Explaining Cascading Failures in Microservices

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1. Software Products
2. Agile Software Engineering
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4. Software Architecture
5. Cloud-based Software
6. Microservices Architecture
7. Security and Privacy
8. Reliable Programming
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Reliable Programming

"I focus here on techniques that help improve the overall reliability of a program

[…]

1. Fault avoidance - You should program in such a way that you avoid introducing faults into your program.

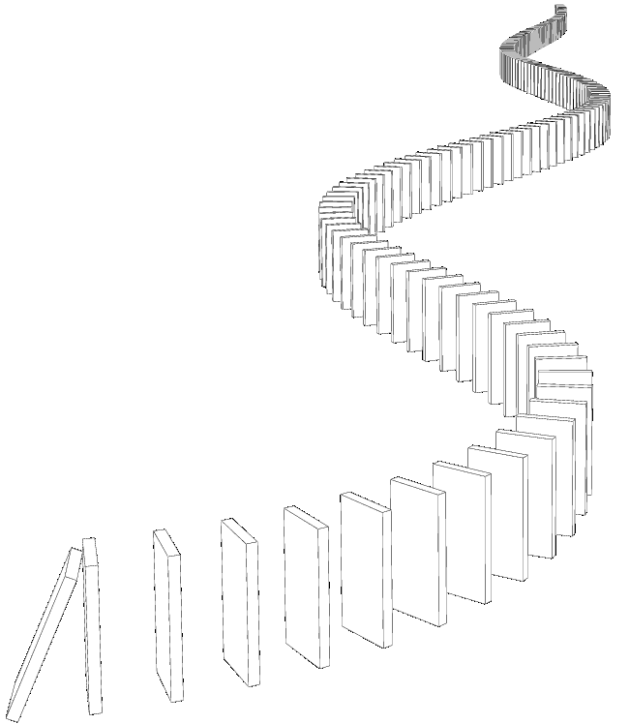
2. Input validation - You should define the expected format for user inputs and validate that all inputs conform to that format.

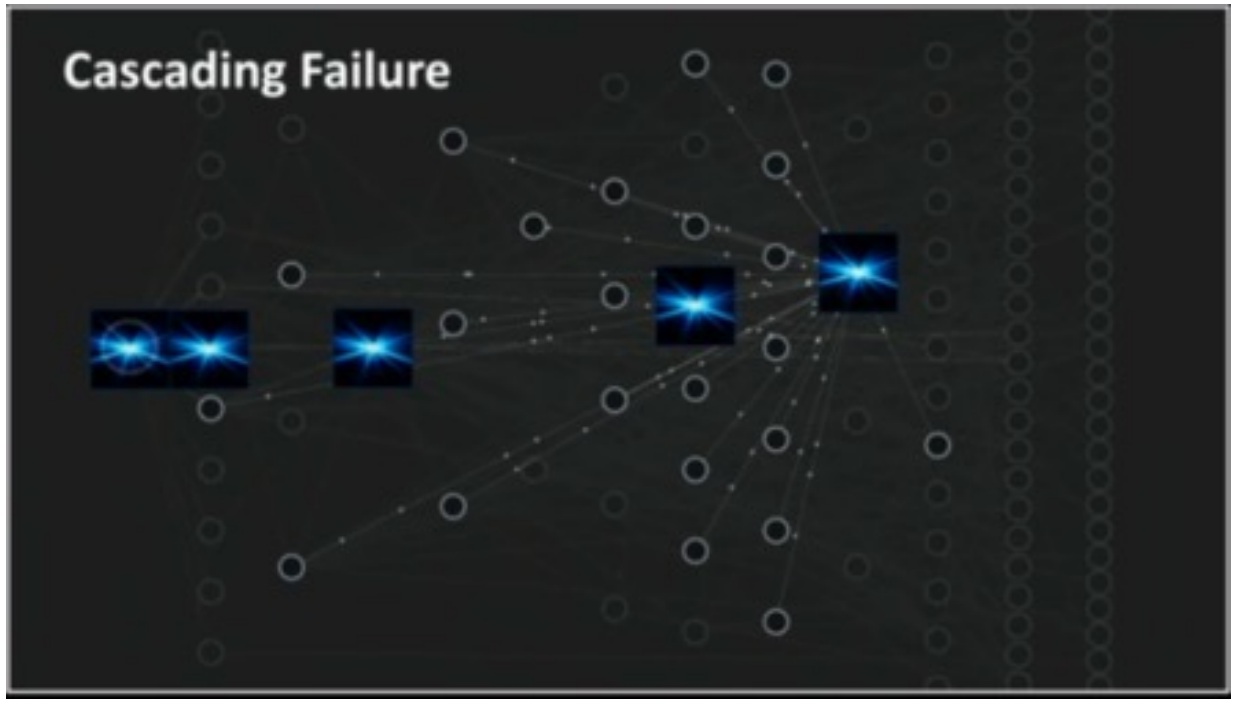
3. Failure management - You should implement your software so that program failures have minimal impact on product users."

