Intelligent future data-aware decision making

Dr Konstantinos (Kostas) Kolomvatsos

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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

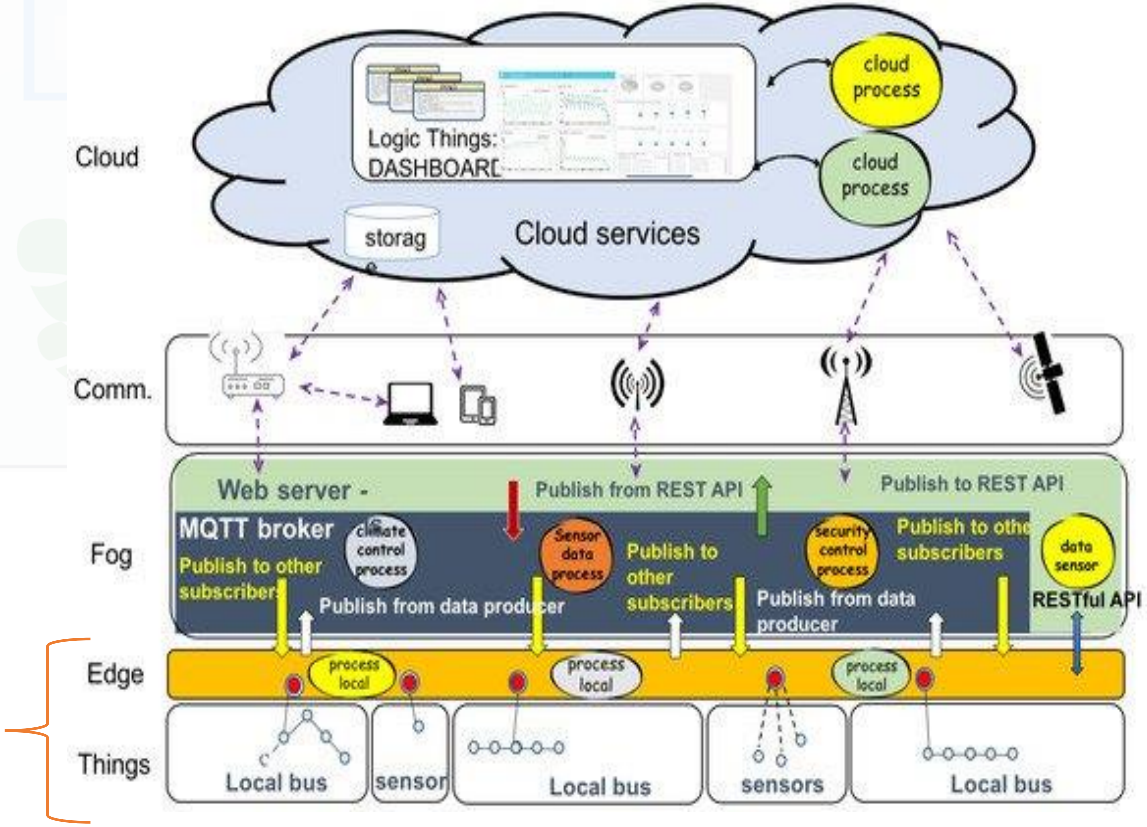
02 Contextual and Fuzzy Logic Reasoning for Pervasive Computing

