Smart Data Distribution in Industrial Manufacturing

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Abstract—Data distribution is a cornerstone of efficient automation for intelligent machines in Industry 4.0. We develop solutions for robust data distribution in smart factories. We describe two test cases demonstrated in H2020 AUTOWARE project. First, we show the collaboration between robotic elements and wireless data services. Second, we show the integration with an industrial fog node which controls the shop-floor devices. We report selected results in much larger scales, obtained via simulations.

Index Terms—Data, Internet of Things, Robotics, Wireless Networks, Manufacturing, Industry 4.0

I. DATA IN INDUSTRIAL ENVIRONMENTS

Industry 4.0 will be characterized, among others, by increasing levels of automation achieved by the collaboration between robots and more in general intelligent machines. Each physical machine is likely to embed higher and higher number of devices (e.g., industrial IoT devices) constantly generating data, to be exchanged and exploit for controlling the collective behavior of the smart factory. In this regard, optimization of the data distribution process is a major objective for industry [1]. The number of technologies to be integrated to realize a smart data distribution system is large. Current data management solutions primarily consider centralized data management approaches, where all data are collected at a central location (usually in some cloud platform) and then distributed across nodes when needed. Due to the expected increase of data generation rate by devices, coupled with the stringent requirements on data delivery for control processes, more distributed solutions are going to be needed, where data are stored on devices closer to where they are needed, and delivered directly from there. In addition, robust solutions are also needed, exploiting all types of wireless communication technologies available, in order to reduce the impact of interference, malfunctioning or unavailability of each specific technology. To this end, AUTOWARE project [2] proposes a hybrid communications management and decentralized data distribution architecture supported by a hierarchical and multi-tier network structure [3]. The proposed solution combines local and decentralized management with centralized decisions to efficiently use the available network resources and meet the requirements of Industry 4.0 applications.

We implemented two test cases so as to highlight the applicability of (mobile and stationary) distributed lightweight data management within an actual industrial environment. In order to demonstrate how we can apply the data management concepts and showcase their feasibility, we designed and implemented a small scale demonstration at the premises of a manufacturing experimentation facility of an AUTOWARE consortium member (IK4-Tekniker), requiring robust data exchange between a heterogeneous set of autonomous factory machines. The core of the concept is regarding how we can use smart data distribution at the manufacturing experimentation facility, so as to achieve: (i) cost-effective operations, (ii) fault tolerance, (iii) dynamic, plug-and-play smart data distribution solutions.

II. FIRST TEST CASE

The set-up of the first test case at the manufacturing experimentation facility is shown in Fig. 1a. A mobile robot is responsible for fetching objects to a robotic bi-manipulator. The objects are located at a set of shelves, where a human operator is responsible for manually loading the objects on the mobile robot. Both the robot and the operator are aware of which object is currently needed at the bi-manipulator, as there is a centralized wireless or wired communication infrastructure, coordinated by a central controller and the data can be sent and received through the communication links. However, due to the harsh conditions in several industrial environments, it is not unusual for the main centralized operational network to go offline, for a variety of reasons. When there is a situation like this in the current scenario, the mobile robot and human operator cannot be aware of which object is currently needed at the bi-manipulator, which in turn results in a failure of the production process. In order to address this problem, we suggested the adoption of a distributed data management approach. More specifically, we employed a secondary, lightweight data distribution layer operating using direct communications between the involved nodes, such that data exchange can survive disruptions of the main network infrastructure. We implemented it by using small, low-cost wireless sensor motes. The proof of this con-
The core concept of the second test case is regarding how we can use smart data distribution at the manufacturing experimentation facility, using an industrial fog node as network controller so as to achieve digital shop-floor reliable data distribution with scalable sensing performance. A fog node is a local server located in the industrial facility premises, which provides localized, cloud-like services to the factory environment. This is therefore an intermediate configuration between the fully centralized one relying on remote cloud services, and the fully distributed one experimented in the first use case. With respect to the first use case, this solution will provide a reliable central point for control, at an additional cost in terms of IT infrastructure equipment. Our purpose is not to compare such solutions, but to showcase that the AUTOWARE data distribution schemes can work in a multitude of decentralized configurations. A typical scenario at the manufacturing experimentation facility involves the integrated fog node to control and communicate with various devices of the shop-floor. Reliable data exchanges between the various devices regarding their status (e.g., sensed temperature levels) at any given time should be possible, regardless the operational conditions of the shop-floor. In order to address this, we implemented the integration of distributed data management on a fog node (MFN 100) provided by an AUTOWARE member of the consortium (TTTech). More specifically, we employed the lightweight data distribution layer and implement it by using small, low-cost wireless sensor motes. The proof of this concept was demonstrated by adopting the data management layer introduced in [4] and by placing four motes in the network as shown in Fig. 2: two acting as data producers and two acting as data proxies (distributed nodes caching the data) as instructed by the algorithm in [4]. Again, the motes used were IEEE 802.15.4 enabled. The existence of multiple data producers and proxies, guarantees that even in the case of failures, the data can still be delivered at the fog node seamlessly. This test case is demonstrating that we can achieve high data redundancy and efficiency with a low-cost approach.

### III. Second Test Case

The manufacturing experimentation facility gives us an important ability to test the methods on real conditions and derive useful indications. However, at the same time, it does not allow us to perform larger scale, or variable experiments, easily and fast. For this reason, and in order to test the scalability of smart data distribution in industrial environments, we developed a simulation model based on the manufacturing experimentation facility layouts. Fig. 3 displays the results on the average data access latency for two different alternative approaches, for different numbers of nodes in the network. Specifically, the first approach is an entirely centralized approach, which, using standard industrial protocols (such as IETF RPL), delivers the data to the nodes requesting them through the central network controller. The second approach employs our smart distributed data management and uses proxies so as to distributively allocate the data across the network [4], [5]. We can see that the efficient management of proxies provided by the smart data distribution process results in a better performance compared to the entirely centralized alternative. The average latency achieved by smart data distribution respects the typical Industry 4.0 constraints (100ms) and always remains lower than the data access latency threshold (red line in Fig. 3).

### References


