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Software Engineering 2

Structure of a Design Document

Software Qualities and Software Architecture

Software Design

Structure of a Design Document (DD)

Purpose of the DD

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- Means of communication
  - Requirements analysts ↔ Architects ↔ Developers
- Baseline for implementation activities
- Traceability: mapping between requirements and components
- Baseline for integration and Quality Assurance
  - Identification of the order of implementation
  - Identification of the integration strategy (bottom-up vs top-down)
  - Supports verification and validation
- Refines the plan and previous estimations
  - size, cost, schedule

Reference structure for DD

(See the R&DD document)

1 Introduction
- Scope
- Definitions, acronyms, abbreviations
- Reference documents
- Overview

2 Architectural Design
- Overview: high-level components and interactions
- Component view
- Deployment view
- Component interfaces
- Runtime view
- Selected architectural styles and patterns
- Other design decisions

Reviews the domain and product, **summary of main architectural styles/choices** (e.g., N-tier / microservices, …)

Describes contents and structure of the remainder of the DD

Informal view (free style notation), major interfaces

Components + interfaces:
component diagrams, composite structure, class diagrams (detailed view)

Infrastructure: deployment diagram(s) including non-logical elements (e.g., load balancer, firewall)

Details for each interface (name, signature, returned objects)

Dynamics of the interactions: sequence diagrams (realization of use cases)

Reference structure for DD

(See the R&DD document)

3 User Interface Design

4 Requirements traceability

5 Implementation, Integration
and test Plan

6 Effort Spent

7 References

Overview of UIs, possibly mockups, may refine what's in the RASD (if present)

Mapping between requirements and design elements

Order in which you plan to implement subsystems and components as well as plan of the integration and test of the integration

Homework

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- Review the DD available on Webeep, direct link
  - https://webeep.polimi.it/pluginfile.php/1116082/mod_folder/content/0/ProjectToBeReviewed/DD.pdf
  - It refers to the assignment described in this document: https://webeep.polimi.it/pluginfile.php/1116082/mod_folder/content/0/ProjectToBeReviewed/Assignment_2022-2023.pdf
- Answer to the questionnaire here (one submission per group):
  - https://forms.office.com/e/JcdhDvDaGu
  - Groups: up to 3 students (same groups for the RASD questionnaire)
  - We will assign up to 1 point to clear and convincing answers
- **Deadline:** November 15th at 23.59 (Rome time)
- Answers will be used as basis for discussion during the lab of November 16th (Proff. Camilli and Rossi) and of November 22nd (Prof. Di Nitto)

Homework — important note (repeat)

- Focus more on content rather than structure

Software Design

Software qualities and architectures

Software qualities and architectures

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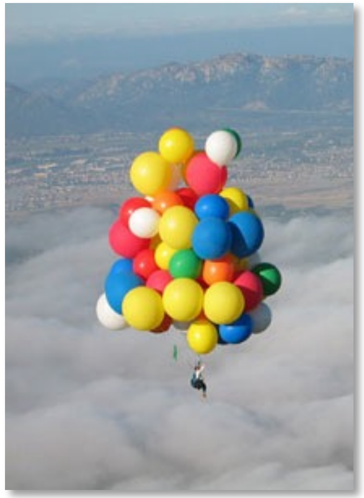
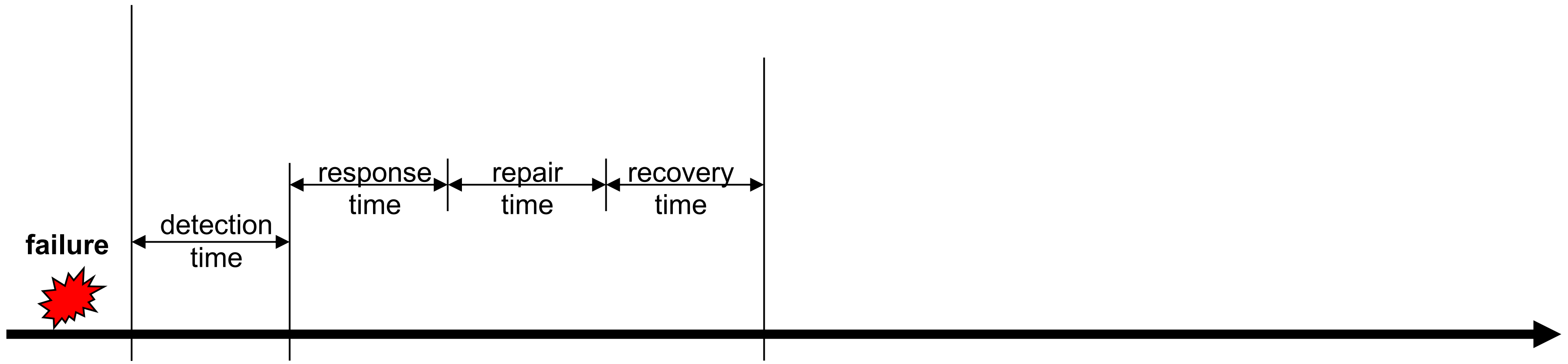
- Several software qualities are directly influenced by architectural choices
  - Scalability
  - Reliability
  - Availability
  - Usability
  - …
- How do we cope with this?
  - We need **metrics** to quantify qualities and specific **methodologies to analyze** the quantitative impact of architectural choices on these qualities
  - **Tactics** to address the issues