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

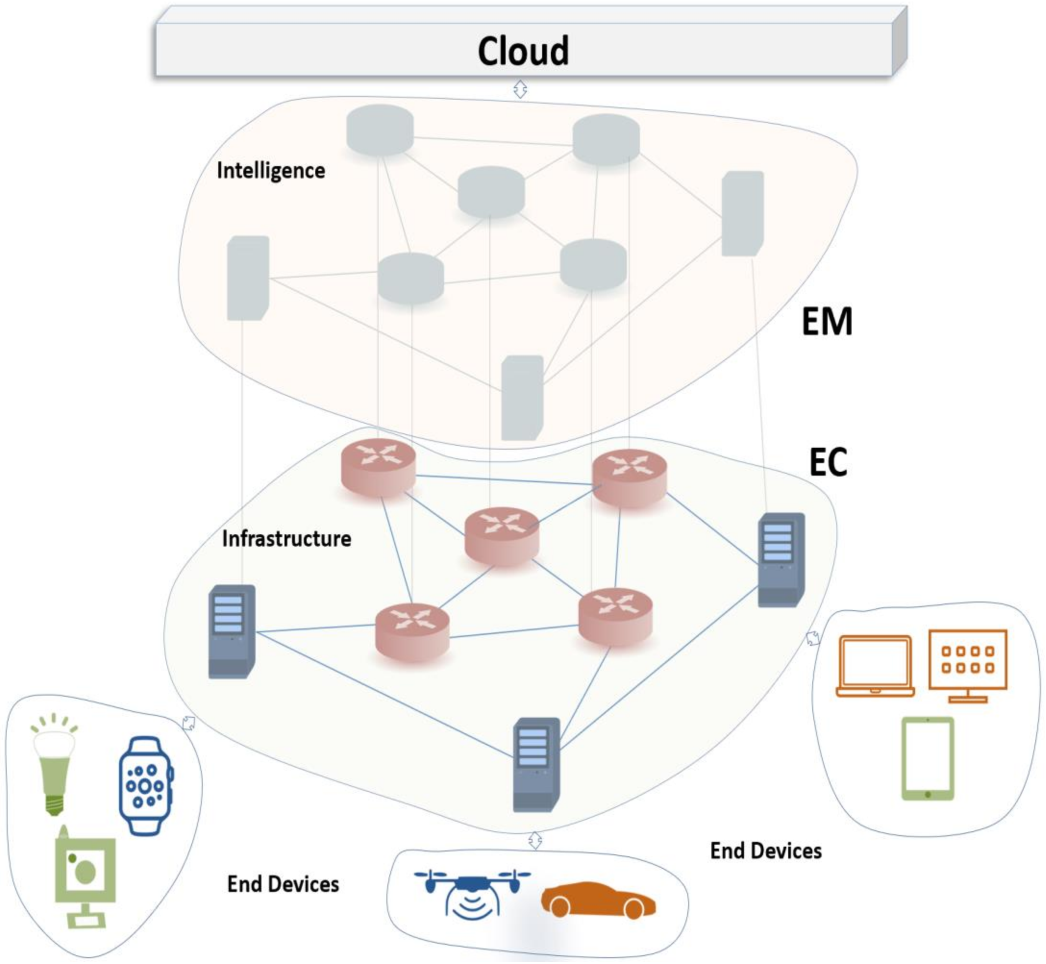


Edge Computing

- 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

Intelligent EC/EM

DATA

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

SERVICES

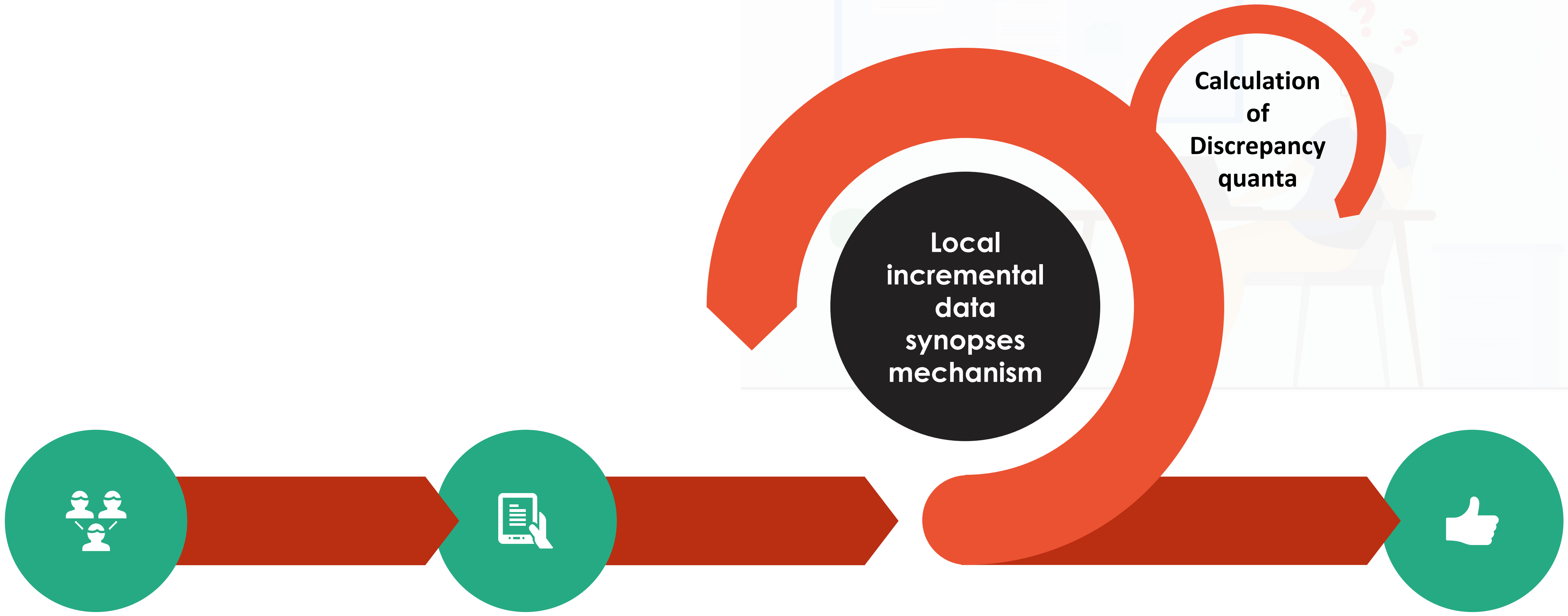
- ✓ Statistical inference upon the demand for services and the contextual performance data of nodes
- ✓ Utility aware decision making model

