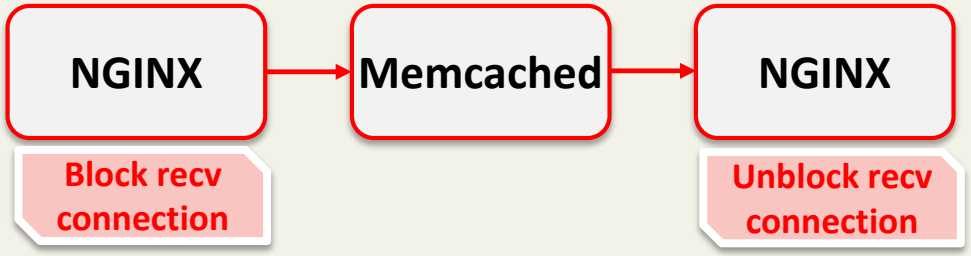

Modeling Dependency Graph & Dataflow

- **Example: 2-tier application & http 1/1.1 protocol**
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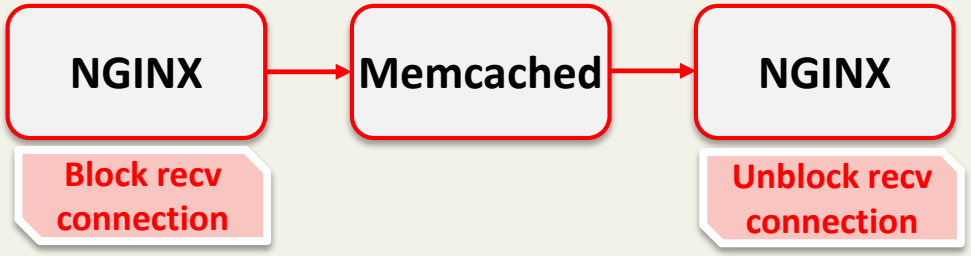

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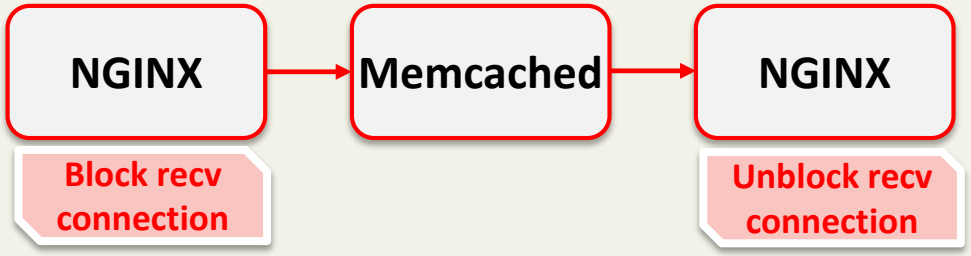

Connection A 1 2

Connection B 3

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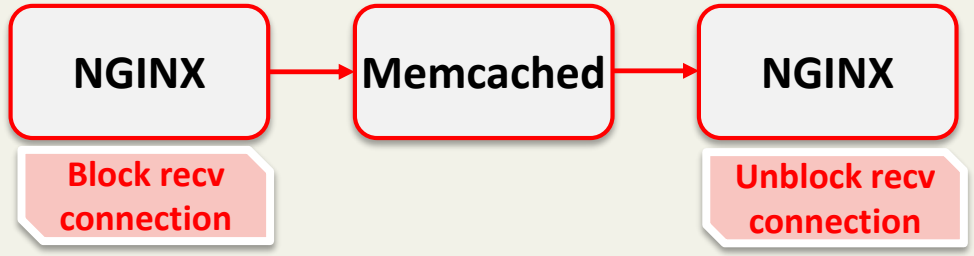
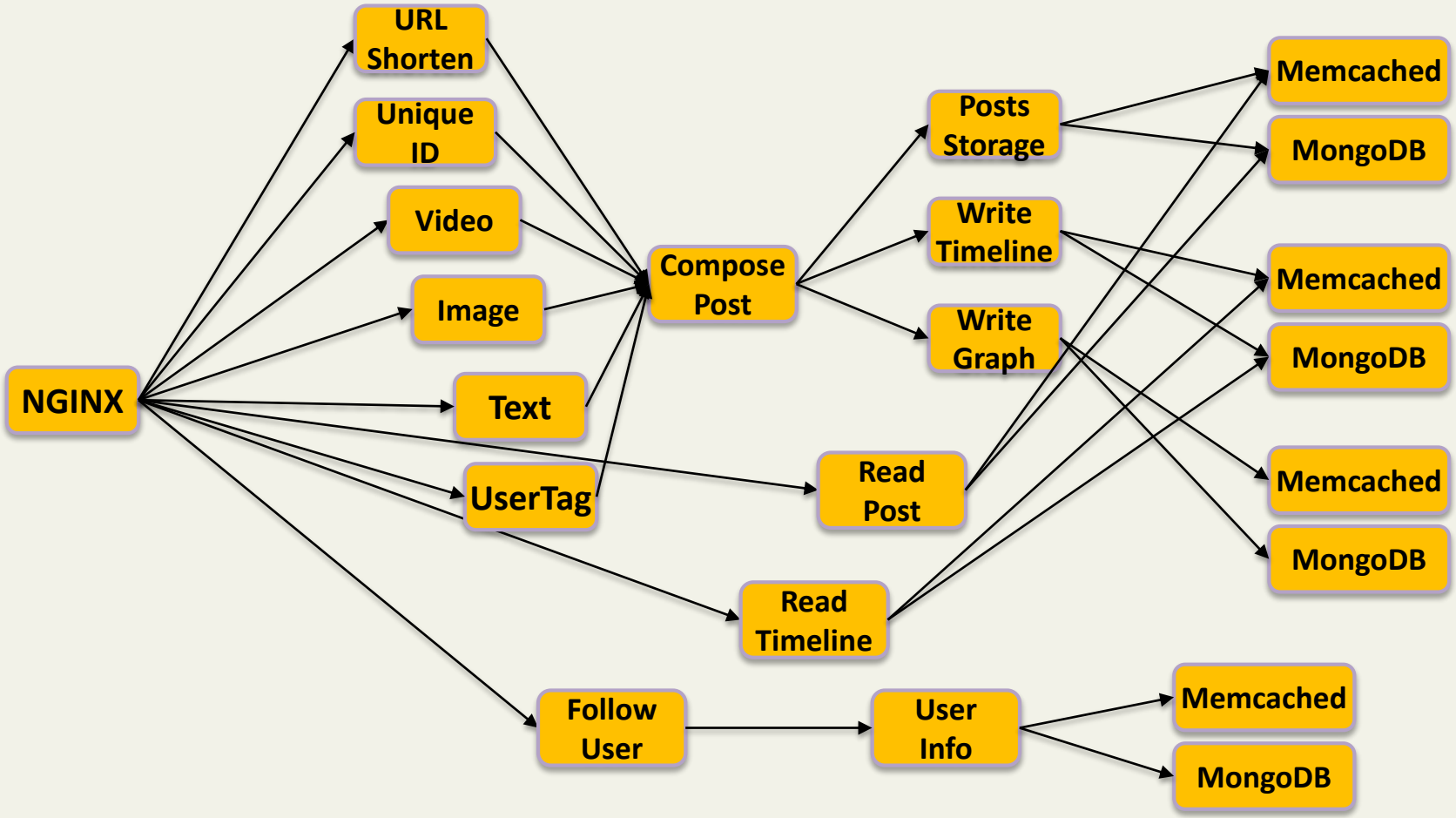


Dependency Graph for Complex Microservices

- Social network application



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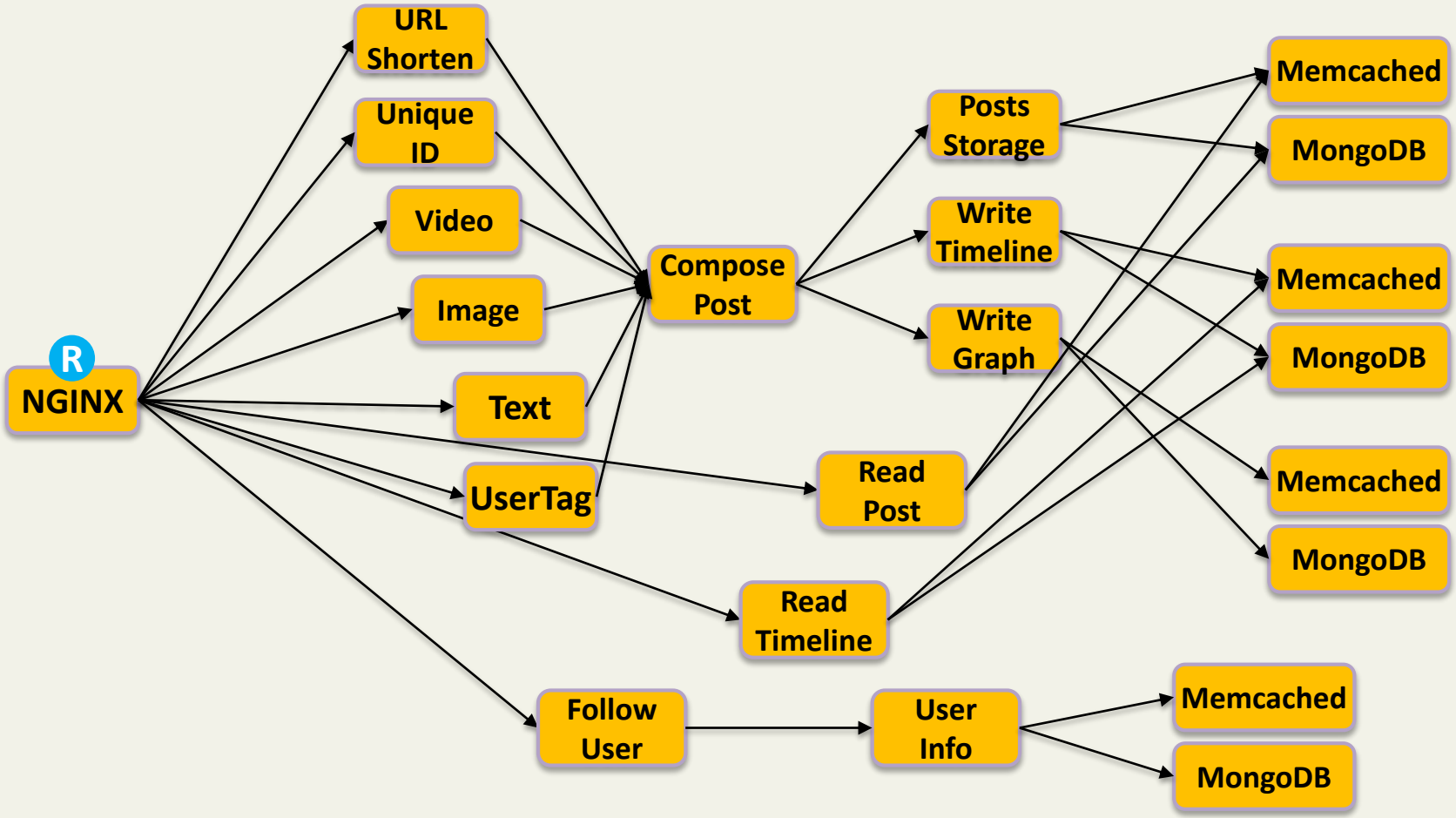

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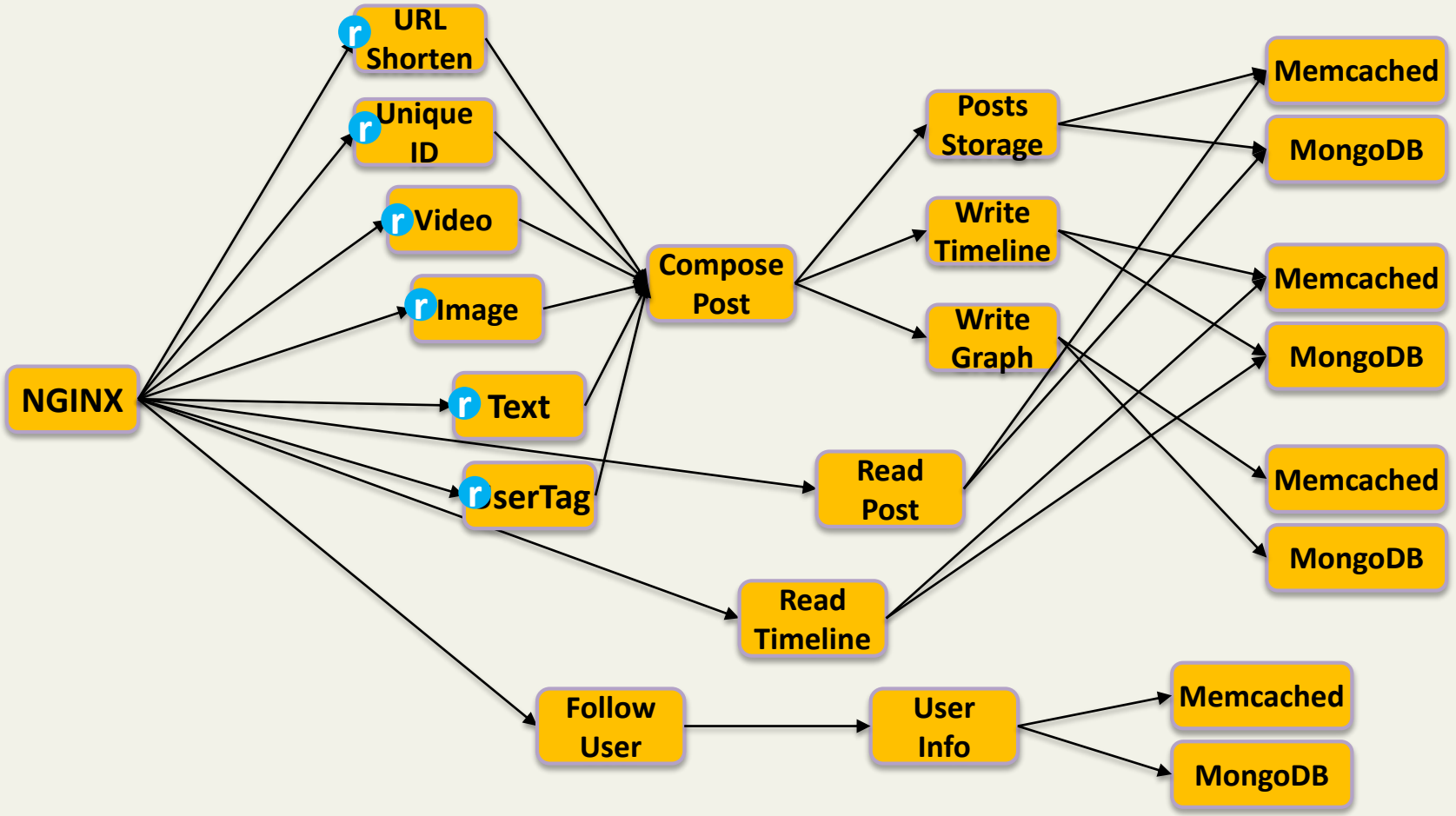

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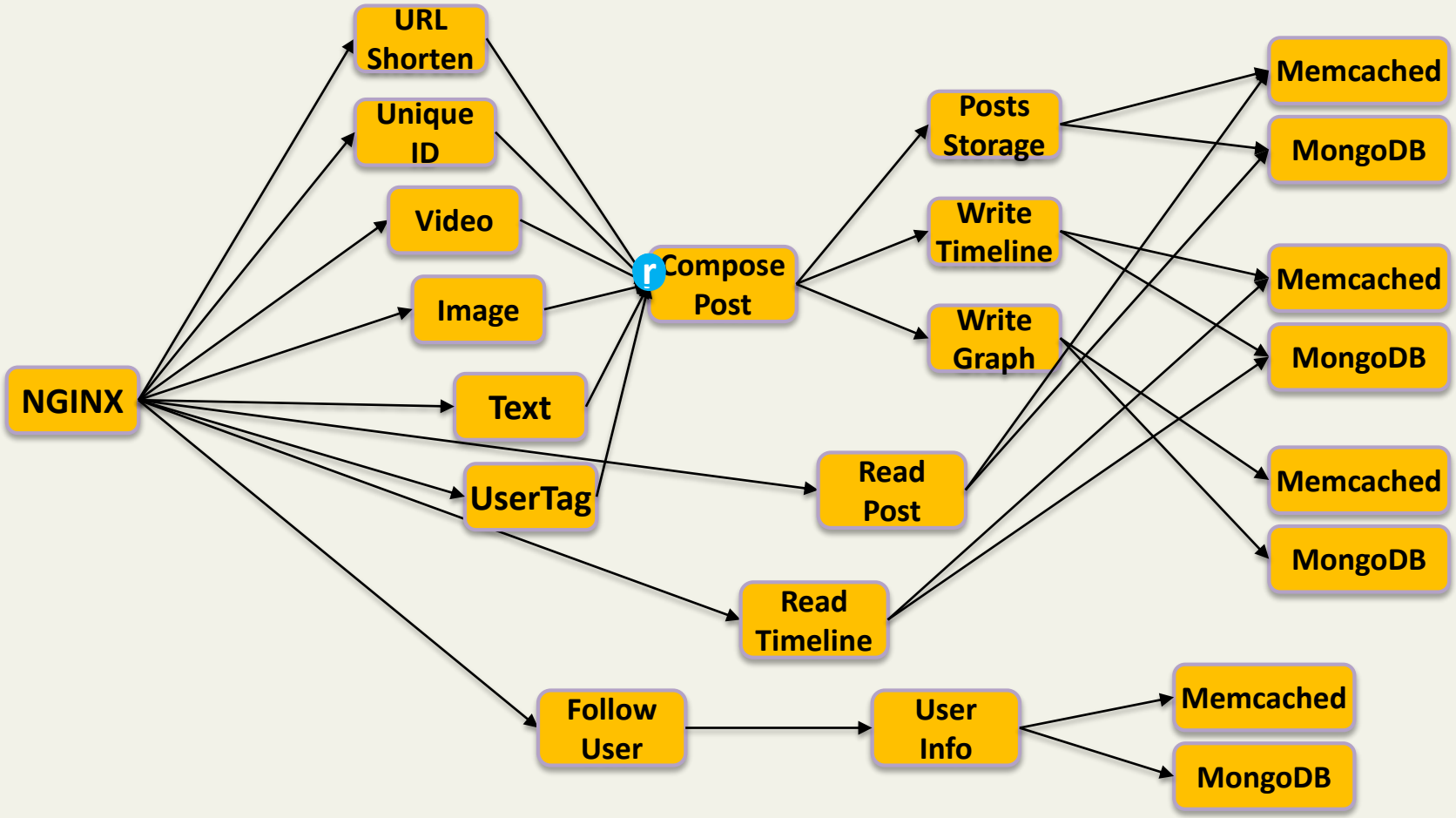