Availability

- A service shall be continuously available to the user
  - **Little downtime** and **rapid** service **recovery**
- The availability of a service depends on:
  - Complexity of the IT **infrastructure** architecture
  - **Reliability** of the individual components
  - **Ability to respond** quickly and effectively to faults
  - **Quality of the maintenance** by support organizations and suppliers
  - **Quality** and scope of the **operational management** processes

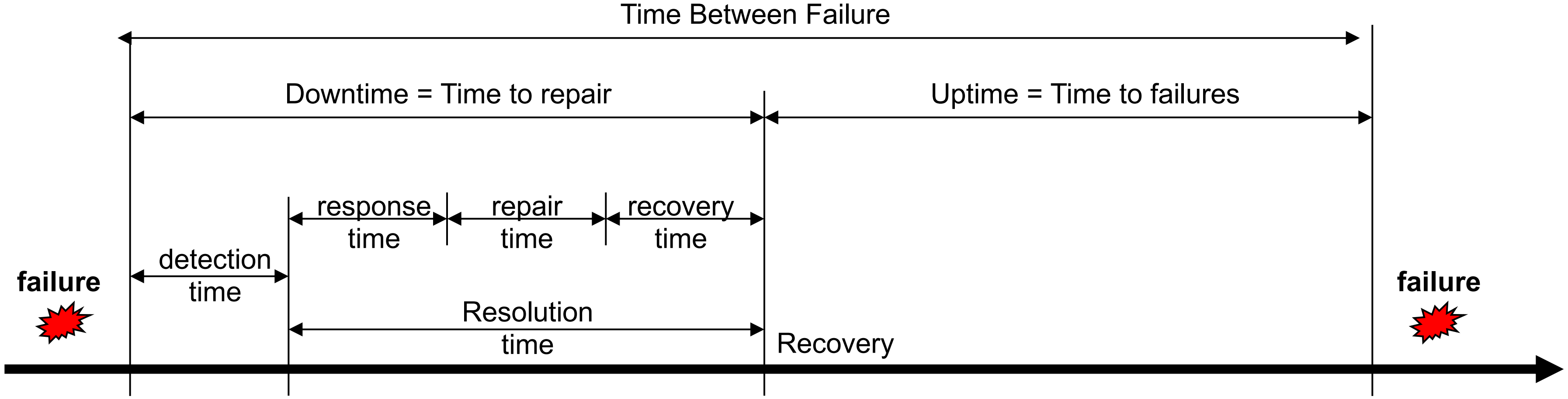


System life-cycle



- **Time of occurrence:** Time at which the user becomes aware of the failure
- **Detection time:** Time at which operators become aware of the failure
- **Response time:** Time required by operators to diagnose the issue and respond to users
- **Repair time:** Time required to fix the service/components that caused the failure
- **Recovery time:** Time required to restore the system (re-configuration, re-initialization,…)

