This project is funded by European Union

Data4Water

12th Symposium and Summer School On Service-Oriented Computing, June 25 – June 29, 2018 in Crete, Greece

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Data4Water

Fraunhofer FOKUS

United Nations Educational, Scientific and Cultural Organization

IHE DELFT Institute for Water Education in partnership with UNESCO

About me …

- Professor at Freie Universität Berlin since 2008, head of **Corporate Semantic Web** chair
- Director of **Data Analytics Center** (DANA) @ Fraunhofer FOKUS
- Professorial Member at Institute of Applied Informatics (InfAI)
- Director RuleML Inc.; Co-Chair Reaction RuleML Working Group
- Invited Expert at W3C, Voting Member OMG, Secretary OASIS LegalRuleML
- Chair Berlin Semantic Web Meetup Group
- Vice-Director Semantic Technologies Institute (STI) Berlin
- Founding Member Event Processing Technical Society (EPTS) and Co-Chair EPTS Reference Architecture Working Group

Outline

- Introduction ICT-supported Water Management and H2020 Data4Water Project
- Application Examples
  - Literature Analysis for Emerging ICT Trends in Water Management
  - Service Level Agreement for Water Resource Management
- Summary

H2020 Data4Water Project Partners

This project is funded by the European Union

Data4Water

http://data4water.eu

UNIVERSITY POLITEHNICA FROM BUCHAREST, Romania

UNIVERSITA' DEGLI STUDI DI MILANO-BICOCCA, Italy

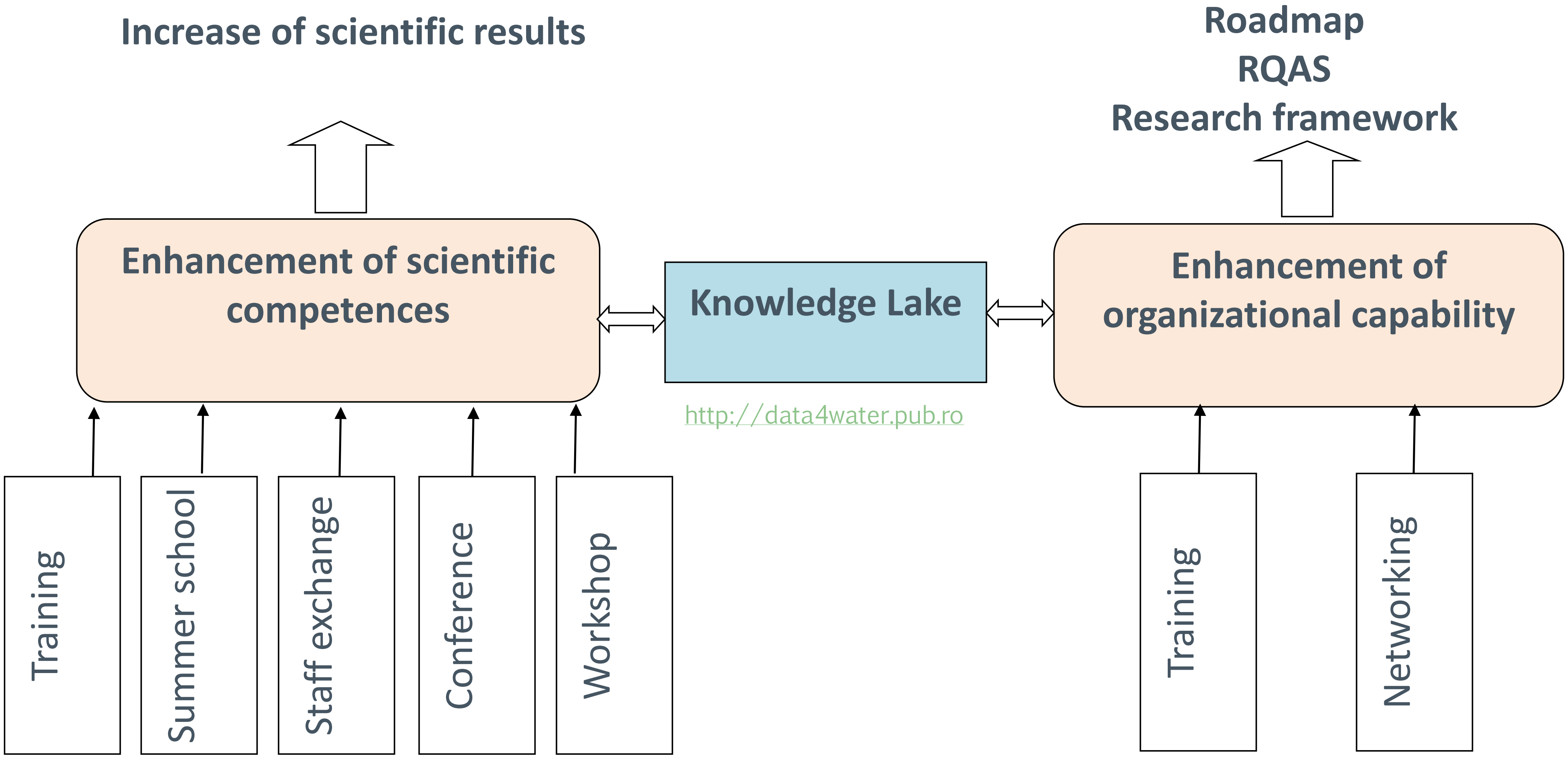
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., FRAUNHOFER INSTITUTE FOR OPEN COMMUNICATION SYSTEMS

IHE-Delft Institute for Water Education, Netherlands

H2020 Data4Water overall objective

› to strengthen research in the field **of smart data driven e-services in water resources management, made available to international community and/or specific stakeholders such as companies, citizens, and authorities**

Project overview



ICT support for Water Management

- Pressures on water resources
- Consequences of climate change
- Need for conservation and sustainability of water resources
- Need for better information and predictions - to understand and to manage water resources
  - water-related decisions are difficult to test on large-scale experiments, hence the importance of computer-based modelling
  - control of water resources must be based on optimal solutions
  - management of water needs a lot of data from various sources

→ need for Computer-based modelling,
Information and Communication Technology (ICT) tools

- modelling, information and communication technology, computer sciences

are applied to problems of aquatic environment

with the purpose of proper management

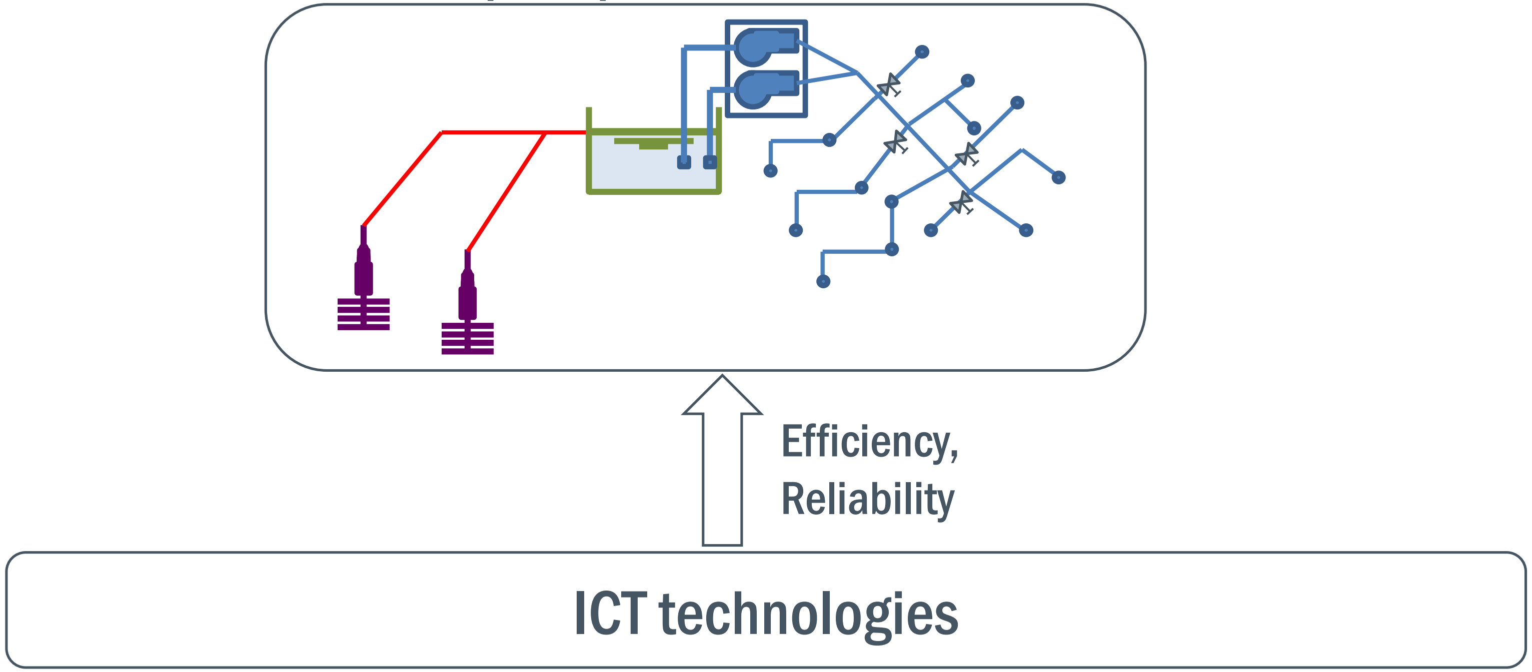
Hydroinformatics
integrates data, models & people

