Building a Digital Twin for Industrial Internet of Things with Interoperability

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***Abstract*—For Internet-of-Things (IoT), 6G, interconnected world, high technological demand, big data and complexity is increasing the requirement of new algorithm designs, protocols and improvement in the existing systems. The fancy IoT term has started to evolve from academics to real life implementation. Tremendous number of organizations and industries require their systems to be upgraded. Industries, however, are in high need for the technological improvement due to the amount of data collected every day. The collection of data is meaningless without being analysed. A stand-alone industry with high amount of OT devices cannot efficiently deal with the data and its analysis, which bring the need for OT/IT convergence and digital twin in industries.**

This paper proposes the steps to build a Digital Twin (DT) for one of the Industrial Internet of Things (IIoT) setup. These steps include the collection of data on the site from OT devices, processing of data near site, OT/IT convergence, uploading of data to the cloud or the wireless transmission of data and interoperability between the physical and DT. Within the processing of data, finding of implementation, some iterations for distributed and parallel computation, and the data processing method are also proposed.

***Keywords*—** Digital Twin, distributed and parallel computing, interoperability, and OT/IT convergence.

I. Introduction

"The Digital Twin (DT) is greatest commonly defined as a software illustration of a physical asset, arrangement, system or process premeditated to prevent, optimise, detect and predict through real time analytics for the provision of business value."

Gratefully, recent and prominent developments in technologies such as Industrial Internet of Things (IIoT), deep learning algorithms, wireless sensor networks, cloud-based platforms and highly efficient computing, an innovative data-driven standard termed as DT has arisen and is currently getting increasing consideration. The DT signifies a high-fidelity digital reflect of the physical object where the former progresses synchronously with the latter throughout their complete life cycle [1]. Engineers rely on DT data and a virtual prototype to improve protective maintenance programs, forerunner next generation business replicas, swiftly improve product growth, and maximize a product's sustainability and efficiency in the ground [2]. DT aids to create inclusive digital models of physical situations with full provision for two-way communication between the DT and the physical asset to enable real time engineering verdicts. One can shape one-way data driven/analytics-based SDEs by connecting assets to an IoT platform on the cloud. Fig. 1 shows an example of DT as an emulator.

Initially, the concept of DT dated back to when NASA used basic coupling ideas during 1960s for a space program (e.g., Apollo 13). Nevertheless, only until around 40 years ahead, the notion started being industrialized through diverse names such as virtual space,

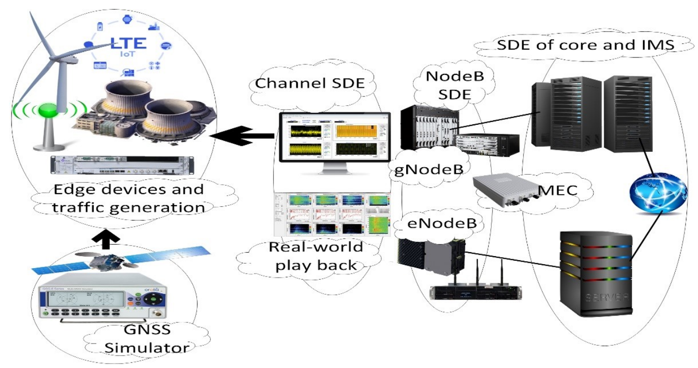

Fig. 1. An example of DT as an Emulator

digital mirror, digital copy and DT [3]. Only as freshly as 2017 has the DT become one of the highest tactical technology trends, widely considered in many industries, including manufacturing, energy, industrial resources and buildings, such as a dual fault analysis method based on DT in for high diagnosis precision in predicting the trend of production quantity; or a DT-based real-time monitoring scheme for mechanical structures to progress the safety of the work situation using IoT and augmented reality [4].

