Chair for Decentralized Information Systems and Data Management
TUM School of Computation, Information and Technology
Technical University of Munich

Cloud Information Systems

Exercise 11

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1. Announcement: Guest Lecture This Week

- Guests: Hetzner Cloud
- Wednesday *15.01.2025*, 12:30 in HS1
- Content of the Talk is **relevant for the exam**

2. Recap: Throughput, Latency

Throughput:

- operations per time unit (e.g., 100 transactions per second)
- can be improved through parallelism

Latency:

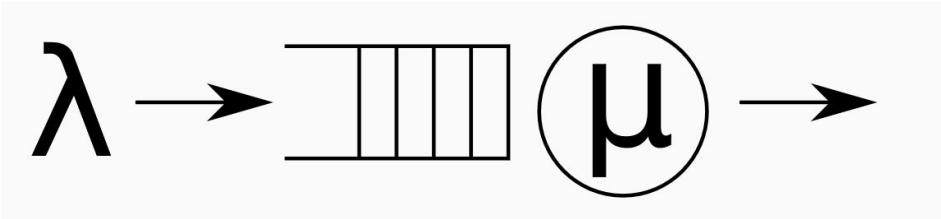
- duration of one operation (e.g., 10ms per transaction)
- harder to improve due to hardware limitations (e.g., network latency)
- scaling can actually increase latency (due to synchronization)

2. Recap: Throughput, Latency

Latency in Cloud-Native Architectures:

- cloud is about plugging together many different (micro-)services
- services call other services call other services…
- at each service: queuing delays, execution times, and network latency

2. Recap: Queuing Theory



- jobs arrive in system with rate λ
- jobs are processed at service station with processing speed μ
- jobs might have to wait (queue is unbounded)
- job inter-arrival times are exponentially distributed
- processing speed is exponentially distributed

→ M|M|1 Queue

2. Recap: Queuing Theory

parameters:

- arrival rate: λ
- processing speed: μ

metrics for M|M|1:

- system utilization: $\rho = \lambda/\mu$
- length of waiting queue: $L_q = \rho^2/(1-\rho)$
- time in waiting queue: $W_q = L_Q/\lambda$
- time in system: $W = W_q + 1/\mu$
- jobs in system: $L = \lambda W$

[Software Architecture for the Cloud, slide 65]

2. Exercise: Queuing Theory

- Repeat the calculations for M|M|1 (“Software Architecture for the Cloud”, slide 65) with
  - $\lambda = 10/s$ and $\mu = 30/s$
- How do the values change when the arrival rate doubles ($\lambda = 20$)?

2. Exercise: Queuing Theory

parameters:

- arrival rate: **λ = 10/s**
- processing speed: **μ = 30/s**

metrics for M|M|1:

- system utilization: $\rho = \lambda/\mu = 10/30 = ⅓$ (~33%)
- length of waiting queue: $L_q = \rho^2/(1-\rho) = (⅓)^2 / (1-⅓) = ⅙$ (~0.1667)
- time in waiting queue: $W_q = L_Q/\lambda = (⅙)/(10/s) = 1/60$ s (~0.01667 s)
- time in system: $W = W_q + 1/\mu = 1/60$ s + 1/(30/s) = 1/20 s (~0.05 s)
- jobs in system: $L = \lambda W = 10/s * 1/20$ s = ½ = 0.5

[Software Architecture for the Cloud, slide 65]

2. Exercise: Queuing Theory

parameters:

- arrival rate: **$\lambda = 20/s$**
- processing speed: **$\mu = 30/s$**

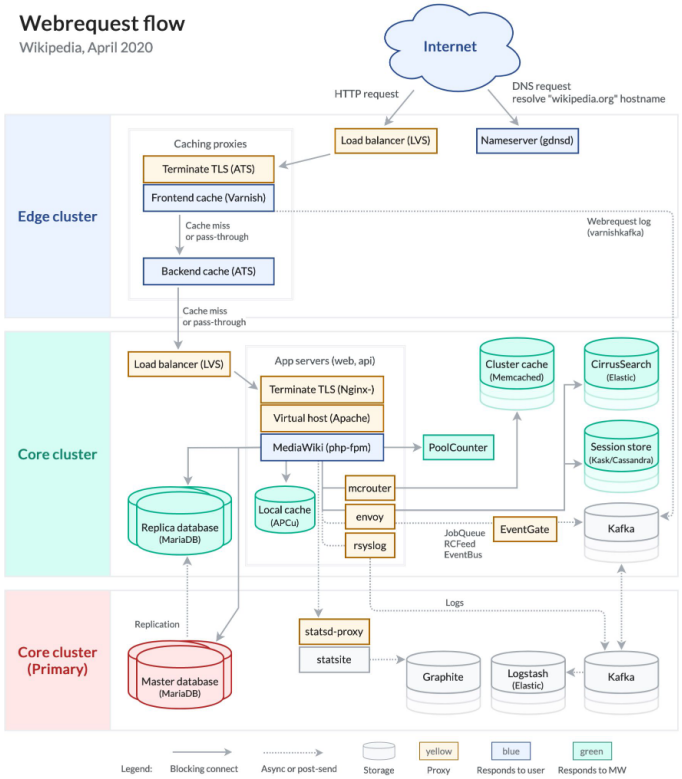
metrics for M|M|1:

