Managing and Testing Ensembles of IoT, Network functions, and Clouds

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and from

H2020 U-test (www.u-test.eu)
H2020 Inter-IoT (http://www.inter-iot-project.eu/)

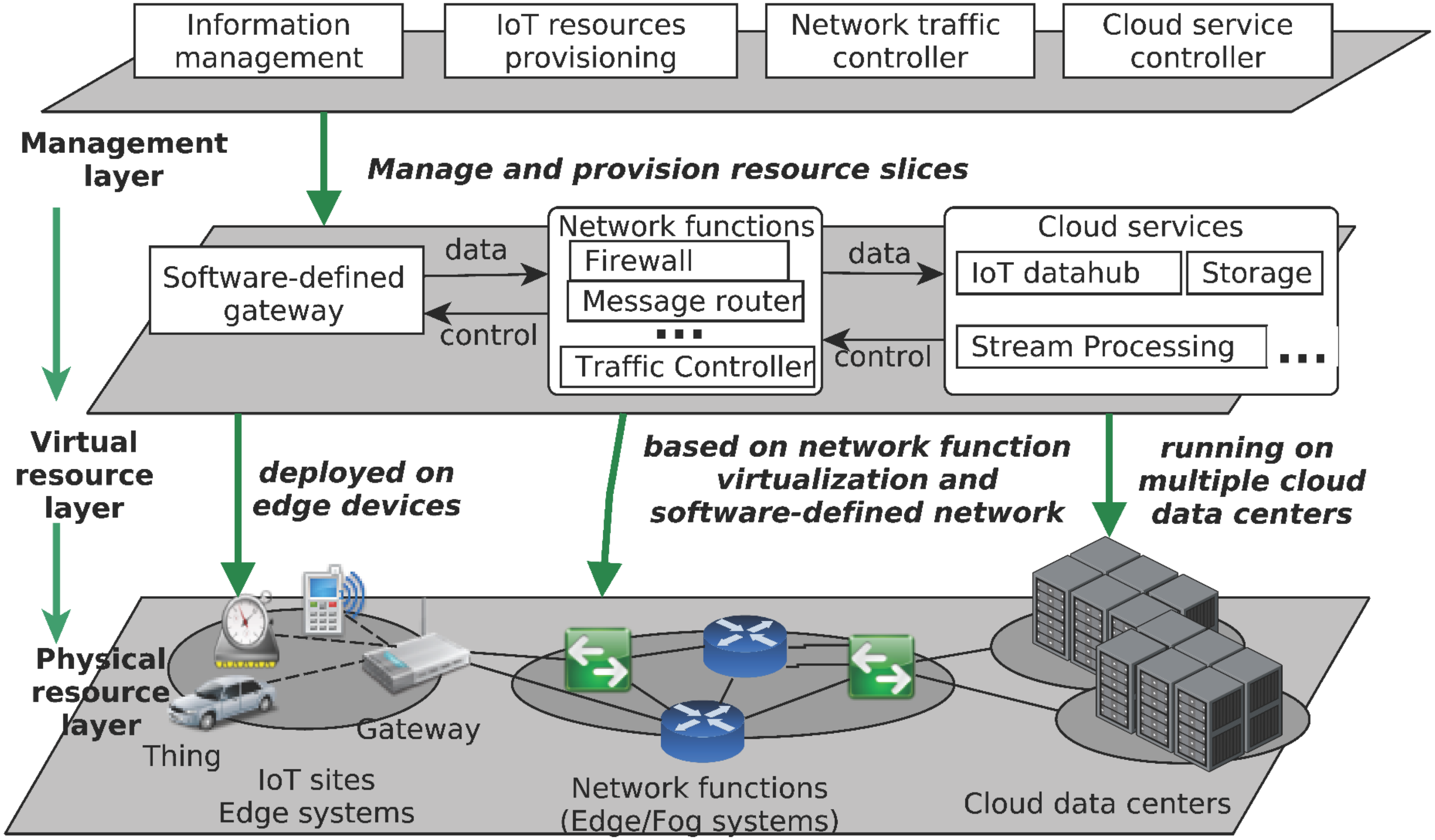
Note: some work are under submission.

Outline

- Application-oriented ensembles of IoT, Network functions and Cloud resources
- Resource Management
- Monitoring
- Uncertainty and Testing Uncertainties of Infrastructures
- Conclusions and Future work

Application-oriented Ensembles of IoT, Network functions, & Clouds: Necessity?

Systems of IoT, Network Functions, and Clouds



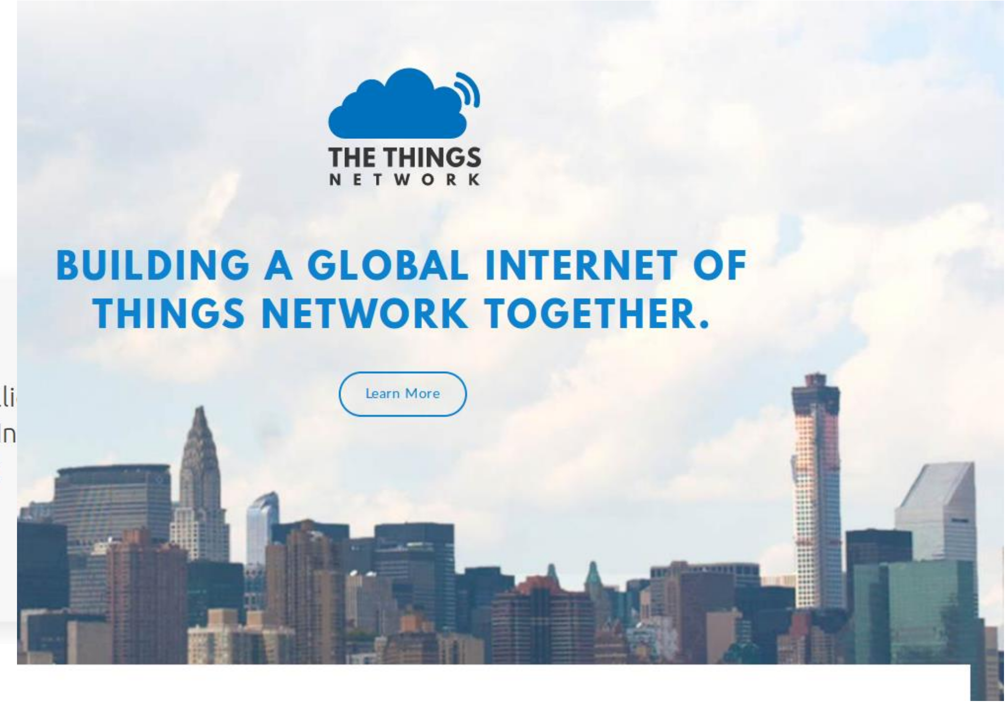
Moving to blending IoT, network functions and cloud resources

- Type 1
  - **Mainly focus** on IoT networks: sensors, IoT gateways, IoT-to-cloud connectivity (e.g., connect to predix.io, IBM Bluemix, Azure IoT, Google Cloud, Amazon IoT, etc.)
- Type 2
  - **Mainly focus** on (public/private) services in data centers: e.g., IoT data hubs, NoSQL databases, and big data ingest systems
- Type 3
  - **Equally focus** on both IoT and cloud sides and have the need to control at both sides
  - Highly interactions between the two sides, including the network in the middle

All types of service models

- Cloud resources as services are known
- NFV/5G coming and more service providers at the edge are available
  - Network function virtualization
- IoT infrastructure-as-a-service
  - Pay-per-use IoT communication
- IoT data-as-a-service Cloud service models
  - Public and private providers

Examples of IoT networks



Enabled by Semtech's LoRa technology, which allows a sensor network to operate on low power while providing strong connectivity over a long distance, the SK Telecom LPWAN covers 99 percent of South Korea's population. The company predicts that it will have over four million things connected to its IoT networks by the end of 2017.

The LoRaWAN™ technology platform based on Semtech's LoRa two-way wireless RF technology is a comprehensive solution for low power, long-range connectivity, which is essential for LPWANs supporting IoT applications. It offers deep penetrability, secure connectivity, long battery lifetime and streamlined implementation for simple network rollout, as well as integration into existing infrastructure.

http://www.sktelecom.com/en/press/detail.do?idx=1172

Price Plan	Data Allowance* (Frequency of communication)	Monthly Flat Rate (VAT Excluded)	Examples of Services	Note
Band IoT 35	100KB	KRW 350	Metering and monitoring services (e.g. Advanced Metering Infrastructure (AMI), environmental monitoring, water leakage monitoring, etc.)	- Discount benefits for long-term contracts: Ranging from a 5% discount for two-year contracts to a 20% discount for 5 year-contracts - Multi-line discount: Ranging from a 2% discount for those using 500 lines to a 10% discount to those who use 10,000 lines
Band IoT 50	500KB	KRW 500		
Band IoT 70	3MB	KRW 700	Tracking services (e.g. locating tracking For people/things, asset management, etc.)	
Band IoT 100	10MB	KRW 1,000		
Band IoT 150	50MB	KRW 1,500	Control service (e.g. safety management, lighting control, shared parking, etc.)	
Band IoT 200	100MB	KRW 2,000		

*Data usage exceeding the data allotment provided will be charged at KRW 0.005 per 0.5KB.

Some application scenarios

- Emergency responses, on-demand crowd sensing, Geo Sports monitoring, cyber-physical systems testing, etc.

Geo Sports: Picture courtesy Future Position X, Sweden

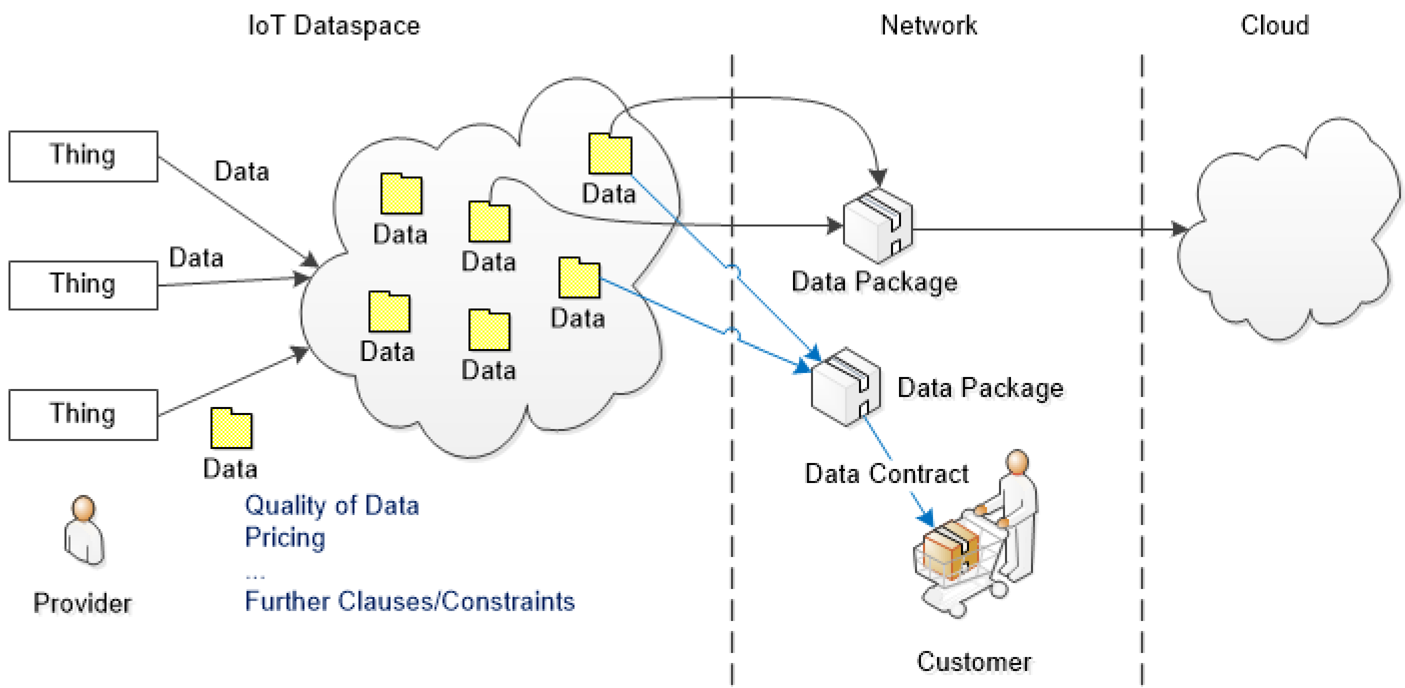
Emergency in a Seaport

- Built a top existing INTER-IoT scenarios
  - Coordinating activities when an accident happens
- Example of actions in a resource slice in a seaport:

1) activating monitoring containers with sensitive goods in the port
2) analyzing and controlling robotic cranes and trucks to make sure that they do not prevent the emergency responses as well as ready to support the responses
3) sending alarms and controlling vessel arrivals and revising transport planning,
4) providing information for operational assistance for the emergency responses
5) activating systems to support the monitoring of people impacted by the accident using devices and platforms for chronic disease and cognitive decline prevention.

