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The productivity impact of the digitally connected 5 – layer stack in manufacturing enterprises

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Abstract

This paper investigates the application of modern industrial internet protocols and network architecture in manufacturing companies, from the perspectives of productivity and sustainability, framed in the fourth industrial revolution paradigm. This is achieved by delving into the existing information systems and devices, their inter-operability and interconnections using industrial internet of things protocols. The paper details a study generating a standard model of data architecture to better unify the different layers of the information systems that typify most manufacturing companies, leveraging their existing digital infrastructure to establish a solid base for further digitalization.

Keywords: Industry 4.0; Industrial Internet of Things (IIoT); MQTT; Manufacturing Execution System (MES); SCADA; Enterprise Scalable Data Architecture (ESDA); Overall Equipment Efficiency (OEE); Self-Cleaning-Data

1. Introduction

In recent years, the manufacturing world has entered a new paradigm that is the widely known as Industry 4.0. In the fourth industrial revolution (4IR) one of the main goals is turning data into information and having access to that information in real time for faster and improved decision-making leading to better company performance [1,2,3].

The primary drawback is the fact that most of the existing IT platforms in manufacturing companies are not inter-operable and tend to be complex and expensive to interconnect. This generates the need for significant manual inputs and outputs that are usually handled by employees updating countless spreadsheets and paperwork instructions, frequently leading to issues with data integrity and time delays [3,4]. Consequently, this can, at worst, render industrial data into an untrusted asset instead of a valuable decision-making resource. Therefore, a worthy challenge for digital transformation of manufacturing is how to ensure trusted, clean data can be turned into valuable information in real-time, by inter-connecting existing legacy data systems and adding new ones [1]. For this purpose, it is essential to explore the use of modern industrial internet of things (IIoT) protocols and network architecture, which are the enabling platforms for creating efficient and reliable data connections, thus freeing up valuable time to achieve higher levels of enterprise agility, productivity and sustainability [2,3].

2. Literature Review

2.1. 4IR and Industrial Internet of Things (IIoT)

The concept of 4IR started during the Hannover fair in 2011 [5] and originated from a project within the German government's high-tech strategy focused on the computerization of manufacturing. The main difference that this new industrial paradigm brings is the transformation of industrial data into information. The IIoT and the digital transformation are mechanisms within the industry 4.0

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movement that turn data into information, enabling the feasibility of the current digitalization of industry. IoT, IIoT, and Industry 4.0 are closely related concepts but cannot be interchangeably used. As defined above, the IIoT is the main technology enabler of 4IR. The Internet of Things (IoT) is the interconnection via the Internet of computing devices embedded in physical objects, enabling them to send and receive data.The most comprehensive definition of IIoT [6,7] is as a system comprising of smart connected objects, information technologies, cloud, and edge computing platforms, which enable the real-time ability to obtain information continuously from different smart objects. There are application domains with different requirements [8], so with the deployment of IoT technologies a continuous flow of information between the different business layers in the information systems hierarchy can be achieved, thus generating more flexible and scalable industrial infrastructures. In the enterprise hierarchy, the data collected from the shop floor smart devices, turns into information at the manufacturing management and operations level. It then moves on to the plant/site level and over to the company executive level [8].

2.2. Barriers and Challenges

The arrival of the new industrial era brought together a "mountain to cross" for the implementation of digital transformation with regards to legacy information systems interconnectivity [9]. In order to provide a value-adding solution for systems integration, it is essential to identify and classify the existing obstacles. A classification of the barriers for adoption has been undertaken based on diverse papers [9,10,11,12,13,14,15] that identify and rank them. By aggregating the commonly referenced factors, the most important barriers have been identified as:

<u>Organisational</u>

- *Legal and contractual uncertainties:* Digitalization poses a challenge for existing laws that have to be updated and actualised as the competition gets fierce. [9].
- *Time constraints:* The constraints related to the time that manufacturing companies have to spend due to the lack of data integrity or a clear data management strategy.
- *Inadequate organizational structure and processes:* Digitalised factory processes will represent physical reality as it is, so chaotic organisations could turn out disastrous digital representations.
- *Security:* An essential topic is the cybersecurity required to preserve the confidentiality of organisational data and know-how.

