Statically and Dynamically verifiable SLA metrics

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COST ARVI meeting

http://www.envisage-project.eu

Motivation

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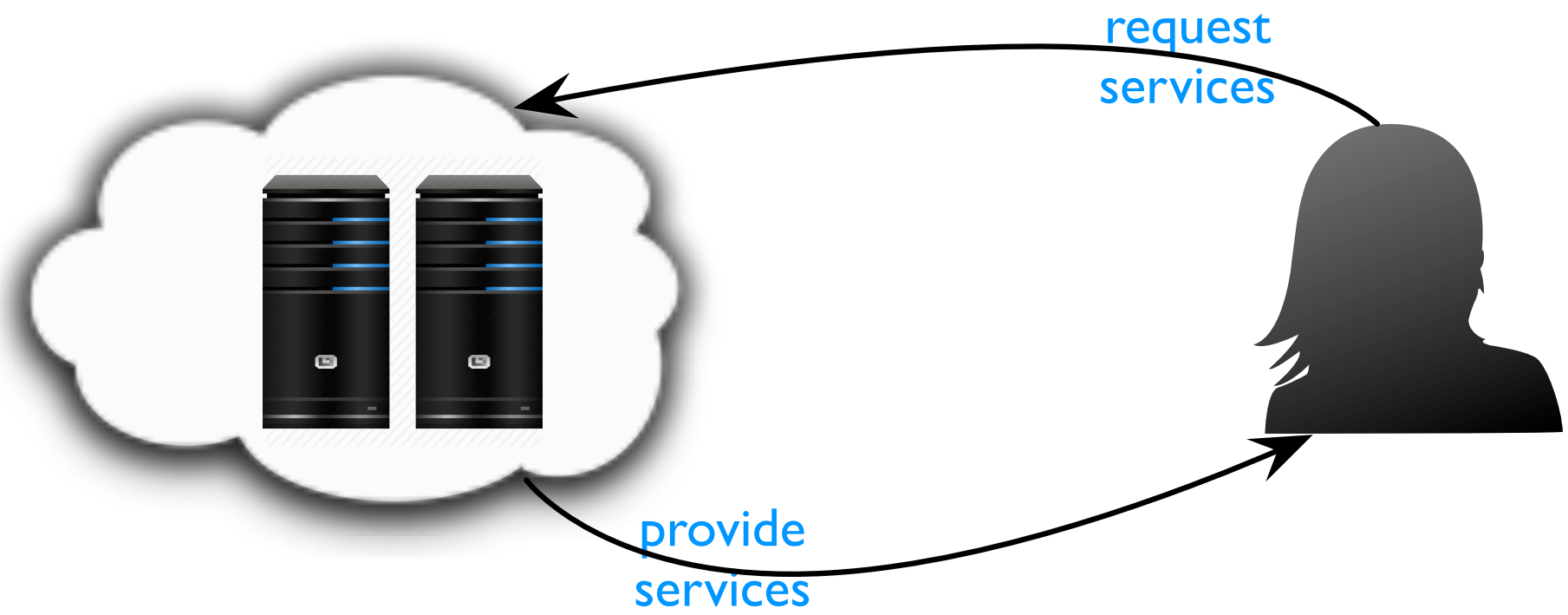

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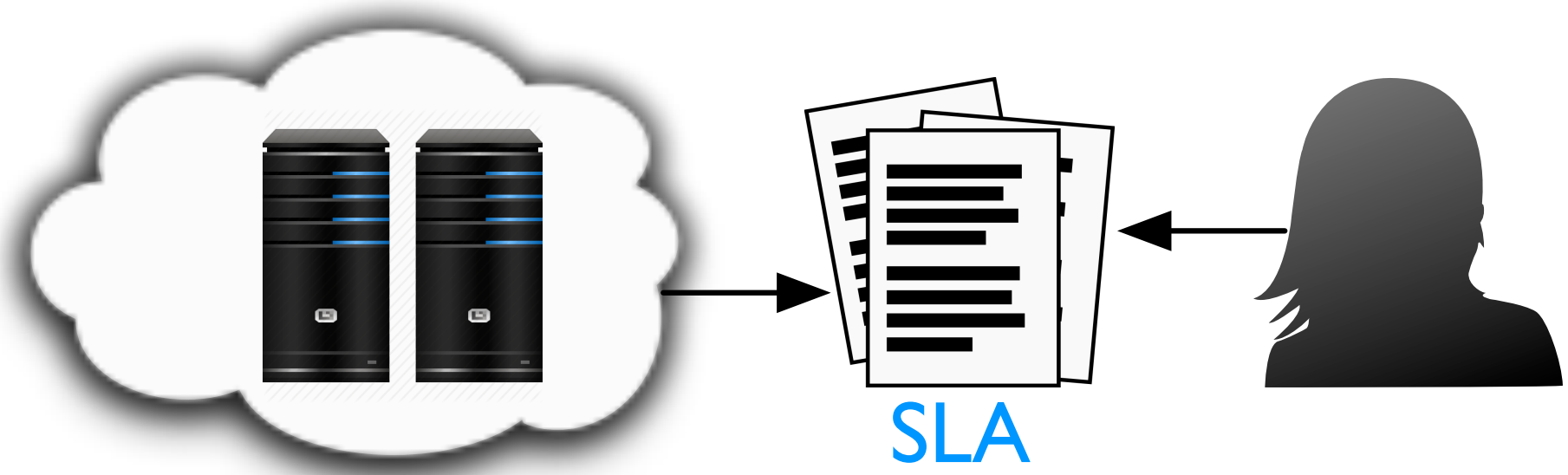

Service Level Agreements (SLAs)

- Legal contracts between service providers and customers
- Define the quality of service
- Informal

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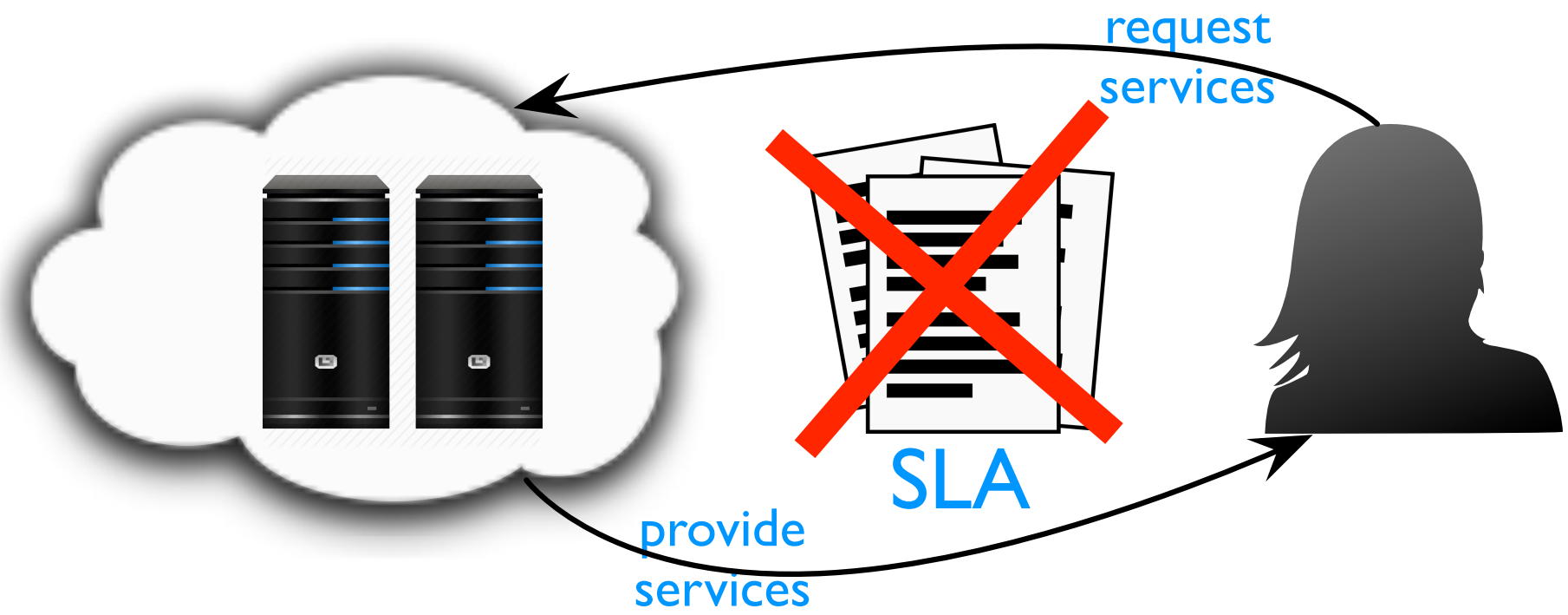