Examples of IoT data services

IoT data as a service can be offered by different types of providers



Florin-Bogdan Balint, Hong-Linh Truong, On Supporting Contract-aware IoT Dataspace Services, the 5th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering (MobileCloud 2017), 6-8 April 2017 in San Francisco, USA
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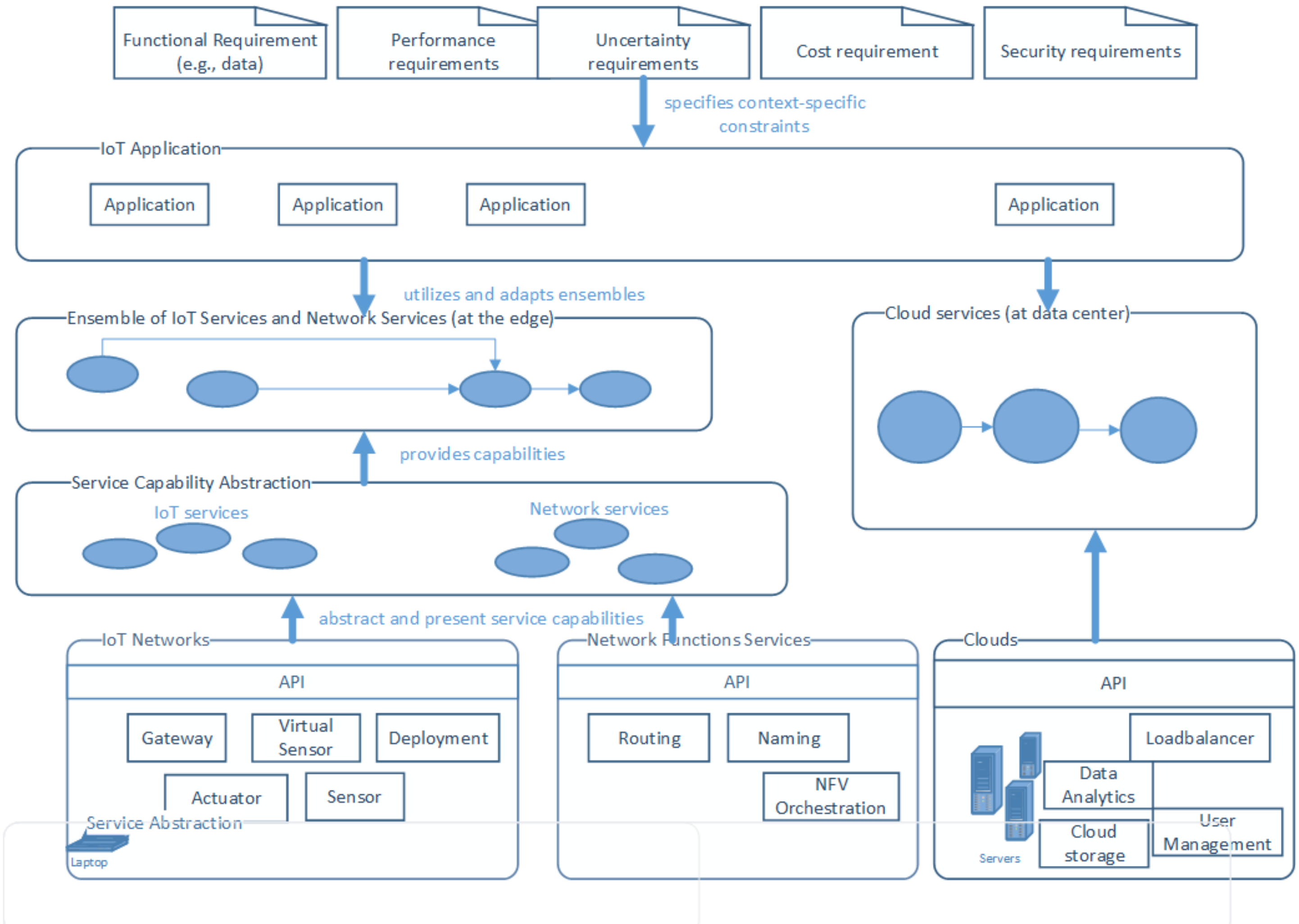
Ensembles of IoT, Network functions and clouds



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Challenges

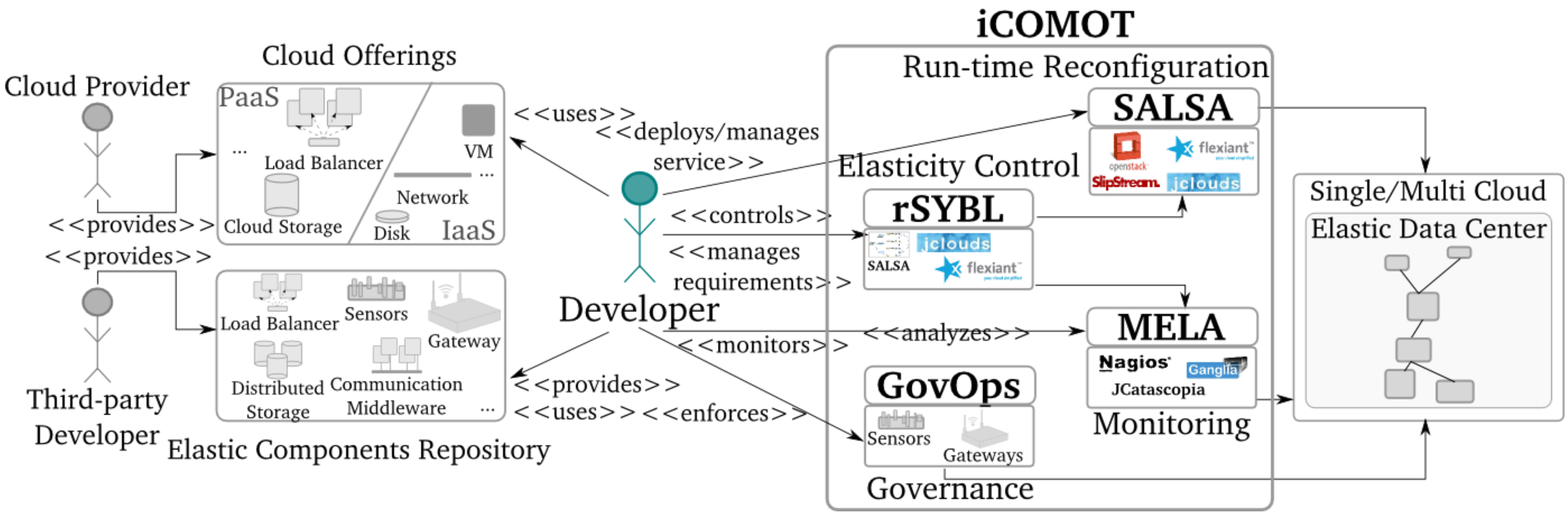
- Modeling distributed IoT, network functions and cloud capabilities in an ensemble
- Slicing end-to-end network of resources
- Composing resources in ensembles of IoT, network functions and clouds
- (Re-)configuring composed resources
- Testing and monitoring

The SINConcept: http://sincconcept.github.io/
Hong-Linh Truong, Nanjangud Narendra, SINC - An Information-Centric Approach for End-to-End IoT Cloud Resource Provisioning, 2016 International Conference on Cloud Computing Research & Innovation (ICCCRI2016), CloudAsia 2016, May 3-5, 2016, Singapore

Tools treating IoT, network functions, and cloud services in an isolated manner are not enough

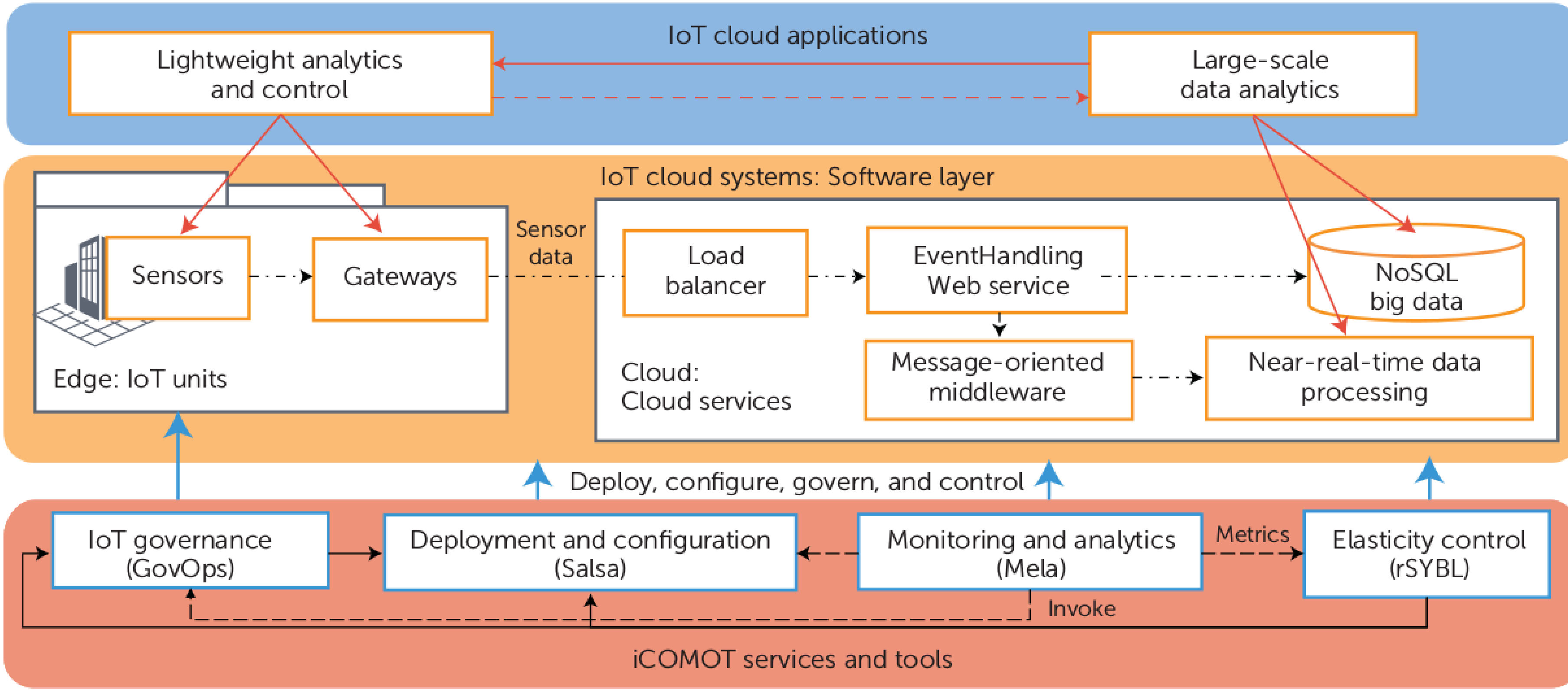
Service engineering analytics for IoT Cloud Systems

We started in 2011 without network functions in our mind!



http://tuwiendsg.github.io/iCOMOT/

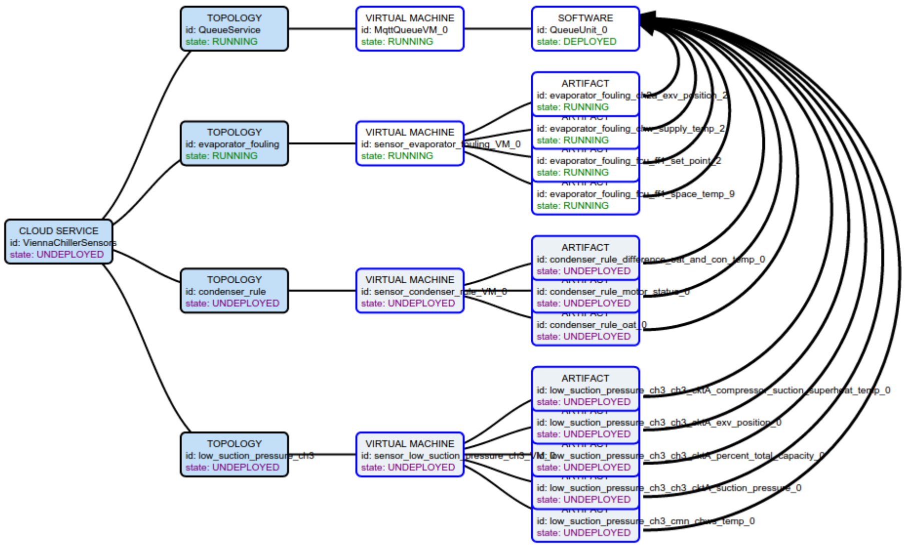
Monitoring, Controlling and Testing IoT Cloud Systems



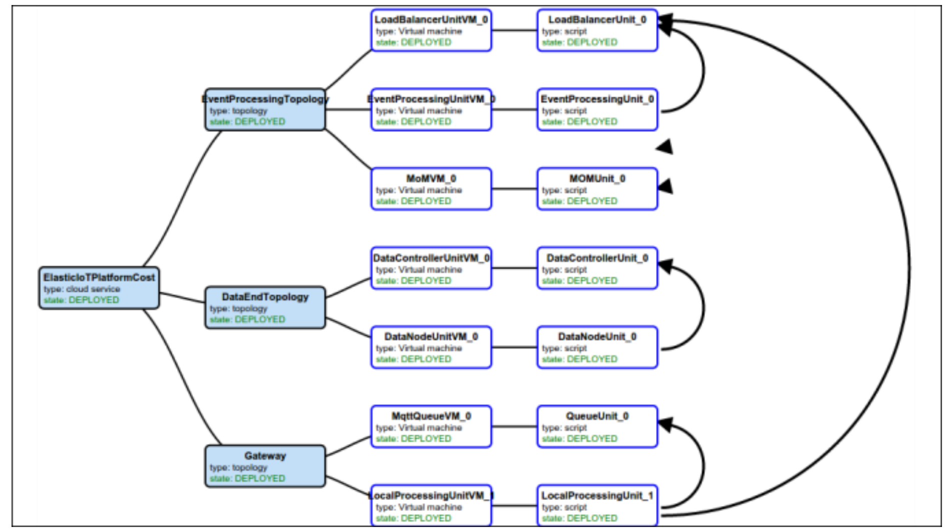
Check: http://tuwiendsg.github.io/iCOMOT/demo.html

Configuration is not done easy for the ensembles

IoT sensors



Cloud Service



- Sensors/gateways and cloud services have different management systems and interfaces