<u>Data</u>

- *Data Integration:* This can be considered one of the highest barriers for adoption of the new industrial paradigm. Most manufacturing companies have numerous IT legacy systems that drive the cost of integration coupled with the scarcity of capable Operational Technology (OT) and Information Technology (IT) integrators.
- *Data quality, reliability, and security:* This barrier somehow derives from the previous one as lack of data integration, generates doubts around quality and reliability in manufacturing employees.
- *The need for large amounts of storage capacity:* Many data architectures are incredibly resource intensive and this drives a need for huge capacity of storage and as a consequence high energy consumption.
- *Performance and scalability:* "Big data analytics (BDA) require massive performance and scalability, which is one of the most crucial challenges in using advanced data analytics tools" [14].

<u>Technology-related barriers</u>

- *Integration and compatibility:* Companies do not have the technology or do not have enough understanding of the IIoT, Big data analytics and related technologies.
- *Lack of a reference architecture for a unified communication protocol:* There is a strong need for a unified communication IIoT protocol to stablish a standard architecture model that enables integration of systems.

<u>Financial</u>

- *Investment (Costs):* The cost of interconnectivity implementation as well as the amount of potential capital investment can be very high.
- *High cost of investment without clear benefits:* There is a lack of understanding and clarity on the tangible benefits in efficiency and productivity, and how these will translate in higher profits by adopting 4IR.

<u>Management</u>

- *Lack of leadership with appropriate skills, competencies and experience:* Lack of change management and leaders that fully understand the new industrial needs and practices.
- *Lack of conscious planning: defining goals, steps and needed resources:* It is strategy and not technology that drives digital change, so the absence of a clear strategic roadmap can mean the failure of the digital transformation efforts in a company.

<u>Human Resources</u>

- *Employees engagement and resistance to change:* Resistance from the workforce to adapt to the new practices and competencies required for digital interconnectivity.
- *Lack of appropriate competencies and skilled workforce (training of staff):* Required retraining and upskilling of the current employees for the new functions.

What becomes clear is the fact that issues related to data management, financial investment and human resources are significant challenges for 4IR adoption and integration.

2.3. The Multi-Layer Automation Stack.

A computer information system is a system composed of people and computers that process or interpret information. These information systems in manufacturing translate into enterprise and control systems. With the arrival of IIoT new mechanisms to connect these arise, but the complexity of multi-vendor and multi-technology systems is increasing due to the incompatibility of the legacy origins of the systems [16]. It is therefore useful and important to refer to the standard for the integration of enterprise and control systems in industrial automation, "ANSI/ISA-95 Enterprise-Control System Integration". This standard (Fig 1) was originally specified for the definition of components, time frame, and operations involved in the different enterprise management levels [17].

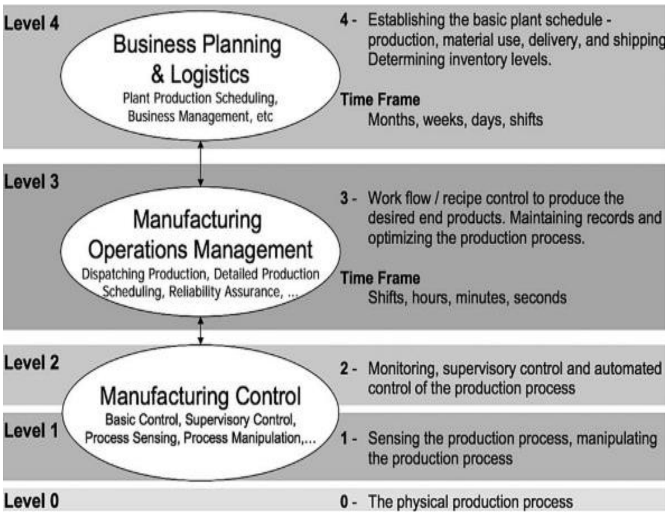

Fig. 1. Functional levels of an industrial system defined by the ISA95

The ISA-95 model can be defined as a pyramid comprising of the different levels of processes and IT systems (Fig 2). This relates not only to the automation control field of each level but also to the whole enterprise system [18]. At the very top, the Enterprise Resource Planning (ERP) system is concerned with business planning and logistics, followed by the Manufacturing

