Addressing Self-Management in Cloud Platforms: a Semantic Sensor Web Approach

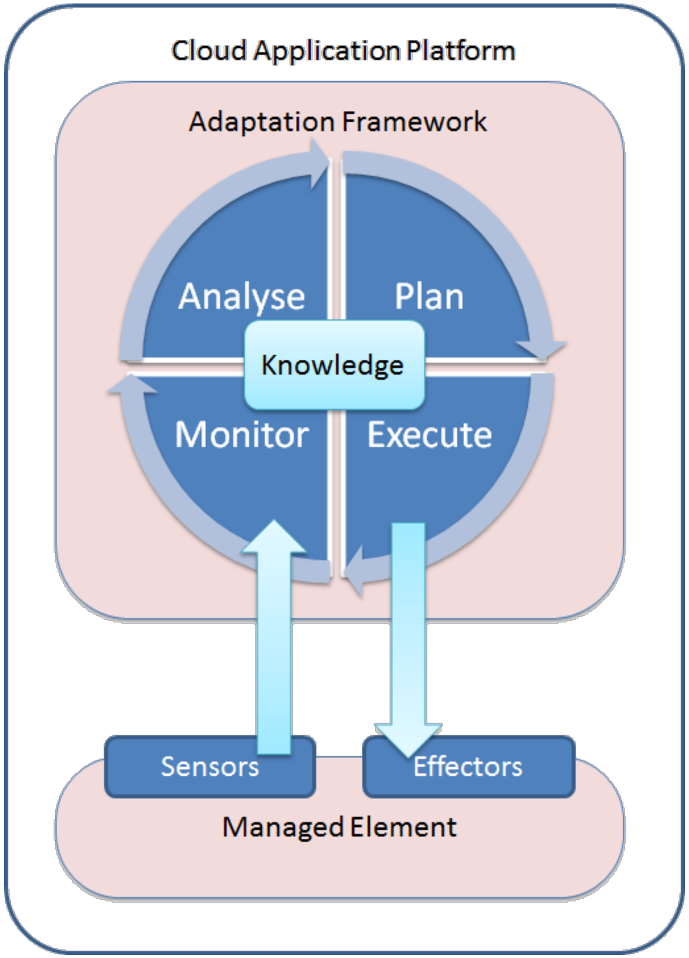
Rustem Dautov	South-East European Research Centre
Iraklis Paraskakis	International Faculty, The University of Sheffield
Dimitrios Kourtesis	
Mike Stannett	The University of Sheffield

20 April 2013

Motivation

- Flexibility of having cloud application platforms with built-in/third-party services comes with a cost
  - The complexity of service-based cloud environments is outgrowing our capacity to manage them in a manual manner
  - E.g., a failure of a notification service
- We need to automate the management process
  - Similar to the introduction of automatic branch exchanges in telephony in 1920s
- Self-management mechanisms have to be developed
  - A self-adaptation framework following the autonomic computing principle and based on IBM's **MAPE-K** model