→Deploy different topologies and configure topologies to work together is hard

Cross IoT and cloud controls

Control for IoT Gateways

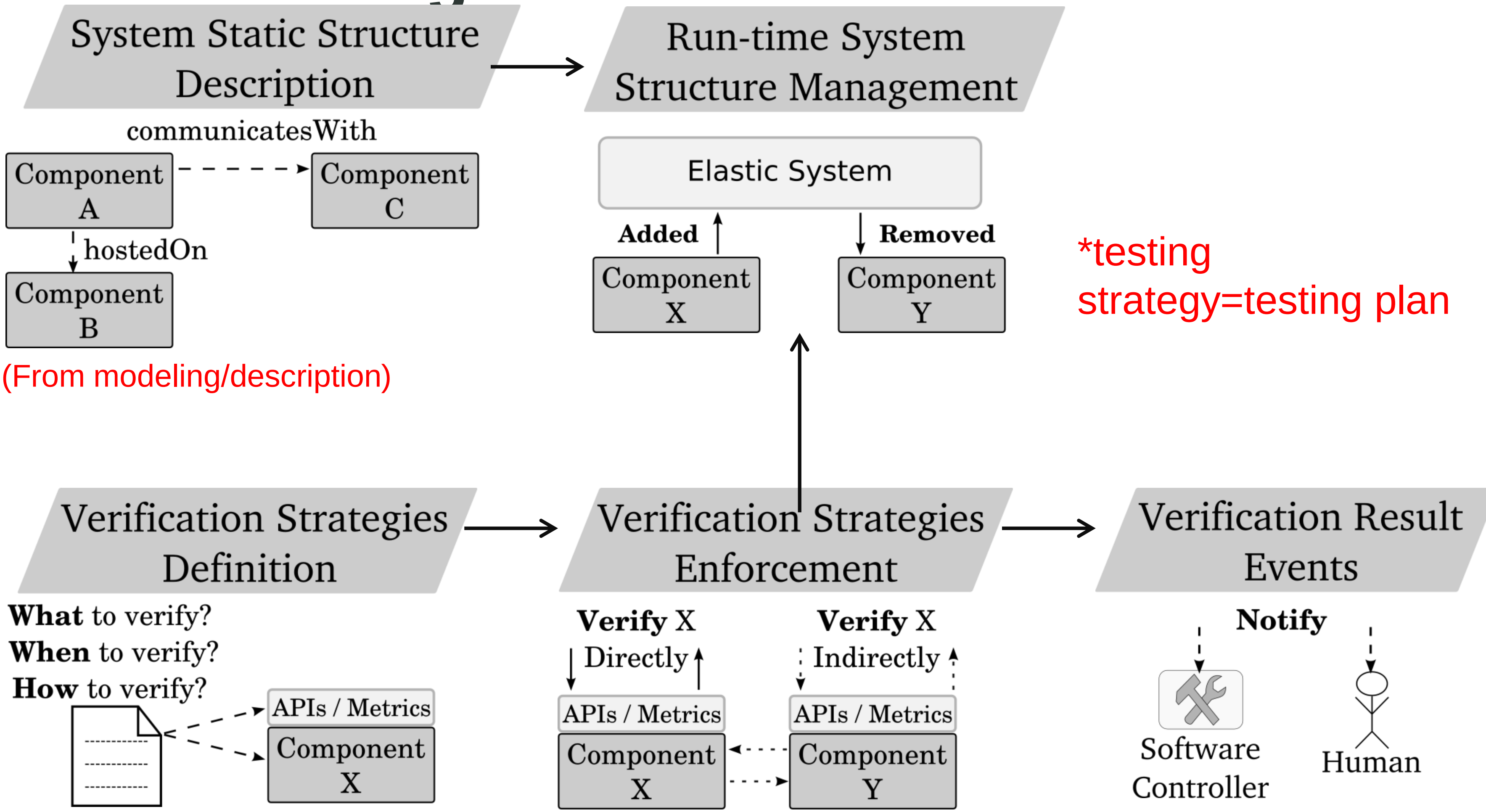
```
/APIManager/governanceScope/invokeScope/cStartStopSensor/start?type=FM5300
{
  "devices": [
    {
      "id": "10.99.0.102:9080",
      "name": "Gateway-10.99.0.102:9080",
      "ipAddress": "",
      "metaInfo": "location=gh1&type=FM5300",
      "meta": {
        "location": "gh1",
        "type": "FM5300"
      }
    },
```

Control for Clouds

```
EP_ST1:STRATEGY CASE avgThroughput
< 200 operations/s AND responseTime
< 100 ms:scaleIn;

EPT_CO1:CONSTRAINT responseTime <
100 ms;

DN_ST1:STRATEGY CASE cpuUsage < 40
%:scaleIn;


DET_CO1:CONSTRAINT cpuUsage < 80 %;
```

- IoT gateways control is very different from cloud controls
- Low-level REST API in IoT gateways management and high level elasticity rules for cloud services
- Different protocols for communicating with resource managers

Too low-level Infrastructure-level Testing



(From modeling/description)

*testing strategy=testing plan

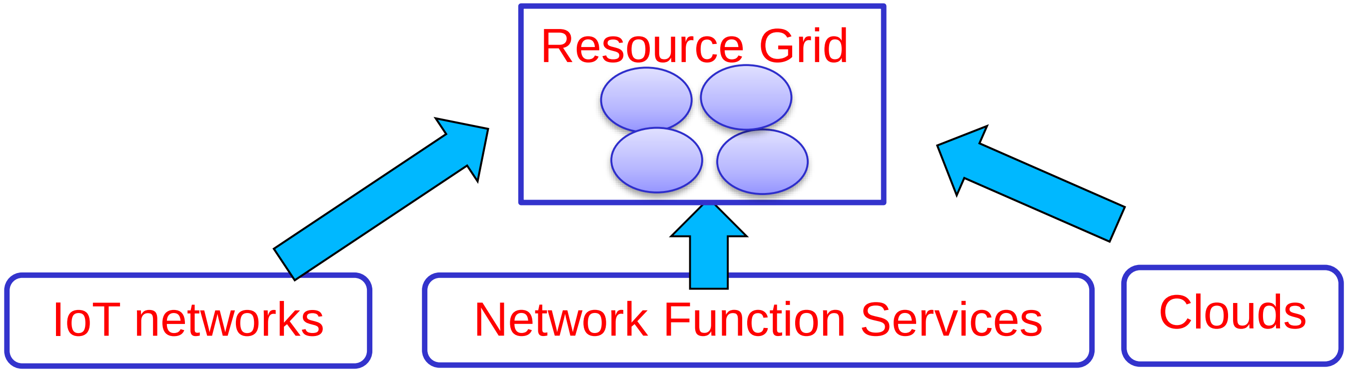
Daniel Moldovan,Hong-Linh Truong, A Platform for Run-time Health Verification of Elastic Cyber-physical Systems, The IEEE International Symposium on Modelling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS 2016), September 19-21, Imperial College, London, UK

Duc-Hung Le, Nanjangud C. Narendra, Hong Linh Truong:

HINC - Harmonizing Diverse Resource Information across IoT, Network Functions, and Clouds. FiCloud 2016: 317-324

HARMONIZING RESOURCES FOR ENSEMBLES?

Integrating diverse types of resources

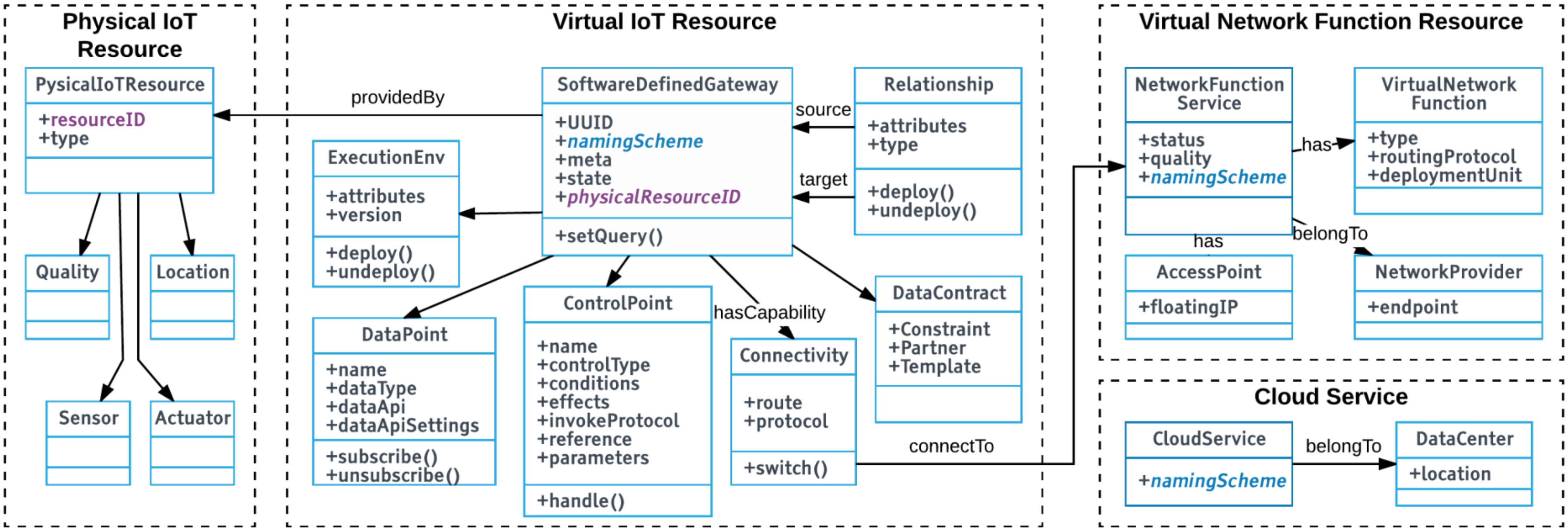


- Make a Resource Grid ready for creating ensembes
  - Harmonize IoT, network functions and cloud resources
- API Integration and Communication
  - Use REST API for obtaining metadata and control of resources
    - Sensoring data can be transferred through different middleware
  - Work with existing metamodel (IoTivity, OpenHAB, IoTDM, ETSI MANO, OCCI, CIMI, etc.)
  - Rely on scalable cloud communication middleware (e.g., AMQP & MQTT)

Examples of existing providers/models

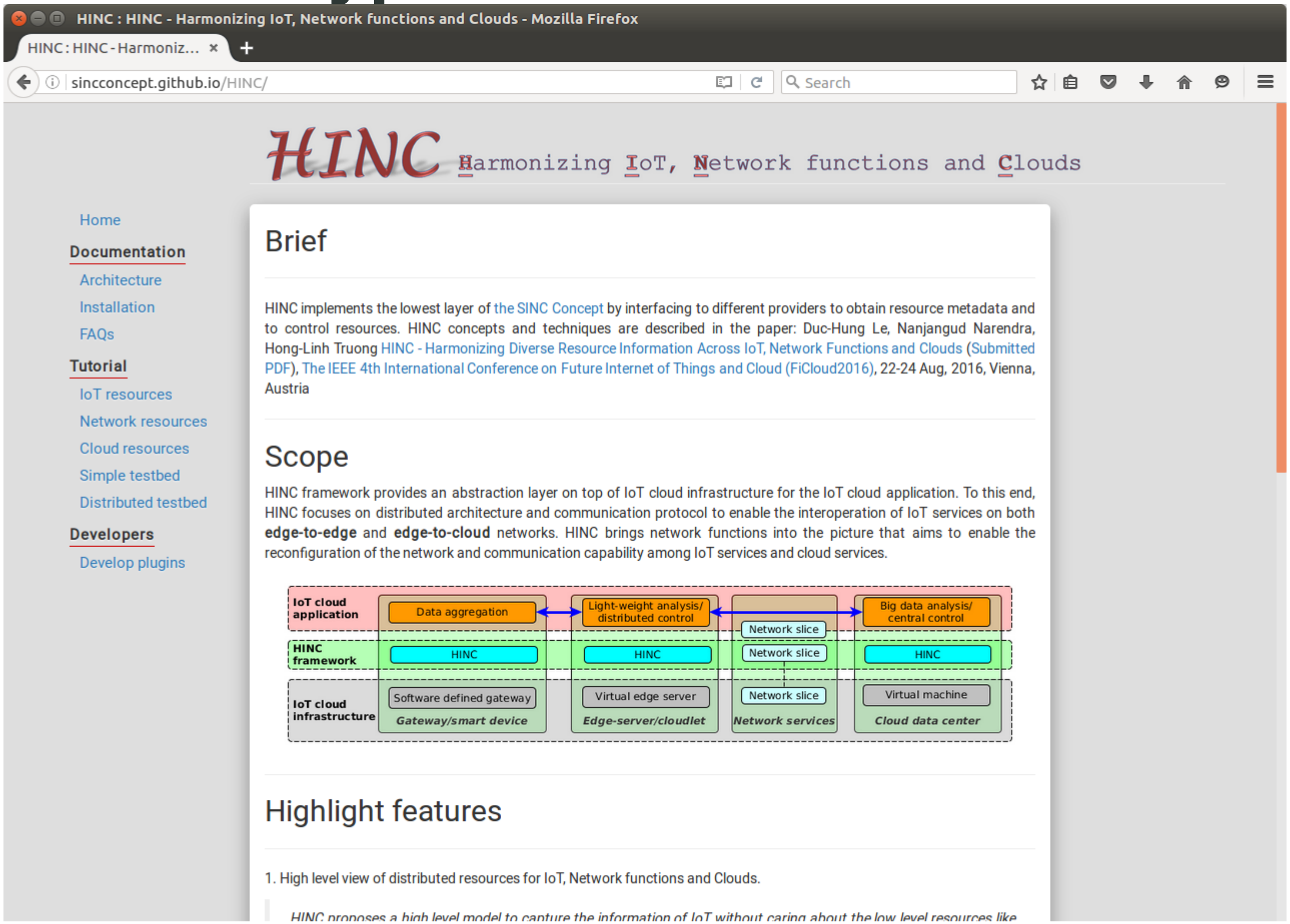
Provider	Category	APIs	Information models
FIWare Orion	IoT	RESTful (NGSI10), one-time query or subscription	High level attributes on data and context
FIWare IDAS	IoT	RESTful for read/write custom models and assets	Low level resource model catalogs
IoTivity	IoT	REST-like OIC protocol, support C++, Java and JavaScript	Multiple OIC model
OpenHAB	IoT	RESTful for query and control IoT resources	Low level resource model catalogs
OpenDayLight	Network	Dynamic REST generated from Yang model (model-driven)	Low level resource model catalogs
OpenBaton	Network	RESTful for network service description	ETSI MANO v1.1.1 data model
OpenStack	Cloud	RESTful, multiple language via SDK, OCCI, CIMI	OpenStack model, OCCI, CIMI

Information model



Physical: Sensor/actualtor/devices in providers' models
Virtual IoT: SD-Gateway and capabilities.
Network functions: edge-to-edge, edge-to-cloud network.
Clouds: VM, data services, data analytics.