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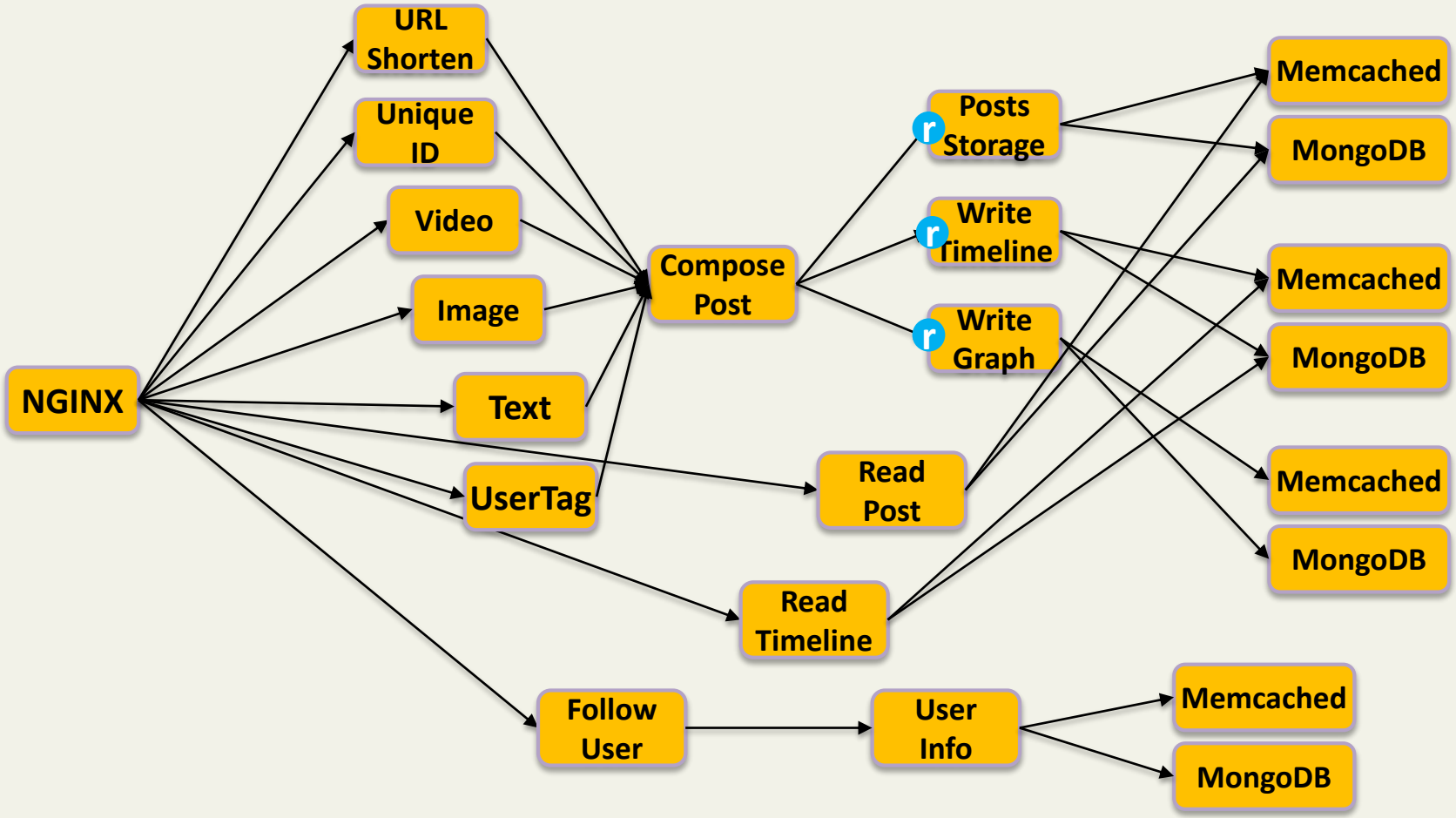

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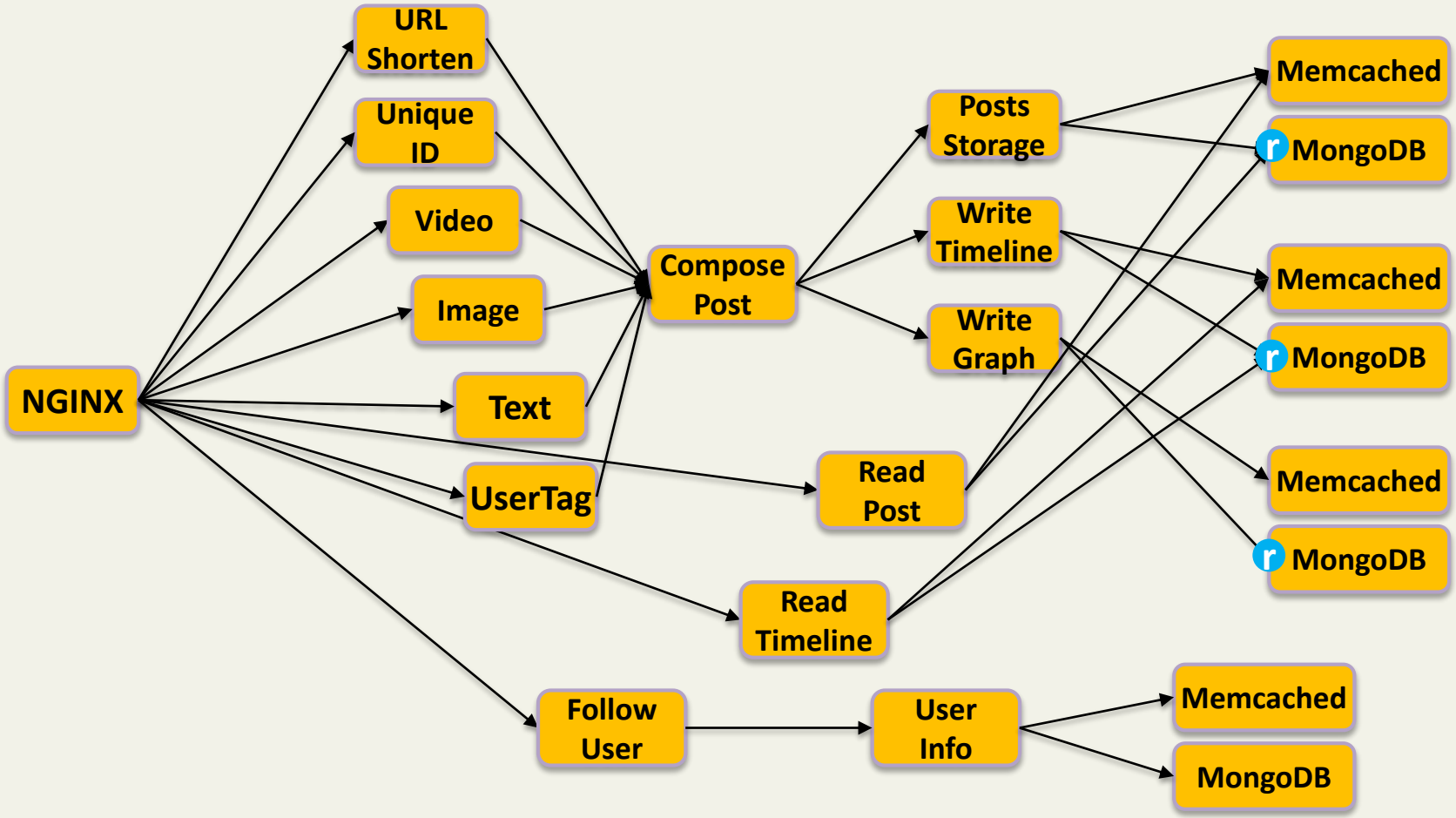

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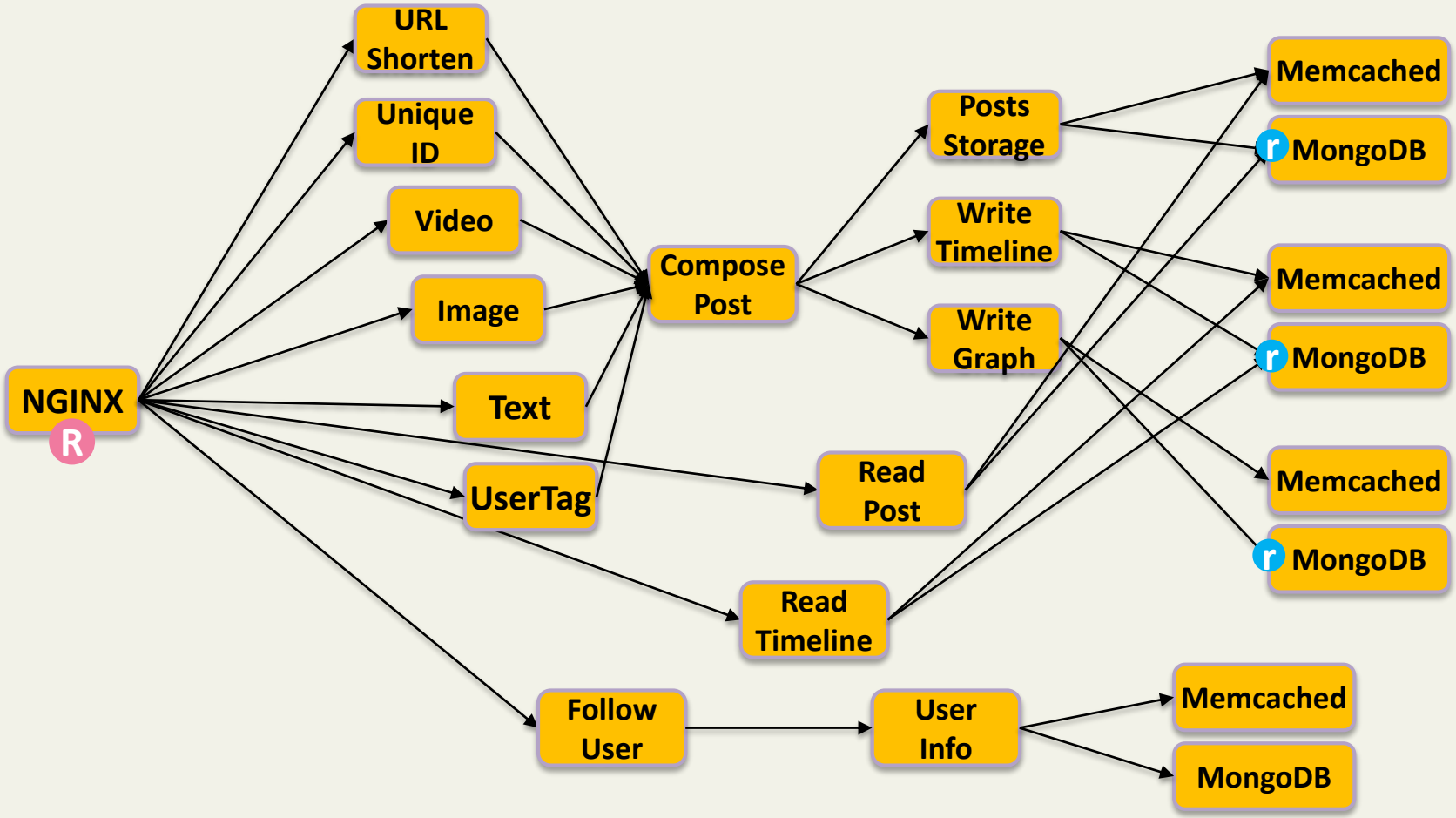

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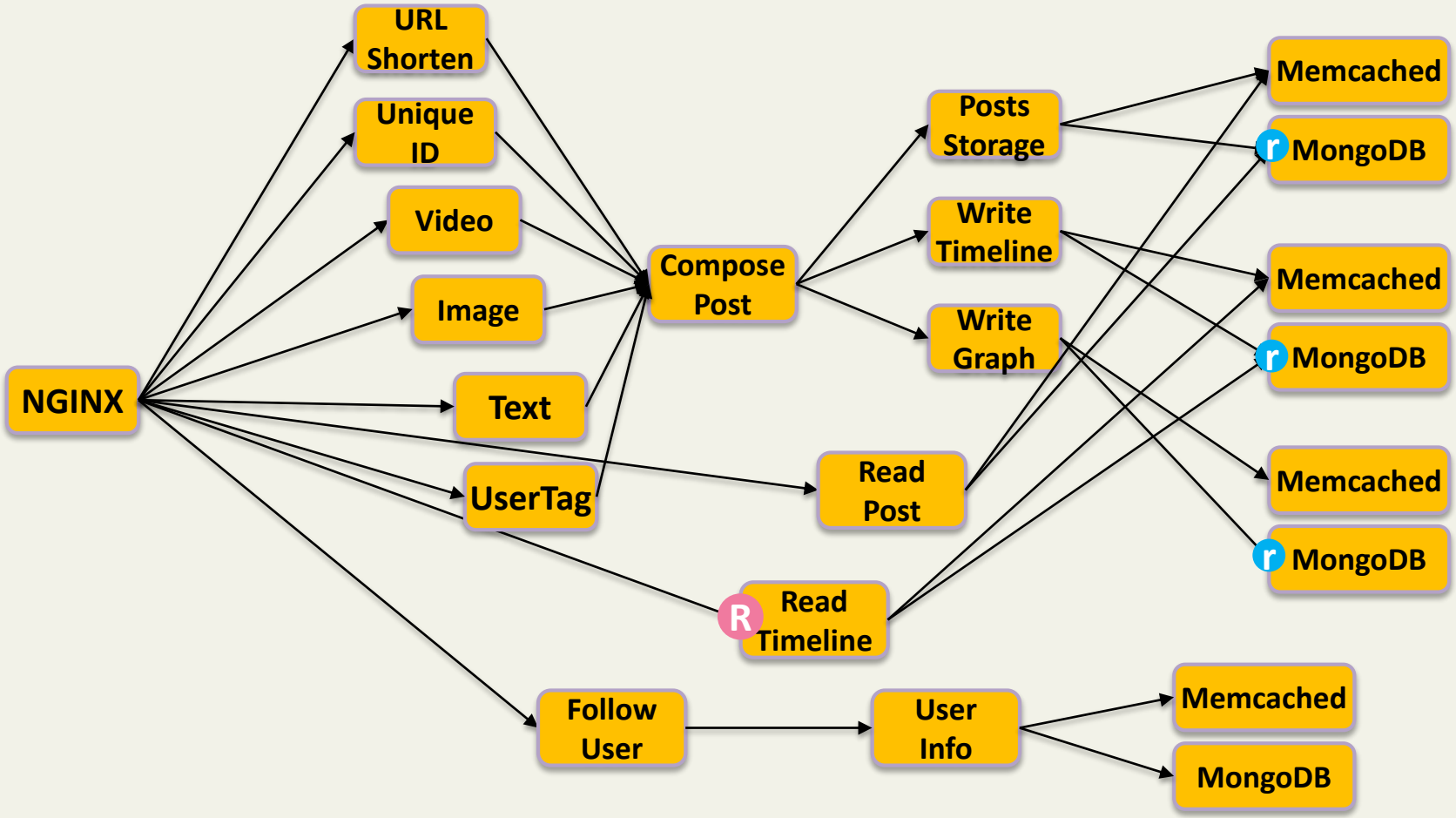

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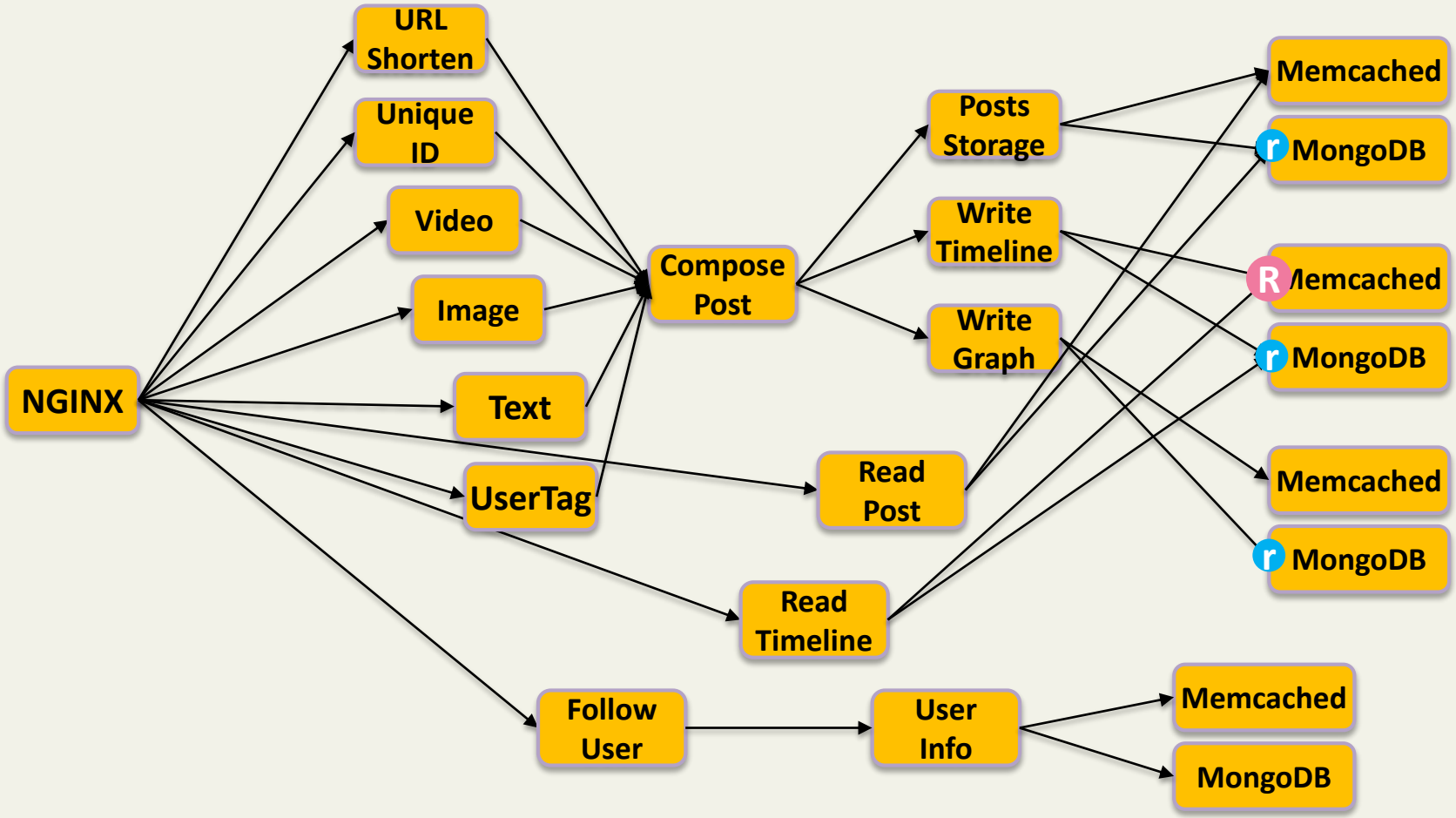