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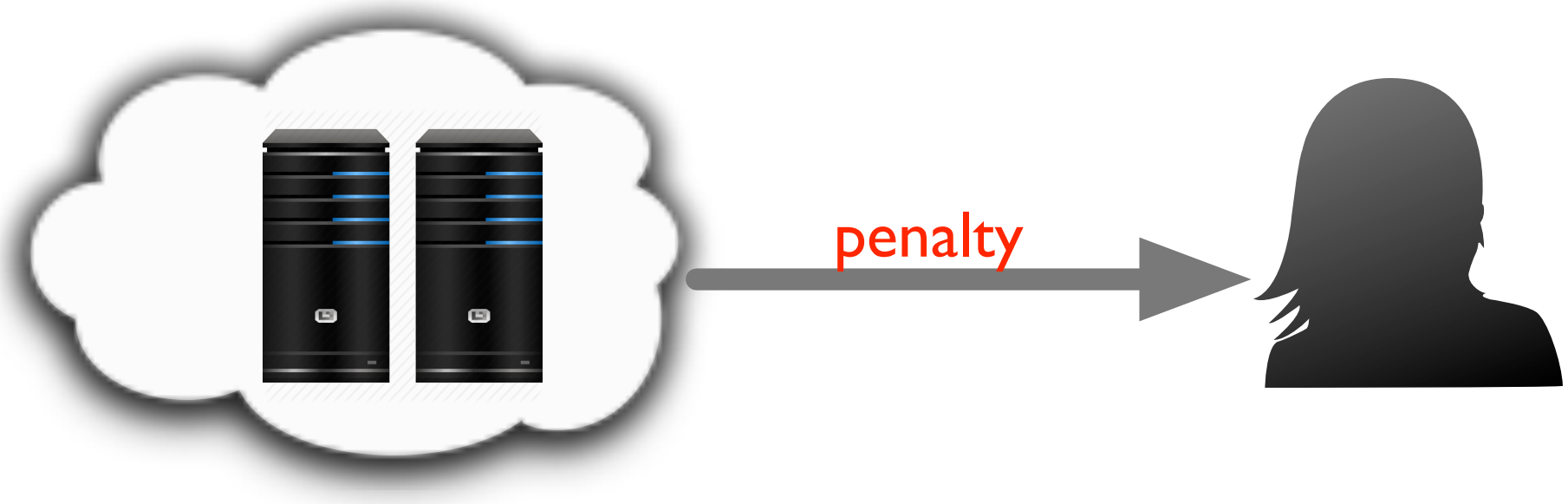

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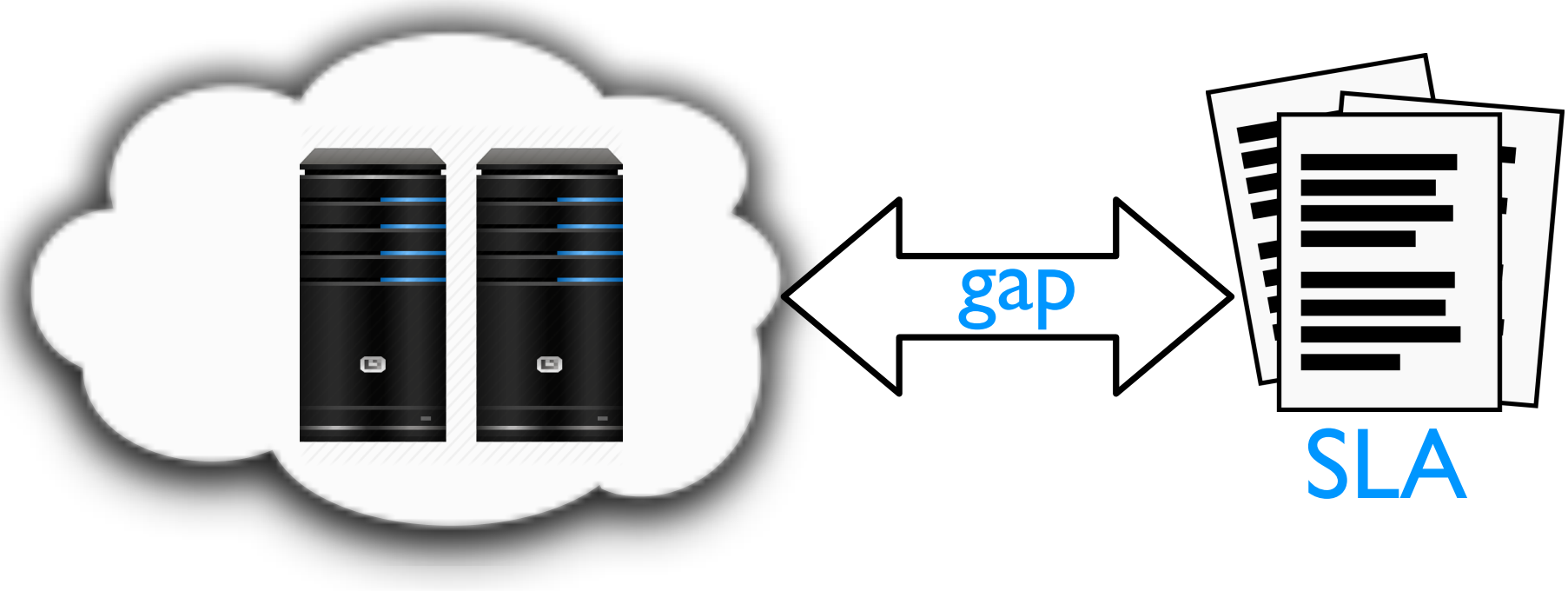
Motivation – The gap between SLAs and services



- Difficult to assess whether a service complies with an SLA or not
- Waste of resources and money

Motivation – Bridge the gap between SLAs and services

Metrics:

1. A means to specify QoS in SLAs
   - Define the boundaries and margins of errors wrt. cloud services
2. Usage:
   - Static time: code evaluation
   - Runtime: service monitoring, balancing, or remediation

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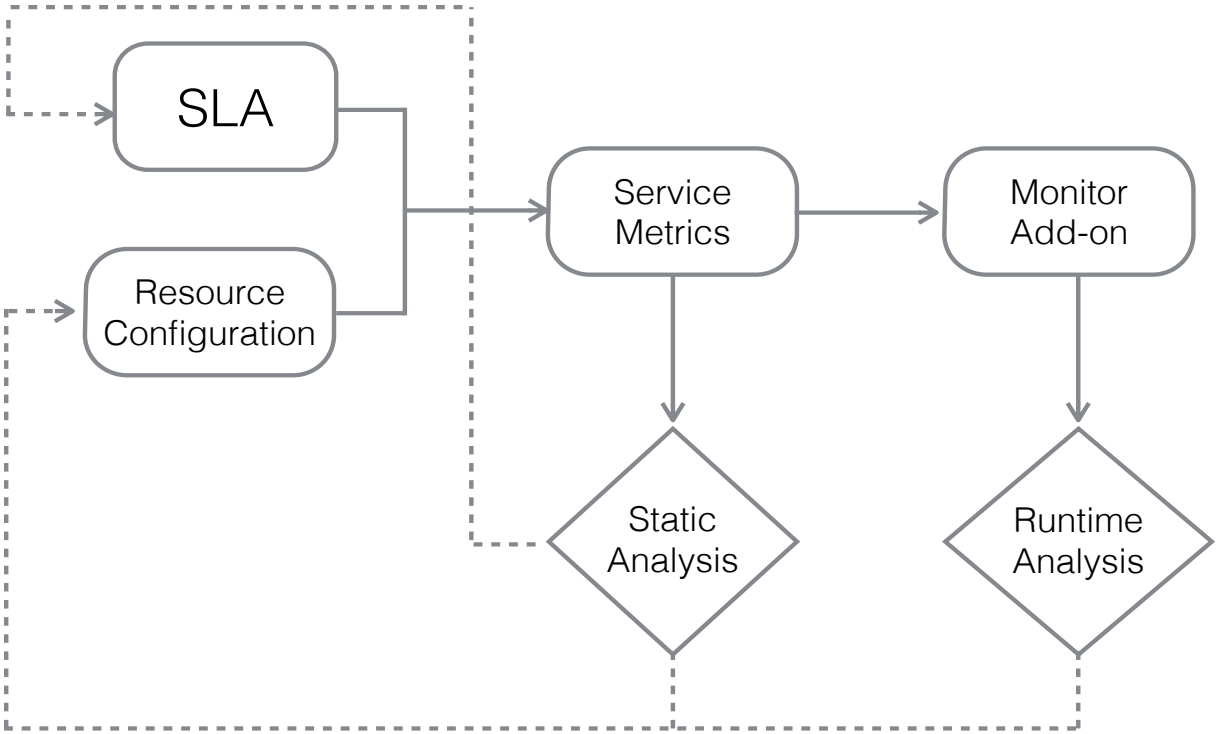
Our approach:

1. Metric functions:
   - A simple formal description of SLA
2. A mathematical framework
   - Statically derives the SLA quality levels from programs
   - Dynamically monitors service behaviours

The Analysis Flow



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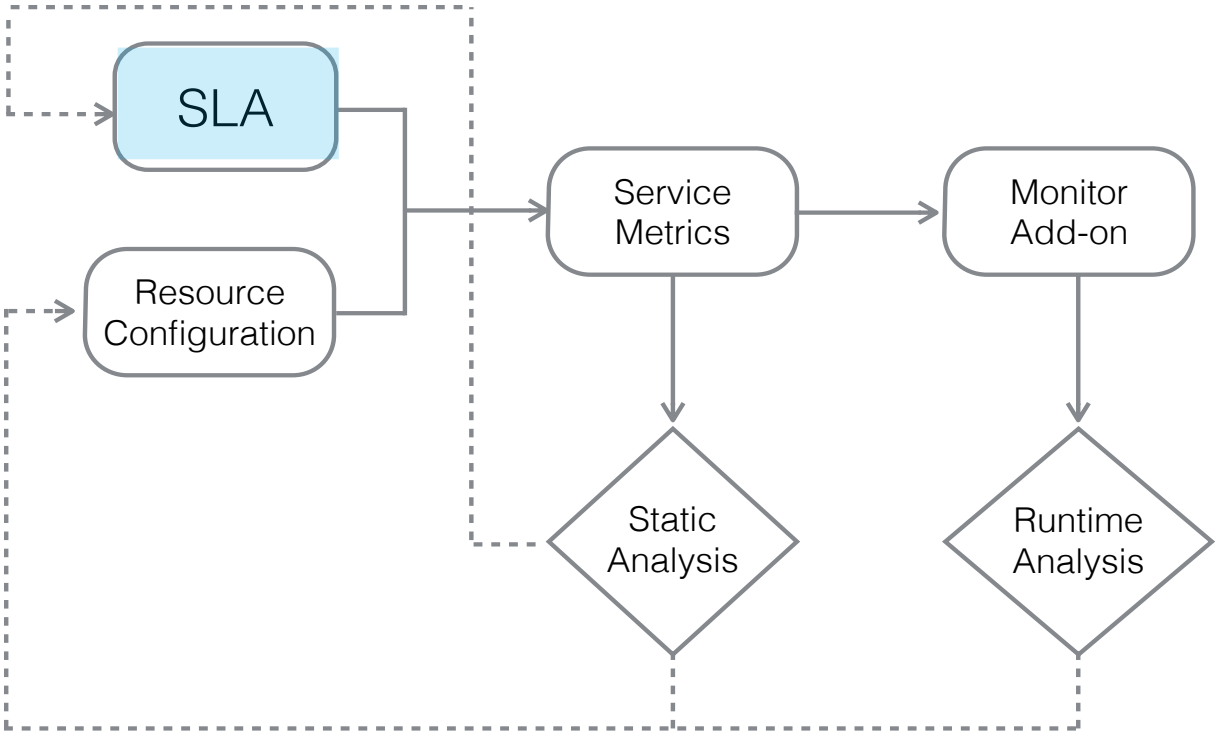