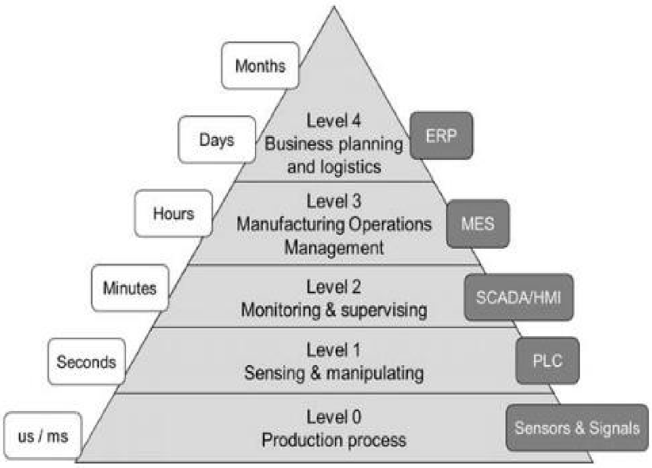

Fig. 2. The automation pyramid according to the ISA 95 model [16]

Execution System (MES), controlling the scheduling of manufacturing operations. Below them is the Supervisory Control and Data Acquisition (SCADA) system for supervision and monitoring of operational clusters and processes, followed by the last two levels related to the shop floor, Programmable Logic Controllers (PLC) and sensors.

This structure has evolved with the new connection protocols and cloud services. The integration of enterprise systems is a way to achieve a continuous flow of information in order to develop an agile and effective reaction capacity to rapidly changing market demands and increase productivity. IIoT protocols are able to "integrate digitally together" (Figure 3) [19] generating a common data source and achieving a real time continuous information flow.

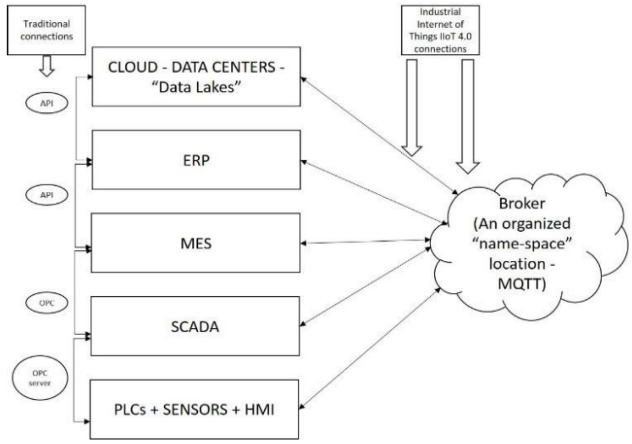

Fig. 3. The 5-Layer Model of Automation – The Automation Stack [19]

There are still many people acting as connecting nodes, communicating data between the different enterprise layers manually [19]. This is mainly because many IT systems run based on vendor standards that do not allow open communications architecture and follow their own proprietary data syntaxes instead [17]. This results in disparate data layers, that have to usually be connected using expensive Application Program Interfaces (API).

To integrate efficiently, it is essential to turn data from different systems into a continuous flow of data consumption and generation at all levels of the enterprise. To that end, there is a principal method based on the current state of practice. Open Platform Communications Unified Architecture (OPC UA) is a standard that various types of systems and devices can use to communicate by sending request and response messages between data clients and servers. It establishes a robust model of communication exchange between machines and devices from different manufacturers, unifying the way of interfacing of physical devices to their interoperable applications in PLCs and sensors on the shop floor connecting to SCADA and also directly between them. On the other hand, Message Queuing Telemetry Transport (MQTT) is a "lightweight" messaging protocol, based on a subscription-publishing data exchange model. Publishers send messages to a server and this server via a middleware (MQTT broker) forwards messages to subscribers. Crucially, the message can be in any data format and as MQTT is optimised for centralized data collection and analysis, it can connect sensors and mobile devices to applications running in a data center, which is another benefit of its usage as a universal protocol (Figure 4). MQTT provides an open architecture, which means its level of flexibility and capacity to connect other systems is far superior to other protocols.

It also reports data only by exception, so the protocol does not update source data variables until the data values of a device or process state change. This makes MQTT not only flexible in terms of architecture and compatibility, but also a more sustainable solution than for example OPC UA, in both resource use and data storage. Remarkably MQTT's "lightweight" coding data payload is only 3% in comparison to the equivalent functions of OPC UA [20], leading to much lower Green House Gas (GHG) emissions from data generation, transmission and storage and therefore constitutes a more sustainable connecting solution.

