On Service Engineering Analytics for IoT Clouds - Techniques and New Directions

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Acknowledgment:

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The H2020 U-Test Consortium – www.u-test.eu

Including joint work with Georgiana Copil, Schahram Dustdar, Duc-Hung Le, Daniel Moldovan, Nanjangud Narendra, Stefan Nastic, Phung H. Phu

Outline

- Scenarios
- IoT, network functions and cloud resources
- Challenges for engineering analytics
- Engineering analytics models and techniques
- Future directions
  - Uncertainty testing and adaptation
  - Information-centric slices of IoT, network functions and cloud services
  - Execution policy
- Conclusions and Future Work

Application scenarios

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

Indian Overfly collapses
figure source: http://timesofindia.indiatimes.com

Geo Sports: Picture courtesy Future Position X, Sweden

- Need to have an end-to-end provisioning of resources
  - E.g., sensors, network function services, storage, virtual machines
  - Short, crucial and heavily workload; elasticity and uncertainties.

Vietnam‘s application scenarios

- Traffic congestion in urban areas
- Agriculture productivity and food safety
- Saltwater intrusion impact monitoring
- Wastewater monitoring

ESA > Our Activities > Observing the Earth > Copernicus > Sentinel-1

Search here

Related links
- GEOGLAM
- CESBIO
- Sarmap
- TU Vienna
- RIICE
- ESA Data User Element (DUE)
- Copernicus
- Sentinel Data Hub portal

In depth
- TOPSAR processing

SENTINEL-1 SEES RICE PADDY DROP IN THE MEKONG DELTA

Rice crop evolution in the Mekong Delta

More about this video

18 April 2016 Europe’s Sentinel-1A satellite has shown that the Mekong River Delta – one of the world’s major rice-growing areas – saw a significant drop in productivity over the past year, illustrating the effect of El Niño on food security.

Since the end of 2015, dry conditions associated with El Niño have strongly affected South East Asia, leading to severe drought, in particular in Vietnam’s Mekong Delta.

River water levels are at the lowest recorded in 90 years in many places, causing more severe and earlier salt water intrusion than previous years.

According to UN humanitarian response reports, local farmers are coping with the drought and increased water salinity by reducing their crop area.

The Sentinel-1 mission is helping to map and monitor rice production. It carries an advanced radar that can see through all weather conditions – essential in cloud-prone South East Asia – and is highly sensitive to changes in waterlogged ground such as rice paddies.

Source: http://www.esa.int

Vietnam blames toxic waste water from steel plant for mass fish deaths

Taiwanese firm Formosa Plastics that owns the plant says it will pay $500m towards clean up and compensation

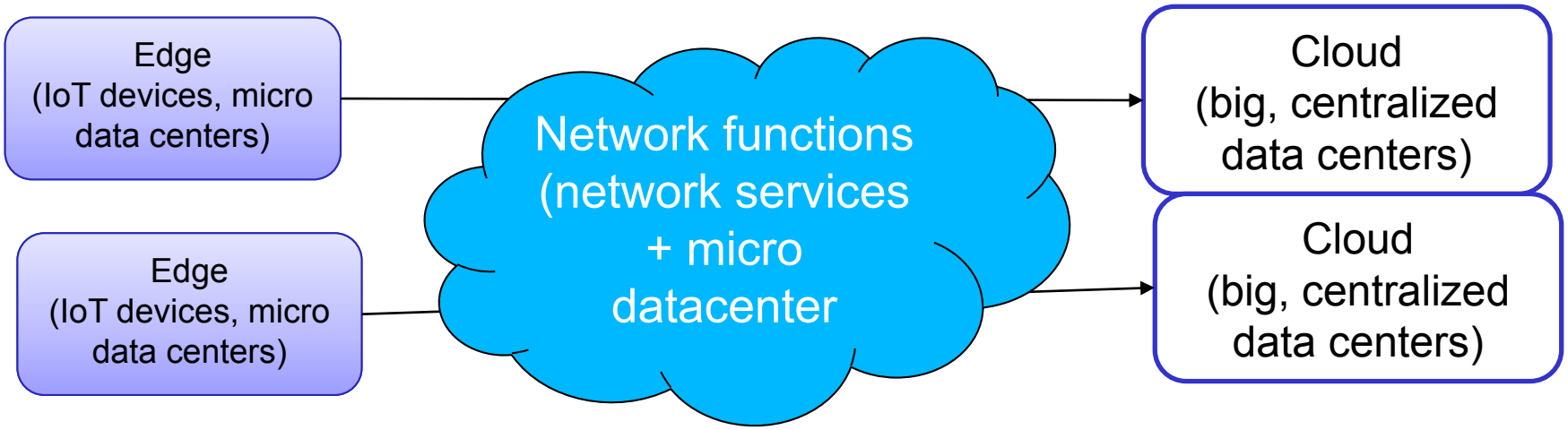
Dead fish lie on the shore in Quang Trach district, Quang Binh province, Vietnam. Photograph: Chi Nam/AP

Source: https://www.theguardian.com

Tien-Dung Cao, Huu-Hanh Hoang, Hiep Xuan Huynh, Binh-Minh Nguyen, Tran-Vu Pham, Quang Tran-Minh, The-Vu Tran, Hong-Linh Truong, IoT Services for Solving Critical Problems in Vietnam: A Research Landscape and Directions, IEEE Internet Computing Magazine, 2016

IoT, network functions and clouds

- Resources: IoT elements (sensors, gateways, networks), micro data centers, network services, cloud VM, storage, etc.



- On-demand resources provisioning across IoT networks (the edge), network functions (the middle) and the clouds (the back-end)

(Elastic) Service models

- Cloud service models
- Networks
  - Network function virtualization
  - Pay-per-use IoT communication
- IoT
  - Fixed IoT infrastructures
  - On-demand IoT
  - Human participation (sensing and analytics)

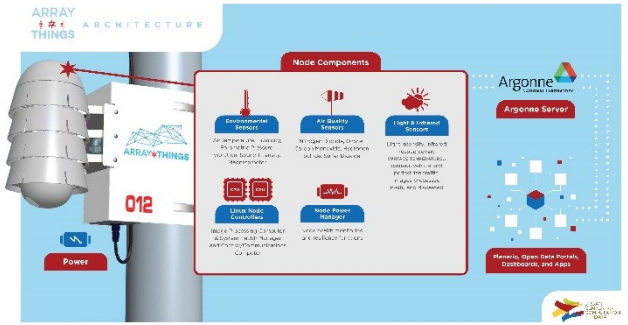
Enabled by Semtech's LoRa technology, which allows a sensor network to operate on low power while providing strong connectivity over a long distance, the SK Telecom LPWAN covers 99 percent of South Korea's population. The company predicts that it will have over four million things connected to its IoT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

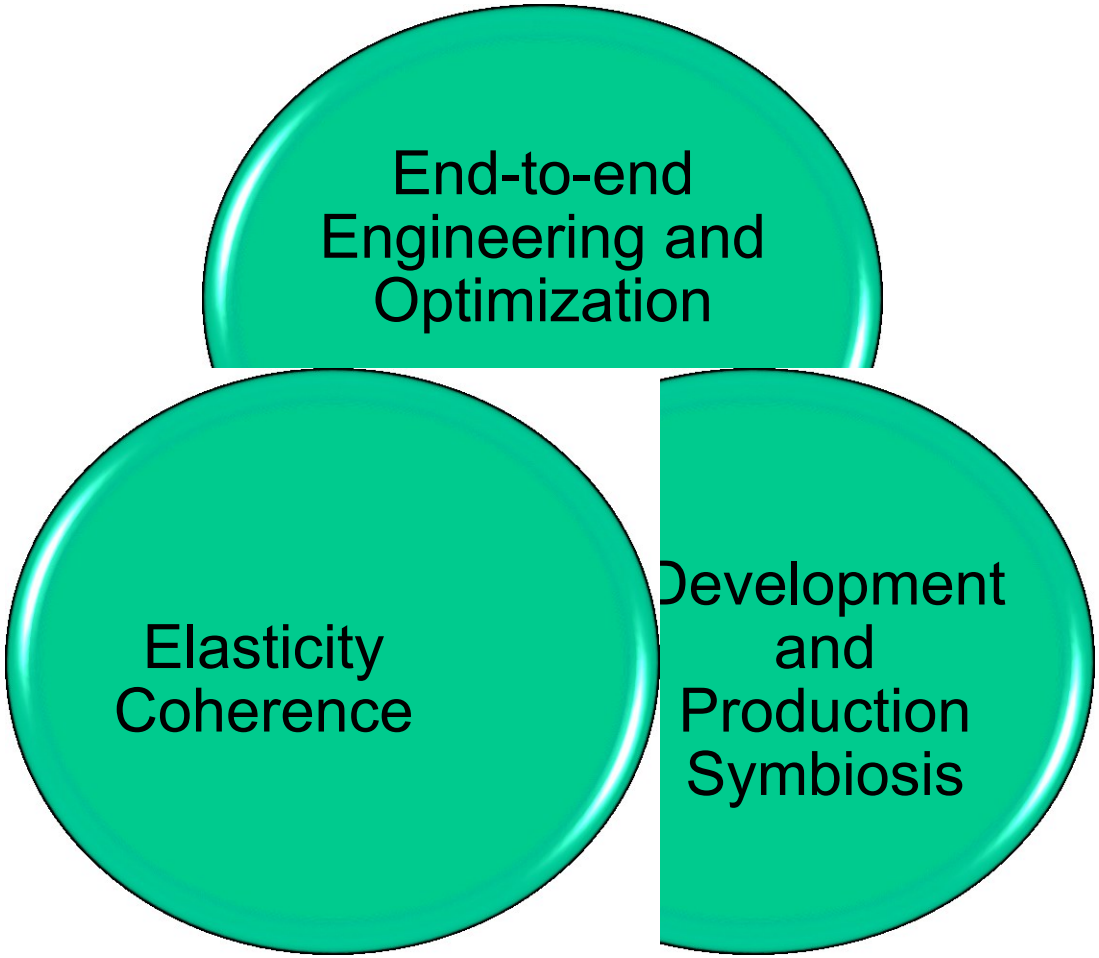
Price Plan	Data Allowance* (Frequency of communication)	Monthly Flat Rate (VAT Excluded)	Examples of Services	Note
Band IoT 35	100KB	KRW 350	Metering and monitoring services (e.g. Advanced Metering Infrastructure (AMI), environmental monitoring, water leakage monitoring, etc.)	- Discount benefits for 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.