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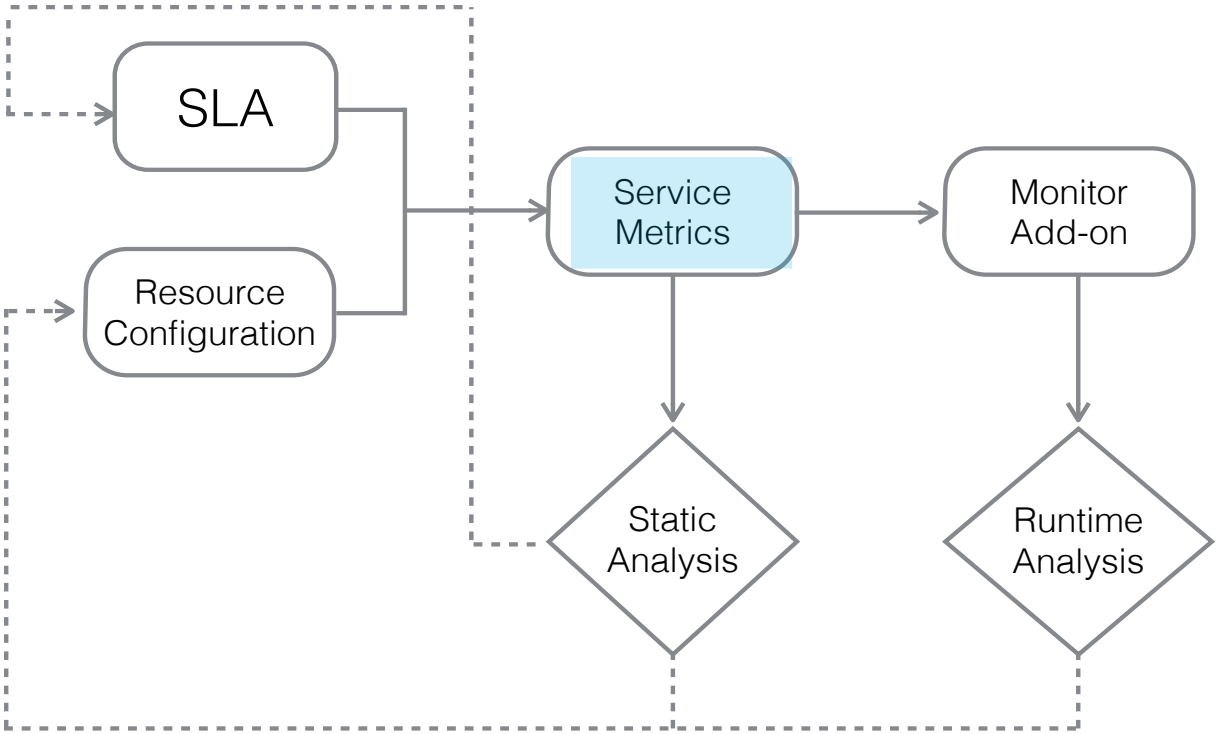

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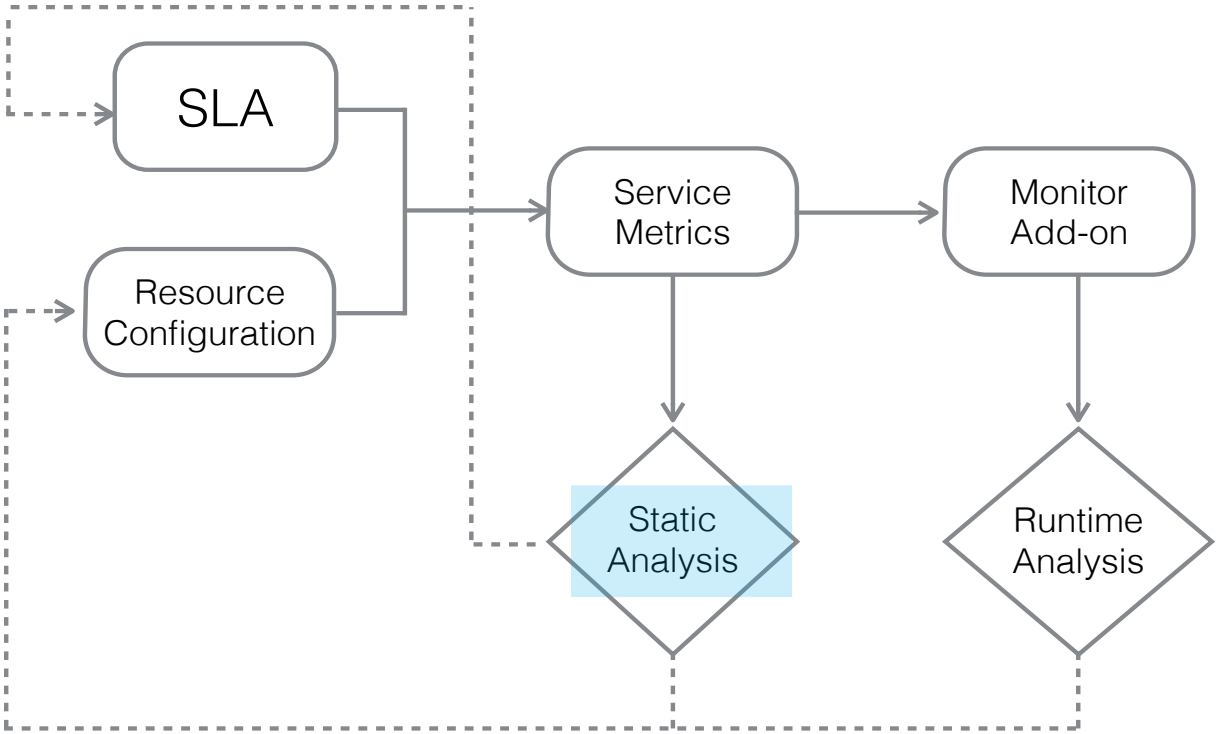

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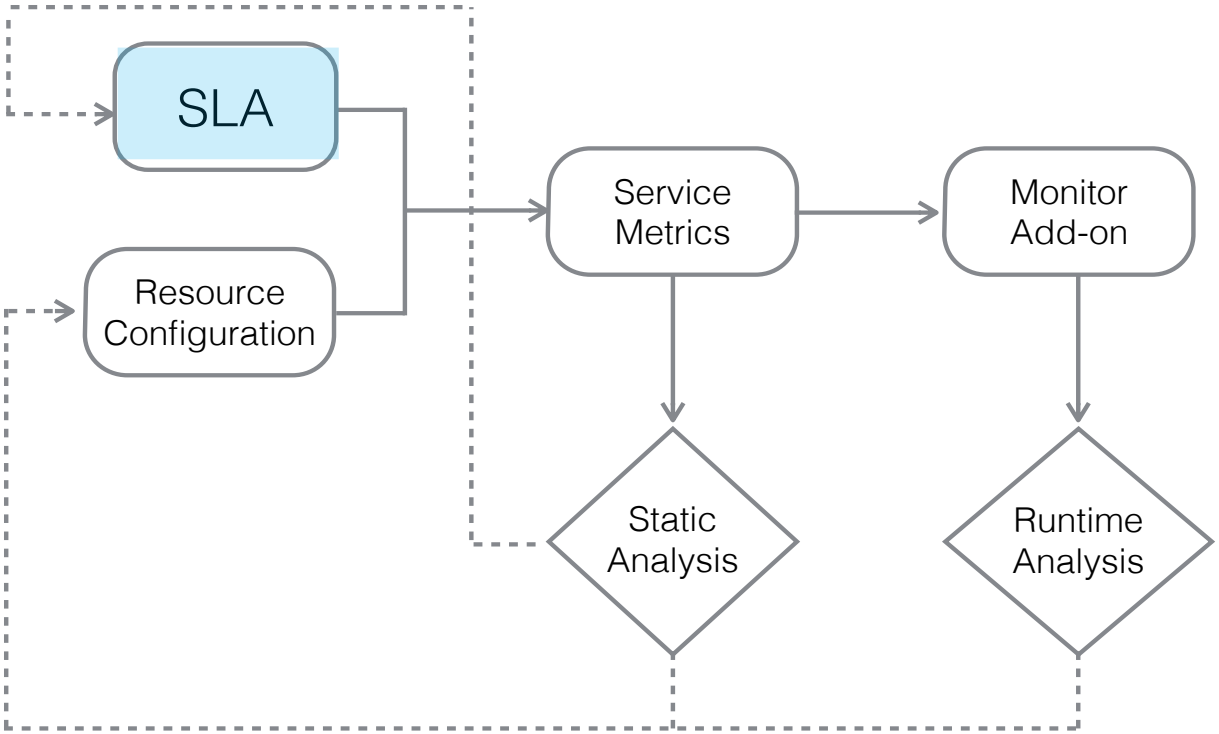