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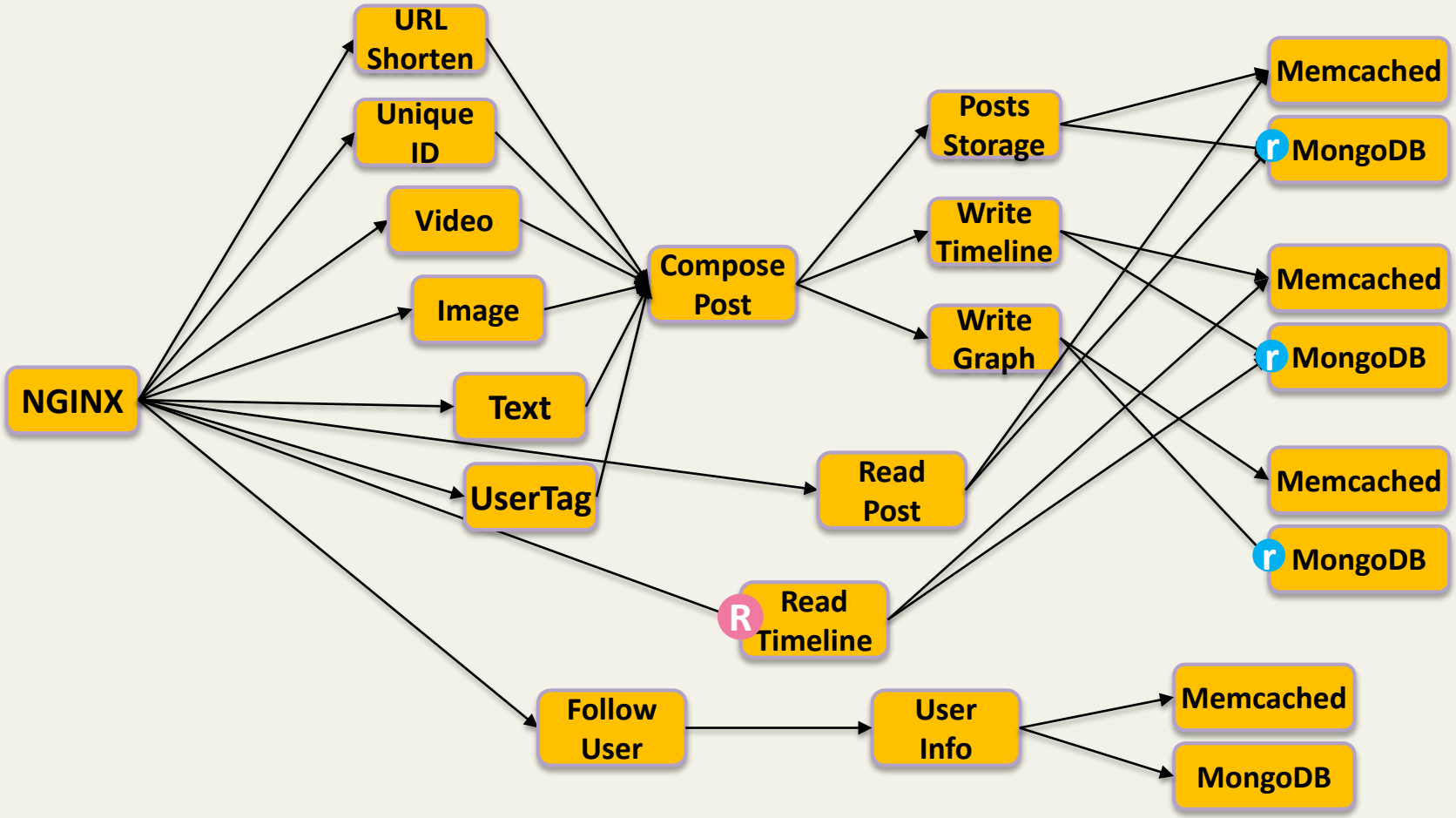

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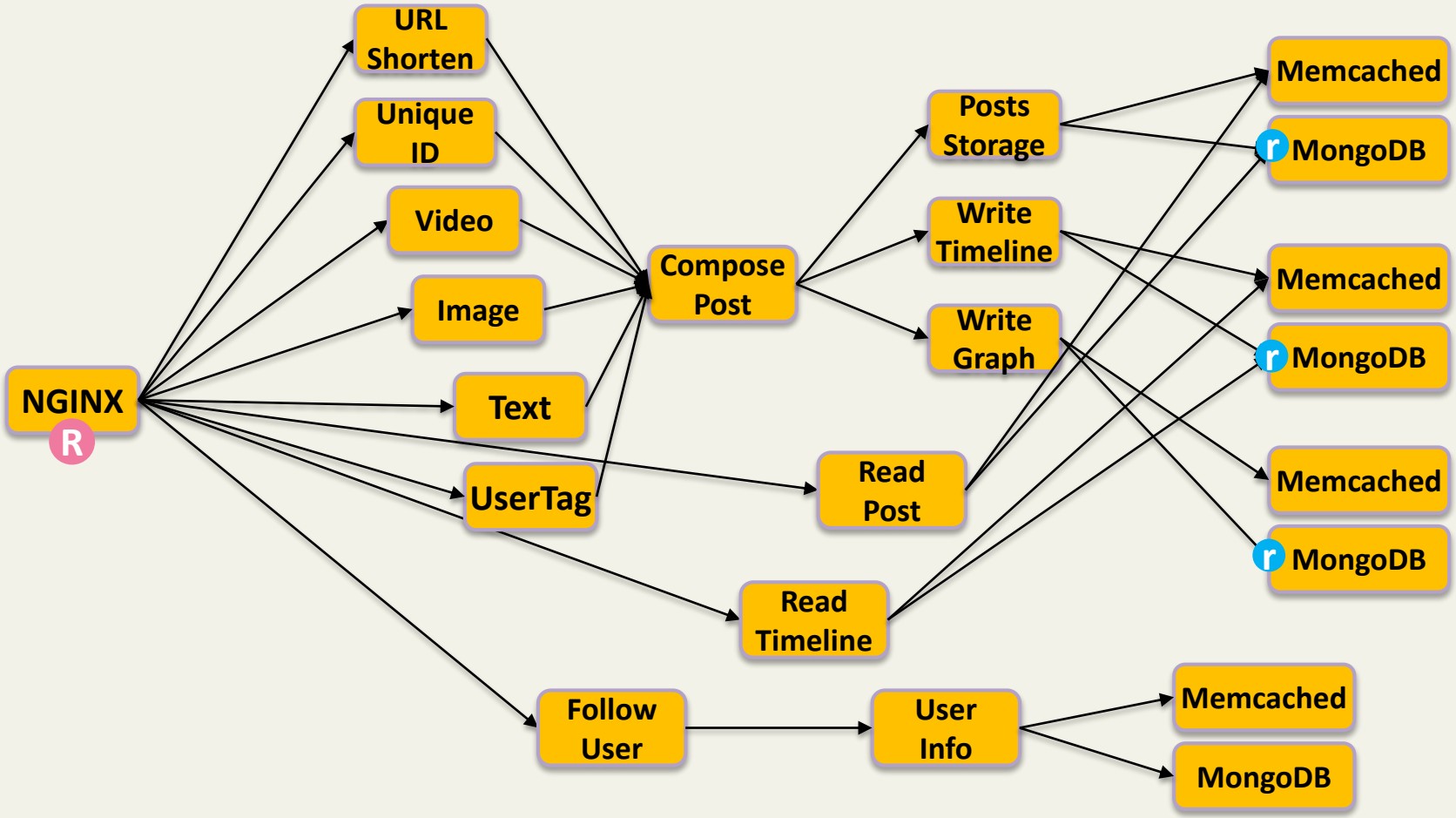

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SIMULATOR INPUTS

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  - Typical queues: network, epoll/kqueue, socket read, disk I/O…
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- **Server & system resources**

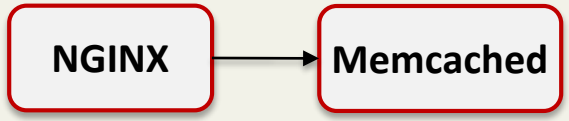
VALIDATION

- **Validation experiments**
  - Multi-tier microservices: 2/3-tier application
  - Load balancing & fanout effects
  - Microservices based on RPC
  - Comparison with BigHouse

- **Server platform for trace collection**
  - 10-server cluster
  - Intel(R) Xeon(R) CPU E5-2660 v3
  - 2 sockets, 10 cores/socket, 2 threads/core
  - Min/max DVFS frequency: 1.2GHz/2.6GHz
  - Network bandwidth: 1Gbps

2/3-Tier Application

- 2-tier application



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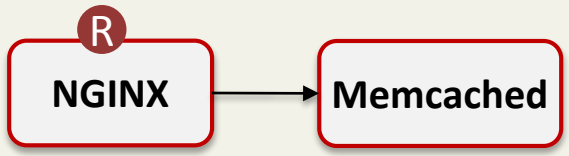

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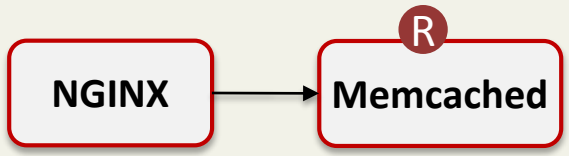

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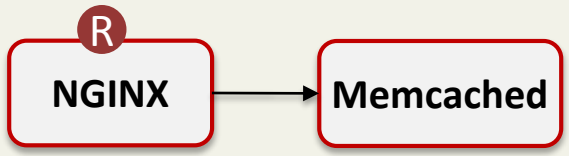

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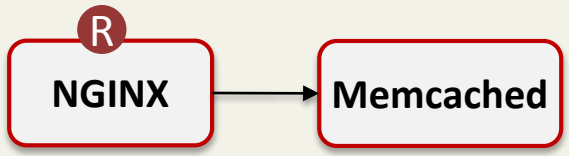

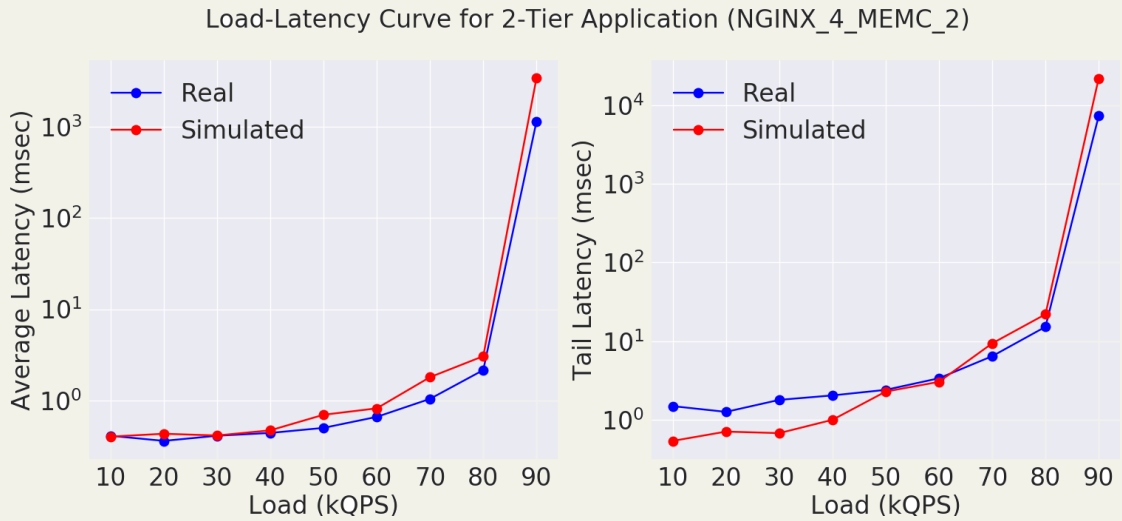

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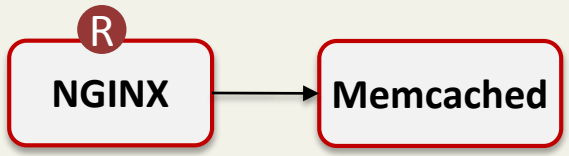

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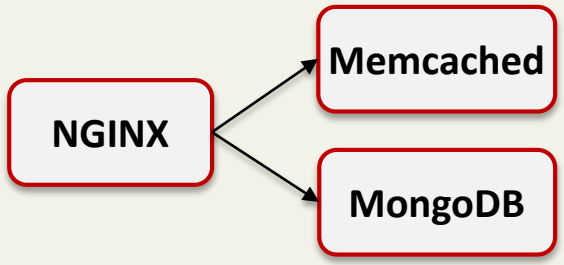

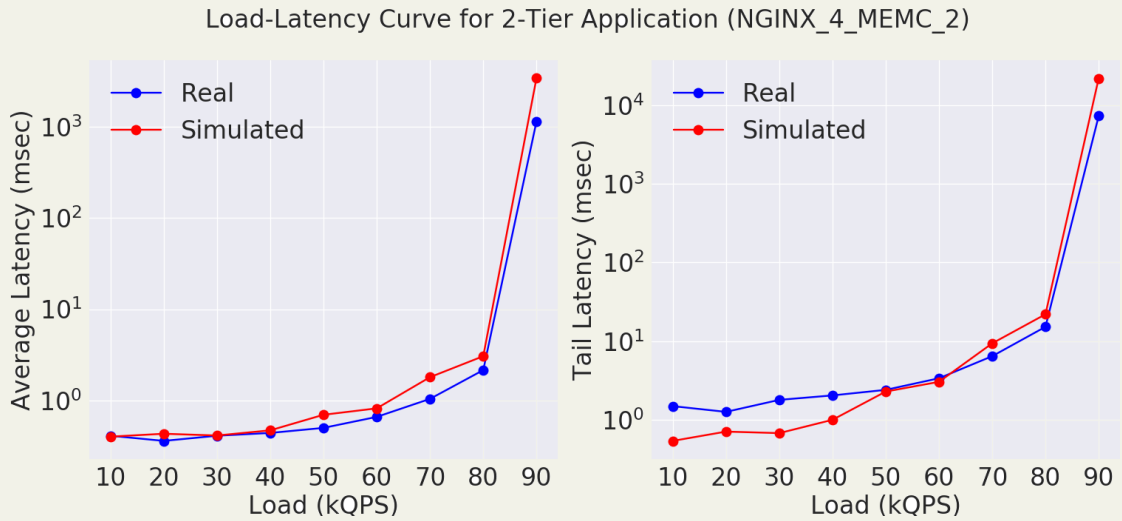

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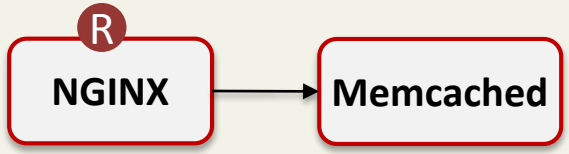

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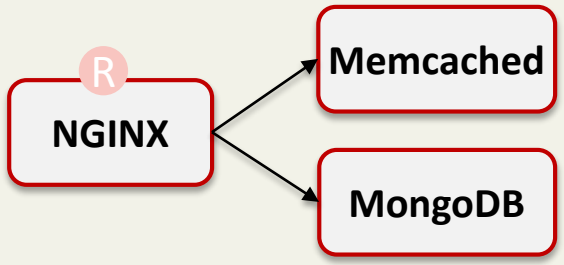

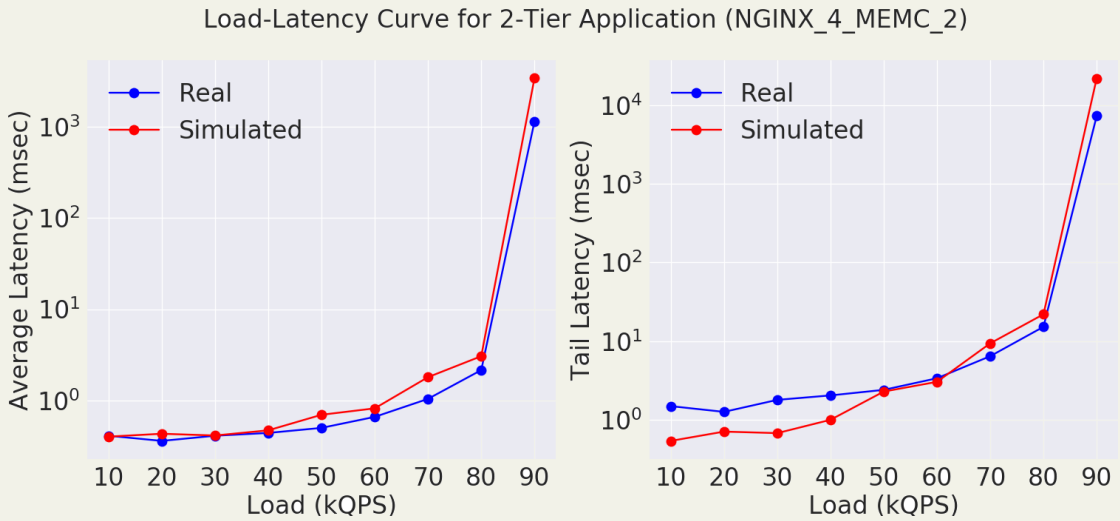

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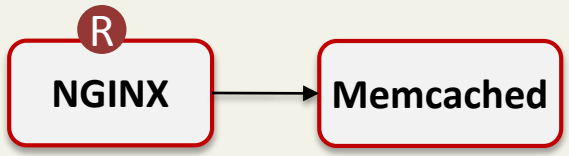

