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1 Introduction

The GHT (hospital merger) concept has been implemented by several countries worldwide. It involves the integration of various categories of hospitals to establish a network comprising specialized and/or non-specialized hospitals. A typical GHT structure comprises three hierarchical levels : a Support Hospital (SH) overseeing Mediator Hospitals (MH) and Local Hospitals (LH)[**1**]. Effectively managing patient allocation within GHT during crises, particularly health emergencies like epidemics, poses a complex challenge. Precise decision-making and control processes are essential among the different components of the GHT to ensure efficient patient management. The organization of decision-making in the GHT requires consideration of various data, falling into two categories : exogenous data, such as the epidemic displacement, and endogenous data, encompassing factors like bed capacity, territorial dimensions, hospital specialties, and staff resources. Research studies [**1**, **2**, **3**, **4**] indicate that decentralized decision-making plays a pivotal role in the success of GHT. Such a decentralized approach is crucial in controlling the complexities of crisis management within the GHT framework.

This paper compare centralized and decentralized decision-making scenarios within the GHT framework (various types of organizations are discussed with different degrees of centralization other than the GHT is presented in [**5**]). In this work, these different decision-making models have been applied to the GHT located in the "Loire" region, France.

The proposed scenarios are formulated by using the Operational Research solver "CPLEX" to optimise decisions and/or interactions between lower-level hospitals and their direct superior (presented by agents) to coordinate these decisions. In the centralized scenario, SH uses CPLEX to make the decision and resolve the MKP (Multidimensional Knapsack Problems : resource allocation problem) for everyone.However, in the decentralized scenario, every hospital will make their own decision and solve their MKP problem, so we will employ multiple CPLEX that interact through holonic interactions.

2 Optimizing patient allocation in the GHT through the solving of the MKP in scenarios with (de-)centralization

In the GHT we have different levels of decision-making and while the studied made on the GHT[1], the problem of the GHT during epidemics is (i) a problem of deprogramming all the interventions, and (ii) a problem of making local decision-making with the knowledge of the environment close to rationality. In the complex, dynamic, and highly uncertain context of such a crisis, it's essential to steer and coordinate resources as precisely as possible.The establishment of a Holonic system in the context of GHT allows proposing a prototype of the system of assistance to its steering for improving its management. The MKP, a combinatorial optimization problem that is NP-complete, is used to solve this problem. [**6**]. The GHT will be modelled as a general knapsack and each hospital at all hierarchical levels as a knapsack. The class of each knapsack will be the class of the patient severity. The capacity of each knapsack will be the number of free beds in each hospital. The free beds will be categorized by category because each hospital may have various specialties and each patient may have a specific illness.

The general objective of the GHT is to allocate patients with the respect of each hospital capacity in order to minimize the cost which presents transportation time of the patient to another hospital taking into account the severity of the patient situation. *Our contribution is the proposition of patients allocation scenarios, simulate them with the simulator Anylogic and compare them.* Each scenario considers one level of (de-)centralization and interactions of resources in the GHT. **SH and LHs do not communicate directly in the GHT.**

The scenarios are shown in Figure 1.

