



Intelligent future data-aware decision making

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Alan Turing Network for AI in Geotechnics

Advanced Research Centre of University of Glasgow



At a Glance



2016 Call
Marie Skłodowska-Curie
Action (MSCA)
Individual Fellowship
School of Computing Science
University of Glasgow

July 2020
Founder of the
Intelligent Pervasive Systems
(iPRISM) Research Group
<http://www.iprism.eu>

- Current Activities:
- Applied Artificial Intelligence and Machine Learning
 - Distributed Intelligence
 - Pervasive Data Science



2013
PhD in Computer Science
National and Kapodistrian
University of Athens

June 2020
Assistant Professor
Department of Informatics
and Telecommunications
University of Thessaly
<http://kostasks.users.uth.gr>

Oct. 2020
Co-Founder of the Intelligent
Systems for Orchestrating
Pervasive Computing Applications
(METIS) Research Lab
<http://metis.cs.uth.gr>

Dec. 2020
Director of the METIS Lab

At a Glance



Intelligent Pervasive Systems
(iPRISM)

<http://www.iprism.eu>

Lead: Dr Konstantinos (Kostas) Kolomvatsos

Research axes:

- Artificial Intelligence
- Applied (Deep) Machine Learning
- Computational Intelligence
- Distributed Intelligence
- Pervasive Computing
- Pervasive Data Science
- Proactive Decision Making
- Applications for Distributed Systems, Internet of Things, Edge Computing
- Predictive Intelligence
- Large Scale Data management



Recent Research



01

Intelligent Systems in Pervasive, Edge Computing and Internet of Things

02

Contextual and Fuzzy Logic Reasoning for Pervasive Computing

03

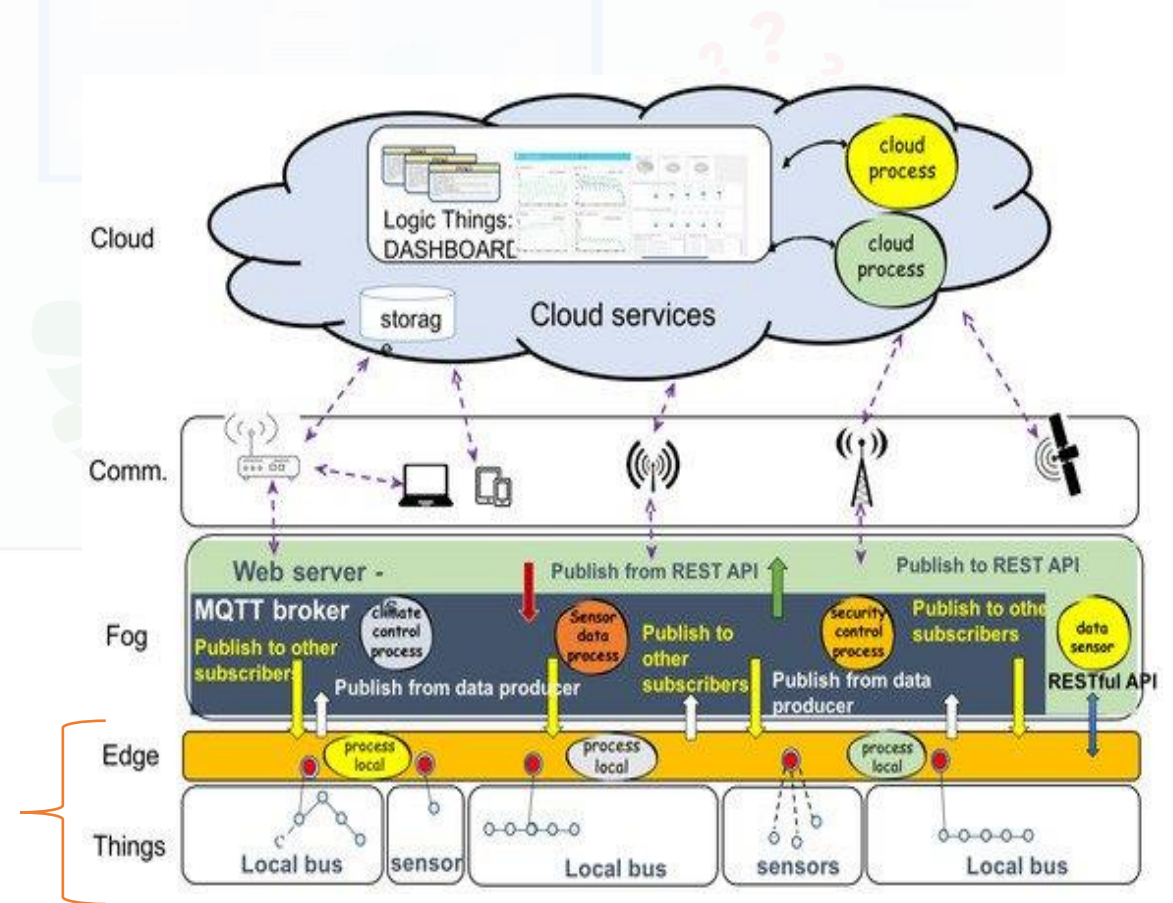
Proactive Reasoning for Autonomous Behaviour and Decision Making