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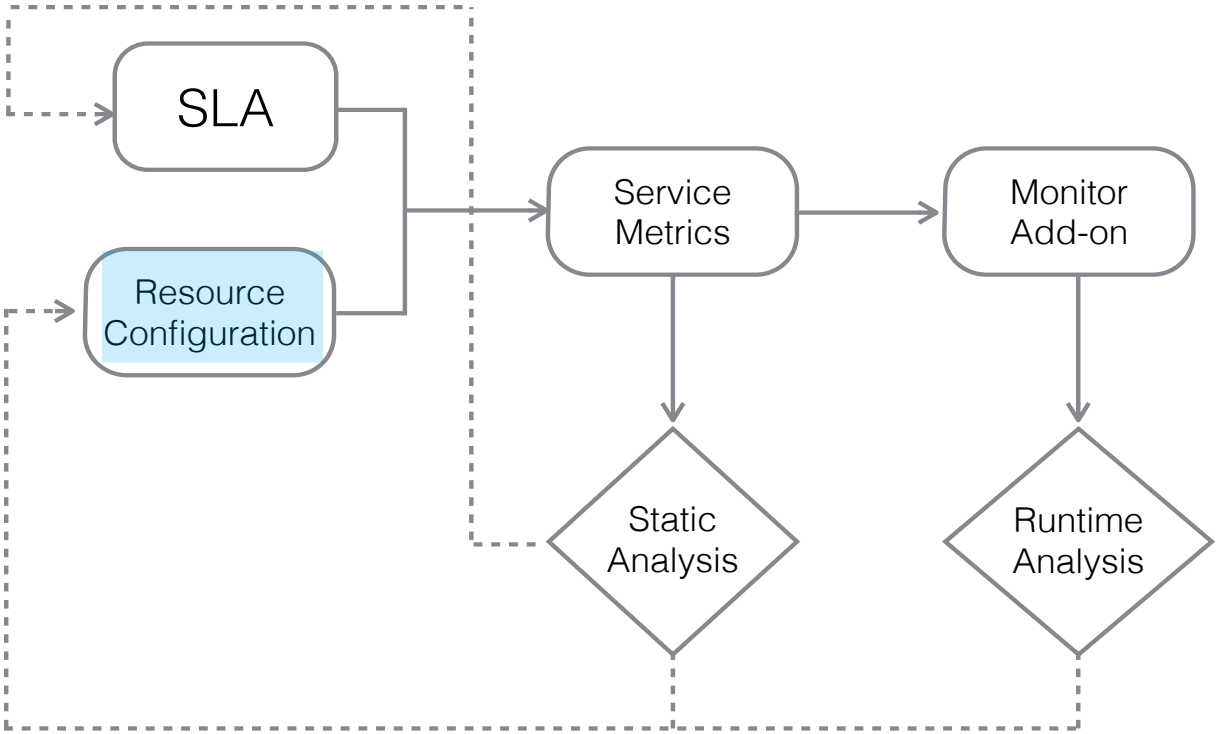

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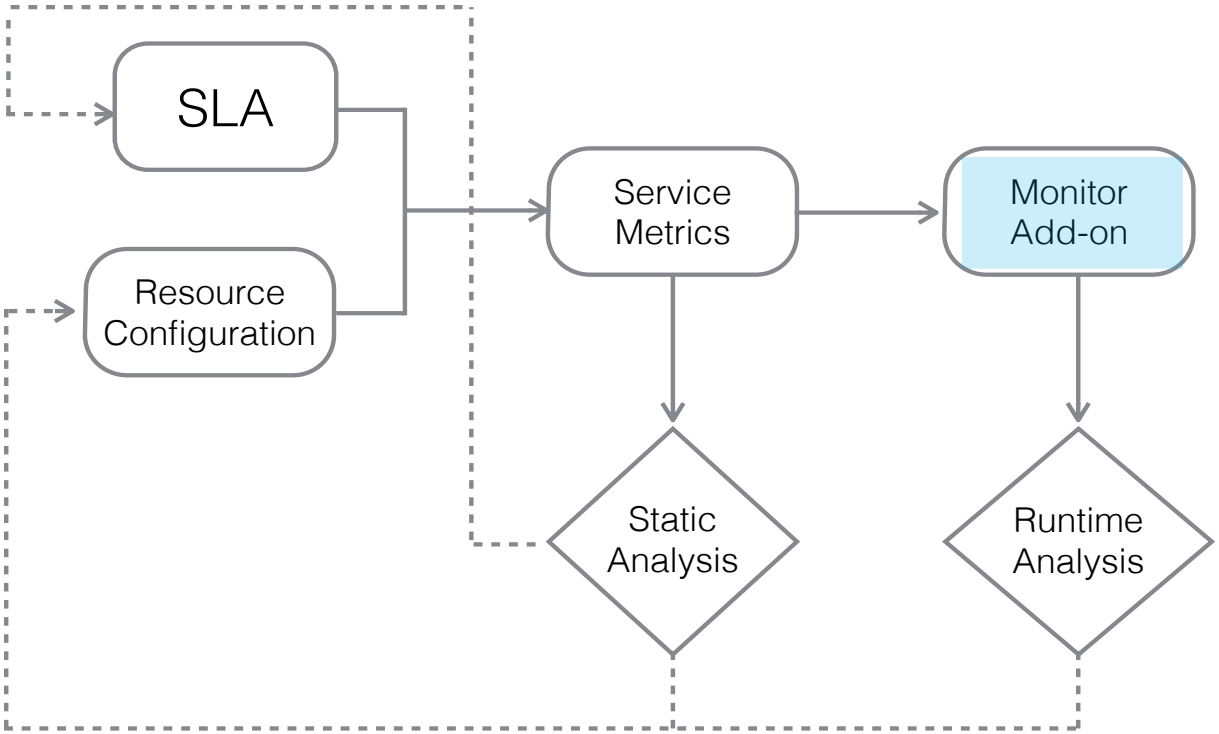

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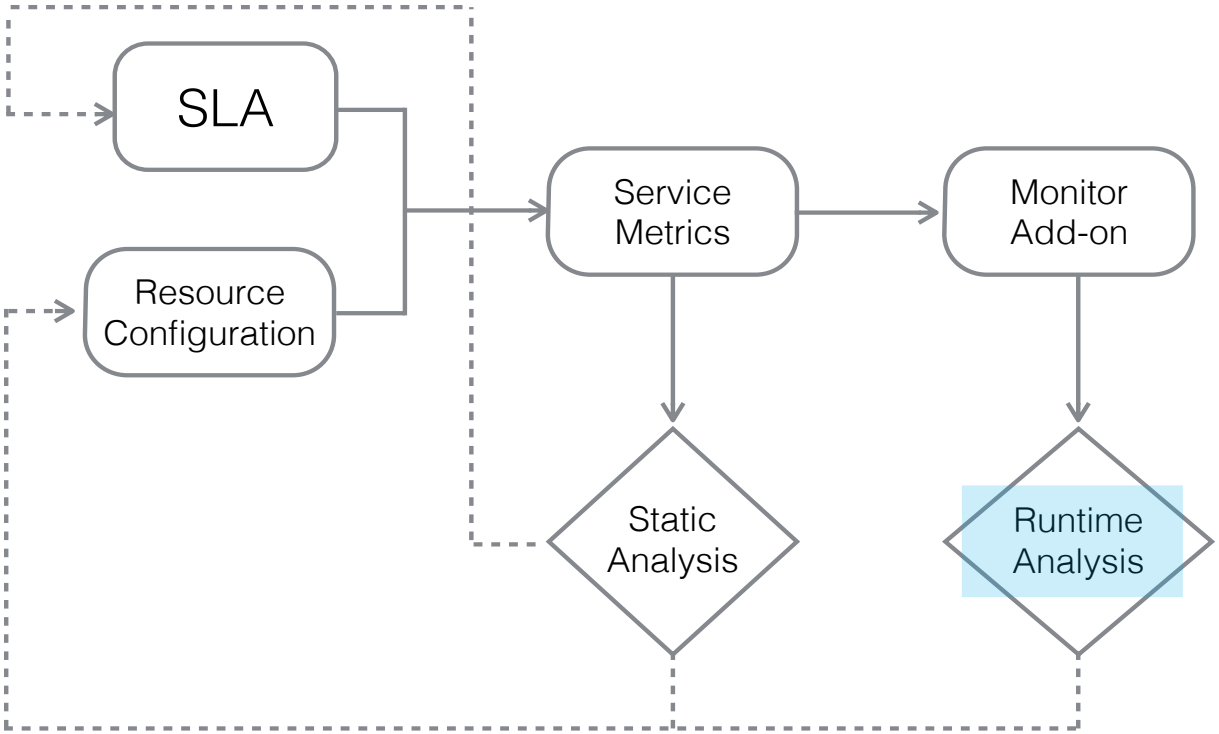