https://arrayofthings.github.io/

Engineering perspectives



Hong Linh Truong, Schahram Dustdar: Principles for Engineering IoT Cloud Systems. IEEE Cloud Computing 2(2): 68-76 (2015)

Research challenges

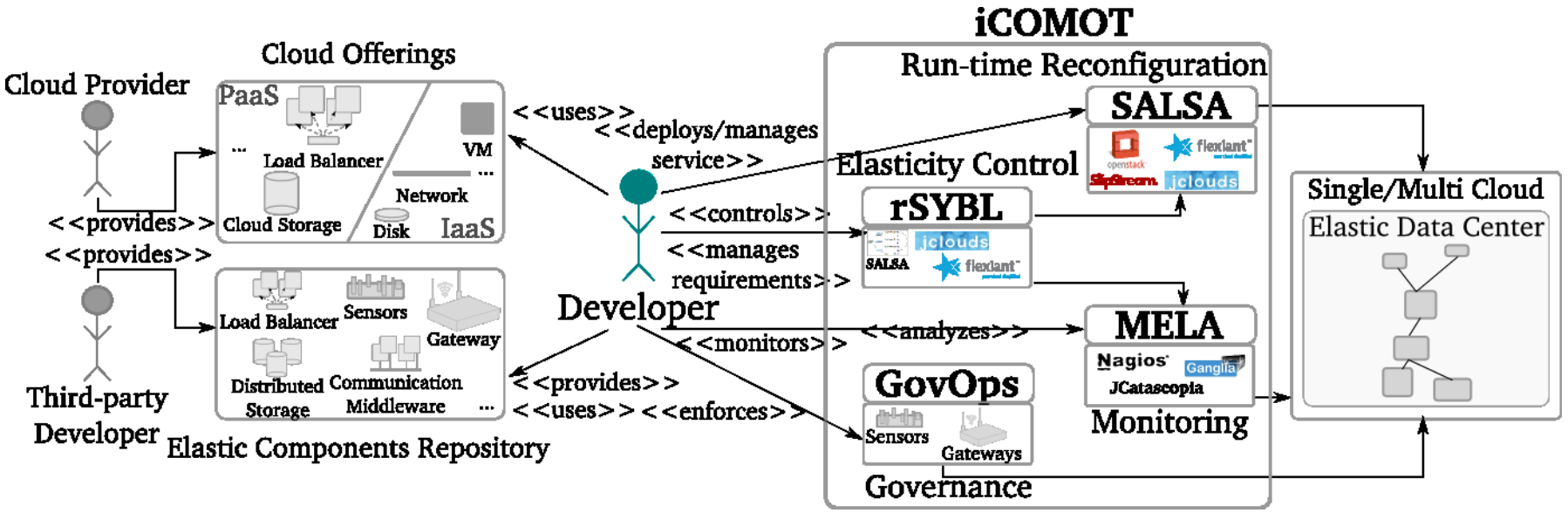
- Virtual resources are provided by different types of infrastructure providers
  - Often there is no coordination among them → inadequate support for elasticity and uncertainties management for the application
- Host-centric information is too low level to find and compose resources
- Diverse types of API for integration and communication
  - API for obtaining metadata versus control of resources
  - Data can be transferred through different middleware
  - Multiple metadata models for IoT, network functions and clouds (IoTivity, OpenHAB, IoTDM, ETSI MANO, OCCI, CIMI, etc.)
- Very hard to test IoT, network functions, and clouds in an end-to-end manner

We need tools for

- Novel execution, composition and management tools
  - Distributed resources management
  - Virtualization and programming techniques for IoT and clouds
  - Adaptation under uncertainties of machines, data, networks, and humans
  - Elasticity coordination of multiple IoT sites and big data centers
  - Smart contract, security and compliance enforcement
- Novel engineering analytics techniques and tools
  - Characterization of end-to-end metrics
  - Resource information in the development and operation phases
  - Deployment, control and analysis tools across IoT, network functions, and cloud systems
  - Testing and monitoring

Configuration, Control, Monitoring and Testing (COMOT) models and techniques

iCOMOT -- Toolsets and actions for IoT Cloud Systems

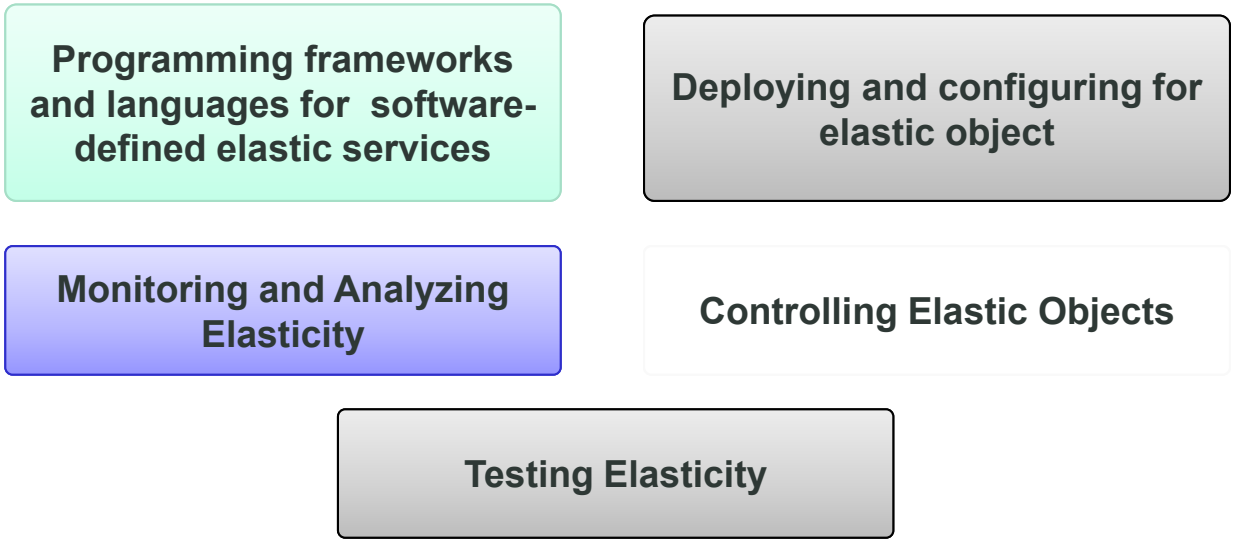


http://tuwiendsg.github.io/iCOMOT/

Hong-Linh Truong, Georgiana Copil, Schahram Dustdar, Duc-Hung Le, Daniel Moldovan, Stefan Nastic, "iCOMOT – a Toolset for Managing IoT Cloud Systems", 16th IEEE International Conference on Mobile Data Management, 15-18 June, 2015, Pittsburg, USA. (Demo)
Hong-Linh Truong, Georgiana Copil, Schahram Dustdar, Duc-Hung Le, Daniel Moldovan, Stefan Nastic, On Engineering Analytics for Elastic IoT Cloud Platforms, The 14th International Conference on Service-Oriented Computing (ICSOC 2016), October 10-13, 2016, Banff, Alberta, Canada