ICT for improved performance of water systems

› Water systems, like any other, have performance goals and objectives

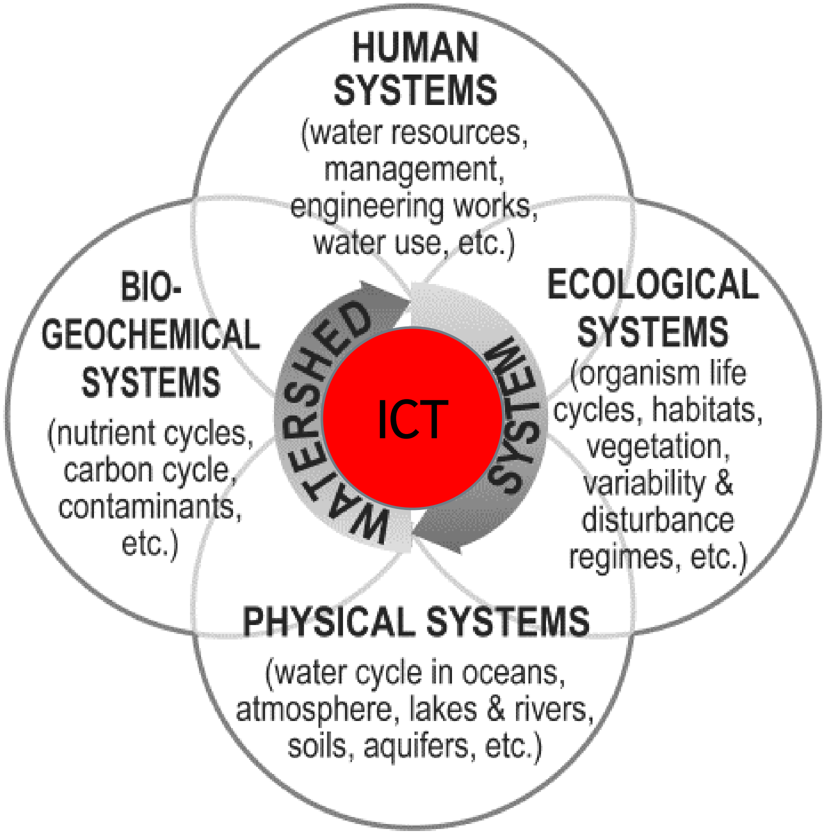
› These need to be met in reliable an efficient manner

› ICT is used for this purposes…



Features of the research field

› Interdisciplinary collaboration in water resource management



Source: M. Muste, “Information-centric systems for underpinning sustainable watershed resource management,” Chapter 21 in “Water Quality and Sustainability” Elsevier, 2013

Features of the research field

- Shift of approach paradigm
  - traditional pillars of the natural systems scientific studies are
    - observation (plus experiment),
    - theory, and
    - analysis (plus computation).
  - modern information and communication technology capabilities
    - allow to address a new class of problems around the organization of data and information leading to knowledge extraction.

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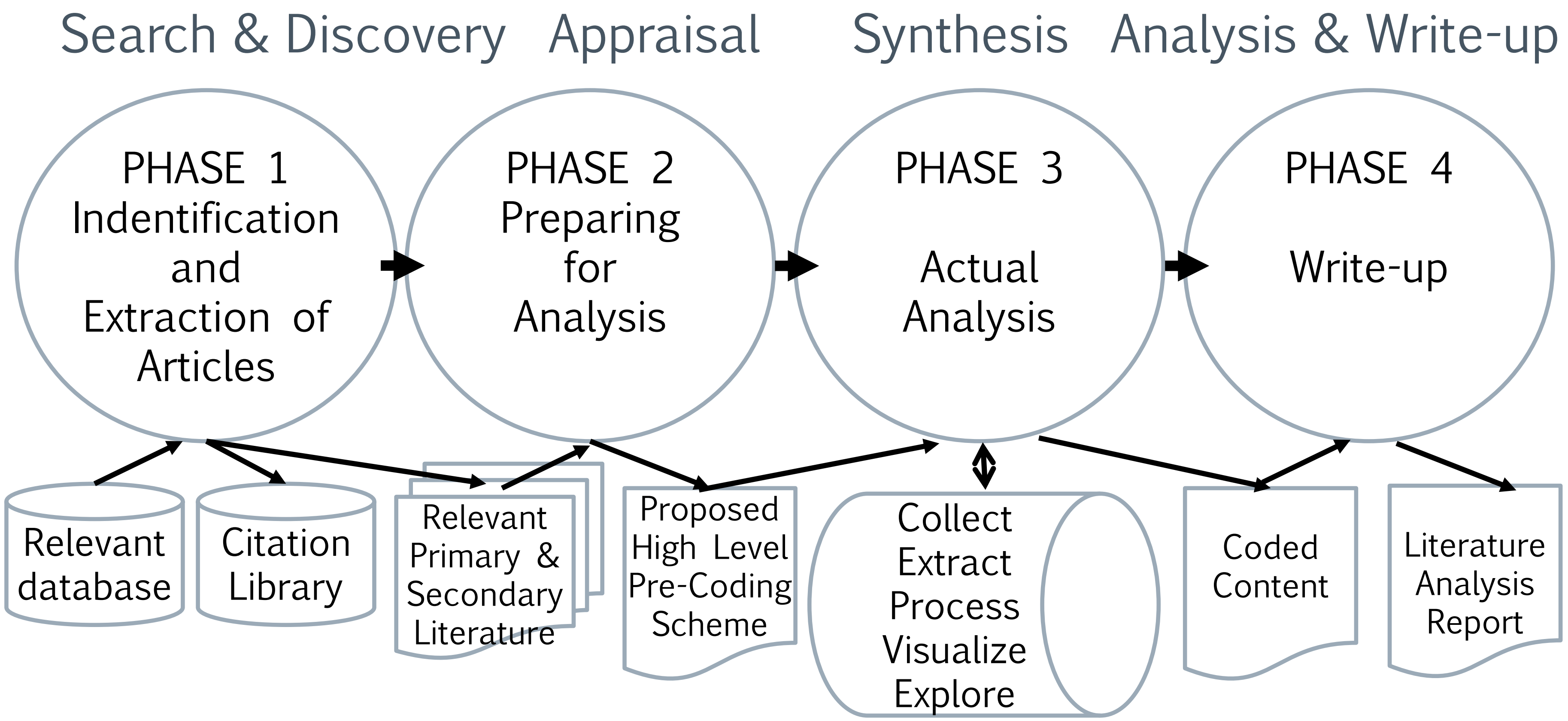
Literature Analysis Process



Literatur Analysis Process - Overview

Phase 1: Identification and extraction of articles

- Selecting the sources
- Search & crawling strategy

Phase 2: Preparing for the analysis

- Introducing coding schemes: What to capture
- Introducing pre-coding guidelines: How to capture

Phase 3: Actual analysis

- Crawl and capture fragments, sentences, paragraphs
- tool-supported text mining analytics & mining
- manual and visual explorative literature analysis

Phase 4: Write-up

- Deriving a descriptive overview of the selected literature
- Reporting on coded findings

- **Definitions**
- **Objectives**
- **Characteristics**
- **Historical analysis**
- **Reported success factors**
- **Reported issues/ failure factors**
- **Research Methods**
- **Theories**
- **Future-work**
- **Contexts of reported studies**