Prototype


HINC : HINC - Harmonizing IoT, Network functions and Clouds - Mozilla Firefox

sincconcept.github.io/HINC/

HINC Harmonizing IoT, Network functions and Clouds

Home

Documentation

Architecture

Installation

FAQs

Tutorial

IoT resources

Network resources

Cloud resources

Simple testbed

Distributed testbed

Developers

Develop plugins

Brief

HINC implements the lowest layer of the SINC Concept by interfacing to different providers to obtain resource metadata and to control resources. HINC concepts and techniques are described in the paper: Duc-Hung Le, Nanjangud Narendra, Hong-Linh Truong HINC - Harmonizing Diverse Resource Information Across IoT, Network Functions and Clouds (Submitted PDF), The IEEE 4th International Conference on Future Internet of Things and Cloud (FiCloud2016), 22-24 Aug, 2016, Vienna, Austria

Scope

HINC framework provides an abstraction layer on top of IoT cloud infrastructure for the IoT cloud application. To this end, HINC focuses on distributed architecture and communication protocol to enable the interoperation of IoT services on both **edge-to-edge** and **edge-to-cloud** networks. HINC brings network functions into the picture that aims to enable the reconfiguration of the network and communication capability among IoT services and cloud services.

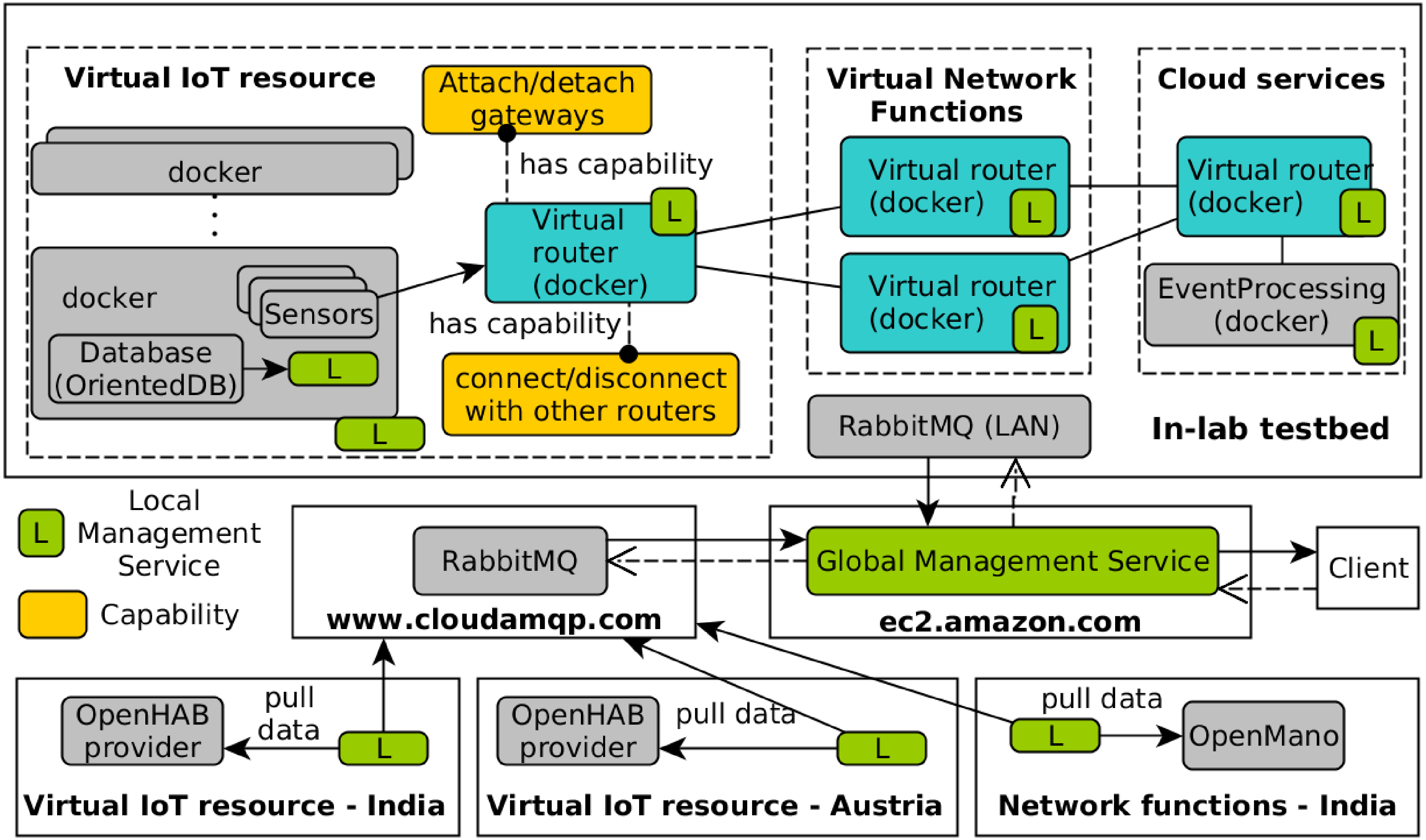
Highlight features

1. High level view of distributed resources for IoT, Network functions and Clouds.

HINC proposes a high level model to capture the information of IoT without caring about the low level resources like

http://sincconcept.github.io/HINC/

Testbed



Virtual IoT resource
Attach/detach gateways
has capability
docker
docker
Sensors
Database (OrientedDB)
L
Virtual router (docker)
has capability
connect/disconnect with other routers
Virtual Network Functions
Virtual router (docker)
Virtual router (docker)
Cloud services
Virtual router (docker)
EventProcessing (docker)
RabbitMQ (LAN)
In-lab testbed
Local Management Service
Capability
RabbitMQ
www.cloudamqp.com
Global Management Service
ec2.amazon.com
Client
OpenHAB provider
pull data
Virtual IoT resource - India
OpenHAB provider
pull data
Virtual IoT resource - Austria
pull data
OpenMano
Network functions - India

Reducing complexity in accessing and control resources

```
// specify the sensors whose sample rate needs to be changed
DataPoint template = new DataPoint('BodyTemperature');
SensorProps sensorProps = new SensorProps();
sensorProps.setRate(5);
template.getExtra().add(new PhysicalResource(sensorProps));
QueryManager queryMng = new QueryManager('ampq://10.99..');
List datapoints = queryMng.QueryDataPoints(template);
```

1. Query data points

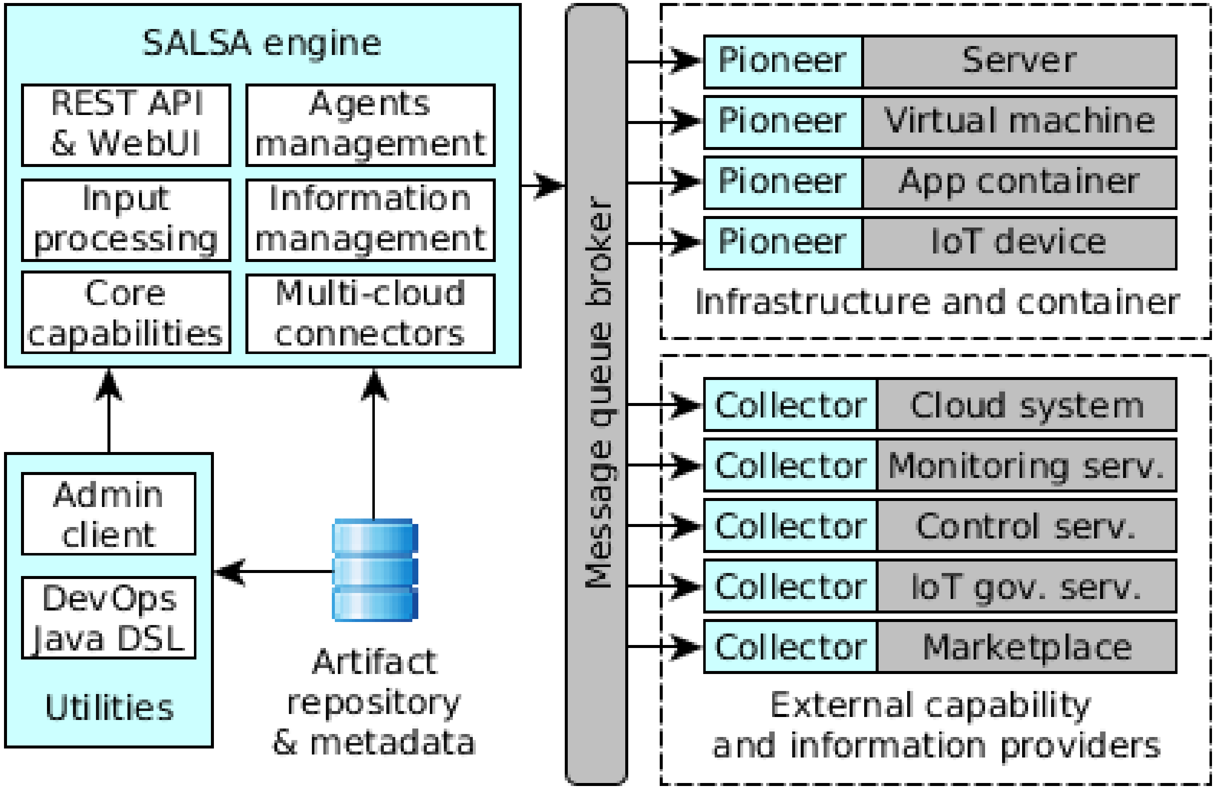
```
// observe the resource and send back the control
for (DataPoint dp : datapoints) {
 DataPointObservator obs = new DataPointObservator(dp) {
  public void onChange(DataPoint newVal) {
   SensorProps props = newVal.getExtra('SensorProps');
   if (props.getRate() > 5) { props.setRate(5); }
   ControlPoint control = newVal.getControl('changeRate',5);
   queryMng.SendControl(control);
 } }; }
```

2. Control the resource

```
// create the template of the query
NetworkFunctionService nfsTemp = new NetworkFunctionService(
nfsTemp.getQuality().setBandwidth("16 GB/s");
CloudService cloudTemplate = new CloudService('storage');
cloudTemplate.hasAttribute("capacity", "1 TB");

// Query the list of resources
QueryManager queryMng = new QueryManager('ampq://10.99..');
List networks = queryMng.QueryNetworkFunctionService(nfsTemp
List storages = queryMng.QueryCloudService(cloudTemplate);
// further queries
```

3. Query network functions and clouds

As we able to get resources → deploy and configuration



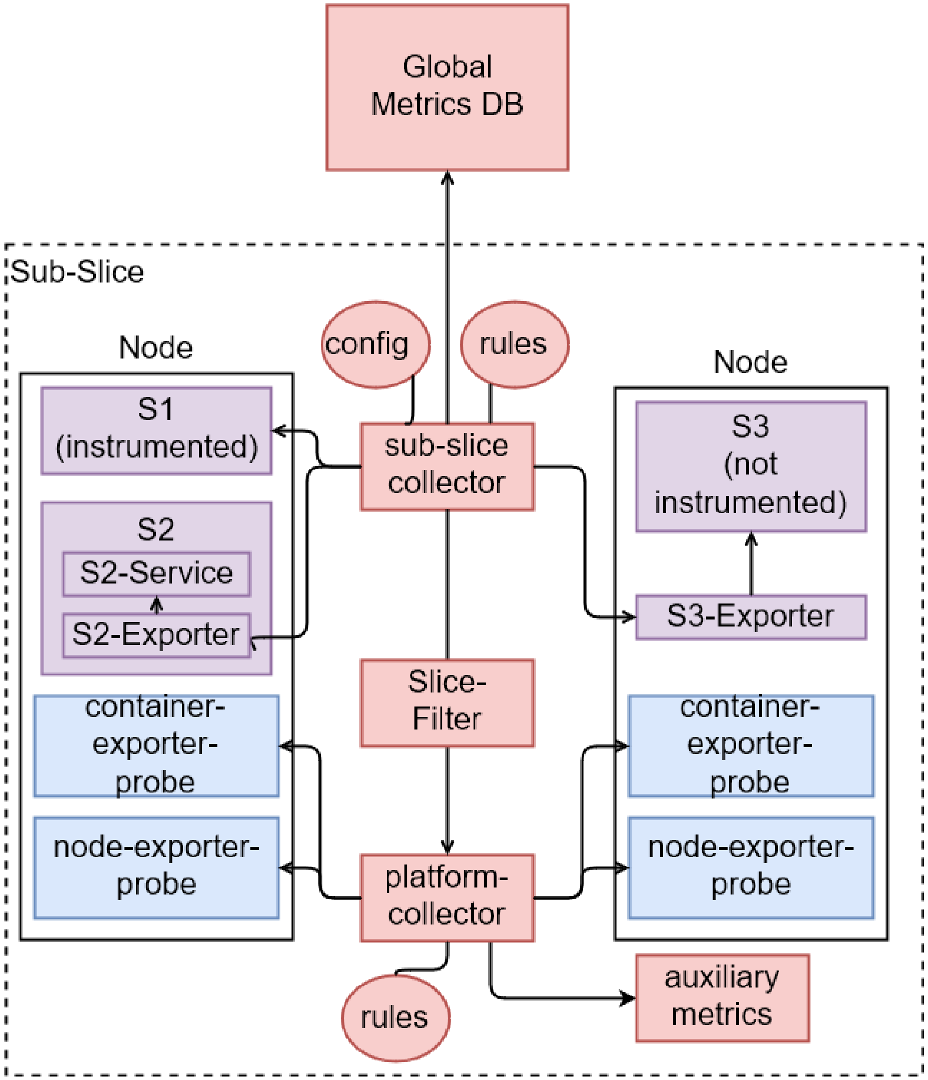
Deployment architecture of SALSA.