Programming Elasticity in IoT Cloud Systems

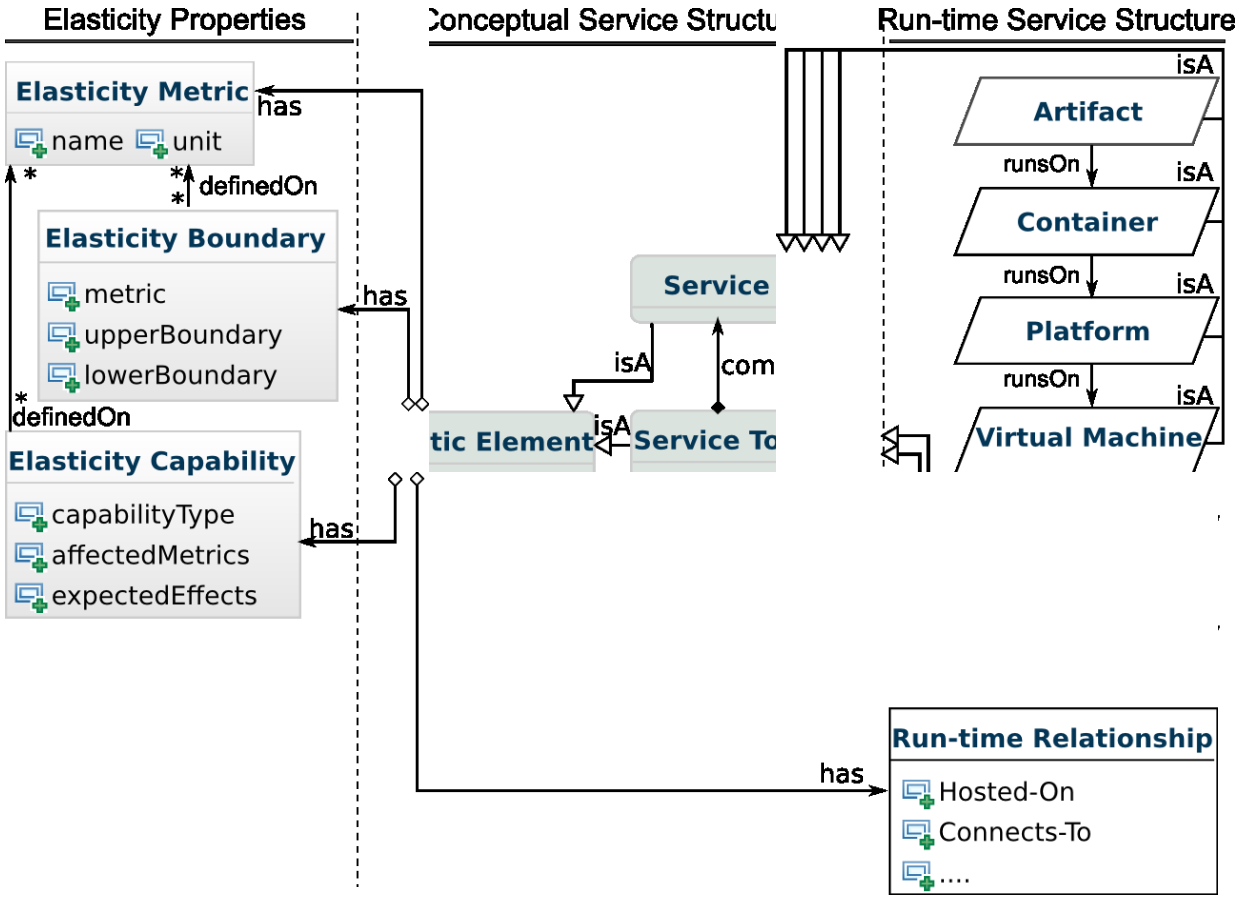
- Conceptualizing elastic objects for IoT elements and cloud services
  - Programming „the world of elastic objects“
- Developing elastic cloud software



Hong Linh Truong, Schahram Dustdar: Programming Elasticity in the Cloud. IEEE Computer 48(3): 87-90 (2015)

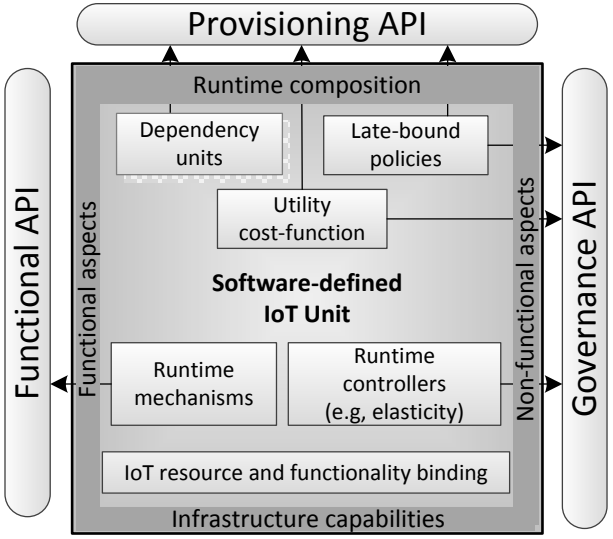
Software-defined Elastic Service in the cloud

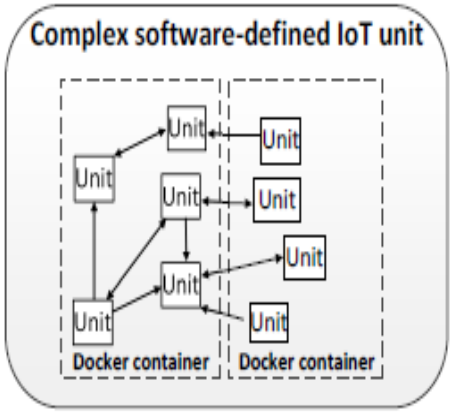
How to represent IoT elements and cloud services under the same view?



Software-Defined IoT Units for IoT and edge systems

- Virtualizing IoTs resources under “service units” with software-defined API for accessing, configuring and controlling units
- Composing and creating gateways and virtual topologies (of multiple gateways)
- Provisioning (atomic and composite) units dynamically and on-demand in cloud and edge computing environments





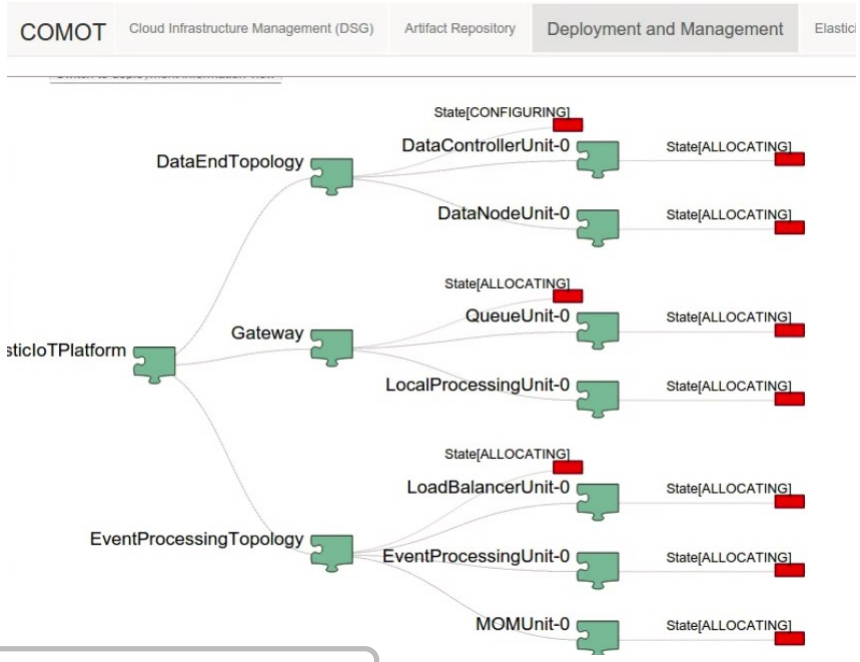
Stefan Nastic, Sanjin Sehic, Le-Duc Hung, Hong-Linh Truong, and Schahram Dustdar (2014). Provisioning Software-defined IoT Cloud Systems. The 2nd International Conference on Future Internet of Things and Cloud (FiCloud-2014), August27-29, 2014, Barcelona, Spain.

Stefan Nastic, Hong Linh Truong, Schahram Dustdar: SDG-Pro: a programming framework for software-defined IoT cloud gateways. J. Internet Services and Applications 6(1): 21:1-21:17 (2015)

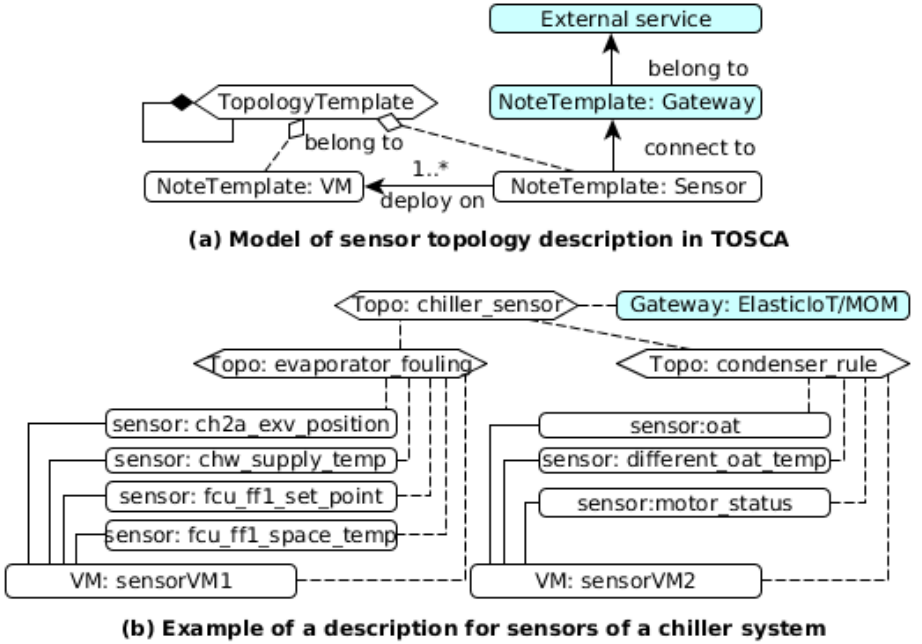
Stefan Nastic, Hong Linh Truong, Schahram Dustdar: A Middleware Infrastructure for Utility-based Provisioning of IoT Cloud Systems, First IEEE/ACM Symposium on Edge Computing, October 27-28, 2016, Washington DC, USA