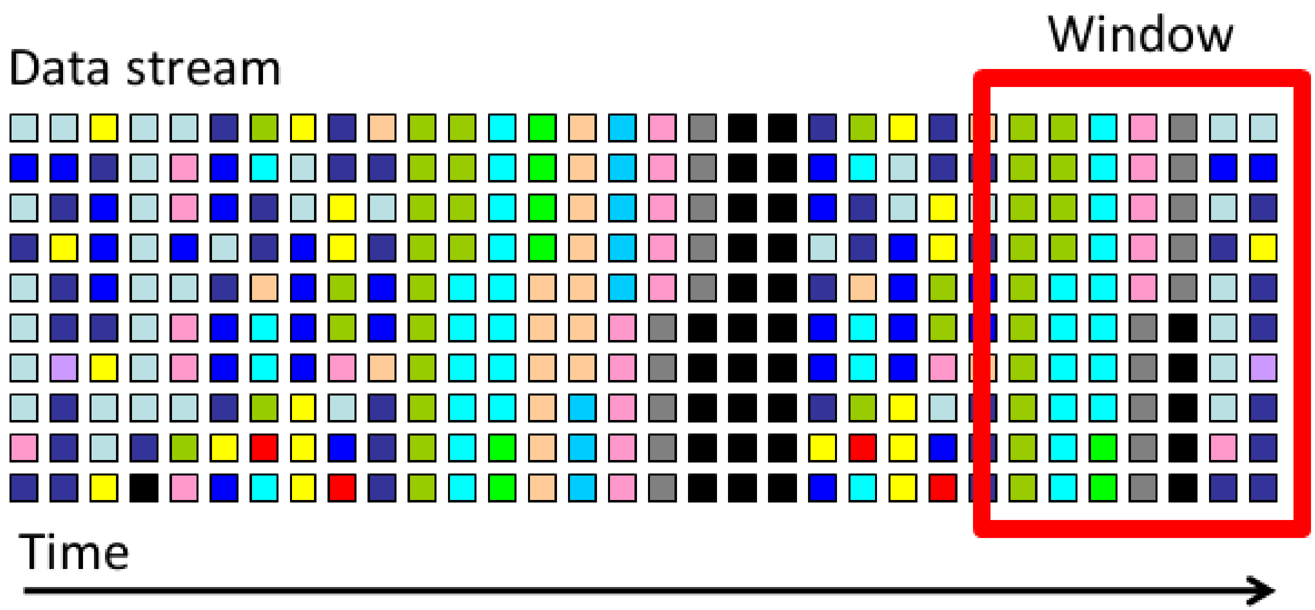
What do we need?



- Describe managed elements for self-reflection
- Encode critical condition patterns
- Homogenise representation of monitored data
- Assess situation and detect critical conditions
- Diagnose problems and reason about possible adaptation strategies

What are we monitoring?

- Data streams from multiple heterogeneous sources:
  - Deployed apps, platform components, 3rd-party services



An analogy

- From the IM perspective, cloud platforms are characterised by:
  - *Dynamism:* data is generated at an unpredictable rate
  - *Distributed nature:* data comes from logically and physically distributed sources
  - *Volume:* the amount of generated data is huge
  - *Heterogeneity:* data is heterogeneous in representation and/or semantics
- These characteristics are also shared by other problem domains
  - **Sensor Web**