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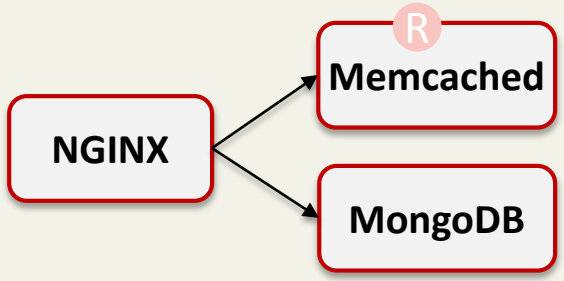

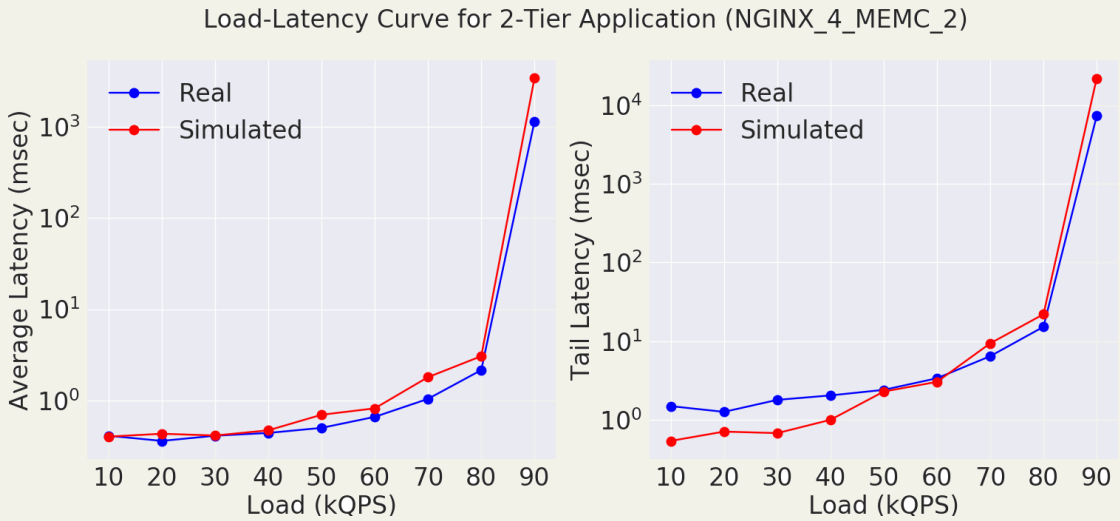

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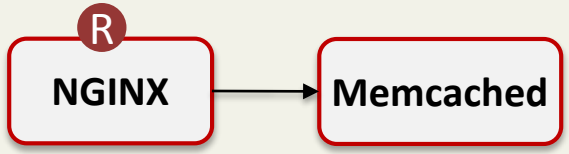

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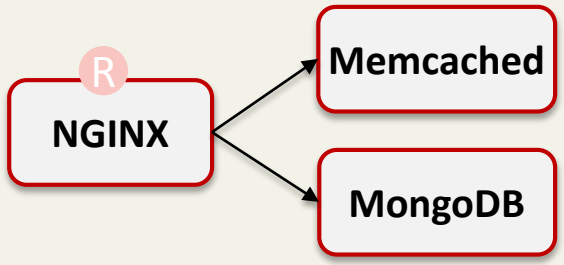

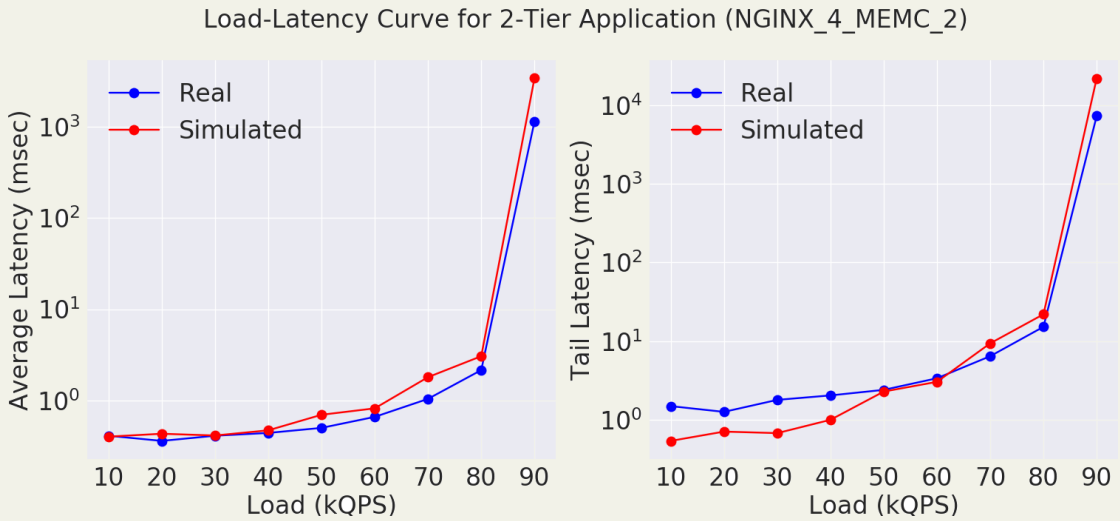

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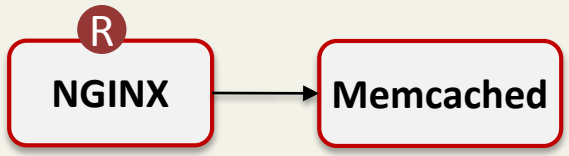

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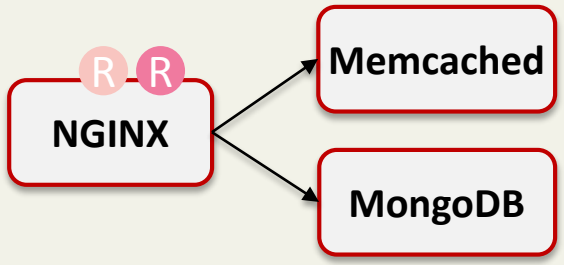

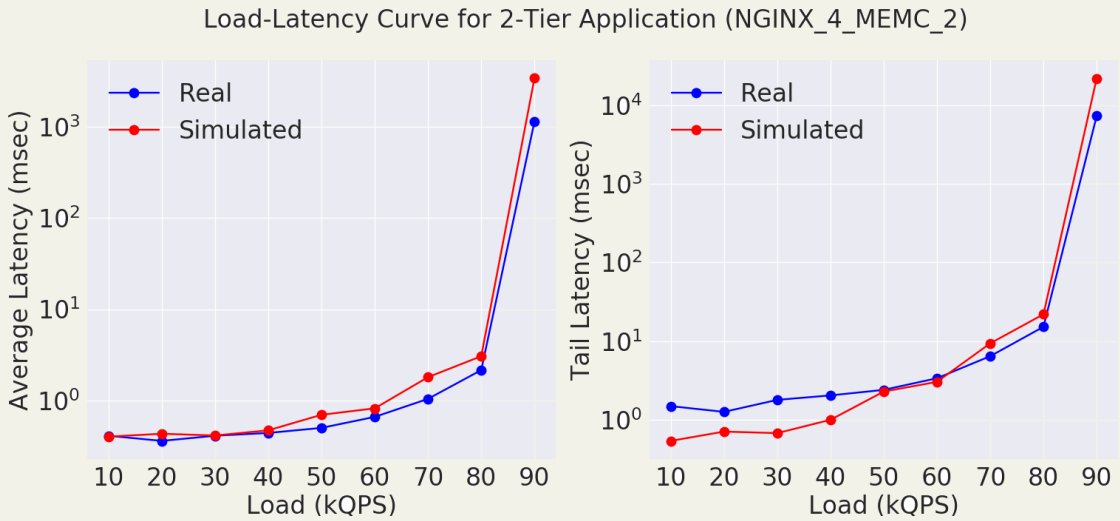

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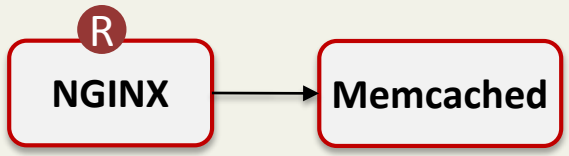

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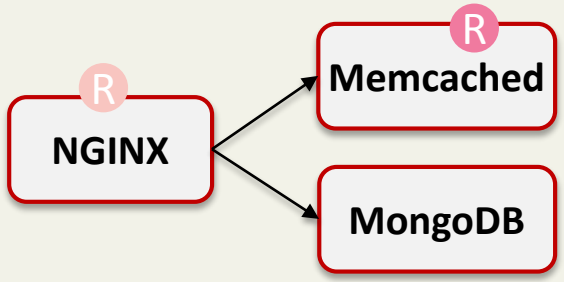

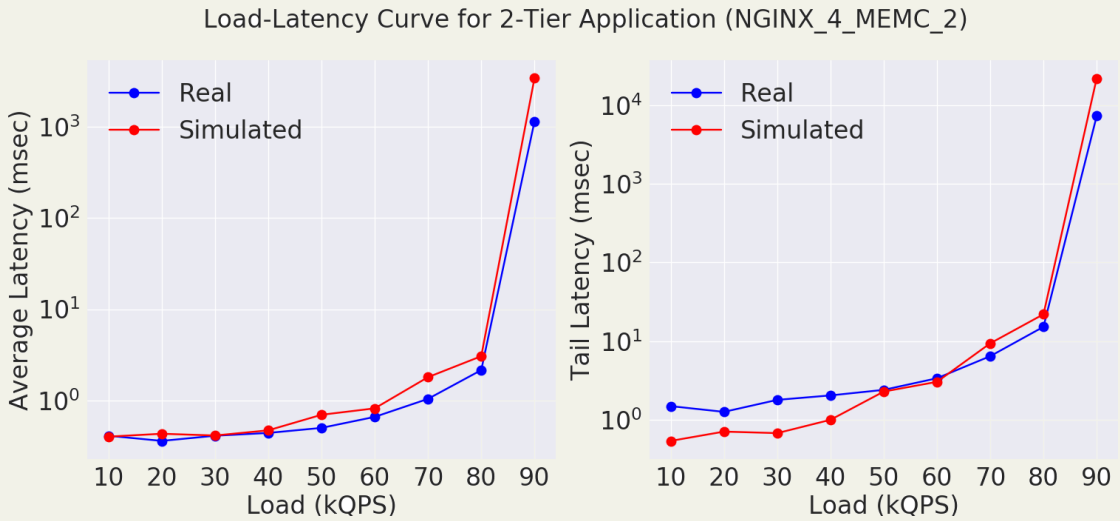

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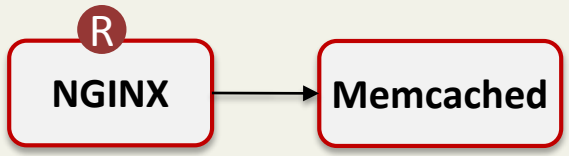

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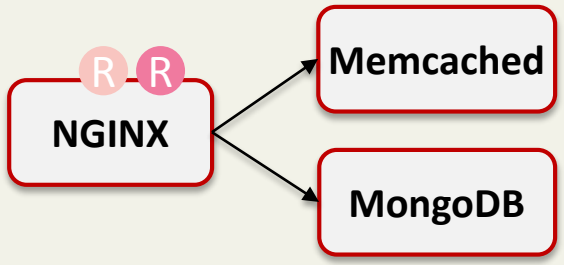

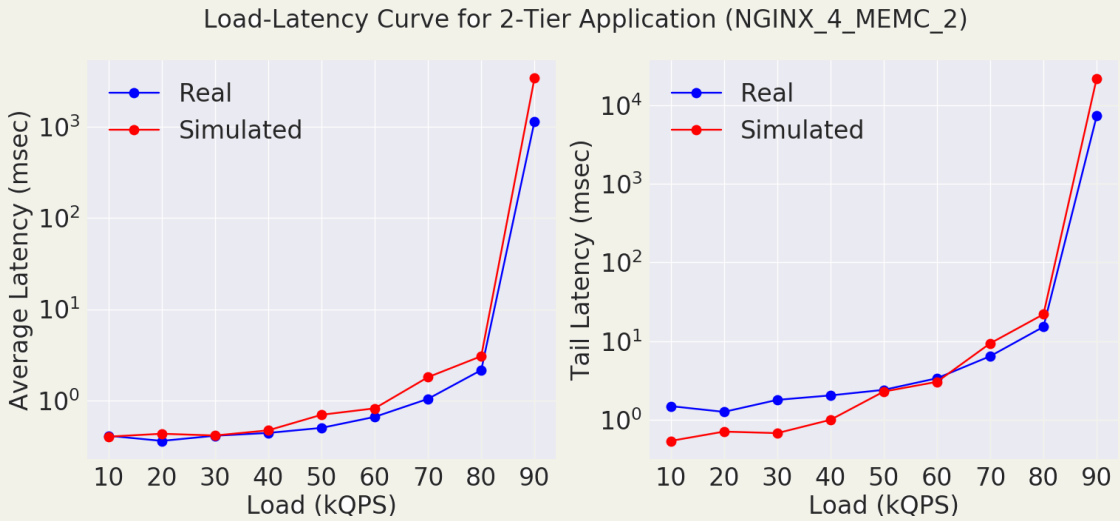

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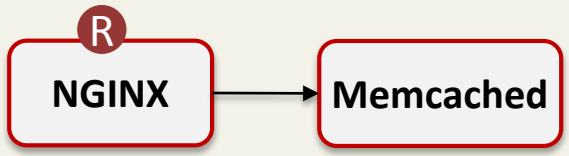

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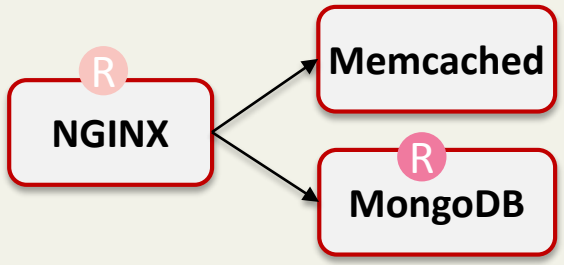

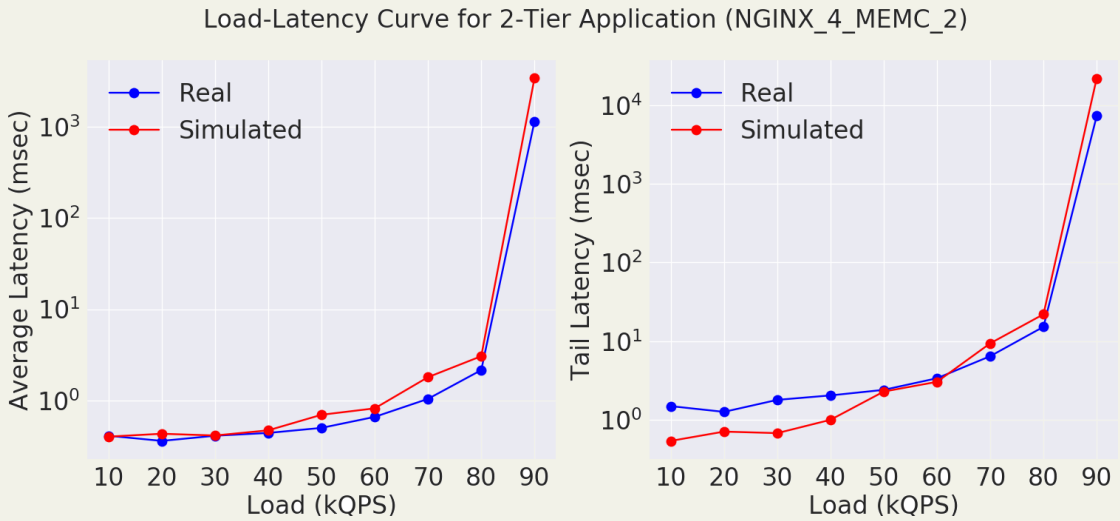

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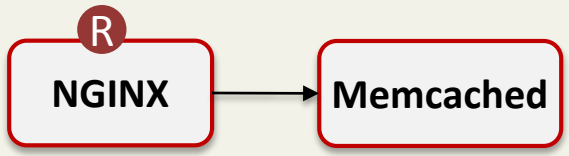

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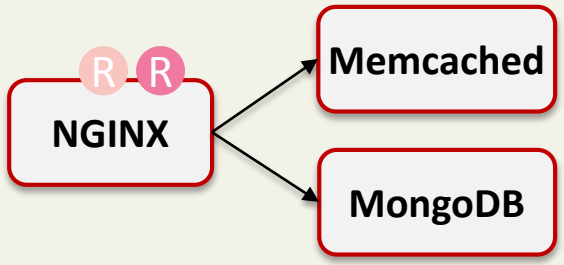