TASKS

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

Research Axis
DATA

Data-aware Matching Inference



IoT devices collect and send data in an upwards mode

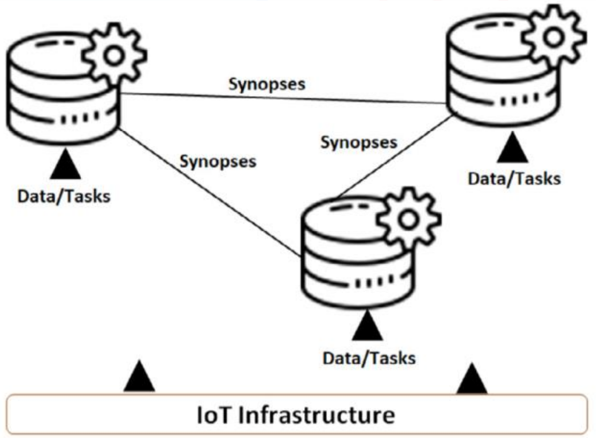
EC nodes receive data and process them

To reduce network overhead, EC nodes share data synopses

Statistical and correlation inference for peers

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

A
EC nodes host a set of services

B
Services are adopted for tasks execution

C
Tasks are reported/requested by end users or applications

D
The mobility and the number of users affect the demand for services

E
A tasks may ‘request’ a service that is not locally present

F
Two choices:
- ✓ Offload the task to peers that host the service
- ✓ Migrate/request the service

G
Proactive mechanism:
Migrate services by analyzing the demand in the ecosystem

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 $t = 1, 2, \ldots$ **do**
$\quad \langle t, T_t, \mathscr{C}_t \rangle = getTask(\mathscr{T});$
$\quad$ Update($\mathbf{d}$);
$\quad$ Calculate($g, \hat{g}$);
$\quad$ getExpectedDemandRankings($\mathbf{d}$);
$\quad$ getExpectedUtilities($\mathbb{E}(G), \mathbb{E}(\hat{G})$);
$\quad$ Calculate($U, \hat{U}$);
$\quad$ 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

Data and Tasks

- ✓ IoT devices collect data
- ✓ Users and applications request tasks execution

Local Repository

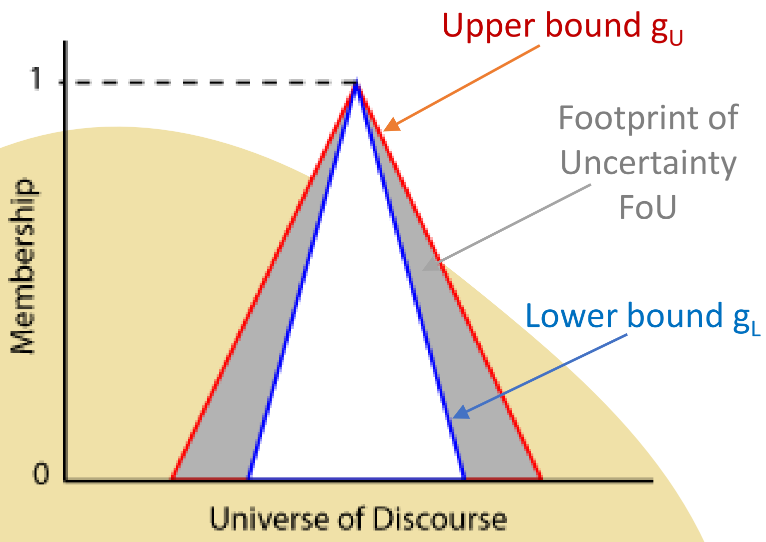
Tasks Manager

Tasks Offloading

Decision Making

- ✓ Select the appropriate peer
- ✓ Manage the uncertainty about the appropriateness of peers

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!