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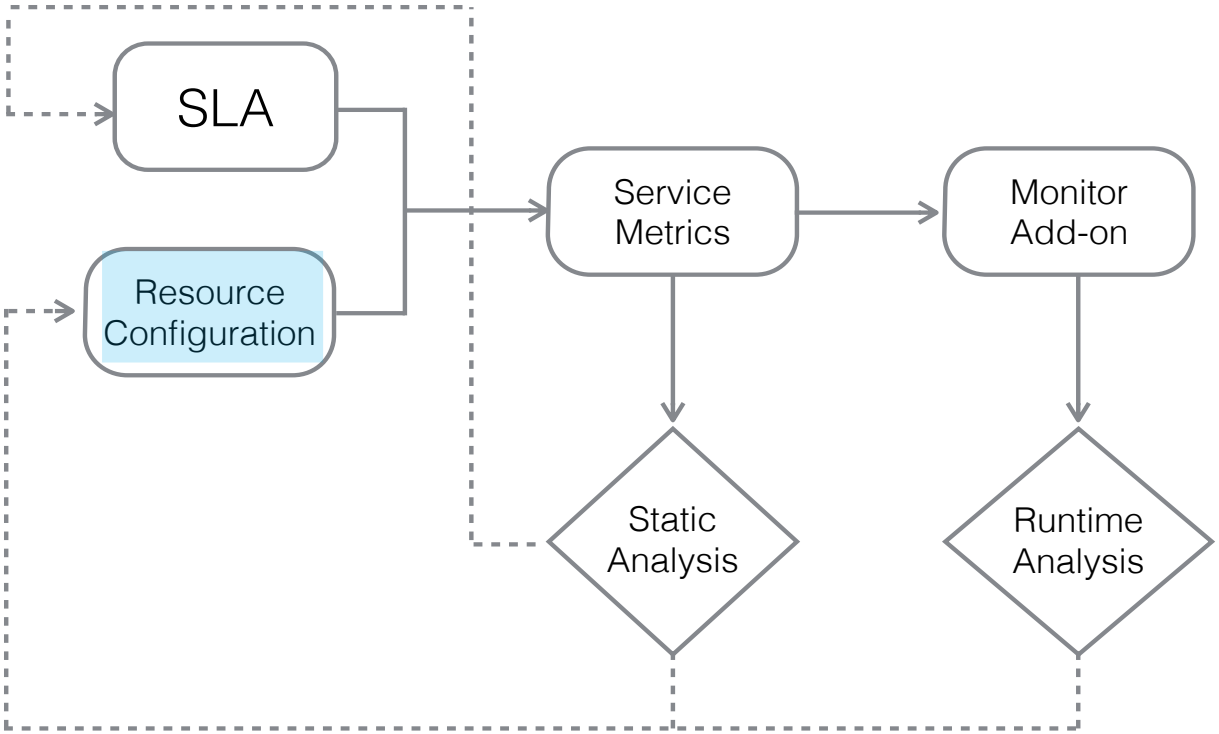

SLAs and performance properties

Metrics for a Query API

"95% of requests is completed within 1 minute, 97% within 3 minutes and 98% within 5 minutes"

AVAILABILITY:

the percentage of timely service provisioning requests

"the service completes 6 queries per minute from 9:00 to 18:00 and 4 queries per minute otherwise"

CAPACITY:

the service throughput

"the service replies to a query request (with the result or with a failure) within 7 minutes"

RESPONSE TIME:

the maximum response time

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SLA – Performance metrics

[1] Cloud service level agreement standardisation guidelines (June 2014)

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Other metrics [1]

security, data management, personal data protection

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the property of being accessible and usable upon demand

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SLA – Performance metrics

AVAILABILITY:

the property of being accessible and usable upon demand

CAPACITY:

the maximum amount of some property of a cloud service.

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SLA – Performance metrics

AVAILABILITY:

the property of being accessible and usable upon demand

CAPACITY:

the maximum amount of some property of a cloud service.

RESPONSE TIME:

the time interval between a cloud service customer event and a cloud service provider response event

Other metrics [1]

security, data management, personal data protection

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Metrics' formalisation: Service metric functions

Service metric functions

- We formalise SLA metrics by means of service metric functions
- Assume $F(\tau)$ and $G(\tau, \delta)$ are two metric functions
- τ is a time interval of the form $[\mathtt{d}.t,\ \mathtt{d}'.t']$
  - $\mathtt{d}$, $\mathtt{d}'$ are days ($\mathtt{d}, \mathtt{d}' \in \{1, \cdots, 365\}$)
  - t, t' are seconds in the day ($t, t' \in \{0, \cdots, 86399\}$)
- δ can be
  - an upper bound to the datasize (in bytes), or
  - a time bound for getting a reply, or
  - an upper bound to the number of resources used by the service.

Percentage of timely service provisioning requests (PTS)

From the SLA

95% of requests is completed within 1 minute, 97% within 3 minutes and 98% within 5 minutes.

Formally

$$\texttt{PTS}_s([1.0,\ 365.86399], x) = \begin{cases} 0,95 & \text{if } x = 60s \\ 0,97 & \text{if } x = 180s \\ 0,98 & \text{if } x = 300s \end{cases}$$

Service Throughput (ST)

From the SLA

the service completes 6 queries per minute from 9:00 to 18:00 and 4 queries per minute otherwise.

Formally

$$\mathtt{ST}_s([1.t,\ 365.t'], 60) = \begin{cases} 4 & \text{if } t = 0 \text{ and } t' = 32399 \\ 6 & \text{if } t = 32400 \text{ and } t' = 64800 // 9am - 6pm \\ 4 & \text{if } t = 64801 \text{ and } t' = 86399 \end{cases}$$

Response Time (RT)

From the SLA

the service replies to a query request (with the result or with a failure) within 7 minutes.

Formally

$$\mathtt{RT}_s([1.0,\ 365.86399]) = 420s$$

Static analysis

Static analysis

Behavioural types

- Abstract descriptions of programs
- Highlight the information for a particular property.
  - service time
  - number of virtual machines

Approach

1. Extract behavioural types from a program
2. Translate ① into abstract descriptions, e.g., equations
3. Solve ② to get, e.g., upper bound of service time

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Example

```
String searchDB(Database DB,
    String s)
{
  String u;
  u = DB.query(s) ;
  job(h) ;
  ......
  return u;
}
```

- `job(h)` needs `h` CPU resources
- the time is $\frac{\text{needed CPU resources}}{\text{allocated CPU resources}}$

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Behavioural type:

```
Service.searchDB(a[x], b[y])
{


 DataBase.query(b[y]) ;
 h/x ;

} : _
```

Example

```
String searchDB(DataBase DB,
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}

class DataBase {
 String query(String s) {
  .....
  job(k);
 }
}
```