MONITORING ENSEMBLES?

Key questions in monitoring

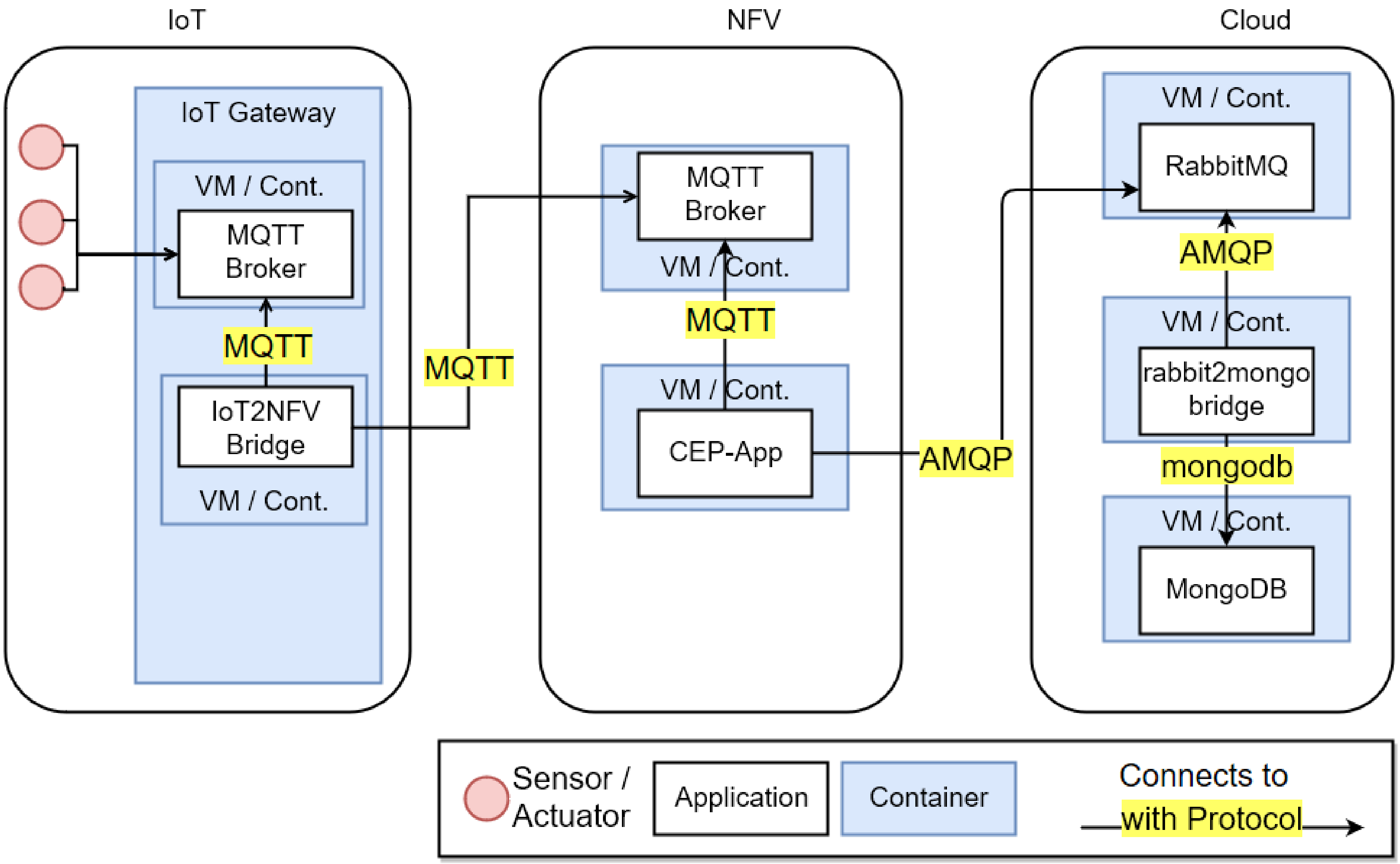
- Which metrics make sense? Memory/CPU usage?
  - We focus on: response time, delay, cost, availability and reliability
- Collect monitoring data from multiple resources of sub-systems
  - Gathering and correlating monitoring
  - Deal with different integration models: through provider interfaces versus instrumentation
- Analytics and visualization

Monitoring components

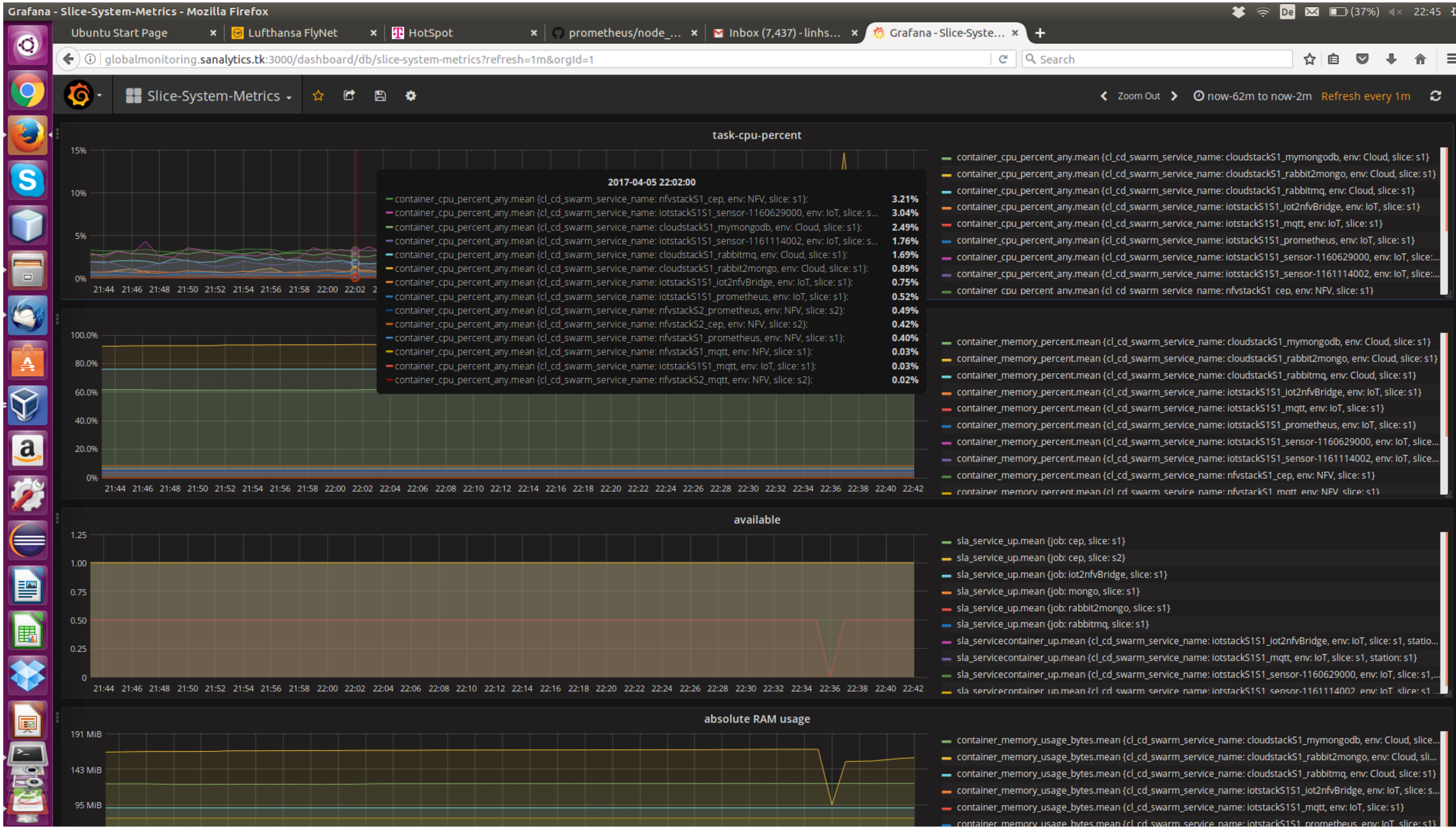


Hong-Linh Truong, Christian Proinger, SANALYTICS – On Monitoring and Analytics of IoT, Network Functions and Clouds. 2017. working paper.

Example of an ensemble



Example of low level metrics



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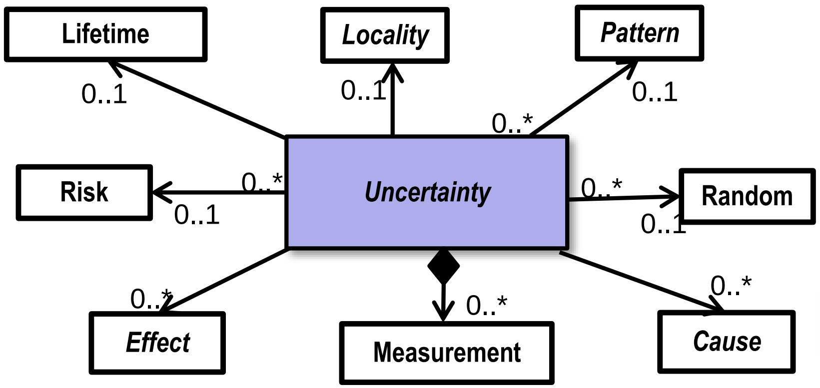
UNCERTAINTY AND APPROACH TO TESTING

Infrastructure uncertainties

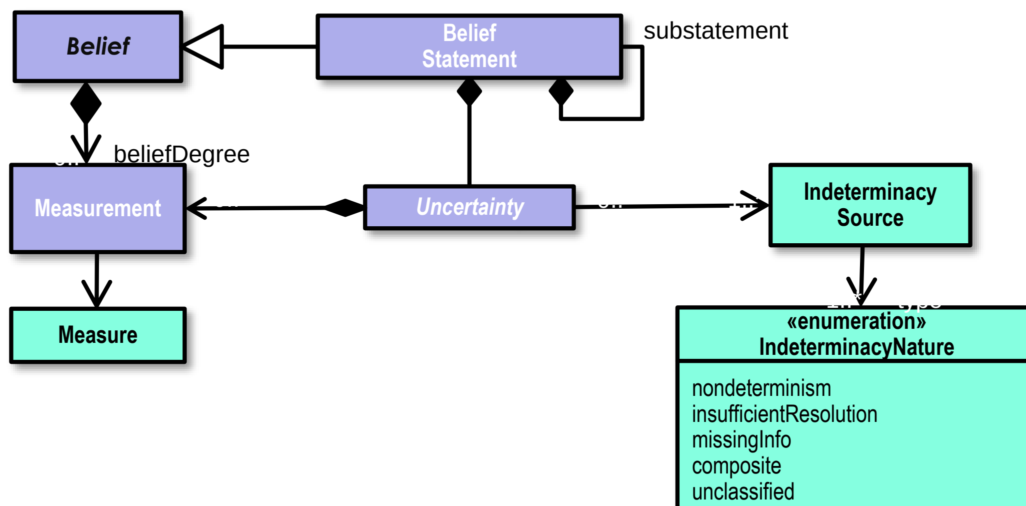
- CPS: includes IoT, network functions and clouds
- An ensemble represents a virtual infrastructure
  - Cross-system and cross-layer
- Goals
  - Characterize and specify possible uncertainties associated with interactions among elements in CPS infrastructures
- Supporting testing uncertainties and uncertainties analytics
  - Conventional aspects, e.g., infrastructural physical resources and typical system operations
  - Emerging novel aspects: data uncertainties (data/data-centric CPS), elasticity of CPS resources (w.r.t function and composition), and Governance (related to business/trustworthiness)

Uncertainty Model



Characterizing Uncertainty

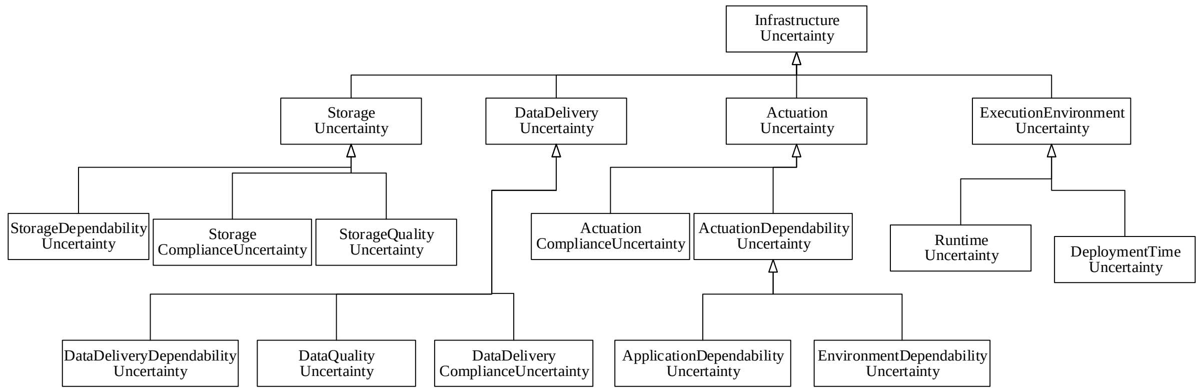
Belief Model



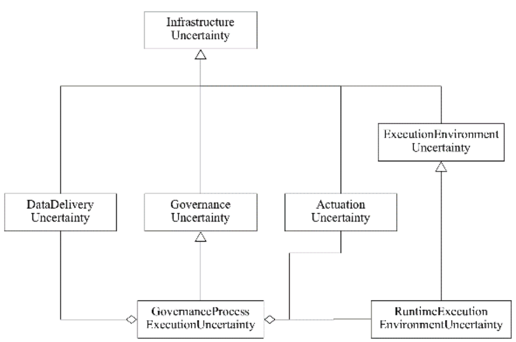
Source: https://www.simula.no/file/d12pdf/download