Data4Water

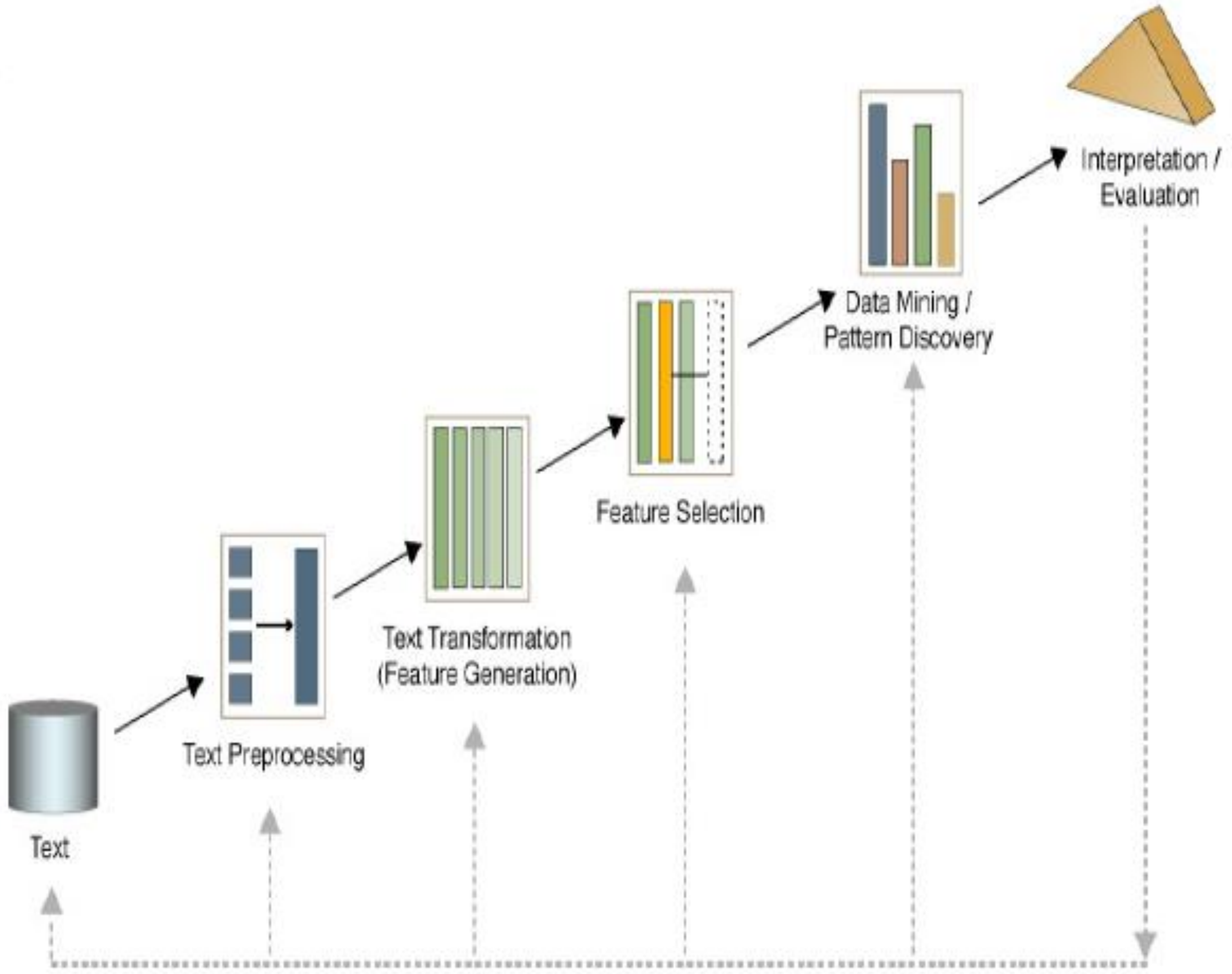
Comparison of different content analysis approaches

Type of content analysis	Study starts with	Timing of defining codes	Source of codes
Conventional content analysis	Observation	Codes are defined during data analysis	Codes are derived from data
Directed content analysis	Theory / Hypothesis	Codes are defined before and during data analysis	Codes are derived from theory or relevant research findings
Summative content analysis	Keywords	Keywords are identified before and during data analysis	Keywords are derived from interest of researchers or review of literature

(Source: Hsieh & Shannon, 2005)

Information Discovery and Text Analytics

1. Discovery
   - Crawling from publication databases
2. Text Preprocessing
   - Syntactic and semantic analysis
3. Features Generation
   - Set of words
4. Features Selection
   - Simple counting
   - Statistics
5. **Text Mining**
   - *Classification* of documents
   - *Clustering* of documents
   - Topic Modeling
6. Analysis of the results
   - Visualization
   - Explorative Analysis



Types of Literature Analysis

- **Systematic Mapping Study**

  A secondary study that aims at classification and thematic analysis of earlier research

- **Bibliometrics**

  Statistical analysis of written publications, such as books or articles

- **Social Network Analysis**

  Examining and investigating social structures (author networks) through network theory

- **Bibliometric Network Analysis**

  Statistical analysis of connections between publications (e.g. citation networks)

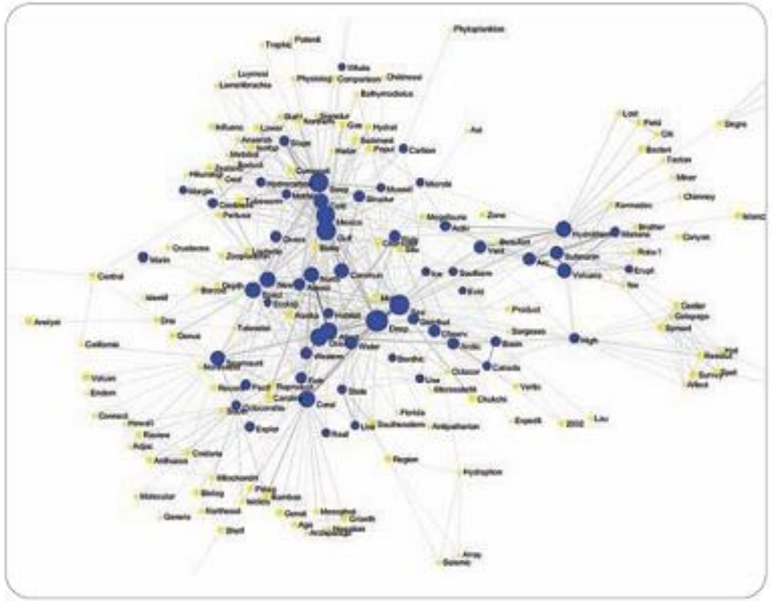
Water Management Literature Analytics with ICT Subjects

- water management
  - backfilling
  - flood control
  - hydraulic structures
  - irrigation management
  - ponding (water management)
  - river regulation
  - stormwater management
  - water allocation
  - water conservation
  - water distribution
  - water reuse
  - water security
  - water utilization
  - water yield
  - wellhead protection

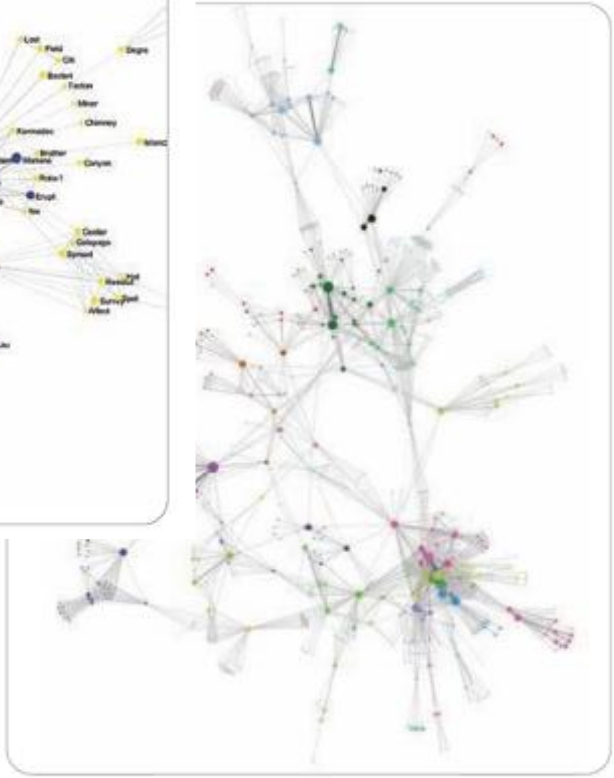
National Agricultural Library Thesaurus (NALT)