Basically, this just means fabricating an enormously complex virtual model that is the precise replica (or twin) of a physical asset. The 'asset' can be a network, a security system, an electric charger, or even a camera monitoring system. Associated sensors on the physical asset assemble data that can be mapped onto the virtual model. In appearance, a DT look like a decisive information about how the physical asset/object is working out in reality. Due to the growing demand of IoT trials in the past few years, DT has recently expanded extensive deliberation. DT represents a energetic digital environment of physical assets, procedures, and systems, which approximately monitors their complete life cycle. By empowering the seamless transmission of data amongst the physical and virtual world, DT will enable the means to monitor, comprehend, and optimize the functions of all physical entities, weather living or non-living.

IoT is the backbone technology of DT for real-time and multi-source data assembly. Furthermore, it assimilates artificial intelligence and software analytics to fashion digitally simulated environments that update and modify along with their physical object. Additionally, DT undertakes modern data visualization systems such as virtual reality (VR) and augmented reality that can offer more explanatory and accessible views [5].Authors of [6], [7] & [8]

focuses on the security issues and solutions which can also used to address the security issues of a DT. DT is a term invented in the early 1990s. Nevertheless, with the current Industry 4.0 standards, and the incorporation of IoT into our lives, DT has become a term more frequently used within the context of technology, superseding its past implications. The hypothesis is, that DT technology builds the foundation for the upcoming generation of control centre core applications. This is authenticated by the comparison of the growth of simulation and control centre technology [1].

A DT interface is a simulation that is completely based on the physical replica of the simulated object itself. The SDE can generalise how an object, invention or a system will work in the forthcoming time after all needed structural changes are implemented. This is completely possible because a DT based simulation is capable of identifying an object's material from which it is made of, distinguish moving portions from static ones and lastly, the use of the simulated product can be programmed into the digital platform for representing its functioning at an enormously accurate level. After this is accomplished, the digital platform can build and manufacture fragments, extensions and even software that can later be combined into the DT itself [1].

Physical and virtual/digital copy are coordinated and optimized continuously to accomplish the best conceivable economic outcomes.

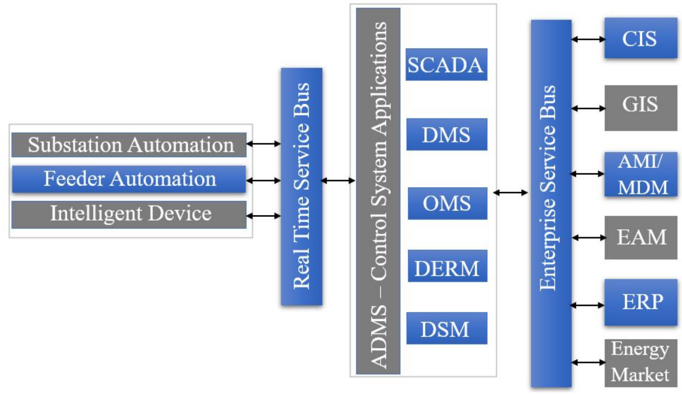

Fig. 2. Integrated OT/IT convergence systems and services

II. Interoperability

Interoperability is the characteristics or ability of a system to communicate, understand, work, interact, exchange information with the other system at present and in the future. It can happen for any scenario and situation. In this paper, we are focused on building a digital twin for the wind turbine and its data processing, where the whole information is being transferred in real-time to the cloud or the central unit. Two kinds of interoperability are involved in the proposed digital twin; OT/IT convergence and physical to digital twin interoperability.

A. *OT/IT Convergence*

For a couple of years, there is an ongoing discussion about bringing IT alongside the OT in the power plants. The reason is to simplify the maintenance operation and uploading of data to the cloud. Bringing IT on the sites or plants needs careful consideration [9]. The other option is to keep them separate and use either OT/IT convergence or the combination of convergence plus IT on the field along OT.

Practically, the discussion of OT/IT convergence comes under IIoT, Industry 4.0 and for the utilities and manufacturing etc. The idea can be related to the high-tech machines in the factories, fleet of trucks, industrial robots, and heavy machinery etc, all can be changed and become progressive with full OT/IT convergence [10].