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Cost Equations

$searchDB(x,y) = query(y) + h/x$

$query(y) = k/y$

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Time estimation

$$\frac{h}{x} + \frac{k}{y}$$

Example

Cost Equations

```
searchDB(x,y) = query(y) + h/x
query(y) = k/y
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Time estimation

$$\frac{15}{x} + \frac{5}{y}$$

Example

Cost Equations

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$$\frac{15}{2} + \frac{5}{1}$$

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Cost Equations

$$\texttt{searchDB}(x,y) = \texttt{query}(y) + h/x$$

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Time estimation

$$\frac{15}{2} + \frac{5}{1} = 12.5$$

Example

Cost Equations

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$\texttt{query}(y) = \texttt{k}/y$

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Cost Equations

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Break $\mathtt{ST}_{\mathtt{searchDB}}$

Adjustment

Time estimation

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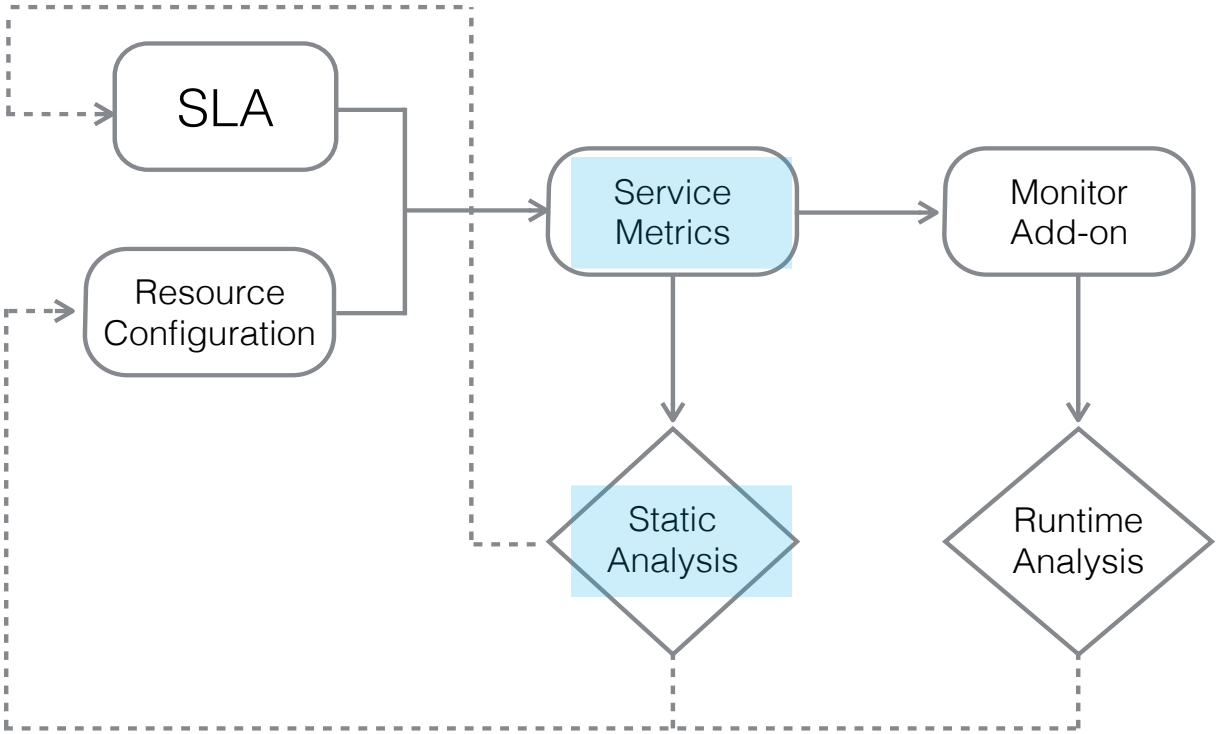

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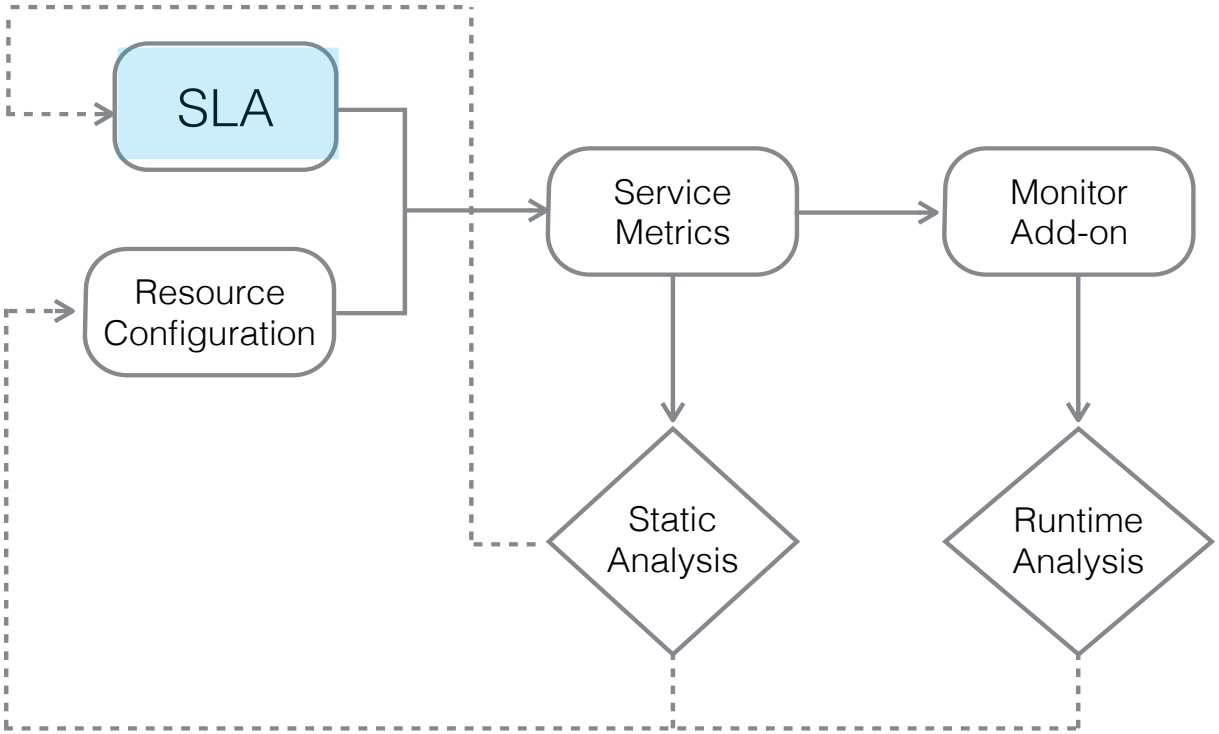
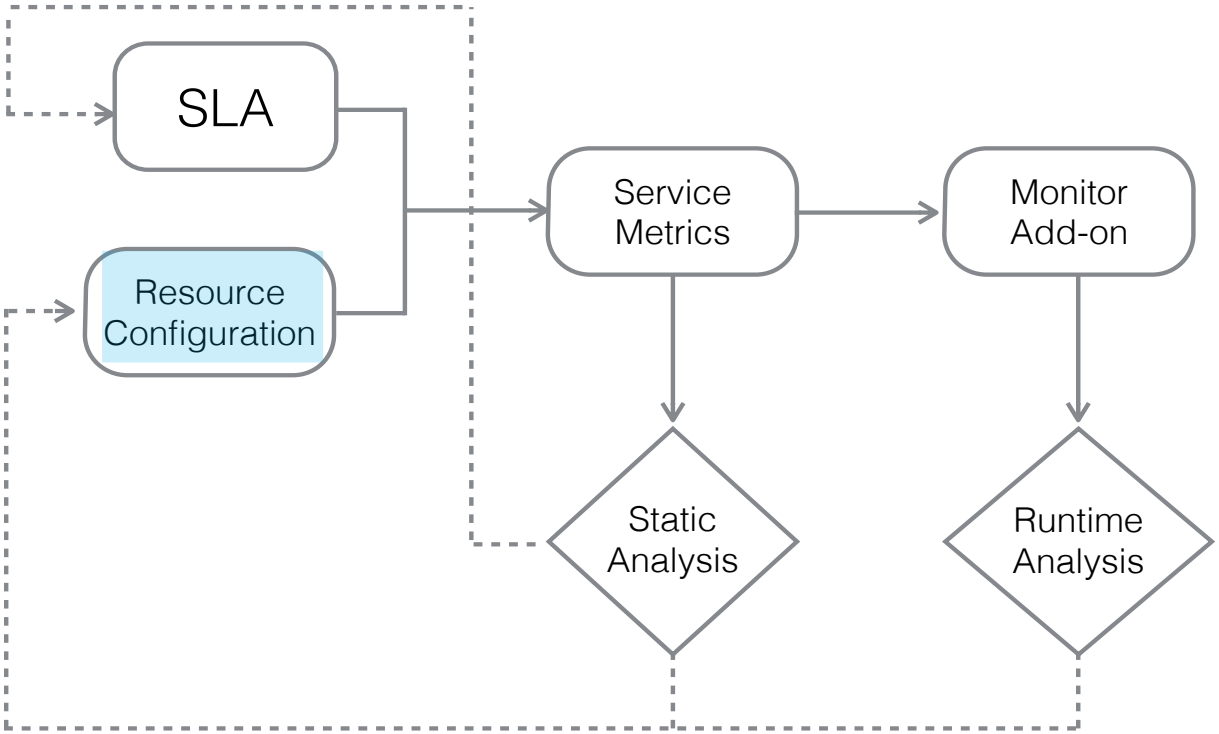


Adjustment

Time estimation

$$\frac{15}{2} + \frac{5}{2} = 10$$



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Satisfy both

Run-time analysis

Monitoring metrics

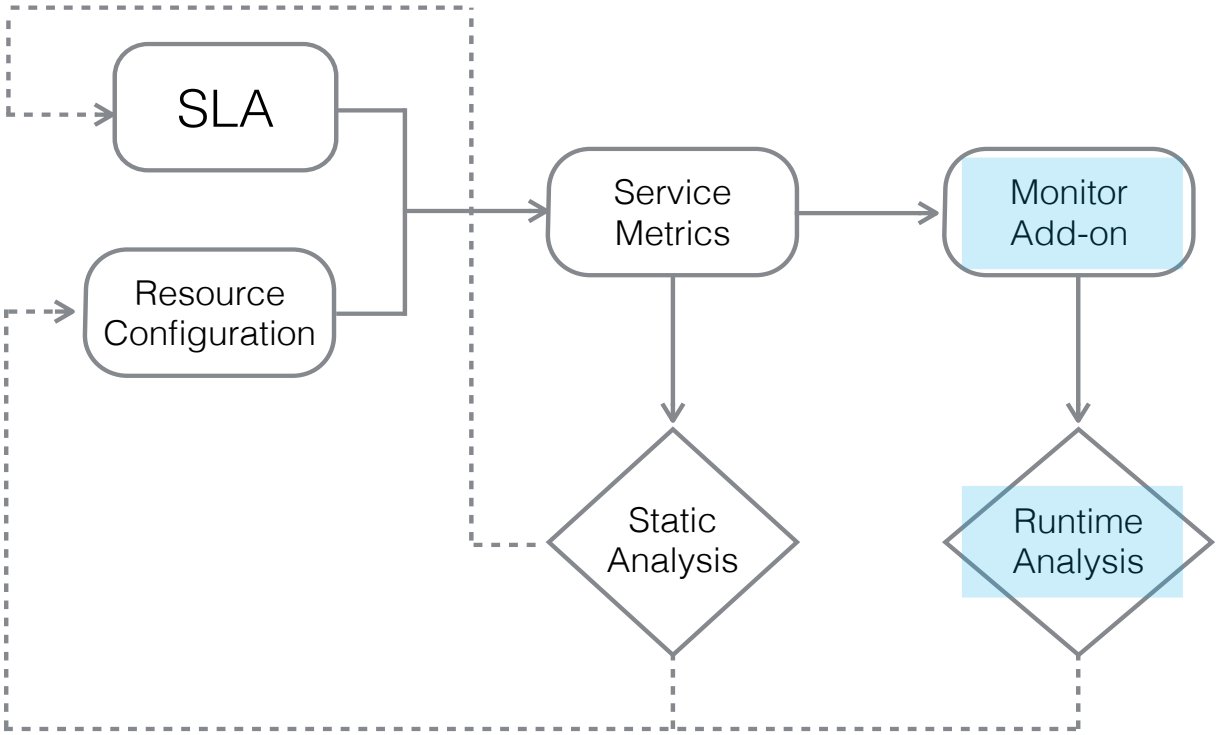
Run-time monitoring

- Observation:
- Reaction:

Monitoring metrics

Run-time monitoring

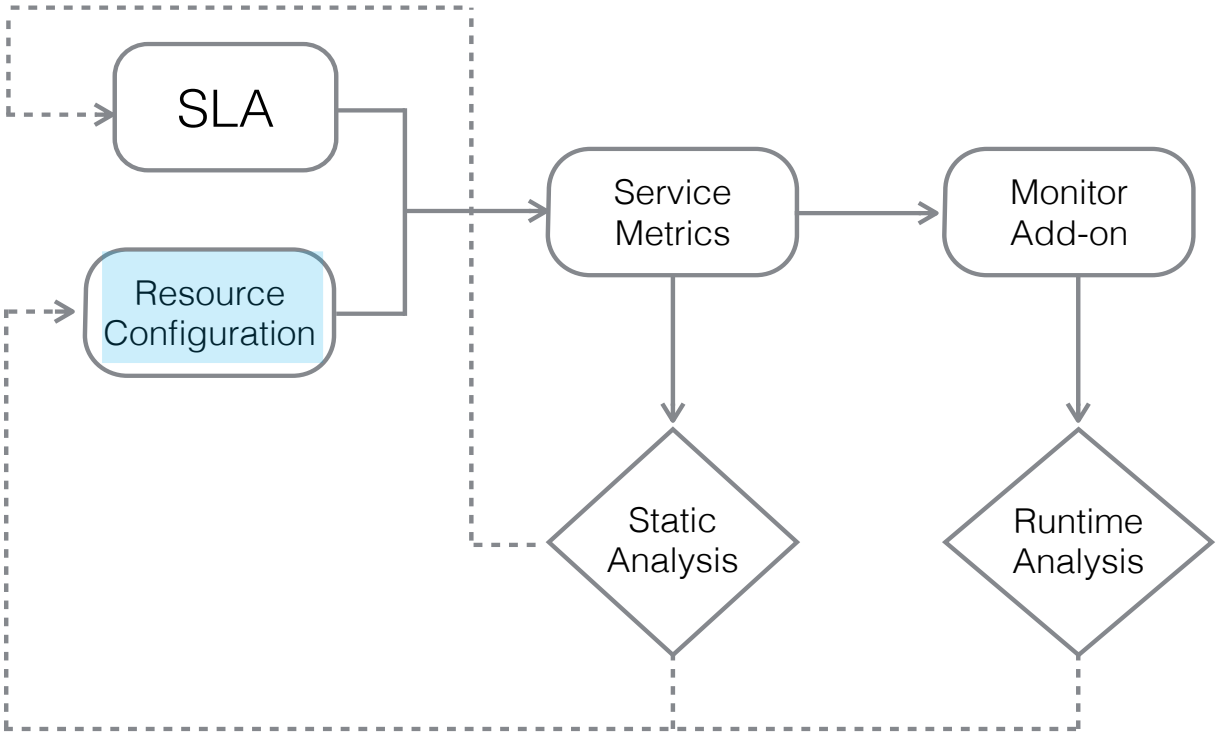
- Observation: measurements on services are taken
- Reaction:



Monitoring metrics

Run-time monitoring

- Observation: measurements on services are taken
- Reaction: adjustments for resource allocations



Observation phase

Service time monitor

- Intercepts all the HTTP invocations/replies to/from a service
- Records the time taken by every request to be completed