Important infrastructure uncertainties classes

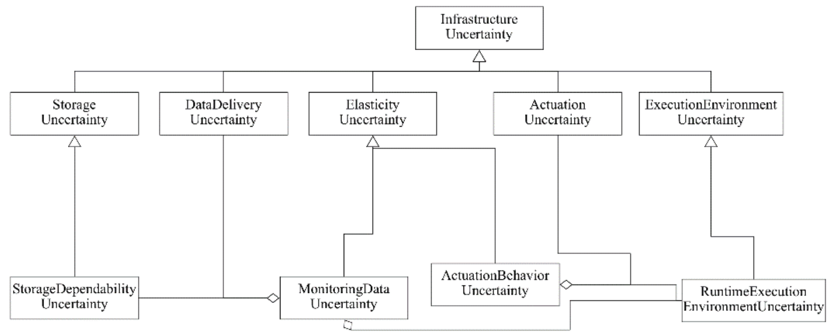
Data



Governance



Elasticity



Examples – UC1 Geo Sports

`Data Delivery` uncertainties

Uncertainties affect the infrastructure capabilities for generating, processing and delivering data

Located in **`Software`** in **`Cyber Environment`**, e.g., software components (execution environments, OS of gateways) in the infrastructure

At **`Runtime`** but **`Sporadic`**

Caused by **`Resource Competition`** (☒ Technological process)

`Indirect` impact on **`Software`**

Risk of this type of uncertainties

Non-functional aspects	Very Low	Low	Medium	High	Extreme
Dependability		■			
Legal/compliance		■			
Quality			■		

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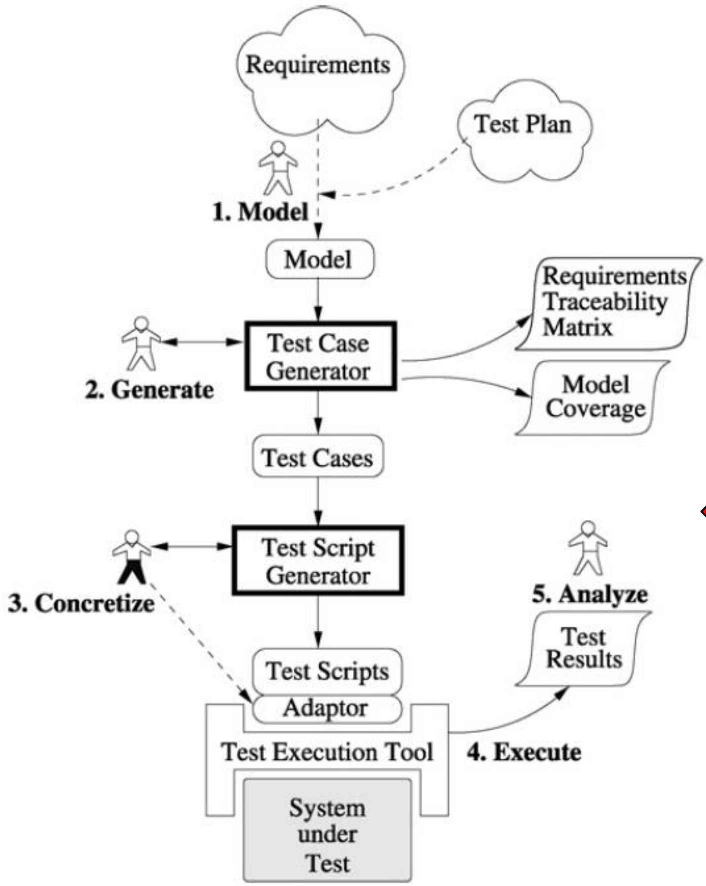
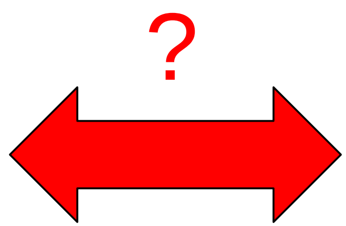
Combining MDE and Elastic Execution

Key observations:

how to combine topdown approach and bottom-up approach to leverage strengths of both models and elastic systems?

Key issues: Two separate worlds





Preparing CPS under Test

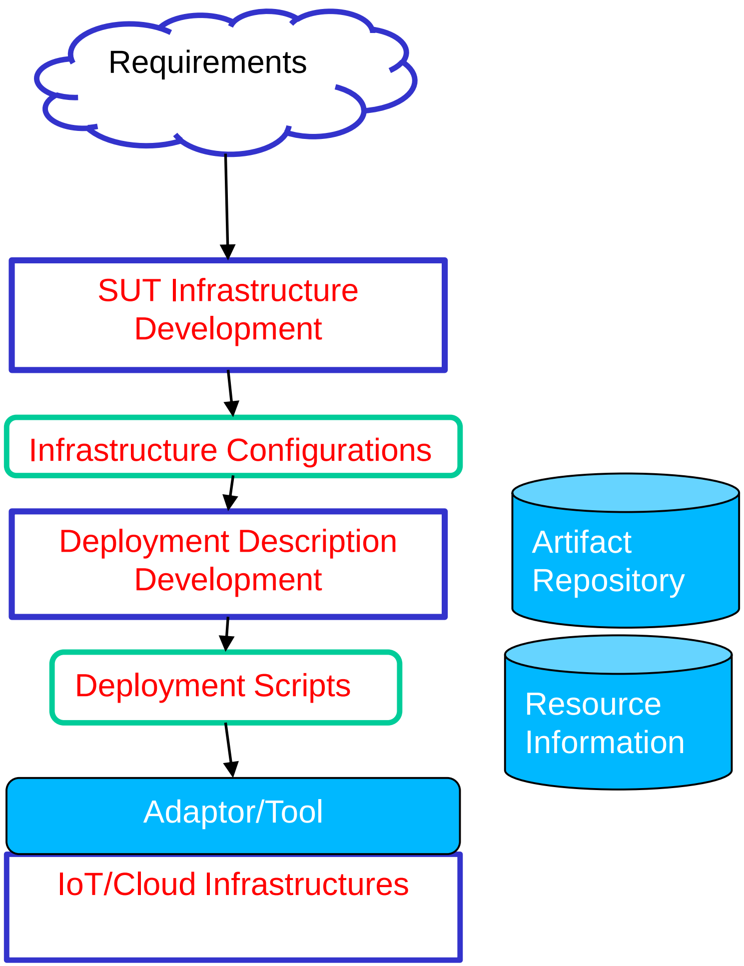
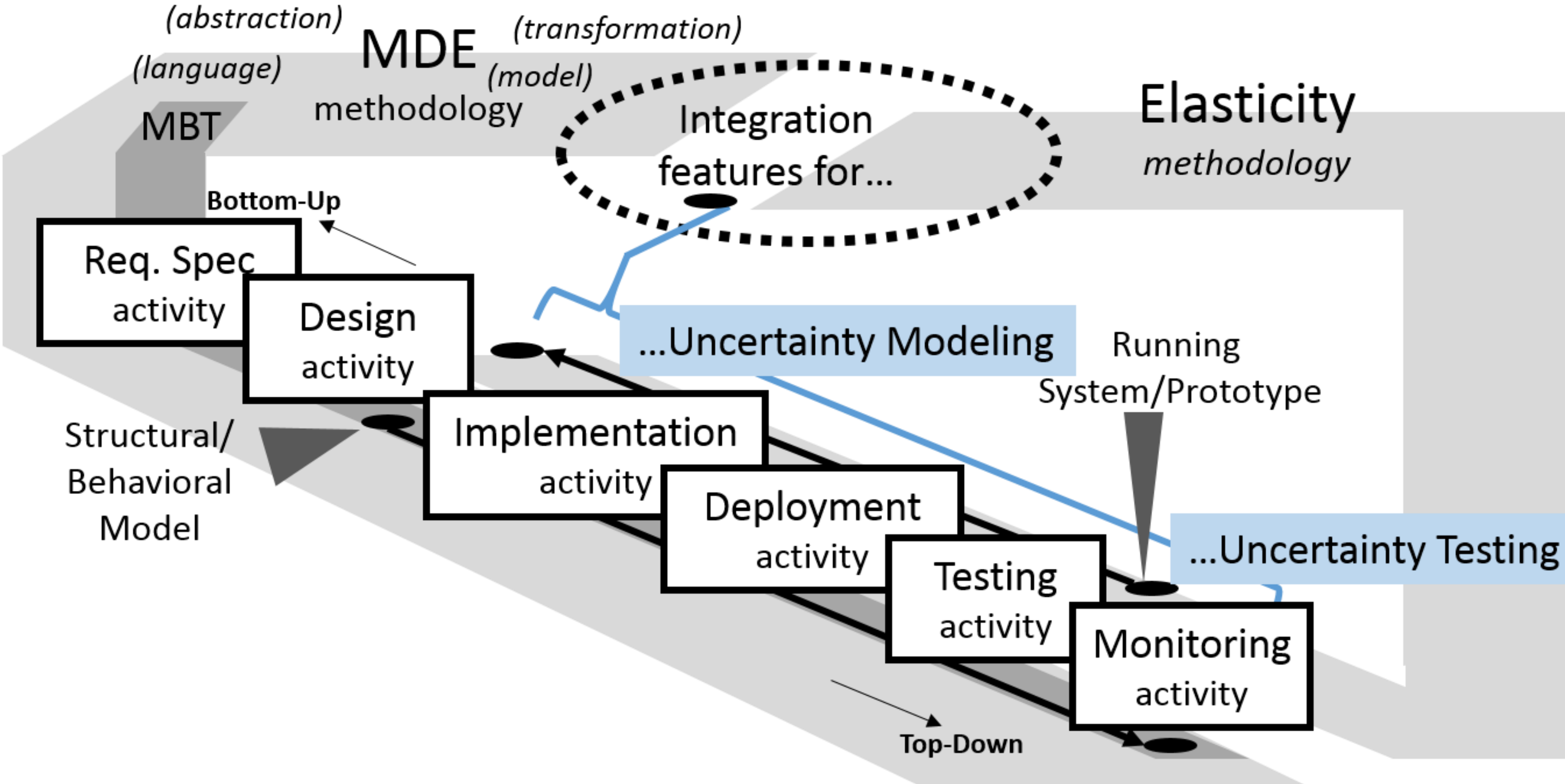


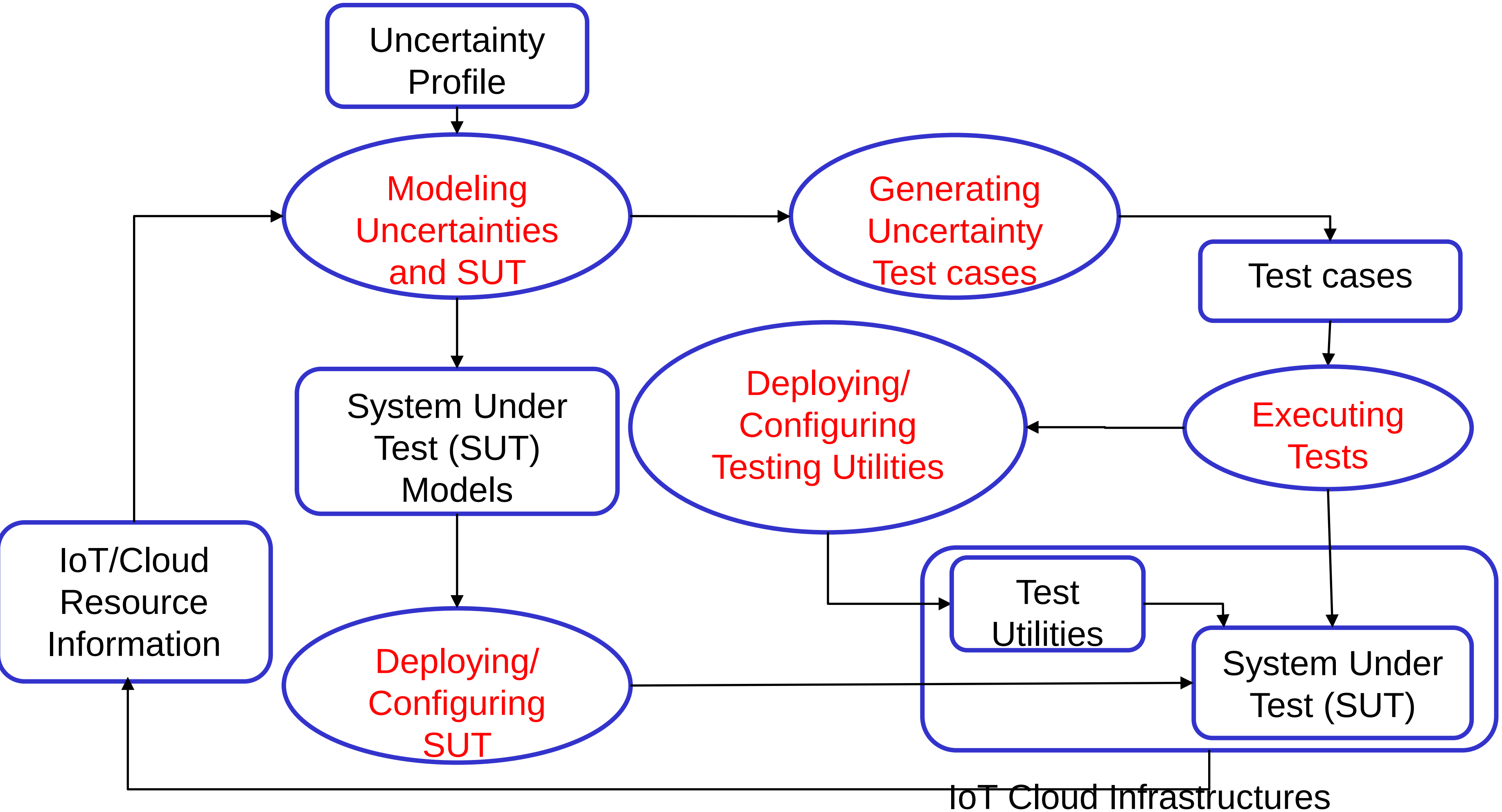
Figure source:
Mark Utting and Bruno Legeard. 2006. *Practical Model-Based Testing: A Tools Approach*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.