IoT Cloud systems configuration

- Well-defined APIs for manipulating and provisioning objects
- Support different types of objects, e.g., VMs, OS containers, services, service containers, IoT sensors, and IoT gateways



Data center services

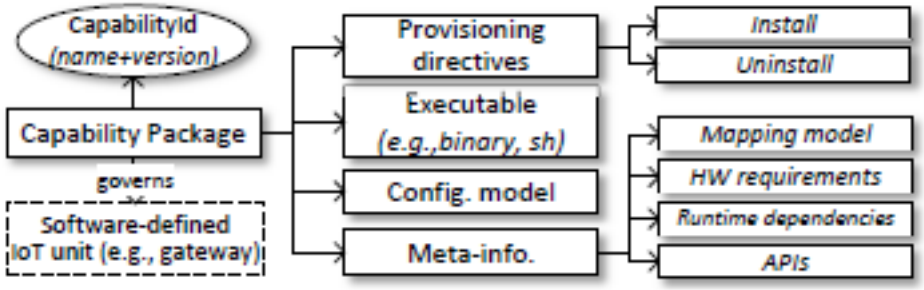


Sensors

https://github.com/tuwiendsg/SALSA

Governance capabilities for IoT

- Governance capabilities:
  - Any function that „manipulates“ an IoT resource
  - Building blocks of operational governance (GovOps) processes
  - Executed „inside“ software-defined machines (SDMs)
- Governance processes/strategies
  - Functional configuration
  - Performance
  - Uncertainty study
  - Risk study



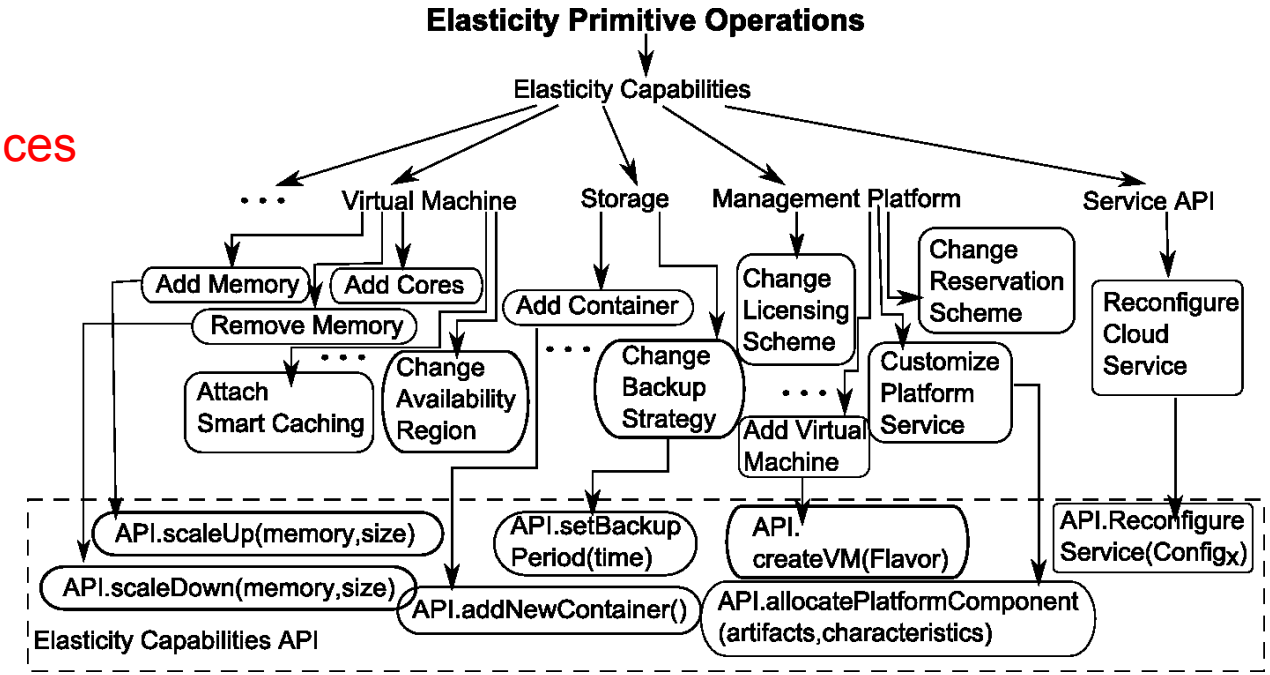
https://github.com/tuwiendsg/GovOps/

Stefan Nastic, Michael Vögler, Christian Inzinger, Hong-Linh Truong, Schahram Dustdar, "rtGovOps: A Runtime Framework for Governance in Large-scale Software-defined IoT Cloud Systems", The 3rd IEEE International Conference on Mobile Cloud Computing, Services, and Engineering, 2015

Elasticity primitive operations

Primitive operations: actions can be performed on elastic objects to change their elasticity states

For the cloud services

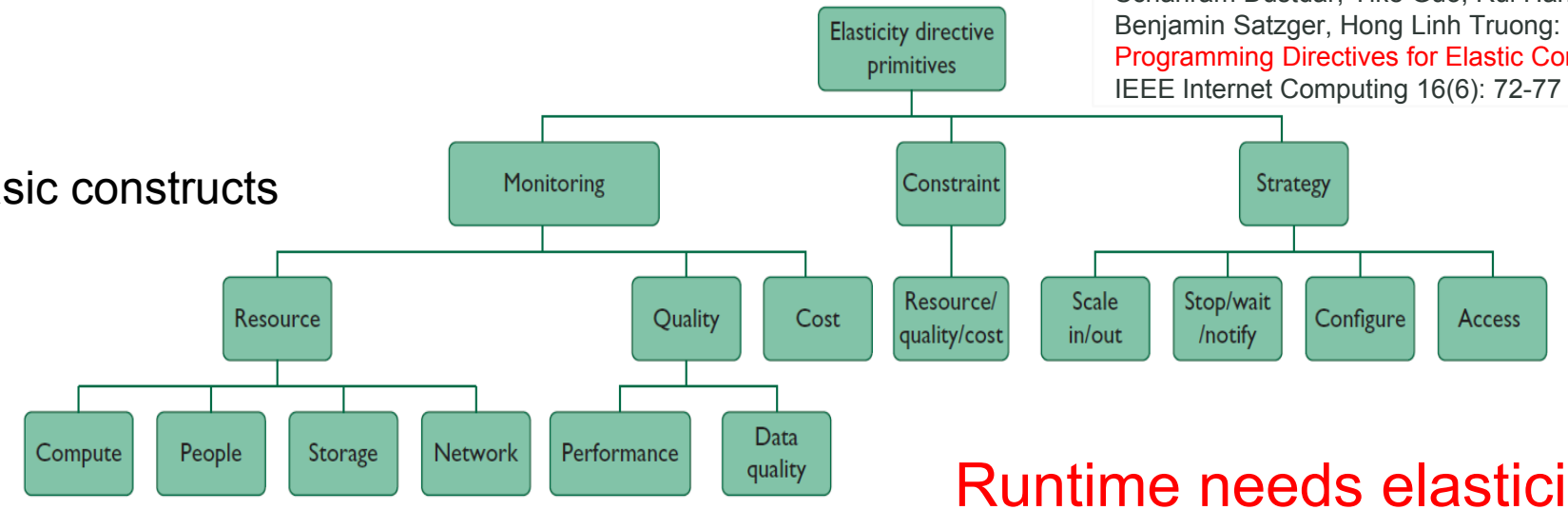


For IoT elements Change communication protocols; change sensor frequency; activating/deactivating sensors, gateways configuration, etc.

Specifying and controling elasticity

Schahram Dustdar, Yike Guo, Rui Han, Benjamin Satzger, Hong Linh Truong: Programming Directives for Elastic Computing. IEEE Internet Computing 16(6): 72-77 (2012)

Basic constructs



SYBL (Simple Yet Beautiful Language) for specifying elasticity requirements

SYBL-supported requirement levels

- Cloud Service Level
- Service Topology Level
- Service Unit Level
- Relationship Level
- Programming/Code Level

Runtime needs elasticity primitive opertations!