Cascading failures and root causes

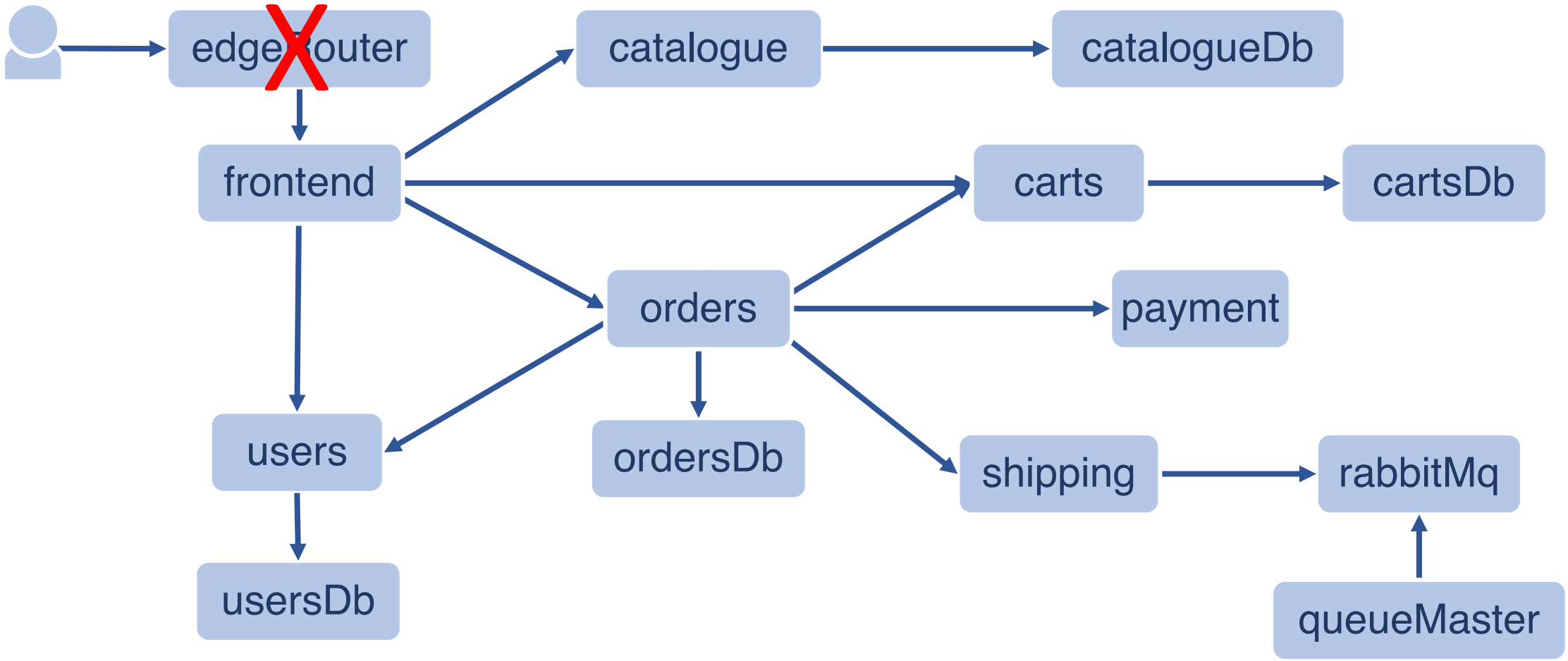
Cascading failures may occur in microservice-based applications