Combining MDE with Elastic Execution



Hong-Linh Truong, Luca Berardinelli, Testing Uncertainty of Cyber-physical Systems in IoT Cloud Infrastructures – Combining Model-Driven Engineering and Elastic Execution, Workshop on Testing Embedded and Cyber-Physical Systems, ISSTA 2017, Santa Barbara, 10-14 July, 2017.

Interwoven test execution and provisioning



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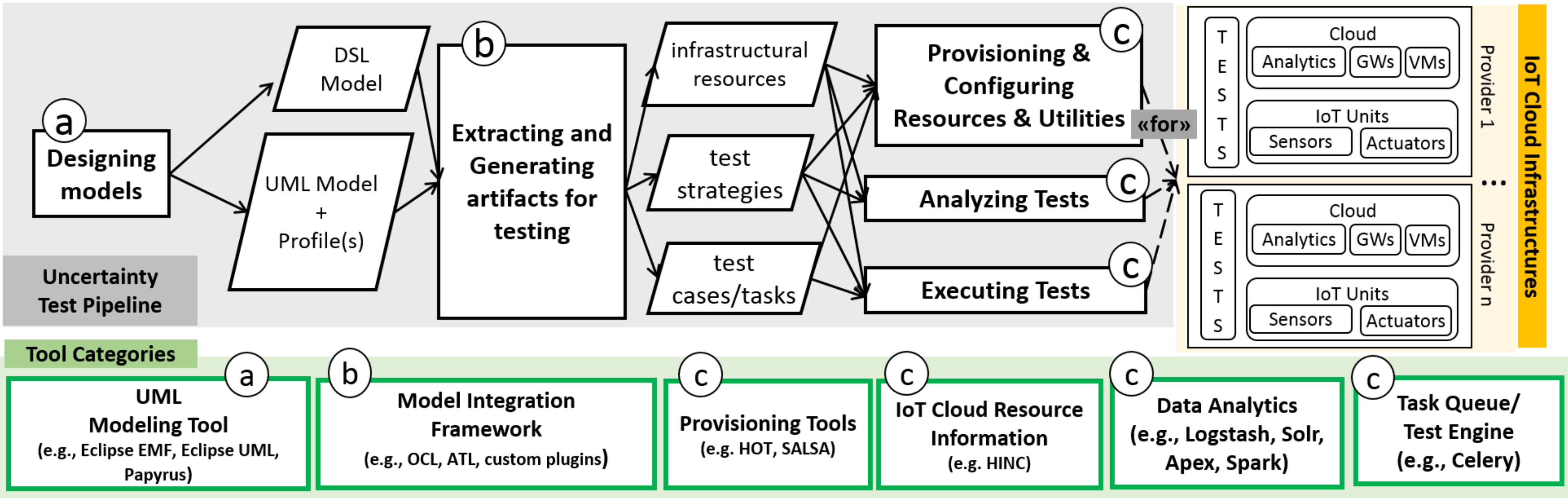
Tool pipelines: from MDE to elastic execution for testing

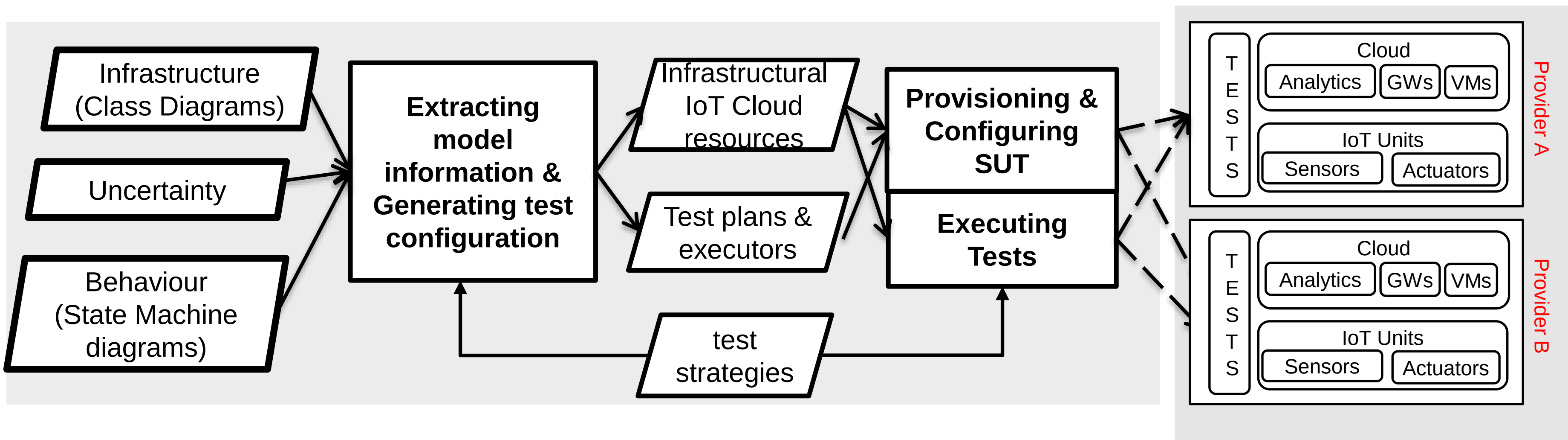


Key thoughts:

- Different algorithms to create suitable deployment configurations based on data uncertainties, cost, and time
- Interactions between testing and elasticity control of IoT and Cloud services

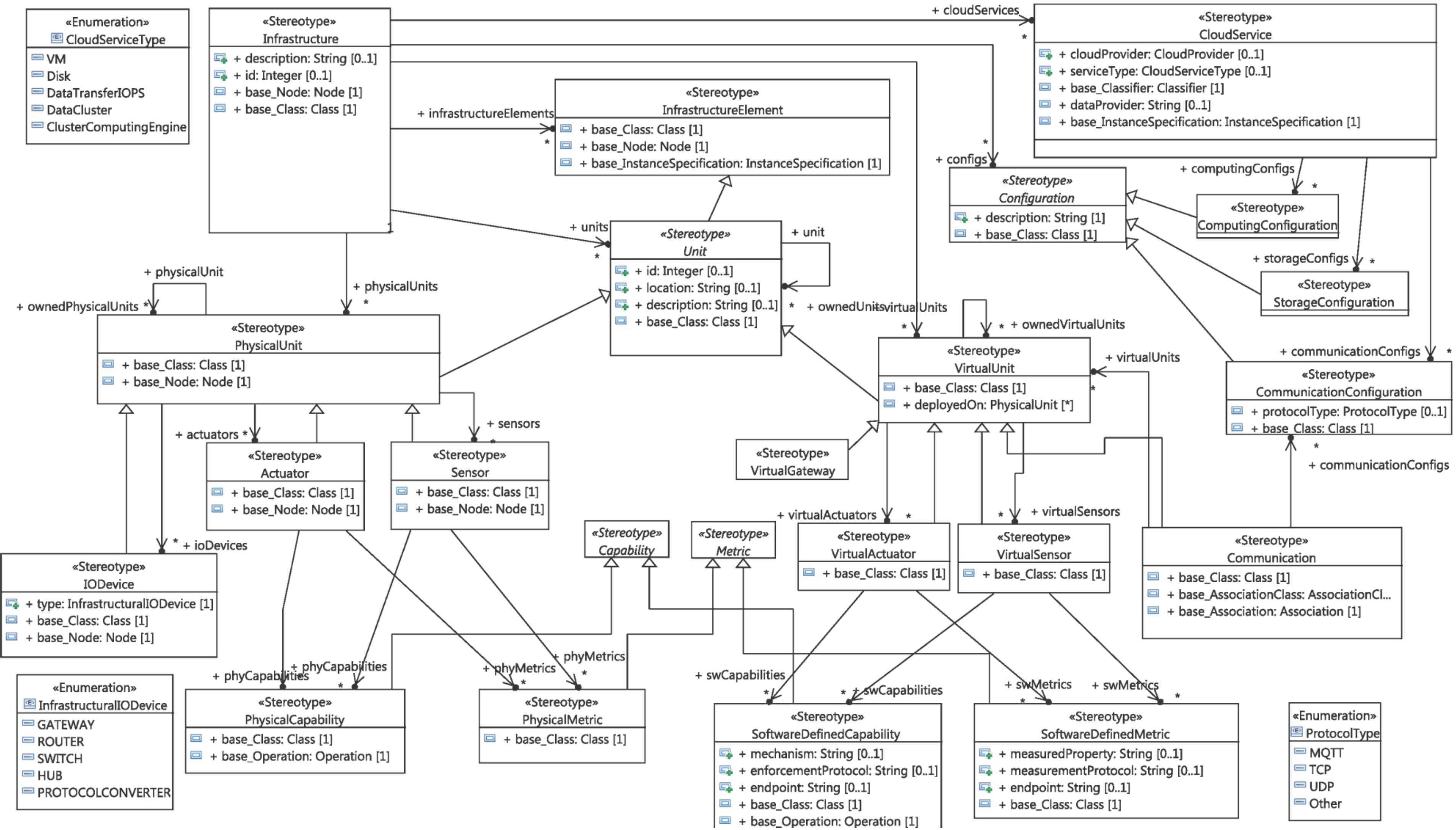
Our current progress

Consider to generate provisioning configurations from SUT models

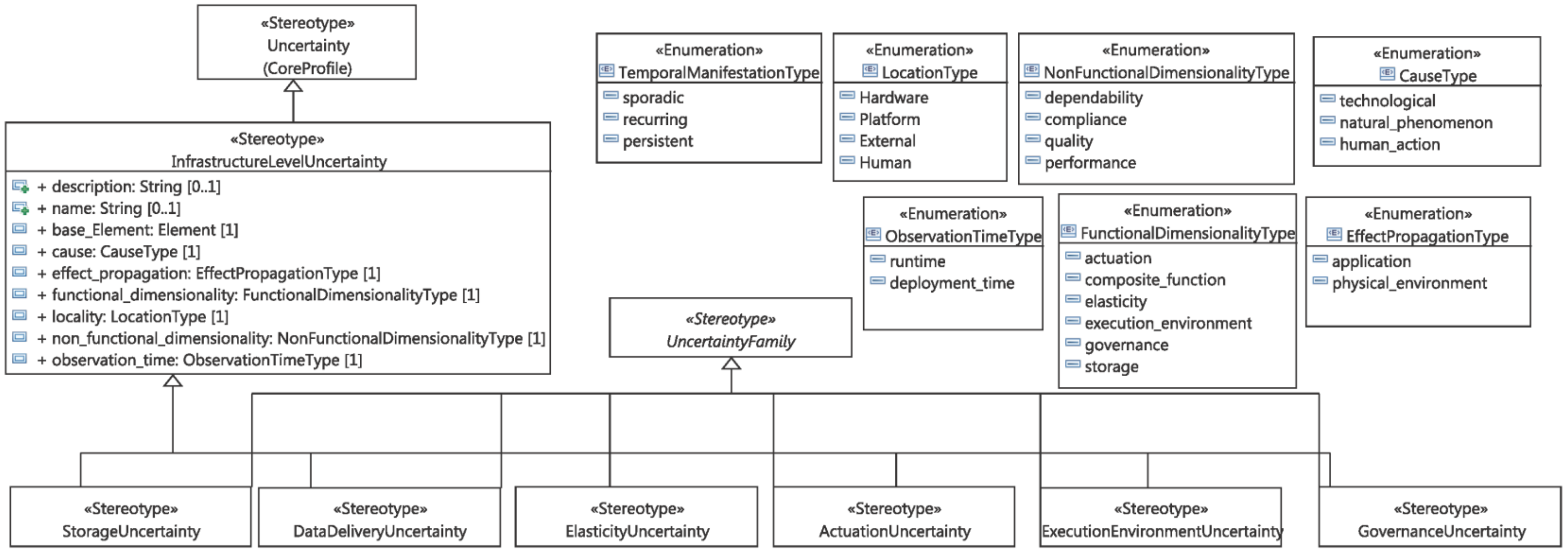


Hong-Linh Truong, Luca Berardinelli, Ivan Pavkovic and Georgiana Copil, **Modeling and Provisioning IoT Cloud Systems for Testing Uncertainties**, 14th EAI International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services (MobiQuitous 2017), Nov 7–10, 2017,Melbourne, Australia