04

Pervasive Data Science Applications

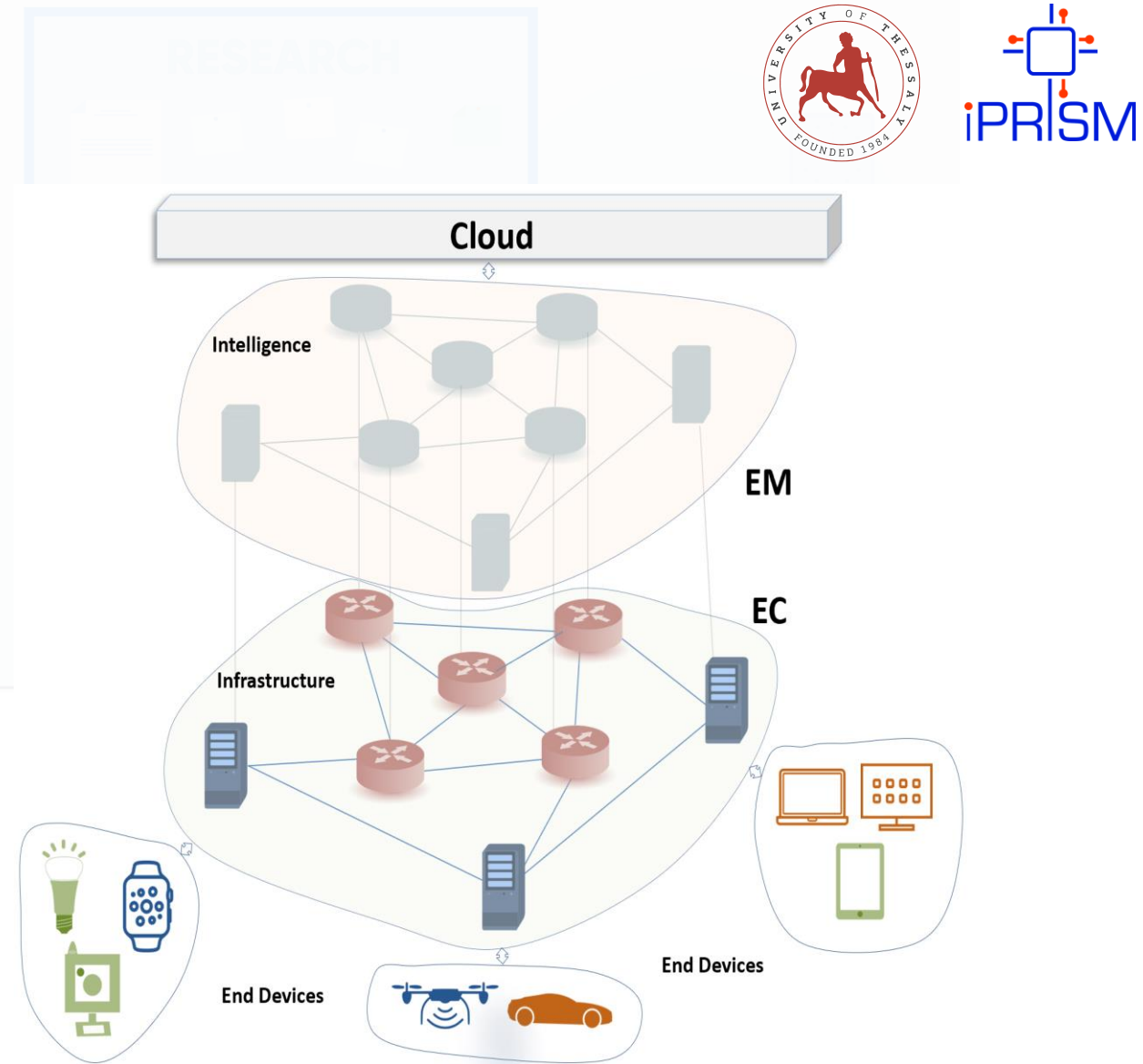
Edge Computing

- Edge Computing (EC) deals with an additional infrastructure above the Internet of Things (IoT)
- EC 'imposes' an ecosystem of processing nodes that can execute tasks upon the collected data
- Gartner shared a report on ten (10) strategic trends affecting the Internet of Things (IoT) from 2019 to 2023 and beyond where the following are identified as the most impactful:
 - Artificial intelligence (AI)
 - The shift from intelligent edge to **intelligent mesh**
 - New IoT user experiences



Edge Computing

- We are at the early stages of the EC revolution to prepare the infrastructure for the new, modern, **Edge Mesh (EM)**