The term IoT is mainly used for the processes where automation is involved with connected devices, information transmission, capacity for data, connectivity and embed intelligence for processes and applications, analysing of data, APIs development and combination of all that and getting into work [10]. Current age is the early age for the IoT evolution which is expanding rapidly. Several industries have started using OT/IT convergence including oil and gas. Nonetheless, it remains challenging and requires maturity for the IIoT developments [10] & [11].

Organizations and industries were focused always on the traditional OT and the technologies that have advanced in along with IT. The demand of IoT is encouraging the OT/IT convergence. The use of DT promotes the positive outcome-based applications that may create another system called "System of Asset". Eventually, true digital industrial transformation is expected along OT/IT convergence, and the DT will be the catalyst [11].

The integration of operational technologies; Remote Terminal Unit (RTU), SCADA, programmable logic controllers, sensors and meter, with IT in real time or nearly real time system leads towards the term OT/IT convergence, as shown in Fig. 2.

Typically, OT and IT have separate systems for the control of budget and strategies, having a vast and successful experience in their own domain The idea of converging both fields do not transfer the abilities or work from field engineers to IT engineers or vice versa. Building a common ground between the two leads towards the success of both with better efficiency, control, monitoring and flexibility. Specialist of both fields can rely on one another and work for the essential organizational success. The increasing complexity of computing in OT, networking and process maturity in the areas that significantly involves IT. Particularly, identity management and network security, is driving the need of convergence. It will help for cost savings in eliminating identical resources running in both OT and IT together. The value for material improvement for effectiveness and the ability of the cross-function staff to fulfil the target of a reliable, secure and streamlined operations.

Communication and computing for controlling physical systems always kept physical devices as their primary focus. Advance communication and computing were often needed to satisfy the unique demands which were different than the business computing demands addressed by IT. The eventual growth in demand, data capacity and reduced prices has made IT as a compelling choice for industrial control system. Challenges were growing and continue to grow in both OT and IT and demands ongoing attention and upgrades.

The specific needs for OT/IT convergence include;

1) Large amount of data, that needs to be converted into meaningful and actionable information.
2) Broad assets that have spread over various locations and geographies.
3) Network connectivity and open standards that allows data sharing across the organization.
4) Demand of a centralized platform to timely deliver the right information, in the required format to the right person/device and to carry out the strategic decisions.
5) Maintain, control and monitor the system operations alongside maintenance costs causing by the infrastructure's age and retirement.

OT/IT convergence in the industries is an ongoing task and will help the systems to become mature and stable. Until it's progressing the surrounding system operations continues to changes in terms of data, diversification of energy resources, change of method and algorithms etc [12].

B. *Physical to Digital Twin Interoperability*

The advancement of the modern times of technology is increasing the amount of data collected in a number of industrial sectors including Architecture, Engineering, and Construction (AEC) projects [13]. With the passage of time, handling, collection, management, analysis and optimization of data is getting difficult. However, DTs along with suitable intelligence can enormously help industries/organizations in terms of making decisions, managing systems, monitoring and handling the real physical twin system.

Numerous use case requires the information exchange between different organizations, however, the missing interoperability between DTs of companies makes it unsuccessful. The interoperability between DTs needs the transformation of the information to the desired formats.

An interoperability enables digital twins' model and its real-world application example with ABB devices, their information models, and the asset administration can be used for obtaining the DTs' interoperability [14], [15]. The approach in [14], [15] enables use cases for connecting industries, customers and manufacturers.

III. Building Digital Twin in Steps

OT/IT convergence, like any other new setup, is also a reasonably expensive responsibility. Considering the huge upfront cost, industries may start small tasks and collection of data [16]. Analysing data with a small start-up can make known operational insights and will clear the idea of a good start. Small and intelligent start can make a system work better and cost effective. Keeping that in mind, in this paper, a plan of execution for building a DT for an IIoT is provided. The following steps, as shown in Fig. 3 can be used for building a digital twin with interoperability to provide an IIoT system.