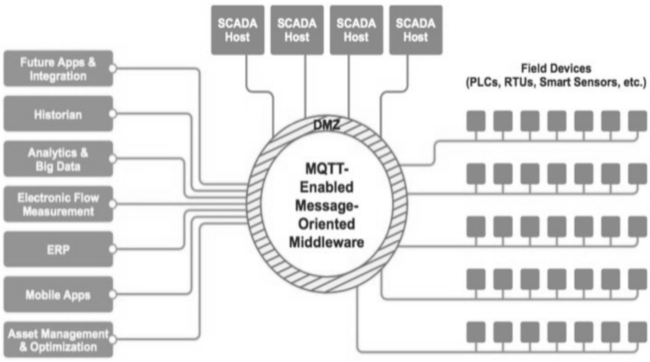

Fig. 4. MQTT as a dominant IIoT message transport protocol for connecting machine data with enterprise software applications [21]

3. Methodology

3.1. Research Design and Approach

The subject of this research is an emerging industry need that does not appear to have many existing and standard functional solutions. Manufacturing enterprise information systems integration for a "single source of data truth", enabling a unified reliable data base for all company systems is not yet common practice. For this reason, this work adopted the research approach of a Delphi methodology. Delphi is a qualitative process of collecting the opinions and articulated experiences of experts using a series of data collection interviews and analysis techniques [22]. It is a methodology that is especially effective and flexible for gathering data to explore an innovative hypothesis, when opinions and criteria from experts are needed to formulate and validate answers to the research question.

The original Delphi method was developed by Norman Dalkey in the 1950's for a U.S. sponsored military project, allowing the participants to express freely their ideas, iterating to achieve certain consensus between them [22]. The typical Delphi method can consist of two or three rounds of iteration followed by proper data collection and analysis with the sample size varying in studies "from 4 to 171 experts" [23]. In this work the simplified Delphi method (Figure 5), consisted of two rounds.

The first round, involved a set of open question interviews, deliberately designed in such a way as to capture the broadest range of opinions and thoughts from the engaged experts. The information gathering from the first round allowed the identification of the common points and extreme views, which guided the design of the second round, during which the experts were presented with the shared views in order to provide more specific ideas and "polish" the raw consensus. As a result, the method facilitated the teasing out of expert opinion on the research question from experienced industry professionals with justified answers relevant to current industry needs and realities. Based on the literature review and initial hypothesis, the interview questions were designed in a way that all the surrounding topics to the initial hypothesis could be adequately nuanced by the experts to clarify their importance.

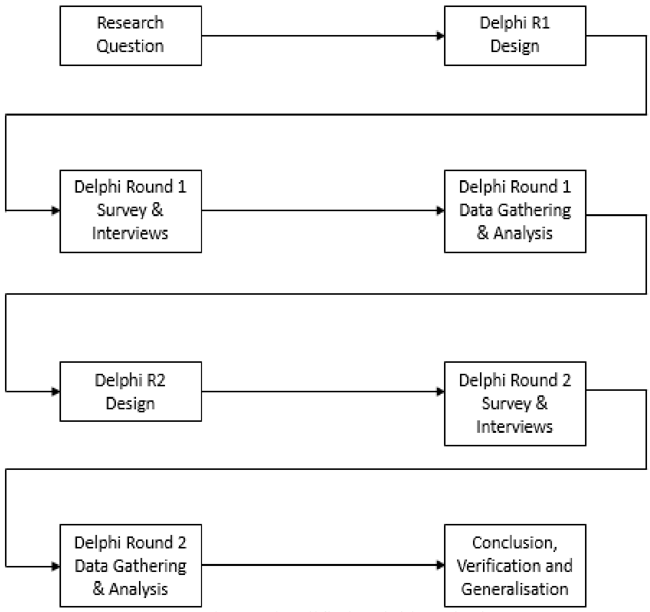

Fig. 5. Simplified Delphi method

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3.2. Initial Hypothesis

Based on the literature review, state of practice in the market, and critical thinking linking the key ideas, the establishment of an initial hypothesis was a critical stage in the method and was articulated as follows:

"The integration of different IT systems in a manufacturing facility, using open source modern IIoT protocols (such as MQTT) can lead to an increase in the visibility of process performance and behaviour (turning data into information), the elimination of paper, and the saving of time. Such effective digital transformation could lead to notable increases in productivity in a more sustainable way."