Emerging Topics and Technology Roadmap for ICT4Water

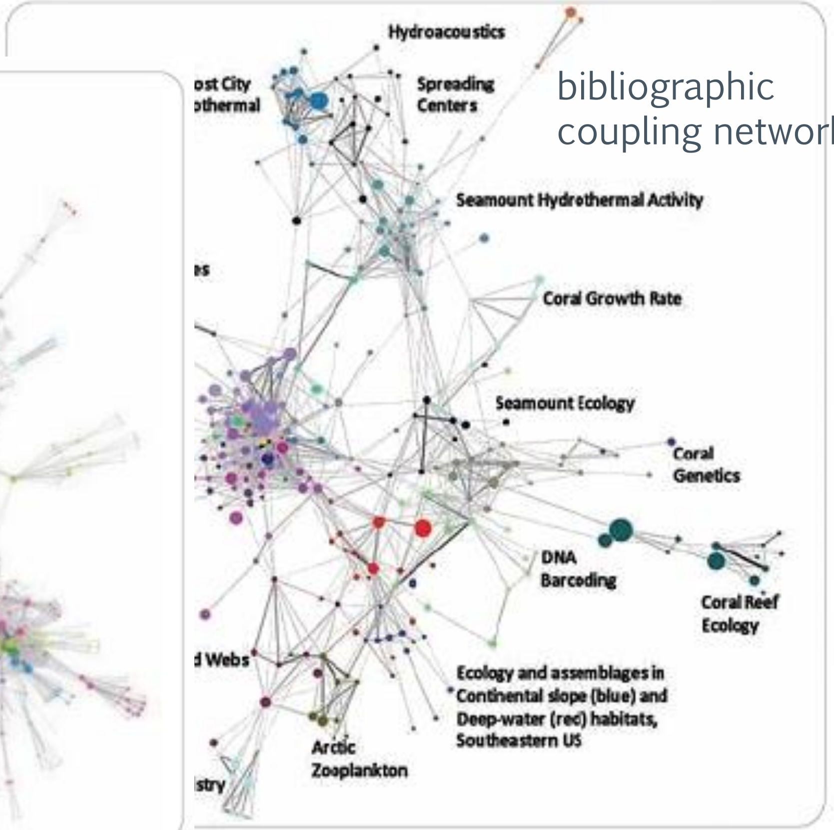
Literature Network Analysis



word co-occurence
network



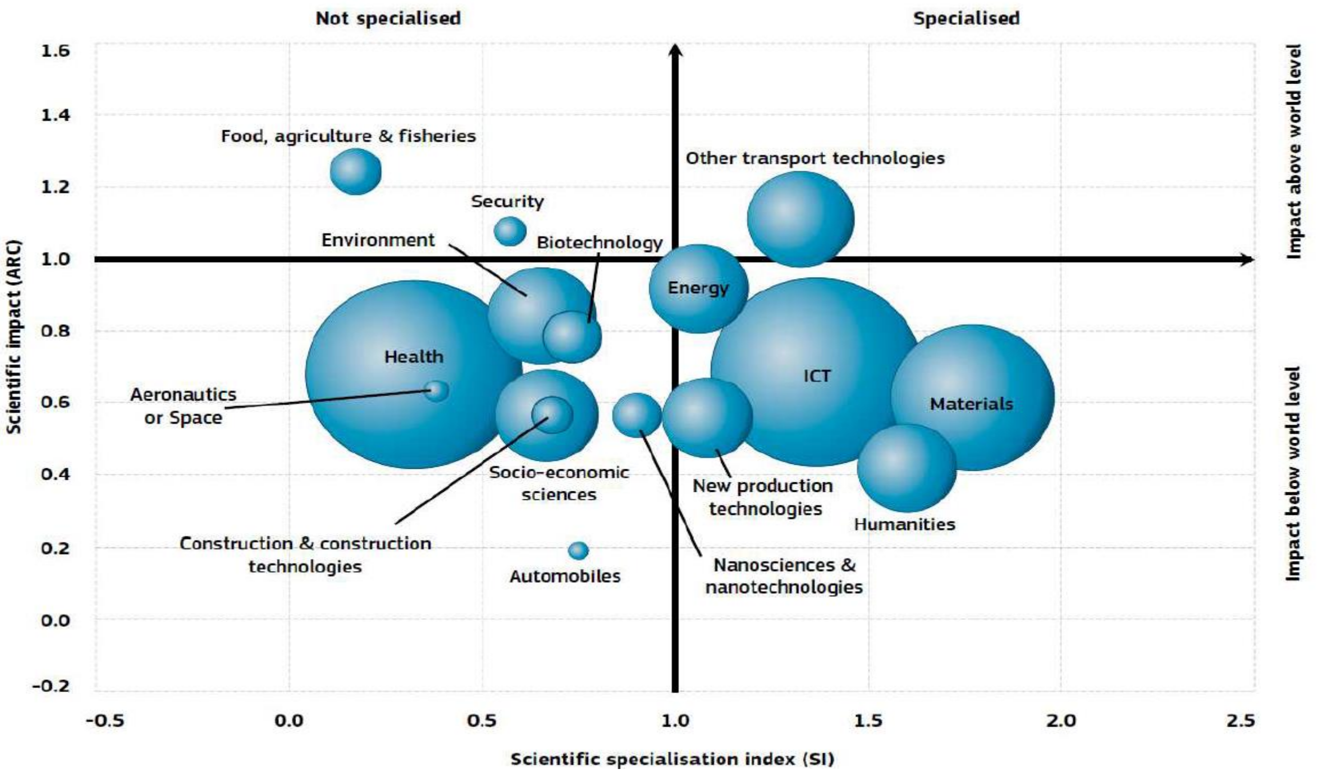
co-author
network



bibliographic
coupling network

Gephi – The Open Graph Viz Plattform

Positional Publication Analysis



Positional analysis of publications in Scopus 2000 – 2010 (source: Digital Agenda Strategy for Romania)

Water Nexus Analysis

Water-food

- Environment:
  - Examining food import and virtual water nexus
  - Improving the efficiency of utilization of green water or the rainwater
  - Preventing depletion of the residual soil moisture
  - Reducing the use of water through a shift to low water consuming crops
- Social & Governance:
  - Promoting design of extension and training programs and public-private partnership
- Economic
  - Microfinance funding model
  - Pro rata pricing system of electricity
- Tools: climate prediction model

Water-energy-food

- Environment:
  - Analyzing the sugar for producing energy as alternative energy
  - Concentrated solar power and woody biomass for producing electricity
  - Investigating the land and water requirements for producing bioethanol from maize
  - Developing trench system to recharge underground aquifers
  - Reduction in irrigation application can result in decline in energy consumption and carbon emission of groundwater use
- Social & Governance:
  - Hydropower investment
  - Power market development
  - Irrigation reform
  - Regional public goods awareness building
- Tools: Multi-scale Integrated Analysis of Social and Ecosystem Metabolism
  - SWAP model
  - Soil Conservation Service Cerrc Number methods
  - Economic calculation (land and water footprints of biofuel)
  - Crop model and integrated Analytical Model

Water-energy

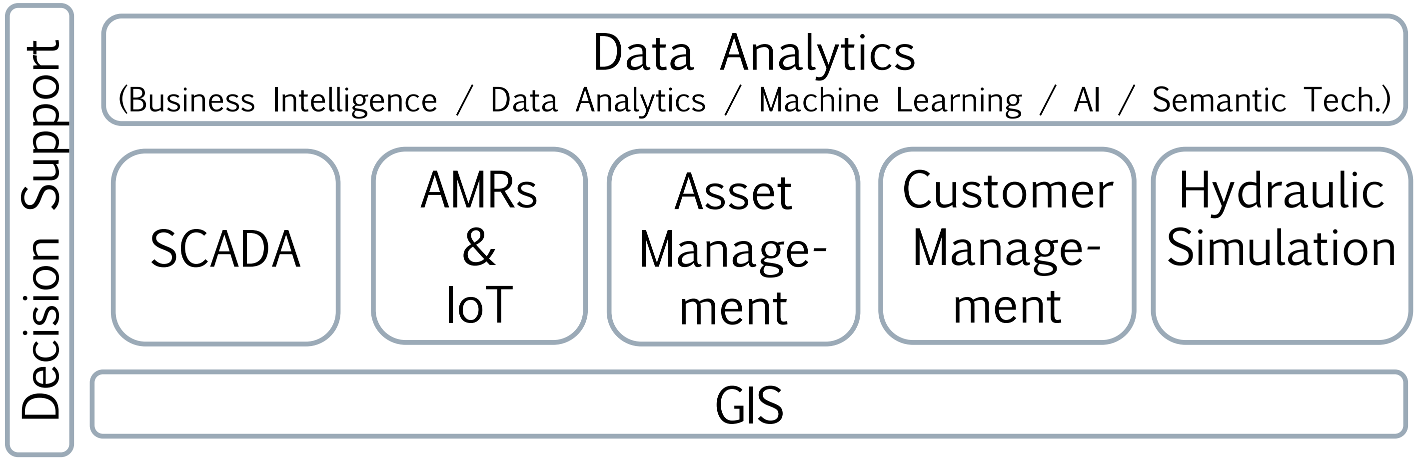
- Environment:
  - Assessment of biofuel (micro-alges)
  - Use of abandoned mines for water storage
  - Use of solar pumps and quench systems for water pumping and billing
  - Waste water treatment plant including shale gas development form a life cycle perspective
- Social & Governance:
  - Improvement of accurate, fine-scale, site-specific data
  - Stakeholder engagement
- Economic: Multiple market management approaches
  - Tariffs and investments
  - Further investigation on life cycle of products
  - Evaluating scenario of carbon and water prices
- Tools: website