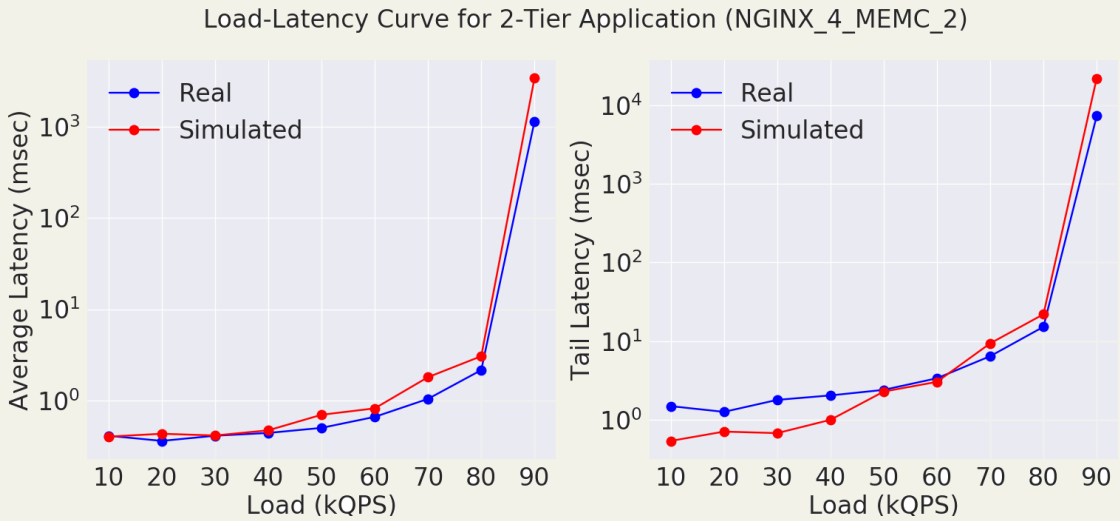

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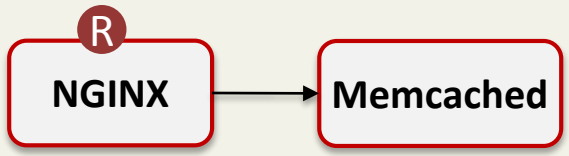

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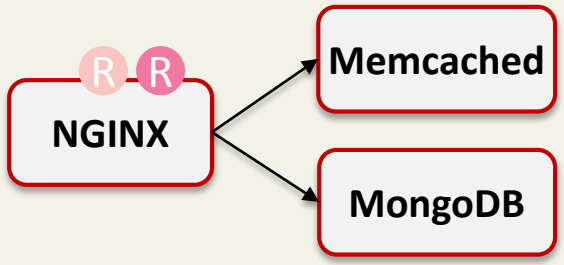
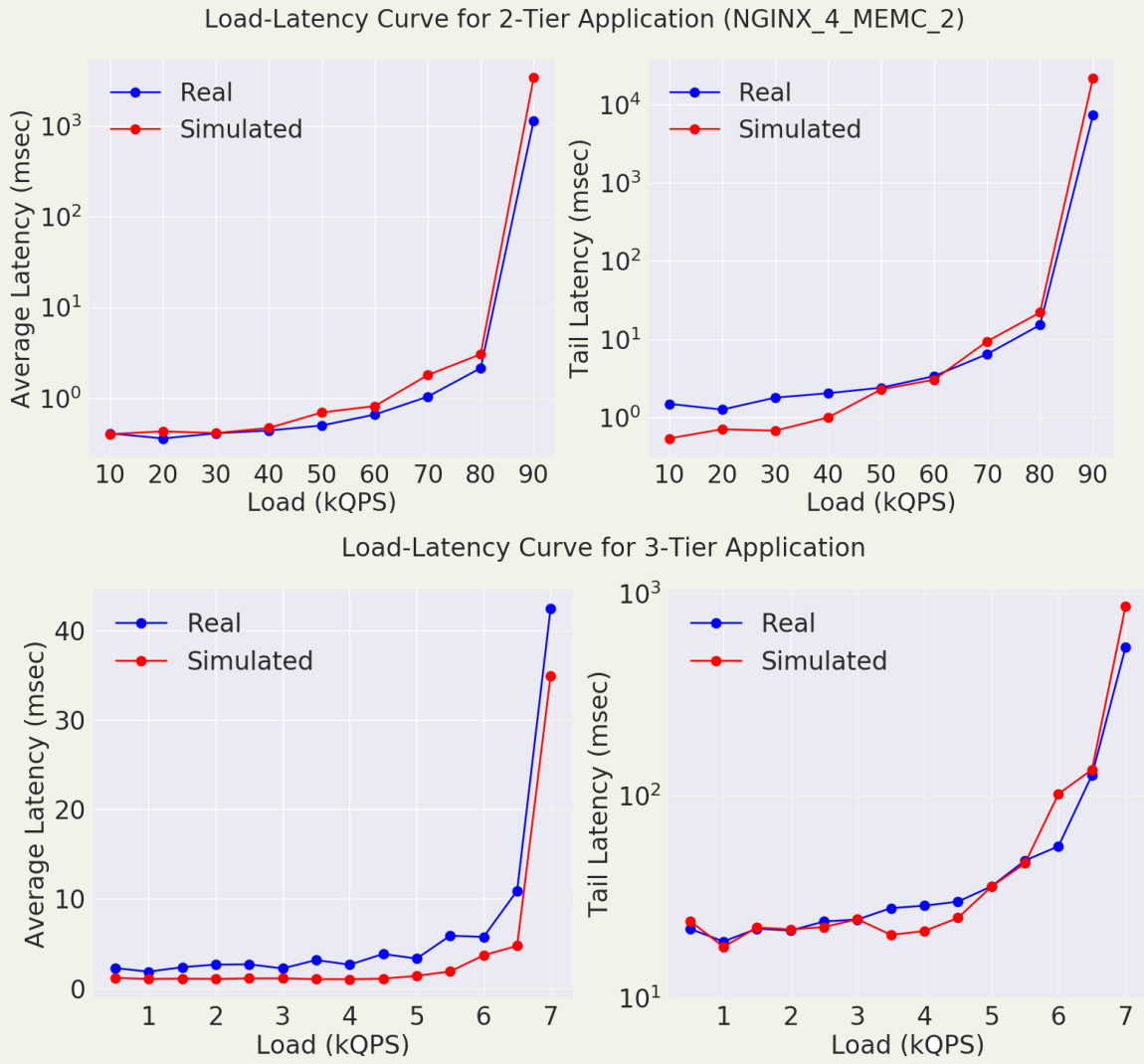
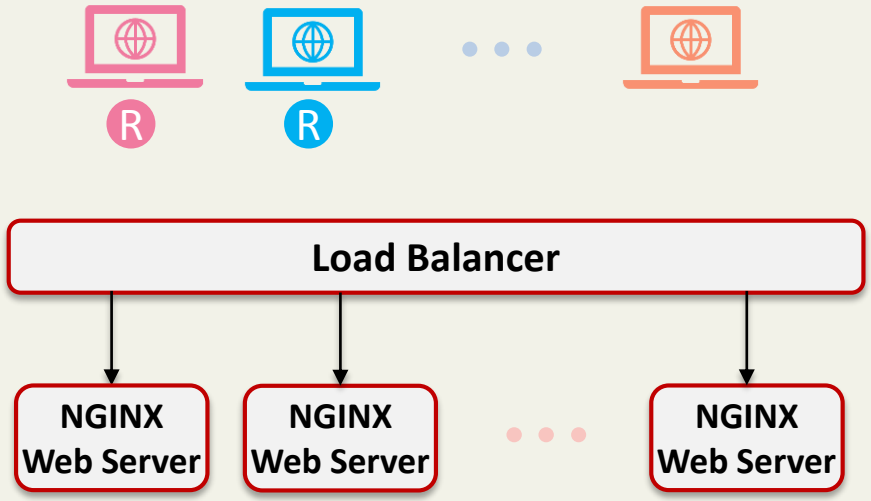




Load Balancing



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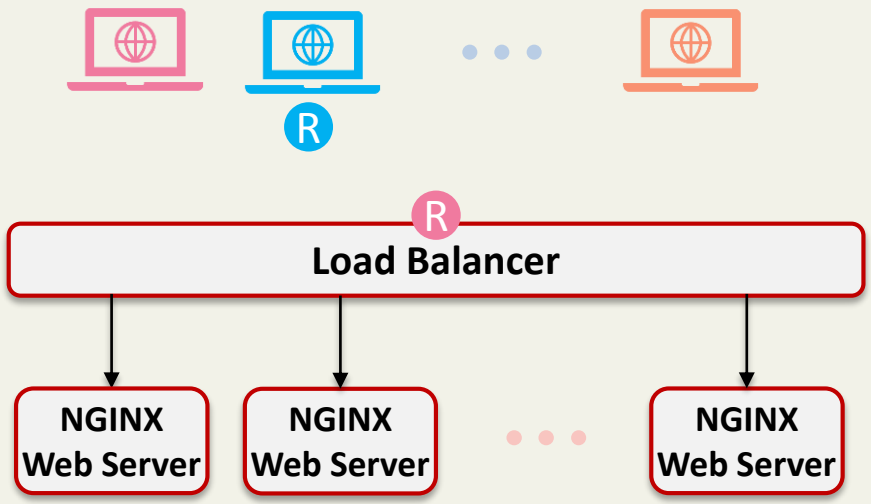

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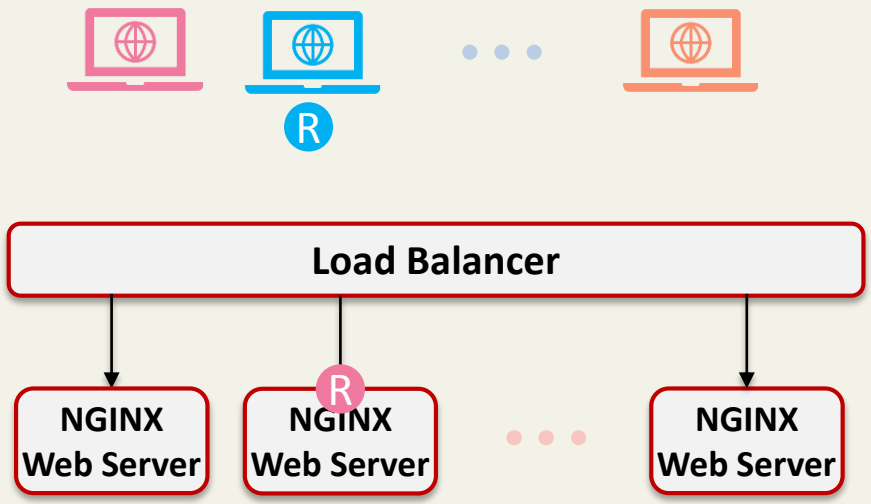

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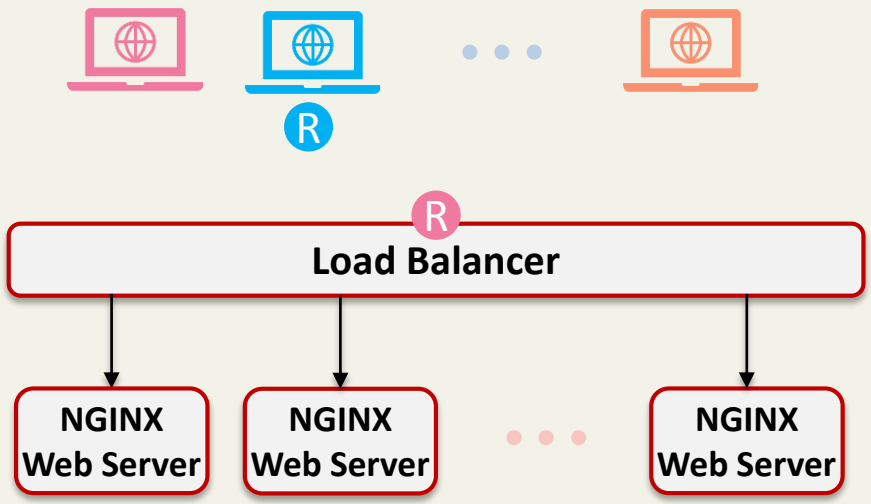

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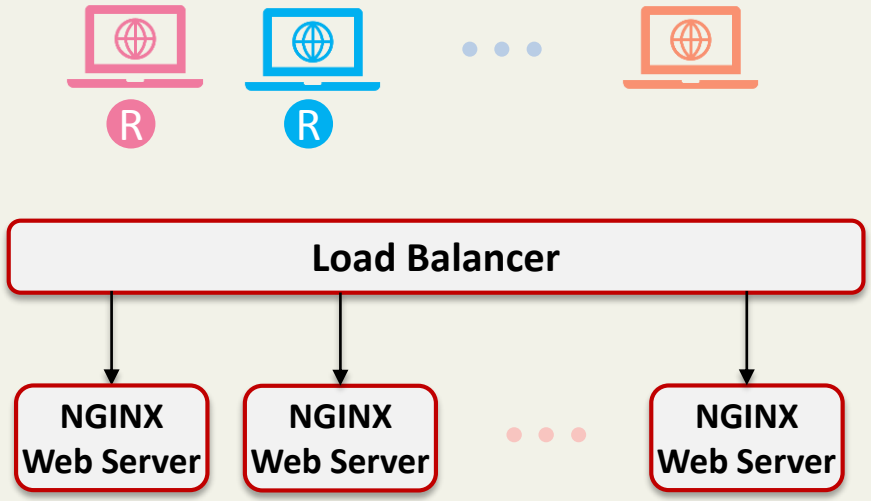

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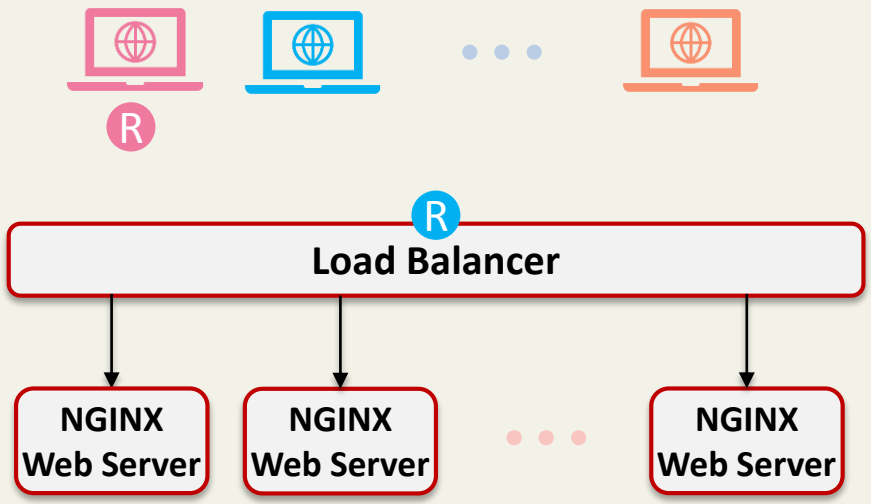

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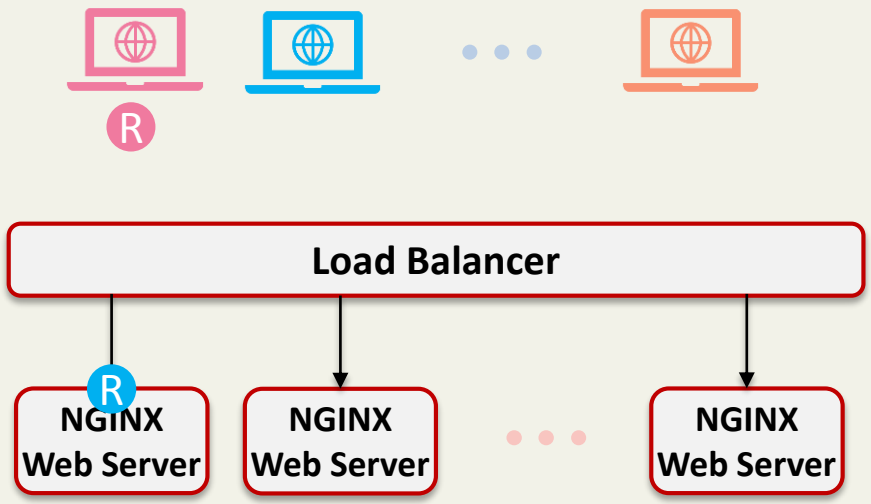

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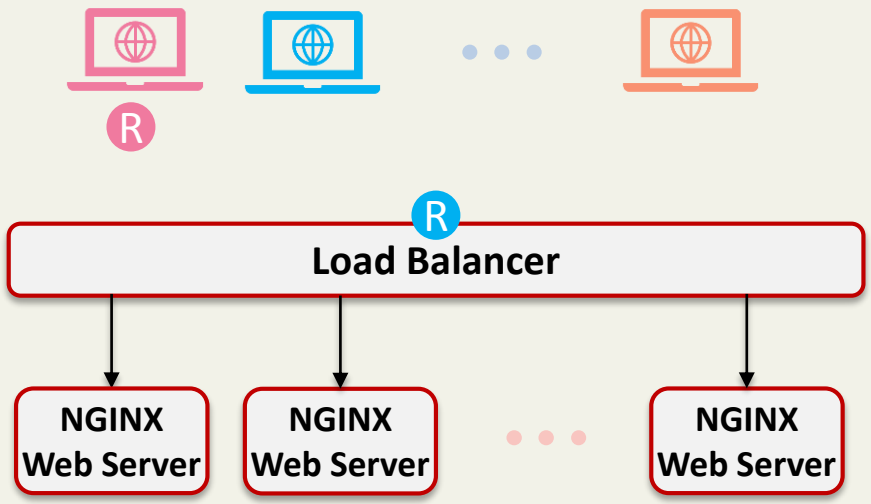