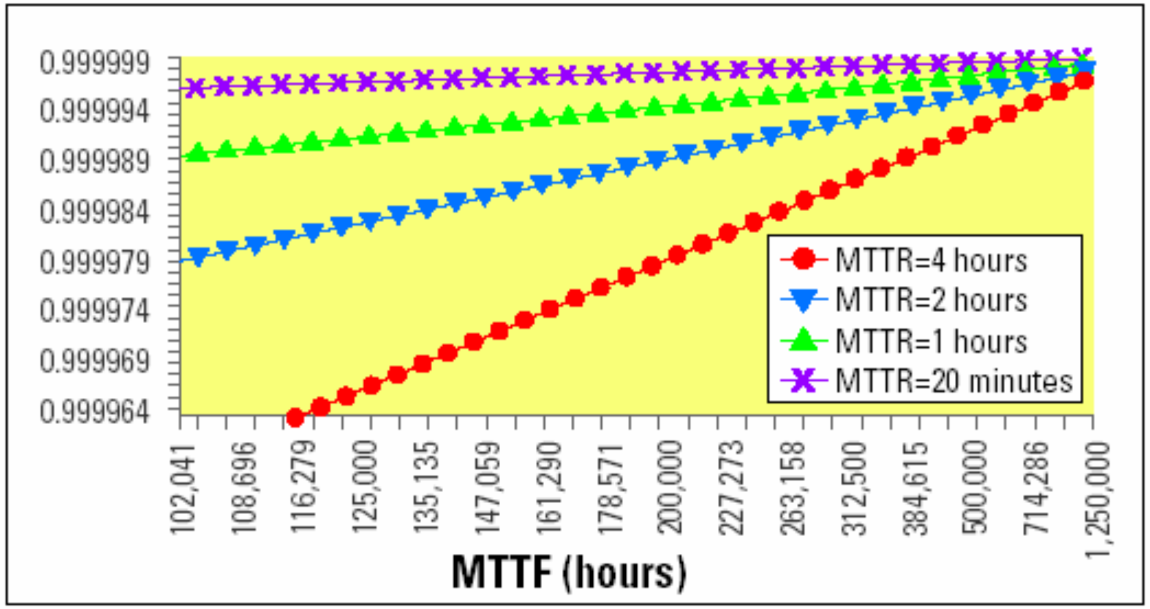
System life-cycle



- **Mean Time to Repair (MTTR):** Average time between the occurrence of a failure and service recovery, also known as the downtime
- **Mean Time To Failures (MTTF):** Mean time between the recovery from one failure and the occurrence of the next failure, also known as uptime
- **Mean Time Between Failures (MTBF):** Mean time between the occurrences of two consecutive failures

Availability metric — definition

- Probability that a component is **working properly** at **time *t***
  - $A = \frac{MTTF}{MTTF+MTTR}$
  - if MTTR small, MTBF $\cong$ MTTF



Nines notation

- Availability is typically specified in **"nines notation"**
- For example, 3-nines availability corresponds to 99.9%, 5-nines availability corresponds to 99.999% availability

Availability	Downtime
90% (1-nine)	36.5 days/year
99% (2-nines)	3.65 days/year
99.9% (3-nines)	8.76 hours/year
99.99% (4-nines)	52 minutes/year
99.999% (5-nines)	5 minutes/year

Availability — analysis methodology

- Availability is calculated by **modeling the system** as an interconnection of **elements in series** and **parallel**
- Elements operating in series
  - Failure of an element in the series leads to a failure of the whole combination
- Elements operating in parallel
  - Failure of an element leads to the other elements taking over the operations of the failed element

Availability in series

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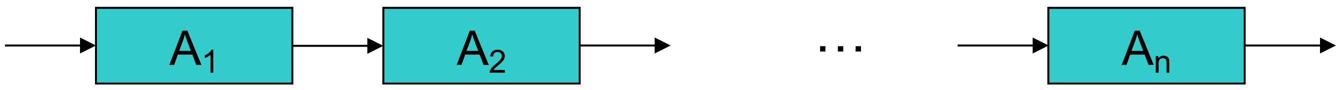
- The combined system is operational only if every part is available
- The combined availability is the **product** of the availability of the component parts



$$A = \prod_{i=1}^{n} A_i$$

Availability in series – A numerical example

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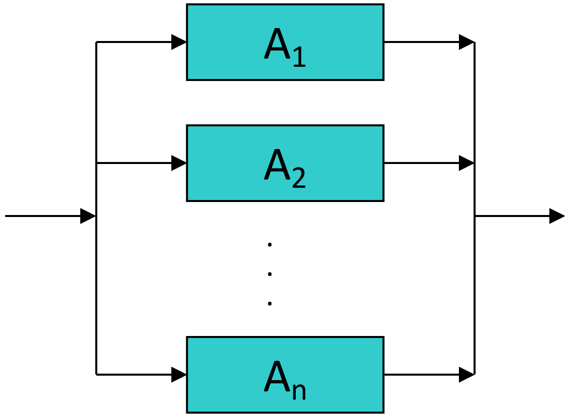
	Availability	Downtime
Component 1	99% (2-nines)	3.65 days/year
Component 2	99.999% (5-nines)	5 minutes/year
Combined	**98.999%**	**3.65 days/year**