Sensor Web

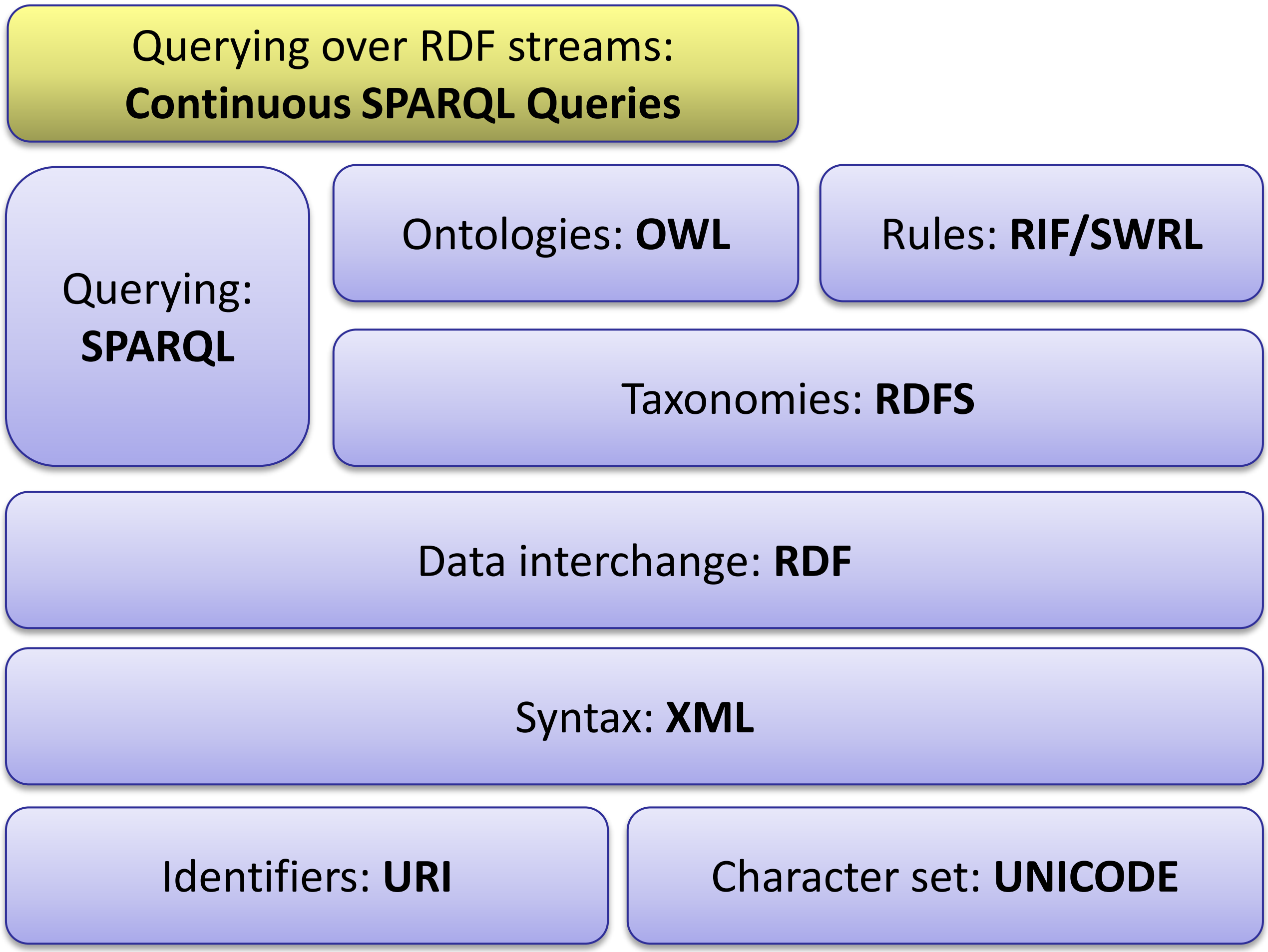
- *Sensor Network* – a computer accessible network of spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, pressure, etc.
- Sensor Web Enablement (SWE) project aims at developing a suite of specifications related to
  - Sensors
  - Sensor data models
  - Sensor Web services

that will be accessible and controllable via the Web.

A promising direction: Semantic Sensor Web (SSW)

- Addresses the challenges of SWE by utilising the Semantic Web technologies
- Enables situation awareness by providing enhanced meaning for sensor observations
  - E.g., RDF annotations to usual XML data
- A *Sensor* is anything that can calculate or estimate a data value:
  - An application component, an SQL query, a Web service, etc.