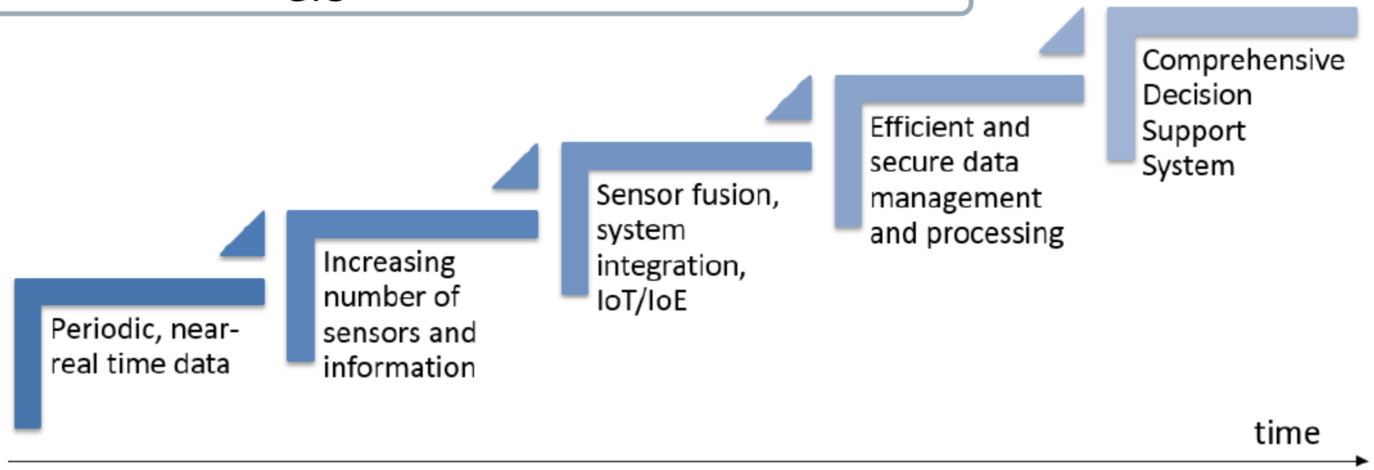
Water-energy-food climate change

- Environment:
  - Reduce vulnerability to climate change induced disaster and environmental degradation taking a longer term
  - Analyzing specific data
- Social & Governance:
  - Development strategies with climate benefits and increase the capability of developing countries
  - Using meteorology and historical data to anchor the relationship of climate change and poverty nexus
  - Addressing the issues of energy use and GhG emissions to associate with water management
- Tools: NDI & NDC

Source: Aiko Endo, Izumi Tsurita, Kimberly Burnett, Pedcris M.Orencio: A review of the current state of research on the water, energy, and food nexus, in Journal of Hydrology: Regional Studies, Volume 11, June 2017, Pages 20-30,
https://doi.org/10.1016/j.ejrh.2015.11.010

Data Analytics in Water Management – ICT Systems





Source: "Emerging topics and technology roadmap for Information and Communication Technologies for Water Management - ICT for Water Management Roadmap", EUROPEAN COMMISSION, Directorate-General for Communications Networks, Content and Technology Smart Cities and Sustainability unit

Technology survey: Prospectives and challenges

- **Section 1 –** ***Introduction***: defines the main concepts and terms used in the document, such as hydroinformatics.
- **Section 2 –** ***Data***: describes the main research directions and challenges regarding
  - data gathering,
  - storing,
  - processing and
  - sharing, for the Water Management systems.

  Several ICT technologies that support such management systems are described, such as streaming data analytics and MapReduce models, as well as the concept of BigData.
- **Section 3 -** ***Water Models***.
  - physically-based models
  - data-driven models

Source: Data4Water D1.1 Technology survey: Prospective and challenges *http://data4water.pub.ro/mod/book/tool/print/index.php?id=104*

Technology survey: Prospectives and challenges

- **Section 4 -** ***ICT based systems for monitoring, control and decision support***
  - Integrated Water Resource Management
  - Event-based monitoring of in stream processes
  - Technologies for near-real-time measurements, leakage detection and localization
  - Cloud Architecture – Datacenters and in-memory computing
  - Mobile Cloud computing
  - Fault tolerance - faults are the norm not the exception
  - Integrated approaches for watershed management
  - Information-centric systems (ICS) for watershed investigation and management
  - Supervisory control and data acquisition systems
  - Decision Support Systems

Technology survey: Prospectives and challenges

- Section 5 - *Participatory / citizen science for water management*:
  - implications of worldwide organizations and communities in the water management field
  - citizen or community science in the context of the European community and, in particular, in Romania
- Section 6 - *Standards:* deals with specific standards needed for the hydroinformatics systems.
- Section 7 - *Priority areas, challenges and research directions in FP7 and H2020 projects*
  - a list with water related FP7 and H2020 projects is provides, along with their main objectives and topics.

Technology survey: Prospectives and challenges

- **Section 8 -** ***Future research directions***
  - Water management solutions that consider synergies across sectors: nexus not only between water and energy, but also with other aspects in Smart Cities land, food, climate change, and smart home ecosystems; need contributions in:
    - monitoring systems
    - predictive models and tools
    - analytical methods to handle climate uncertainty
    - user access to modelling results
    - high performance decision support
  - Improved solutions for social perceptions of water
    - adaptive pricing strategies, legal and policy challenges

Technology survey: Prospectives and challenges

- Section 8 - *Future research directions (cont.)*
  - Reduced total cost of ownership for Water ICT
    - accurate monitoring and understanding of water use, demand and related risks
    - cost-effective technical solutions addressing sensing, analysis, engagement
    - business models with energy consumption monitoring,
    - improved leakage detection technologies
    - analysis (understanding TCO/benefit ratio)
  - Increase interoperability by the use of standards for
    - data formats, vocabularies, procedures,
    - metadata – centralized metadata catalogue
    - software (API)
    - Decision Support Systems – comparability between implementations (technologies, algorithms)
    - common frameworks and KPIs for objective assessment of improvements
  - Measure results in the application of ICT for water management
    - define new indicators related to water management.

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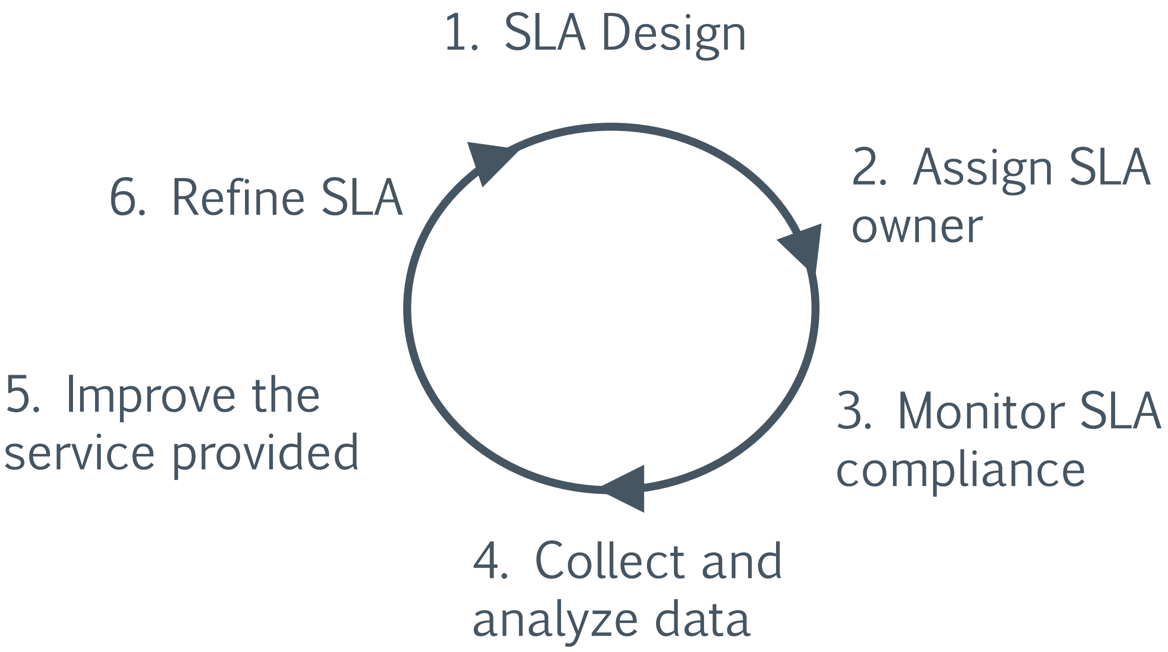
Service Level Agreements

A SLA is a contract that describes the performance criteria a provider promises to meet while delivering a service. It typically also sets out the rights and obligations each person has in a particular context or situation, the remedial actions to be taken and any penalties that will take effect if the performance falls below the promised standard.