Current SYBL implementation

in Java using Java annotations

```
@SYBLAnnotation(monitoring=„“,constraints=„“,strategies=„
“)
```

in XML

```
<ProgrammingDirective><Constraints><Constraint
name=c1>...</Constraint></Constraints>...</Programm
ingDirective>
```

as TOSCA Policies

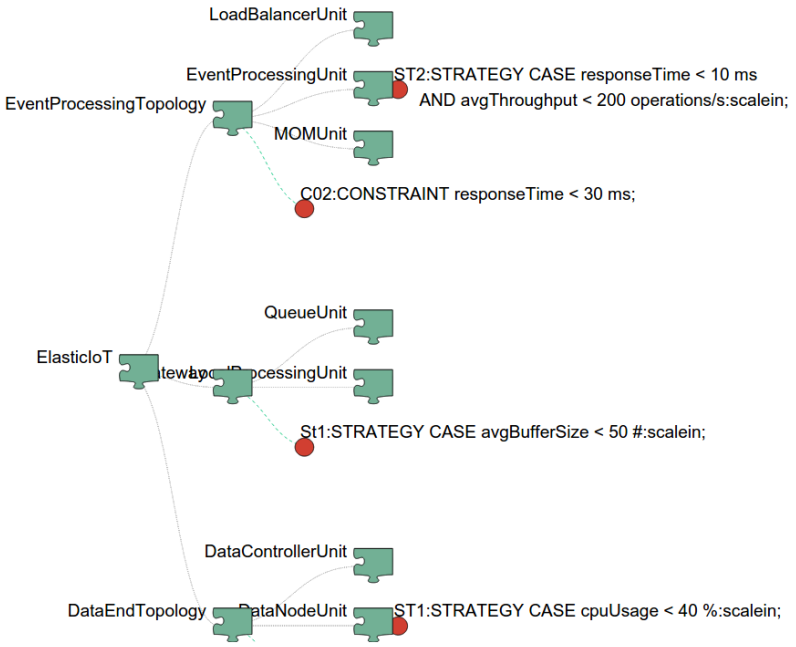
```
<tosca:ServiceTemplate name="PilotCloudService">
<tosca:Policy name="St1"
policyType="SYBLStrategy"> St1:STRATEGY
minimize(Cost) WHEN high(overallQuality)
</tosca:Policy>...
```

High level elasticity control

#SYBL.CloudServiceLevel
Cons1: CONSTRAINT responseTime < 5 ms
Cons2: CONSTRAINT responseTime < 10 ms
WHEN nbOfUsers > 10000
Str1: STRATEGY CASE fulfilled(Cons1) OR fulfilled(Cons2): minimize(cost)

#SYBL.ServiceUnitLevel
Str2: STRATEGY CASE ioCost < 3 Euro : maximize(dataFreshness)

#SYBL.CodeRegionLevel
Cons4: CONSTRAINT dataAccuracy>90% AND cost<4 Euro

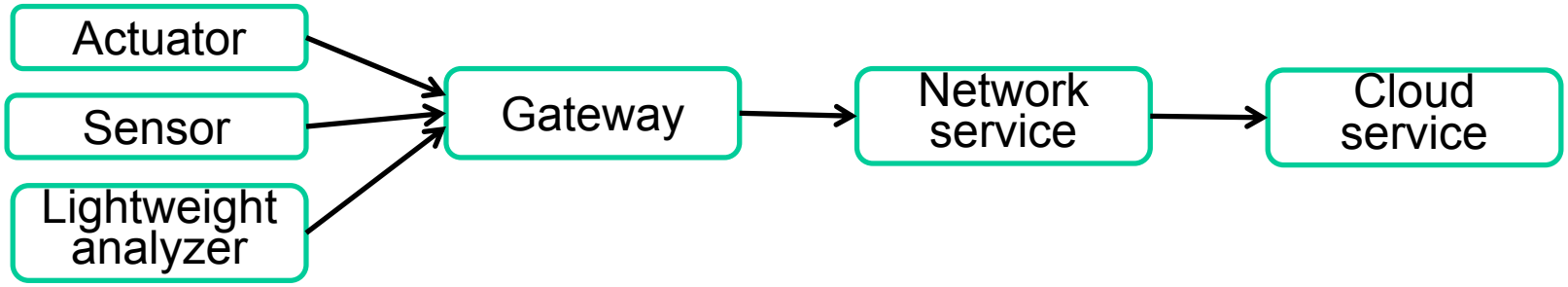


https://github.com/tuwiendsg/rSYBL

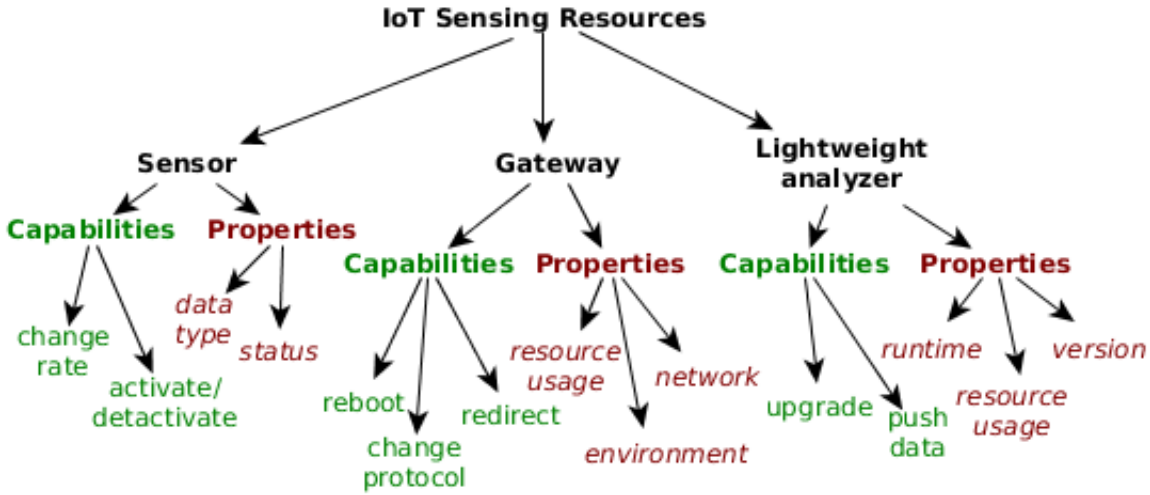
Georgiana Copil, Daniel Moldovan, Hong-Linh Truong, Schahram Dustdar, "SYBL: an Extensible Language for Controlling Elasticity in Cloud Applications", 13th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid), May 14-16, 2013, Delft, Netherlands
Copil, Georgiana ; Moldovan, Daniel ; Truong, Hong-Linh ; Dustdar, Schahram: rSYBL: a Framework for Specifying and Controlling Cloud Services Elasticity, ACM TOIT 2016.

IoT cloud configuration and state information collection

End-to end resources slice for applications



- Multiple types of sensing resources:
- Property: state and metadata.
- Capability: action for the configuration.