- **Downtime = (1-A)*365 days/year**
- The availability of the entire system is negatively affected by the low availability of Component 1
- **A chain is as strong as the weakest link!**

Availability in parallel

- The combined system is operational if at least one part is available
- The combined availability is **1 - P(all parts are not available)**



$$A = 1 - \prod_{i=1}^{n}(1 - A_i)$$

Availability in parallel – A numerical example

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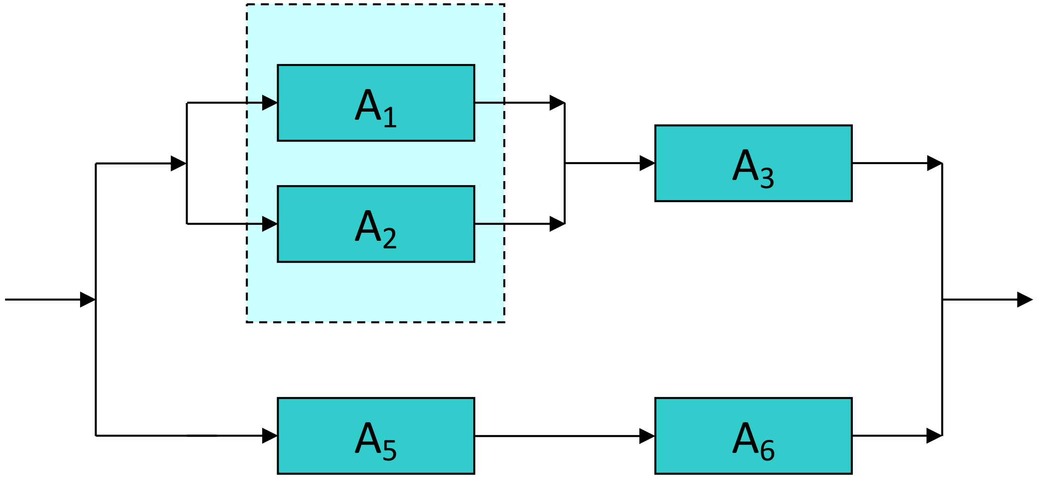
	Availability	Downtime
Component 1	99% (2-nines)	3.65 days/year
Component 2	99% (2-nines)	3.65 days/year
Combined	**99.99% (4-nines)**	**52 minutes/year**

- Downtime = (1-A)*365 days/year
- Even though components with very low availability are used, the overall availability of the system is much higher