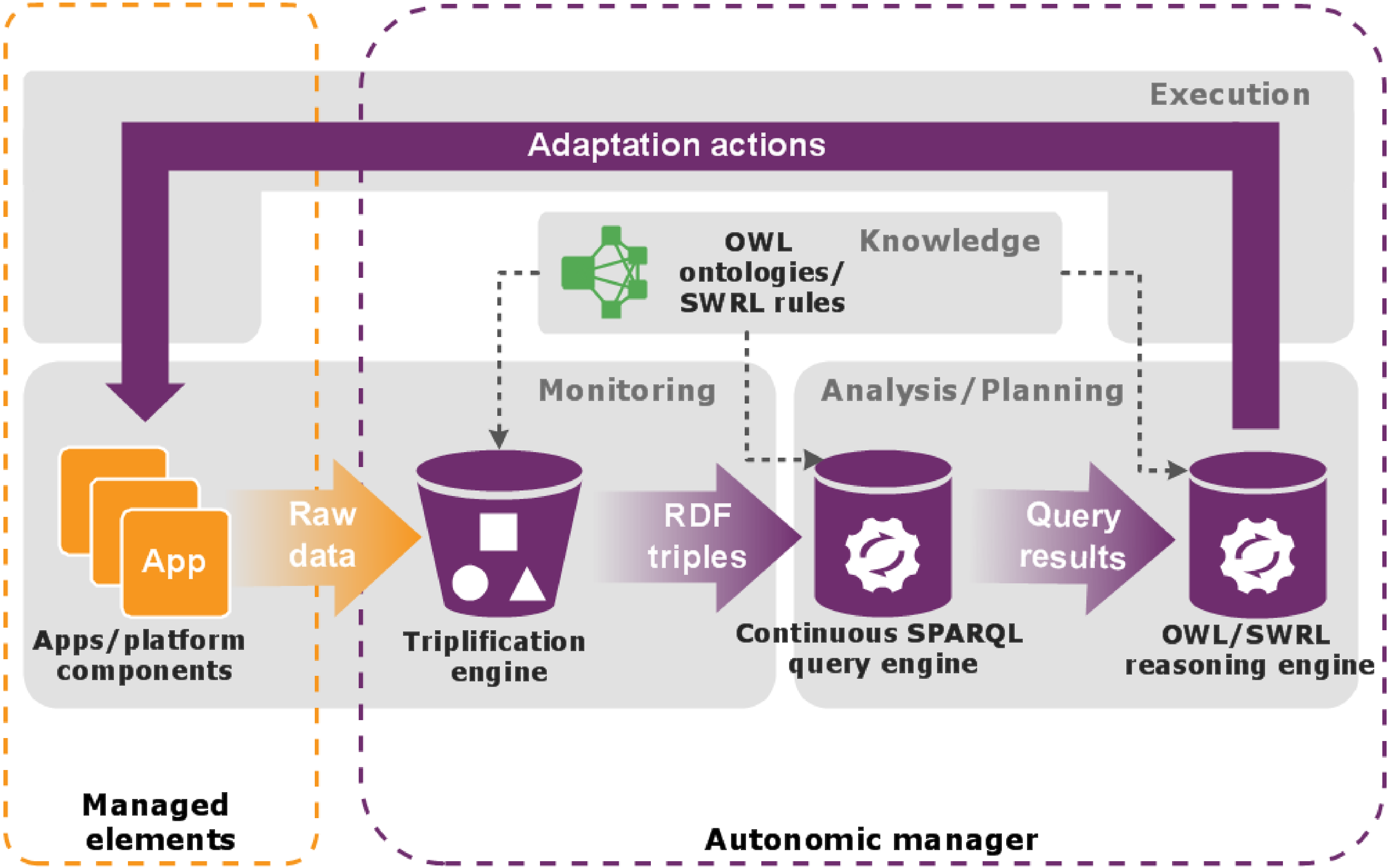
Semantic Web technologies



Addressing the needs

• Describe managed elements for self-reflection	OWL ontologies
• Consume data from multiple heterogeneous sources • Homogenise data representation	RDF / RDF Streams
• Encode critical condition patterns • Assess situation and detect critical conditions	Continuous SPARQL Queries
• Diagnose problems and reason about possible adaptation strategies	OWL / SWRL