Determining the root cause of a cascading failure is crucial



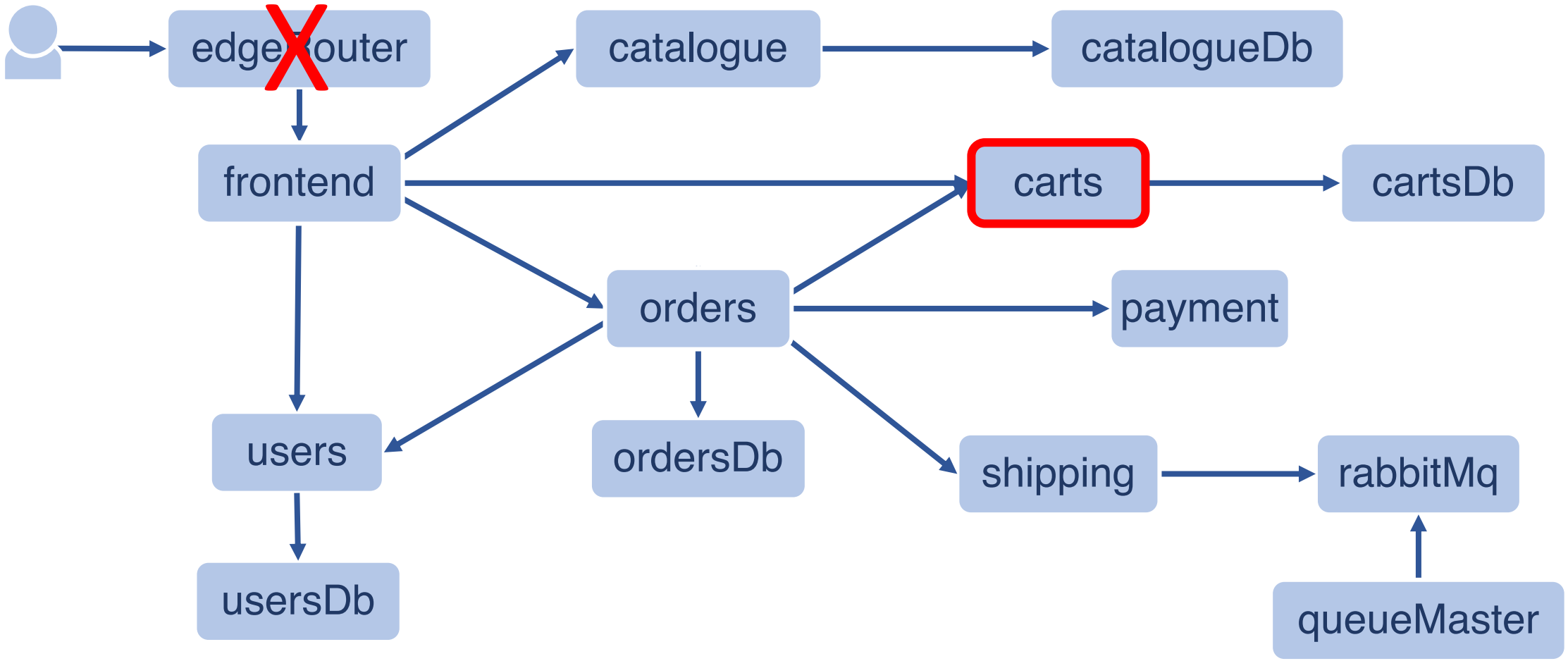


Example



edgeRouter service failed … why?