- **Mission critical systems are designed with redundant components!**

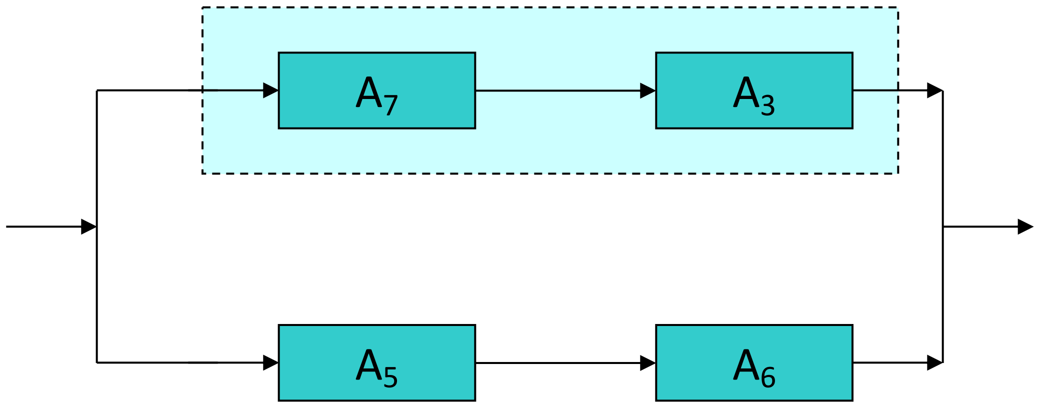
Availability of complex systems

$$A_7=1-(1-A_1)(1-A_2)$$

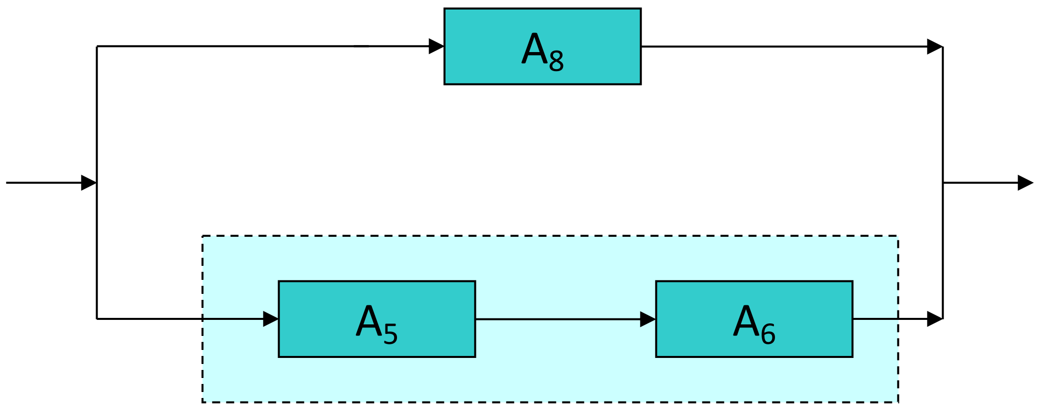


Availability of complex systems

$$A_8 = A_7 A_3$$



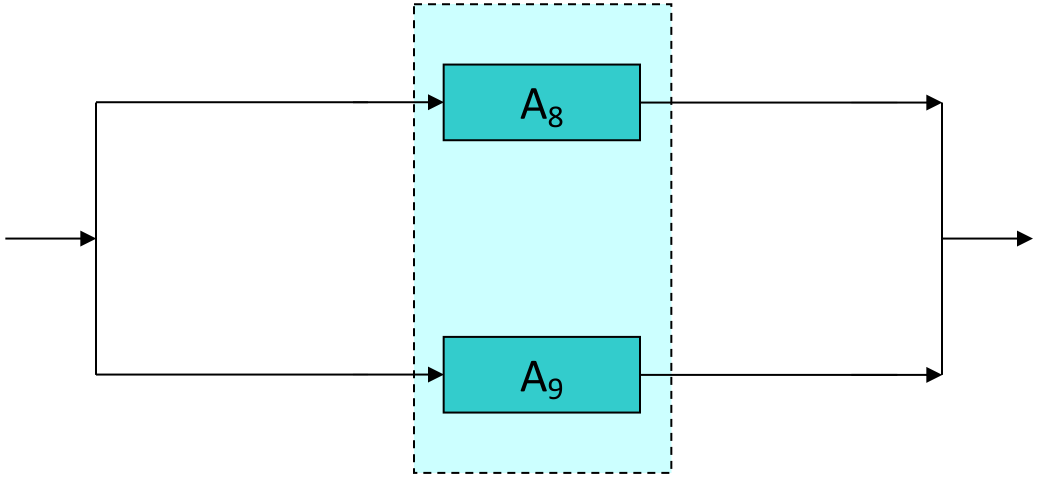
Availability of complex systems



$$A_9 = A_5 A_6$$

Availability of complex systems

$$A=1-(1-A_8)(1-A_9)$$

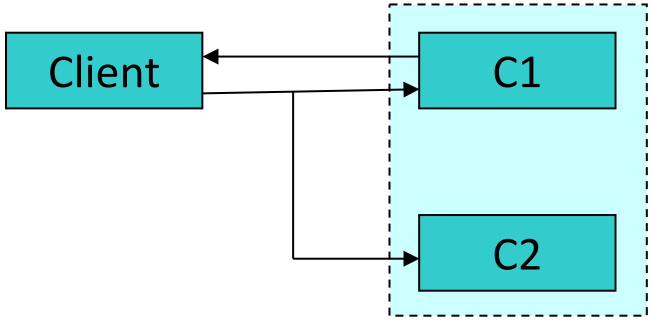


Tactics for Availability

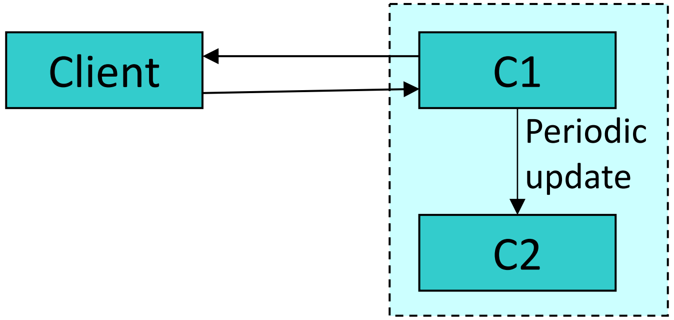
- **Tactic** = Design decisions that influence the control of one or more quality attributes