- EM provides a ‘virtual’ layer (a computational/processing overlay) that enables the cooperation between heterogeneous EC nodes to conclude a cooperative infrastructure close to end users
- Operators can/should/will open the ecosystem to third-parties, allowing them to rapidly deploy innovative applications and content



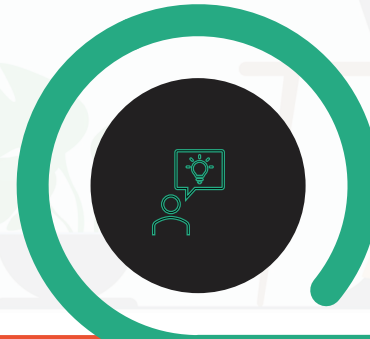
Research Questions



How to define the network and computing model?



How to distribute data processing?

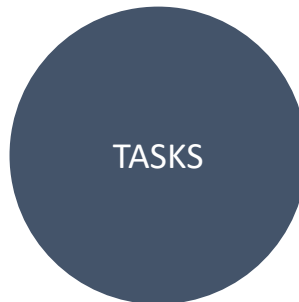


How to jointly optimize computation?



How to be stateful, i.e., exhibit different behaviour even for the same data according to the conditions met at a time instance?

Research Axes



- ✓ A data map of the ecosystem in support of data-aware decision making
- ✓ Proactive inference of nodes 'matching' based on their data