```
void monitor_service_time() {
   (service,method,msg,client,m_id) = HttpRequest.intercept();
   time_start = time();
   reply = service.method(msg);
   time_end = time();
   HttpResponse.send(client,reply,m_id);
   log(m_id,time_start,time_end);
}
```

Percentage of timely service provisioning requests

`percentage` method

takes as input a time window and returns `true` if the percentage of requests complies with the definition of $\texttt{PTS}_s$

```
boolean percentage(Log_file d, Time t_begin, Time t_end){
   boolean v = true ;

   /* retrieve from the log the total number of messages served in the time window */
   nmb_msg = get_total_messages(d, t_begin, t_end) ;

   /* check whether the SLA percentages of served requests
      correspond to the observed ones */
    nmb_msg_completed = find(t_begin, t_end, 60) ;
    v = v && (nmb_msg_completed/nmb_msg <= 0.95) ; //95% in 1 min
    nmb_msg_completed = find(t_begin, t_end, 180) ;
    v = v && (nmb_msg_completed/nmb_msg <= 0.97) ; //97% in 3 mins
    nmb_msg_completed = find(t_begin, t_end, 300) ;
    v = v && (nmb_msg_completed/nmb_msg <= 0.98) ; //98% in 5 mins

   return v;
}
```

Service Throughput

`throughput` method

takes as input a logfile and a time window and returns `true` if the throughput complies with the definition of ST_s

```
boolean throughput(Log_file d, Time t_begin, Time t_end){
    int daily = 0;
    int nightly = 0;

    /* collects the number of the served requests during the two
      specified time-frames */
    for each (m_id, time_init, time_end) in d {
      if ((time_init >= 32400) && (time_init <= 64800)) // 9:00—18:00
            daily = daily + 1 ;
      else nightly = nightly + 1 ;
    }

    /* return true if 6 queries per minute are completed in 9:00-18:00
       and 4 queries per minute in the remaining time */
    return ( ((daily/60*9)>6) && ((nightly/60*15)>4) );
  }
```

Example

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- [Static Analysis] The initial 2 CPU resources respect the SLA.
- The `throughput` method records only 4 requests per minute.

Example

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Reaction

Configure resource allocation

Reaction phase

`reaction` method

verifies every 300s whether the percentage of timely service provisioning requests is reached and, in case of failures, adds one more CPU