- **Replication**
  - Very simple to manage in case of stateless components
  - Various strategies in case of statefull components
- **Forward error recovery**
- **Circuit breaker** (see the patterns for microservices)

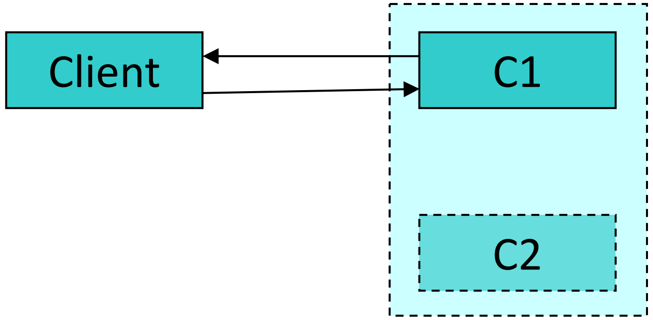
Replication approaches



Hot spare: C1 is leading, C2 is always ready to take over

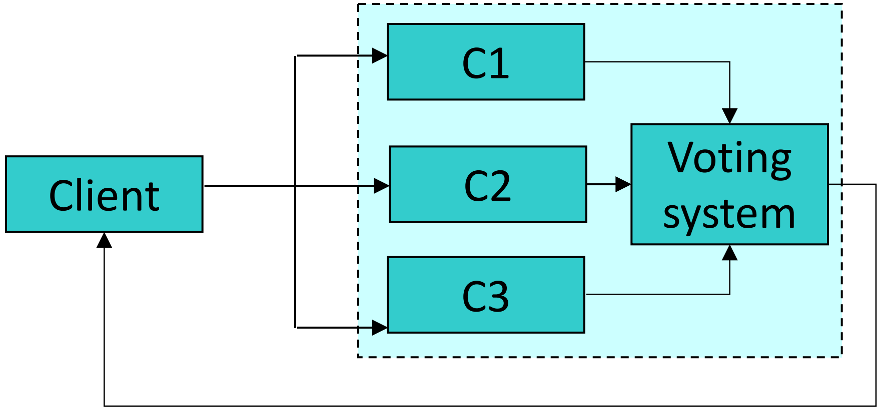


Warm spare: C1 is leading and periodically updating C2.
If C1 fails, some time might be needed to fully update C2

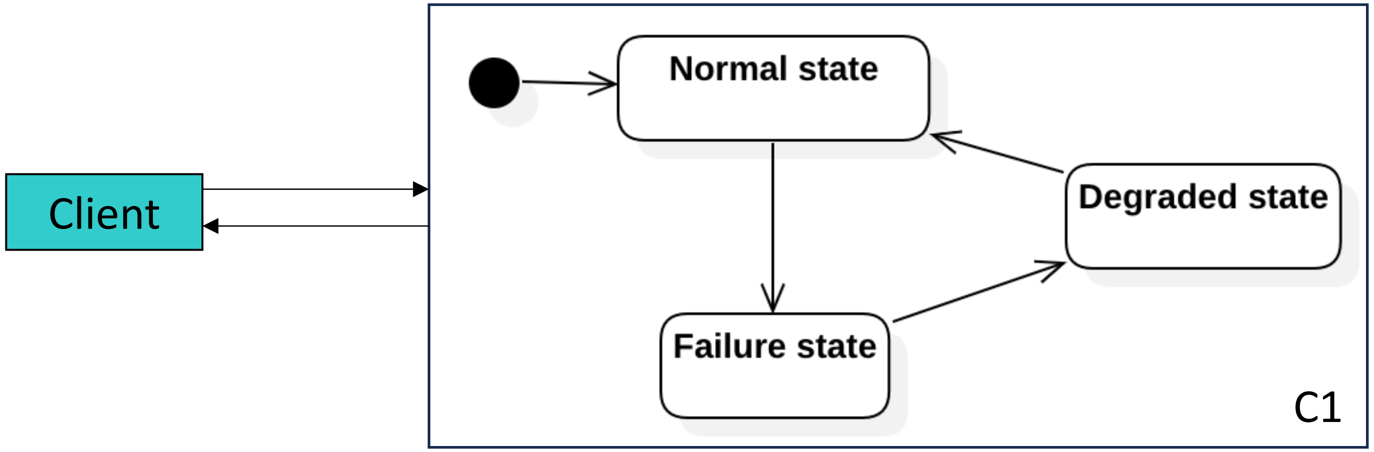


Cold spare: C2 is dormant and started and updated only when needed

Triple modular redundancy: C1, C2, and C3 are all active.
The produced result is the one produced by the majority.
Good when reliability is also important