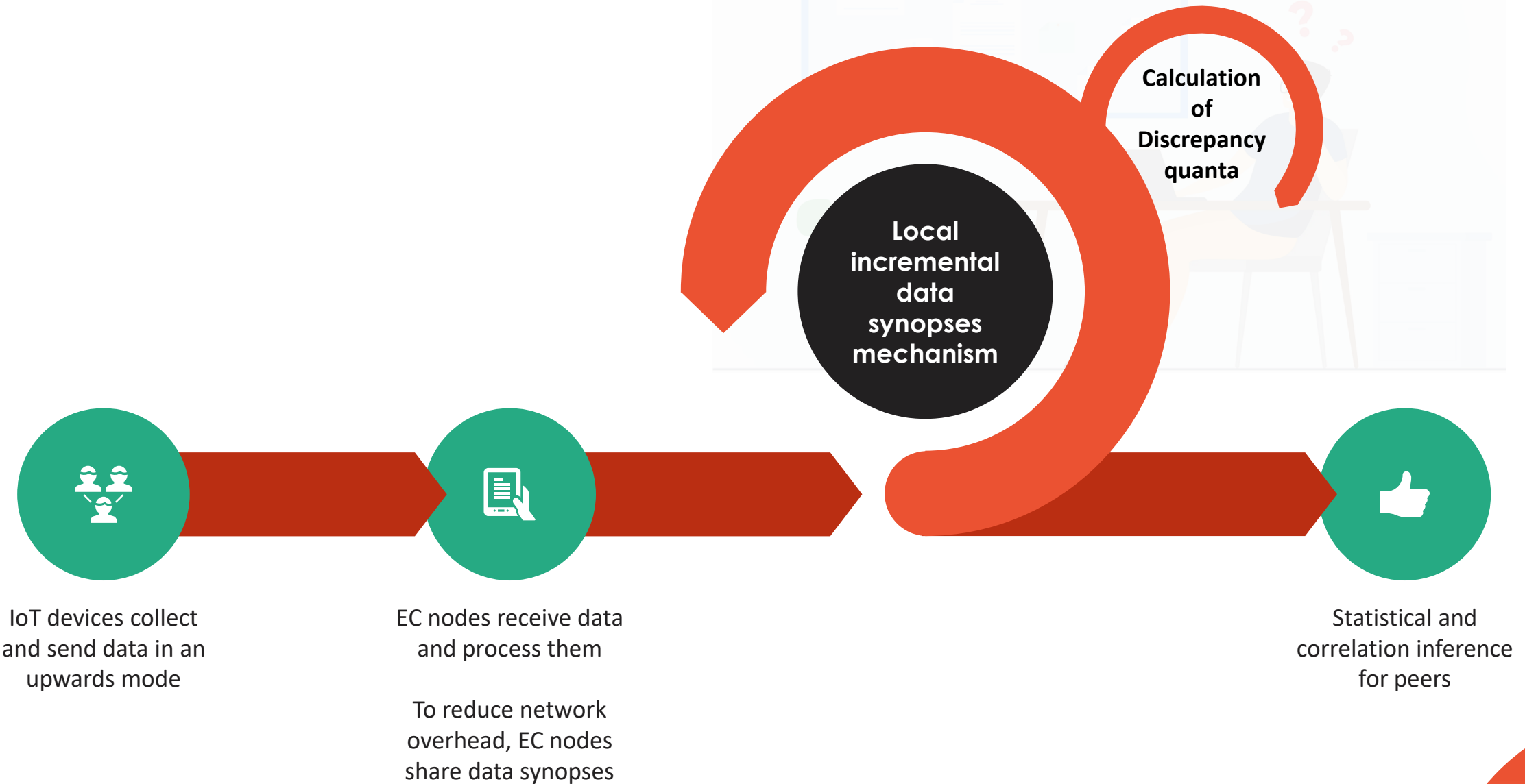
- ✓ Statistical inference upon the demand for services and the contextual performance data of nodes
- ✓ Utility aware decision making model

- ✓ Tasks offloading based on uncertainty-driven decision making model
- ✓ Data-driven automated inference mechanism



**Research Axis
DATA**

Data-aware Matching Inference



Data-aware Matching Inference



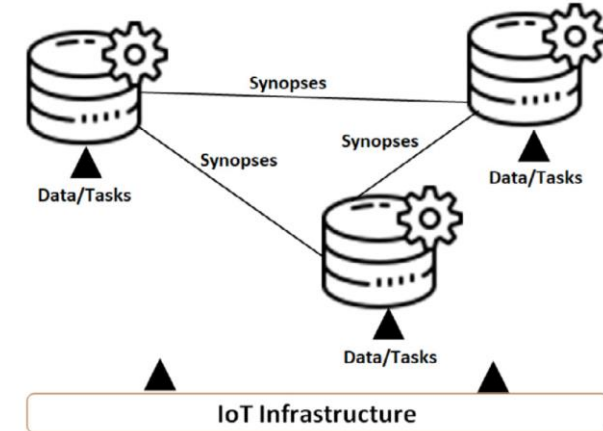
● EC nodes, at regular intervals, exchange the calculated synopses

● Nodes receive data synopses from their peers

● A node continuously monitors the discrepancy quanta with peers

● The discrepancy quantum is calculated as the absolute value of the difference between two synopses

● We generate the time series of the discrepancy quanta (sliding window) upon which the proposed 'inference process' is applied