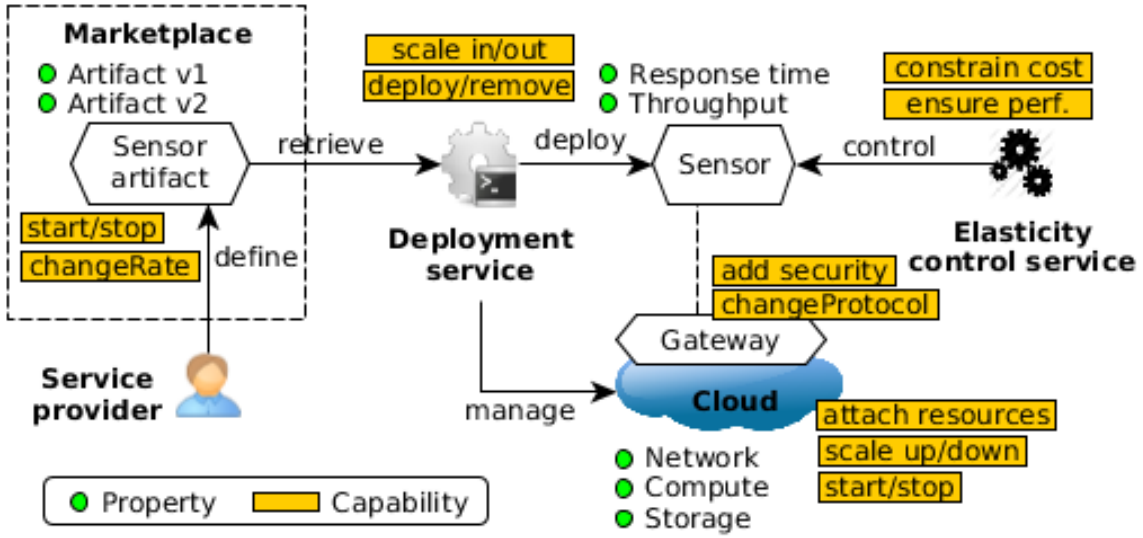


https://github.com/tuwiendsg/SALSA

Information collection

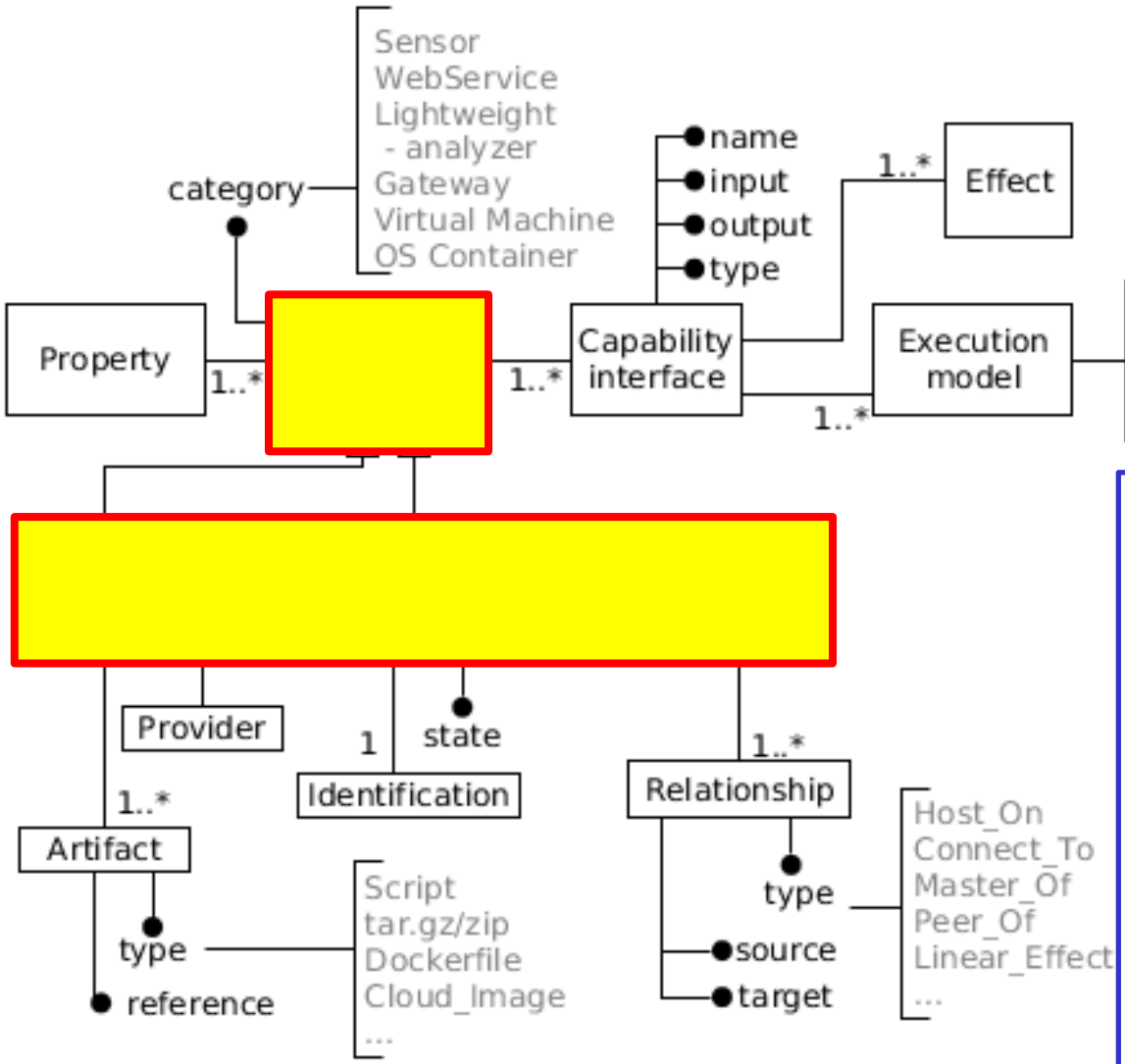
At development time – third-party providers: from repository (e.g., Chef, Dockerhub), marketplace (e.g., Amazon EC2), metadata service (WSO2 IoT marketplace) using different adaptors

Sensing resources: not just sensors



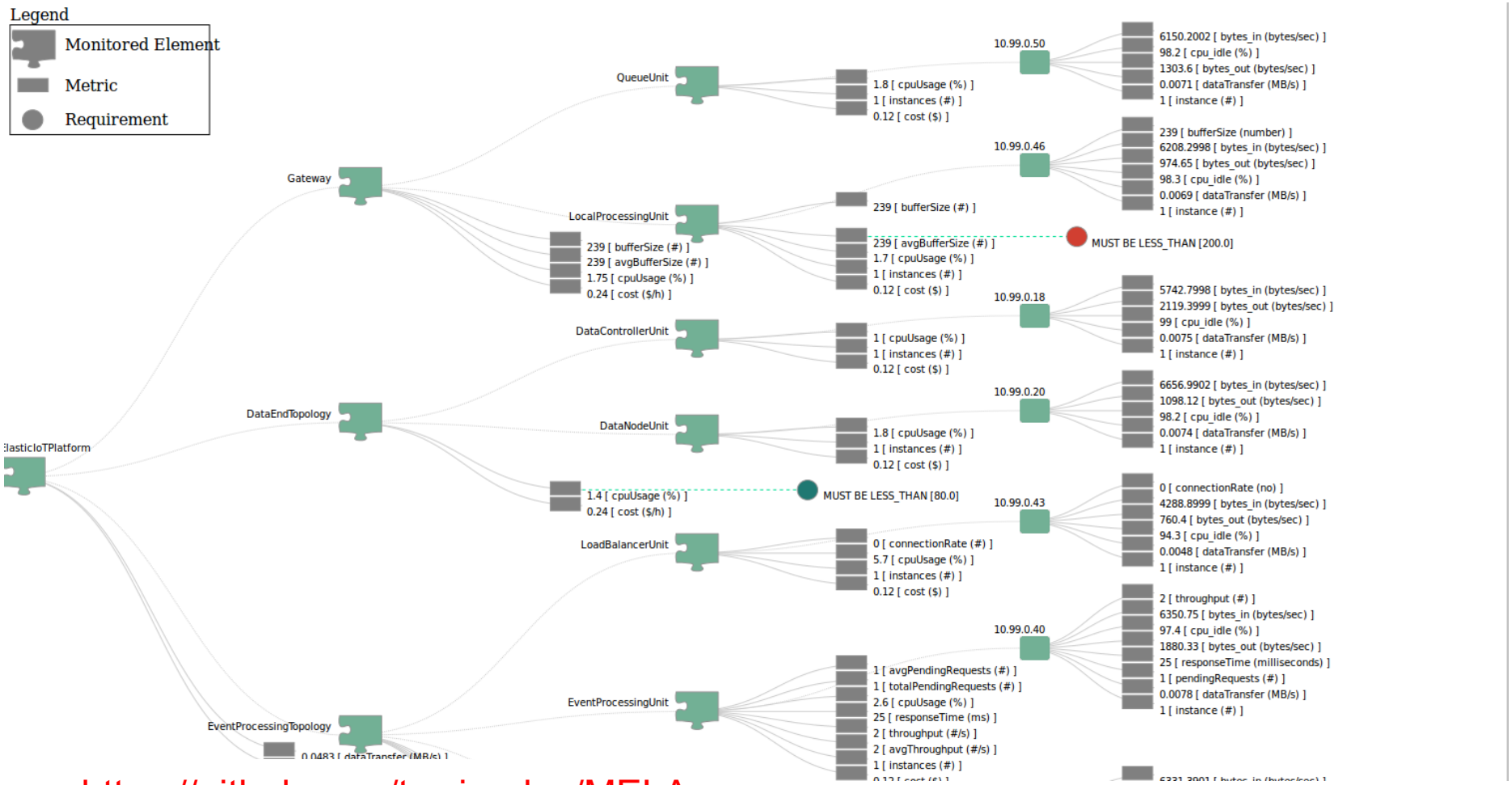
At runtime – management services: from deployment service, monitoring, and controller using domain-specific data model from management service, and resource relationships

Capturing information



- Abstract sensing resources as “service”
- Support dynamic configuration via “capability interface”
- Cover development and operation phases.
- Link static and dynamic information.