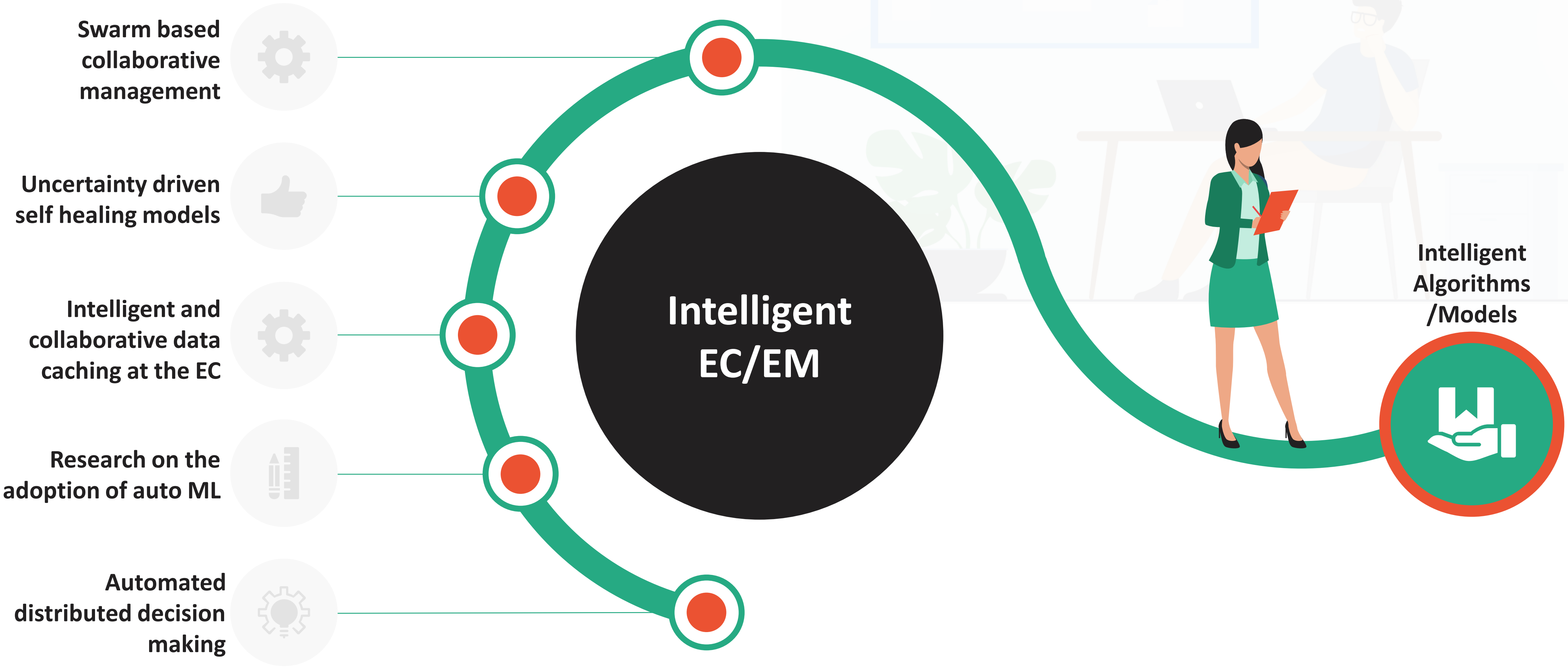
Smoothing
We consider the room for execution in peers

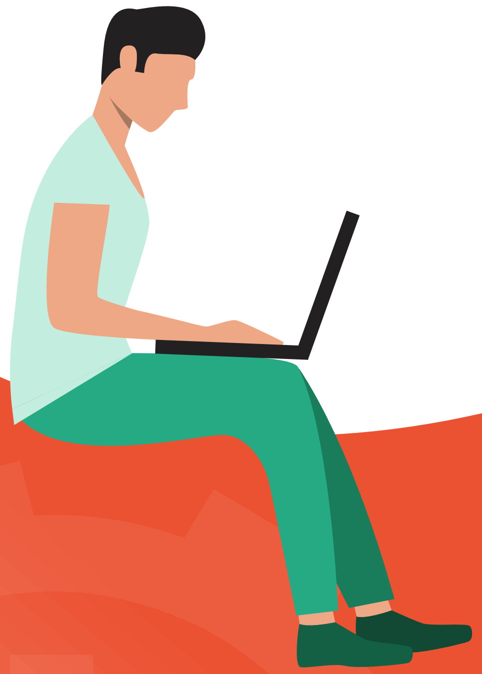
Reward A
If the PoA is over/below a threshold, a reward/penalty is applied

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