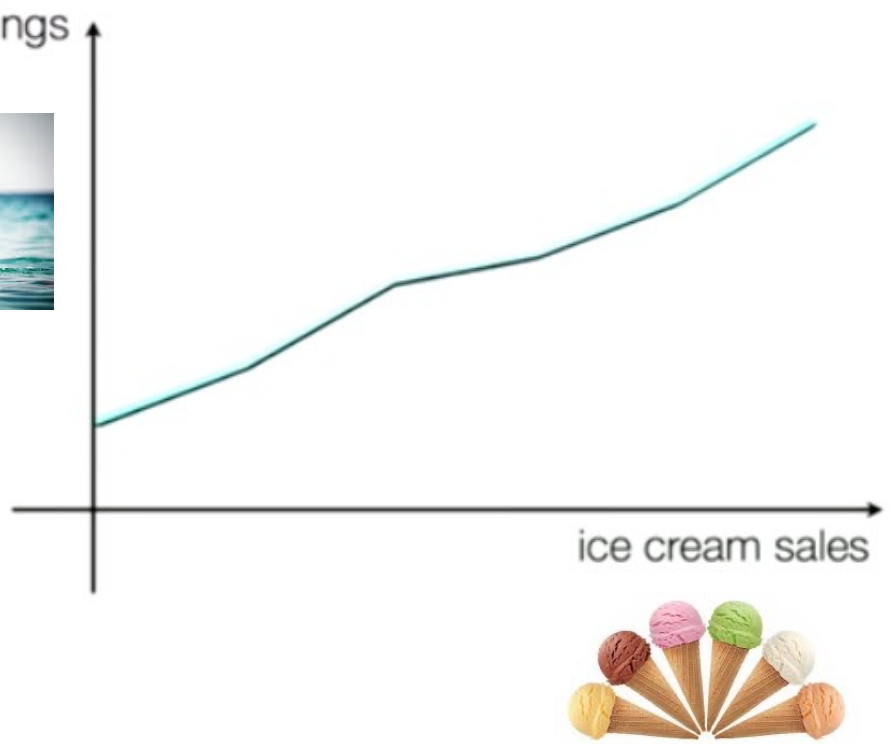
Example



ML-based approaches: … it was *carts*'s fault, most probably

Importance of explanations

Correlation is not causation



Yahoo's data center in Santa Clara witnessed a downtime for almost 12 hours in 2010
Squirrels chewed down the cables through which data got transferred

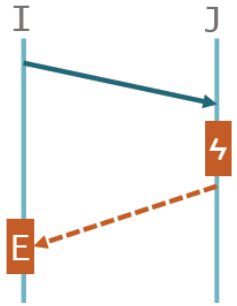
Importance of explanations (cont.)

The availability of **explanations** of root cause analyses would permit to avoid cascading failures by intervening

- both on the failing service and
- on (only) the services failing in cascade

A declarative approach to failure root cause analysis for microservices

1) Define causal relations between events



If *service I logged a failure/timeout E at the end of an interaction with J*

and *J logged an internal error during such interaction*

then *add E to the explanation and analyse the cause of the internal error at J*

If *service I logged an internal error E*

then *I is the root cause of E*

2) Let the inference engine work!

```
?- causedBy(event, Explanation, RootCause).
```

Logged events

Analysis of (distributed) applications logs containing

- The id of logging **service** (name and instance)
- A **timestamp**
- The logged **event**

```
internal                    // internal business logic
sendTo(Dst,Id)              // sent request
received(Id)                // received request
timeout(Dst,Id)             // expired timeout
errorFrom(Dst,Id)           // error reply returned
```

- And its (Syslog) **severity**

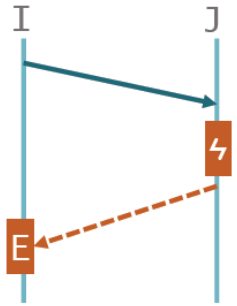
```
emerg/alert/crit/err        // errors
warning                     // warning
notice/info/debug           // info
```

Causal relations

Identify the causal relations among events occurring in separate service instances

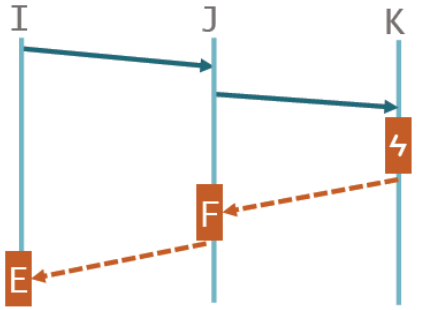
- 5 recursive cases
- 3 base cases

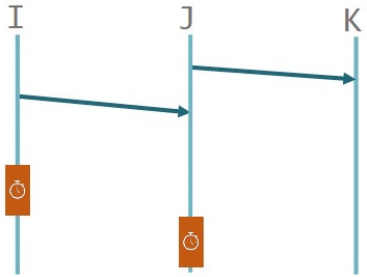
Recursive cases



Internal error of invoked service instance - *A failure/timeout event E at service I, occurring at the end of an interaction with J, was caused by an internal error at J. Recur to explain the internal error at J.*

Failed interaction of invoked service instance - *A failure/timeout event E at service I was caused by a failure event F at J, which in turn was caused by a failed interaction of J with K. Recur to explain the failure event at J.*