3.3. Data Analysis

The output of the process are 8 interviews with experts from top companies as Google Cloud, Rolls-Royce, Amazon Web Services, along with well-known independent industry consultants and academic professors. The interviews where divided into the following thematic sections:

- Common practice in industrial environments
- Impact on productivity and sustainability of IT systems integration
- Barriers for connection and information flow
- IIoT protocols and architecture trends

These sections where divided in different questions to gather the opinion of the experts in a thorough and structured way, so as to allow for the analysis to easily clarify if the proposed initial solution is "feasible" or at least supported by the experience and views of the consulted experts. Once the interviews were completed, a qualitative coding process followed in order to analyse the interview data. Coding is essentially a methodology to categorise the data collected through a process of qualitative research [24]. Evidently, qualitative research around upcoming topics can only be evaluated by the identification of patterns in ideas and concepts that point towards one common direction.

Based on this initial division in topics, dimensions and parameters, the data was classified and separated. The analysis made evident the strong consensus amongst experts around the problem of manual data transition, the systems integration needs in the market and the issue with existing data distrust.

It is curious that both the ideas that suppose the biggest innovation and the ones that represent the consensus between most experts, point in the same direction: the confirmation of the initial hypothesis of the Delphi method. These findings validated again from the consulted experts, act as backup for the proposed solution and close the Delphi loop.

Figure 6 depicts the frequency analysis of the participating experts' opinions that have been most commonly coded.

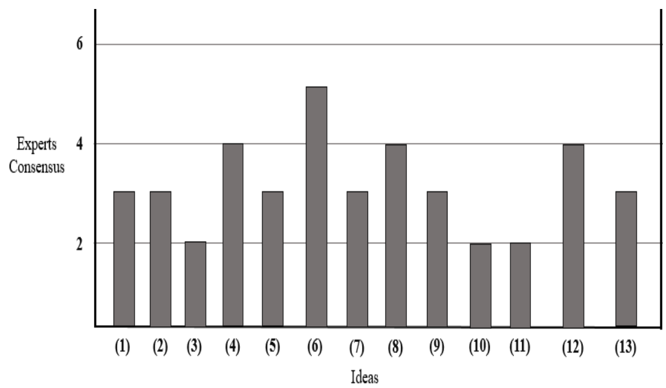

Fig. 6. Consensus Ideas

The ideas that had the biggest consensus (Figure 6) were:

(1) Apply IIoT with a strategic view, in the medium- and long-term progression of digital transformation.
(2) Importance of Senior Lead vision commitment and digital strategy.
(3) It is an economic and not tech decision to integrate. There is a lack of experience and resources to make the investment.
(4) Data transition made manually between systems in many enterprises. Also, expensive APIs.
(5) Distrust on data.
(6) Manufacturing enterprises are static and reluctant to change. Basic systems or lack of them in SMEs.
(7) SCADA and MES have to be more responsive, cheaper, and able to reduce the planning cycle.
(8) Infrastructure in place prior to connecting digital on top and need to be connected to a central database.
(9) Reducing cost barriers for SMEs democratizing the digitalisation.
(10) Essential for the industry to move to TCP/IP telecom protocols that are lightweight.
(11) Robust legacy systems only allow to use data in their own platforms.
(12) Market need for integration, and essential need for systems integration unified with a business view.
(13) Most customers are starting to use data and digitalise higher up in the enterprise hierarchy, they do not start on the production plant floor.

Ideas 4, 6, 8, 12 (with 4,5,4,4 experts proposing the same idea) are the most accepted and proposed by the experts, making evident the current lack of integration between industrial systems, the reluctance to change and the need of setting a digital infrastructure in terms of the foundation for digital transformation. This can be achieved easier by an architecture that integrates data together, using lightweight protocols that are accessible and open source.

4. Proposed Model

An integrated digital representation of the plant is the essential baseline for the deployment of big data analytics and AI tools that can optimise decision-making and drive even bigger increases in productivity and profits. As Hans-Henrick and Trienekens [25] opined: "Establishing clear communication and simplified information exchange are key elements in building long term system integrations that can support business requirements".

4.1. Industrial Internet of Things Enabler

Within IIoT there are numerous connectivity protocols and standards that can be used depending on the business need. Given the findings from the Delphi process, the protocol selected for this study is MQTT, defined in mqtt.org as follows: "MQTT is a machine-to-machine (M2M)/"Internet of Things" connectivity protocol. It was designed as an extremely lightweight publish/subscribe (Figure 7) messaging transport".