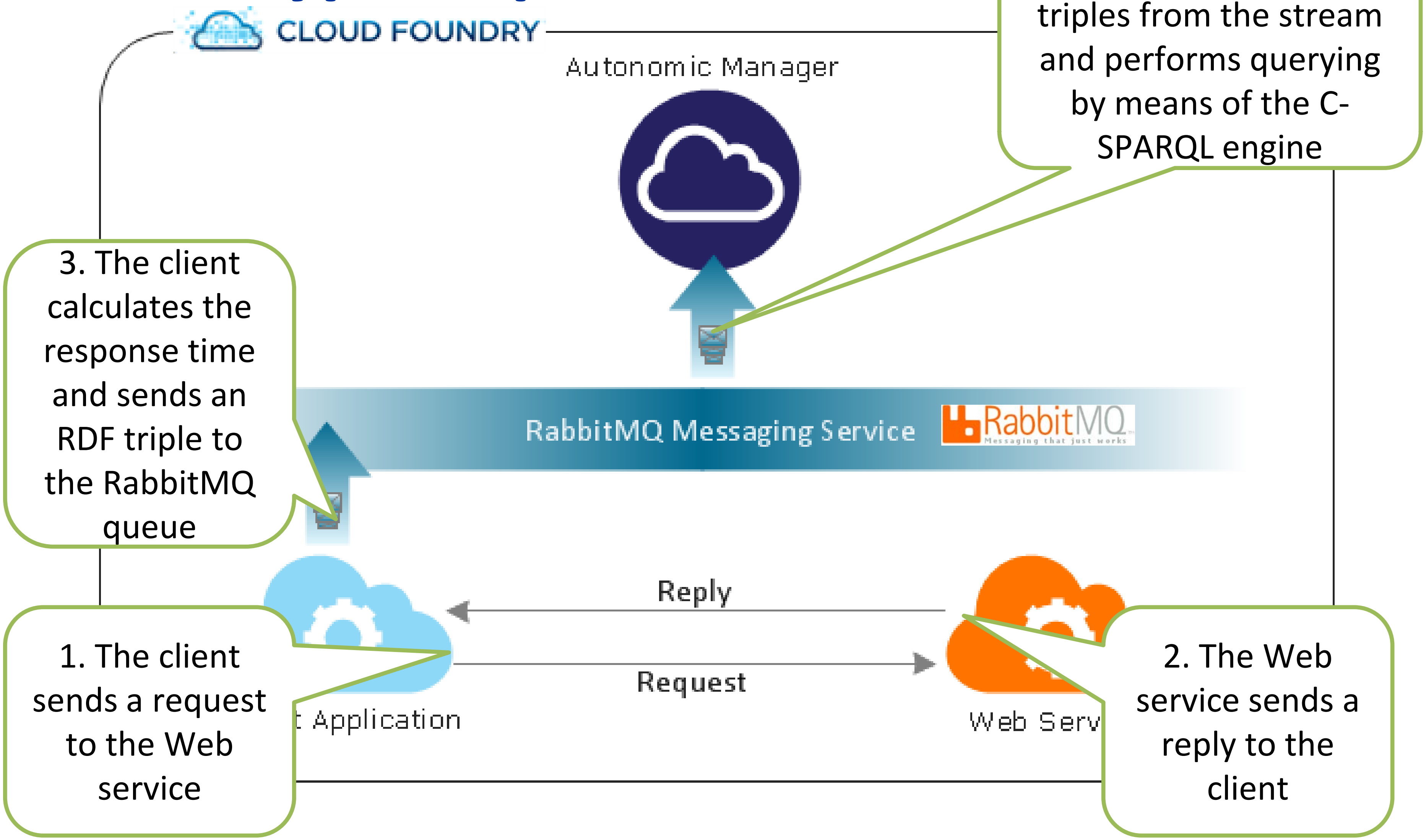
Conceptual architecture



Simple use case

- A number of applications are deployed on a cloud platform and rely on a built-in notification service.
- The notification service gets overloaded and cannot process all incoming requests.
- We need to detect such situations and switch over some of the dependent applications to an external substitute.
  - Response time threshold = 5 sec
- The prototype autonomic manager was deployed on CloudFoundry and developed in Java Spring using:
  - OWL API library
  - C-SPARQL library

