

Cloud manufacturing Service operations management by Blockchain Technology

In recent years, many pivotal factors of manufacturing industries have experienced a radical transformation. Globalization of resource gathering, unforeseen advancement in information technologies, etc. are just a small fraction of massive changes in manufacturing industries. These changes have triggered a new manufacturing revolution in the beginning of 21st century named as Industry 4.0. Using the power of Internet of Things (IoT), Industry 4.0 connects manufacturing resources in which they can be managed by a central authority. To facilitate the application of manufacturing resources, Industry 4.0 (at its ultimate objective) implements servitization as the ultimate solution in which every manufacturing resources and capabilities can be treated as a service. However, Industry 4.0 is a juvenile subject in manufacturing area with many gaps to be explored. Service composition¹ is one of the most interesting topics in the literature of Industry 4.0. Industry 4.0 in its nature involves hundreds of thousands components in the system. Service composition issues inherit the same characteristic too. In other words, service composition problems involve many service providers and tasks which are needed to be matched based on a number of criteria. The massiveness of service composition context regarding the number of components in the system as well as the complexity of these problems (service composition categorize as NP-hard) is an extremely complex challenge in that providing a good solution for the problem in a reasonable time is practically impossible even with the most powerful HPCs available. Considering the dynamic nature of manufacturing environment especially in Industry 4.0, if the manager fails to provide the solution in a reasonable time, many customers would leave the system at the cost of system's revenue and reputation. To the date, this problem seems to be unsolved in the literature.

Blockchain technology is a novel idea conceptualized for the very first time by an anonymous person under the pseudonym Satoshi Nakamoto in 2008. Blockchain is the core technology for the world's first cryptocurrency called Bitcoin. Blockchain is a distributed ledger consisting of an infinite set of Blocks any of them are programmed to record transactions among network's components (also known as miners). Miners are enthusiastic entities seeking to solve a crypto-puzzle to gain some fortune. Crypto-puzzle is ascribed to the problem of extracting coins and validating them in consensus mechanism which is an extremely hard problem and requires a lot of computational power, energy and time. Miner would compete with one another to solve these crypto-puzzle faster than the others, since only the winner miner (the miner with the fastest response time) can submit its answer and be granted with the specific reward. Besides solving crypto-puzzles, each miner is responsible to validate incoming transactions in the form of Block in the consensus mechanism. To do so, each miner can and has to get a copy of Blockchain and stores it locally. This feature is one of the most popular aspects of Blockchain in that all transaction are transparent to all individuals while the individual responsible for that transaction remain unknown. The transparency of Blockchain prevents any ill-will attacker to tamper with information of Blockchain because other system's components with a copy of the Blockchain can detect it.

Considering the effectiveness of Blockchain technology in the financial realm, the implementation of Blockchain concept in the manufacturing area seems to do the trick for the aforementioned challenge in service composition problems. The original service composition problem suffers from the plurality of components (service providers and tasks). Therefore, dividing the problem into a number of sub-problems can mitigate the problem so that each sub-problem contains only a small fraction of the original problem. In a real-world problems, for instance, the original service composition issue may have more than 5000 service providers and 1000 tasks while this problem can be divided to a number of sub-problems each of which consists less than 100 service providers. Solving sub-problems is up to

¹ Since every service provider in real-world problems has its own limitation _ either technical limitation or technological limitation_ it is hard to assume that a single service provider can manage to handle entire customer's demand by its own. Combining a number of service providers in the form of a service-bundle seems to be the solution. Service composition issues have been scrutinized for the past few years and a number of novel ideas have been proposed to establish a solid concept.

Solvers which are corresponding concept as miners in the original Blockchain. Each Solver may be a single person with limited computational power (such as a laptop or personal computer) or a huge enterprise with hundreds of teraflops computational power. Therefore, how to allocate each sub-problem to an appropriate Solver needs to be examined. After allocating sub-problems to suitable Solvers, each Solver may start solving designated supply-matching problem and provide a solution. Once the solution is extracted, it needs to be validated through other Solvers in order to ensure that the solution remains conforming with central management rules. If the solution passes the validation process successfully it can be added to the Blockchain. The new Blockchain would be broadcasted to entire network component and the cycle would be repeated. This approach can be considered as a new heuristic method to discover a reasonable good starting point in small fraction of time for meta-heuristic approaches such as genetic algorithm and it is expected that using this approach improves the overall quality of meta-heuristic methods.