Forward error recovery



- When C1 is in the failure state, a recovery mechanism moves it to the degraded state
- In the degraded state, C1 continues to be available even if not fully functional

EXTRA MATERIAL

Performance

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- *Performance is an indicator of how well a software system or component meets its requirements for timeliness.*
  - Connie U. Smith, Lloyd G. Williams, *Performance Solutions: A Practical Guide to Creating Responsive, Scalable Software*, 2001, Addison-Wesley Professional.
- Sometimes, performance defined as efficient use of resources
- Performance is connected to scalability: ability of a system to continue to meet its response time or throughput objectives as the demand for the software functions increases
- Multiple metrics available:
  - Response time
  - Throughput
  - CPU utilization
  - Memory utilization
  - I/O operations

EXTRA MATERIAL

Tactics for performance

- Control resource demand
  - Control input
    - Manage event arrival
    - Manage sampling rate
    - Bound event queues' size
    - Prioritize events
  - Improve efficiency of software
    - Reduce indirection
    - Co-locate interacting resources
    - Bound execution time
    - Improve algorithm efficiency
- Manage resources including computation and data
  - Increase resources
  - Introduce concurrency
  - Add multiple replicas and a load balancer
  - Add data replication and/or caching
  - Schedule resources
  - Split input and handle it

EXTRA MATERIAL

Introducing data replication - Twitter example

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- Two main operations
  - Post tweet: a user can publish a message
    - Data from 2012: 4.6k requests/s on average, 12k requests/s at peak
  - Home timeline: a user can view the tweets posted by the people they follow
    - 300k requests/s
- Scalability challenge: cope with the number of connections between followers and followee

Martin Kleppmann, Designing Data-Intensive Applications : The Big Ideas Behind Reliable, Scalable, and Maintainable Systems, O'Reilly Media, Incorporated, Ed: 2017, ISBN: 9781449373320

EXTRA MATERIAL

Twitter example – design approach 1

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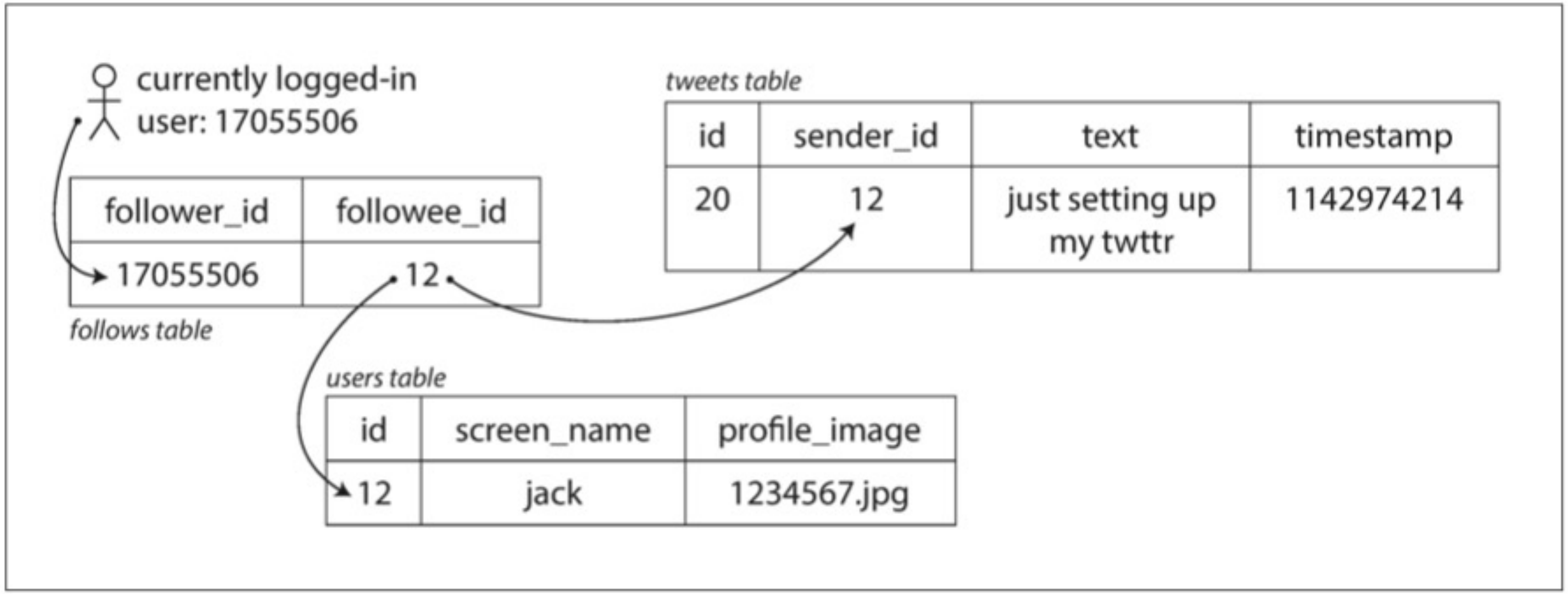
- Tweets are stored in a tweets table
- Any time a user requests the home timeline, we look up at the followed people and retreve their tweets