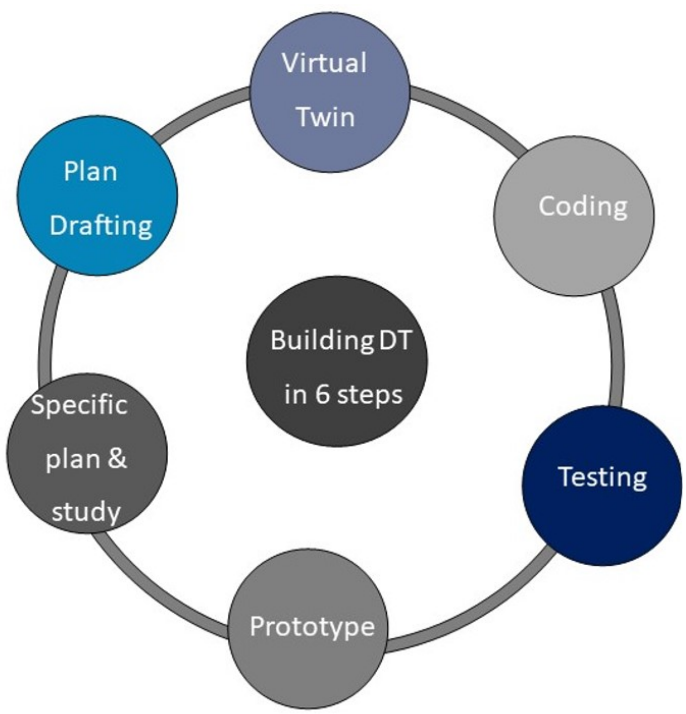

Fig. 3. Step that can be used for building a digital twin for an OT/IT convergence to provide an IIoT system or any other system.

1) Specific plan and study: The first step is to narrow down the idea and aim of a particular industrial setup. It is important to set the goal. Once the industrial setup/industry is finalized, all resources need to be listed down with the possibility of their availability. Specifically in this paper, a wind turbine power plant is being considered for listing down the OT technology resources. For building a DT for its OT/IT convergence between wind turbine power plant and IT, a number of resources and their knowledge is required, for e.g., type of data collection on the industrial plant, involvement of human/labours, machines, mode/method of data collection, intelligence involvement, heath monitoring data for human and machine, short and long distance involved communication, fiber optics or the wireless communication frequencies or both, required bandwidth and latency etc. The devices/tools which are involved on the industrial location are wind turbine, sensors, data monitoring devices, live data collection and storage devices, processors and software.

Before finalization of any of the software and resources, familiarization with cost, problems, solutions, legal formalities and techniques are also needed to be studied and highlighted.

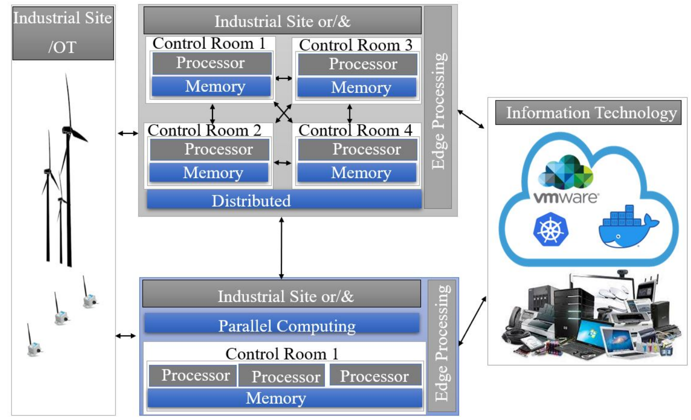

Fig. 4. A planning setup for the overall digital twin. It includes three choices of the interoperability plan; distributed computing, parallel computing and both.

2) Plan Drafting: Fig. 4 shows the overall plan for building interoperability or OT/IT convergence DT. It shows that the data is being captured by the sensors present in the field with turbine, there are local control unit/units that deal with the processing and storage of data, the whole data or selective data is then being transferred in real-time to the IT (a cloud), the data is further being analysed by the IT for monitoring and other purposes. As shown in Fig. 4, the DT can be iterated for three different computing scenarios; distributed computing, parallel computing or a combination. The final DT will be decided for either one of the computing techniques or a mixture of all, depending on the quality of output obtained.