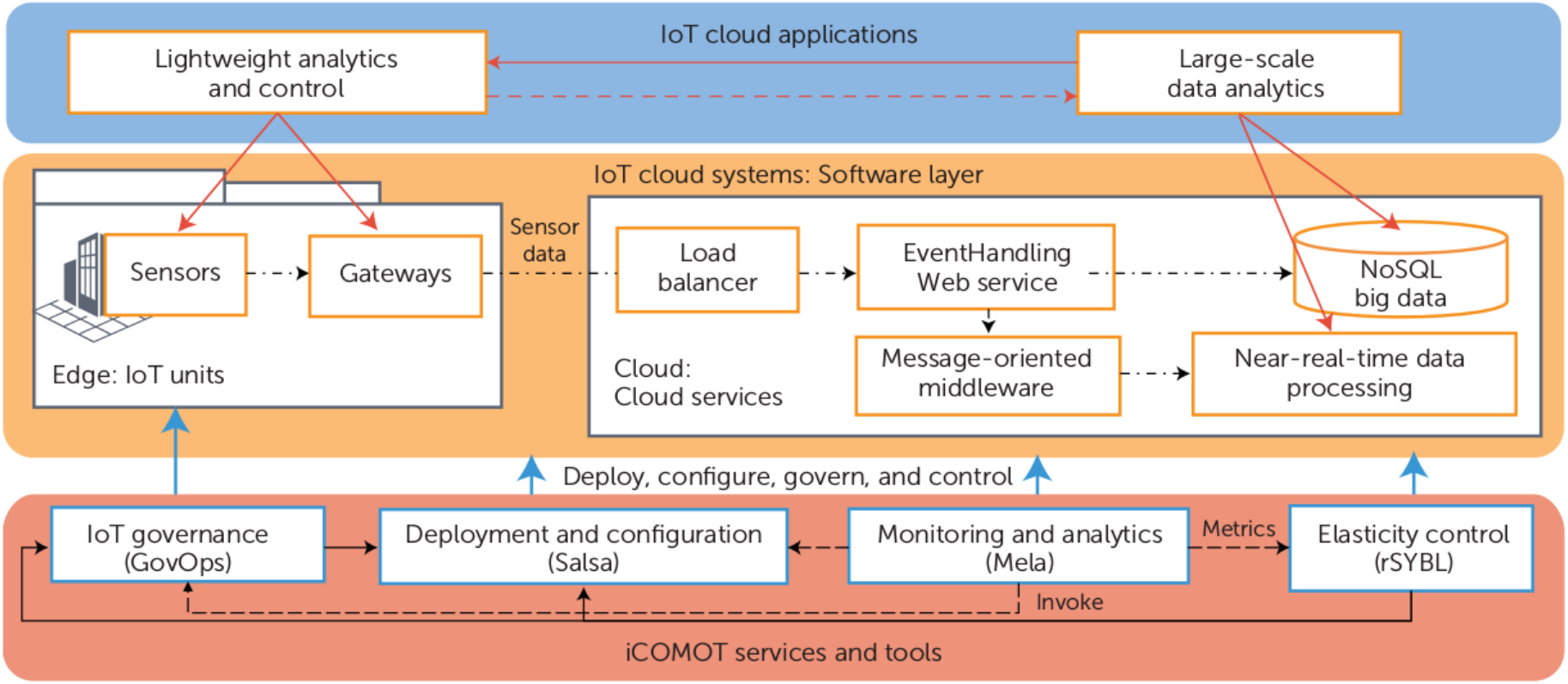
IoT Cloud Elasticity Monitoring



https://github.com/tuwiendsg/MELA

Daniel Moldovan, Georgiana Copil, Hong-Linh Truong, Schahram Dustdar, "MELA: Elasticity Analytics for Cloud Services", International Journal of Big Data Intelligence, 2015, Vol. 2, No. 1

Monitoring, Controlling and Testing IoT Cloud Systems



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

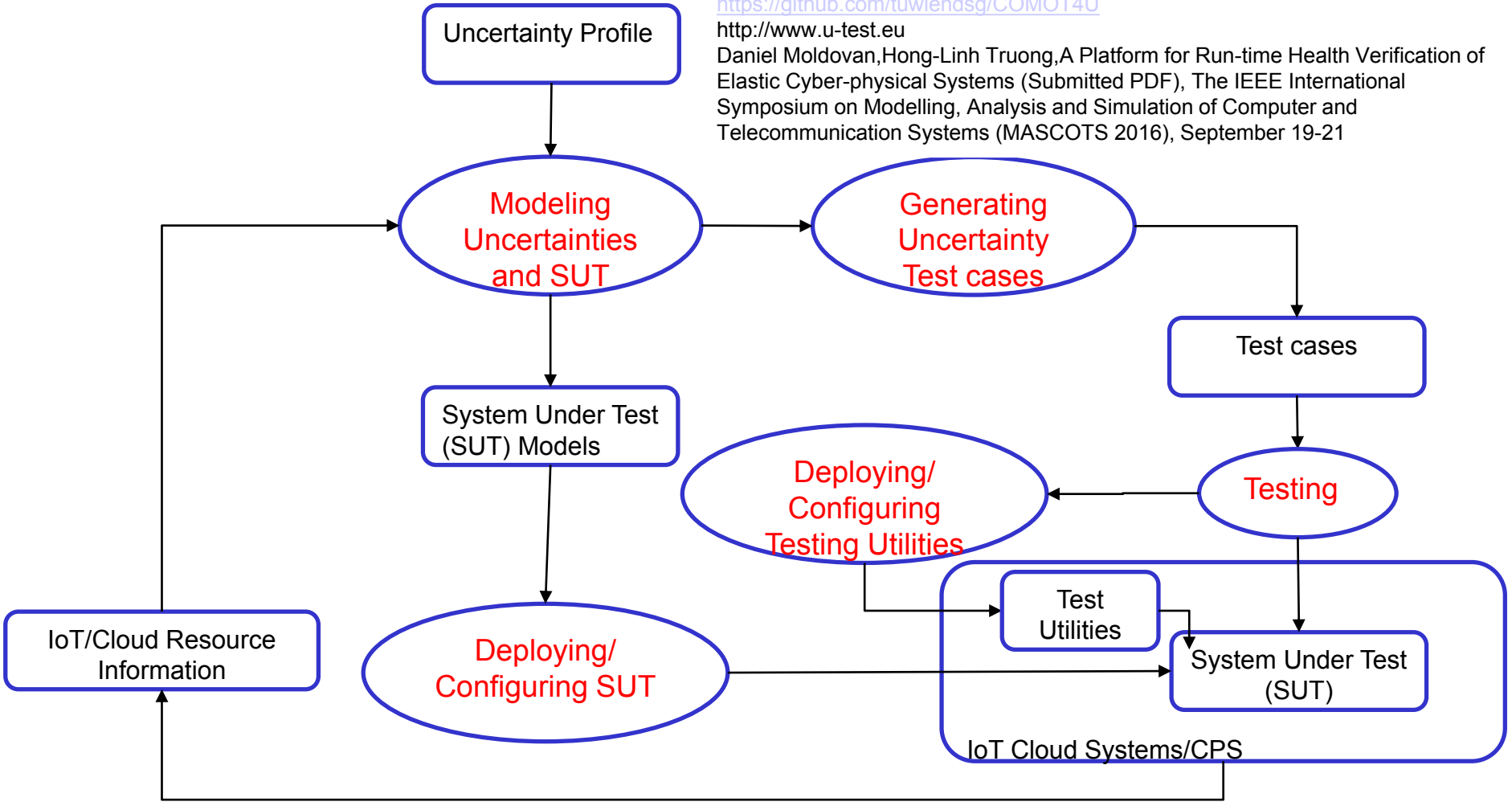
FUTURE DIRECTIONS

Dealing with Uncertainty

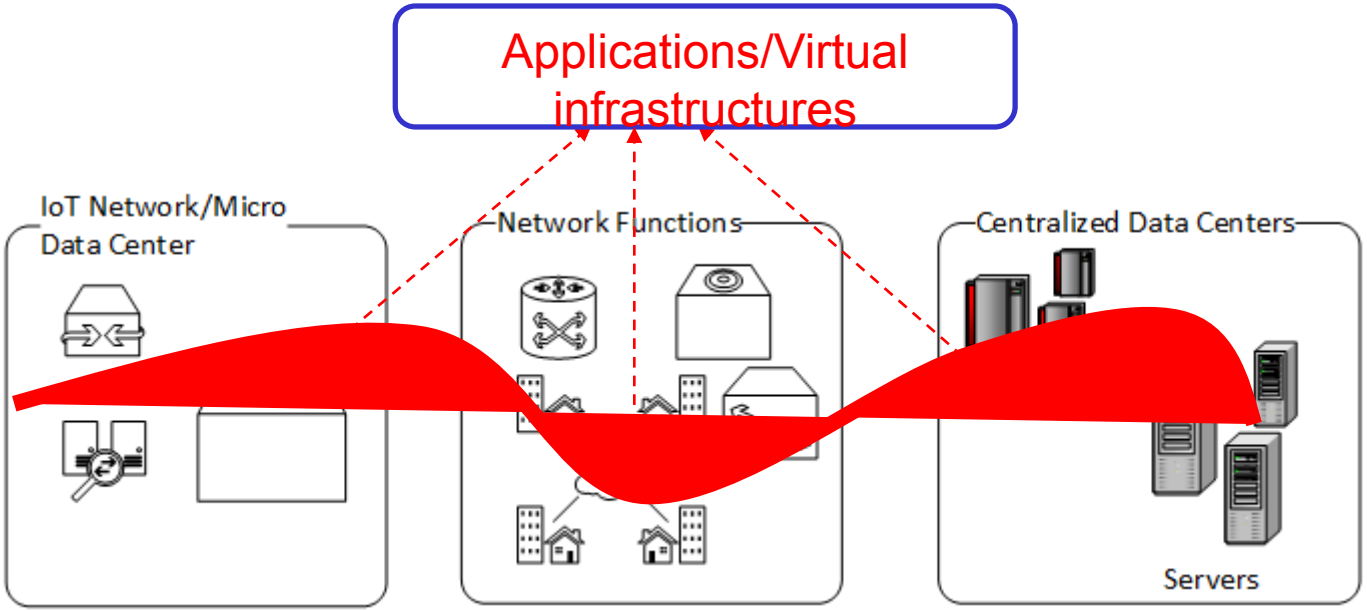
- The presence of uncertainty is pervasive in IoT Clouds
  - Strongly influence function, composition, business, and trustworthiness of IoT Cloud systems
- Emerging types of uncertainties due to the change of
  - Conventional aspects, e.g., infrastructural physical resources and typical system/application operations
  - Emerging novel aspects: data uncertainties (data/data-centric systems), actuations and elasticity of resources, and data governance
- How to discover them and then deal with them?
  - Uncertainty analytics through testing (H2020 U-Test objectives)
  - Also adaptation of resources considering uncertainties