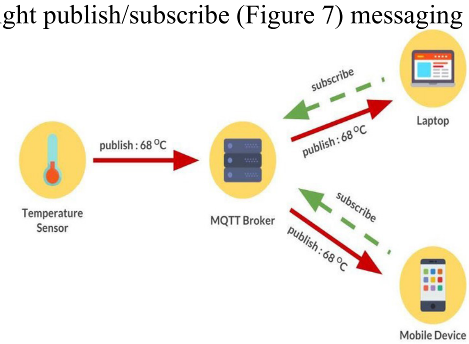

Fig. 7. MQTT publish-subscribe protocol [26]

The key characteristics that makes this protocol ideal for systems integration are:

- MQTT works with publishing/subscribing data but has no formal structure. It provides an open architecture that seeks to invest on the knowledge on the integrators that can model the architecture instead of investing a lot of money on the system itself.
- MQTT reports by exception. This means that it generates only valuable data. The actuators in the architecture have to subscribe for the information that they consume and publish for others to subscribe, so each layer only consumes and produces the information strictly necessary.
- MQTT is a lightweight code syntax. It collects more data with less bandwidth than other protocols. The protocol is compatible with most of the programming languages, so it makes it easy to connect most coded elements.

The two main actors on this architecture are the "clients" and the "broker". Clients can be different devices ranging from Micro Electromechanical Machine Sensors (MEMS) and PLCs to entire server and software, consuming and generating data. Depending on its function in the architecture, a client acts as a "publisher", "subscriber" or both. To access specific data required, a client "subscribes" to a determined topic or "tag" that acts like the http:// routes in the commonly used internet web addresses. At the same time the publisher is providing values that the broker (server) connects to, storing their values and keeping track of the subscribers. This makes for scalability in accommodating different devices and levels (topics) of data, as for example in a house equipped with MQTT connected devices (Figure 8). For the case of this paper, it proposed that different clients (SCADA, MES, etc.) can publish and subscribe data in real time from a structured architecture that scales from the top enterprise strategic C-suit level (i.e. the company name id) to the asset level (i.e. machine/sensor).

Fig. 8. MQTT topics house example

4.2. Enterprise Scalable Data Architecture (ESDA)

A connectivity architecture termed "Enterprise Scalable Data Architecture" (ESDA) is proposed that defines the topic routes to accessing information. The architecture will enable the collection and classification of the data transmitted by the publishers of the IIoT system devices and then allow this information to be received by the subscribers. This structure is indicative, but its open nature means that it can be adapted to any existing system. ESDA follows a structure that goes from the enterprise level, to the asset topic level i.e. "top-floor to shop-floor" (Figure 9). Level 0 is the enterprise, whilst level 1 refers to the plant level, which depending on the size of the company can be one or numerous. Such layering in the architecture is essential in case the company grows or acquires other facilities that have to be integrated. Then, inside each plant, level 2 defines the different production lines (or product lines) existing in the facilities. Level 3 is the stage of each industrial asset or machine itself that at the same time will have a topological classification of its data.

The division in different levels of hierarchy has designed so that it offers the capacity of aggregating and distributing indexes from the more specific levels, to the more strategic ones. As an example for the proposed architecture in the paper, the Overall Equipment Effectiveness (OEE) metric was selected as an indicator that can be related from the operational effectiveness of a specific equipment or line, to the effectiveness of the plant as an aggregation of distributed indices, so they are meaningful in both an individual and aggregated way. This distributed Holonic [27] conception (each level is an entire whole system, but at the same time a part of a bigger one) allows agility and scalability when managing data from different sources, furthermore, allows to diagnose issues by being able to drill down at deeper levels of detail in the business without losing the thread of the associated data, thus avoiding the issue of data mistrust.