- system utilization: $\rho = \lambda/\mu = 20/30 = ⅔$ (~66%)
- length of waiting queue: $L_q = \rho^2/(1-\rho) = (⅔)^2 / (1-⅔) = 4/3$ (~1.33)
- time in waiting queue: $W_q = L_Q/\lambda = (4/3)/(20/s) = 1/15$ s (~0.0667 s)
- time in system: $W = W_q + 1/\mu = 1/15$ s + $1/(30/s) = 1/10$ s (~0.1 s)
- jobs in system: $L = \lambda W = 20/s * 1/10$ s = 2

[Software Architecture for the Cloud, slide 65]

3. Exercise: Wikipedia Lift-and-Shift Architecture

- Move existing architecture to the Cloud as-is
  - Each Data Center is replaced by a deployment in a different AWS region
  - Every on-premises server becomes one EC2 instance
- Estimated 2500 EC2 instances needed at the current scale ($3000/year each) = $7.5M/year
- High egress cost from AWS to public internet = $12M/year
- TCO ≈ $20M



3. Exercise: Cloud-Native Architecture

- Every component is replaced by an off-the-shelf AWS service
- New architecture:
  - geo-distributed HTTP caching → Amazon CloudFront [$8.4M/year]
  - load balancer → Amazon Elastic Load Balancer (ELB) [$1.9M/year]
  - application server →Keep custom PHP implementation [$1.5M/year]
  - database → AWS Aurora [$400K/year]
  - image storage → S3 [$42K/year]
- TCO ≈ $12M
- Where should we focus to reduce cost further?

3. Replace S3?

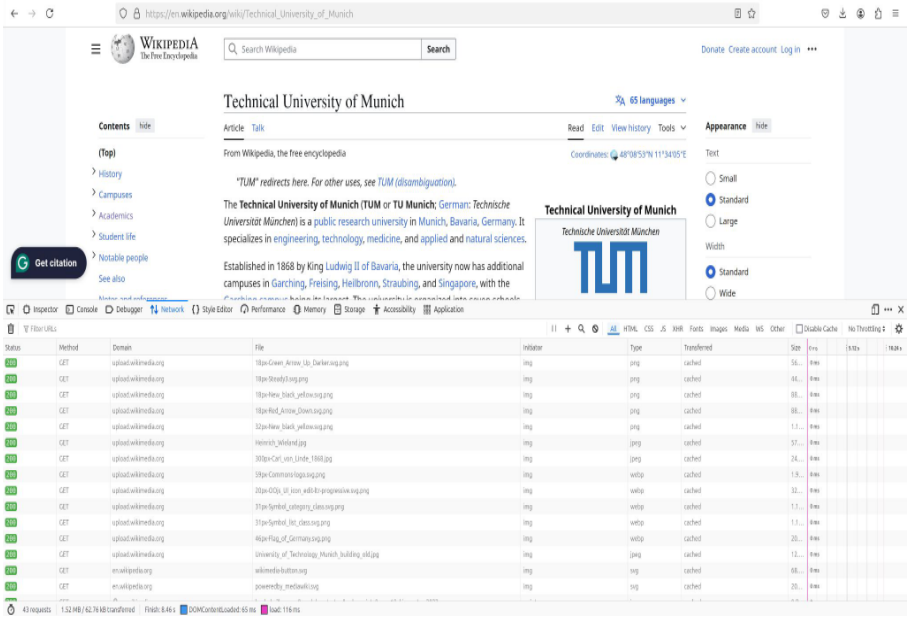
- Competing Object Stores with S3-compatible API
- S3 only $42K of TCO; how will this help us?

https://developers.cloudflare.com/r2/pricing/

https://docs.hetzner.com/storage/object-storage/overview/

3. Replacing S3 with Cloudflare R2

- Cost dominated by AWS Cloudfront CDN
- Minimum traffic cost: $0.025 per GB
- Request cost: $1 per 1M HTTP requests
- Wikipedia:
  - Requests (assuming 10 requests per view): $2.4M/year
  - Traffic (assuming 1MB per view): $6M/year
  - Total: $8.4M/year
- ~50% of Page consist of Images



3. Replacing S3 with Cloudflare R2

	AWS S3	Cloudflare R2
Storage Cost [100TB/year]	$24K	$18K
GET Request Cost [GET/sec]	$12K	$11K

- But, we also save on Egress Cost:
  - R2 does not charge for Egress to Public Internet
  - Assuming 50% of Traffic is Images: $6M/year * 50% = $3M

Potential Issues with R2 Migration?

- Latency?
  - Seems to be (slightly) worse than S3 (See Comparison)
- Undisclosed Egress/Rate Limits?
  - Bandwidth is not free (that's why other companies are charging for it)
  - At some Traffic Volume, Cloudflare will likely fail our Requests
- Added Architecture Complexity
  - Interoperability with AWS Cloudfront?
  - Loose advantage of having everything from one vendor

3. Why should Wikipedia (not) move to the Cloud?

- Strategic Reasons
  - Avoid Vendor Lock-In
  - AWS contrary to Wikipedia Ideology
- Lack of Benefit from Cloud Architecture
  - Stable Workload
  - Already an established Player with stable growth
- Years of Expertise
  - Architecture purpose-built for Wikipedia Use Case
  - Employee Salary can amortized over the large Cluster

4. Questions