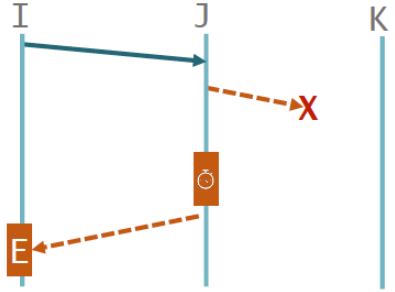


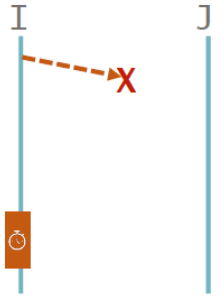


Timed-out interaction of invoked service instance - *A timeout event at service I was caused by a timeout at J, which in turn was caused by a timeout related to an interaction of J with K. Recur to explain the timeout at J.*

Recursive cases (cont.)

Unreachability of a service called by invoked service instance *– A failure/timeout event E at service I was caused by a timeout at J, which occurred since the request sent by J was never received by K. Recur to explain the timeout at J.*





Unreachability of invoked service instance *- A timeout event at I was caused by a non-received request in an interaction of I with J. Recur to explain why J was unreachable.*

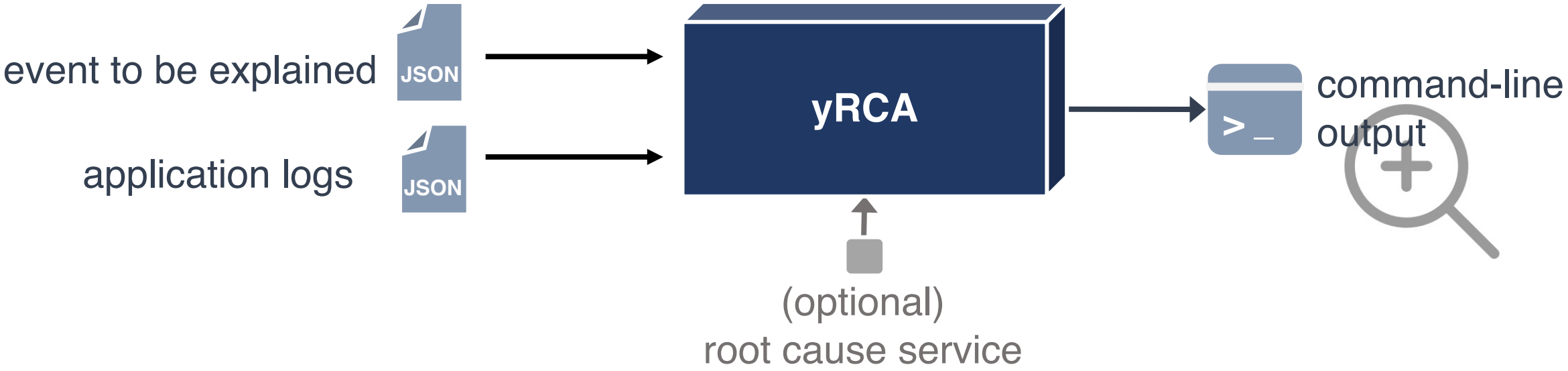
Base cases

Internal service error *- Internal failure event logged by a service, identifying the service itself as the root cause for such an event.*

Temporary service unreachability *- Service considered temporarily unreachable as it previously logged some information.*

Unstarted service *- Service never logged any information.*

yRCA prototype



https://github.com/di-unipi-socc/yRCA

yRCA on the example

```
[0.615]: edgeRouter: Error response (code: 500) received from frontend
(request_id: [<requestId>])
      -> frontend: Error response (code: 500) received from orders
         (request_id: [<requestId>])
      -> orders: Failing to contact carts (request_id: [<requestId>]). Root
         cause: <exception>
      -> carts: unreachable
[0.385]: edgeRouter: Error response (code: 500) received from frontend
(request_id: [<requestId>])
      -> frontend: Failing to contact carts (request_id: [<requestId>]). Root
         cause: <exception>
      -> carts: unreachable
```