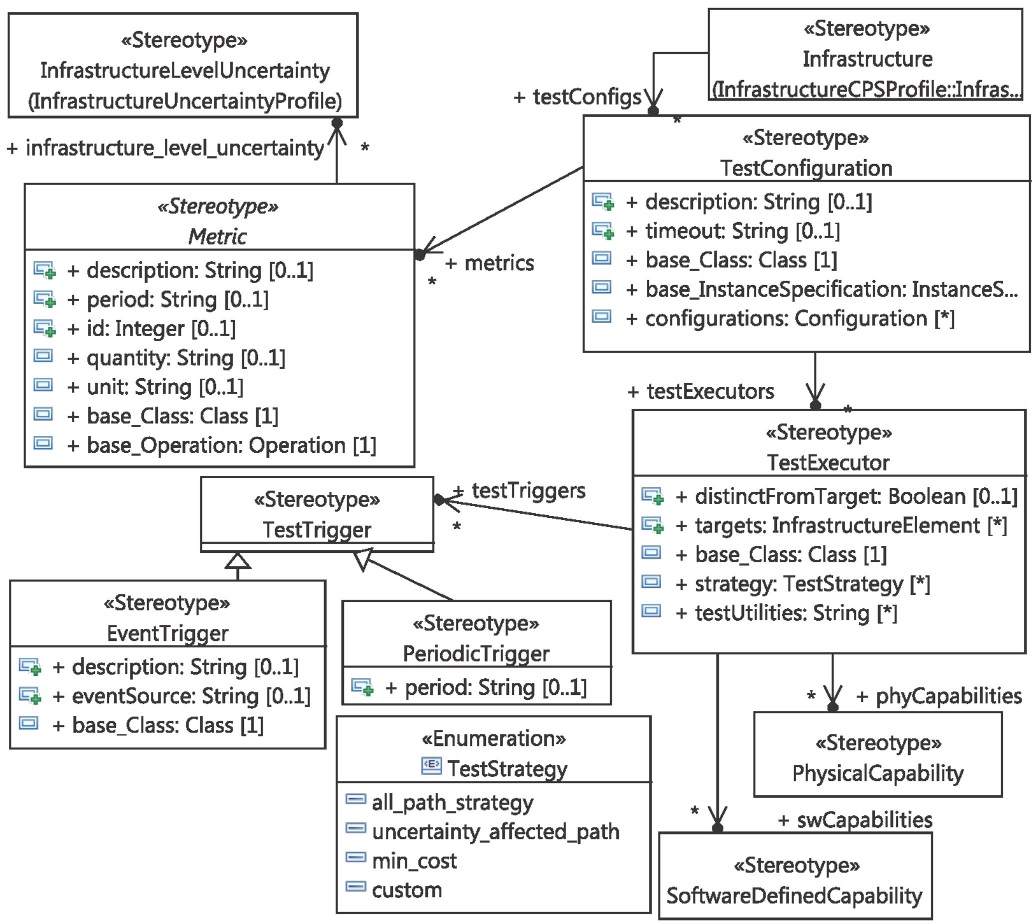
IoT and Cloud Resource Profile



Uncertainty Profile

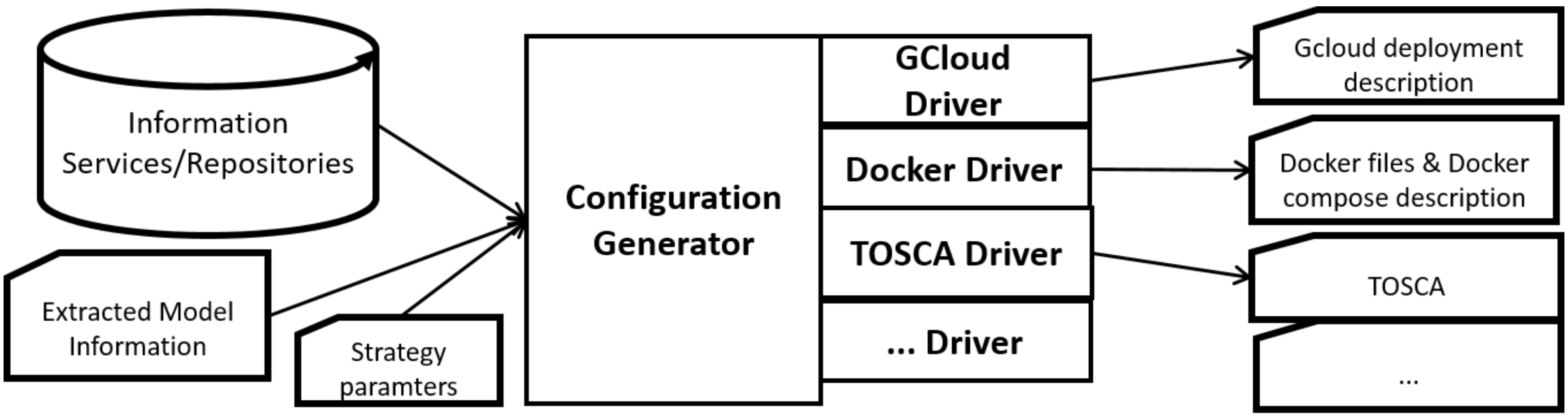


Generic models for Task Executor



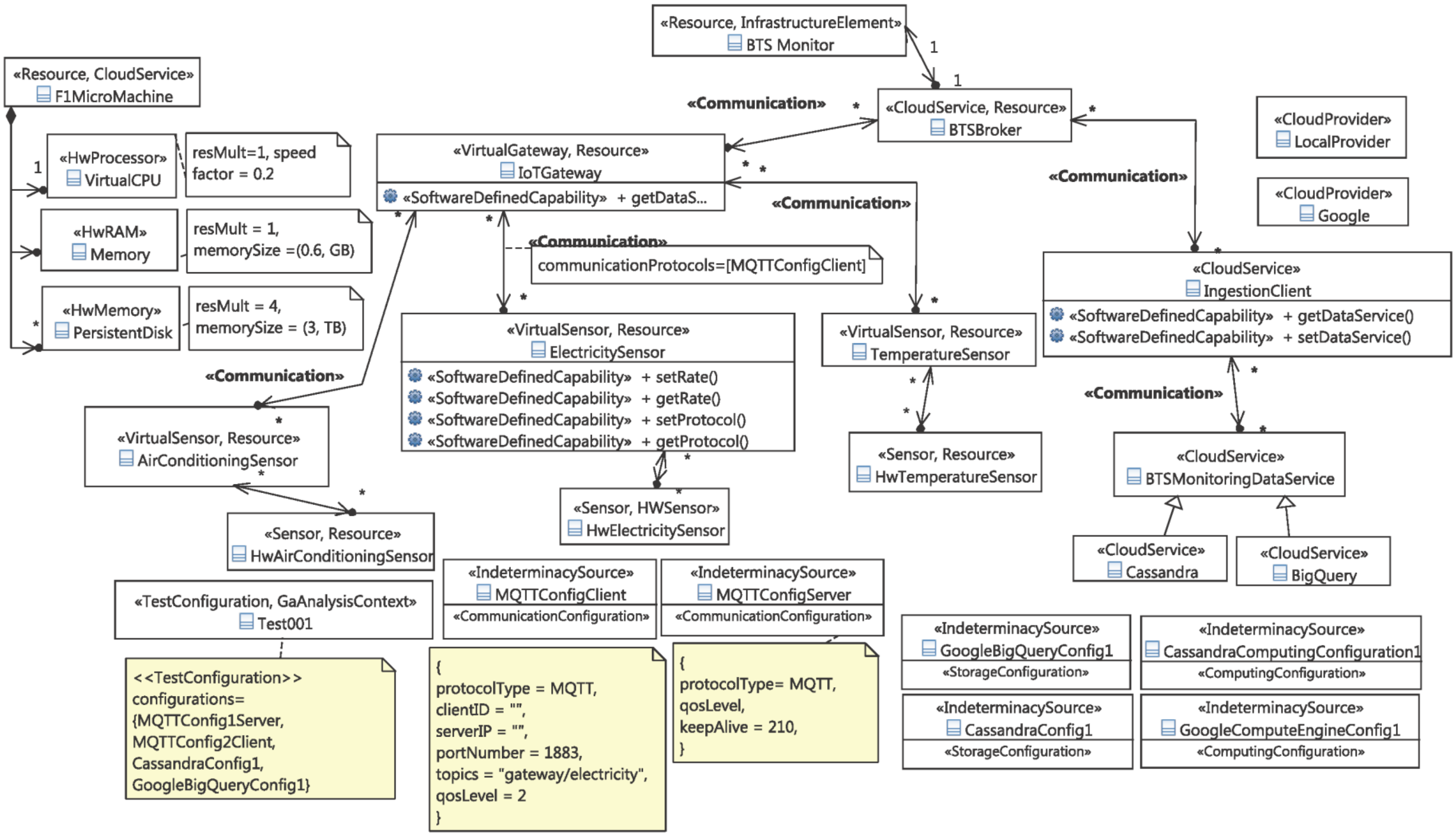
Tasks for testing also including deployment and reconfiguration of ensembles.

Configuration Generation and Deployment

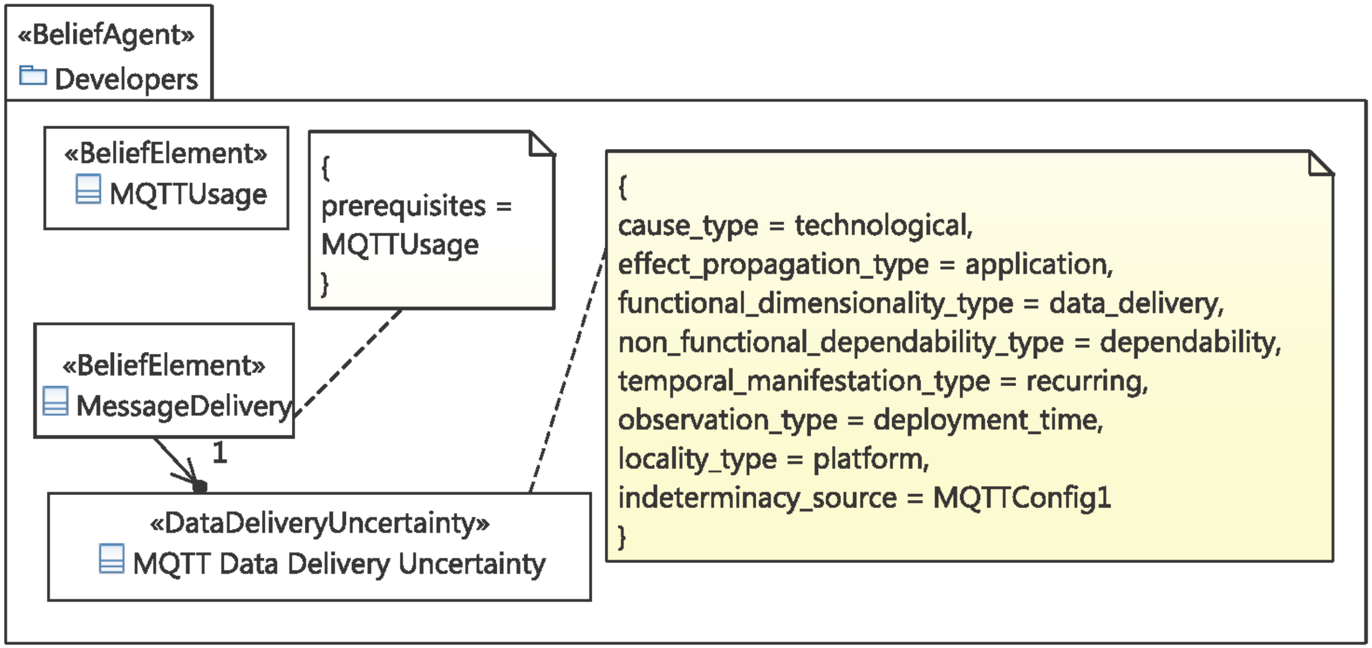


- Reuse well-known tools for deployment
- Utilize different information services
  - Runtime and (future) uncertainty analytics

Example of BTS monitoring



Example of BTS monitoring



Examples

Enriched model information for deployment configurations


```
"MQTTConfig1":	{
	"name": "MQTTConfigServer",
	"protocolType": "MQTT",
	"qosLevel": [],
	"type": "CommunicationConfiguration"
}
"MQTTConfig2":	{
	"name": "MQTTConfigClient",
	"protocolType": "MQTT",
	"clientID": "",
	"serverIP": "35.189.187.208",
	"portNumber": 1883,
	"topics": ["/gateway/electricity"],
	"qosLevel": [2],
	"type": "CommunicationConfiguration"
}
```


Generated deployment description


```
services:
  ingest:
    build: .
    volumes:
      - ./:/t4u
  electricitysensor:
     image:
"localhost:5000/t4u/mqttsensor/realsensor:v01"
  iotgateway:
     image:
"localhost:5000/t4u/cloudservice/mqttbroker:v01"
```

Summary

- Ensembles of IoT, network functions and clouds
  - Important for various types of applications
  - SINC: a conceptual framework
- Elasticity and Uncertainties
  - We need to consider more data and network aspects.
  - Adaptation and optimization under uncertainties
  - Modeling and testing uncertainties are very challenging
  - Testing uncertainties require fundamental changes in testing techniques: deal with elasticity and virtualization

→ We need new set of tools and techniques for managing and testing ensembles.

Future work

- **Current research topics**
  - APIs for programming resource queries and controls (http://sincconcept.github.io/HINC/)
  - Configuration tools (http://tuwiendsg.github.io/SALSA/)
  - Uncertainty testing and analytics (https://github.com/tuwiendsg/COMOT4U/)
  - Monitoring and analytics
  - Ensemble requirement modeling, composition algorithms and optimization
  - Interoperability issues (http://www.inter-iot-project.eu/)
  - Policy execution

Check http://rdsea.github.io and https://github.com/tuwiendsg/COMOT4U for new update

Thanks for your attention!

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