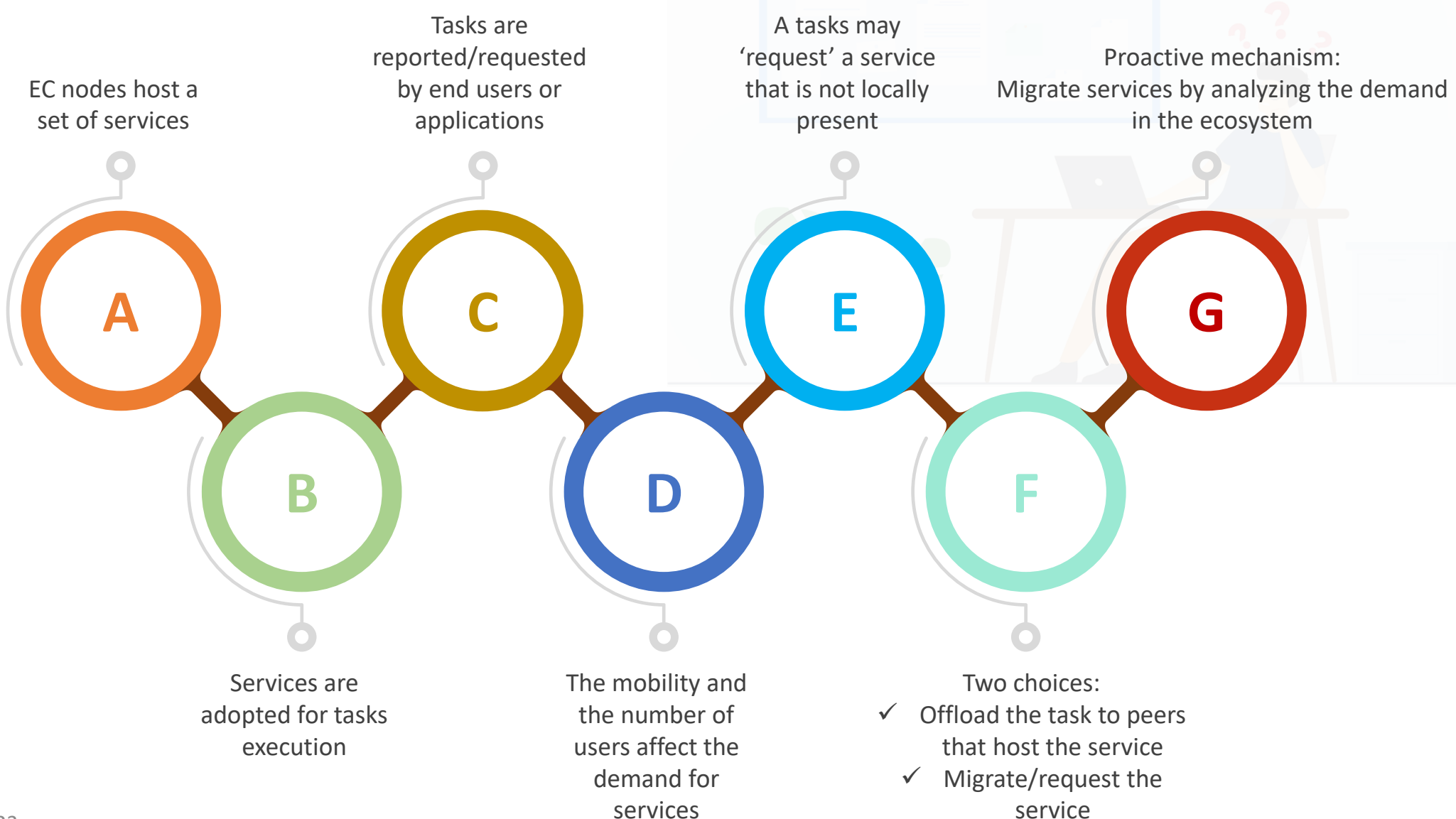


- ✓ We define the **Matching Synopses Indicator** (MSI)
- ✓ When required (e.g., to offload a task or 'borrow'/'lend' data from/to peers), every node can interact with peers exhibiting the highest MSI (a sub-set can be adopted)



**Research Axis
SERVICES**

Services Management Scenario



Services Management Scenario



We propose a model that deals with the decision of ***where to migrate a service***



The optimal migration strategy is intractable due to the dynamics of the EC ecosystem

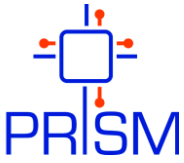


Tasks offloading can be affected by an additional level of decision and delays in the response



Services migration should be carefully decided due to the resource constraints

Utility Based Model



Statistical Inference

Order statistics for analyzing the demand of a service



Utility based Decision Making

Utility of the local presence of a service is compared to the utility of offloading tasks



