UMR 7039

Thesis topic (expected beginning sept. 2023) supervised by Michael DAVID – William DERIGENT

"Dynamic reconfiguration of a scalable network of communicating objects (under service and energy constraints) by simulation "

Tags: Digital Twin, Internet of Things (IoT), Network Control, Energy Efficiency, Online Simulation, Multi-Agent System, Software Defined Network

Background

Advances in the miniaturization of micro-electronic systems, coupled with those in the field of embedded networks, make it possible to design «smart» objects, whose intrinsic matter itself forms a network of communicating elements. An object or a set of this kind of objects make it possible to exploit all the promises of the Internet of Things (IoT). **Dynamic reconfiguration (by fusion or disintegration) of the network formed by such objects requires the definition of an appropriate control system with the aim of minimizing the energy consumption of objects while guaranteeing their respective information collection services**.

Problematic

A network of communicating elements is modelled by a related graph *G = (N, L)* where *N* represents the set of Nodes of the graph and *L* is the set of non-oriented Links between nodes. Recovery energy techniques and development of low-energy or energy-efficient communication protocols help to limit energy consumption and extend the life of a static network of communicating objects [Rault 2015; …]. Similarly, various decentralized network organization strategies have been proposed to optimize the data collection [Delgado 2014]. Generally, the questioning of the communication structure is locally initiated by the network nodes. The ambition is to "manage the collection of information" and the network structure by an external controller according to the principles of "edge-computing" and the "Software Defined Networking" paradigm. Through this work, it is a matter of **prolonging the open-loop optimization of the physical part, by an online simulation in the digital space allowing to decide whether to reorganize the physical part**. The modeling of decision-making processes can be done by applying work concerning the management of manufacturing systems [Miradamadi 2009], which very often use the concept of Multi-Agent Systems [Hoang 2012].

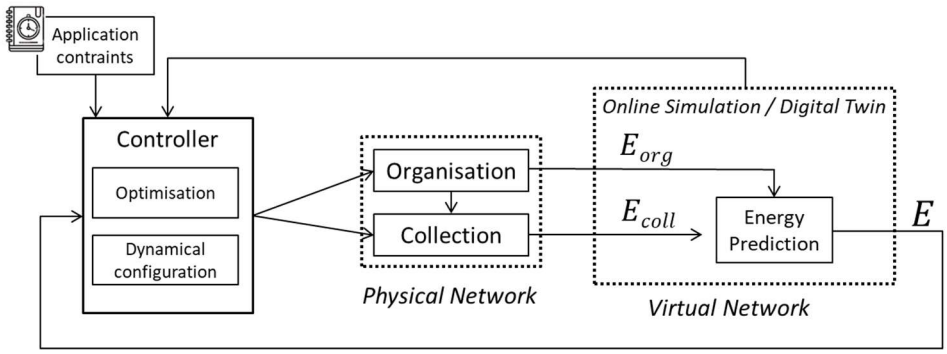

Figure 1 Thesis problematics overview

The simulation allows to predict the future amount energy of objects according to the current communication structure and to consider the questioning of this structure by continually testing other candidate solutions. Because the context of object can change (object lifecycle and therefore of service change, or encounter other

objects, or because some nodes have little or no more energy), it will be necessary to update the communication structure and therefore proceed to the organization phase again. Thus, two distinct periods are to be considered for the energy prediction of the network of objects (see fig. 1):

- a collection period during which the network cyclically pulls the data up to a collector node for external processing (i.e. $E_{, \text{Coll}}$, the energy consumed during a collection phase). This phase will be repeated until the controller decides to reorganize the WSN.
- An organisation period during which a new structure defined by the on-line simulation is established (E_{Org}, the energy consumed during the implementation phase of the new organisation);

Designing the generic «middleware» allowing the monitoring of a scalable network of communicating objects is the main challenge. The following sub-issues will need to be addressed (non-exhaustive list):

a. Represent the digital twin and simulate a network of communicating objects,

b. Define and model the control of a static network based on the on-line simulation,

c. Drive data collection from a scalable network in an optimal manner.

The main scope of this work will be production and logistics systems in the field of either manufacturing or construction. This work can be applied to the concept of «communicating matter» (MC) developed several years ago at CRAN [Kubler 2012, Mekki 2016, Wan&al. 2020]. Through the ANR McBIM (Communicating Material for BIM) project, led by the CRAN, the optimization of physical data collection was studied in the work of LAAS [Loubet&al. 2018] and CRAN [Wan&al. 2019; Wan&al. 2020], without taking into account the "services" aspect. Thus, this thesis would incorporate this notion based on the work developed in the McBIM project.

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