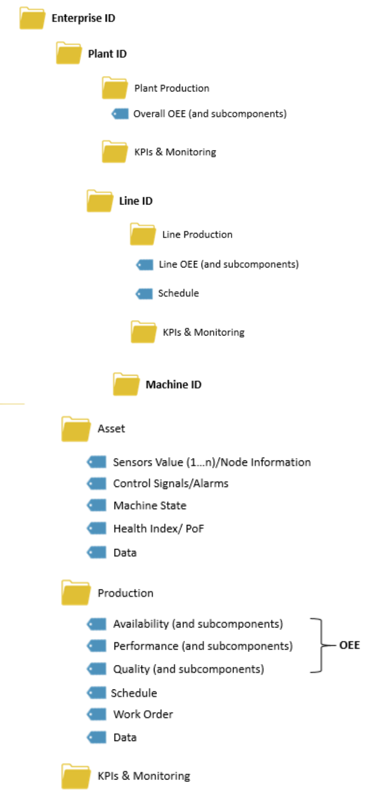

Fig. 9. ESDA structure

Prior to explaining the different section publishers and subscribers it can be seen that there is a data folder labelled "KPIs & Monitoring". This folder will contain post-processed data from various "clients" and external tools that can be used to build meaningful dashboards and indicators. Thus, it will play the role of a data "historian", meaning a repository of tagged data that can be used to provide reports of what valuable and relevant information has been used and examined. Depending on the levels of the architecture, the type of enterprise, production, machines and business objectives, the values and data recorded in this folder will vary.

The aforementioned aggregated key indicator in the ESDA is the OEE performance metric from Nakajima [28], derived from the information in the MES and SCADA systems at the asset level and then aggregated to generate line and plant level records of performance. In ESDA, when the expression "and subcomponents" is mentioned, it serves as an abbreviation to represent the following expression and variables:

$$\mathrm{OEE} = \mathrm{A} \times \mathrm{P} \times \mathrm{Q} \quad (1)$$

$$\text{Availability Rate (A)} = \frac{\textit{Planned Production Time} - \textit{Down Time}}{\textit{Planned Production Time}} \quad (2)$$

$$\text{Performance Efficiency (P)} = \frac{\textit{Theoretical Cycle Time x Output}}{\textit{Planned Production Time} - \textit{Down Time}} \quad (3)$$

$$\text{Quality Rate (Q)} = \frac{\textit{Total Production} - \textit{Defect Amount}}{\textit{Total Production}} \quad (4)$$

At level 1, the plant level is defined by the ID from the ERP system, to be identified inside the enterprise. To have the overall numbers of plant performance for each facility, data are published from the MES and the calculations made in an OEE engine or algorithm. In the "KPIs & Monitoring" folder, values calculated as orders fulfilled, on-time delivery, or capacity, will be recorded to have a wider view of the meaningful indicators of the plant.

The next level in the ESDA hierarchy refers to the production line and data comes from the OEE calculations in MES. It is essential to have the line production schedule from the master production schedule (MPS), to control the production orders in the line that will allow to have intelligent rescheduling, calibrating the schedule depending on line-performance, availability and operational state of the line assets. Apart from this, the folder referring to the indicators will perform the same way as it does in the previous level, adding KPIs as utilisation or capacity of the line. The industrial machine level is critical for the architecture, understanding each asset as a productive unit itself and as a part of the production flow. From an asset management perspective, it is essential to record the data from the PLC and Sensors that define the asset digitally, as well as the control actions and notable alarms from the SCADA system.

The other dimension of the ESDA, is the architecture presented to integrate the systems from the factory floor to the enterprise level (Figure 10). The different clients of the MQTT systems will monitor, publish, and subscribe information, whilst the broker (server) will create and classify the data, store values, and keep track of subscribers. Firstly, any plant floor device enabled by MQTT connects to the broker publishing information. There can also be a connection between the broker and OPC UA-connected equipment. The SCADA and MES systems platforms can be installed with an MQTT module solution, or even migrate to IIoT enabling platforms that have been created and designed for the development of digitalised industrial systems.

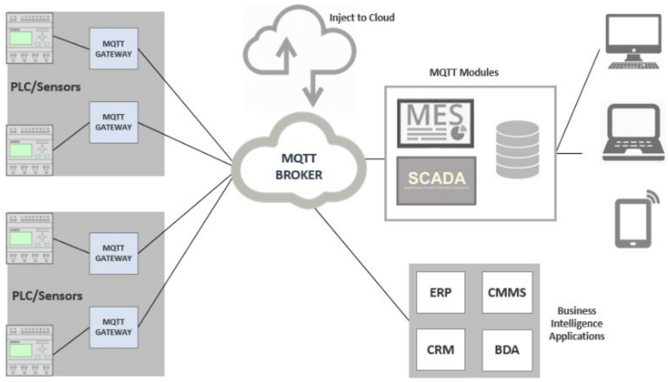

Fig. 10. ESDA Plant Level Architecture

MQTT can also be used to publish into a SQL database. The database has to be initialised with a "skeleton" or table according to the ESDA hierarchy structure and then it can be scaled up adding more data categories and entities. For the business intelligence (BI) application in ERPs, there are MQTT modules or platforms as for example in SAP that offers its "ABAP" programming platform with the Application Programming Interface (API) to implement an MQTT client.