Target

Aggregate a statistical inference technique with utility based decisions

Utility Based Model



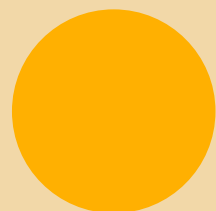
Algorithm Local Decision Making

```
for  $t = 1, 2, \dots$  do  
   $\langle t, T_t, \mathcal{C}_t \rangle = \text{getTask}(\mathcal{T});$   
  Update( $\mathbf{d}$ );  
  Calculate( $g, \hat{g}$ );  
  getExpectedDemandRankings( $\mathbf{d}$ );  
  getExpectedUtilities( $\mathbb{E}(G), \mathbb{E}(\hat{G})$ );  
  Calculate( $U, \hat{U}$ );  
  Decision =  $\max(U, \hat{U})$ ;  
end for
```



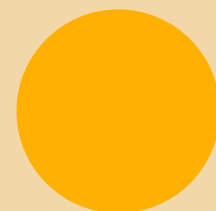
Receive

*Get tasks, parameters
and constraints*



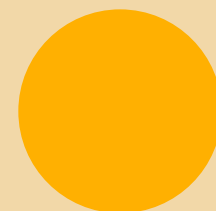
Update

*Update the demand
and load*



Estimate

*Get the expected ranking
and utilities for Decisions
(keep locally the service vs
offload the task)*



Decide

*Get the appropriate
decision*

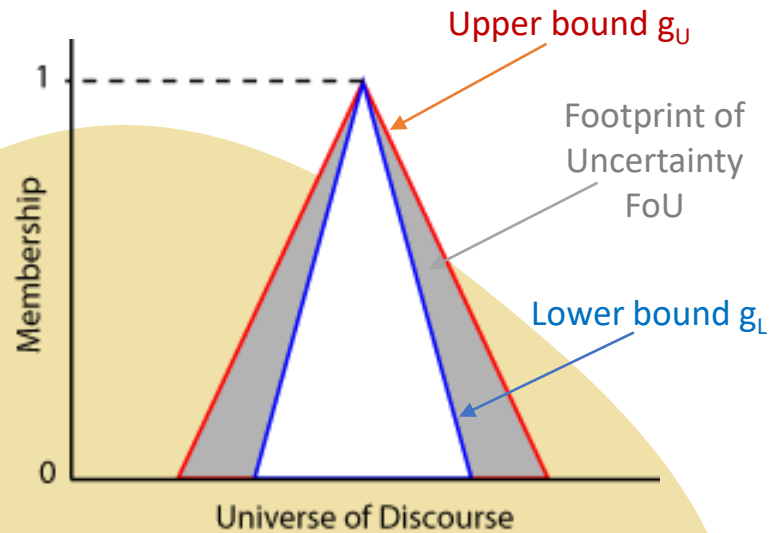


Research Axis TASKS

Task Offloading



Uncertainty Management



Inputs

- ✓ Load of the peer
- ✓ Speed of processing
- ✓ Estimate of the required processing steps



Output

Potential of Allocation (PoA):
depicts the belief that a task will be efficiently in a peer



How to define membership functions?
Answer: from data
> Type-2D sets



Type-2 Fuzzy Sets

Type-2 fuzzy sets and systems generalize standard Type-1 fuzzy sets and systems so that more uncertainty can be handled

Reward and Decision Making

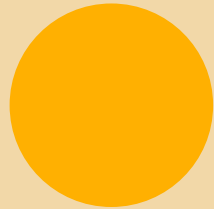


Calculate the total reward and select the winner!