- <u>SLA Main Objectives:</u>
  - Verifiable, objective agreements
  - Know risk distribution
  - Trust and reduction of opportunistic behaviour
  - Fixed rights and obligations
  - Support of short and long term planning and further SLM processes
  - Decision Support: Quality signal (e.g. assessment of new market participants)
  - ...

➔ *SLAs are an essential component of the legal contract between a service consumer and the provider.*

SLA Life Cycle



Paschke, A., Schnappinger-Gerull, E.: **A Categorization Scheme for SLA Metrics**, Multi-Conference Information Systems **(MKWI06)**, Passau, Germany, 2006.

Service Level Objective – SLA Metrics

SLA metrics *are used to measure and manage performance compliance to SLA commitments. They play a key role in metering, accounting and reporting and provide data for further analysis and refinement of SLAs in the analysis phase.*

➔ SLA metrics are the heart of a successful agreement and are a critical long term success factor.

Use Case: SLA metrics that measure the performance of a Monitoring Wireless Sensor Network (MWSN) service

Name	Unit
Service availability	Time hour, percent
(Maximum) down-time	Hours or percent
Monitoring Wireless Sensor Network failure rate	Number
Periods of operation	Time
Latency times	ms
Accessibility in case of problems	Yes/No
Number and types of nodes	Number and type
Energy consumed	Watt

George Iordache, Adrian Paschke, Mariana Mocanu and Catalin Negru: Service Level Agreement Characteristics of Monitoring Wireless Sensor Networks for Water Resource Management (SLAs4Water), in SIC Journal (Studies in Informatics and Control), Special Issue Advanced Services in Heterogeneous Distributed Systems, 11/2017

Service Level Availability

- Possible availability issues, e.g. malfunctioning of one or more nodes, communication delay, volatile bandwidth , ..
- **service availability = MTTF / (MTTF + MTTR),**
- Example SLA rules:

"*If the **average availability** falls below 98% then the **mean time to repair** must be less than 10 min.*"

Periods of Operations

- Monitoring schedules, maintenance schedules e.g. for sensors, updates, operation schedules etc.
- Examples

Schedule	Time	Availability	Response Time
Prime	8 -18	99%	4 sec.
Standard	18-8	95%	10 sec.
Maintenance	0-4 *	30%	-

- “*There might be an* ***unscheduled period of time*** *which will be* ***triggered by the customer.*** *During this period* ***bandwidth must be doubled.***”

Rights and Obligations - Accessibiltiy

- Rights to repair, update, etc. require accessiblity and required expertise
- Access allowed: yes / no
  - can be dependent on conditions and assigned to roles
- Example
- “*The provider is **obliged** to repair an unavailable service in* $t_{time\text{-}to\text{-}repair}$. *If she fails to do so (**violation**) the customer is **permitted** to cancel the contract.*”

Level	Role	Time-to-Repair	Rights / Obligations
1	Process Manager	10 Min.	Start / Stop Service
2	Chief Quality Manager	Max. Time-to-Repair	Change Service Levels
3	Control Committee	-	All rights

Maximum Down Time

- Planned Down Time, e.g. maintenance, and unplanned downtime when service is stopped, e.g. due to hardware or network failures

  => predictive maintenance, multi-path routing

- Maximum down time % (per month or per year) = sum(downtimes time spans) / time span (month or year)
- Example SLA rule
  - *If the maximum down-time for one month is above 0.1% then the service provider is obliged to pay a penalty of 10%*

Failure Rate

- Number of failures during the life cycle time
- **λ = number of failures / life cycle time period**
- **Mean Time Between Failures MTBF = $1/\lambda$**
- **Example SLA rule:**
- *If the failure rate for one year is above 0.0011 failures per hour then the service provider is obliged to pay a penalty of 5%*

Latency Times

› Important for data aggregation

› **latency times** in terms of fractions of seconds (e.g. ms) or multiples of seconds

› Example SLA rule:

If the latency times is bigger than 100ms then after two such violations the service provider is obliged to pay a penalty of 5% for every new violation

Number of nodes and types

- refers to how many monitoring nodes and their types were specified in the SLA contract (during design time)

- Examples
- *If the MWSN number of nodes parameter has the value below the agreed value (e.g. 5 nodes) then the MWSN provider needs to solve this problem in 10 minutes otherwise it will pay a penalty of 10% for this violation*
- *If the MWSN types of nodes parameter is smaller than the agreed ones (e.g. 5 different types of nodes) then the MWSN provider needs to solve this problem in 10 minutes otherwise it will pay a penalty of 10% for this violation*

Energy Consumption

› MWSN energy consumed parameter refers at how much energy in terms of Watts the MWSN consumes

› Example SLA rule:

› *If the monthly cost of a Monitoring Wireless Sensor Network is bigger than a specified sum per month (e.g. 100$) then the MWSN customer can revoke the contract with the provider*

Application Example: Water Quality Monitoring Wireless Sensor Networks (WQMWSN) - Availability

- there is a need for robust sensors because the operation of these sensors in a water environment can generate sensor malfunctioning; in the case of node(s) malfunctioning the node(s) that is(are) broken need(s) to be replaced;
- the process of sensor maintenance should be as less frequent as it is possible, and it should last as little time as it is possible;
- providing a power source (battery) that allows the WQMWSN provider to deploy the WQMWSN for as long time as possible; the lifetime of the power source depends on various aspects such as the sensor(s) type and monitoring frequency

WQMWSN Down-time and Failure-Rate

- WQMWSN typically operates on batteries that are replaced when discharged in a certain period of operation
- weekly calibration of the network must be done to get correct results
- possibility that one or more nodes of the network doesn’t function any more
  - data transmitted by the WQMWSN is continuously monitored and actions are taken usually after a cycle time which is specified in the order of minutes, e.g. 20 minutes, 30 minutes
- **failure rate** usually this parameter depends on the ability of the WQMWSN to function when one or more sensor node(s) stop(s) functioning
  - Monitor sensors and replace them (at best pro-active predictive maintenance)