Testing Uncertainties in IoT Cloud/Cyber-Physical Systems

https://github.com/tuwiendsg/COMOT4U
http://www.u-test.eu
Daniel Moldovan,Hong-Linh Truong,A Platform for Run-time Health Verification of Elastic Cyber-physical Systems (Submitted PDF), The IEEE International Symposium on Modelling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS 2016), September 19-21



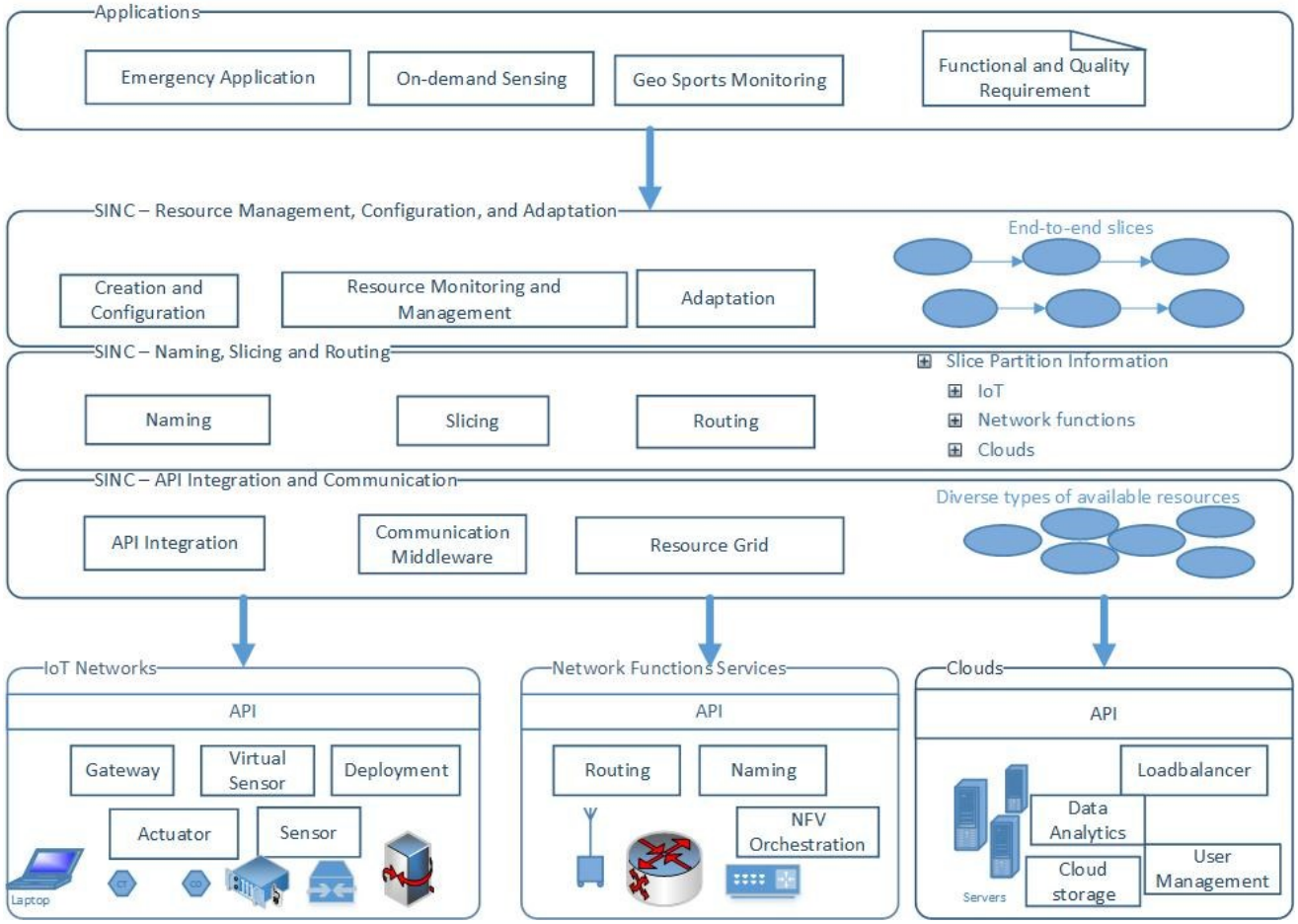
Information-centric resource slice model, provisioning & management



End-to end Resource slice

→ SINC: A conceptual framework for slicing IoT, network functions and cloud resources

SINC conceptual framework



http://sincconcept.github.io/

Hong-Linh Truong, Nanjangud Narendra, **SINC -- An Information-Centric Approach for End-to-End IoT Cloud Resource Provisioning**, International Conference on Cloud Computing Research & Innovation, CloudAsia 2016, May 3-5, 2016

Duc-Hung Le, Nanjangud Narendra, Hong-Linh Truong **HINC - Harmonizing Diverse Resource Information Across IoT, Network Functions and Clouds** The IEEE 4th International Conference on Future Internet of Things and Cloud (FiCloud2016), 22-24 Aug, 2016, Vienna, Austria

Execution policy enforcement for IoT services

- Execution policy enforcement foundations
  - Crucial for service contracts, incident management, security and privacy assurance
- Challenges for execution policy enforcement in IoT cloud systems
  - Multiple stakeholders
  - New business models
    - E.g., IoT marketplaces and smart data contracts
  - Complex chains of data and control flows
  - Virtualization, dynamisms and elasticity
  - Uncertainties create security and privacy problems and vice versa

Execution policy enforcement

- Software-defined machines profiles capturing building blocks for IoT Gateways and edge servers
- New execution policy specifications for software-defined IoT units
- Different policy utilities for manipulating IoT services in IoT gateways and edge server to enforce policies
- Integration techniques between instrumentation, deployment and policy enforcement
- Security properties and their threat models for Interaction patterns for Data flows from IoT to clouds and for Cloud-to-IoT Control flows

Phung H. Phu, Hong-Linh Truong, P4SINC – An Execution Policy Framework for IoT Services, 2016. In submission.

Conclusions

- **Novel scenarios and service models**
  - Require new techniques for provisioning and management of complex IoT, network functions and clouds
- **Engineering Analytics for IoT cloud systems**
  - Virtualization, software-defined capabilities and elasticity for dealing with complex IoT elements and cloud services
  - Coordinating elasticity across IoT platforms and cloud platforms is needed
  - Engineering IoT cloud systems needs a complex set of tools
- **Generic concepts and techniques must be customized for specific environments**
  - E.g., in Vietnam we have different infrastructures and cost models

Outlook (1)

- Elasticity coordination
  - across edge and cloud systems
- SINCConcept
  - Incorporate network function virtualization (NFV) services, distributed resource management
- Test and analyze uncertainties (U-test)
- Execution policy, security and privacy assurance for IoT services
- IoT data analytics

Outlook (2)

Solving complex critical Vietnam/developing worlds situations with IoT and data analytics

vitalconet.github.io

Overview

We are a group of Viet university researchers, freelancers, and companies with a common interest on smart solutions based on IoT and Data Analytics for different application domains in Vietnam. We establish this collaboration network in order to foster joint effort between academics and industries in the development of IoT solutions.

VitalConet Charter

Our collaboration network is operated in the basis of volunteering effort. We create an ecosystem for different stakeholders to exchange ideas and enable them to collaborate. Intellectual Properties associated with a particular research and development work are established through a multual agreement among involved parties in the work. See more our charter here

Research and Development

Currently, we focus on IoT solutions for smart cities and smart agricultures in Vietnam. Some concrete joint research activities at the moment are:
+ IoT data marketplaces for smart cities
+ Smart Grain Warehouse Management in Mekong delta
+ Strengthening Critical IoT Software Development and Training in Highly Volatile and Unreliable Environments

Working groups

A working group focuses research activities in a specific area. Current working groups are
Smart Agriculture

Publications

Several partners from the network have jointly published various types of publications. Publications can be white pages, scenarios, technical briefs and reviwed scientific conferences and journals. Check the list of publications:
Tien-Dung Cao, Huu-Hanh Hoang, Hiep Xuan Huynh, Binh-Minh Nguyen, Tran-Vu Pham, Quang Tran-Minh, The-Vu Tran, Hong-Linh Truong, IoT Services for Solving Critical Problems in Vietnam: A Research Landscape and Directions, (Submitted PDF), IEEE Internet Computing Magazine, 2016.Submitted
Tien-Dung Cao, Tran-Vu Pham, Quang-Hieu Vu, Hong-Linh Truong, Duc-Hung Le, Schahram Dustdar MARSA: A Marketplace for Realtime Human-Sensing Data, Transactions on Internet Technology, 2016, Accepted
Tien-Dung Cao, Hong-Linh Truong, Analyzing and Conceptualizing Monitoring and Analytics as a Service for Grain Warehouses, 8th Asian Conference on Intelligent Information and Database Systems, (c)Springer-Verlag, 14-16 March 2016, Da Nang, Vietnam

Vietnam Journal of Computer Science

http://www.springer.com/40595)

Special issue on
IoT Systems, Services and Analytics for Developing Worlds

Thanks for your attention!

Questions?

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TU Wien

http://rdsea.github.io