3) Virtual Twin: In this stage, all of the hardware and software needs to be short listed after the literature survey. Firstly, the virtualization and the cloud platform are needed to developed. There will be two such platforms that will be merged; from edge to the processor and then processor to cloud. Initially, a physical sensor or the stored data can be considered.

For the OT/IT convergence, high amount of data, real-time transmission, IT setup and software is essential to provide the IIoT. For replicating its DT, the best choice is to develop a virtual DT, where the whole setup requires a high processor and sensors/stored data/real time data. For an initial setup, it is recommended to use a single processing device and then increase the processing power at a later stage.

A number of communication frameworks and algorithms are available for OT/IT convergence. Some are licenced and others are open communication frameworks. Licenced software is commercially available and can provide several advantages over free open communication frameworks. However, for the start-up and practice, open communication frameworks can be used. Open communication protocols are IEC61850, Message Queuing Telemetry Transport (MQTT), MODBUS, Open Field Message Bus (OpenFMB), Open Platform Communications United Architecture (OPC UA), Open Automated Demand Response (OpenADR) and Open Charge Point Protocol (OCPP). Alongside, some additional software are needed for virtualization like hypervisor, Docker, Kubernetes and VMware.

4) Coding: The programming phase will require some data engineer and programmers. For each communication framework, some basic and general programming is usually readily available. For open communication framework currently, a lot of programming is available online, however, it usually does not work completely. Therefore, good programmers are needed. For setting up the core open communication framework, knowledge of Java, python, docker, Kubernetes etc is desired. Several different sets of programs are required for the edge to processor, processor to cloud communication, overall edge to cloud (transmitting data from edge to processor and processor to cloud), data translation using MQTT/MODBUS/DNP3 or a program for obtaining data (e.g., temperature/humidity) from a sensor.

5) Testing: Once the coding part is done, it is time to debug and fix the errors. These errors may include the support of specific operating systems (Linux/Microsoft/others), version of python/java, hardware compatibility etc. This will take suitable amount of time, specially, if the case is to find the right hardware and software.

6) Prototype: For building a prototype, either the stored data from the industry/wind turbine plant is needed to check for the right measurements and accuracy, or alternatively any sensor for some other type of data can be used to see the real-time data monitoring and management.

IV. Proposed Data Management and Transmission

Data monitoring and analysis is getting cumbersome with the advancement of technology. A number of techniques including Artificial Intelligence and Machine Learning have been given, still the real-time large data monitoring is a difficult task. As we are moving towards IIoT with the requirement of OT/IT convergence, a number of literature suggest to transfer limited data to the cloud for preventing the problems of bandwidth, latency and data rate. In this paper, for the management, alongside data iteration through distributed and parallel computing, it is proposed to transmit the data intelligently without compromising the quality and quantity of data.

The wind speed and the rpm of the turbine depends on the temperature. For example, on a wind power plant, sensors are recording rpms and temperature, the reading is being recorded with respect to temperature. The flowchart of Fig. 5 shows the control room or processors where the data is being captured and analysed in the beginning stage, for instance not each processor deals with the readings collected from all turbines in the field. To avoid the system being cumbersome, each processor deals with only 5 turbines. Fig. 5 shows the process of a single processor only. This can be extended for multiple processors in parallel, distributed or a combined computing. The sensors' readings are being recorded in sets of 30 min each, after every 30 min, another set of readings is made. The processor makes the slot of readings for 30 min, if the temperature does not change for more than 0.5 degrees. If the temperature increases or decreases during any 30 min of duration, the set of readings will change to the new set and the previous set will be averaged at the last recorded reading before the charge of temperature. After any set of readings is completed, the data is saved in the storage, the average of the set will be calculated in the real-time and forwarded to the central analysing center or uploaded to the cloud. The data will be captured for the duration whilst the turbines are in the working mode.

This will reduce the amount of data that needs to be forwarded in real time, latency, required bandwidth and increases throughput. For high precision, depending on the need, amount of data and processing, time can be reduced (e.g, 15min or 5min).