WQMWSN Number and Type of Nodes

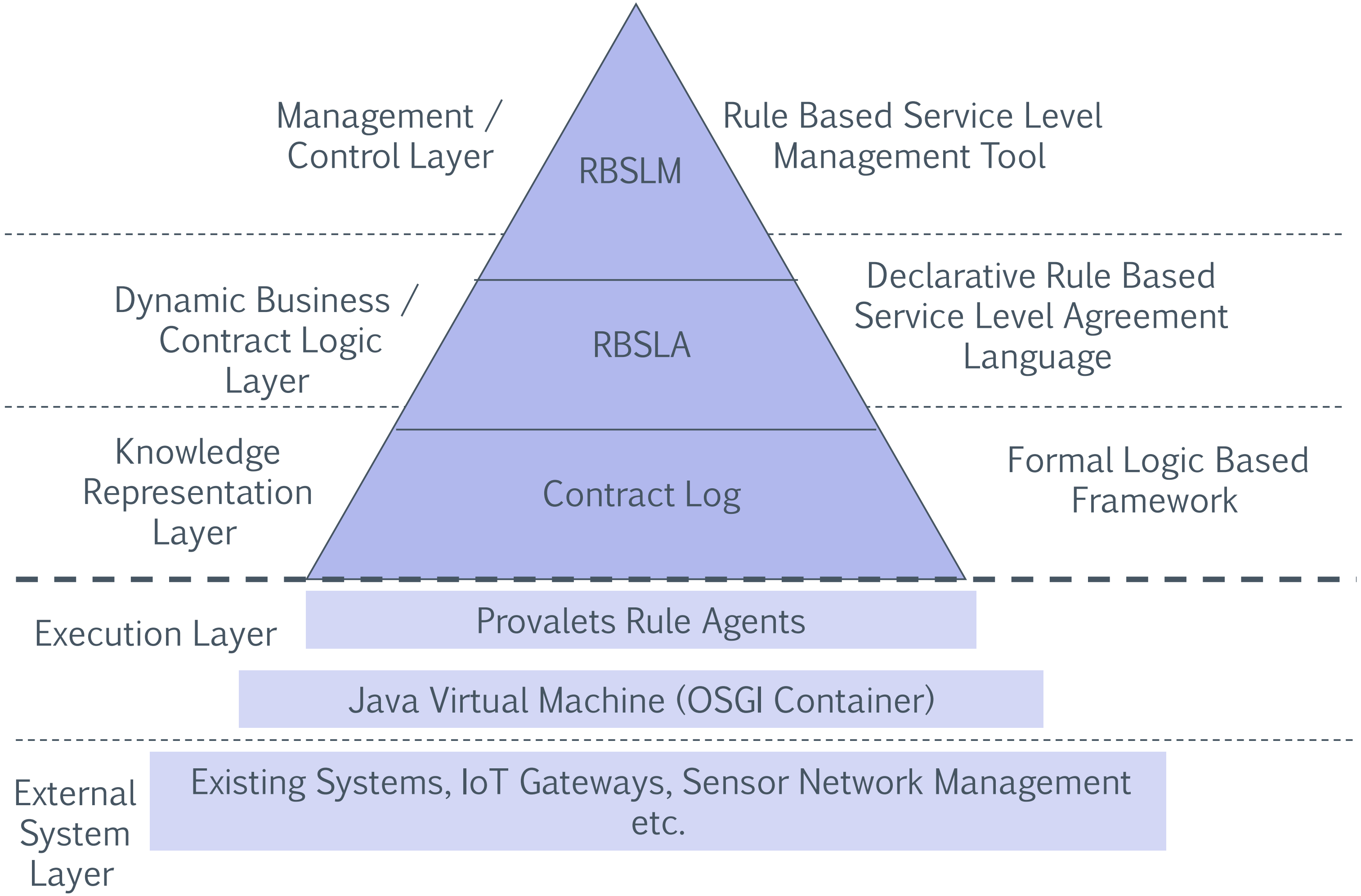
- Dependent on the type of measurements of the WQMWSN, e.g.
- WQMWSN 1
  - I. Submersible Temperature Meter;
  - II. Water pH Meter;
  - III. Water Conductivity Meter;
  - IV. Dissolved Oxygen Sensor;
  - V. Water Turbidity Meter;
  - VI. Water Level Meter.
- WQMWSN 2
  - I. pH sensor that senses the acidity of the water,
  - II. temperature sensor and
  - III. turbidity sensor based on photo-transistor.
- WQMWSN 3
  - I. fluctuations in pH,
  - II. temperature,
  - III. dissolved oxygen.

Summary WQMWSN Optimization

SLA parameter	How to optimize the design characteristic
Availability	Choose good quality, robust sensors
	Use a powerful battery (with a long life)
Down-time	Continuously monitor the WQMWSN
Failure rate	Choose good quality, robust sensors
Periods of operation	Choose a powerful battery (with a long life)
Latency	Choose the WQMWSN components and deploy them in such a way that the sleep / wake up periods are in concordance with the necessities of the WQMWSN customer and reduce the costs of the network
Accessibility	The provider offers either training if the customer needs to have access to perform repairs, upgrades or other changes, or in the case access is not required, the provider must have an optimal maintenance strategy for the WQMWSN in place
Number and types of nodes	The provider offers to the customer the type and number of sensors required by the SLA contract
Energy consumed	Choose low energy WQMWSN

Implementation: Rule-based Service Level Agreements (RBSLA)

http://rbsla.ruleml.org



Adrian Paschke, Martin Bichler: **Knowledge representation concepts for automated SLA management**. Decision Support Systems, 46(1): 187-205 (2008)

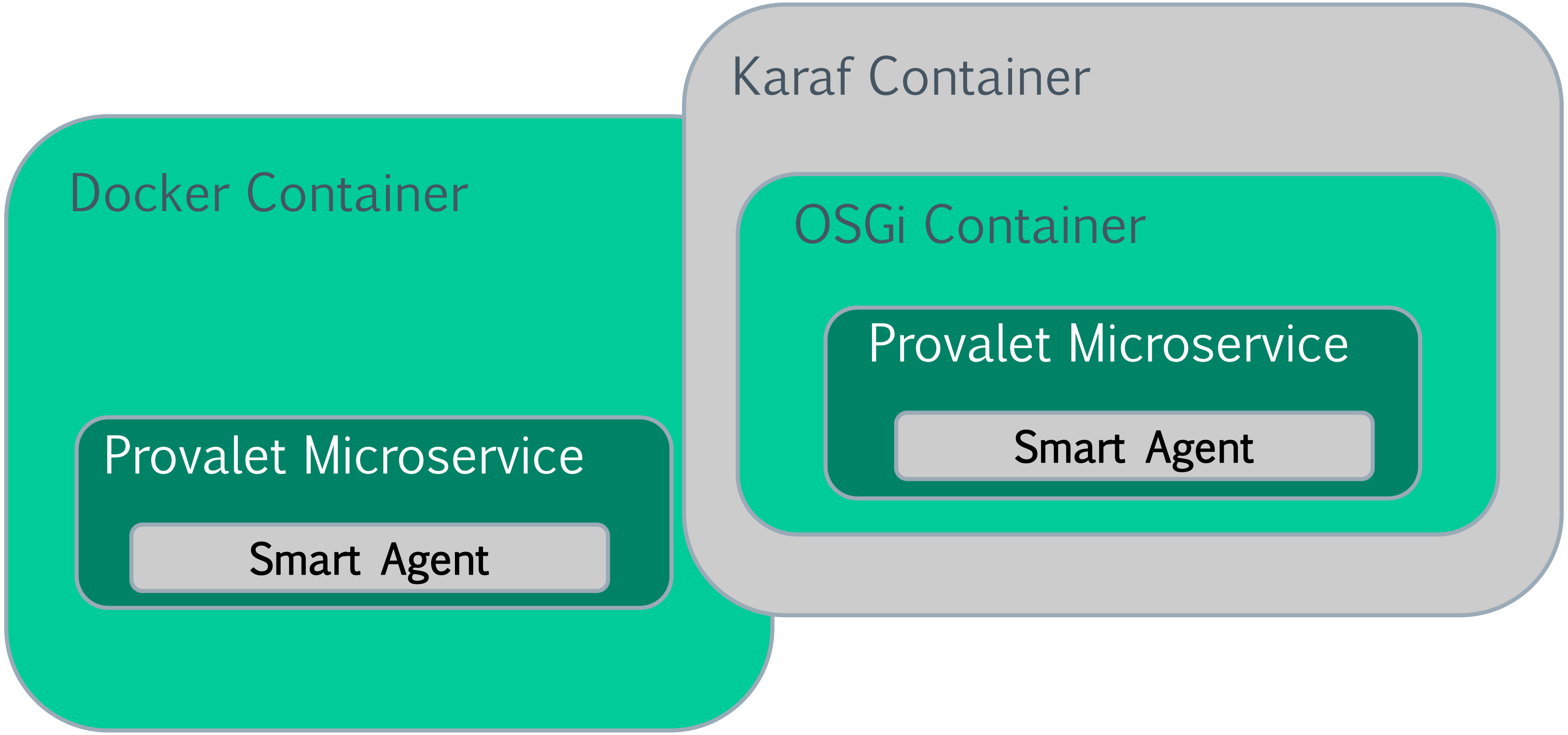
ContractLog - Semantic Knowledge Representation and Reasoning

http://rbsla.ruleml.org/ContractLog

Logic	Usage
Horn Logic	Derivation Rules (rule chaining) + Negation as Failure, Procedural Attachments, External Data Integration, Typed Logic
Event-Condition-Action rules (ECA)	Active behaviour (events, actions) + Update primitives for Active Rules
Event Calculus	Temporal reasoning over effects of events on fluents (contract tracking)
Defeasible logic	Conflict resolution, default rules and priority relations of rules.
Deontic logic	Rights and obligations with violations an exceptions of norms.
Description logic	Contract vocabularies, domain-specific concepts (term typing)

Paschke, A., Bichler, M., Dietrich, J.: ContractLog: **An Approach to Rule Based Monitoring and Execution of Service Level Agreements**, International Conference on Rules and Rule Markup Languages for the Semantic Web **(RuleML 2005)**, Galway, Ireland, 2005.