Prototype implementation



Sample OWL ontology

```
@prefix : <http://www.seerc.org/ontology.owl#> .
<http://www.seerc.org/ontology.owl> rdf:type owl:Ontology .
        :Service                rdf:type        owl:Class .
        :Time                   rdf:type        owl:Class .
        :hasResponseTime        rdf:type        owl:ObjectProperty ,
                                rdfs:domain     :Time .
        :isEquivalent           rdf:type        owl:ObjectProperty ,
                                                owl:SymmetricProperty ;
                                rdfs:range      :Service ;
                                rdfs:domain     :Service .
        :hasHighResponseTime    rdf:type        owl:DatatypeProperty ,
                                rdfs:range      xsd:Boolean .
        :hasValue               rdf:type        owl:DatatypeProperty ,
                                rdfs:range      xsd:int .
        :needsSubstitution      rdf:type        owl:DatatypeProperty ,
                                rdfs:range      xsd:Boolean .
```

Sample RDF stream

- Each RDF triple represents a change in response time from a service and annotated with a timestamp
- The sample stream represents a sudden increase in a service's response time

```
@prefix ex:<http://www.seerc.org/ontology/>

ex:#Service1 ex:hasResponseTime; 1000. [2012-09-18 13:24:52]
ex:#Service1 ex:hasResponseTime; 890.  [2012-09-18 13:24:54]
ex:#Service1 ex:hasResponseTime; 1110. [2012-09-18 13:24:56]
ex:#Service1 ex:hasResponseTime; 1300. [2012-09-18 13:24:58]
ex:#Service1 ex:hasResponseTime; 5450. [2012-09-18 13:25:13]
ex:#Service1 ex:hasResponseTime; 6000. [2012-09-18 13:25:20]
ex:#Service1 ex:hasResponseTime; 6700. [2012-09-18 13:26:15]
```

Sample C-SPARQL query

- The sample C-SPARQL query is registered against a data stream and triggers whenever response time from a service exceeds 5000 ms.

```
PREFIX ex:<http://www.seerc.org/ontology/>

SELECT DISTINCT ?service
FROM STREAM http://www.seerc.org/stream
    [RANGE 60s STEP 1s]
WHERE { ?service ex:hasResponseTime ?time .
    FILTER (?time > 5000) }
```

Sample SWRL rules

```
Rule 1: Has high response time
      Service(?s1) ^ Time(?t) ^
      hasResponseTime(?s1, ?t) ^
      greaterThan(?t,5000) ->
      hasHighResponseTime(?s1, true)

Rule 2: Needs substitution
      hasHighResponseTime(?s1, true) ^
      Service(?s2) ^ isEquivalentTo(?s1, ?s2)
      -> needsSubstitution(?s1, ?s2)
```

Results

- We can:
  - monitor response time from services;
  - detect whether response time from a service is exceeding its threshold
  - generate a diagnosis and suggest an adaptation strategy
- Further experiments:
  - Scalability
  - Portability across several application platforms
  - Accuracy

Initial experiments

Number of threads	Request frequency	Number of queries	Results
1 thread	1 request/sec	1	Critical conditions detected within 1 second
100 threads	1 request/sec	1	Critical conditions detected within 1 second
500 threads	1 request/sec	1	The client application crashes due to the limitation of 512 MB RAM
1 thread	1 request/sec	1000	Critical conditions detected within 1 second
1 thread	1 request/sec	5000	The monitor crashes due to the limitation of 512 MB RAM
400 threads	1 request/sec	4000	Critical conditions detected within 1 second

Further work

- Defining evaluation and testing strategies
  - Important aspects: scalability, flexibility, analysis support, performance
- Further developing and experimenting
  - Demonstrating the “reasoning power” of the approach
  - Porting the framework to OpenShift and AppScale
  - Extending the monitoring scope to several parameters

Thank you!

Questions?