V. Laboratory Analysis

Fig. 6 shows the practical setup including a raspberry pi 64arm processor and a 64amd processor. These processors are used for the partial implementing of the proposed DT. There are 6 steps for building the whole proposed model, however. The implemented steps in this paper include OT/IT convergence with randomly generated stored data. For building the setup open communication framework, MQTT protocol, Java, docker and docker compose.

A. Findings

A number of observations have been recorded for the implementation of the partial twin. There are plenty of restrictions and limitation for such kind of inexpensive virtual implementation. Some of the important findings includes; 1) The use of docker-compose is impossible to use on an arm processor to this date, which is the main limitation for the implementation, 2) An amd processor has no such limitation and compatible software are usually available, 3) Amd processors are comparatively expensive and bigger in size, hence, our extended research will include finding of a cloud platform which is suitable and flexible for arm processor, 4) Although a raspberry pi support linux and other operating systems, however, for connecting a real-time sensor it only supports raspbian.

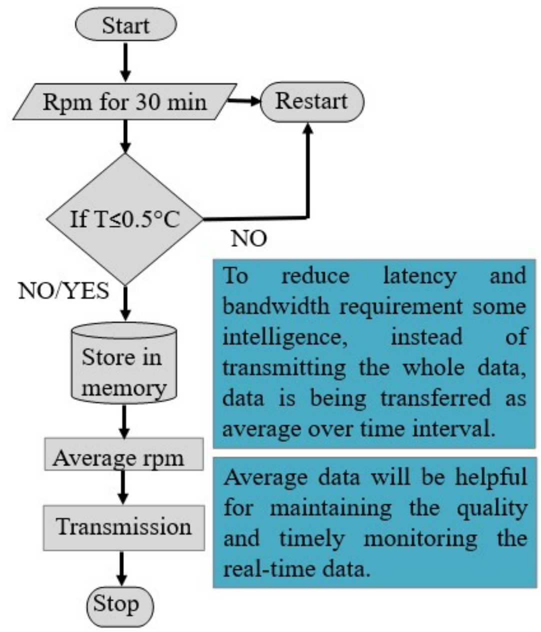

Fig. 5. Proposed Data Transfer for reduced Latency and Bandwidth

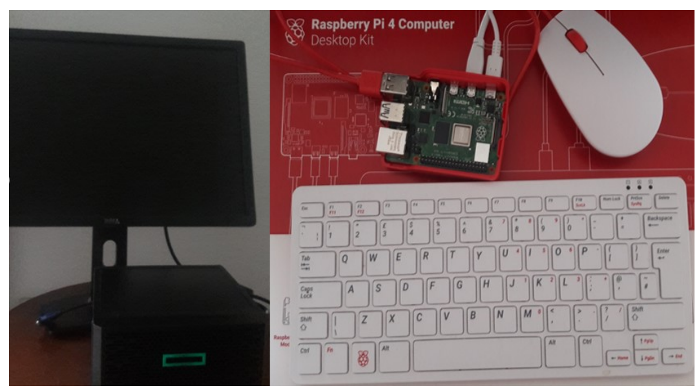

Fig. 6. Practical Setup for Building a Digital Twin

VI. Conclusion

IIoT has started to implement in several industries around the world due to the high amount of data and its management, however, the process has not reached to its full maturity and still being refined. A lot of work is needed to be done. There are several technical approaches that needs to be included for building an IIoT system. For the right and inexpensive approach, it is suggested to build a DT before physically implementing the technology in any industry, avoidance may cause several other issues besides cost, e.g., security, privacy, and denial-of-service etc.

This paper proposes three approaches for building a successful IIoT system. A 6-step model is proposed for building the DT step by step, then within the steps, a draft has been plotted for the choice of iterations between distributed and parallel computation for obtaining the desired results and finally a method of data processing is given, specifically for the wind turbine industry, for obtaining the communication with better latency, data rate and bandwidth. This work will be extended to a journal in upcoming future.

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