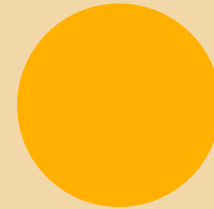
Smoothing

We consider the room for execution in peers



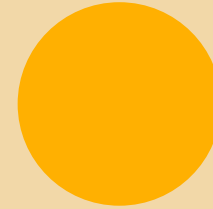
Reward A

If the PoA is over/below a threshold, a reward/penalty is applied



Reward B

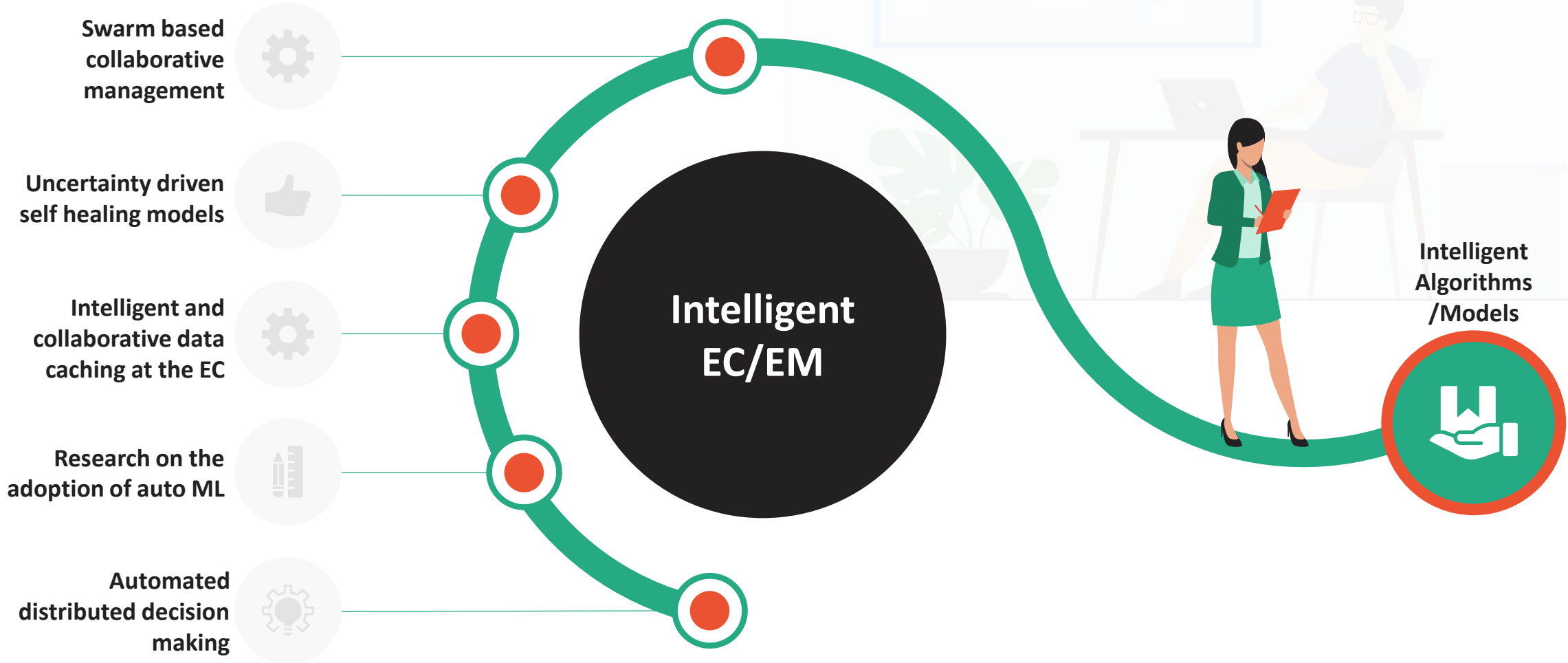
If data in the peer are similar to task requirements a reward/penalty is applied

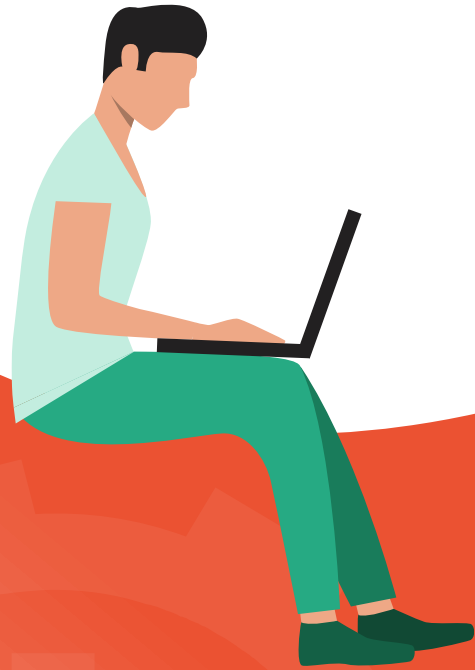


Reward C

If the communication cost is below a threshold a reward/penalty is applied

Future Research Directions





THANK YOU

More Publications, Datasets, Presentations can be found at:

<http://kostasks.users.uth.gr>

<http://www.iprism.eu>

Email: kostasks@uth.gr