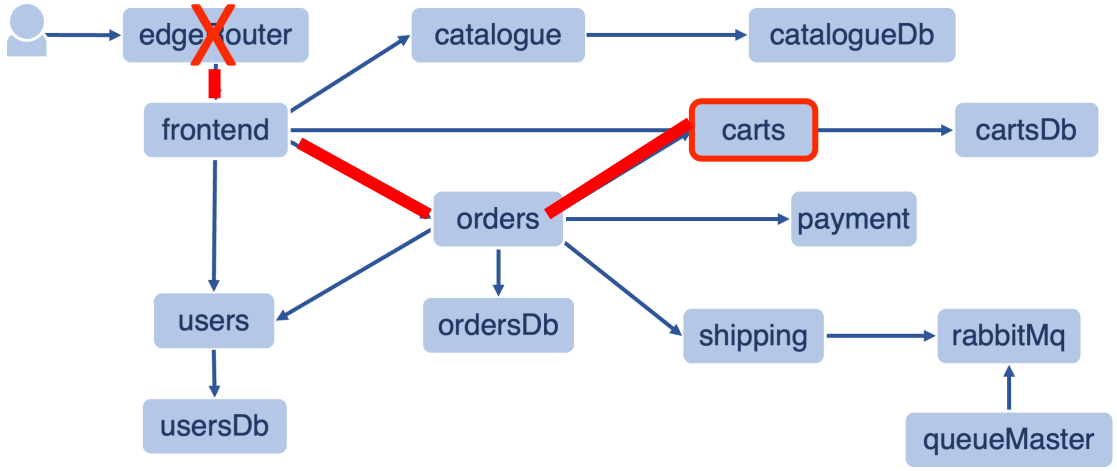
probability

root cause

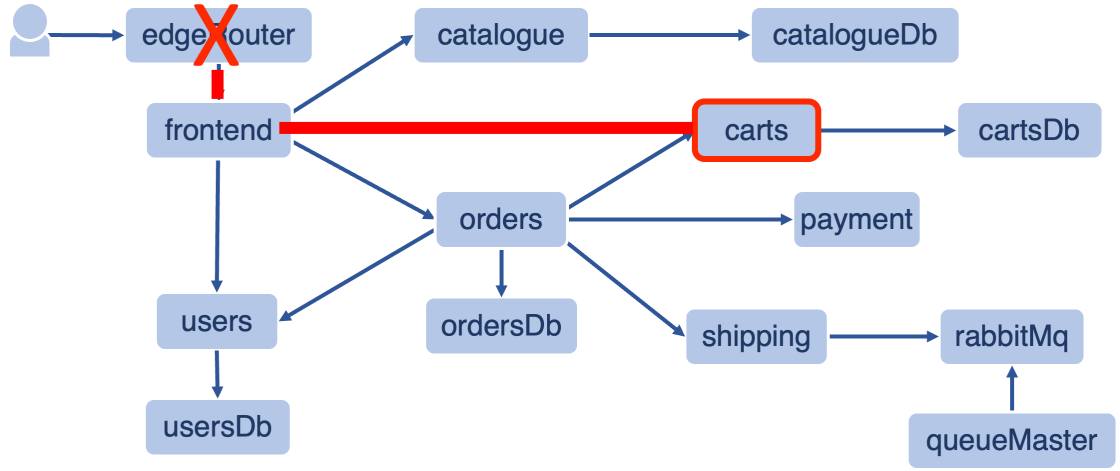
explanation
(cascading failures)

yRCA on the example

61.5%



38.5%



yRCA assessment

Controlled experiments (with Chaos Echo testbed)

- End-user **load** varying from 1 to 100 requests per second
- Service **interaction probability** varying from 0.1 to 1
- Failure **cascade length** varying from 1 to 4

} only one service set to fail on its own, giving a **ground thruth**

- Service **failure probability** varying from 0.1 to 1

} any service can fail

Successfull detection of failure root cause: 99.74% of cases

Low number of false positive (3 explanations in the worst case)

Conclusions

+ Declarative root cause analysis (RCA) technique capable of

  (1) determining root causes and of

  (2) explaining cascading failures

  in microservice-based applications

+ Open source prototype implementation available

+ Good experimental assessment

Future work

- Assessment with industrial applications and with other chaos testing approaches
- Graphical tool visualising cascading failures and suggesting countermeasures
- Deal with with incomplete logs

J. Soldani, S. Forti, A. Brogi. Failure Root Cause Analysis for Microservices, Explained. 22nd International Conference on Distributed Applications and Interoperable Systems (DAIS 2022).