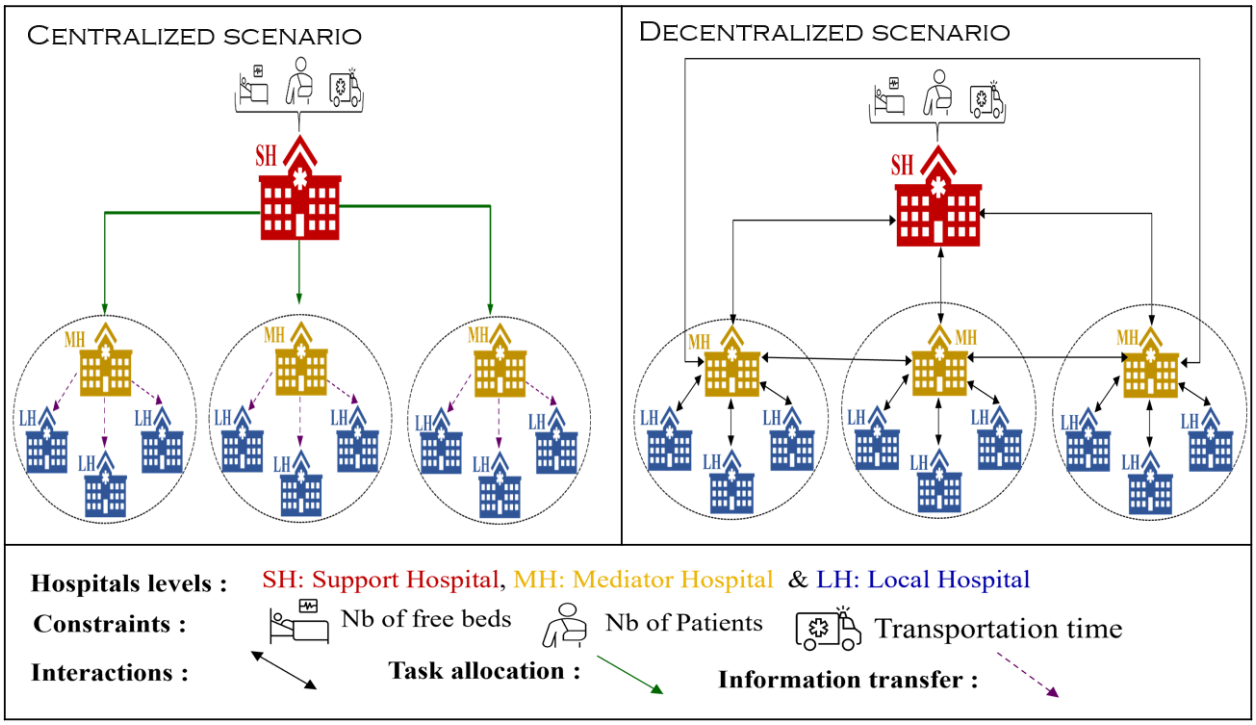

FIG. 1 – Centralized and decentralized scenarios.

2.1 Centralized scenario

In the centralized scenario, the allocation is performed by SH which makes its decision considering all the constraints of itself, MHs and LHs (number of beds and staff available). That is, SH allocates patients for the other hospitals in order to minimize the cost of the affection of patients given the lack of information on beds available in other hospitals. This

decision is sent to the MHs, which then distribute it to the LHs belonging to the same group. Hence throw the simulation made by Anylogic, SH solves the problem of assigning all patients to all hospitals in the GHT. This allows SH to make overall optimal decisions from the point of view of allocation in relation to distances, but less effective from the point of view of visibility of the free beds. In addition, the calculation time is very long when he has a large number of patients to allocate because of both size and computational complexity of the problem.

2.2 Decentralized scenario

In the decentralized scenario, the decision is shared between all hospitals regardless of their hierarchical position. There is interaction between SH and MHs. LHs don't interact with each other ; they communicate with others through their MH. The problem is modeled by the CNP (contract net protocol) in which, if a hospital has a higher number of patients than its available number of beds, it takes the role of the"Host". This host makes its decision by proposing patients and/or free beds to other hospitals. Then, each other hospital "Guest" makes their local decision taking account of their own constraints and send it to the host, who will take the final decision for all the other hospitals. From a technical point of view, all hospitals are considered as agents, and constraints are calculated by the agents' local CPLEX. Through the simulation made by Anylogic the advantage of doing the calculation in agents' CPLEX is the fact that such a splitting of the problem into smaller problems reduces the calculation time of each agent while parallelizing these calculations on these different agents and the disadvantage is that the solution found by the interactions between (i) LHs and MHs only, and (ii) LHs/MHs and SH may be less effective overall.

3 Conclusions and future work

After simulating and comparing the (de-)centralized scenarios, a hybrid scenario is currently under modeling and implementation. In this scenario, the first decision will be made with a centralized process by the SH considering the available constraints then the decentralized process will start to adapt the constraints and discuss the decision made by the SH. With this scenario, our goal is to make a compromise between the reactivity of the decentralized process and the optimality of the centralized process. These scenarios will be evaluated and cooperated with data coming from GHT "Loire" in France.

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