The last thing to cover is the connection between the different facilities of an enterprise. If the enterprise that applies ESDA to its infrastructure has more than one plant, the architecture of the system needs a way to connect the different plants as part of a total. The way to connect different factories of the same enterprise in the cloud is shown in Figure 11. The cloud can have more benefits than simple "data lakes", by acting as a collaborative space for the company and its customers and suppliers. With ESDA and MQTT the information reported to the cloud is "quality" clean data that has been classified and reported by exception. This renders the plant data to be a valuable asset which can enable better decision making in enterprise-level planning. The idea is to have a full "enterprise MES" living in the cloud that goes down the enterprise hierarchy to the asset level, achieving a sales-to production closed loop relationship. This is the ultimate goal for industry 4.0 facilitating speed and productivity.

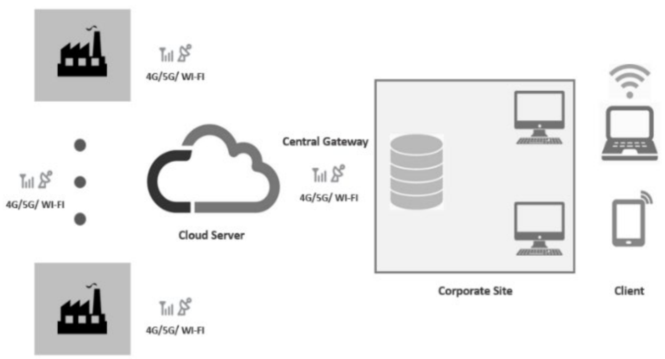

Fig. 11. ESDA Enterprise Level Architecture

5. Discussion and Conclusions

The main purpose of this research was to investigate the possible consequences of connecting legacy IT systems in terms of productivity and sustainability. The real motivation combines the willingness to apply new technologies, with the real conviction that digitalisation can improve the manufacturing sector. This is of interest for manufacturing enterprises since digitalisation and the Industry 4.0 paradigm have been gaining a lot of interest and at times hype, contrasting with the current state of manufacturing companies.

If a construction company starts building a new house starting from the roof, it will not make sense for anyone, but somehow the adoption of Industry 4.0 in manufacturing has frequently been approached in a similar way. Without a digitalised ontological structure connecting existing systems efficiently and simply, building big data analytics and artificial intelligence tools cannot achieve breakthrough benefits. Following this reasoning, the research began with the need of defining the real productivity and sustainability impact of building the basis for the “digital plant”.

MQTT can be seen as an equivalent to a “WhatsApp”-type of communications layer over the TCP/IP base. Using this lightweight, sustainable, and open architecture protocol, allows stateful communications between manufacturing system assets to further process data into information. This approach can add value in decision making aiding productivity without the acquisition of expensive equipment and technology platforms from automation vendors.

MQTT’s “reporting by exception” functionality, gives the capability to the data architect of selecting just the data that is deemed important and necessary. This means each request for data is an actual need for useful information and avoids a data glut that can overwhelm a manufacturing company and enlarge its carbon footprint. Furthermore, by generating reports of what information is necessary at each moment, these can act as a base to train predictive AI algorithms. Investing in such technology following the ESDA approach could offer a credible lower-cost path to digital transformation leveraging existing assets and know-how.

Further work could involve a case-study validation of the ESDA-MQTT approach in an actual manufacturing plant. The proposed model intends to act as the digital infrastructure of an Industry 4.0 plant, establishing the foundations to build smart analysis tools based on it. Through the Delphi research, it became apparent that experts are aware of the thorny issue of amassed untagged and unstructured data in manufacturing and the fact that as a result, identifying useful correlations is extremely challenging. With an ESDA associated to a data base, the credible historical records of key process parameters of the plant and the business as whole, can be stored and generate insightful reports by analysing trends and their evolving nature. Furthermore, the possibility of the concept of “self-correcting” data, meaning self-structured and auto-categorised data, can become a reality through the proposed architecture and was of great interest to the Delphi consulted experts.

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