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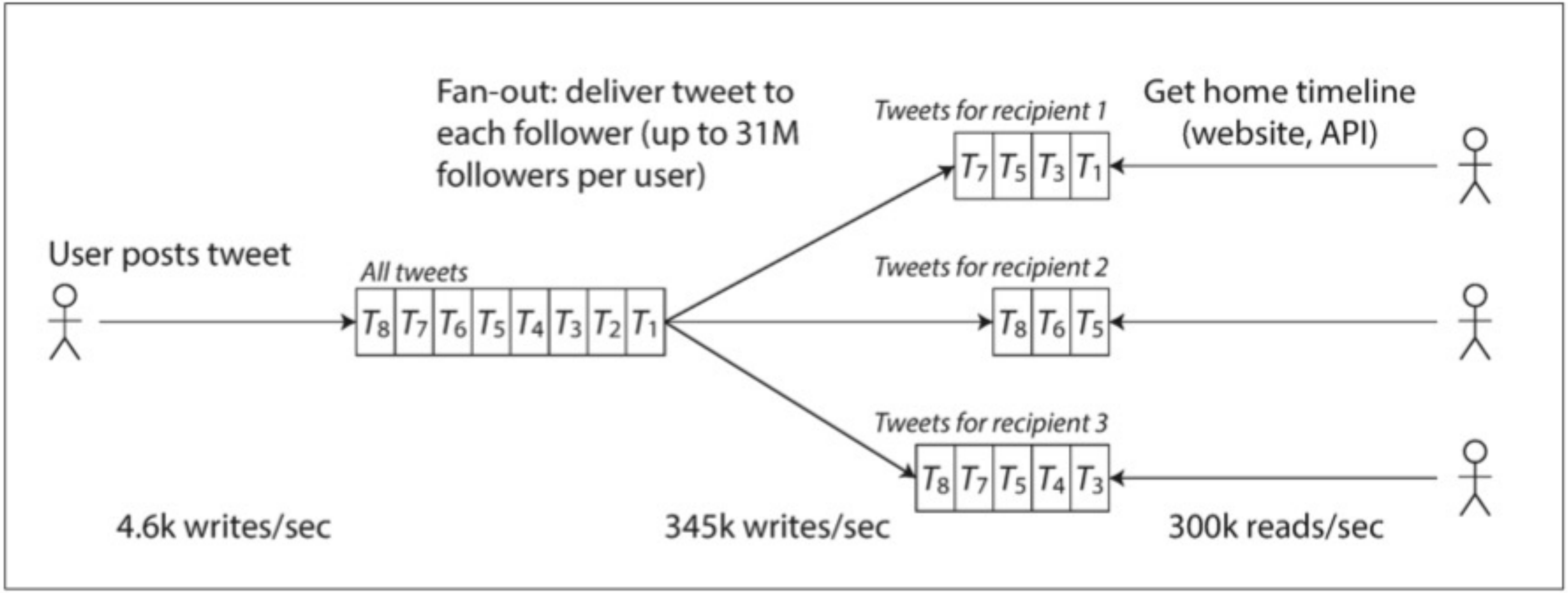
EXTRA MATERIAL

Twitter example – design approach 2



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