Provalets – Micro-service Rule Agents



Adrian Paschke: **Provalets – Component-based Mobile Agents for Rule-based Data Access, Processing and Analytics**, Special Issue on Linked Data in Business in Journal of Business & Information Systems Engineering (BISE), 5/2016

Edge Intelligence Solutions

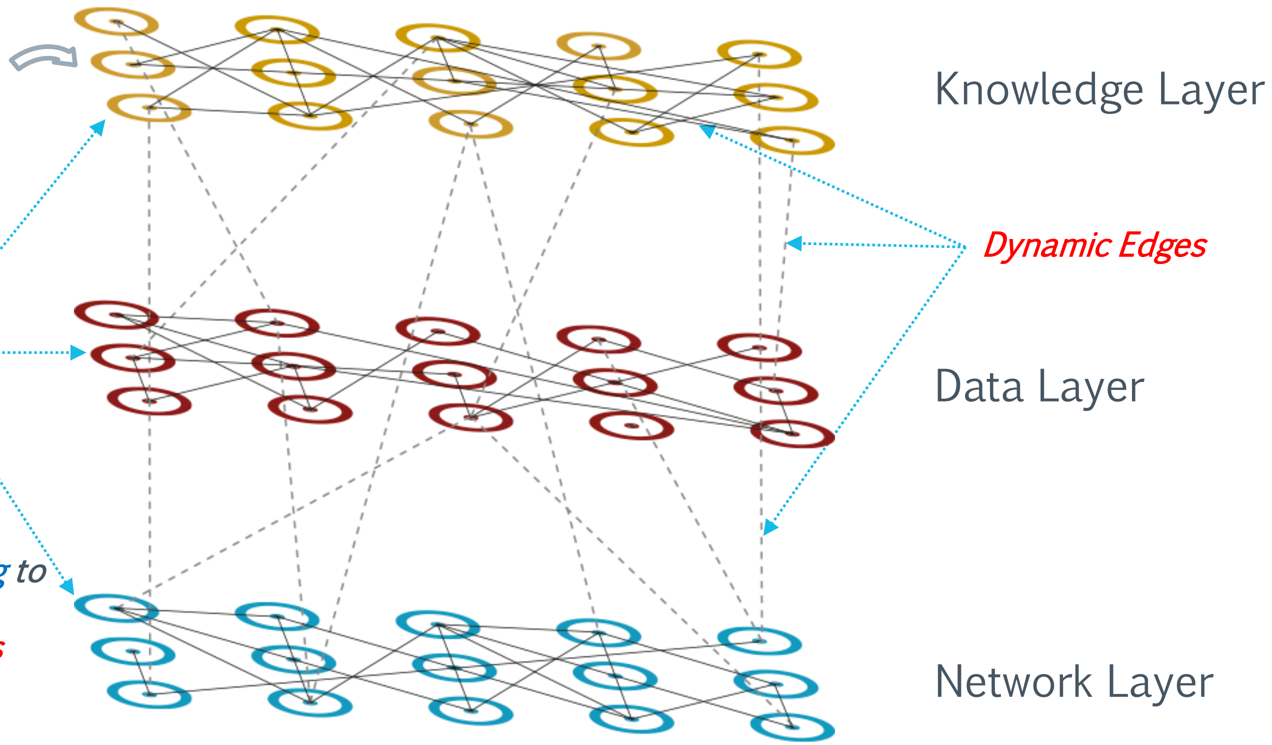
Service Level Agreements with Service Level Objectives

⇩

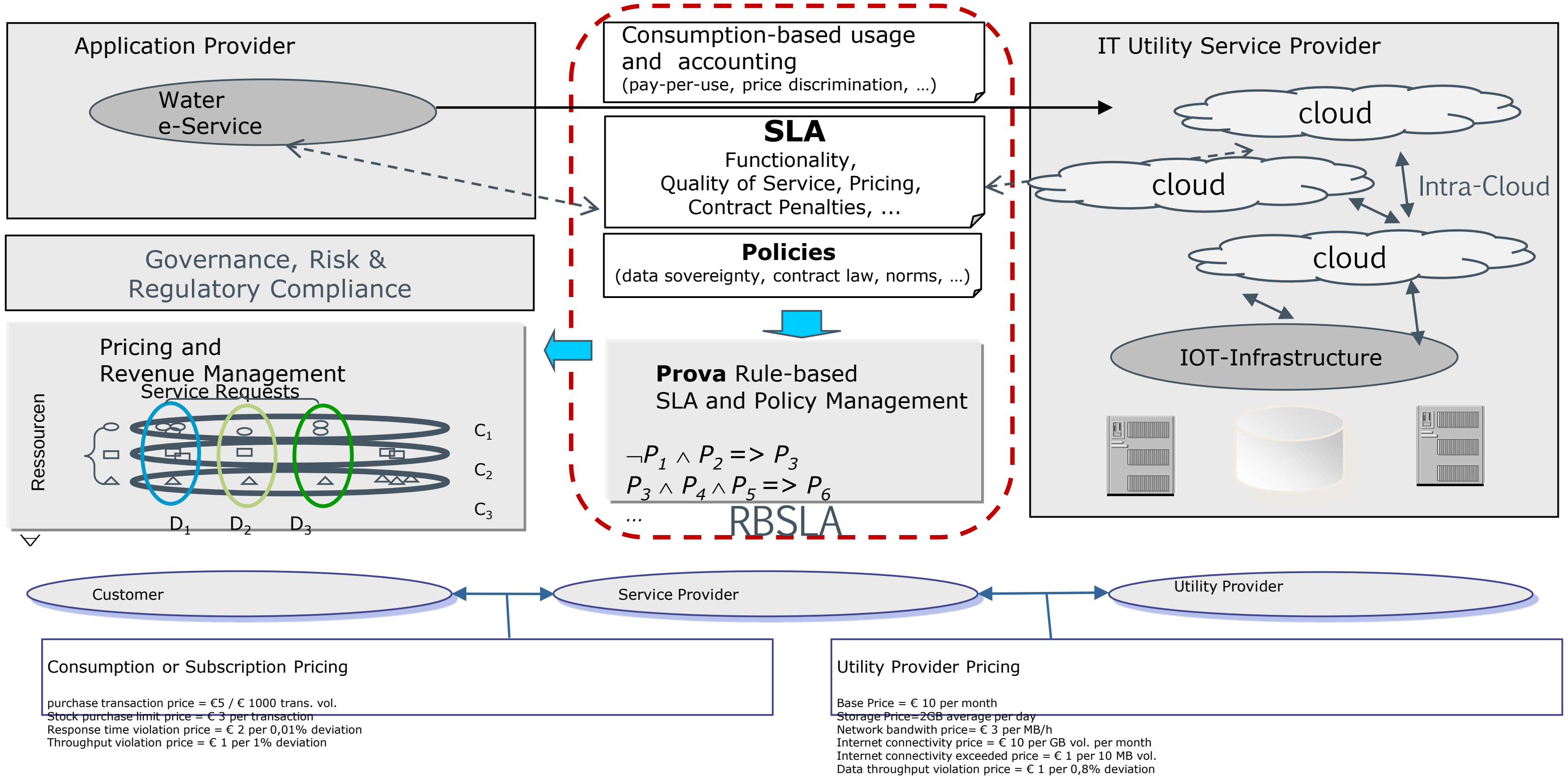
Dynamic Task Decompo-sition, Knowledge-based Mapping, Data-driven real-time Execution

⇩

Local Cognitive Edge Processing to address encapsulation, privacy hiding and security at the edges



IT Service Management - SLA-based Utility Computing and Policy Solution



Summary

- water management is a complex system with interrelated processes surrounding the water cycle and the water nexus
- new ICT-supported water management approaches require processing of a huge amount of data with different levels of quality, accessibility and availability to achieve (SLA-based) performance goals and objectives
- often the data acquisition needs to be acquired, transmitted and accessed in real time and processed at the edge for real-time decisions and reactions as well as post-processed in the cloud, e.g. for calibration and validation of models.

Thank you!

DATA4WATER

Project website: **http://data4water.eu**

Networking and Knowledge E-Environment

http://data4water.pub.ro

Data4Water: Network of Excellence and Partnership in Smart Data for Water Management.

Join us on LinkedIn - https://www.linkedin.com/groups/13502078

This project is funded by the European Union

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