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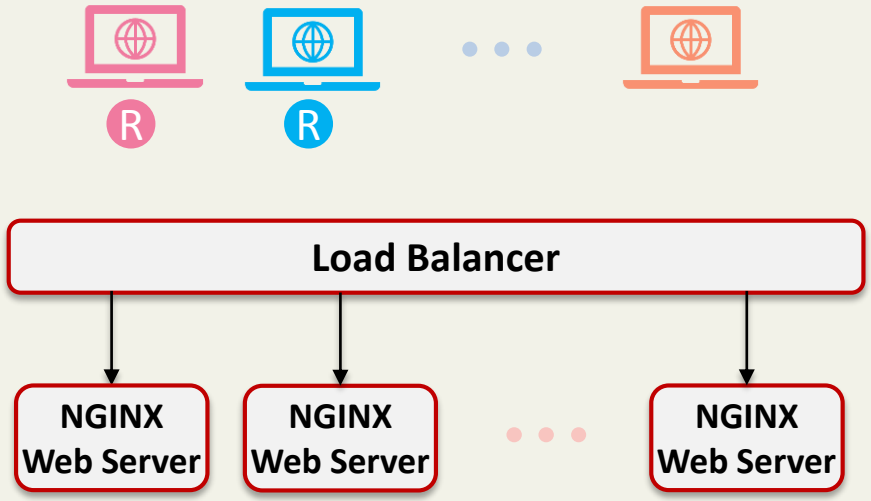
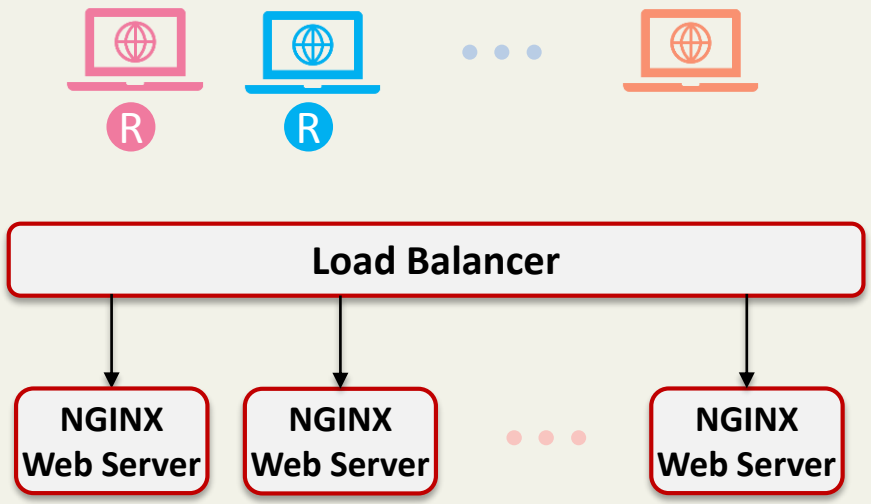
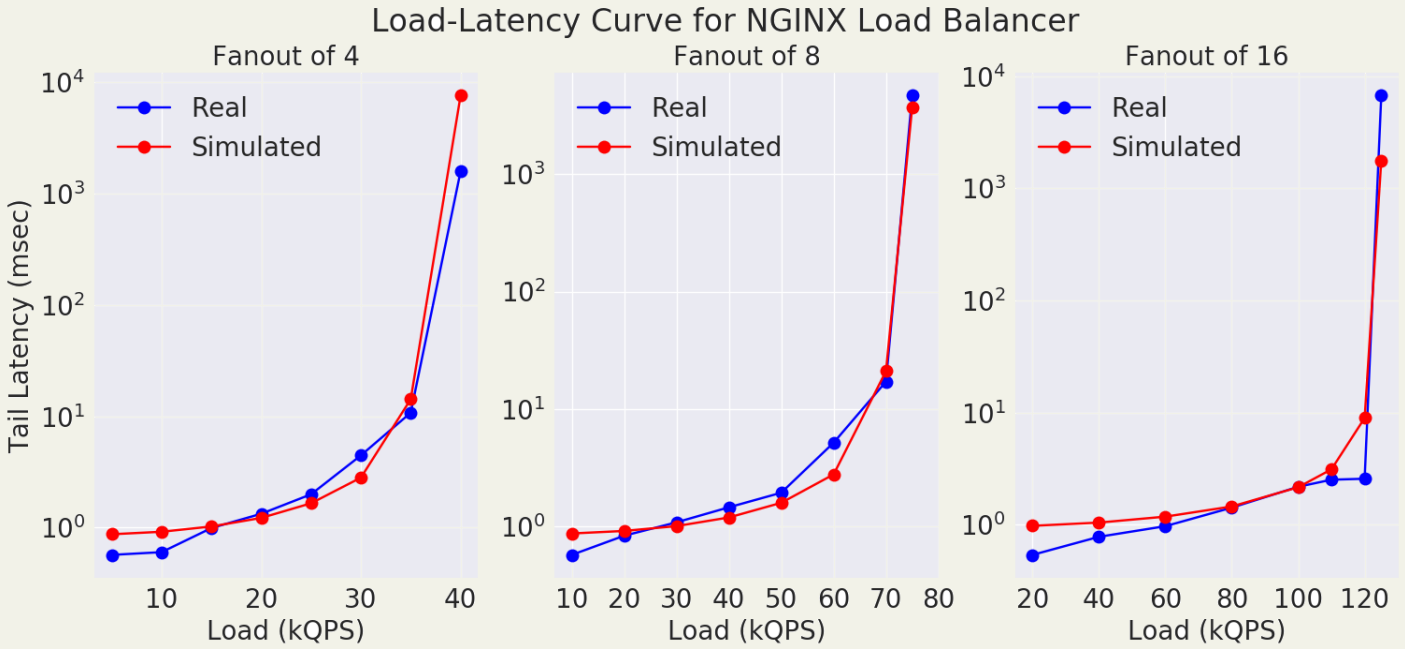


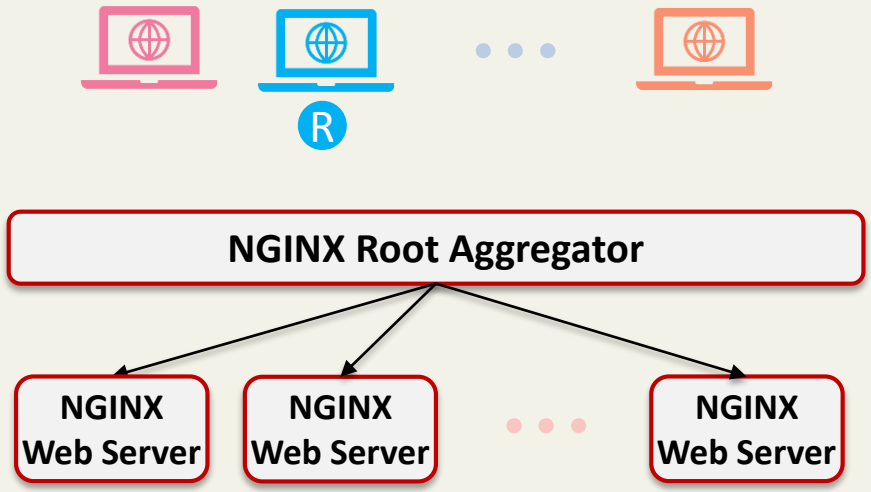
Load Balancing

- Linear throughput increase from cluster size of 4 to 8
- Sub-linear increase from cluster size of 8 to 16





Request Fanout



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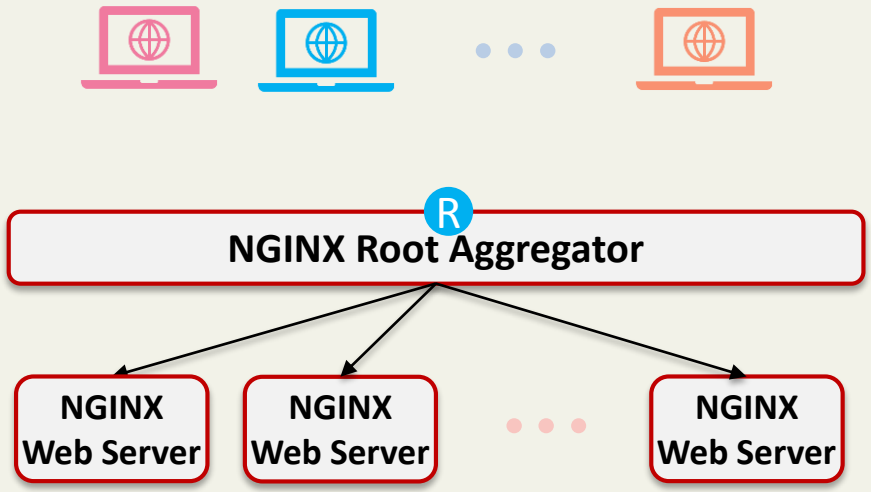

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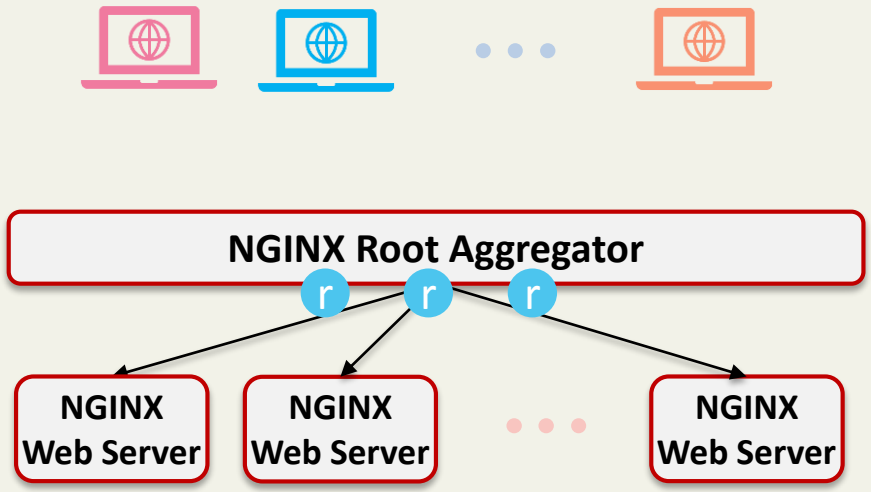

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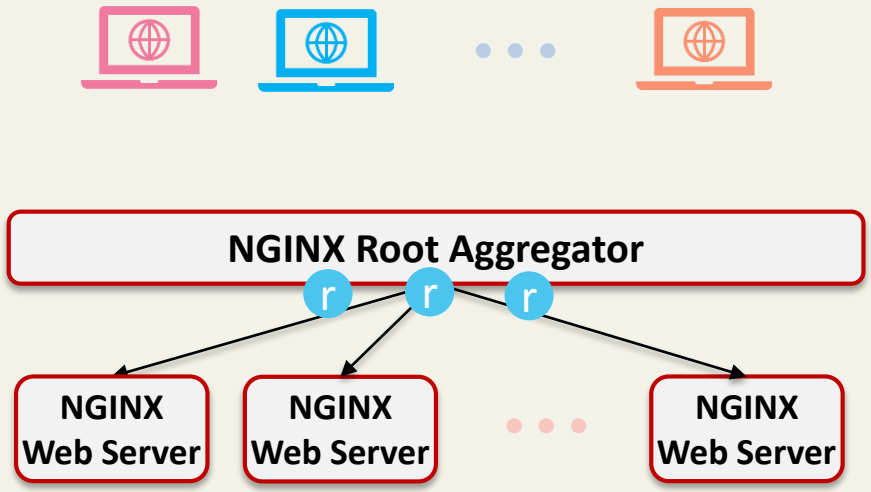

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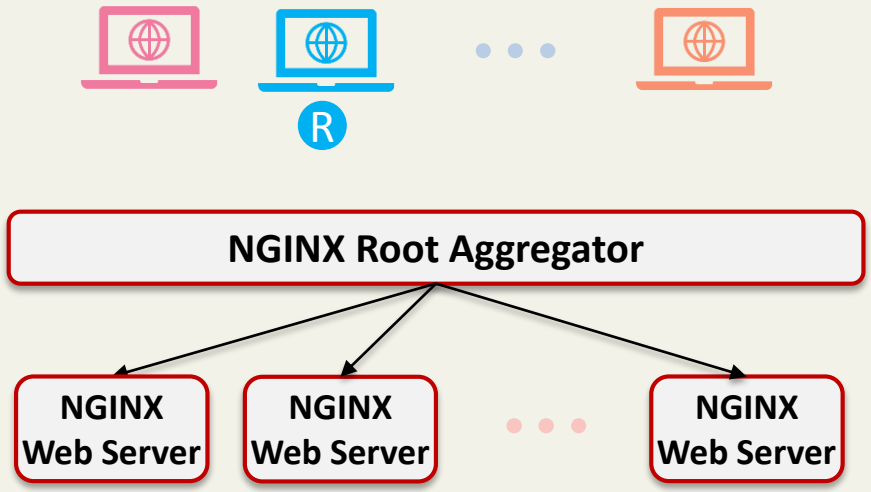
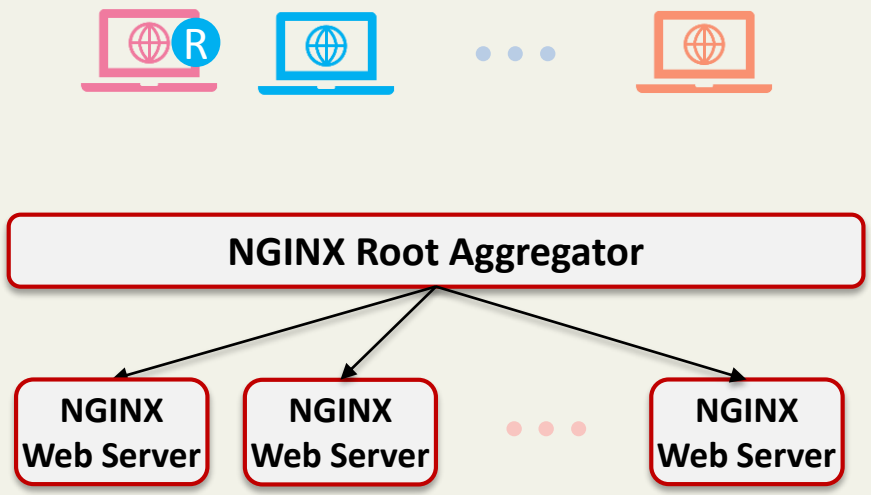
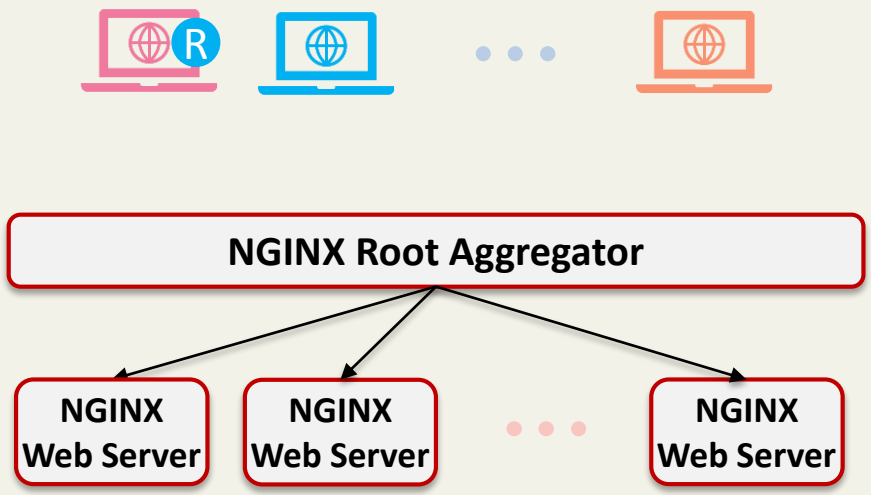


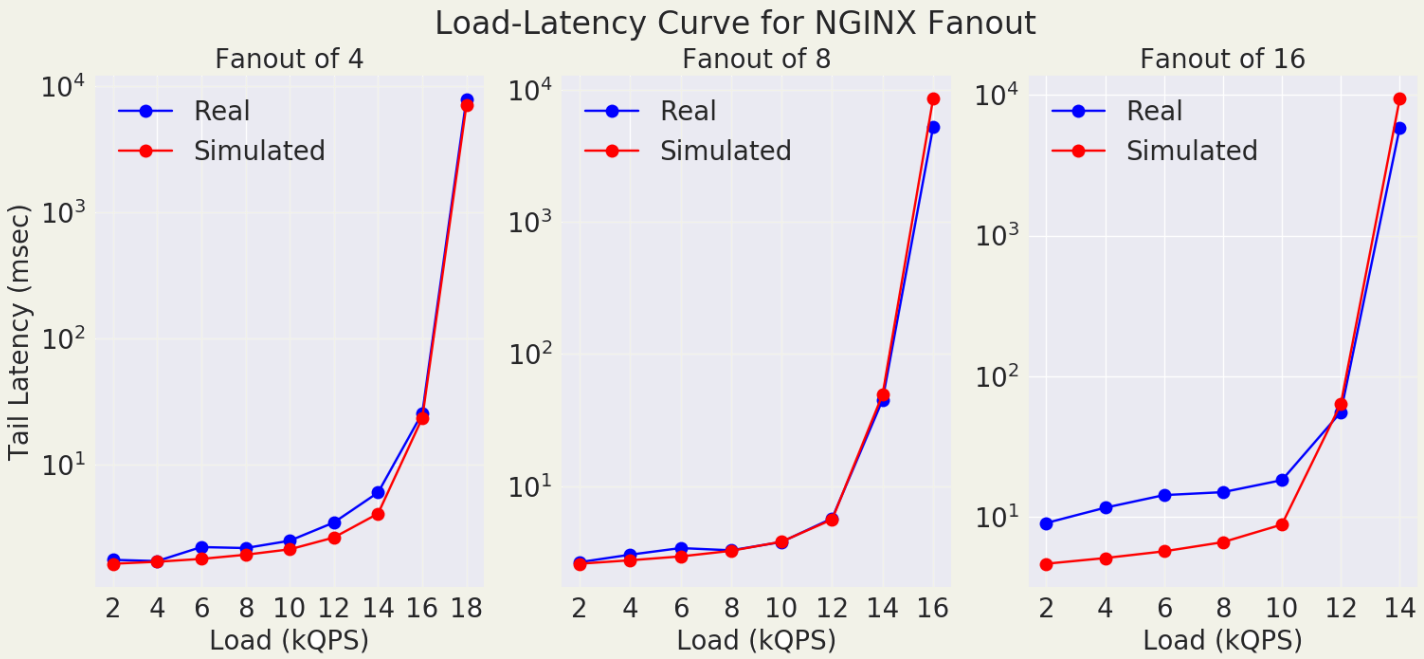
Request Fanout



Request Fanout

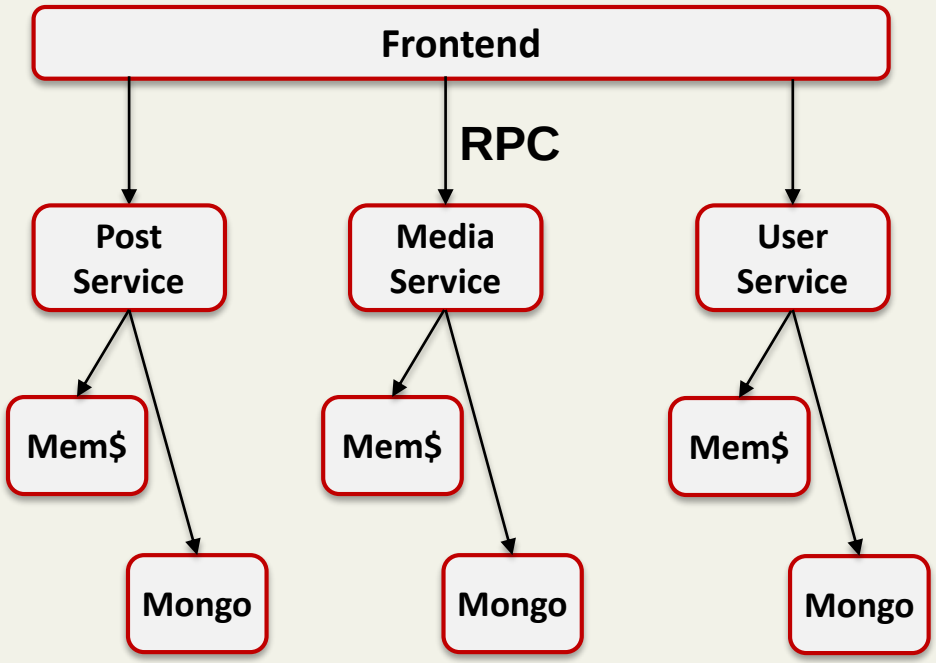
- **Throughput decreases with request fanout**