```
void reaction(Service s) {
  Time t ; Bool v ;
  t = time() ;
  idle(300) ;
  v = percentage(d,t, t+300) ;
  if (!v) MonitoringPlatform ! allocate(s) ;
}
```

Example

$$\texttt{ST}_{\texttt{searchDB}}([1.t,\ 365.t'], 60) = \begin{cases} 4 & \text{if } t = 0 \text{ and } t' = 32399 \\ 6 & \text{if } t = 32400 \text{ and } t' = 64800\ //9am - 6pm \\ 4 & \text{if } t = 64801 \text{ and } t' = 86399 \end{cases}$$

$$\texttt{RT}_{\texttt{searchDB}}([1.0,\ 365.86399]) = 420s$$

- [Static Analysis] The initial 2 CPU resources respect the SLA.
- The `throughput` method records only 4 requests per minute.
- The `reaction` method requests 1 additional CPU resource.
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Budget metric function

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- When the runtime CPU reallocation is triggered by the `throughput` monitor, the nightly budget is not met anymore.
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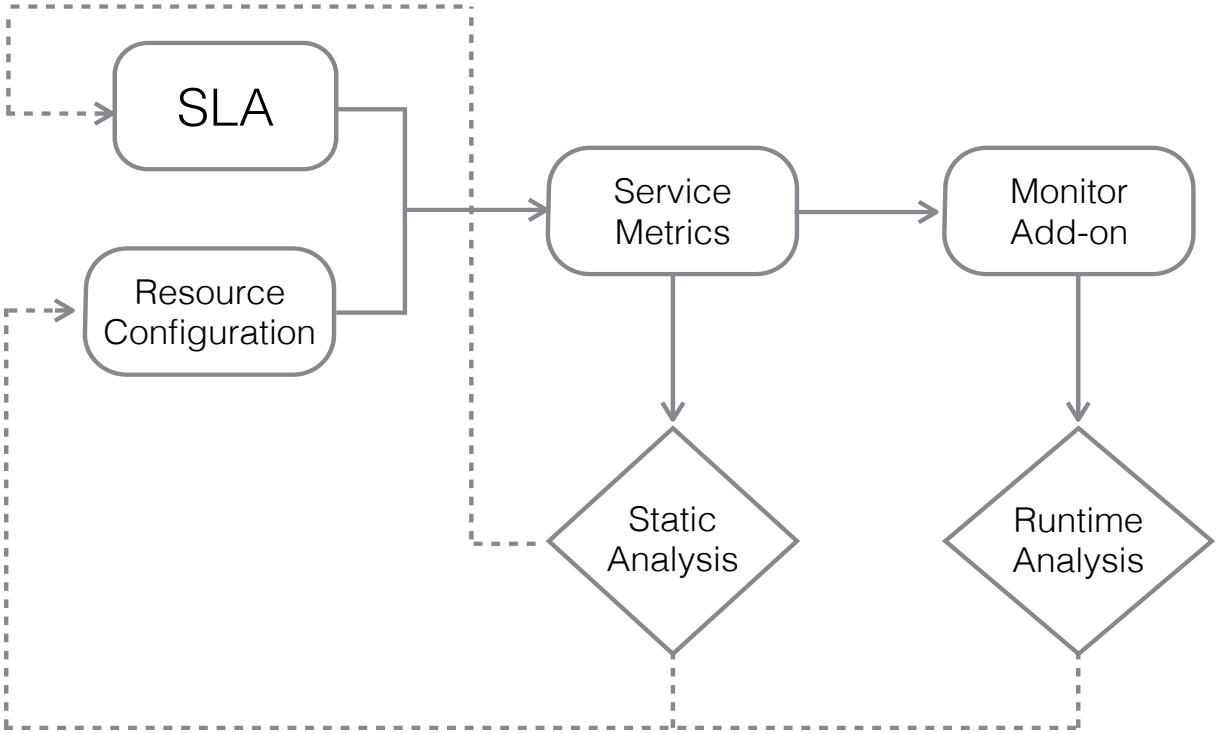
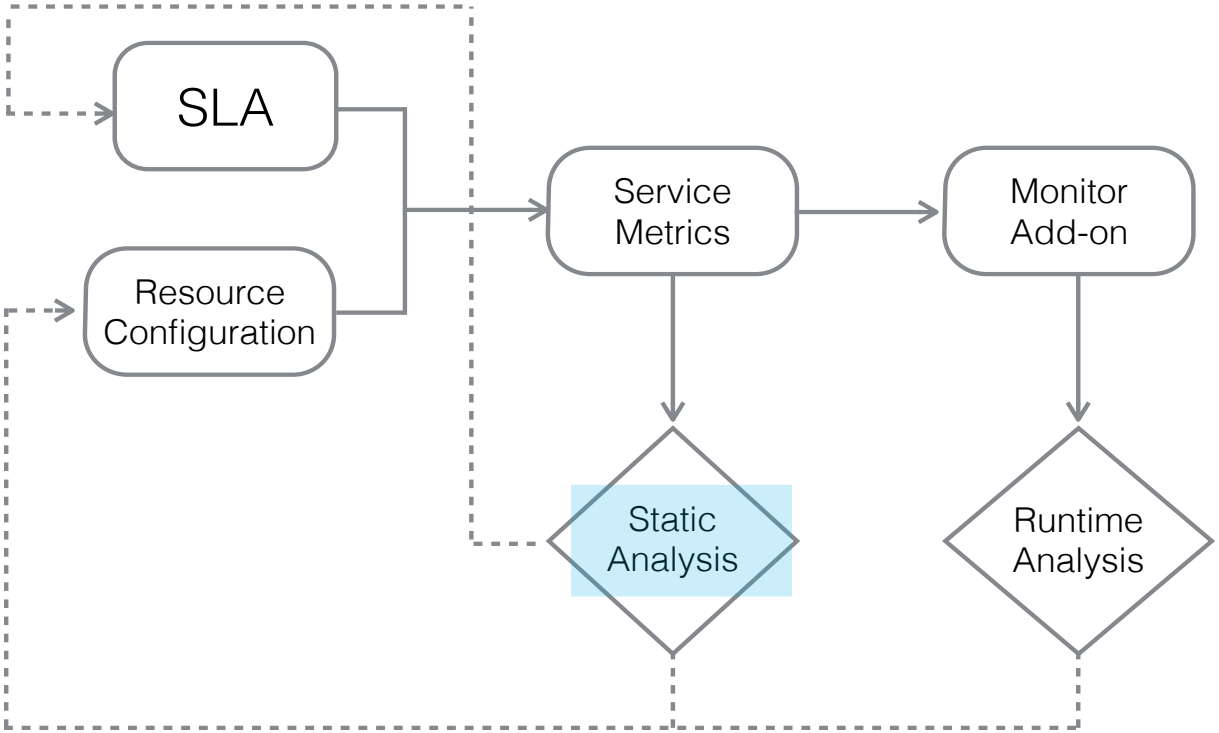
Summary

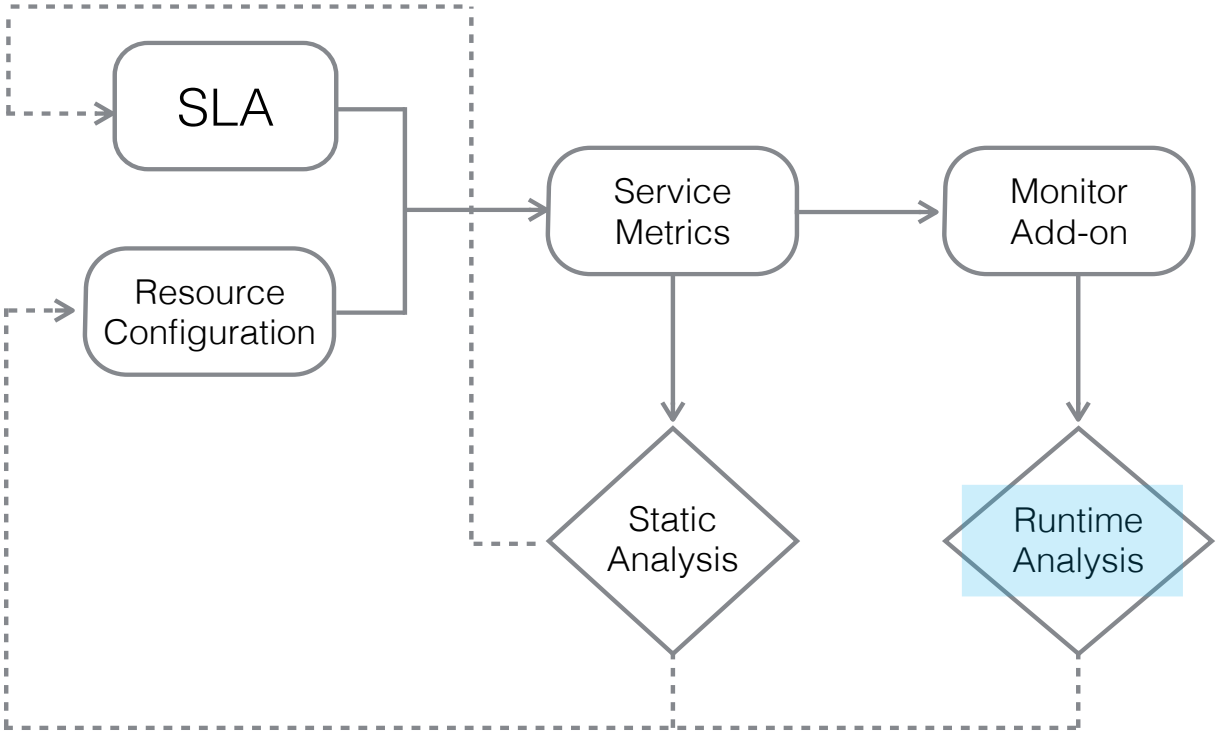

SLA
Resource Configuration
Service Metrics
Monitor Add-on
Static Analysis
Runtime Analysis

Summary



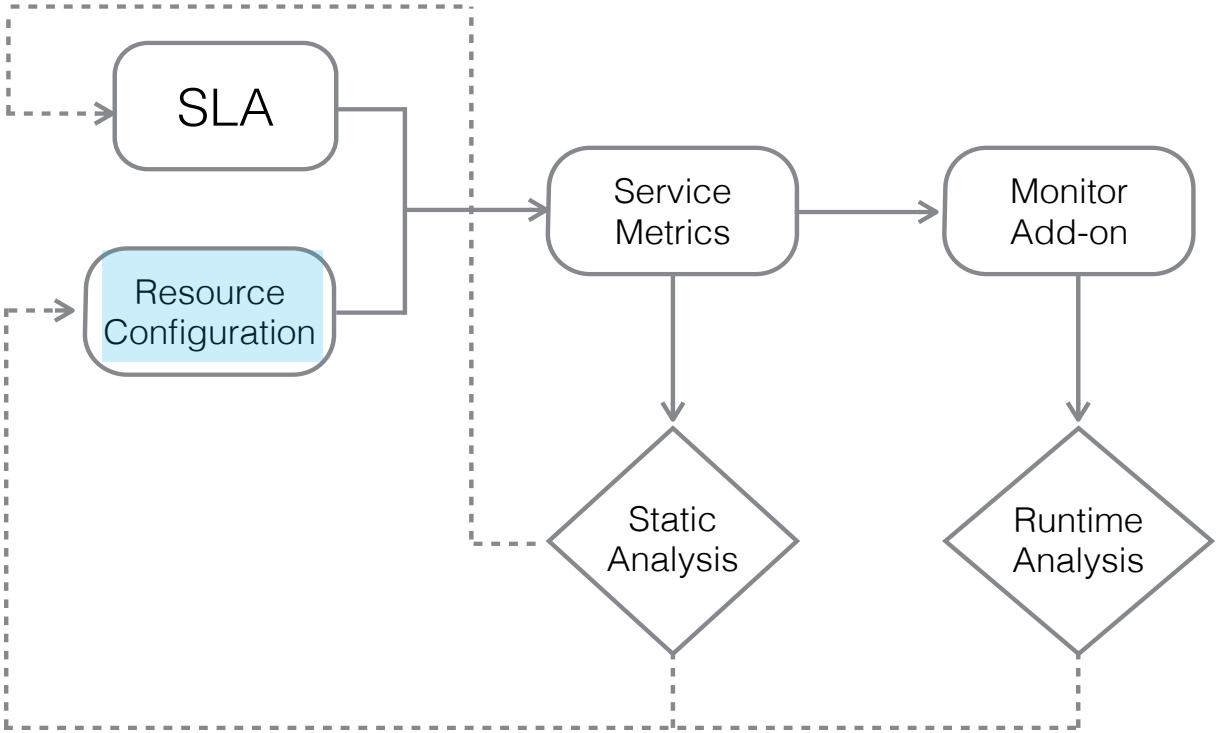
- Maximum number of virtual machines
- Upper bound of response time

Summary



- Availability
- Budget compliances

Summary



- A monitoring platform for resource (de-)allocation.

Summary

Static Analysis

- Static analysis of cloud elasticity. (PPDP'15).
  A. Garcia, C. Laneve, M. Lienhardt
- Time Complexity of Concurrent Programs. (FACS'15).
  E. Giachino, E. B. Johnsen, C. Laneve, K. I Pun

Runtime monitoring

- Formal verification of service level agreements through distributed monitoring. (ESOCC'15).
  B. Nobakht, S. de Gouw, and F. S. de Boer

SLA metric approach

- Statically and Dynamically verifiable SLA metrics.
  (Theory and Practice of Formal Methods).
  E. Giachino, S. De Gouw, C. Laneve, and B. Nobakht.