RPC & Large-Scale Microservices

- Simplified social network



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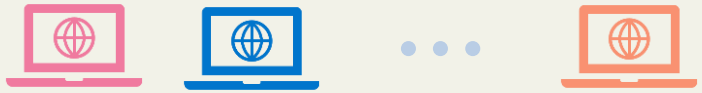

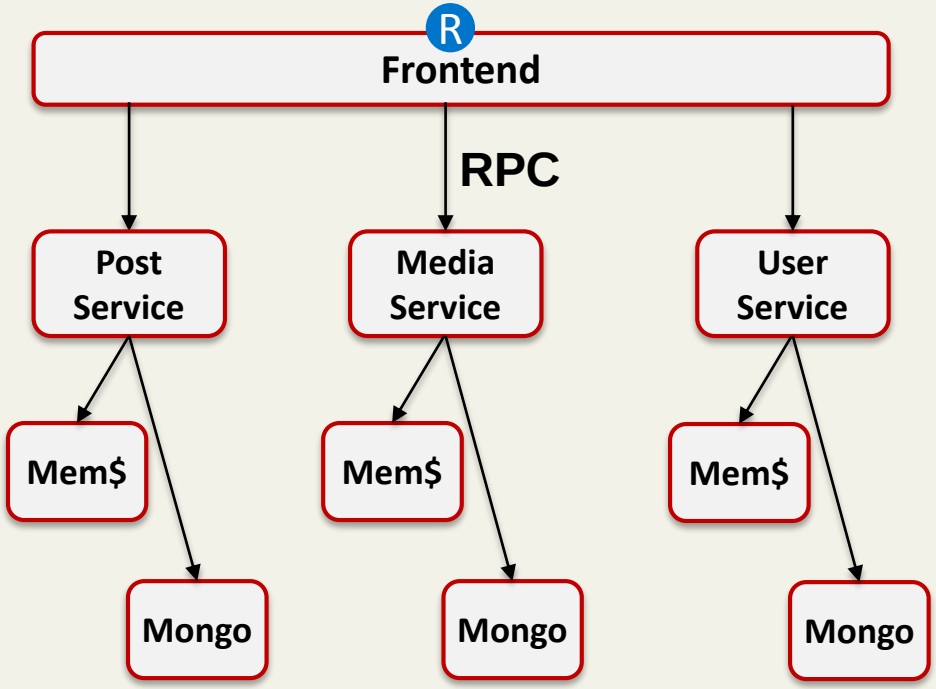

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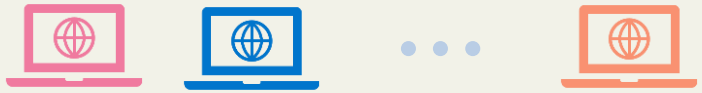

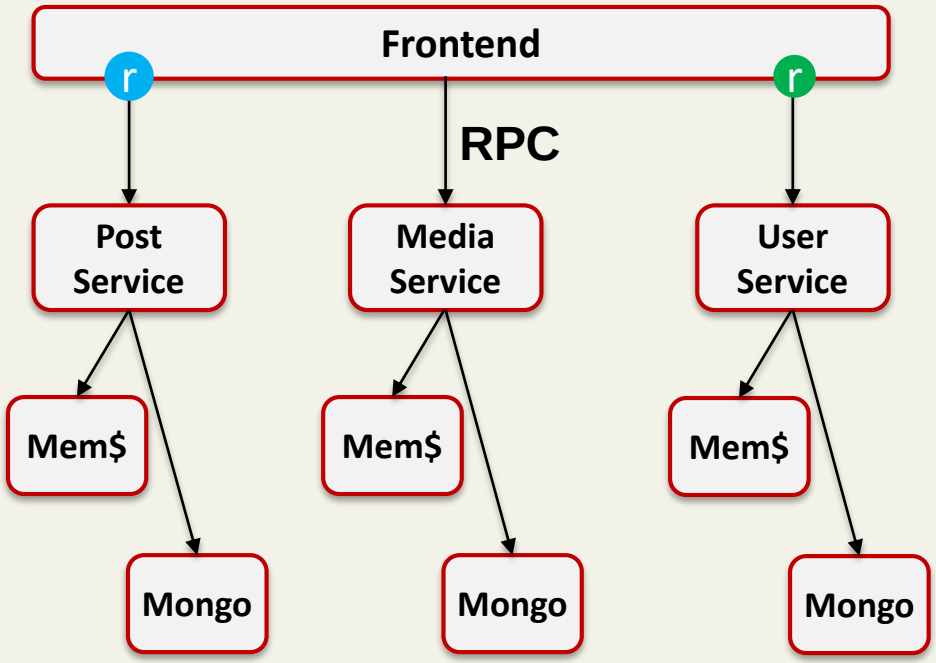

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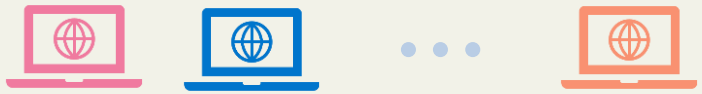

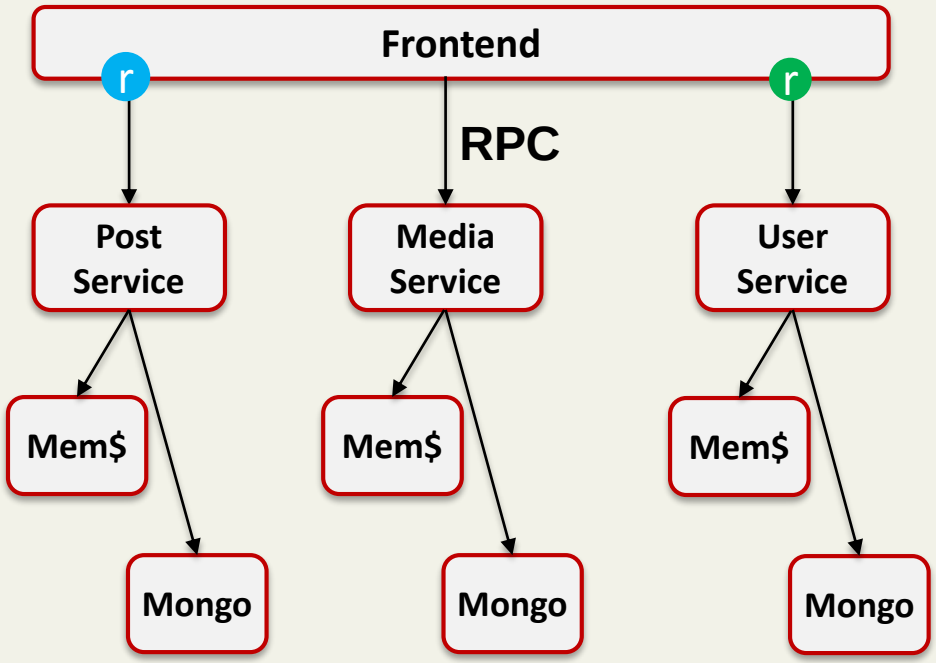

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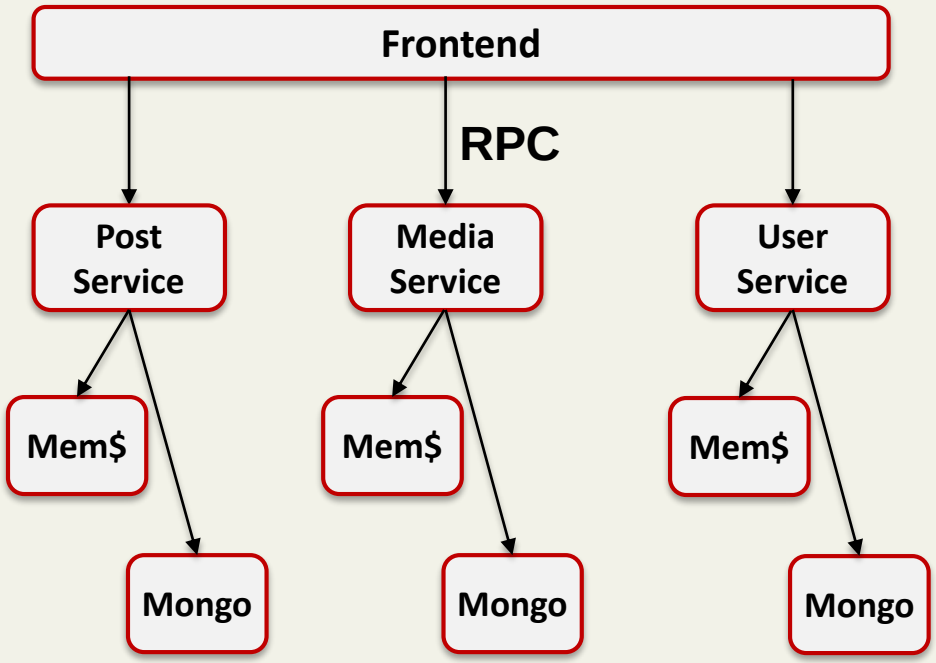

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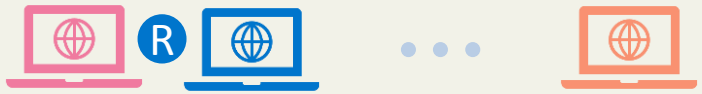

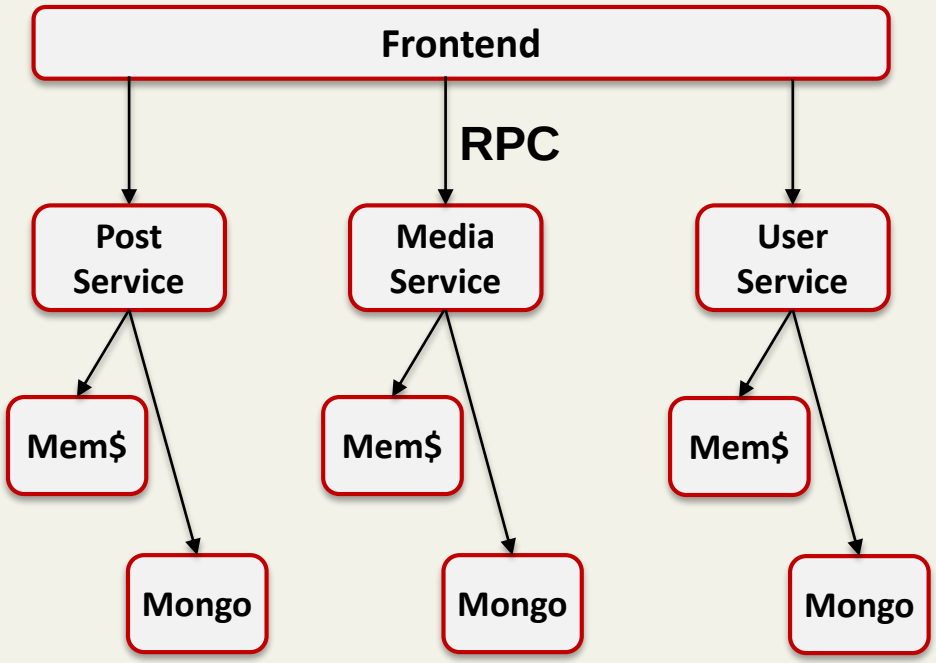

RPC & Large-Scale Microservices

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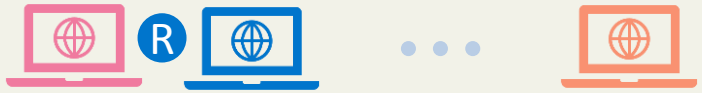
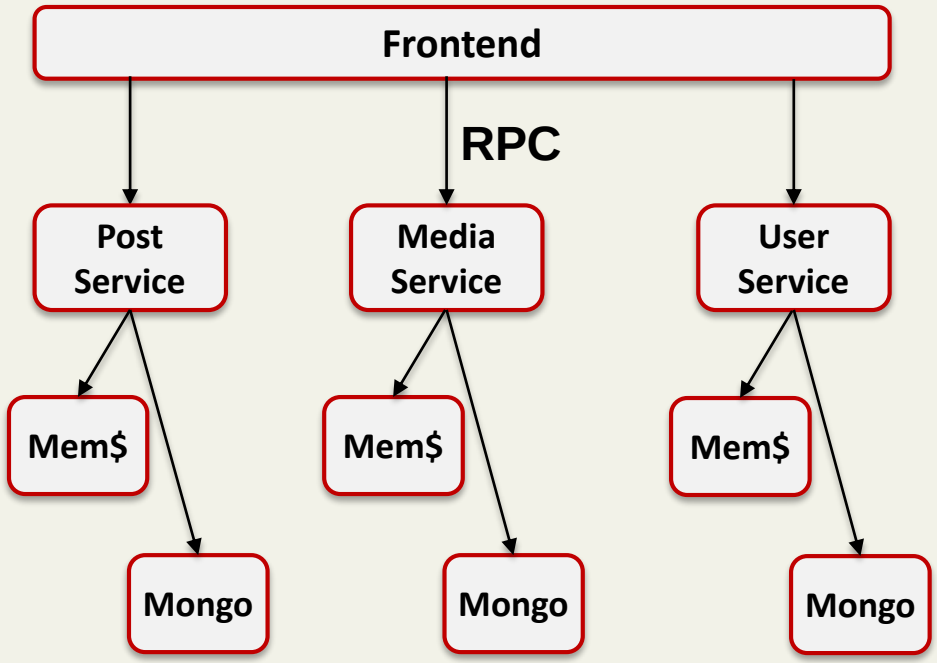
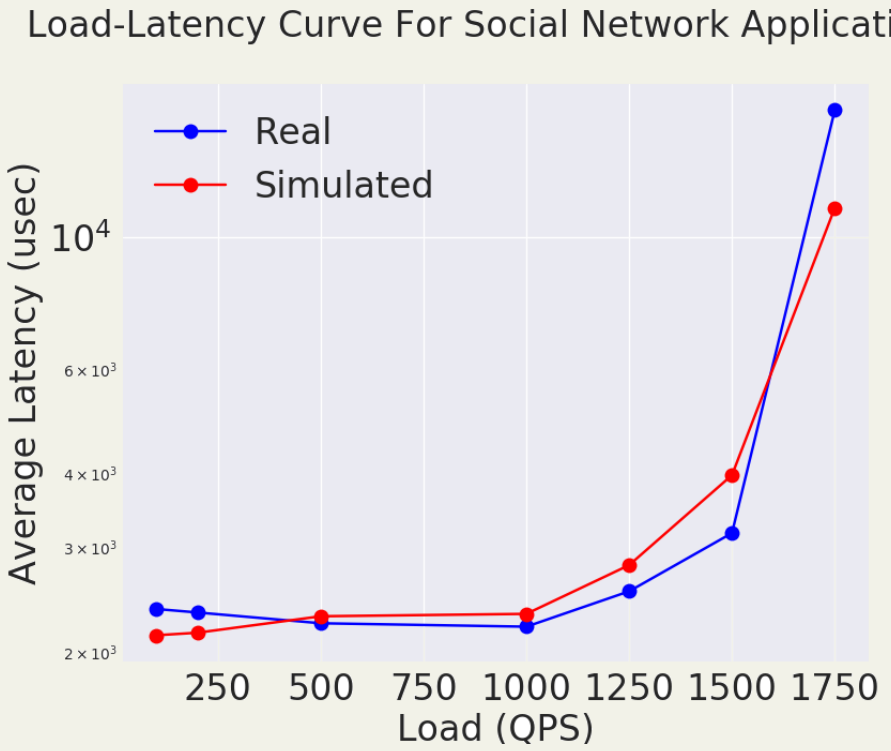
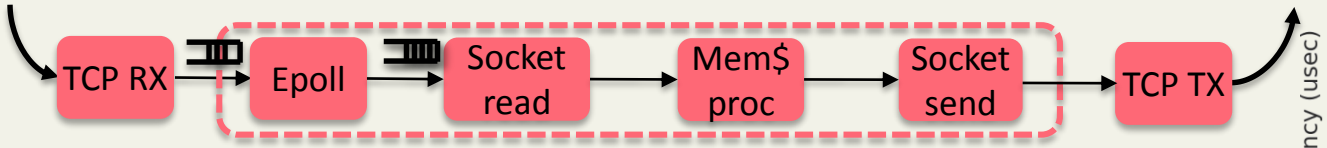


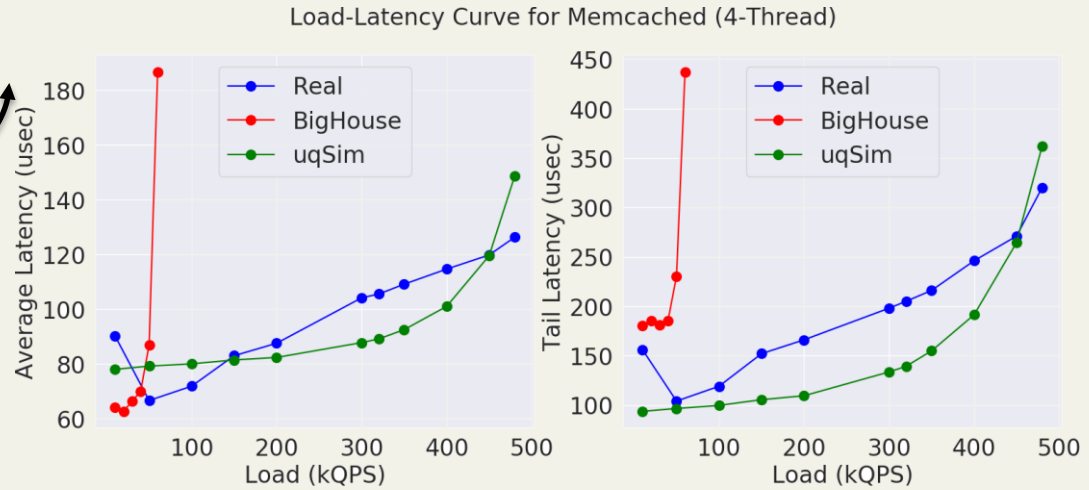




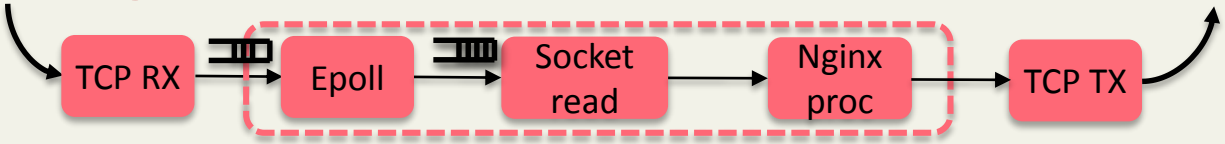
Comparison With BigHouse

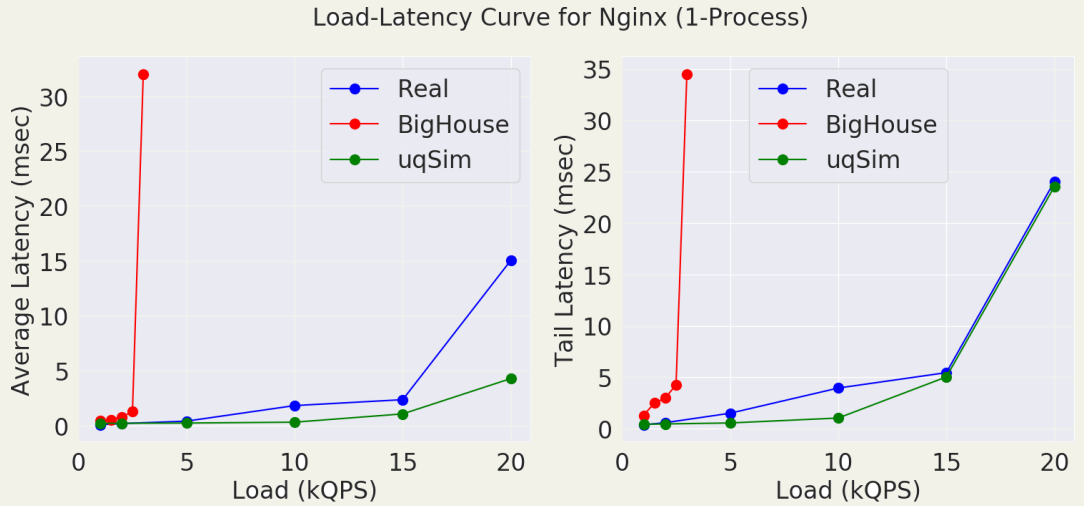
- **Memcached**





- **NGINX**





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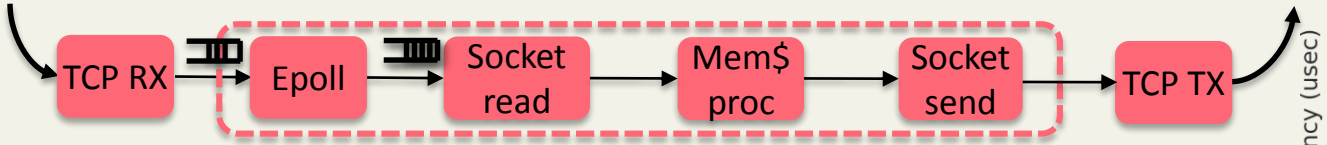
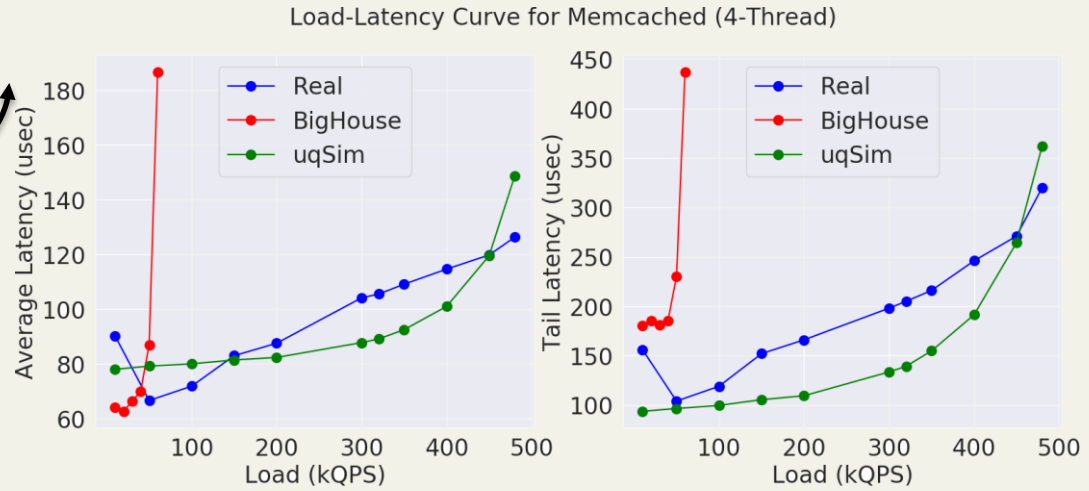


  - BigHouse saturates at 50kQPS
  - μqSim & real server saturates at 450kQPS



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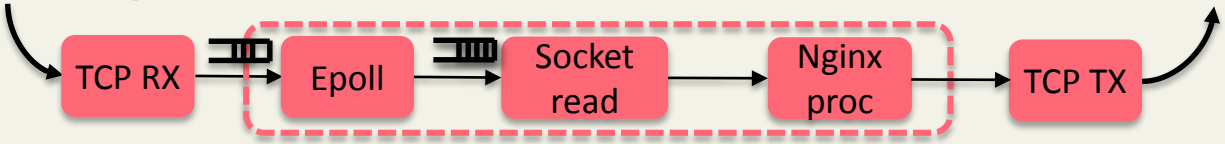

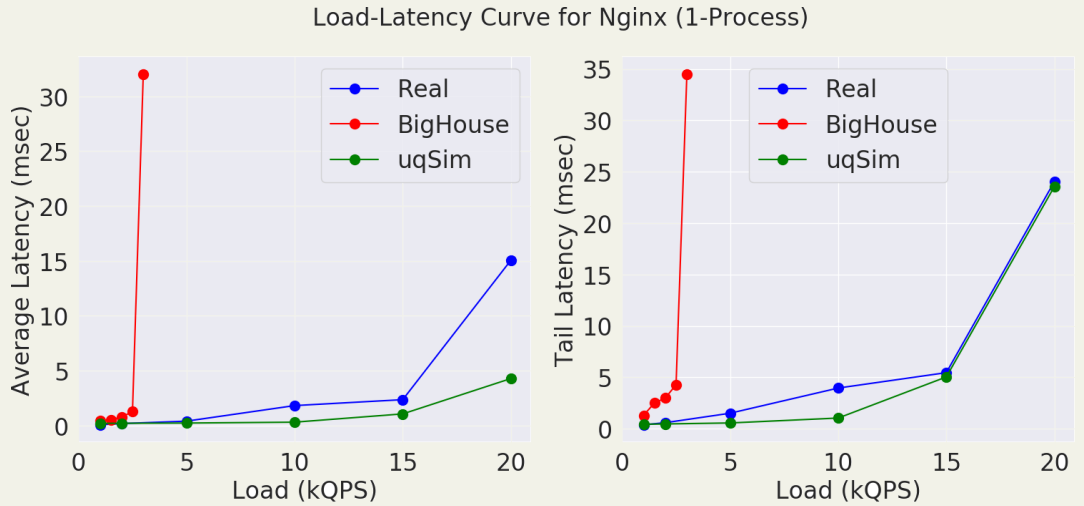

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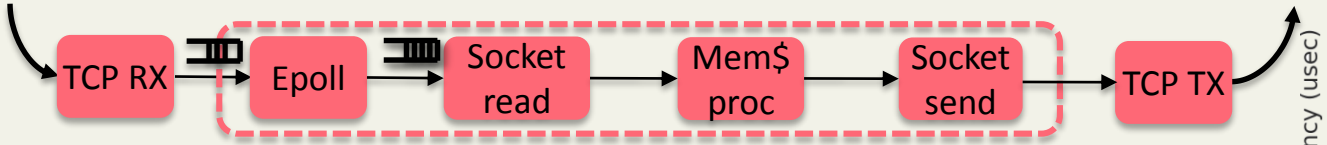

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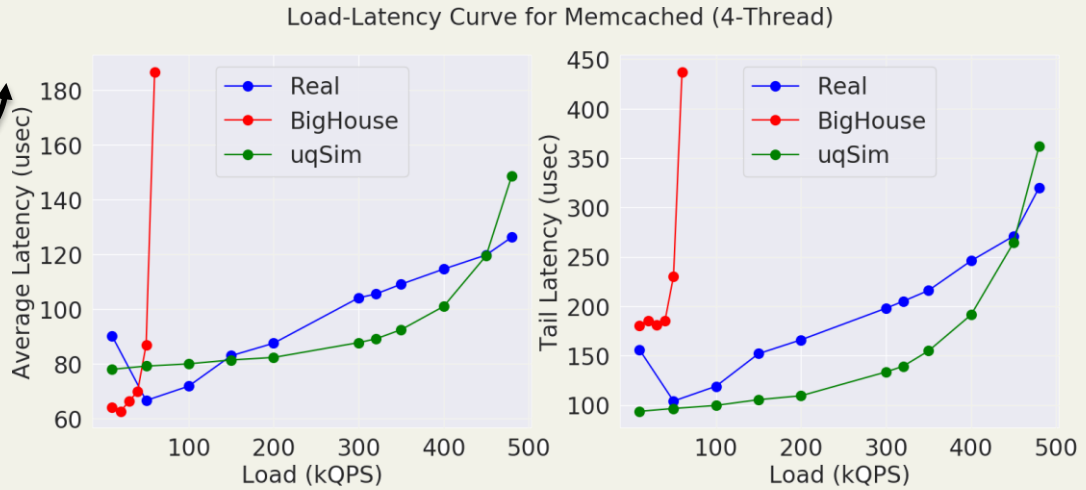

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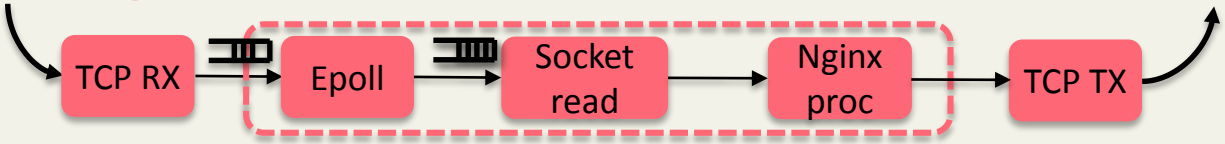
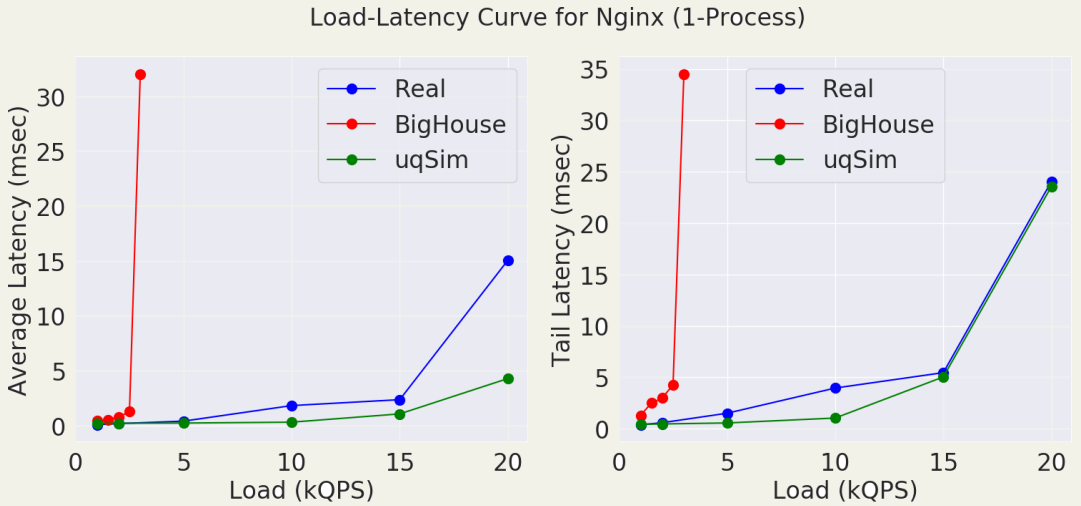


- BigHouse saturates at 2.5kQPS
- μqSim & real server saturates at 15kQPS



Simulation Speed

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  - Simulated input load
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- **Future work**
  - Parallelizing simulation
  - Each thread simulates a partition of the network

Conclusion

- **Microservices introduce new system challenges**
  - Need scalable simulation techniques to study large scale effects
- **μqSim: validated microservice simulator**
  - Modeling the internal queueing structure of individual microservices
  - Modeling dataflow behavior across the microservices
  - Validated against simple & complex microservices and accurately capturing throughput/latency
  - Planning to open source @ microservices.ece.cornell.edu

Thanks & Questions

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Speed Comparison With BigHouse (Backup)

μqSim simulated real time	5s	20s	60s	
μqSim simulation time	12.8 s	51.2s	154.1 s	
BigHouse warmup samples	**5 x50k**	**20 x50k**	**60 x50k**	**5000**
BigHouse simulation time	8.2s	28.7s	154s	1.2s

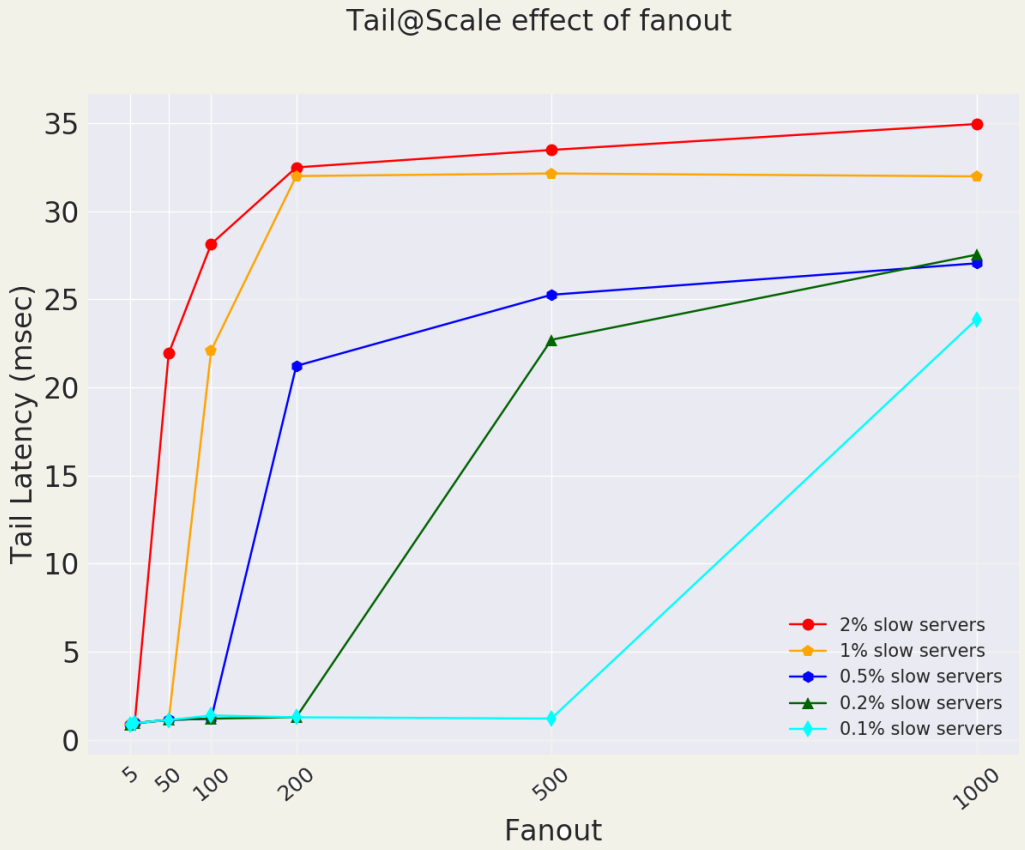
4-thread Memcached at 50k

μqSim simulated real time	5s	20s	60s	
μqSim simulation time	0.7s	2.7s	8.1s	
BigHouse warmup samples	**5 x2k**	**20 x2k**	**60 x2k**	**5000**
BigHouse simulation time	9s	23s	64s	7.1s

1-process NGINX at 2k

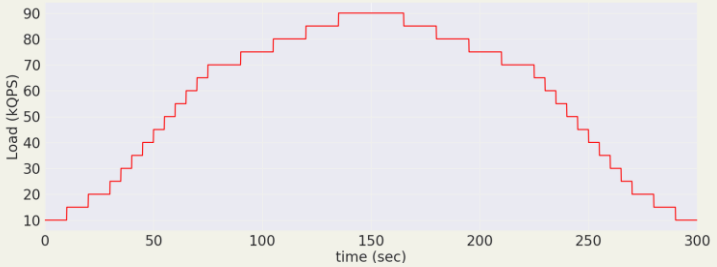
Use Cases – Tail@Scale (Backup)

- For simple single-tier single stage
- Different Cluster Sizes
- Different Fraction of Slow Servers



Use Cases – Power Management (Backup)

- **End-to-End QoS Target**
  - 5ms
- **Input Load**
  - Diurnal pattern



- **Results**